Environmental Safety & Health
Environmental Protection Division
P.O. Box 1663, K491
Los Alamos, New Mexico 87545
(505) 665-6592/FAX (505) 665-3811

National Nuclear Security Administration
Los Alamos Site Office, A316
3747 West Jemez Road
Los Alamos, New Mexico 87545
(505) 667-5794/FAX (505) 667-5948

Date: February 14, 2012
Refer To: ENV-DO-12-0005
LAUR: 12-00672

Mr. Jerry Schoeppner, Acting Chief
Ground Water Quality Bureau
New Mexico Environment Department
Harold Runnels Building, Room N2261
1190 St. Francis Drive
P.O. Box 26110
Santa Fe, NM 87502

Dear Mr. Schoeppner:

SUBJECT: DISCHARGE PERMIT APPLICATION FOR THE TA-50 RADIOACTIVE LIQUID WASTE TREATMENT FACILITY AND THE TA-52 ZERO LIQUID DISCHARGE SOLAR EVAPORATION TANKS

The US Department of Energy and Los Alamos National Security, LLC (DOE/LANS) are in receipt of your November 18, 2011, letter (Appendix A) requiring a comprehensive and up-to-date application for the Technical Area (TA)-50 Radioactive Liquid Waste Treatment Facility (RLWTF) and the TA-52 Zero Liquid Discharge (ZLD) Solar Evaporation Tanks by February 16, 2012. Per your request, enclosed are three copies of the required Discharge Permit application and supporting documentation. Also enclosed is the $100.00 filing fee required by regulation.

In a December 7, 2011, letter (Appendix A) to the New Mexico Environment Department (NMED), DOE/LANS requested an additional 90 days to submit the required application. The referenced extension request was denied by the NMED in a December 30, 2011, response (Appendix A). On January 17, 2012, DOE/LANS submitted a request for a short 45-day extension to submit information on certain portions of the application. In a January 27, 2012, letter (Appendix A) the NMED granted the requested 45-day extension for certain portions of the Discharge Permit application pertaining to sections B-7, B-8, B-14, B-15, B-16, and B-18, as well as bullet items 9, 10, 11, and 16 from the November 18, 2011, letter. The information pertaining to these sections and bullets will be submitted under separate cover by April 2, 2012. LANL understands the restriction on discharges to the TA-52 ZLD Solar Evaporation Tanks prior to NMED approval.

The US Department of Energy and Los Alamos National Security, LLC have initiated construction of the TA-52 ZLD Solar Evaporation Tanks. Construction is expected to be completed during 2012.

Please contact Bob Beers at (505) 667-7969 of the Water Quality and RCRA Group (ENV-RCRA) if you have questions.

Sincerely,

Alison M. Dorries
Division Leader
Environmental Protection Division
Los Alamos National Laboratory

Sincerely,

Gene E. Turner
Environmental Permitting Manager
Environmental Projects Division
Los Alamos Site Office
Department of Energy

AMD:GET:BB/lm

Enclosures: a/s

Cy: Joni Arends, Concerned Citizens for Nuclear Safety, Santa Fe, NM, w/enc.
Jonathan M. Block, New Mexico Environmental Law Center, Santa Fe, NM, w/enc.
James Bearzi, NMED/SWQB, Santa Fe, NM, w/enc.
John Kieling, NMED/HWB, Santa Fe, NM, w/enc.
Hai Shen, LASO-EO, w/enc., A316
Kevin W. Smith, LASO-OOM, w/o enc., A316
Gene Turner, LASO-EO, w/enc., A316
Steve Yanicak, LASO-GOV, w/enc., M894
Carl A. Beard, PADOPS, w/o enc., A102
Michael T. Brandt, ADESH, w/o enc., K491
Alison M. Dorries, ENV-DO, w/o enc., K491
Scotty Jones, ENV-DO, w/o enc., K491
Mike Saladen, ENV-RCRA, w/enc., K490
Bob Beers, ENV-RCRA, w/enc., K490, (w/o enc., 2010 ESR)
Bob Mason, TA-55 DO, w/o enc., E583
Cliff Kirkland, TA-55-RLW, w/enc., E505
Chris del Signore, TA-55-RLW, w/enc., E518
Victor Salazar, TA-55-RLW, w/o enc., E518
Randy Johnson, ENV-ES, w/enc., E500
Dianne Wilburn, ESHQ-DR, w/o enc., E503
ENV-RCRA File, (12-0038) w/enc., M704
IRM-RMMSO, (U1102277), w/enc., A150

GROUNDWATER DISCHARGE PERMIT DP-1132

APPLICATION FOR THE

TA-50 RADIOACTIVE LIQUID WASTE TREATMENT FACILITY (RLWTF)

and the

TA-52 ZERO LIQUID DISCHARGE SOLAR EVAPORATION TANKS

Submitted by

LOS ALAMOS NATIONAL SECURITY, LLC

And the

US DEPARTMENT OF ENERGY

FEBRUARY 2012

LA-UR-12-00672

ENV-DO-12-0005

Los Alamos NATIONAL LABORATORY EST. 1943

An Equal Opportunity Employer / Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

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Requested Information

Table Addressing Requested Items from November 18, 2011 NMED Letter 1

Ground Water Discharge Permit Application

Part A 2

Part B 8

Part C 18

Appendix A – LANL/NMED Communications RE: DP-1132

Copies of the Following LANL/NMED Communications:

January 27, 2012, NMED Letter RE: Approval of Time Extension to Submit Application, DP-1132, Radioactive Liquid Waste Treatment Facility (RLWTF) 1

January 17, 2012, LANL Letter Subject: Request For Consideration of Short Time Extension For Specific Items For Permit Application DP-1132, Radioactive Liquid Waste Treatment Facility (RLWTF) And Zero Liquid Discharge Evaporative Tanks (ZLD) 5

December 30, 2011, NMED Letter RE: Denial Of Time Extension To Submit Application, DP-1132, Radioactive Liquid Waste Treatment Facility (RLWTF) 9

December 7, 2011, LANL Letter Subject: Request For An Extension To Submit An Updated Discharge Permit Application For The Radioactive Liquid Waste Treatment Facility (DP-1132) 19

November 18, 2011, NMED Letter RE: Response to Notice of Intent To Discharge 27

August 11, 2011, LANL Letter RE: Sixty Percent Design, Evaporation Tanks, TA-50 Radioactive Liquid Waste Treatment Facility 32

September 15, 2008, LANL Letter Subject: Request For Additional Information, DP-1132, Radioactive Liquid Waste Treatment Facility 41

June 11, 2008, NMED Letter RE: Request For Additional Information, DP-1132, Radioactive Liquid Waste Treatment Facility 49

November 1, 2007, LANL Letter Subject: Notice Of Intent To Discharge, Evaporation Tanks, TA-50 Radioactive Liquid Waste Treatment Facility 52

Appendix B – Process Diagrams and Description

Process Schematic – RLW-SD-PFD-001 1

RLWTF Treatment Units – Scaled Floor Plan 2

TA-50 RLWTF Units and Processes 3

Appendix C – NPDES Outfall #051

NPDES Permit No. NM0028355,. Outfall #051 1

Appendix D – Groundwater Quality

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Appendix E – Well Logs

Well Logs

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Appendix F – Geology

Soil Information

Soil Types 1

Geotechnical Investigations

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TA-52 Zero Liquid Discharge Solar Evaporation Tanks 14

Plan and Map Views of Stratigraphic Units Beneath MDA C 21

Appendix G – Contingency Plan

Contingency Plan – to be submitted under separate cover by April 2, 2012 1

Appendix H – Closure Plan

Closure Plan 1

Appendix I – Referenced Documents

Compact Disc (CD) Containing the Following Documents 1

Los Alamos National Laboratory's Hydrogeologic Studies of the Pajarito Plateau: A Synthesis of Hydrogeologic Workplan Activities (1994-2004). LA-14263-MS.

2009 Hydrogeologic Site Altas. LAUR-09-3763.

Groundwater Level Status Report for 2010 Los Alamos National Laboratory. LA-14437-PR

Conceptual Models of Vadose Zone Flow and Transport Beneath The Pajarito Plateau, Los Alamos, New Mexico. Vadose Zone Journal, Vol. 4, August 2005

NRCS Soil Survey of Sandoval County Area, New Mexico, Parts of Los Alamos, Sandoval, and Rio Arriba Counties.

2006 Mortandad Canyon Investigation Report. LA-UR-06-6752.

2011 Interim Facility-Wide Groundwater Monitoring Plan, Revision 1. LA-UR-11-6958.

Compact Disc (CD) Containing the Following Document 2

Environmental Surveillance at Los Alamos During 2010. LA-14445-ENV.

Appendix J - Maps

Map #1 - Location Map with Treatment Units, Lagoons, Tanks, Roads, Buildings, Supply Wells, Monitoring Wells, Canyons, Water Bodies, Property Boundaries, Other Permitted Discharges, and North Arrow 1

Map #2 - TA-50 RLWTF, RLW Collection System, NPDES Outfall #051, TA-52 ZLD Solar Evaporation Tanks, and 100-Year Flood Plain Map 2

Map #3 - LANL Soils Map 3

Map #4 - TA-50 Radioactive Liquid Waste Treatment Facility (RLWTF) Storm Drain System Map 4

In response to the November 18, 2011 letter from NMED (See Appendix A), the requested items are addressed in the following locations:

1.	The estimated volumes, sources (technical area and building) and wastestream characteristics of all influent wastewater that LANL receives, or intends to receive, at the RLWTF.	A-8, A-10, B-1, Appendix B
2.	A description of the conveyance methods used to transport wastewater to the RLWTF for each source.	A-8, B-1, Appendix B
3.	A description of waste characterization and metering systems used to determine influent wastestream characteristics and volumes entering the RLWTF.	B-12
4.	A description of the review and amendment process for LANL's internal Waste Acceptance Criteria (WAC) for all incoming wastewater received at the RLWTF. This should include LANL's process for ensuring the WAC relates to the current treatment technologies and processes.	The amendment and review process for changes to LANL's Waste Acceptance Criteria (WAC) involves several reviews. A WAC facilitator distributes proposed WAC attachments to owners and reviewers, including regulatory Subject Matter Experts (SMEs). The facilitator will assist the owners to ensure that revisions are complete and that technical content is correct. Once revisions are agreed to, LANL's policy office conducts a final review, completes specific paperwork, and issues final WAC amendments. At RLWTF, the type of review will depend on the proposed WAC amendment, and can include review of the quality of treated wastewaters, revisions to state or federal discharge standards, the treatment process, including planned changes to process equipment, and administrative review.
5.	A description of operational procedures for receiving wastes from each generator.	Information falls under the granted time extension and will be submitted under separate cover by April 2, 2012.
6.	A schematic of the treatment process in its entirety for each wastestream (from collection to final disposal).	Appendix B
7.	Descriptions, locations, construction materials and sizing for each component of the treatment processes for each type of wastestream being treated at the RLWTF.	B-6, Appendix B
8.	Descriptions, locations and designs for all secondary storage and auxillary emergency units intended to receive, treat or store wastewater received at the facility.	B-6, Appendix B
9.	Proposed processes for the operation, inspection and maintenance for the facility as it pertains to the collection lines, treatment units and effluent storage disposal units.	Information falls under the granted time extension and will be submitted under separate cover by April 2, 2012.

10.	Procedures and corrective actions for addressing acute failures at the facility.	Information falls under the granted time extension and will be submitted under separate cover by April 2, 2012.
11.	Procedures and corrective actions for addressing long-term maintenance issues at the facility.	Information falls under the granted time extension and will be submitted under separate cover by April 2, 2012.
12.	Record drawings for all components of the facility, if available.	B-5
13.	Construction plans and specifications for all components of the facility which are under construction or are proposed for construction.	B-5
14.	A proposed effluent monitoring plan, identifying analytes and sample locations/frequency. The proposal should consider discharge frequencies, incoming waste characteristics and the constituents listed under 20.6.2.3103 NMAC and Subsection WW of20.6.2.7 NMAC.	B-13
15.	Proposed flow and metering systems used to determine effluent discharge volumes for each of the discharge locations.	B-12
16.	Proposed ground water monitoring locations for ground water sources most likely to be impacted by intentional and unintentional discharges from the RLWTF. The proposal should identify geohydrology of the potentially impacted areas, existing monitoring well locations and construction.	Information falls under the granted time extension and will be submitted under separate cover by April 2, 2012.
17.	Actions which LANL would implement should partial or full closure of the facility occur.	B-19
18.	A scaled facility plan showing the facility's components including influent collection lines, storage units, major treatment units and disposal units.	Appendix B
19.	All other information sought in NMED's application for Discharge Permit Sections A through C. Please note that for the purposes of public notification, the "discharge site" as it relates to this facility encompasses the central collection system lines, the treatment and storage facilities and all discharge locations for the treated effluent.	See Attached Application

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NEW MEXICO ENVIRONMENT DEPARTMENT
GROUND WATER QUALITY BUREAU

DISCHARGE PERMIT APPLICATION

Type of Application. Check appropriate box.

- ☐ Application for new Discharge Permit -- new facility
- ☒ Application for new Discharge Permit -- existing (unpermitted) facility (DP-1132)
- ☐ Application for Discharge Permit Renewal
- ☐ Application for Discharge Permit Modification
  "Modification" is defined as a change to the permit requirements that result from a change in the location of the discharge, a significant increase in the quantity of the discharge, or a significant change in the quality of the discharge.
- ☐ Application for Discharge Permit Renewal and Modification

For an existing Discharge Permit, please indicate: DP Number _____ Expiration date _____

Checklist of Application Components.

☒ Part A: Administrative Completeness.	*Instructions for completing the application are included on the form itself and on Supplemental Instructions for Parts A and B.* *You may fill out the application manually, or a Microsoft Word version may be downloaded from www.nmenv.state.nm.us (Ground Water Quality) and filled out electronically.*
☒ Part B: Operational, Monitoring, Contingency and Closure Plans, with required attachments. *Choose appropriate option*: ☐ Septic Tank System ☒ General – Various Facility Types	
☒ Part C: Site Information, with required attachments.	
☒ $100 Filing Fee, payable to the New Mexico Environment Department. *Required from all applicants.* An additional fee will be assessed prior to permit issuance. Permit fees are listed in Section 20.6.2.3114 NMAC.	

Certification. Signature must be that of the person named in Item A-3 of Part A of the application.

I certify under penalty of law that I am knowledgeable about the information contained in this application. The information is, to the best of my knowledge and belief, true, accurate and complete.

Signature: _____ Date: 2/14/12

Printed Name/Title: Alison M. Dorries, Division Leader, ENV, Los Alamos National Security, LLC

Signature: _____ Date: 2/15/12

Printed Name/Title: Kevin W. Smith, Manager, Los Alamos Site Office, US Department of Energy

Send three complete copies of this application and the filing fee to:

Program Manager
Ground Water Pollution Prevention Section
New Mexico Environment Department
PO Box 5469
Santa Fe, NM 87502

LA-UR-12-00672
ENV-DO-12-0005

GROUND WATER DISCHARGE PERMIT APPLICATION
PART A: ADMINISTRATIVE COMPLETENESS
All Facilities

A-1. Facility Information. See Supplemental Instructions to determine what constitutes the "facility." The physical location of the facility must be provided. If the facility does not have an address, the location can be described by road intersections, mile posts, or landmarks, as appropriate.

Facility Name	Los Alamos National Laboratory (LANL or the Laboratory)
Former Names (if any)	NA
Physical address/location *(mandatory)*	Los Alamos, New Mexico
	County Los Alamos
Mailing address	P.O. Box 1663 Mail Stop K491
	Los Alamos, NM 87545
Contact person	Alison M. Dorries
Title	Division Leader, Environmental Protection Division (ENV)
Telephone number(s)	505-665-6952
Fax number	505-665-3811 E-mail address adorries@lanl.gov

A-2. Type of Discharge and Type of Facility. See Supplemental Instructions.

Type of discharge: ☐ Domestic ☐ Agricultural ☒ Industrial ☐ Mining

Type of facility: The Radioactive Liquid Waste Treatment Facility (RLWTF) is a wastewater facility for the treatment of hazardous and radioactive liquid waste.

A-3. Applicant Information. The applicant is the person or entity (e.g., corporation, partnership, organization, municipality, etc.) legally responsible for the discharge and for complying with the terms of the Discharge Permit. If the applicant is an entity, then the name and title of a contact person must be provided. This application must be signed by the applicant or contact person named here.

Applicant Name	US Department of Energy (DOE)[1] Los Alamos National Security, LLC (LANS)[2]
Mailing address	[1]3747 West Jemez Road, Los Alamos, NM 87545 [2]P.O. Box 1663, MS K491, Los Alamos, NM 87545
Contact person	[1]Kevin W. Smith, Los Alamos Site Office, DOE [2]Alison M. Dorries, LANS
Title	[1]Manager [2]Division Leader
Telephone number(s)	[1](505) 667-5105 [2](505) 665-6952
Fax number	[1](505) 606-2004 [2](505) 665-3811
E-mail address	[1] kevin.smith@nnsa.doe.gov, [2] adorries@lanl.gov

A-4. Consultant Information (if applicable). If the consultant is a company or organization, then the name and title of a contact person must be provided.

Consultant/Firm Name: NA

Mailing address:

Contact person:

Title:

Telephone number(s):

Fax number: E-mail address:

A-5. Permit Contact Information (if applicable). If someone other the applicant listed in Item A-3 or a consultant listed in Item A-4 is a primary contact for this application and/or facility, list here.

Permit Contact Name: Robert Beers

Title: Environmental Professional, Water Quality & RCRA Group, LANS

Mailing address: P.O. Box 1663, MS K490

Los Alamos, NM 87545

Telephone number(s): 505-667-7969

Fax number: 505-665-9344 E-mail address: bbeers@lanl.gov

A-6. Ownership.

The applicant owns (check as appropriate): ☒ the facility* ☐ some discharge sites ☐ all discharge sites

***Department of Energy (DOE) Facility**

If other parties own the facility or any of the discharge sites, attach their names and contact information.

A-7. Discharge Quantity.

Your Discharge Permit will specify a maximum discharge volume, which is typically expressed as the maximum number of gallons per day that may be treated and/or disposed of. Please indicate below the maximum discharge volume for your facility. You must show how it was determined in Part B of your application. For further explanation, see Supplemental Instructions for Part B.

Maximum discharge volume: 40,000 gallons per day

A-8. Processing, Treatment, Storage and Disposal System. Briefly describe how wastewater, sludge, etc. is processed, treated, stored, and/or disposed of at your facility. See Supplemental Instructions for examples of system components.

The Radioactive Liquid Waste Treatment Facility (RLWTF) consists of (a) an underground collection system that conveys water to Technical Area (TA) 50 from generators at LANL, (b) structures at TA-50, and (c) Zero Liquid Discharge Solar Evaporation Tanks at TA- 52. At Technical Area 50, Building 50-01 is the primary structure; it houses treatment equipment, process tanks, analytical laboratories, and offices. Adjacent TA-50 structures primarily provide for additional water storage: 50-02 (influent), 50-66 (influent), 50- 90 (influent), 50-248 (secondary waters), and 50-250 (emergency).

The RLWTF receives and treats radioactive liquid waste (RLW) from generators at Los Alamos National Laboratory. RLW includes small volumes, less than one percent of total influent, that are also characteristically hazardous for corrosivity, which are treated using elementary neutralization. The RLWTF has (1) a main treatment process for low-level RLW, (2) a process for treating transuranic RLW, and (3) a secondary treatment process for waste streams from both the low-level and transuranic processes.

1) The main treatment process consists of influent collection and storage, the treatment of low-level RLW, and the discharge of treated water to the environment. Treatment steps include clarification, filtration, ion exchange, and reverse osmosis. Discharge to the environment is via NPDES Outfall #051, solar evaporation at the TA-52 Zero Liquid Discharge (ZLD) Solar Evaporation Tanks, or mechanical evaporation at TA-50-257. Two secondary streams are generated by primary treatment, sludge and reverse osmosis concentrate; they are sent to the secondary treatment process.

2) Transuranic RLW treatment consists of influent collection and storage, treatment of the transuranic RLW, and sludge treatment. Treated water is not discharged; it either receives additional treatment (secondary reverse osmosis) or is sent to storage tanks in Building 50-248 for disposition as bottoms. Sludge from the treatment process is concentrated, solidified with cement, and shipped to the Waste Isolation Pilot Plant as a solid transuranic waste.

3) The secondary treatment process treats wastes from the primary and transuranic treatment lines. It consists of a rotary vacuum filter to treat sludge from the main treatment process, secondary reverse osmosis to treat reverse osmosis concentrate from the main process and/or effluent from the transuranic process, and a bottoms disposal step. Wastes from the secondary treatment process are disposed as low-level radioactive solid waste.

A-9. Discharge Locations. List the locations of your facility and of all components of your processing, treatment, storage and/or disposal system. Examples of components include septic tanks, lagoons, leachfields, irrigation sites, mine stockpiles, etc. Additional examples are listed in the Supplemental Instructions. Latitude and longitude are optional unless township, range and section are not available.

Components	Township	Range	Section(s)	Latitude	Longitude
RLWTF Mechanical Evaporator (50-257)	19N	6E	22	35° 51’ 58.3”	-106° 17’ 48.5”
NPDES Outfall #051 (NM0028355)	19N	6E	22	35° 51’ 54”	-106° 17’ 52”
TA-52 Zero Liquid Discharge Solar Evaporation Tanks (currently under construction)	19N	6E	22	35° 51' 36"	-106° 17' 12"

A-10. Discharge Quality.

Indicate the expected quality of the discharge -- wastewater, leachate, sludge, etc. -- generated, stored, treated, processed and/or discharged at your facility. List the contaminants of concern and the expected concentrations. *Not all facilities need to characterize influent quality.* See Supplemental Instructions for typical contaminants and additional guidance.

Effluent quality data is collected under two compliance monitoring programs. Each of these monitoring programs is discussed briefly below.

- **NPDES Compliance Effluent Monitoring** for the RLWTF’s NPDES Outfall #051 in Mortandad Canyon is conducted in accordance with monitoring requirements of the Laboratory’s NPDES Permit No. NM0028355. See Appendix C for a list of NPDES permit analytes and monitoring frequencies.

- **DP-1132 Voluntary Effluent Monitoring** has been conducted since the first quarter of 1999 for NO3-N, fluoride, TDS, and perchlorate. Flow-proportioned, weekly composite samples are prepared from each tank of effluent discharged to Mortandad Canyon during a 7-day period. Analytical results are reported to the NMED Ground Water Quality Bureau quarterly.

Based on the past 10 years of influent and effluent monitoring data the Laboratory has identified the potential contaminants of concern as shown in the table below. Contaminant concentrations listed in the table below are the average influent and effluent results from monitoring conducted during 2008, 2009, and 2010. No effluent was discharged to NPDES Outfall #051 during the second half of 2010, except for two discharges in November 2010, and all of 2011. As a result, no effluent data is available for 2011.

RLWTF Effluent Potential Contaminants of Concern.

Expected or Known Contaminants	Expected or Known Contaminants Indicate units: mg/L, CFU/100 ml, etc.	
	Incoming (Influent)	Final (Effluent)
Ammonia-N	9.6 mg/L	3.74 mg/L
Nitrate-N	12.9 mg/L	5.33 mg/L
Nitrite-N	0.45 mg/L	1.58 mg/L
Nitrate + Nitrite-N	NA	6.6 mg/L
Perchlorate	307 ug/L	0.78 ug/L
TKN	11.4 mg/L	4.6 mg/L
Benzo(a)pyrene	<MDL*	0.83 ug/L
Benzo(b)flouranthene	<MDL*	0.78 ug/L
pH [min/max]	3.1/8.5 su	7.0/7.5 su

*Less than the Method Detection Limit for influent utilizing analytical method SW-846:8270C with an analytical laboratory reported MDL of 1 ug/L.

For **new** septic tank systems, you may either fill out the chart above or simply check one of the following options:

☐ typical domestic wastewater

☐ low-strength domestic wastewater (large gray water component; e.g., laundromat, spa, etc.)

☐ high-strength domestic wastewater (low water use; e.g., RV park, low-flow toilets at campground, etc.)

A-11. Ground Water Conditions.

All applicants must provide the depth to and pre-discharge TDS concentration of the ground water that could be affected by the discharge. Refer to Supplemental Instructions for details on how to obtain these values.

Indicate the depth to the most shallow ground water beneath the discharge site. If there are multiple discharge sites, indicate the range of depths.	Indicate pre-discharge total dissolved solids (TDS) concentration of most shallow ground water beneath the discharge site. Attach copies of analyses.
Depth to water (feet): NPDES Outfall #051 - <1 foot to alluvial; 1262 feet to regional RLWTF – 1306 feet to regional ZLD – 1274 feet to regional	TDS (mg/L): NPDES Outfall #051 – 255 mg/L (alluvial) ZLD – 162 mg/L max (regional)
Reference: ☒ Measurement, nearby monitoring well ☐ Measurement, nearby supply well ☐ Well log from nearby well (attach copy) ☐ Office of the State Engineer http://www.ose.state.nm.us/	Reference: ☒ Analysis from upgradient monitoring well ☐ Analysis from on-site supply well ☐ Analysis from shallow nearby supply well ☐ Concentration provided in previous Discharge Permit application

☐ Report or study (give citation here and attach relevant portion): ☐ Other (describe):	☒ Report or study (give citation here and attach relevant portion): **R-15 information from Table S5-8 from the 2010 Environmental Surveillance at Los Alamos during 2010 attached in Appendix I** ☐ Other (describe):

A-12. Public Notice. See Supplemental Instructions.

a) The public notice packet including instructions and materials should be sent to:

☐ Applicant ☐ Consultant ☒ Other: Permit Contact (A-5)

b) Copies of the public notice packet (excluding sign) should be sent to:

☐ Applicant ☐ Consultant ☒ Other: Permit Contact (A-5)

c) The applicant is required to provide public notice of this application by placing a display ad in a newspaper of general circulation near the location of the proposed discharge. Indicate newspaper you intend to place the ad in:

Newspaper: Los Alamos Monitor

d) *For new or modification applications only:* The applicant must post a sign for 30 days in a conspicuous location at or near the facility, as approved by NMED. One sign must be posted for each 640 contiguous acres or less of the discharge site. An additional notice must be posted at an off-site location conspicuous to the public. Describe the locations below where you intend to post the notices. You may also attach sketches or photographs.

At or near facility: *2 by 3 feet in size*

The TA-50 RLWTF, TA-52 Zero Liquid Discharge Solar Evaporation Tanks, and NPDES Outfall #051 are all located in T19N, R6E, Section 22. The Radioactive Liquid Waste Collection System spans four additional Sections: 16, 17, 20, and 21. Accordingly, a sign will be posted at each of the following five locations:

1. Pecos Drive at the entrance to the TA-50 RLWTF (Section 22)
2. Pajarito Road at the entrance to the Vehicle Access Control Station (Section 21)
3. Intersection of Pajarito Road and Diamond Drive (Section 20)
4. Intersection of Embudo Road and Diamond Drive (Section 17)
5. Park & Ride bus stop at the intersection of Diamond Drive and West Jemez Road (Section 16)

Off-site location: *flyer size*

A flyer size notice will be posted at the LANL Public Reading Room at the J. Robert Oppenheimer Study Center and Research Library, located on West Jemez Road at Casa Grande, Los Alamos, NM

GROUND WATER DISCHARGE PERMIT APPLICATION
PART B: OPERATIONAL, MONITORING, CONTINGENCY AND CLOSURE PLANS GENERAL FORM (VARIOUS FACILITY TYPES)

Operational Plan *[Section 20.6.2.3106.C, 3109.C NMAC]*

B-1. Source(s) of the Discharge. Describe what generates the wastewater, sludge or other discharges processed and/or disposed of at your facility. Identify all sources. Attach additional pages, if needed. See Supplemental Instructions.

The Radioactive Liquid Waste Treatment Facility receives influent from the following sources:

- Process water from radiochemistry laboratories, duct washing systems, radiological areas, boilers, and process areas. The annual average influent volume is 18,150 gallons per day.

- Cooling water from systems located in radiological areas. The annual average influent volume is 1,232 gallons per day.

- Storm and surface water (including samples) collected from sumps, manholes, and vaults. The daily influent volume varies and the annual average is 268 gallons per day.

- Environmental Restoration (ER) waste water generated by groundwater monitoring and sampling activities performed at LANL. The daily influent volume varies and the annual average is 50 gallons per day. Influent is accepted in 2,000 gallon batches.

B-2. Discharge Quantity. Describe the methods/calculations used to determine the maximum discharge volume listed in Item A-6 in Part A of your application. Attach additional pages, if needed. See Supplemental Instructions.

The maximum possible discharge from the RLWTF is 40,000 gallons per day as determined by the volume of the two effluent Frac tanks (20,000 gallons each) at RLWTF as discharges are conducted on a batch basis.

B-3. **Site Map.** Attach a site map showing the components of your proposed system and relevant surrounding features, clearly labeled, such as:

- treatment units
- lagoons
- tanks
- sumps
- manure separators
- land application fields
- domestic wastewater reuse areas
- pits
- stockpiles
- leachfields
- sludge drying beds
- roads
- buildings
- supply wells
- monitoring wells
- extraction/injection wells
- arroyos
- nearby water bodies such as ponds or canals
- property boundaries
- other permitted discharges
- required setbacks
- north arrow

If map is not to scale, mark distances on the map.

☒ Site map is attached.

See Appendix B for a scaled floor plan of the RLWTF treatment units. See Appendix J for Map #1 – Location Map and Map #2 – TA-50 RLWTF, RLW Collection System, NPDES Outfall #051, Zero Liquid Discharge Solar Evaporation Tanks, and 100-year Flood Plain.

B-4. **Flood Protection**. Describe the methods used to prevent flooding and run-off at the facility (tank protection, berms, diversion channels, etc.)

The RLWTF and TA-52 Zero Liquid Discharge Solar Evaporation Tanks, with the exception of the NPDES Outfall #051, are located outside of the 100-year flood plain, see Map #2 in Appendix J for the flood plains. The RLWTF is served by a functional storm water drain system consisting of a series of drainage swales and culverts that convey storm water around the facility as shown on Map #4 in Appendix J.

B-5. **Plans and Specifications.** For new facilities and for new components of existing systems, attach plans and specifications certified by a New Mexico registered professional engineer. *[Section 20.6.2.1202 NMAC]*

The RLWTF maintains facility drawings which include site, architectural, mechanical, electrical, instrumentation,structural and process details. Drawings include a facility as-built set (approximately 600 drawings)and process and instrumentation diagrams associated with low-level, transuranic and secondary treatment processes (approximately 60 drawings). See Appendix B for the RLWTF process schematic and a scaled floor plan of the RLWTF treatment units.

The drawings are available for review at TA-50 RLWTF. Arrangements for the review can be made with the Permit Contact Listed in A-5.

☐ Not applicable because no new facilities are proposed.

☐ Plans and specifications are attached.

☒ Plans and specifications were previously submitted.

Submittal date(s): **60% design package for the TA-52 Zero Liquid Discharge (ZLD) Solar Evaporation Tanks was submitted on August 11, 2011, ENV-RCRA-11-0136.**

B-6. Description of Components. Provide descriptive details of all components of your processing, treatment, storage and/or disposal system. Include all components listed under Item A-8 in Part A.

See Appendix B for a detailed list and description of major components at RLWTF, the process schematic, and for a scaled floor plan of the treatment units at RLWTF.

B-7. Operational Plan. Attach a detailed description of how you operate your processing, treatment, storage and/or disposal system.

Animal feeding operations: include stormwater management, nutrient management plans, method for mixing irrigation and wastewater.

Domestic wastewater treatment facilities: include pre-treatment, solids management, vegetation management for land application.

Facilities using reclaimed domestic wastewater above ground: include proposed water quality classification(s), effluent monitoring, setbacks, irrigation schedules, etc. that will result in protection of public health and the environment. Please refer to *NMED Ground Water Quality Bureau Guidance: Above-Ground Use of Reclaimed Domestic Wastewater* for further information. A copy of the guidance document is available on the NMED website www.nmenv.state.nm.us under "Ground Water Quality".

Per the January 27, 2012 NMED letter (See Appendix A) granting a 45-day extension, this item will be addressed and information will be submitted to NMED under separate cover by April 2, 2012.

☐ Operational plan is attached.

☐ Operational plan was previously submitted. Submittal date(s): _____

B-8. System Maintenance. Attach a description of the operations and maintenance procedures which ensure that your processing, treatment and disposal system functions properly; e.g., inspections, pumping schedules, equipment maintenance, etc.

Per the January 27, 2012 NMED letter (See Appendix A) granting a 45-day extension, this item will be addressed and information will be submitted to NMED under separate cover by April 2, 2012

☐ O & M procedures are attached.

☐ O & M procedures were previously submitted. Submittal date(s): _____

B-9. Backflow Prevention. If wastewater is used for land application or irrigation, describe methods used to protect wells from contamination by wastewater backflow. For new facilities or new systems at an existing facility, only air gap or reduced pressure valve assemblies are acceptable methods.

a) Clearly describe and/or sketch the location of air gaps or devices and attach specifications.

NA – effluent is not reused.

b) Describe how devices are maintained.

NA

B-10. Water Rights. Animal feeding operations which land apply wastewater must attach documentation of irrigation water rights for the proposed land application fields, sufficient to sustain the intended crop rotation.

☐ Water right documentation is attached.

☒ Not applicable.

B-11. Past Ground Water Monitoring Results. *This item applies only to existing facilities seeking renewal and/or modification of a Discharge Permit that required ground water monitoring.*

a) Attach a graph or a table showing all analytical results from ground water sampling at your facility. If preparing graphs, a separate graph should be developed for each constituent, except that nitrate and TKN may be shown on the same graph. Multiple wells may be shown on the same graph. See Supplemental Instructions for sample table and graph.

b) If the monitoring results indicate that ground water standards have been violated or that there is an upward trend approaching standards, attach a description of what actions you have taken or will take to address the elevated concentrations. Ground water standards are listed in Section 20.6.2.3103 NMAC. See the Supplemental Instructions for frequently referenced standards.

Groundwater beneath the Pajarito Plateau occurs in three modes, two of which are perched. Perched groundwater is a zone of saturation with limited extent that is retained above less permeable layers and is separated from underlying groundwater by unsaturated rock.

The three modes of groundwater occurrence are: (1) perched alluvial groundwater in canyon bottoms; (2) discontinuous zones of intermediate-depth perched groundwater whose location is controlled by availability of recharge and by subsurface changes in rock type and permeability; and (3) the regional aquifer beneath the Pajarito Plateau. The regional aquifer extends throughout the neighboring Española Basin.

Los Alamos National Laboratory routinely analyzes groundwater samples to monitor water quality beneath the Pajarito Plateau and the surrounding area. The Laboratory conducts groundwater monitoring and characterization programs to comply with the requirements of the Department of Energy (DOE) Orders and New Mexico and federal regulations. The objectives of the Laboratory's groundwater programs are to determine compliance with waste discharge requirements and to evaluate any impact of Laboratory activities on groundwater resources.

Most of the groundwater monitoring conducted during 2011 was carried out according to the 2011 Interim Facility-Wide Groundwater Monitoring Plan approved by the New Mexico Environment Department (NMED) under the Compliance Order on Consent (Consent Order). See Appendix I for the 2011 Interim Facility-Wide Groundwater Monitoring Plan. Additionally, voluntary quarterly groundwater

monitoring has been conducted continuously since 1999 at select alluvial wells in Mortandad Canyon to evaluate the impacts of effluent discharges from the RLWTF though NPDES Outfall #051.

Groundwater monitoring and associated investigations have shown a linkage between the shallow alluvial groundwater zone that first receives effluent from the RLWTF and underlying intermediate-depth (500 to 800 feet below ground surface) and regional (~1000 feet below ground surface) groundwater zones. The connection between these zones appears to occur in a relatively small area downstream of NPDES Outfall #051 (See Appendix I, 2006 Mortandad Canyon Investigation Report).

Monitoring-well data were compared to applicable standards for the period from 2000 to present for four alluvial wells, three intermediate-depth wells, and two regional wells. Time-series plots are provided as Figures 2 through 12 in Appendix D for contaminants that have shown exceedances of a standard for the period 2000 to present. The plots show decreasing concentrations over time for the alluvial wells indicating relatively rapid response to the improvements in the treatment process at RLWTF that were put in place in 2000. Plots for the intermediate-depth and regional wells are indicative of contamination that migrated to those zones likely over the scale of decades.

Chromium contamination in the deeper zones is likely attributable to the chromate that was used to treat cooling water at the power plant in Sandia Canyon until 1972; these earlier discharges are the source for hexavalent chromium concentrations discovered in intermediate groundwater and the regional aquifer beneath Sandia and Mortandad Canyons. Figure 1 in Appendix D shows that total chromium concentrations in the TA-50 RLWTF's effluent from 2001 to 2010 did not exceed the groundwater standard of 50 µg/L.

Additional detailed information on the quality of the alluvial, intermediate-depth, and regional groundwater can be found in Chapter 5 of the 2010 Environmental Surveillance Report (Appendix I)

Monitoring Plan *[Section 20.6.2.3107.A NMAC]*

B-12. Discharge Volumes. Describe how and where the monthly discharge volume at your facility will be. For all measuring devices, provide type, location, and units of measure including multipliers (e.g., gallons, gallons x 100, acre-ft, etc.) See Supplemental Instructions. Attach additional pages, if necessary.

Discharges of treated water to the environment are measured by the following methods:

- Low-level influent: Low-level RLW influent volumes are determined by daily water balance. The levels of process vessels and tanks are continuously monitored with information transmitted electronically to the RLWTF control room. Level changes are converted to volume

changes, which are summed daily. Influent is determined as the sum of tank volume changes plus volumes of water discharged to the environment and water removed as sludge. Tank level and other volume information is reviewed daily to assure activities and tank level changes agree with actual plant operations.

- Transuranic influent: Transuranic influent is received in batches from TA-55, with influent collected in either the acid tank or caustic tank in Building 50-66. Level probes for these tanks are linked electronically to the RLWTF control room. Operators monitor and record tank level changes during each influent batch transfer. Influent volumes are calculated from the difference between beginning and ending tank levels.

- Discharge to the environment by mechanical evaporation at 50-257: Treated water is fed to the evaporator from the effluent Frac tanks in Room 34B; water is typically fed continuously during the normal work week, including overnight. Volumes are read in gallons from a water meter on the evaporator feed line.

- Discharge to the environment by solar evaporation: Treated water is discharged to the TA-52 Zero Liquid Discharge Solar Evaporation Tanks from either of the effluent Frac tanks in Room 34B, or from TK38 in Room 38. Discharges occur in batches. The volume, in gallons, of each discharge is calculated from the change in tank level. If discharges are from the effluent Frac tanks, which are horizontal tanks, before- and after-discharge tank volumes are determined from a table that correlates tank level and volume of water in the tank. If discharges are from TK38, pre and post discharge tank volumes are read directly from markings on this translucent vertical tank.

- Discharge to the environment via NPDES Outfall #051: Treated water is discharged from either of the effluent Frac tanks in Room 34B, or from TK38 in Room 38. Discharges occur in batches. The volume, in gallons, of each discharge is calculated from the change in tank level. If discharges are from the effluent Frac tanks, which are horizontal tanks, before- and after-discharge tank volumes are determined from a table that correlates tank level and volume of water in the tank. If discharges are from TK38, pre and post discharge tank volumes are read directly from markings on this translucent vertical tank.

B-13. Discharge Quality Monitoring. Discharge Permits typically require that the discharge (treated wastewater, sludge, septage, etc.) be sampled on a regular basis. The frequency of sampling varies by type of facility, as do the contaminants of concern. Domestic and agricultural Discharge Permits typically require sampling for total Kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3-N), total dissolved solids (TDS) and chloride on a quarterly or semi-annual basis. *(continued on next page)*

If reclaimed domestic wastewater will be discharged for above ground uses, testing of the discharge for additional parameters is appropriate. Please refer to the *NMED Ground Water Quality Bureau Guidance: Above-Ground Use of Reclaimed Domestic Wastewater* for further information.

In the space below, provide a description or sketch of the sampling point(s) to be used for sampling the discharge at your facility.

The sampling point for effluent discharges from the North & South Frac Tanks is TA-50, Building 1, Room 34B.

The sampling point for effluent discharges from the TK38 tank is Room TA-50, Building 1, Room 38.

Optional: In the space below (or as an attachment), you may propose revisions or additions to the standard discharge quality monitoring requirements. If you do, provide the rationale for your proposal.

Proposed Monitoring Plan for Treated Effluent Discharged to Mortandad Canyon through NPDES Outfall #051.

LOCATION	PARAMETER	NOTES	FREQUENCY
Effluent Tank**	Batch Volume (gallons)	1	Per batch
Effluent Tank**	Total Nitrogen	1, 2	Quarterly
Effluent Tank**	Total Dissolved Solids	1	Quarterly
Effluent Tank**	Perchlorate	1	Quarterly
Effluent Tank**	Human Health Standards	1, 3	Annual
Effluent Tank**	Domestic Water Supply Standards	1, 4	Annual
Effluent Tank**	Irrigation Standards	1, 5	Annual
Effluent Tank**	Volatile & Semivolatile Organics	1, 6	Annual
Effluent Tank**	Radiochemistry	1, 7	Annual
Effluent Tank**	PCBs	1, 8	Annual

**North & South Frac Tanks or TK38

NOTES:

1. The Discharge Permit Sampling Points are: at the Frac tanks in Room 34B or at TA-50 Building 1, Room 38.
2. Total Nitrogen: TKN, Ammonia, NO3+NO2-N.
3. Human Health Standards (20.6.2.3103A): Ag, As, Ba, Cd, CN, Cr, F, Hg, NO3-N, Pb, Se, U.
4. Domestic Water Supply Standards (20.6.2.3103B): Cl, CU, Fe, Mn, SO4, Zn, TDS, pH.
5. Irrigation Standards (20.6.2.3103C): Al, B, Co, Mo, Ni.
6. Volatile & Semivolatile Organics (20.6.2.7WW, 20.6.2.3103) by EPA Methods 624 and 625.
7. Radiochemistry (20.6.2.3103A): Combined Ra-226 and Ra-228.
8. PCBs (20.6.2.3103A): EPA Method 608.

Proposed Monitoring Plan for Treated Effluent Discharged to the Zero Liquid Discharge Solar Evaporation Tanks at TA-52.

LOCATION	PARAMETER	NOTES	FREQUENCY
Effluent Tank**	Batch Volume (gallons)	1	Per batch
Effluent Tank**	Total Nitrogen	1, 2	Quarterly
Effluent Tank**	Total Dissolved Solids	1	Quarterly
Effluent Tank**	Perchlorate	1	Quarterly
Effluent Tank**	Human Health Standards	1, 3	Annual
Effluent Tank**	Domestic Water Supply Standards	1, 4	Annual
Effluent Tank**	Irrigation Standards	1, 5	Annual
Effluent Tank**	Volatile & Semivolatile Organics	1, 6	Annual
Effluent Tank**	Radiochemistry	1, 7	Annual
Effluent Tank**	PCBs	1, 8	Annual

**North & South Frac Tanks or TK38

NOTES:

1. The Discharge Permit Sampling Points are: at the Frac tanks in Room 34B or at TA-50 Building 1, Room 38.
2. Total Nitrogen: TKN, Ammonia, NO3+NO2-N.
3. Human Health Standards (20.6.2.3103A): Ag, As, Ba, Cd, CN, Cr, F, Hg, NO3-N, Pb, Se, U.
4. Domestic Water Supply Standards (20.6.2.3103B): Cl, CU, Fe, Mn, SO4, Zn, TDS, pH.
5. Irrigation Standards (20.6.2.3103C): Al, B, Co, Mo, Ni.
6. Volatile & Semivolatile Organics (20.6.2.7WW, 20.6.2.3103) by EPA Methods 624 and 625.
7. Radiochemistry (20.6.2.3103A): Combined Ra-226 and Ra-228.
8. PCBs (20.6.2.3103A): EPA Method 608.

B-14. Ground Water Quality Monitoring. Discharge Permits typically require that ground water samples be collected quarterly from properly constructed monitoring wells located downgradient from discharge locations. The samples must be analyzed for contaminants of concern. For most domestic and agricultural Discharge Permits, the typical contaminants of concern are total Kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3-N), total dissolved solids (TDS) and chloride.

Optional: In the space below (or as an attachment), you may propose revisions or additions to the standard ground water monitoring requirements. If you do, provide the rationale for your proposal.

Per the January 27, 2012 NMED letter (See Appendix A) granting a 45-day extension, this item will be addressed and information will be submitted to NMED under separate cover by April 2, 2012.

For existing facilities:

Indicate number of existing monitoring wells: 9

Attach copies of monitoring well logs.

☒ Well logs attached. ☐ Well logs cannot be located.

See Appendix E. ☐ Well logs previously submitted.
Submittal date(s): _____

Attach copy of monitoring well survey (typically not applicable if fewer than 3 monitoring wells).

☒ Survey attached. ☐ No survey has been conducted.

See Appendix J for Map #1 – Location Map. ☐ Survey previously submitted.
Submittal date(s): _____

B-15. Other Monitoring. In addition to discharge volumes, discharge quality monitoring and ground water sampling, Discharge Permits typically require the following monitoring, depending on the type of facility:

- inspection and pumping of septic tanks, grease tanks, lift stations
- inspection of leachfields
- inspection of lagoons
- process testing for treatment plants
- land application data sheets (LADS)
- tracking of chemical fertilizer applications to land application areas
- soil sampling (agricultural and selected other facilities land applying wastewater)
- harvested plant material testing (agricultural facilities)

Optional: In the space below (or as an attachment), you may propose revisions or additions to the other standard monitoring requirements for your type of facility. If you do, provide the rationale for your proposal.

Per the January 27, 2012 NMED letter (See Appendix A) granting a 45-day extension, this item will be addressed and information will be submitted to NMED under separate cover by April 2, 2012.

Contingency Plan *[Section 20.6.2.3107.A.10 NMAC]*

B-16. System Failure. Describe your contingency plan in the event there is a failure of your wastewater or discharge system (e.g., wastewater back-up, pump failure, pipe breaks, tank overflow, leachfield failure, saturated fields etc.)

Per the January 27, 2012 NMED letter (See Appendix A) granting a 45-day extension, this item will be addressed and information will be submitted to NMED under separate cover by April 2, 2012.

B-17. Contingency Leachfield Location. *This item applies only if your disposal system includes a leachfield.* Identify a location on your site map (Item B-3) for a contingency leachfield in the event that your leachfield must be replaced. If no land is available for a contingency leachfield at an existing facility, describe how you will address a failed leachfield. New facilities must provide for a contingency leachfield location.

NA

B-18. Other Contingencies. Discharge Permits typically contain standard contingencies to address:

- exceeding wastewater quality limits
- violation of ground water or surface water standards
- spills or illegal releases of wastewater
- migration of soil nitrogen
- loading nitrogen above limit

Propose additional contingency plans, if appropriate:

Per the January 27, 2012 NMED letter (See Appendix A) granting a 45-day extension, this item will be addressed and information will be submitted to NMED under separate cover by April 2, 2012.

Closure Plan *[Section 20.6.2.3107(A)11 NMAC]*

B-19. Facility Closure and Post-Closure Monitoring. Discharge Permits contain standard requirements to address the closure of part or all of your discharge system, as follows:

- cap or plug lines to prevent the flow of wastewater to treatment or disposal system
- empty and remove or backfill tanks
- empty lagoons, perforate or remove liners, re-grade to surface topography
- appropriately dispose of solids
- regrade and cover stockpiles at mine facilities
- continue ground water monitoring for at least two years, longer as appropriate
- enact contingency plans if ground water standards are violated
- financial assurance may be required.

Propose additional closure plans in the space below or as an attachment, if appropriate:

See Appendix H for Closure Plan.

Please Note: You must also complete Part C of the application.

GROUND WATER DISCHARGE PERMIT APPLICATION
PART C: SITE INFORMATION
All Facilities

C-1. **Area Map.** Attach a current area map showing roads and clearly mark the location of your facility.

See Appendix J for Map #1 – Location Map.

C-2. **Directions to Site.** Provide driving directions to the site from the nearest town or, if located in a town, from an easily identifiable location.

From Santa Fe, NM, take US-285 north to Pojoaque, NM. Take NM-502 west towards Los Alamos, NM. Because access to the RLWTF Facility requires entry through one of the Los Alamos National Laboratory's Pajarito Corridor Vehicle Access Portals, visitors without a LANL badge must be escorted to the project site. Visits to the project site may be coordinated through the point of contact listed in A-5 of this application.

C-3. **Topographic Map.** Attach a copy of the appropriate US Geological Survey topographic map. You may provide just the relevant portion. USGS maps are available at many outdoor equipment stores or bookstores, from the USGS at www.usgs.gov or 1-888-ASKUSGS, and from commercial websites.

On the map clearly indicate the location of your facility. Also identify the approximate locations of all wells within 1,000 feet of your discharge locations. The Office of the State Engineer has a searchable database of supply wells on its website at www.ose.state.nm.us.

☒ USGS map attached with facility location and neighboring wells marked. **See Appendix J for Map #1 – Location Map.**

C-4. **Flood Potential.** Attach a copy of the latest Federal Emergency Management Agency (FEMA) flood map with your facility's location clearly marked, to the best of your ability. Information about how to obtain this map, formally known as a Flood Insurance Rate Map (FIRM) is available at www.fema.gov, insurance agencies or county government offices. A site specific analysis may be substituted.

☒ FEMA map or site-specific analysis attached. **See Appendix J for Map #2 which includes the 100-year flood plain coverage.**

☐ Previously submitted and still up-to-date. Submittal date(s): _____

C-5. **Soils.** Attach either:

a) A copy of the appropriate Natural Resource Conservation Service (NRCS) soil survey map, with your site clearly identified to the best of your ability. Include the descriptive information for soils associated with the discharge locations. To obtain the map, contact your local NRCS office – there is one in every county.

b) A site-specific assessment showing the soils classifications. This is preferred over the more generalized NRCS surveys.

☒ NRCS soil survey or site-specific assessment attached.

- **See soil type descriptions in Appendix F.**
- **See Appendix J for LANL Soils Map #3.**
- **See Appendix I for NRCS Soil Survey of Sandoval County Area, New Mexico, Parts of Los Alamos, Sandoval, and Rio Arriba Counties.**

☐ Previously submitted. Submittal date(s): _____

C-6. **Geology.** Provide information on the geology beneath the site by attaching relevant portions of geologic reports, well logs for on-site or nearby wells, or site specific assessments. A variety of geology publications and resources are available from the New Mexico Bureau of Geology and Mineral Resources at http://geoinfo.nmt.edu or 505-835-5420 (Socorro). Well logs are available from the New Mexico State Engineer's Office at http://www.ose.state.nm.us/.

☒ Geologic report attached. ☐ Well log(s) attached.

See Appendix F for bore hole locations and bore hole information for the following areas:

- **TA-50 RLWTF.**
- **TA-50-0250 (WMRM)**
- **Zero Liquid Discharge Solar Evaporation Tanks at TA-52**

See Appendix F for the Plan and Map Views of Stratigraphic Units Beneath MDA C.

☐ Geologic information previously submitted. Submittal date(s): _____

C-7. Ground Water Hydrology. Ground water hydrology refers to the occurrence, distribution, movement and chemistry of ground water. The ground water hydrology at your site will determine in large part whether your discharge will adversely affect ground water quality. You may need to present detailed information in order to "demonstrate that the Discharge Permit will not result in concentrations in excess of the standards of Section 20.6.2.3103 NMAC or the presence of any toxic pollutant." (20.2.3106.C.7 NMAC)

At a minimum, provide information below on the direction of ground water flow. Ground water may not flow in the same direction as water on the surface of the ground. A monitoring well survey is one of the best methods to determine the direction of ground water flow at a particular site. Such surveys are routinely required for many Discharge Permit locations.

If a survey is not available, check with well drillers, the city water department, staff at the Office of the State Engineer, environmental consultants or other knowledgeable persons in your area. In addition, relevant reports have been published for some areas. See the OSE website at www.ose.state.nm.us or the NMBGMR website at http://geoinfo.nmt.edu.

Direction of ground water flow: Southeast.

If ground water flow shifts seasonally, describe here: NA

Reference:

☐ On-site well survey attached. ☐ Previously submitted. Submittal date(s): _____

☐ Nearby well survey attached. ☐ Previously submitted. Submittal date(s): _____

☒ Other. Specify: **See Appendix I for (CD) containing the following LANL reports:**

1. **2009 Hydrogeologic Site Atlas. LAUR-09-3763.**
2. **Groundwater Level Status Report for 2010 Los Alamos National Laboratory. LA-14437-PR.**
3. **Los Alamos National Laboratory's Hydrogeologic Studies of the Pajarito Plateau: A Synthesis of Hydrogeologic Workplan Activities (1994-2004). LA-14263-MS.**
4. **Conceptual Models of Vadose Zone Flow and Transport Beneath the Pajarito Plateau, Los Alamos, New Mexico. Vadose Zone Journal.**
5. **2006 Mortandad Canyon Investigation Report. LA-UR-06-6752.**
6. **2011 Interim Facility-Wide Groundwater Monitoring Plan, Revision 1. LA-UR-11-6958.**

☐ Relevant portion attached.

☐ Previously submitted. Submittal date(s): _____

Attach any additional information available about ground water hydrology at the site.

C-8. Other Permitted Discharge Locations. If applicable, list other locations of wastewater or stormwater discharges on your site that are not described in this application and indicate what permits apply to them. Examples include discharges from small septic systems (covered by Liquid Waste Permits, discharges to surface waters under a NPDES permit, a discharge covered by a separate Discharge Permit, etc. Be sure these other discharge locations are identified on the site map required in Item B-3.

Discharge Type	Permit Identification
RLWTF (this application)	NPDES Permit No. NM028355 Outfall #051; GW Discharge Permit Application DP-1132
SWWS Plant	NPDES Permit No. NM028355 Outfall 13S; GW Discharge Permit DP-857
HEWTF	NPDES Permit No. NM028355 Outfall 05A055
Cooling Towers (7)	NPDES Permit No. NM028355 Outfalls 03A022, 03A027, 03A048, 03A113, 03A158, 03A160, 03A181
Power Plant	NPDES Permit No. NM028355 Outfall 001
Septic Systems (12)	GW Discharge Permit Application DP-1589
Stormwater from SWMUs	NPDES Individual Stormwater Permit NM0030759
Stormwater from Construction Sites	NPDES Stormwater Construction General Permit Program
Stormwater from Industrial Facilities	NPDES Stormwater Multi-Sector General Permit Program NMR05A734, NMR05A735

C-9. Other Information. Describe below or attach any additional information to demonstrate that your proposed discharge plan will be protective of ground water quality, public health and property.

APPENDIX A

LANL/NMED COMMUNICATIONS RE: DP-1132

TABLE OF CONTENTS

COPIES OF THE FOLLOWING LANL/NMED COMMUNICATIONS:

1. JANUARY 27, 2012, NMED LETTER RE: APPROVAL OF TIME EXTENSION TO SUBMIT APPLICATION, DP-1132, RADIOACTIVE LIQUID WASTE TREATMENT FACILITY (RLWTF)
2. JANUARY 17, 2012, LANL LETTER SUBJECT: REQUEST FOR CONSIDERATION OF SHORT TIME EXTENSION FOR SPECIFIC ITEMS FOR PERMIT APPLICATION DP-1132, RADIOACTIVE LIQUID WASTE TREATMENT FACILITY (RLWTF) AND ZERO LIQUID DISCHARGE EVAPORATIVE TANKS (ZLD)
3. DECEMBER 30, 2011, NMED LETTER RE: DENIAL OF TIME EXTENSION TO SUBMIT APPLICATION, DP-1132, RADIOACTIVE LIQUID WASTE TREATMENT FACILITY (RLWTF)
4. DECEMBER 7, 2011, LANL LETTER SUBJECT: REQUEST FOR AN EXTENSION TO SUBMIT AN UPDATED DISCHARGE PERMIT APPLICATION FOR THE RADIOACTIVE LIQUID WASTE TREATMENT FACILITY (DP-1132)
5. NOVEMBER 18, 2011, NMED LETTER RE: RESPONSE TO NOTICE OF INTENT TO DISCHARGE
6. AUGUST 11, 2011, LANL LETTER RE: SIXTY PERCENT DESIGN, EVAPORATION TANKS, TA-50 RADIOACTIVE LIQUID WASTE TREATMENT FACILITY
7. SEPTEMBER 15, 2008, LANL LETTER SUBJECT: REQUEST FOR ADDITIONAL INFORMATION, DP-1132, RADIOACTIVE LIQUID WASTE TREATMENT FACILITY
8. JUNE 11, 2008, NMED LETTER RE: REQUEST FOR ADDITIONAL INFORMATION, DP-1132, RADIOACTIVE LIQUID WASTE TREATMENT FACILITY
9. NOVEMBER 1, 2007, LANL LETTER SUBJECT: NOTICE OF INTENT TO DISCHARGE, EVAPORATION TANKS, TA-50 RADIOACTIVE LIQUID WASTE TREATMENT FACILITY

January 27, 2012, NMED Letter RE: Approval of Time Extension to Submit Application, DP-1132, Radioactive Liquid Waste Treatment Facility (RLWTF)

MS 1/31/12

NEW MEXICO
ENVIRONMENT DEPARTMENT

Resource Protection Division

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Governor
JOHN A. SANCHEZ
Lieutenant Governor

DAVE MARTIN
Cabinet Secretary
BUTCH TONGATE
Deputy Secretary
JAMES H. DAVIS, Ph.D.
Division Director

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

January 27, 2012

Anthony R. Grieggs, Group Leader
Environmental Protection Division
Water Quality & RCRA (ENV-RCRA)
P.O. Box 1663, Mail Stop K490
Los Alamos, NM 87545

RE: Approval of Time Extension to Submit Application, DP-1132, Radioactive Liquid Waste Treatment Facility (RLWTF)

Dear Mr. Grieggs:

On November 18, 2011, the New Mexico Environment Department (NMED) notified Los Alamos National Laboratory (LANL), by certified mail (copy enclosed), that a complete and current Discharge Permit application for the RLWTF was required to be submitted within 90 days (by February 16, 2012). On December 9, 2011, NMED received your request for a 90-day time extension to submit the required Discharge Permit application, which was denied on December 30, 2012. A request for a 45-day extension for submittal of certain portions of the application was submitted to NMED, via e-mail on January 18, 2012 (copy enclosed). LANL may not discharge to the Zero Liquid Discharge Evaporative Tanks prior to NMED's approval which may be delayed due to the timeframe in which a full application for the RLWTF is received and reviewed by NMED. **NMED hereby approves a 45-day extension (due by April 1, 2012) to submit the three elements specifically referenced in LANL's letter dated January 17, 2012. All other elements for the Discharge Permit application are required to be submitted to NMED by February 16, 2012.**

If you have any questions regarding this matter, please contact Clint Marshall, Program Manager of the Ground Water Pollution Prevention Section, at 505-827-0027 or Jennifer Fullam at 505-827-2909.

Sincerely,

James H. Davis, Ph.D.
Director, Resource Protection Division

JD:JF

enc: Letter from NMED to LANL requiring Discharge Permit application, dated November 18, 2011
E-mail (dated January 18, 2012) from Bob Beers, LANL, with attachment (dated January 17, 2012) requesting extension

cc: James Bearzi, NMED SWQB (w/o enclosures)
Richard Powell, NMED SWQB (w/o enclosures)
John Kieling, NMED HWB (w/o enclosures)
Steven Yanicak, NMED-DOE-Oversight Bureau (w/o enclosures)
Hai Shen, LASO-EO, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)
Gene Turner, LASO-EO, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)
Michael T. Brandt, ADESH, Los Alamos National Laboratory, K491, Los Alamos, NM 87545 (w/o enclosures)
Carl A. Beard, PADOPS, Los Alamos National Laboratory, A102, Los Alamos, NM 87545 (w/o enclosures)
J. Chris Cantwell, ADESHQ, Los Alamos National Laboratory, K491, Los Alamos, NM 87545 (w/o enclosures)
Randy Johnson, ENV-ES, Los Alamos National Laboratory, E500, Los Alamos, NM 87545 (w/o enclosures)
Michael Saladen ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos, NM 87545 (w/o enclosures)
Robert Mason, TA-55-DO, Los Alamos National Laboratory, E583, Los Alamos, NM 87545 (w/o enclosures)
Hugh McGovern, TA-55-RLW, Los Alamos National Laboratory, E518, Los Alamos, NM 87545 (w/o enclosures)
Pete Worland, TA-55-RLW, Los Alamos National Laboratory, E518, Los Alamos, NM 87545 (w/o enclosures)

Susan L. McMichael, LC-LESH, Los Alamos National Laboratory, A187, Los Alamos, NM 87545 (w/o enclosures)

Bob Beers, ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos NM, 87545 (w/ enclosures)

Jon Block, Staff Attorney, New Mexico Environmental Law Center, 1405 Luisa Street, Ste. 5, Santa Fe, NM 87505(w/ enclosures)

Joni Arends, Executive Director, Concerned Citizens for Nuclear Safety, 107 Cienega Street, Santa, Fe, NM 87501(w/ enclosures)

January 17, 2012, LANL Letter Subject: Request For Consideration of Short Time Extension For Specific Items for Permit Application DP-1132, Radioactive Liquid Waste Treatment Facility (RLWTF) and Zero Liquid Discharge Evaporation Tanks (ZLD)

Environmental Safety & Health
Environmental Protection Division
P.O. Box 1663, K491
Los Alamos, New Mexico 87545
(505) 665-6952FAX (505) 665-3811

National Nuclear Security Administration
Los Alamos Site Office, A316
3747 West Jemez Road
Los Alamos, New Mexico 87545
(505) 667-5794/FAX (505) 667-5948

Date: January 17, 2012
Refer To: ENV-DO-12-0001
LAUR: 12-10069

Mr. James H. Davis, Director
Resource Protection Division
New Mexico Environment Department
Harold Runnels Building
1190 St. Francis Drive
P.O. Box 5469
Santa Fe, NM 87502-5469

Dear Mr. Davis:

SUBJECT: REQUEST FOR CONSIDERATION OF SHORT TIME EXTENSION FOR SPECIFIC ITEMS FOR PERMIT APPLICATION DP-1132, RADIOACTIVE LIQUID WASTE TREATMENT FACILITY (RLWTF) AND ZERO LIQUID DISCHARGE EVAPORATIVE TANKS (ZLD)

On January 3, 2012, the National Nuclear Security Administration (NNSA) and Los Alamos National Security, LLC (LANS) for the Los Alamos National Laboratory received your response denying our request to extend the deadline to submit a Discharge Permit (DP) application for the RLWTF and the proposed Zero Liquid Discharge Evaporative Tanks (ZLD). This request followed your November 19, 2011 letter requiring NNSA/LANS to submit a comprehensive and up-to-date permit DP application by February 16, 2012 for RLWTF, and to include the ZLD tanks in this application. NNSA/LANS fully supports your intent to advance the permit process, and recognize that submittal of the updated permit application is the first step towards timely permit review and issuance. With this in mind, we have thoroughly reviewed the detailed list of 19 items and the additional information required by the permit application in your November 19, 2011 letter. Our review has concluded that with additional resources and significant effort, we can commit to deliver the majority of the requested items by February 16, 2012. However, for the following reasons, we respectfully request that you consider providing us a short 45-day extension until April 3, 2012 to submit the following limited items described below:

- Proposed processes for the operation, inspection and maintenance for the facility as it pertains to collection lines, treatment units and effluent storage disposal units

- Procedures and corrective actions for addressing acute failures and long-term maintenance issues at the facility
- Proposed groundwater monitoring locations for ground water sources most likely to be impacted by intentional and unintentional discharges from the RLWTF. The proposal should identify geohydrology of the potentially impacted areas, existing monitoring well locations and construction.

The above technical documents pertain to existing procedures for RLWTF which will require significant review and coordination among differing groups at the facility. Procedures for the planned ZLD tanks have not been developed. Construction of the ZLD tanks is estimated for the summer of 2012. Procedures will be available prior to operation of the ZLD system. Further, as a practical matter, these procedures must undergo LANL's unique institutional security review which requires final procedures to be submitted for review at least a week prior to public release. Additionally, we discussed with NMED staff the challenges of traditional groundwater monitoring approaches for the RLWTF and ZLD tanks in the context of the Laboratory's complex hydrogeology, and understand that an alternate approach to groundwater monitoring should be presented in the DP application. Development of this approach for inclusion into the application will require additional resources and time. We are hopeful that the additional requested time will enable us to submit a complete permit application, and will facilitate permit review and timely permit issuance.

Thank you for your consideration of our request. If you need additional information, feel free to contact Robert Beers, LANS at (505) 667-7969 or Gene Turner, NNSA at (505) 667-5794 if you need additional information concerning the status of the Laboratory's corrective action activities.

Sincerely,

Alison Dorries
Division Leader
Environmental Protection Division
Los Alamos National Laboratory

Sincerely,

Gene E. Turner
Environmental Permitting Manager
Environmental Projects Office
Los Alamos Site Office
National Nuclear Security Administration

AD:MS:GET/lm

Cy: Hai Shen, LASO-EO, A316
Gene Turner, LASO-EO, A316
Steve Yanicak, LASO-GOV, M894
Carl A. Beard, PADOPS, A102
Michael T. Brandt, ADESH, K491
Alison Dorries, ENV-DO, K491
Scotty Jones, ENV-DO, K491

Cy (continued):
Randy Johnson, ENV-ES, E500
Mike Saladen, ENV-RCRA, K490, (E-File)
Robert Beers, ENV-RCRA, K490
Robert C. Mason, TA-55-DO, E583
Clifford Kirkland, TA-55 RLW, E518
Chris Del Signore, TA-55-RLW, E518
Susan L. McMichael, LC-LESH, A187
Lisa Cummings, LASO-OC, A316
Jonathan M. Block, NMELC, Santa Fe, NM
Charles de Saillan, NMED, Santa Fe, NM
Taylor, Valdez, ENV-DO, K404, (E-File)
ENV-RCRA File, (12-0013) w/enc., M704
IRM-RMMSO, w/enc., A150

December 30, 2011, NMED Letter RE: Denial of Time Extension To Submit Application, DP-1132, Radioactive Liquid Waste Treatment Facility (RLWTF)

NEW MEXICO
ENVIRONMENT DEPARTMENT

Resource Protection Division

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James H. Davis, Ph.D.

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Governor
JOHN A. SANCHEZ
Lieutenant Governor

DAVE MARTIN
Cabinet Secretary
BUTCH TONGATE
Deputy Secretary
JAMES H. DAVIS, Ph.D.
Division Director

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

December 30, 2011

Anthony R. Grieggs, Group Leader
Environmental Protection Division
Water Quality & RCRA (ENV-RCRA)
P.O. Box 1663, Mail Stop K490
Los Alamos, NM 87545

RE: Denial of Time Extension to Submit Application, DP-1132, Radioactive Liquid Waste Treatment Facility (RLWTF)

Dear Mr. Grieggs:

On November 18, 2011, the New Mexico Environment Department (NMED) notified Los Alamos National Laboratory (LANL), by certified mail (copy enclosed), that a complete and current Discharge Permit application for the RLWTF was required to be submitted within 90 days (by February 16, 2011). On December 9, 2011, NMED received your request for a time extension to complete the required Discharge Permit application (copy enclosed). NMED is determined to advance the permitting process in a timely manner. With that in mind, an extension of the deadline for the submission of an application would only prolong and perhaps inhibit the facility's ability to implement and discharge to the proposed Zero Liquid Discharge Evaporative Tanks (ZLD). **NMED therefore denies the time extension for submission of the Discharge Permit application.**

In order to effectively and efficiently process the Discharge Permit application, NMED provided a list of elements which should be included in the submittal. Mr. Robert Beers, with Los Alamos National Laboratory, has requested a meeting with NMED to discuss the specific elements in NMED's November 18, 2011 letter to ensure the application is submitted in its entirety and to prevent further delays in the permitting process. NMED remains committed to working with LANL to clarify the specific elements that must be addressed in the application and is planning to meet with LANL staff within the first two weeks of January. It is anticipated that the outcome of the technical discussion will provide constructive information which will advance the application process.

If you have any questions regarding this matter, please contact Clint Marshall, Acting Program Manager of the Ground Water Pollution Prevention Section, at 505-827-0027 or Jennifer Fullam at 505-827-2909.

'12 JAN 3 PM3:19:24

Sincerely,

James H. Davis, Ph.D.
Director, Resource Protection Division

JD:JF

enc: Letter from NMED to LANL requiring Discharge Permit application, dated November 18, 2011
Letter from LANL to NMED requesting extension, dated December 9, 2011, NMED

cc: James Bearzi, NMED SWQB (w/o enclosures)
Richard Powell, NMED SWQB (w/o enclosures)
John Kieling, NMED HWB (w/o enclosures)
Steven Yanicak, NMED-DOE-Oversight Bureau (w/o enclosures)
Hai Shen, LASO-EO, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)
Gene Turner, LASO-EO, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)
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Bob Beers, ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos NM, 87545 (w/ enclosures)

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RESOURCE PROTECTION DIVISION

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Environmental Protection Division
Water Quality & RCRA Group (ENV-RCRA)
P.O. Box 1663, Mail Stop M704
Los Alamos, New Mexico 87545
(505) 667-0666/FAX: (505) 667-5224

Date: December 7, 2011
Refer To: ENV-RCRA-11-0270
LAUR: 11-12157

Mr. James H. Davis, Director
Resource Protection Division
New Mexico Environment Department
Harold Runnels Building
1190 St. Francis Drive
P.O. Box 5469
Santa Fe, NM 87502-5469

Dear Mr. Davis:

SUBJECT: REQUEST FOR AN EXTENSION TO SUBMIT AN UPDATED DISCHARGE PERMIT APPLICATION FOR THE RADIOACTIVE LIQUID WASTE TREATMENT FACILITY (DP-1132)

The US Department of Energy and Los Alamos National Security, LLC (DOE/LANS) are in receipt of your November 18, 2011, letter (Enclosure 1) requiring a comprehensive and up-to-date Discharge Permit application for the Radioactive Liquid Waste Treatment Facility (RLWTF) within 90 days of the letter's date (by February 16, 2012). For reasons explained below, DOE/LANS request an additional 90 days to prepare a Discharge Permit application for the RLWTF.

DOE/LANS have appreciated working with you and your staff on this matter. The goal is to submit a new Discharge Permit application for the RLWTF that is complete and satisfactory at the time of submittal. Addressing each of the 19 bullets listed in the above-referenced letter will require a significant level of effort by DOE/LANS technical staff. Further, the administrative record identified in the letter will need to be carefully reviewed, and supplemented as appropriate. Meetings between our respective representatives will be needed to ensure the information provided is responsive and focused correctly. For these reasons and because the Laboratory is closed during the holiday season, DOE/LANS respectfully request an extension of the application deadline to May 16, 2012.

Please contact Bob Beers at (505) 667-7969 if you have questions regarding this request.

Sincerely,

A R Grieggs

Anthony R. Grieggs
Group Leader
Water Quality & RCRA Group

Enclosures: a/s

Cy: ✓Hai Shen, LASO-EO, A316
✓Gene Turner, LASO-EO, A316
✓Steve Yanicak, LASO-GOV, M894
✓Carl A. Beard, PADOPS, A102
✓Michael T. Brandt, ADESH, K491
✓Randy Johnson, ENV-ES, E500
✓Mike Saladen, ENV-RCRA, K490, (E-File)
✓Robert Beers, ENV-RCRA, K490, (E-File)
✓Robert C. Mason, TA55-DO, E583
✓Hugh McGovern, TA-55 RLW, E518
✓Pete Worland, TA-55-RLW, E518
✓Susan L. McMichael, LC-LESH, A187
ENV-RCRA File, M704
IRM-RMMSO, A150

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Deputy Secretary
JAMES H. DAVIS, Ph.D.
Division Director

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

November 18, 2011



Anthony R. Grieggs, Group Leader
Environmental Protection Division
Water Quality & RCRA (ENV-RCRA)
P.O. Box 1663, Mail Stop K490
Los Alamos, NM 87545

RE: Response to Notice of Intent to Discharge and Discharge Permit Required for Zero Liquid Discharge Tanks, AI 856: PRD20070004 and Updated Application Submittal Required for the Radioactive Liquid Waste Treatment Facility (RLWTF), DP-1132

Dear Mr. Grieggs:

The Ground Water Quality Bureau of the New Mexico Environment Department (NMED) received a Notice of Intent from Los Alamos National Laboratory (LANL) on November 8, 2007 for the facility referenced above. NMED responded in writing with a request for additional information which required LANL to submit 60% plans and specifications for the proposed structure, information pertaining to ground water which may be impacted should a release occur, operation and maintenance procedures for the tanks, information on the potential concentration of the wastestream due to evaporation, and seismic studies for the area in which the tanks are to be constructed. NMED received a response to the requested information from LANL on September 15, 2008 which provided most of the requested information and stated that plans and specifications would be submitted once available. NMED received the plans and specifications for the evaporative tanks on August 19, 2011 along with an addendum dated October 19, 2011. The notice describes LANL's intent to discharge up to 3.6 million gallons annually of treated effluent from the RLWTF to two evaporative concrete tanks equipped with synthetic liners and leak detection systems. The total operating volume of the tanks is approximately 754,036 gallons (100,800 cubic feet). The notice, along with the subsequent information submitted upon NMED's request, satisfies the requirements of Subsection A of 20.6.2.1201 New Mexico Administrative Code (NMAC) of the New Mexico Water Quality Control Commission (WQCC) Regulations, 20.6.2 NMAC. The proposed discharge is located within the boundaries of Los Alamos National Laboratory at

35°51'37"N, 106°16'57"W, approximately 2.5 miles southeast of Los Alamos in Section 23, Township 19N, Range 06E, Los Alamos County.

NMED has reviewed the information provided in accordance with Subsection D of 20.6.2.1201 NMAC and because the proposed evaporative tanks contain an effluent or leachate which may move directly or indirectly into ground water, NMED has determined that **a Discharge Permit is required for the proposed discharge.** NMED considers the proposed evaporative tanks to be a component of the RLWTF, therefore they must be included in the Discharge Permit for this facility.

Any appeal of this determination that a Discharge Permit is required must be made to the New Mexico WQCC within 30 days of receipt of this letter, in accordance with Subsection B of 20.6.2.3112 NMAC. A copy of the WQCC Regulations, 20.6.2 NMAC, is available at http://www.nmcpr.state.nm.us/nmac/_title20/T20C006.htm.

Upon further review of the file for the RLWTF, NMED has noted the following:

- An application for a Discharge Permit was submitted to NMED on April 16, 1996 for the discharge of 41,770 gallons per day of treated low level radioactive wastewater from the RLWTF to a tributary of Mortandad Canyon (referred to as Effluent Canyon).
- The application identified potential upgrades to the system which were to enhance the treatment process and provide alternate discharge capabilities for the facility.
- The treated effluent from the RLWTF is currently authorized to be discharged to an outfall (Outfall 051) under a United States Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) Permit (NM0028355) last issued on August 1, 2007, and subsequently modified on July 17, 2007, May 13, 2011, and October 11, 2011.
- Numerous Notices of Planned Changes have been submitted to EPA for treatment system upgrades and facility changes under the NPDES Permit for Outfall 051. Copies of these notices were submitted to NMED on the following dates: April 21, 1998, March 18, 1999, April 3, 2000, June 13, 2000, May 7, 2002, March 14, 2003, April 18, 2003, January 12, 2004, May 14, 2007, May 6, 2008, August 19, 2010, September 16, 2010, and February 23, 2011.
- In addition to the Notices of Planned Changes, numerous notices concerning minor modifications to the facility have been submitted to NMED as addendums to the original Discharge Permit application. NMED received copies of these submissions which were dated March 23, 1999, December 8, 2000, November 8, 2007, August 25, 2010, September 27, 2010, December 15, 2010, and March 22, 2011.
- NMED has engaged in numerous meetings, inspections and written correspondence regarding the RLWTF in order to compile accurate information on the facility in preparation for drafting a Discharge Permit that will accurately reflect the activities conducted at the RLWTF.
- In September 2003, a draft of Discharge Permit DP-1132 was sent to LANL which was subsequently Public Noticed on April 18, 2005, beginning a 30-day comment period.
- On April 27, 2005, in response to multiple requests from interested parties, a second public comment period was granted on the proposed Discharge Permit (extending the comment period for approximately 90 days, until August 4, 2005).

- NMED received comments and requests for a public hearing regarding the draft Discharge Permit from both interested parties and LANL.
- Through continued discussions with LANL, correspondence, site inspections and the above referenced Notice of Intent, it has become apparent that the facility has significantly modified treatment processes, discharge volumes and locations of the discharge when compared to the original application submitted to NMED on August 16, 1996.
- As it pertains to any future Discharge Permits to be issued by the NMED Ground Water Quality Bureau (GWQB), this *facility* has been determined to include the central influent collection lines leading to the RLWTF, all components which are part of the wastewater treatment process and all locations where the treated wastewater is disposed, including all surface discharges as well as non-surface discharges such as evaporative tanks (as described in the above referenced Notice of Intent). This determination by the NMED-GWQB is based on information provided in the original application for a Discharge Permit along with subsequent information provided to NMED by LANL.

Given the extensive and fractured exchange of information concerning this facility, along with changes at the RLWTF that have occurred during the lengthy permitting process and planned future changes, NMED views LANL's August 16, 1996 Discharge Permit application to be inconsistent with the current and planned discharge activities associated with the RLWTF. **Therefore, NMED requires that LANL submit a comprehensive and up-to-date Discharge Permit application for the RLWTF within 90 days of the date of this letter (by February 16, 2011).**

When submitted, the application (copy enclosed) should be completed in its entirety and specifically address the following:

- The estimated volumes, sources (technical area and building) and wastestream characteristics of all influent wastewater that LANL receives, or intends to receive, at the RLWTF.
- A description of the conveyance methods used to transport wastewater to the RLWTF for each source.
- A description of waste characterization and metering systems used to determine influent wastestream characteristics and volumes entering the RLWTF.
- A description of the review and amendment process for LANL's internal Waste Acceptance Criteria (WAC) for all incoming wastewater received at the RLWTF. This should include LANL's process for ensuring the WAC relates to the current treatment technologies and processes.
- A description of operational procedures for receiving wastes from each generator.
- A schematic of the treatment process in its entirety for each wastestream (from collection to final disposal).
- Descriptions, locations, construction materials and sizing for each component of the treatment processes for each type of wastestream being treated at the RLWTF.
- Descriptions, locations and designs for all secondary storage and auxillary emergency units intended to receive, treat or store wastewater received at the facility.
- Proposed processes for the operation, inspection and maintenance for the facility as it pertains to the collection lines, treatment units and effluent storage disposal units.
- Procedures and corrective actions for addressing acute failures at the facility.
- Procedures and corrective actions for addressing long-term maintenance issues at the facility.

- Record drawings for all components of the facility, if available.
- Construction plans and specifications for all components of the facility which are under construction or are proposed for construction.
- A proposed effluent monitoring plan, identifying analytes and sample locations/frequency. The proposal should consider discharge frequencies, incoming waste characteristics and the constituents listed under 20.6.2.3103 NMAC and Subsection WW of 20.6.2.7 NMAC.
- Proposed flow and metering systems used to determine effluent discharge volumes for each of the discharge locations.
- Proposed ground water monitoring locations for ground water sources most likely to be impacted by intentional and unintentional discharges from the RLWTF. The proposal should identify geohydrology of the potentially impacted areas, existing monitoring well locations and construction.
- Actions which LANL would implement should partial or full closure of the facility occur.
- A scaled facility plan showing the facility's components including influent collection lines, storage units, major treatment units and disposal units.
- All other information sought in NMED's application for Discharge Permit Sections A through C. Please note that for the purposes of public notification, the "discharge site" as it relates to this facility encompasses the central collection system lines, the treatment and storage facilities and all discharge locations for the treated effluent.

When submitting the comprehensive and up-to-date Discharge Permit application, you must complete and submit three copies along with the $100 filing fee.

If you have any questions, please contact either Jennifer Fullam at (505) 827-2909 or Clint Marshall, Acting Program Manager of the Ground Water Pollution Prevention Section, at (505) 827-0027.

Sincerely,

James H. Davis, Ph.D.
Director, Resource Protection Division

JD:JF

Enc: Applying for a Discharge Permit: General Information
Discharge Permit Application

cc: Robert Italiano, District Manager, NMED District II (w/o enclosures)
NMED Santa Fe Field Office (w/o enclosures)
DP Required File (w/o enclosures)
James Bearzi, NMED SWQB (w/o enclosures)
Richard Powell, NMED SWQB (w/o enclosures)
John Kieling, NMED HWB (w/o enclosures)
Steven Yanicak, NMED-DOE-Oversight Bureau (w/o enclosures)

Hai Shen, LASO-EO, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)

Gene Turner, LASO-EO, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)

Eric Trujillo, LASO-NSM, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)

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Pete Worland, TA-55-RLW, Los Alamos National Laboratory, E518, Los Alamos, NM 87545 (w/o enclosures)

Keith Orr, PMF-FUNCT, Los Alamos National Laboratory, M984, Los Alamos, NM 87545 (w/o enclosures)

Roy Maestas, CM-STRS, Los Alamos National Laboratory, P299, Los Alamos, NM 87545 (w/o enclosures)

Joe Brophy, PMF-FUNCT Los Alamos National Laboratory, P137, Los Alamos, NM 87545 (w/o enclosures)

Ed Artiglia, ES-PE, Los Alamos National Laboratory, P137, Los Alamos, NM 87545 (w/o enclosures)

Bob Beers, ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos NM, 87545 (w/ enclosures)

December 7, 2011, LANL Letter Subject: Request For An Extension To Submit An Updated Discharge Permit Application For the Radioactive Liquid Waste Treatment Facility (DP-1132)

Los Alamos
NATIONAL LABORATORY
EST. 1943

Environmental Protection Division
Water Quality & RCRA Group (ENV-RCRA)
P.O. Box 1663, Mail Stop M704
Los Alamos, New Mexico 87545
(505) 667-0666/FAX: (505) 667-5224

Date: December 7, 2011
Refer To: ENV-RCRA-11-0270
LAUR: 11-12157

Mr. James H. Davis, Director
Resource Protection Division
New Mexico Environment Department
Harold Runnels Building
1190 St. Francis Drive
P.O. Box 5469
Santa Fe, NM 87502-5469

Dear Mr. Davis:

SUBJECT: REQUEST FOR AN EXTENSION TO SUBMIT AN UPDATED DISCHARGE PERMIT APPLICATION FOR THE RADIOACTIVE LIQUID WASTE TREATMENT FACILITY (DP-1132)

The US Department of Energy and Los Alamos National Security, LLC (DOE/LANS) are in receipt of your November 18, 2011, letter (Enclosure 1) requiring a comprehensive and up-to-date Discharge Permit application for the Radioactive Liquid Waste Treatment Facility (RLWTF) within 90 days of the letter's date (by February 16, 2012). For reasons explained below, DOE/LANS request an additional 90 days to prepare a Discharge Permit application for the RLWTF.

DOE/LANS have appreciated working with you and your staff on this matter. The goal is to submit a new Discharge Permit application for the RLWTF that is complete and satisfactory at the time of submittal. Addressing each of the 19 bullets listed in the above-referenced letter will require a significant level of effort by DOE/LANS technical staff. Further, the administrative record identified in the letter will need to be carefully reviewed, and supplemented as appropriate. Meetings between our respective representatives will be needed to ensure the information provided is responsive and focused correctly. For these reasons and because the Laboratory is closed during the holiday season, DOE/LANS respectfully request an extension of the application deadline to May 16, 2012.

Please contact Bob Beers at (505) 667-7969 if you have questions regarding this request.

Sincerely,

A R Grieggs

Anthony R. Grieggs
Group Leader
Water Quality & RCRA Group

Enclosures: a/s

Cy: Hai Shen, LASO-EO, A316
Gene Turner, LASO-EO, A316
Steve Yanicak, LASO-GOV, M894
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Robert Beers, ENV-RCRA, K490, (E-File)
Robert C. Mason, TA55-DO, E583
Hugh McGovern, TA-55 RLW, E518
Pete Worland, TA-55-RLW, E518
Susan L. McMichael, LC-LESH, A187
ENV-RCRA File, M704
IRM-RMMSO, A150

NEW MEXICO
ENVIRONMENT DEPARTMENT

Resource Protection Division

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James H. Davis, Ph.D.

SUSANNA MARTINEZ
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JAMES H. DAVIS, Ph.D.
Division Director

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

November 18, 2011

U1102277
IRM RMMSO Record Copy

Anthony R. Grieggs, Group Leader
Environmental Protection Division
Water Quality & RCRA (ENV-RCRA)
P.O. Box 1663, Mail Stop K490
Los Alamos, NM 87545

RE: Response to Notice of Intent to Discharge and Discharge Permit Required for Zero Liquid Discharge Tanks, AI 856: PRD20070004 and Updated Application Submittal Required for the Radioactive Liquid Waste Treatment Facility (RLWTF), DP-1132

Dear Mr. Grieggs:

The Ground Water Quality Bureau of the New Mexico Environment Department (NMED) received a Notice of Intent from Los Alamos National Laboratory (LANL) on November 8, 2007 for the facility referenced above. NMED responded in writing with a request for additional information which required LANL to submit 60% plans and specifications for the proposed structure, information pertaining to ground water which may be impacted should a release occur, operation and maintenance procedures for the tanks, information on the potential concentration of the wastestream due to evaporation, and seismic studies for the area in which the tanks are to be constructed. NMED received a response to the requested information from LANL on September 15, 2008 which provided most of the requested information and stated that plans and specifications would be submitted once available. NMED received the plans and specifications for the evaporative tanks on August 19, 2011 along with an addendum dated October 19, 2011. The notice describes LANL's intent to discharge up to 3.6 million gallons annually of treated effluent from the RLWTF to two evaporative concrete tanks equipped with synthetic liners and leak detection systems. The total operating volume of the tanks is approximately 754,036 gallons (100,800 cubic feet). The notice, along with the subsequent information submitted upon NMED's request, satisfies the requirements of Subsection A of 20.6.2.1201 New Mexico Administrative Code (NMAC) of the New Mexico Water Quality Control Commission (WQCC) Regulations, 20.6.2 NMAC. The proposed discharge is located within the boundaries of Los Alamos National Laboratory at

35°51'37"N, 106°16'57"W, approximately 2.5 miles southeast of Los Alamos in Section 23, Township 19N, Range 06E, Los Alamos County.

NMED has reviewed the information provided in accordance with Subsection D of 20.6.2.1201 NMAC and because the proposed evaporative tanks contain an effluent or leachate which may move directly or indirectly into ground water, NMED has determined that **a Discharge Permit is required for the proposed discharge.** NMED considers the proposed evaporative tanks to be a component of the RLWTF, therefore they must be included in the Discharge Permit for this facility.

Any appeal of this determination that a Discharge Permit is required must be made to the New Mexico WQCC within 30 days of receipt of this letter, in accordance with Subsection B of 20.6.2.3112 NMAC. A copy of the WQCC Regulations, 20.6.2 NMAC, is available at http://www.nmcpr.state.nm.us/nmac/_title20/T20C006.htm.

Upon further review of the file for the RLWTF, NMED has noted the following:

- An application for a Discharge Permit was submitted to NMED on April 16, 1996 for the discharge of 41,770 gallons per day of treated low level radioactive wastewater from the RLWTF to a tributary of Mortandad Canyon (referred to as Effluent Canyon).
- The application identified potential upgrades to the system which were to enhance the treatment process and provide alternate discharge capabilities for the facility.
- The treated effluent from the RLWTF is currently authorized to be discharged to an outfall (Outfall 051) under a United States Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) Permit (NM0028355) last issued on August 1, 2007, and subsequently modified on July 17, 2007, May 13, 2011, and October 11, 2011.
- Numerous Notices of Planned Changes have been submitted to EPA for treatment system upgrades and facility changes under the NPDES Permit for Outfall 051. Copies of these notices were submitted to NMED on the following dates: April 21, 1998, March 18, 1999, April 3, 2000, June 13, 2000, May 7, 2002, March 14, 2003, April 18, 2003, January 12, 2004, May 14, 2007, May 6, 2008, August 19, 2010, September 16, 2010, and February 23, 2011.
- In addition to the Notices of Planned Changes, numerous notices concerning minor modifications to the facility have been submitted to NMED as addendums to the original Discharge Permit application. NMED received copies of these submissions which were dated March 23, 1999, December 8, 2000, November 8, 2007, August 25, 2010, September 27, 2010, December 15, 2010, and March 22, 2011.
- NMED has engaged in numerous meetings, inspections and written correspondence regarding the RLWTF in order to compile accurate information on the facility in preparation for drafting a Discharge Permit that will accurately reflect the activities conducted at the RLWTF.
- In September 2003, a draft of Discharge Permit DP-1132 was sent to LANL which was subsequently Public Noticed on April 18, 2005, beginning a 30-day comment period.
- On April 27, 2005, in response to multiple requests from interested parties, a second public comment period was granted on the proposed Discharge Permit (extending the comment period for approximately 90 days, until August 4, 2005).

- NMED received comments and requests for a public hearing regarding the draft Discharge Permit from both interested parties and LANL.
- Through continued discussions with LANL, correspondence, site inspections and the above referenced Notice of Intent, it has become apparent that the facility has significantly modified treatment processes, discharge volumes and locations of the discharge when compared to the original application submitted to NMED on August 16, 1996.
- As it pertains to any future Discharge Permits to be issued by the NMED Ground Water Quality Bureau (GWQB), this *facility* has been determined to include the central influent collection lines leading to the RLWTF, all components which are part of the wastewater treatment process and all locations where the treated wastewater is disposed, including all surface discharges as well as non-surface discharges such as evaporative tanks (as described in the above referenced Notice of Intent). This determination by the NMED-GWQB is based on information provided in the original application for a Discharge Permit along with subsequent information provided to NMED by LANL.

Given the extensive and fractured exchange of information concerning this facility, along with changes at the RLWTF that have occurred during the lengthy permitting process and planned future changes, NMED views LANL's August 16, 1996 Discharge Permit application to be inconsistent with the current and planned discharge activities associated with the RLWTF. **Therefore, NMED requires that LANL submit a comprehensive and up-to-date Discharge Permit application for the RLWTF within 90 days of the date of this letter (by February 16, 2011).**

When submitted, the application (copy enclosed) should be completed in its entirety and specifically address the following:

- The estimated volumes, sources (technical area and building) and wastestream characteristics of all influent wastewater that LANL receives, or intends to receive, at the RLWTF.
- A description of the conveyance methods used to transport wastewater to the RLWTF for each source.
- A description of waste characterization and metering systems used to determine influent wastestream characteristics and volumes entering the RLWTF.
- A description of the review and amendment process for LANL's internal Waste Acceptance Criteria (WAC) for all incoming wastewater received at the RLWTF. This should include LANL's process for ensuring the WAC relates to the current treatment technologies and processes.
- A description of operational procedures for receiving wastes from each generator.
- A schematic of the treatment process in its entirety for each wastestream (from collection to final disposal).
- Descriptions, locations, construction materials and sizing for each component of the treatment processes for each type of wastestream being treated at the RLWTF.
- Descriptions, locations and designs for all secondary storage and auxillary emergency units intended to receive, treat or store wastewater received at the facility.
- Proposed processes for the operation, inspection and maintenance for the facility as it pertains to the collection lines, treatment units and effluent storage disposal units.
- Procedures and corrective actions for addressing acute failures at the facility.
- Procedures and corrective actions for addressing long-term maintenance issues at the facility.

- Record drawings for all components of the facility, if available.
- Construction plans and specifications for all components of the facility which are under construction or are proposed for construction.
- A proposed effluent monitoring plan, identifying analytes and sample locations/frequency. The proposal should consider discharge frequencies, incoming waste characteristics and the constituents listed under 20.6.2.3103 NMAC and Subsection WW of 20.6.2.7 NMAC.
- Proposed flow and metering systems used to determine effluent discharge volumes for each of the discharge locations.
- Proposed ground water monitoring locations for ground water sources most likely to be impacted by intentional and unintentional discharges from the RLWTF. The proposal should identify geohydrology of the potentially impacted areas, existing monitoring well locations and construction.
- Actions which LANL would implement should partial or full closure of the facility occur.
- A scaled facility plan showing the facility's components including influent collection lines, storage units, major treatment units and disposal units.
- All other information sought in NMED's application for Discharge Permit Sections A through C. Please note that for the purposes of public notification, the "discharge site" as it relates to this facility encompasses the central collection system lines, the treatment and storage facilities and all discharge locations for the treated effluent.

When submitting the comprehensive and up-to-date Discharge Permit application, you must complete and submit three copies along with the $100 filing fee.

If you have any questions, please contact either Jennifer Fullam at (505) 827-2909 or Clint Marshall, Acting Program Manager of the Ground Water Pollution Prevention Section, at (505) 827-0027.

Sincerely,

James H. Davis, Ph.D.
Director, Resource Protection Division

JD:JF

Enc: Applying for a Discharge Permit: General Information
Discharge Permit Application

cc: Robert Italiano, District Manager, NMED District II (w/o enclosures)
NMED Santa Fe Field Office (w/o enclosures)
DP Required File (w/o enclosures)
James Bearzi, NMED SWQB (w/o enclosures)
Richard Powell, NMED SWQB (w/o enclosures)
John Kieling, NMED HWB (w/o enclosures)
Steven Yanicak, NMED-DOE-Oversight Bureau (w/o enclosures)

Hai Shen, LASO-EO, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)

Gene Turner, LASO-EO, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)

Eric Trujillo, LASO-NSM, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)

Carl A. Beard, PADOPS, Los Alamos National Laboratory, A102, Los Alamos, NM 87545 (w/o enclosures)

J. Chris Cantwell, ADESHQ, Los Alamos National Laboratory, K491, Los Alamos, NM 87545 (w/o enclosures)

Randy Johnson, ENV-ES, Los Alamos National Laboratory, E500, Los Alamos, NM 87545 (w/o enclosures)

Michael Saladen ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos, NM 87545 (w/o enclosures)

Robert Mason, TA-55-DO, Los Alamos National Laboratory, E583, Los Alamos, NM 87545 (w/o enclosures)

Hugh McGovern, TA-55-RLW, Los Alamos National Laboratory, E518, Los Alamos, NM 87545 (w/o enclosures)

Pete Worland, TA-55-RLW, Los Alamos National Laboratory, E518, Los Alamos, NM 87545 (w/o enclosures)

Keith Orr, PMF-FUNCT, Los Alamos National Laboratory, M984, Los Alamos, NM 87545 (w/o enclosures)

Roy Maestas, CM-STRS, Los Alamos National Laboratory, P299, Los Alamos, NM 87545 (w/o enclosures)

Joe Brophy, PMF-FUNCT Los Alamos National Laboratory, P137, Los Alamos, NM 87545 (w/o enclosures)

Ed Artiglia, ES-PE, Los Alamos National Laboratory, P137, Los Alamos, NM 87545 (w/o enclosures)

Bob Beers, ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos NM, 87545 (w/ enclosures)

External Correspondence Traveler

Los Alamos NATIONAL LABORATORY EST.1943

Document Identification				
ESH&Q. #:		Enclosures:	Attachments:	LAUR No.
ENV-Group:	ENV-RCRA	Yes: ☐	Yes: ☐	11-12157
Doc. #:	11-0270	No: ☐	No: ☐	
Is this a response to an action item		Yes: ☐	No: ☐	
Email ☐		Document Date:	12/02/2011	
Memo ☐		Due Date:	N/A	
Letter ☐				

To:	Jim Davis
Subject:	Request for an Extension to Submit an Updated Discharge Permit Application for the Radioactive Liquid Waste Treatment Facility (DP-1132)
Action:	
Background / Issues	On November 18, 2011, the NMED requested a new Discharge Permit application from LANL for the TA-50 RLWTF. The NMED asked for the application within 90 days of the date of the letter; accordingly, the application deadline is February 16, 2012. Due to the complexity and scope of the application, and the upcoming holiday season, it will be difficult for LANL to submit a complete application by February 16, 2012. The attached letter is a request for a 90-day extension until May 16, 2012.

			Date
From (Ghost Writer)	Bob Beers		12/8/11
Author	Anthony R. Greiggs	ARG	12/8/11
Group Leader	Anthony R. Grieggs		
Deputy Group Leader	Tina Marie Sandoval		
Division Leader	Dennis L. Hjeresen	N/A	
ADC Review			
DUSA / SAFE-7			
LC-LESH Review	Susan McMichael	SMM	12/8/11 8:45
Coordinated with Facility or Program	Hugh McGovern		
	Gene Turner	verbal OK,	12/8/11 @ 2:45
	Mike Saladen		12/8/11

Comments: By COB 12/9/11

Hand Deliver: ☑ **Express Mail:** ☐ **FedEX:** ☐ **CRRR:** ☐ **Regular Mail Service:** ☐

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Time: 9:20	**Date:** 12/8/11	E File sent to WQ Team	

November 18, 2011, NMED Letter RE: Response to Notice of Intent To Discharge

NEW MEXICO
ENVIRONMENT DEPARTMENT

Resource Protection Division

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JAMES H. DAVIS, Ph.D.
Division Director

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

November 18, 2011

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Anthony R. Grieggs, Group Leader
Environmental Protection Division
Water Quality & RCRA (ENV-RCRA)
P.O. Box 1663, Mail Stop K490
Los Alamos, NM 87545

RE: Response to Notice of Intent to Discharge and Discharge Permit Required for Zero Liquid Discharge Tanks, AI 856: PRD20070004 and Updated Application Submittal Required for the Radioactive Liquid Waste Treatment Facility (RLWTF), DP-1132

Dear Mr. Grieggs:

The Ground Water Quality Bureau of the New Mexico Environment Department (NMED) received a Notice of Intent from Los Alamos National Laboratory (LANL) on November 8, 2007 for the facility referenced above. NMED responded in writing with a request for additional information which required LANL to submit 60% plans and specifications for the proposed structure, information pertaining to ground water which may be impacted should a release occur, operation and maintenance procedures for the tanks, information on the potential concentration of the wastestream due to evaporation, and seismic studies for the area in which the tanks are to be constructed. NMED received a response to the requested information from LANL on September 15, 2008 which provided most of the requested information and stated that plans and specifications would be submitted once available. NMED received the plans and specifications for the evaporative tanks on August 19, 2011 along with an addendum dated October 19, 2011. The notice describes LANL's intent to discharge up to 3.6 million gallons annually of treated effluent from the RLWTF to two evaporative concrete tanks equipped with synthetic liners and leak detection systems. The total operating volume of the tanks is approximately 754,036 gallons (100,800 cubic feet). The notice, along with the subsequent information submitted upon NMED's request, satisfies the requirements of Subsection A of 20.6.2.1201 New Mexico Administrative Code (NMAC) of the New Mexico Water Quality Control Commission (WQCC) Regulations, 20.6.2 NMAC. The proposed discharge is located within the boundaries of Los Alamos National Laboratory at

35°51'37"N, 106°16'57"W, approximately 2.5 miles southeast of Los Alamos in Section 23, Township 19N, Range 06E, Los Alamos County.

NMED has reviewed the information provided in accordance with Subsection D of 20.6.2.1201 NMAC and because the proposed evaporative tanks contain an effluent or leachate which may move directly or indirectly into ground water, NMED has determined that **a Discharge Permit is required for the proposed discharge.** NMED considers the proposed evaporative tanks to be a component of the RLWTF, therefore they must be included in the Discharge Permit for this facility.

Any appeal of this determination that a Discharge Permit is required must be made to the New Mexico WQCC within 30 days of receipt of this letter, in accordance with Subsection B of 20.6.2.3112 NMAC. A copy of the WQCC Regulations, 20.6.2 NMAC, is available at http://www.nmcpr.state.nm.us/nmac/_title20/T20C006.htm.

Upon further review of the file for the RLWTF, NMED has noted the following:

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- The application identified potential upgrades to the system which were to enhance the treatment process and provide alternate discharge capabilities for the facility.
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- As it pertains to any future Discharge Permits to be issued by the NMED Ground Water Quality Bureau (GWQB), this *facility* has been determined to include the central influent collection lines leading to the RLWTF, all components which are part of the wastewater treatment process and all locations where the treated wastewater is disposed, including all surface discharges as well as non-surface discharges such as evaporative tanks (as described in the above referenced Notice of Intent). This determination by the NMED-GWQB is based on information provided in the original application for a Discharge Permit along with subsequent information provided to NMED by LANL.

Given the extensive and fractured exchange of information concerning this facility, along with changes at the RLWTF that have occurred during the lengthy permitting process and planned future changes, NMED views LANL's August 16, 1996 Discharge Permit application to be inconsistent with the current and planned discharge activities associated with the RLWTF. **Therefore, NMED requires that LANL submit a comprehensive and up-to-date Discharge Permit application for the RLWTF within 90 days of the date of this letter (by February 16, 2011).**

When submitted, the application (copy enclosed) should be completed in its entirety and specifically address the following:

- The estimated volumes, sources (technical area and building) and wastestream characteristics of all influent wastewater that LANL receives, or intends to receive, at the RLWTF.
- A description of the conveyance methods used to transport wastewater to the RLWTF for each source.
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- A description of the review and amendment process for LANL's internal Waste Acceptance Criteria (WAC) for all incoming wastewater received at the RLWTF. This should include LANL's process for ensuring the WAC relates to the current treatment technologies and processes.
- A description of operational procedures for receiving wastes from each generator.
- A schematic of the treatment process in its entirety for each wastestream (from collection to final disposal).
- Descriptions, locations, construction materials and sizing for each component of the treatment processes for each type of wastestream being treated at the RLWTF.
- Descriptions, locations and designs for all secondary storage and auxillary emergency units intended to receive, treat or store wastewater received at the facility.
- Proposed processes for the operation, inspection and maintenance for the facility as it pertains to the collection lines, treatment units and effluent storage disposal units.
- Procedures and corrective actions for addressing acute failures at the facility.
- Procedures and corrective actions for addressing long-term maintenance issues at the facility.

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- Construction plans and specifications for all components of the facility which are under construction or are proposed for construction.
- A proposed effluent monitoring plan, identifying analytes and sample locations/frequency. The proposal should consider discharge frequencies, incoming waste characteristics and the constituents listed under 20.6.2.3103 NMAC and Subsection WW of 20.6.2.7 NMAC.
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- Proposed ground water monitoring locations for ground water sources most likely to be impacted by intentional and unintentional discharges from the RLWTF. The proposal should identify geohydrology of the potentially impacted areas, existing monitoring well locations and construction.
- Actions which LANL would implement should partial or full closure of the facility occur.
- A scaled facility plan showing the facility's components including influent collection lines, storage units, major treatment units and disposal units.
- All other information sought in NMED's application for Discharge Permit Sections A through C. Please note that for the purposes of public notification, the "discharge site" as it relates to this facility encompasses the central collection system lines, the treatment and storage facilities and all discharge locations for the treated effluent.

When submitting the comprehensive and up-to-date Discharge Permit application, you must complete and submit three copies along with the $100 filing fee.

If you have any questions, please contact either Jennifer Fullam at (505) 827-2909 or Clint Marshall, Acting Program Manager of the Ground Water Pollution Prevention Section, at (505) 827-0027.

Sincerely,

James H. Davis, Ph.D.
Director, Resource Protection Division

JD:JF

Enc: Applying for a Discharge Permit: General Information
Discharge Permit Application

cc: Robert Italiano, District Manager, NMED District II (w/o enclosures)
NMED Santa Fe Field Office (w/o enclosures)
DP Required File (w/o enclosures)
James Bearzi, NMED SWQB (w/o enclosures)
Richard Powell, NMED SWQB (w/o enclosures)
John Kieling, NMED HWB (w/o enclosures)
Steven Yanicak, NMED-DOE-Oversight Bureau (w/o enclosures)

Hai Shen, LASO-EO, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)

Gene Turner, LASO-EO, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)

Eric Trujillo, LASO-NSM, Los Alamos National Laboratory, A316, Los Alamos, NM 87545 (w/o enclosures)

Carl A. Beard, PADOPS, Los Alamos National Laboratory, A102, Los Alamos, NM 87545 (w/o enclosures)

J. Chris Cantwell, ADESHQ, Los Alamos National Laboratory, K491, Los Alamos, NM 87545 (w/o enclosures)

Randy Johnson, ENV-ES, Los Alamos National Laboratory, E500, Los Alamos, NM 87545 (w/o enclosures)

Michael Saladen ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos, NM 87545 (w/o enclosures)

Robert Mason, TA-55-DO, Los Alamos National Laboratory, E583, Los Alamos, NM 87545 (w/o enclosures)

Hugh McGovern, TA-55-RLW, Los Alamos National Laboratory, E518, Los Alamos, NM 87545 (w/o enclosures)

Pete Worland, TA-55-RLW, Los Alamos National Laboratory, E518, Los Alamos, NM 87545 (w/o enclosures)

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Roy Maestas, CM-STRS, Los Alamos National Laboratory, P299, Los Alamos, NM 87545 (w/o enclosures)

Joe Brophy, PMF-FUNCT Los Alamos National Laboratory, P137, Los Alamos, NM 87545 (w/o enclosures)

Ed Artiglia, ES-PE, Los Alamos National Laboratory, P137, Los Alamos, NM 87545 (w/o enclosures)

Bob Beers, ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos NM, 87545 (w/ enclosures)

August 11, 2011, LANL Letter RE: Sixty Percent Design, Evaporation Tanks, TA-50 Radioactive Liquid Waste Treatment Facility

Los Alamos
NATIONAL LABORATORY
EST. 1943

Environmental Protection Division
Water Quality & RCRA Group (ENV-RCRA)
P.O. Box 1663, K490
Los Alamos, New Mexico 87545
(505) 667-0666/FAX (505) 667-5224

National Nuclear Security Administration
Los Alamos Site Office, A316
3747 West Jemez Road
Los Alamos, New Mexico 87545
(505) 667-5794/FAX (505) 667-5948

Date: August 11, 2011
Refer To: ENV-RCRA-11-0136
LAUR: 11-11041

Mr. Jerry Schoeppner, Acting Chief
Ground Water Quality Bureau
New Mexico Environment Department
Harold Runnels Building, Room N2250
1190 St. Francis Drive
P.O. Box 26110
Santa Fe, NM 87502

Dear Mr. Schoeppner:

SUBJECT: SIXTY PERCENT DESIGN, EVAPORATION TANKS, TA- 50 RADIOACTIVE LIQUID WASTE TREATMENT FACILITY

In November 2007, Los Alamos National Laboratory (the Laboratory) submitted a notice of intent (NOI) to the New Mexico Environment Department (NMED) to discharge treated effluent from the Technical Area 50 (TA-50) Radioactive Liquid Waste Treatment Facility (RLWTF) to three proposed aboveground evaporation tanks. On June 11, 2008, the NMED replied to the Laboratory's NOI with a request for additional information on six items (Enclosure 1). In the Laboratory's September 15, 2008, reply (Enclosure 2), all six items were addressed except for item 1, listed below:

1. *Submit 60% complete plans and specifications of the facility. Include detailed information regarding the construction of the evaporation tanks.*

The lack of project funding over the past several years has delayed design and construction of the evaporation tanks. The 60% design package was finally completed on July 28, 2011, and is now available for your review. Enclosure 3 contains a compact disc (CD) with the 60% complete plans and specifications for the construction of two (2) aboveground evaporation tanks. The third tank originally proposed has been dropped from the design. The mesa top location at TA-52 has not changed.

Given the design (concrete walls and floor with two synthetic liners and leak detection alarms) and the depth to groundwater (1260 ft), no reasonable potential exists that liquid in the evaporation tanks will move directly or indirectly into groundwater. Therefore, the evaporation tanks are not subject to the permitting requirement of 20.6.2.3104 and 3106 NMAC. Further, even if discharges to the evaporation tanks were considered a discharge subject to the permitting requirements of 20.6.2.3104 and 3106 NMAC, the effluent meets all of the listed numerical standards of 20.6.2.3103 NMAC, has a total nitrogen concentration of 10 mg/L or less, does not contain any toxic pollutant, and is therefore exempt from the permitting requirements under 20.6.2.3105.A NMAC.

Because of the accelerated design and construction schedule for this project, the Laboratory respectfully requests that the NMED review the enclosed plans and specifications and determine that no discharge permit is required. At your request and convenience, Laboratory engineers familiar with the enclosed design are available to meet with you and your staff to answer questions.

Please contact Bob Beers at (505) 667-7969 of the Water Quality and RCRA Group (ENV-RCRA) if you have questions.

Sincerely,

Anthony R. Grieggs
Group Leader
Water Quality & RCRA Group
Los Alamos National Laboratory

Sincerely,

Gene E. Turner
Environmental Permitting Manager
Environmental Projects Office
Los Alamos Site Office
National Nuclear Security Administration

ARG:GET:BB/lm

Enclosures: a/s

Cy: Hai Shen, LASO-EO, w/o enc., A316
Gene Turner, LASO-EO, w/o enc., A316
Eric Trujillo, LASO-NSM, w/o enc., A316
Steve Yanicak, LASO-GOV, w/o enc., M894
Carl A. Beard, PADOPS, w/o enc., A102
J. Chris Cantwell, ADESHQ, w/o enc., K491
Randy Johnson, ENV-ES, w/o enc., E500
Mike Saladen, ENV-RCRA, w/o enc., K490, (E-File)
Robert Mason, TA-55-DO, w/o enc., E583
Hugh McGovern, TA-55 RLW, w/o enc., E518
Pete Worland, TA-55-RLW, w/o enc., E518
Keith Orr, PMF-FUNCT, w/o enc., M984

Cy (continued):
Roy Maestas, CM-STRS, w/o enc., P299
Joe Brophy, PMF-FUNCT, w/o enc., P137
Ed Artiglia, ES-PE, w/o enc., P137
ENV-RCRA File, w/enc., K490
IRM-RMMSO, w/enc., A150

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ENVIRONMENT DEPARTMENT

Ground Water Quality Bureau

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Lieutenant Governor

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Secretary
JON GOLDSTEIN
Deputy Secretary

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

June 11, 2008

Anthony R. Grieggs, Group Leader
Environmental Protection Division
Water Quality & RCRA (ENV-RCRA)
P.O. Box 1663, Mail Stop K490
Los Alamos, NM 87545

RE: Request for Additional Information, DP-1132, Radioactive Liquid Waste Treatment Facility

Dear Mr. Grieggs:

The New Mexico Environment Department (NMED) received a ground water Discharge Permit application from you on April 16, 1996 for the above referenced facility and a Notice of Intent for the discharge of effluent water to evaporative tanks (zero liquid discharge facility) on November 8, 2007. The application proposes the discharge of up to 3.6 million gallons per year of industrial wastewater.

NMED has reviewed the Notice of Intent in accordance with the New Mexico Water Quality Control Commission Regulations (20.6.2 NMAC). The following additional information is necessary in order for NMED to determine if the zero liquid discharge facility will require a New Mexico Environment Department Ground Water Discharge Permit:

1. Submit 60% complete plans and specifications of the facility. Include detailed information regarding the construction of the evaporation tanks.

2. Submit information regarding ground water near the facility that is most likely to be impacted should a release occur. This should include the most shallow aquifers located down gradient of the facility prior to the Rio Grande.

3. Submit procedures for the operation and maintenance of the evaporation tanks. Please include estimated cleaning timelines and methodologies.

4. Submit information on the concentration of waste in the tanks due to evaporation.

5. Submit seismic studies conducted in accordance to 40 CFR § 264.18 (a)

Following submission of the requested additional information, NMED will act upon your Notice of Intent to discharge. Your cooperation is appreciated. If you have any questions, you may reach me at (505) 827-2909.

Sincerely,

Jennifer Fullam
Environmental Scientist
Ground Water Pollution Prevention Section

cc: James Bearzi, NMED Hazardous Waste Bureau
John Young, NMED Hazardous Waste Bureau
Marcy Leavitt, NMED SWQB
Ralph Ford-Schmidt, NMED-DOE Oversight Bureau
Bob Beers, Environmental Protection Division, Water Quality & RCRA Ground , P.O. Box 1663, Mail Stop K490, Los Alamos, New Mexico 87545
Mike Saladen, ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos, NM 87545 (W/O enclosure)

Los Alamos
NATIONAL LABORATORY
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Environmental Protection Division
Water Quality & RCRA (ENV-RCRA)
P.O. Box 1663, Mail Stop K490
Los Alamos, New Mexico 87545
(505) 667-7969/FAX: (505) 665-9344

Date: September 15, 2008
Refer To: ENV-RCRA-08-169
LA-UR: 08-04520

Ms. Jennifer Fullam
Ground Water Pollution Prevention Section
Ground Water Quality Bureau
New Mexico Environment Department
Harold Runnels Building, Room N2261
1190 St. Francis Drive
P.O. Box 26110
Santa Fe, NM 87502

Dear Ms. Fullam:

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION, DP-1132, RADIOACTIVE LIQUID WASTE TREATMENT FACILITY

I have received your June 11, 2008, letter (Enclosure 1) requesting additional information for Los Alamos National Laboratory's November 8, 2007, Notice of Intent (NOI) for the discharge of treated effluent from the TA-50 Radioactive Liquid Waste Treatment Facility (RLWTF) to proposed evaporation tanks. I have listed each of your requests below, along with the Laboratory's response.

1. *Submit 60% complete plans and specifications of the facility. Include detailed information regarding the construction of the evaporation tanks.*

As the Laboratory indicated in the November 8, 2007, NOI, detailed plans and specifications for the evaporation tanks will be submitted to your agency once they become available. To date, no contract has been signed by the Laboratory for the final design of the evaporation tanks.

2. *Submit information regarding ground water near the facility that is most likely to be impacted should a release occur. This should include the most shallow aquifers located down gradient of the facility prior to the Rio Grande.*

The proposed site is a mesa top location at Technical Area (TA)-52. The approximate elevation of the proposed site is 7160 ft above mean sea level (MSL). Two regional aquifer wells are located within approximately 1500 ft of the proposed site: Los Alamos County water supply well PM-5 (7095 ft above MSL), and the Laboratory's regional aquifer monitoring well R-14 (7062 ft above MSL).

The static water level at both PM-5 and R-14 is approximately 5900 ft above MSL; this places the depth of the regional aquifer at the proposed project site at approximately 1260 ft below ground surface (bgs). No perched zone of saturation was encountered during drilling at R-14 (*Hydrologic Tests at Characterization Well R-14*, LA-14107MS, August 2004). In 2008, a new regional aquifer monitoring well will be installed on the mesa top in the vicinity of the evaporation tanks. The well, R-46, will be sited downgradient of Material Disposal Area (MDA) C and upgradient of water supply well PM-5 to ensure the safety of the supplied water.

Given the depth to ground water at the proposed project site (1260 ft bgs), the potential for impact to groundwater, should a release occur, is low. The nearest shallow aquifer (alluvial) is in Mortandad Canyon, approximately one mile away via the Ten Site Canyon watercourse. The depth to alluvial ground water in Mortandad Canyon at the Ten Site Canyon confluence is approximately 40 ft.

3. *Submit procedures for the operation and maintenance of the evaporation tanks. Please include estimated cleaning timelines and methodologies.*

In accordance with Laboratory requirements, a Standard Operating Procedure (SOP) will be prepared before the evaporation tanks are placed into service. The SOP will provide detailed instructions for the operation and maintenance of the facility. A copy of the SOP will be submitted to your agency once it is available for release.

4. *Submit information on the concentration of waste in the tanks due to evaporation.*

Treated effluent discharged to the evaporation tanks from the TA-50 RLWTF will have a composition of approximately 99.95 percent water and 0.05 percent solids; product from the reverse osmosis (RO) treatment unit has, on average, a Total Dissolved Solids (TDS) concentration of less than 500 mg/L (0.05 percent solids). Airborne dust and dirt blowing into the tanks will be the primary source of solids. When solids are removed from the tank, they will be characterized and managed in accordance with the applicable waste management requirements.

5. *Submit seismic studies conducted in accordance with 40 CFR § 264.18 (a).*

Conducting seismic studies in accordance to 40 CFR § 264.18 (a) is not a requirement of the New Mexico Water Quality Control Commission (NM WQCC) regulations. The proposed evaporation tanks will receive treated effluent from the TA-50 RLWTF. The tanks are therefore exempt from RCRA requirements as part of a Clean Water Act (CWA) wastewater treatment facility permitted by the Environmental Protection Agency (EPA) under NPDES Permit No. NM0028355. The specifications package that you will receive as part of the project's final design (see request #1) will include the seismic standards used in the engineering design of the evaporation tanks.

Please contact Bob Beers (505-667-7969) if you have any questions or need any additional information.

Sincerely,

A R Grieggs

Anthony R. Grieggs, Group Leader
Water Quality & RCRA Group (ENV-RCRA)

BB/lm

Enclosure: a/s

Cy: William Olson, NMED/GWQB, w/enc, Santa Fe, NM
Robert George, NMED/GWQB, w/enc, Santa Fe, NM
Glenn Saums, NMED/SWQB, w/enc, Santa Fe, NM
James Bearzi, NMED/HWB, w/enc, Santa Fe, NM
Steve Yanicak, NMED/OB/LASO, w/enc, J993
Hai Shen, LASO/EO, w/enc, A316
Gene Turner, LASO/EO, w/enc, A316
Michael Mallory, PADOPS, w/enc, A102
Richard S. Watkins, ADESHQ, w/enc, K491
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Phil Wardwell, LC-LESH, w/enc, A187
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Keith R. Orr, PP-WEP, w/enc, P137
ENV-DO File, w/enc., J978
ENV-RCRA, File, w/enc., K490
IRM-RMMSO, w/enc., A150

September 15, 2008, LANL Letter Subject: Request For Additional Information, DP-1132, Radioactive Liquid Waste Treatment Facility

Los Alamos
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Environmental Protection Division
Water Quality & RCRA (ENV-RCRA)
P.O. Box 1663, Mail Stop K490
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(505) 667-7969/FAX: (505) 665-9344

Date: September 15, 2008
Refer To: ENV-RCRA-08-169
LA-UR: 08-04520

Ms. Jennifer Fullam
Ground Water Pollution Prevention Section
Ground Water Quality Bureau
New Mexico Environment Department
Harold Runnels Building, Room N2261
1190 St. Francis Drive
P.O. Box 26110
Santa Fe, NM 87502

Dear Ms. Fullam:

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION, DP-1132, RADIOACTIVE LIQUID WASTE TREATMENT FACILITY

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1. *Submit 60% complete plans and specifications of the facility. Include detailed information regarding the construction of the evaporation tanks.*

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Please contact Bob Beers (505-667-7969) if you have any questions or need any additional information.

Sincerely,

A R Grieggs

Anthony R. Grieggs, Group Leader
Water Quality & RCRA Group (ENV-RCRA)

BB/lm

Enclosure: a/s

Cy: William Olson, NMED/GWQB, w/enc, Santa Fe, NM
Robert George, NMED/GWQB, w/enc, Santa Fe, NM
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Keith R. Orr, PP-WEP, w/enc, P137
ENV-DO File, w/enc., J978
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IRM-RMMSO, w/enc., A150

ENCLOSURE 1

NEW MEXICO
ENVIRONMENT DEPARTMENT

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CERTIFIED MAIL – RETURN RECEIPT REQUESTED

June 11, 2008

Anthony R. Grieggs, Group Leader
Environmental Protection Division
Water Quality & RCRA (ENV-RCRA)
P.O. Box 1663, Mail Stop K490
Los Alamos, NM 87545

RE: Request for Additional Information, DP-1132, Radioactive Liquid Waste Treatment Facility

Dear Mr. Grieggs:

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Sincerely,

Jennifer Fullam
Environmental Scientist
Ground Water Pollution Prevention Section

cc: James Bearzi, NMED Hazardous Waste Bureau
John Young, NMED Hazardous Waste Bureau
Marcy Leavitt, NMED SWQB
Ralph Ford-Schmidt, NMED-DOE Oversight Bureau
Bob Beers, Environmental Protection Division, Water Quality & RCRA Ground , P.O. Box 1663, Mail Stop K490, Los Alamos, New Mexico 87545
Mike Saladen, ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos, NM 87545 (W/O enclosure)

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Environmental Scientist
Ground Water Pollution Prevention Section

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Ralph Ford-Schmidt, NMED-DOE Oversight Bureau
Bob Beers, Environmental Protection Division, Water Quality & RCRA Ground , P.O. Box 1663, Mail Stop K490, Los Alamos, New Mexico 87545
Mike Saladen, ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos, NM 87545 (W/O enclosure)

June 11, 2008, NMED Letter RE: Request For Additional Information, DP-1132, Radioactive Liquid Treatment Facility

NEW MEXICO
ENVIRONMENT DEPARTMENT

Ground Water Quality Bureau

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Deputy Secretary

GW_00118

CERTIFIED MAIL – RETURN RECEIPT REQUESTED

June 11, 2008

Anthony R. Grieggs, Group Leader
Environmental Protection Division
Water Quality & RCRA (ENV-RCRA)
P.O. Box 1663, Mail Stop K490
Los Alamos, NM 87545

RE: Request for Additional Information, DP-1132, Radioactive Liquid Waste Treatment Facility

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1. Submit 60% complete plans and specifications of the facility. Include detailed information regarding the construction of the evaporation tanks.

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Jennifer Fullam
Environmental Scientist
Ground Water Pollution Prevention Section

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Bob Beers, Environmental Protection Division, Water Quality & RCRA Ground , P.O. Box 1663, Mail Stop K490, Los Alamos, New Mexico 87545
Mike Saladen, ENV-RCRA, Los Alamos National Laboratory, K490, Los Alamos, NM 87545 (W/O enclosure)

November 1, 2007, LANL Letter Subject: Notice of Intent To Discharge, Evaporation Tanks, TA-50 Radioactive Liquid Waste Treatment Facility

GW_00185

Los Alamos
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EST.1943

Environmental Protection Division
Water Quality & RCRA (ENV-RCRA)
P.O. Box 1663, Mail Stop K490
Los Alamos, New Mexico 87545
(505) 667-0666/FAX: (505) 667-5224

Date: November 1, 2007
Refer To: ENV-RCRA: 07-184
LA-UR: 07-4794

Mr. William C. Olson
Ground Water Quality Bureau
New Mexico Environment Department
P.O. Box 26110
Santa Fe, NM 87502-6110

Mr. James Bearzi
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Bldg. 1
Santa Fe, NM 87505-6313

SUBJECT: NOTICE OF INTENT TO DISCHARGE, EVAPORATION TANKS, TA-50 RADIOACTIVE LIQUID WASTE TREATMENT FACILITY

Dear Mr. Olson and Mr. Bearzi:

This letter and enclosures constitute a Notice of Intent (NOI) to discharge pursuant to 20.6.2.1201 NMAC regarding Los Alamos National Laboratory's (Laboratory) plan to construct three evaporation tanks. The above-ground tanks would receive part or all of the treated effluent from the Laboratory's TA-50 Radioactive Liquid Waste Treatment Facility (RLWTF). The evaporation of treated effluent at these tanks would significantly reduce or, at times, eliminate discharges at NPDES Outfall 051. The RLWTF discharge is into Mortandad Canyon, pursuant to NPDES Permit NM0028355. It is the Laboratory's view that a groundwater discharge permit will not be required for this project because there is no reasonable probability or likelihood that liquid contained in the evaporation tanks will move into groundwater, either through a leak or by overflow. Additional information is presented below and in the following enclosures:

- Enclosure 1.0 is a completed NMED-Ground Water Quality Bureau NOI form.
- Enclosure 2.0 is a preliminary location map.
- Enclosure 3.0, per your agency's request, is the Laboratory's analysis of the applicability of the Wastewater Treatment Unit (WWTU) exemption under the federal RCRA regulations for those facilities regulated under the federal CWA.
- Enclosure 4.0 is EPA FAXBACK #13526, January 16, 1992.
- Enclosure 5.0 is Federal Register Vol. 61, No. 68, *Land Disposal Restrictions Phase III—Decharacterization Wastewaters, Carbamate Wastes, and Spent Potliners* (40 CFR Parts 148, 268, 271, and 403); specifically relevant to this NOI are pages 15569 to 15574 containing land disposal restrictions applicable to zero dischargers.

Enclosure 4.0 states that the primary reason of the wastewater treatment exemption is to avoid imposing duplicative requirements pursuant to both a NPDES permit and a RCRA permit for the same unit. The FAXBACK also defines the requirements that must be met for the WWTU exemption to apply.

Enclosure 5.0 is an EPA preamble dealing with Land Disposal Restrictions, which we are providing in response to questions from Steve Pullen. Any material removed from the evaporation tanks during cleaning will be characterized and managed appropriately. Further, Section III.A. of the Federal Register in Enclosure 5.0 states that land disposal treatment standards apply only to the following types of facilities:

"(1) facilities treating formerly characteristic wastes in surface impoundments whose ultimate discharge is subject to regulation under either section 402 or 307 of the CWA." The ZLD evaporation tanks at LANL will meet the definition of a tank or tank system in 40 CFR §260.10, they are not surface impoundments; thus, the tanks are not within the first type of facility to which land disposal requirements apply.

"(2) permitted and unpermitted zero dischargers engaging in treatment that is equivalent to that of the CWA-regulated facilities (see 40 CFR 268.37(a) defining CWA-equivalent treatment), including facilities treating formerly characteristic waste in tanks prior to release on the land for such purposes as irrigation or land treatment." The proposed ZLD tanks will not release effluent on the land for such purposes as irrigation or land treatment. In addition, the proposed ZLD tanks will not conduct treatment that meets the description of CWA-equivalent treatment[1], therefore, land disposal regulations do not apply to the evaporation tanks under these criteria either. This Federal Register further clarifies that the treatment standards do not apply to facilities that discharge to navigable water or POTWs or that manage decharacterized waste in treatment systems without surface impoundments.

Conceptual Tank Design

Each of the three evaporation tanks will have an area of approximately 0.7 to 1.0 acres providing a total evaporation area of 2.1 to 3.0 acres. The total depth of each basin will be approximately 4 ft. Multiple modeling scenarios using conservative input parameters show that the actual operating depth will range from approximately 1.4 to 2.2 ft depending upon the volume of effluent discharged to the tanks, precipitation, and the final tank sizes selected; these operating depths will provide a minimum freeboard of approximately 1.8 ft. The tanks will be constructed with reinforced-concrete walls and floors, and with the water surface open to the atmosphere. The concrete tanks will be sealed with a curing compound and all joints will be watertight. A liner system will be installed in each concrete tank consisting of primary and secondary geomembrane liners separated by a geosynthetic drainage material for leak detection. The wall of the tanks will be self-supporting. Depth to regional groundwater at the project site is approximately 1260 ft.

[1] CWA-equivalent treatment means biological treatment for organics, alkaline chlorination or ferrous sulfate precipitation of cyanide, precipitation/sedimentation for metals, reduction of hexavalent chromium, or other treatment technology that can be demonstrated to perform equally or greater than these technologies.

Quality of Effluent

All effluent discharged to the evaporation tanks will be fully treated by RLWTF treatment operations and will comply with all applicable NPDES permit limits and all of the listed numerical standards of 20.6.2.3103 NMAC. Effluent discharged to the evaporation tanks will receive the same level of treatment and will be of equal quality to that effluent discharged to Mortandad Canyon at NPDES Outfall 051. The quality of the RLWTF's effluent is routinely reported to the NMED through the following documents:

1. NPDES Monthly Discharge Monitoring Reports (DMRs) submitted to NMED, Surface Water Quality Bureau;
2. RLWTF Annual Operating Reports submitted to the NMED, Ground Water Quality Bureau (the 2006 RLWTF Annual Report was submitted on June 11, 2007; ENV-RCRA: 07-0135, LA-UR-07-3447); and
3. DP-1132 quarterly monitoring reports submitted to the NMED, Ground Water Quality Bureau.

For the reasons indicated above, no groundwater permit is required. As explained above, there is no reasonable probability that liquid in the evaporation tanks will move directly or indirectly into groundwater [*See* Amended Final Order, In the Matter of: No Discharge Plan Required McKinley Paper Co. (July 13, 1993) (determining no discharge permit required for discharges to closed-loop, zero discharge system comprised of U-drains, lift stations and piping)]. Further, even if the discharges to the tanks were considered a discharge subject to the permitting requirements of 20.6.2.3104 NMAC, as discussed above, the effluent meets all of the listed numerical standards of 20.6.2.3103 NMAC, has a total nitrogen concentration of 10 mg/L or less, does not contain any toxic pollutant, and is therefore exempt from the permitting requirements under 20.2.3105.A NMAC.

We are sending this NOI well in advance of beginning construction as we want to complete all regulatory requirements in a timely fashion. Detailed plans and specifications will be submitted to your agency once they become available.

This letter is not intended to fully answer to the information requested in the October 26, 2007, letter from James Bearzi to Donald L. Winchell and Richard S. Watkins regarding the exemption status of the TA-50 RLWTF. The response to that letter will be forthcoming under separate cover.

We look forward to receiving your response to this NOI and position paper. Please contact Bob Beers (505-667-7969) if you have any questions or need any additional information.

Sincerely,

A. R. Grieggs

Anthony R. Grieggs
Group Leader
Water Quality & RCRA (ENV-RCRA) Group
ARG:BB/lm

ARG:BB/lm

Enclosures: a/s

Cy: Tracy Hughes, NMED OGC, Santa Fe, NM
Marcy Leavitt, NMED SWQB, Santa Fe, NM
George Schuman, NMED GWQB, Santa Fe, NM
Robert George, NMED GWQB, Santa Fe, NM
Jake Knutson, NMED GWQB, Santa Fe, NM
John Young, NMED HWB, Santa Fe, NM
Steve Pullen, NMED HWB, Santa Fe, NM
Dave Cobrain, NMED HWB, Santa Fe, NM
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Mike Saladen, ENV-RCRA, MS K490
Bob Beers, ENV-RCRA, MS K490
Holly Wheeler-Benson, ENV-RCRA, MS K490
Marc Bailey, ENV-RCRA, MS K490
Pete Worland, EWMO-RLW, MS E518
Ed Artiglia, PE-DO, MS E554
Craig Douglas, RLW, MS E0518
Phil Wardwell, LC-LESH, MS A187
ADESHQ Files, MS K491
LC Fileroom, MS A187
LC/LESH File, MS A187
ENV-RCRA File, MS K490
IRM-RMMSO, MS A150

ENCLOSURE 1.0

1. Name and Address of person making discharge:

Los Alamos National Laboratory
Attn: Bob Beers
P.O. Box 1663, Mail Stop K490
Los Alamos, NM 87545

Phone: 505-667-7969 (office)
505-665-9344 (fax)

2. Location of discharge (give township, range, section, ¼ section, miles from closest town and street address, if applicable):

Los Alamos National Laboratory
Technical Area (TA)-52. See Enclosure 2.0.
35° 51' 37"N, 106° 16' 57"W (NAD27), USGS Frijoles (NM) Quadrangle

3. Type of operation generating the discharge:

Treated effluent evaporation tanks (3)

4. Description of the source of the discharge:

Treated effluent from TA-50 RLWTF treatment unit operations

5. Estimated concentration of contaminants in the discharge:

Effluent quality is documented in the following reports submitted to the NMED in 2006-07:

- NPDES Monthly Discharge Monitoring Reports (DMRs) submitted to NMED, Surface Water Quality Bureau,
- RLWTF Annual Operating Reports submitted to the NMED, Ground Water Quality Bureau (the 2006 RLWTF Annual Report was submitted on June 11, 2007; ENV-RCRA: 07-0135, LA-UR-07-3447), and
- DP-1132 quarterly monitoring reports submitted to the NMED, Ground Water Quality Bureau.

6. Means of the discharge (to a lagoon, watercourse, septic tank/leachfield, etc.):

Treated effluent will be transferred from the TA-50 RLWTF to the evaporation tanks via a pipeline.

7. Estimated daily flow rate of the discharge:

Evaporation Tanks Design Basis: 13.6 million liters per year (3.6 million gallons per year).

8. Estimated depth to ground water:

Approximately 1260 ft to regional ground water.

Signature: A R Grieggs **Title:** Group Leader

Printed name: Anthony R. Grieggs **Date:** 11/2/07

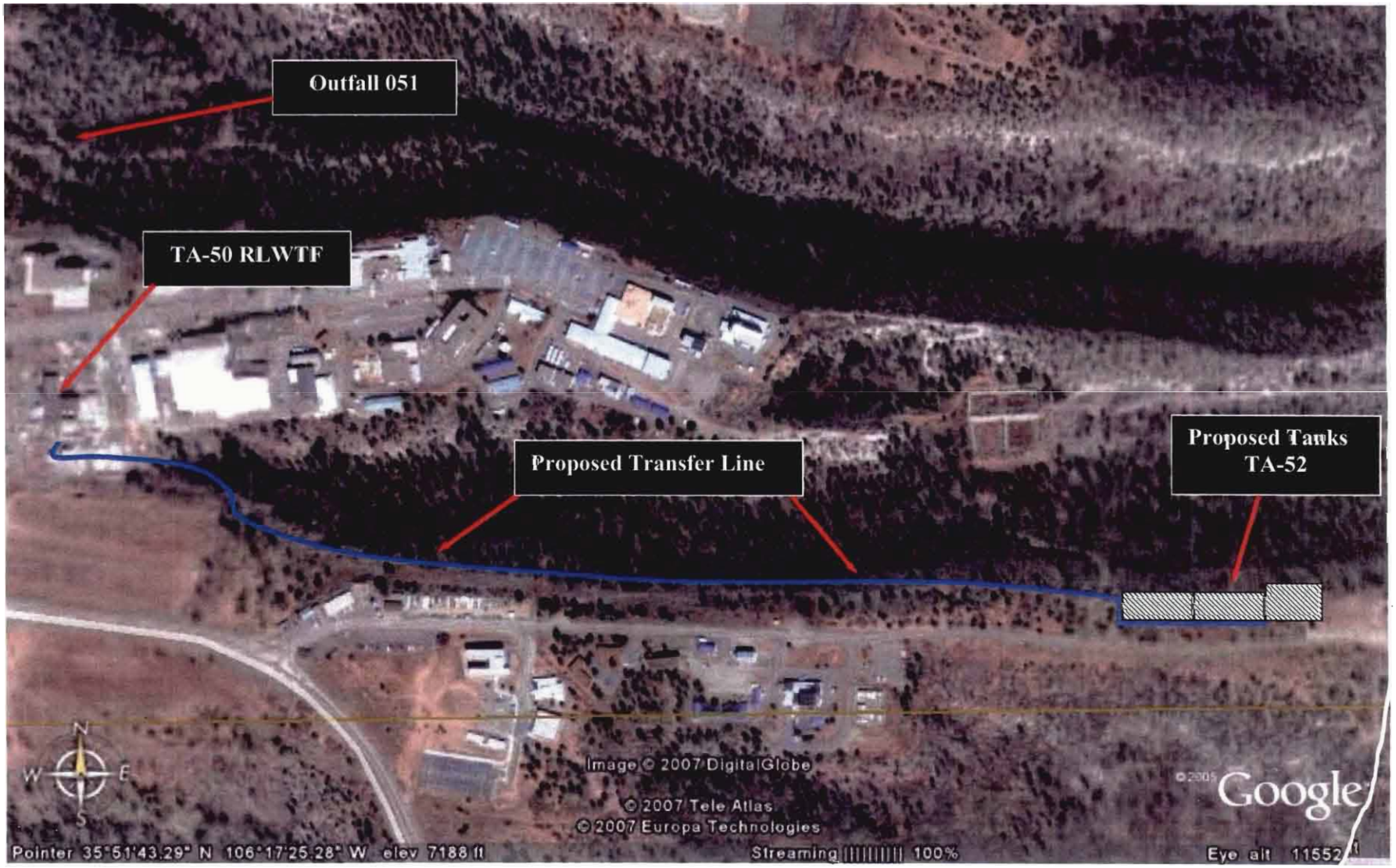
Providing additional information such as maps, plans and specifications, laboratory analyses, and/or a detailed description of the discharge will help NMED to process this NOI in a more timely manner. Please return this form to:

NMED Ground Water Quality Bureau
P.O. Box 26110
Santa Fe, New Mexico 87502

Telephone: 505-827-2900
Fax: 505-827-2965

ENC URE 2.0

NPDES PERMIT NO. NM0028355
Proposed RLWTF Effluent Evaporation Tanks
LA-UR-07-4794



ENCLOSURE 3.0

Position Paper

TA-50 RLWTF Zero Liquid Discharge Evaporation Tanks

Under Los Alamos National Laboratory's NPDES Permit No. NM0028355, the TA-50 Radioactive Liquid Waste Treatment Facility (RLWTF) discharges treated effluent from Outfall 051 to Mortandad Canyon. Permit conditions, including effluent limitations and monitoring requirements, for Outfall 051 can be viewed online at http://www.lanl.gov/environment/h2o/docs/NM0028355_LANL_NPDES2007.pdf. The proposed change to the RLWTF includes the addition of three concrete evaporation tanks to receive treated effluent, so that the discharge from Outfall 051 is significantly reduced or eliminated. Reducing or eliminating the amount of water discharge from Outfall 051 will, in turn, reduce the potential for the migration of legacy contaminants in Mortandad Canyon by reducing surface flow.

The evaporation tanks will be an integral part of the RLWTF which is a wastewater treatment facility regulated under the Clean Water Act (CWA). Therefore, a RCRA permit is not required for this project. The Environmental Protection Agency (EPA) provided some discussion in 53 FR 34080 (September 2, 1988) which states that: "the wastewater treatment unit exemption is intended to cover only tank systems that are part of a wastewater treatment facility that (1) produces a treated wastewater effluent which is discharged into surface waters or into a POTW sewer system and therefore is subject to the NPDES or pretreatment requirements of the Clean Water Act, or (2) produces no treated wastewater effluent as a direct result of such requirements."

Further guidance relative to zero discharge facilities is provided in Enclosure 4.0, EPA FAXBACK # 13526, January 16, 1992.

Federal RCRA regulations, adopted by reference by the EIB (20.4.1 NMAC), provide that a RCRA permit is not required for wastewater treatment units (WWTUs). Further, 40 CFR 270.1(c)(2), states that "The following persons are among those not required to obtain a RCRA permit: . . . (v) Owners and operators of . . wastewater treatment units as defined in 40 CFR 260.10." The definition of a WWTU in 40 CFR 260.10 contains three requirements. The RLWTF meets these three requirements as follows:

First, RLWTF and its associated evaporation tanks (once constructed) are "part of a wastewater facility that is subject to regulation under . . . Section 402 . . . of the Clean Water Act." The RLWTF is currently subject to regulation under Section 402 of the federal Clean Water Act, as Outfall 51 of NPDES Permit No. NM0028355.

Second, the RLWTF receives and treats or stores influent that is a hazardous waste, in that it may contain corrosive characteristic (D002) mixed wastewater. This influent will be treated before it is discharged to the evaporation tanks.

Third, the structure containing the wastewater must meet the definition of a "tank" or "tank system" in 40 CFR 260.10. A "tank" is defined as "a stationary device, designed to contain an accumulation of hazardous waste which is constructed primarily of non-earthen materials (e.g., wood, concrete, steel, plastic) which provide structural support." As noted above, the evaporation tanks will be constructed of concrete; the concrete walls will provide structural support to contain the liquid inside. A "tank system" includes the associated ancillary equipment of a tank; for example, the sump.

ENCLOSURE 4.0

FAXBACK #13526

EXEMPTION FROM PERMITTING REQUIREMENTS FOR WASTE WATER TREATMENT UNITS
PPC 9522.1992(01)

United States Environmental Protection Agency
Washington, D.C. 20460
Office of Solid Waste and Emergency Response

January 16, 1992

Mr. Thomas W. Cervino, P.E.
Colonial Pipeline Company
Lenox Towers
3390 Peachtree Road, N.E.
Atlanta, Georgia 30326

Dear Mr. Cervino:

This letter is in response to your August 9, 1991 correspondence requesting a clarification of the conditions under which waste water treatment units qualify for an exemption from RCRA permitting requirements. In your letter you explained that Colonial Pipeline Company has several locations that generate waste waters that are hazardous under the toxicity characteristic, and you asked whether a RCRA permit would be required for a new treatment unit that you are considering.

The primary reason for the waste water treatment exemption is to avoid imposing duplicative requirements pursuant to both a NPDES permit and a RCRA permit for the same unit. As you are aware, in order for a unit to qualify for this exemption contained in 40 CFR_264.1(g)(6), it must:

(1) Be part of a waste water treatment facility that is subject to regulation under either Section 402 or 307(b) of the Clean Water Act;

(2) Receive, treat, or store influent waste water; or generate, accumulate, treat, or store a waste water treatment sludge; and,

(3) Meet the definition of tank or tank system in 40 CFR _260.10.

The main question that you raised concerns the first criteria: i.e., which units are considered subject to the Clean Water Act. As you are aware, the Agency provided some discussion of this requirement in 53 FR 34080 (September 2, 1988) which states that:

"the wastewater treatment unit exemption is intended to cover only tank systems that are part of a wastewater treatment facility that (1) produces a treated wastewater effluent which is discharged into surface waters or into a POTW sewer system and therefore is subject to the NPDES or pretreatment requirements of the Clean Water Act, or (2) produces no treated wastewater effluent as a direct result of such requirements."

It is important to note that it is not necessary that the Clean Water Act permits actually be issued for the units to be eligible for the RCRA exemption; it is sufficient that the facility be subject to the requirements of the Clean Water Act.

Based on a review of the information provided, EPA has determined that any of the treatment systems (including the proposed treatment unit) at the Colonial Pipeline facilities which are currently permitted, were ever permitted, or should have been permitted under NPDES, all meet the first test of the Section 264.1(g)(6) exemption. The key issue is whether the treatment system ever had a discharge to surface water, and thus was ever permitted (or should have been permitted) under NPDES. If there was never a discharge to surface waters, then the exemption criteria is not satisfied. You also mentioned that some of your facilities employ wastewater treatment systems which are regulated in accordance with other applicable state laws, rules, and regulations. Without more specific information regarding these state requirements and permits, EPA cannot address whether these facilities would qualify for the exemption. However, as discussed above, the exemption in the federal regulations would only be available if the state requirements stem from the identified sections of the Clean Water Act.

With regard to the question of a "zero discharge" facility, EPA would like to clarify the difference between a facility that produces no treated wastewater as a direct result of Clean Water Act requirements and units that are not required to obtain an NPDES permit because they do not discharge treated effluent. In the first case, the facility would have had a surface water discharge at one time, but has since eliminated the discharge as a result of, or by exceeding, NPDES or pretreatment requirements. Such facility would qualify for the waste water treatment unit exemption under RCRA. In the second case, the facility never had a surface water discharge, and therefore was never subject to NPDES permitting or Clean Water Act requirements (53 FR 34080). The RCRA exemption is not available in these cases. (We should point out that the language you referred to on page 2 of the May 22, 1984 memo on zero discharge has been further refined and clarified by recent program policies and interpretations.)

There is another management option that my staff has discussed with you on the phone. That approach would be to treat your waste water in tank units pursuant to the generator accumulation exemption of 40 CFR _262.34. This provision allows generators of hazardous wastes to treat or store such wastes in tanks or containers for short periods of time (i.e., 90 days) without obtaining a RCRA permit, provided that all the conditions of _262.34 are met, including compliance with specified tank or container standards in 40 CFR Part 265. In many cases air strippers may be considered tank units under RCRA and might be eligible for this exemption. Of course, as long as the treated waste water meets a hazardous waste listing description or exhibits a hazardous waste characteristic it must

continue to be managed as a hazardous waste.

If you have facility-specific questions, please contact individual in the appropriate EPA Regional Offices. For Region III (Philadelphia), contact Ms. Susan Sciarratia at (215) 597-7259 and for Region IV (Atlanta), contact Ms. Beth Antley at (404) 347-3433. Should you have further questions about this letter, please contact Glenn Strahs of my staff at (202) 260-4782.

Sincerely,
Sylvia K. Lowrance, Director
Office of Solid Waste

cc: Kathy Nam, OGC; EPA RCRA Branch Chiefs, Regions I-X; Barbara Simcoe, ASTSWMO

Enclosure 5.0

Federal Register

Monday
April 8, 1996

Part II

Environmental Protection Agency

40 CFR Part 148, et al.
Land Disposal Restrictions Phase III; Final Rule and Partial Withdrawal and Amendment of Final Rule

4. Comments Received on Technical Basis for BDAT
VI. Improvements to the Existing Land Disposal Restrictions Program
A. Completion of Universal Treatment Standards
1. Addition of Constituents to Table 268.48
2. Wastewater Standard for 1,4-Dioxane
3. Revision to the Acetonitrile Standard
B. Aggressive Biological Treatment as BDAT for Petroleum Refinery Wastes
C. Dilution Prohibition
1. Inorganic Metal-Bearing Wastes
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4. Table of Inorganic Metal Bearing Wastes
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E. Clean Up of 40 CFR Part 268
1. Section 268.8
2. Sections 268.10–268.12
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VII. Capacity Determinations
A. Introduction
B. Capacity Analysis Results Summary
VIII. State Authority
A. Applicability of Rules in Authorized States
B. Abbreviated Authorization Procedures for Specified Portions of Today's Rule
C. Effect on State Authorization
IX. Regulatory Requirements
A. Regulatory Impact Analysis Pursuant to Executive Order 12866
1. Methodology Section
a. Methodology for Estimating the Affected Universe
b. Cost Methodology
c. Economic Impact Methodology
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2. Results
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B. Regulatory Impact Analysis for Underground Injected Wastes
C. Regulatory Flexibility Analysis
D. Paperwork Reduction Act
X. Unfunded Mandates Reform Act

I. Background

A. Summary of the Statutory Requirements of the 1984 Hazardous and Solid Waste Amendments, and Requirements of the 1993 Consent Decree With the Environmental Defense Fund

The Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA), enacted on November 8, 1984, largely prohibit the land disposal of untreated hazardous wastes that do not meet treatment standards established by EPA under section 3004(m). Once a hazardous waste is prohibited, the statute provides only two options for legal land disposal: meet the treatment standard for the waste prior to land disposal, or dispose of the waste in a land disposal unit that has been found to satisfy the statutory no migration test. A no migration unit is one from which there will be no migration of hazardous constituents for as long as the waste remains hazardous. RCRA sections 3004 (d), (e), (f), (g)(5).

The amendments also require the Agency to set levels or methods of treatment, if any, which substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste so that short term and long term threats to human health and the environment are minimized. RCRA section 3004(m)(1). To date, the Agency has implemented this provision by establishing treatment standards for chemical constituents in hazardous wastes based on the performance of the best demonstrated available technology (BDAT) to treat the waste. EPA may establish treatment standards as specified technologies, as constituent concentration levels in treatment residuals, or both. When treatment standards are set as levels, the regulated community may use any technology not otherwise prohibited (such as impermissible dilution) to treat the waste.

It should be noted that the Agency has proposed risk-based exit levels—levels at which wastes are no longer considered hazardous for purposes of RCRA subtitle C—for the majority of hazardous constituents found in listed hazardous wastes in the Hazardous Waste Identification Rule (HWIR) (60 FR 66344, December 21, 1995). Wastes meeting these levels either before or after treatment consequently could be disposed in units not subject to RCRA hazardous waste management requirements (e.g., landfills without subtitle C permits). A consent decree approved by the U.S. District Court for the District of Columbia requires EPA to finalize the HWIR exit levels by December 15, 1996. In the same notice, the Agency proposed to allow the exit levels for some constituents to serve as alternative, risk-based LDR treatment standards satisfying the "minimize threat" standard of section 3004(m). Where these risk-based levels are higher (less restrictive) than current BDAT treatment standards, they will effectively supersede the BDAT requirements. See *Hazardous Waste Treatment Council* v. *EPA*, 886 F.2d 355, 362–63 (D.C. Cir. 1989).

EPA was required to promulgate land disposal prohibitions and treatment standards by May 8, 1990 for all wastes that were either listed or identified as hazardous at the time of the 1984 amendments (RCRA sections 3004 (d), (e), and (g)(5)), a task EPA completed within the statutory timeframe. EPA was also required to promulgate prohibitions and treatment standards for wastes identified or listed as hazardous after the date of the 1984 amendments within six months after the listing or identification takes effect (RCRA section 3004(g)(4)).

The Agency did not meet this latter statutory deadline for all of the wastes identified or listed after the 1984 amendments. As a result, a suit was filed by the Environmental Defense Fund (EDF). EPA and EDF signed a consent decree that establishes a schedule for adopting prohibitions and treatment standards for newly identified and listed wastes. (*EDF* v. *Reilly*, Cir. No. 89–0598, D.D.C.). EPA also entered into a settlement agreement with the environmental petitioners in *Chemical Waste Management* v. *EPA*, 976 F.2d 2 (D.C. Cir. 1992), cert. denied 113 S. Ct. 1961 (1993) regarding the procedural effect of the mandate entered in that case. This settlement calls for EPA to take action to implement the portions of the opinion dealing with centralized management of wastewaters that initially exhibit a hazardous waste characteristic within specified timeframes.

Today's rule fulfills several provisions of the settlement agreement and proposed consent decree. First, the rule amends the treatment standards for initially characteristic wastewaters managed in centralized wastewater management systems containing land disposal units. Three specific fact patterns are covered by the rule: (1) Where the wastewaters are ultimately discharged and are subject to limitations or standards established under the Clean Water Act (CWA) and the treatment system preceding discharge includes a surface impoundment; (2) where a facility with initially characteristic wastes treats those wastes with CWA-equivalent treatment but ultimately uses a form of land disposal (such as spray irrigation) that is not regulated under the CWA as the final means of disposing of the treated wastewaters; and (3) the initially characteristic wastes are injected into Class 1 non-hazardous deep wells subject to regulation under the Safe Drinking Water Act (SDWA). In all cases, the wastewaters no longer exhibit a characteristic at the point of land disposal. The amended treatment standards require treatment that destroys, immobilizes, or removes the hazardous constituents present in the initially characteristic wastewaters (referred to as "underlying hazardous

setting out circumstances where such responses are exempt from RCRA permitting requirements.) During the development of the proposed Military Munitions Rule: Hazardous Waste Identification and Management; Explosives Emergencies; Redefinition of On-site proposed rule (60 FR 56468, November 8, 1995), the Department of Defense, the military services, and other Federal agencies raised concerns that LDR requirements requiring treatment of underlying hazardous constituents might impede the most effective emergency responses involving these materials. If a responding team had to determine LDR applicability before deactivating an explosive subject to an emergency response, the response could be significantly delayed or complicated. Furthermore, concern about LDR applicability might discourage the team from responding at all. This discussion serves as EPA's initial response to these comments.

EPA agrees that the primary goal in emergency responses to explosives is the safe and prompt elimination of immediate threats to human life and property, and the Agency would be concerned if LDR or other regulatory requirements complicated these responses. The issue is too important and potentially complicated to resolve in today's rule. Therefore, EPA is temporarily deferring final action while it considers this issue further.

In deferring action for this limited class of reactive wastes, EPA notes that emergency responses present issues different from routine management of reactive wastes, where there is no competing consideration of need for immediate action to prevent an imminent threat. In non-emergency response management situations, as discussed earlier, the Agency believes these wastes can be fully treated to minimize both short and long-term threats posed by land disposal of wastes.[1] EPA also is amending the treatment standards for wastes exhibiting the toxicity characteristic to include standards for underlying hazardous constituents.

Toxic wastes can also contain underlying hazardous constituents in the same potentially harmful concentrations as ICR wastes. 60 FR at 11706. Today's final rule consequently conforms standards for toxic characteristic hazardous wastes to assure treatment of underlying hazardous constituents as well, when such constituents are present at levels exceeding the minimize threat level (as established either by the current technology-based standards or, if risk-based levels are established, exceeding a risk-based level.) Thus, the prohibitions and standards in today's rule will apply to ignitable, corrosive, reactive and toxic characteristic wastes, as just discussed.

II. Miscellaneous Issues for Which EPA Is Not Finalizing an Approach in This Final Rule

A. Treatment Standards for Organobromine Wastes

Organobromine wastes are not yet listed as hazardous. EPA anticipates making a final listing determination in a future rulemaking.

Although EPA proposed treatment standards for organobromine wastes, it clearly would be putting the cart before the horse to promulgate treatment standards in advance of a determination of whether the wastes are hazardous. The Agency intends to establish treatment standards for organobromine wastes should these wastes are listed in the future.

B. Potential Prohibition of Nonamenable Wastes From Land-Based Biological Treatment Systems

The proposed rule contained an extensive discussion of whether certain wastes should be prohibited from placement in biological treatment surface impoundments because they are not amenable to biological treatment. To allow more time to gather comments, the Agency has decided to address this issue in the LDR Phase IV rule, which was proposed on August 22, 1995 (60 FR 43654) and is scheduled to be finalized in June of 1996.

C. Certain Sections of Completing Universal Treatment Standards

The LDR Phase III proposed rule included a section on the completion of universal treatment standards (60 FR at 11727, March 2, 1995). Possible nonwastewater universal treatment standards (UTS) for eleven constituents were discussed in the proposal, and comments and data were solicited. In general, commenters felt more data should be gathered before EPA proposes nonwastewater standards for these constituents, and EPA agrees. EPA had also solicited comment and data on extending certain universal treatment standards to fill gaps in the § 268.40 table of universal treatment standards where "NA" appeared for either the wastewater or nonwastewater form of a regulated hazardous constituent. Commenters were opposed to this, stating that it would be arbitrary to add a standard to a waste code where before there was none without supporting data. The Agency again agrees. Therefore, EPA is not taking final action at this time.

D. Prohibition of Hazardous Waste as Fill Material

EPA proposed to prohibit use of hazardous waste as fill material. 60 FR at 11732. Because issues raised in the proposal are related to those in a number of other pending rulemakings, including the Hazardous Waste Identification Rule, and the proposed rule relating to land-based uses of hazardous waste K061 (59 FR 67256 (Dec. 29, 1994)), EPA is not taking final action on the proposal at this time.

E. Point of Generation

The Agency discussed possible changes that could be made to the "point of generation"—or point at which LDR requirements attach to a hazardous waste (see 60 FR 11717, March 2, 1995). The Agency is still considering the options discussed in the proposal and potentially other options not discussed. The Agency will reopen the point of generation issue for further comment, and is intending to finalize an option in a future rulemaking.

F. Prohibition on Using Iron Filings to Stabilize Spent Foundry Sand

The Agency proposed designating the practice of adding iron dust/filings to spent foundry sand as impermissible dilution (60 FR 11731, March 2, 1995). The Agency is gathering data on the stability of the chemical bond formed between the iron and lead in the spent foundry sand. After the Agency analyzes these data, as well as further studies the public comments on this issue, it may take final action on the proposal.

III. End-of-Pipe Equivalence: Treatment Standards for Clean Water Act (CWA) and CWA-Equivalent Wastewater Treatment Systems

A. Types of Facilities to Which Treatment Standards Apply

As explained above, the D.C. Circuit established a standard of so-called end-of-pipe equivalence, allowing CWA treatment systems with surface impoundments to dilute characteristic wastes before land disposal in those impoundments without violating LDR requirements, provided the treatment system destroys, immobilizes, or removes an equivalent amount of hazardous constituent as if the characteristic waste were treated separately to meet RCRA standards. EPA

[1] EPA also notes that it is not reopening the issue of open burning/open detonation of reactive wastes. In 1986, EPA determined that such activities are not a form of land disposal. See 51 FR at 40580 (Nov. 7, 1986).

characteristic waste containing metal and organic underlying hazardous constituents and the waste was treated sequentially by means not involving impermissible dilution, there could be different compliance points for the metal and organic hazardous constituents.

EPA notes, however, that if alternative points of compliance are utilized, enforcement would normally be pursuant to RCRA, not the Clean Water Act. This is by necessity, since CWA permits (or, for indirect dischargers, control mechanisms) would not normally apply to effluent quality before final discharge. See further discussion on means of implementing today's standards below in this preamble.

C. Why CWA Limitations and Standards Can Also Be RCRA Treatment Standards

As explained above, when a hazardous constituent is already subject to a CWA industry category or Water Quality Criteria-based limitation, or a case-by-case industrial POTW limitation or standard, the Agency believes (and the final rule provides) that the CWA limitations and standards satisfy RCRA section 3004(m) requirements and consequently become the RCRA treatment standard for purposes of demonstrating equivalent treatment. EPA believes that this is an obvious and effective means of integrating CWA and RCRA requirements, in accord with the court's objective. 976 F. 2d at 22; RCRA section 1006(b). This approach was generally supported by commenters as a reasonable means of satisfying the court's mandate and the underlying policy of integration of the two statutes.

Several commenters, however, argued that CWA limitations and standards could not be equivalent to RCRA because such standards can reflect (among other things) "the cost of achieving such effluent reduction", and "the age of equipment and facilities involved". CWA section 304(b)(2)(B) (factors to be considered in determining Best Available Technology). EPA disagrees. While it is true that technology-based standards developed to address toxic pollutants from various industrial categories are developed after consideration of levels that can be achieved through application of the best available technology economically achievable, the CWA limitations and standards nevertheless represent the best evaluation of what technically advanced wastewater treatment is capable of achieving for a particular industry's (or, in some cases, particular plant's) wastewater. Although there is no requirement that a particular treatment technology must be used to achieve the facility's limits, it is expected that plants utilizing BAT will have treated their effluent so that there are substantial reductions in concentration and mass of hazardous constituents. As the Agency has stated many times, EPA believes that section 3004(m) is satisfied by treatment that substantially destroys, immobilizes, and removes the hazardous constituents that are present in the waste, notwithstanding that minor amounts of hazardous constituents remain after treatment. Put another way, the statute does not require that every conceivable threat posed by land disposal be eliminated by treatment. 55 FR at 6641 and n. 1 (Feb. 26, 1990); 56 FR at 12355 (March 25, 1991); 57 FR 37259 (August 18, 1992); 55 FR at 22596 (June 1, 1990). In fact, the legislative history states explicitly that the treatment standards are not to be technology forcing, but rather are to utilize the available effective treatment technologies. 130 Cong. Rec. S. 1978 (daily ed. July 25, 1984) (statement of Sen. Chaffee); 56 FR at 12355. That is precisely what EPA has done here.

Second, with specific regard to use of CWA limitations, EPA notes that virtually all of the current LDR treatment standards for wastewaters are already drawn from CWA limitations and standards. See 55 FR at 22601 (wastewater standards for U and P wastes and F039, which essentially became the universal treatment standards, were transferred from treatment data from CWA programs), and see also the Final BDAT Background Document for U and P Wastes and Multi-Source Leachate (F039) Volume C (documenting that most of existing RCRA wastewater standards were transferred from CWA limitations and standards). Moreover, the technologies that are often used to achieve CWA limitations and standards are, in most cases, the same technologies upon which the RCRA Universal Treatment Standards are based. As EPA has already stated, "because most treatment technologies cannot be so precisely calibrated as to achieve, for example, 3.5 ppm rather than 2.7 ppm, the likely result is that the same amount of treatment will occur." 59 FR at 47989 (Sept. 19, 1994). Since frequently the same technologies are used to treat wastewaters, EPA expects the degree of treatment to be comparable.

EPA also emphasizes that RCRA section 1006(b) requires EPA (among other things) to integrate provisions of RCRA and the CWA when implementing RCRA, and to avoid duplication to the maximum extent possible with CWA requirements. The Agency feels it is accomplishing this requirement by allowing a constituent-specific, CWA treatment standard to satisfy RCRA 3004(m). The Agency reiterates that a technology-based CWA limitation or standard for a hazardous constituent satisfies RCRA because such a limitation or standard directly reflects the capability of BAT technologies to treat a specific industry's or facility's wastewater, whereas the RCRA UTS for wastewaters were developed by transferring performance data from various industries, and thus EPA need not make that same transfer when industry-specific (or plant-specific) wastewater treatment data is available.

A water-quality based limitation would also satisfy RCRA section 3004(m). A CWA water quality-based limitation must be at least as stringent as the limitations required to implement an existing technology-based standard. (See CWA section 301(b)(1)(c).) Even where there is no existing BAT limitation for a toxic or nonconventional pollutant, a permit writer must determine whether BAT would be more stringent than the applicable water quality-based limitation, and again, must apply the more stringent of the two potential limitations. (40 CFR 125.3(c)(2).)

If a facility has received a Fundamentally Different Factors (FDF) variance, the limitations established by that variance also satisfy RCRA requirements. Limitations established by the FDF variance process are technology-based standards reflecting facility-specific circumstances, and hence can appropriately be viewed as BDAT as well, just as with RCRA treatability variance standards. See 51 FR at 40605 (Nov. 7, 1986).

EPA also believes that there are adequate constraints in the CWA implementing rules to prevent these end-of-pipe standards from being achieved by means of simple dilution. First, many of the effluent limitation guidelines and standards regulate the mass of pollutants discharged, and thus directly regulate not only the concentration of pollutant discharged but the degree of wastewater flow as well. Even where rules are concentration-based, NPDES permit writers can set requirements which preclude excessive water use, and EPA has so instructed permit writers. (See 58 FR 66151, December 17, 1993, encouraging permit writers to estimate reasonable rate of flow per facility and factor that flow limit into the permit.) These permit conditions can take the form of best management practices,

2. Where Permits Do Not Contain a Limitation for a Hazardous Constituent

If the CWA permit either does not contain a limitation for the pollutant or does not regulate the pollutant through an indicator, or in cases when this rule becomes effective before the reissuance of a facility's permit, the RCRA universal treatment standards would apply as they do for any other RCRA hazardous wastestream. In this situation, the owner or operator of a facility has several choices. The owner/operator could do nothing, in which case the hazardous constituent would be subject to the UTS. These standards would be implemented by rule, and thus would not be embodied in a CWA permit. Enforcement consequently would be solely under RCRA. As noted earlier, the point of compliance could, but need not be, at the end-of-pipe point of discharge.

In the alternative, a facility could seek amendment of its NPDES permit pursuant to § 122.62(a)(3), requesting that the applicable permitting authority modify the permit at reissuance, or sooner, to add limits for the underlying hazardous constituents reflecting BAT for that pollutant at the facility.[3] Assuming proper design and operation of the wastewater treatment technology, a permit writer in such a case could modify the permit to add a limitation for the pollutant based on Best Professional Judgement reflecting actual BAT treatment (40 CFR 125.3(c)). Modification requests would be processed pursuant to the procedures found at § 124.5. The modified permit limitation would be a CWA requirement and enforceable solely under that statute, but would be deemed by the Agency to satisfy RCRA 3004(m), so that meeting UTS per se would not be required.

A final alternative is for the facility to seek a RCRA treatability variance. EPA is amending the grounds for granting such a variance to include situations where a facility is treating decharacterized wastes by treatment identified as BAT or NSPS (New Source Performance Standards), the technology is designed and operated properly, but is not achieving the UTS (see § 268.44(a)).

3. Indirect Dischargers

The same alternatives exist for indirect dischargers. If an underlying hazardous constituent is regulated by a categorical PSES, PSNS, or by a local limit in a control mechanism reflecting PSES or PSNS—level treatment, then that standard satisfies both RCRA and the CWA. In addition, if there is no pretreatment standard (i.e., PSES/PSNS) for an underlying hazardous constituent, because the Agency determined that there was no pass through, then section 3004(m) is satisfied and the RCRA standard for that underlying hazardous constituents does not apply.

If an underlying hazardous constituent is not regulated nationally by a PSES or PSNS, or by a local limit, it becomes subject to the UTS for that constituent. That UTS would be enforced as a RCRA standard. However, in cases where an underlying hazardous constituent is not already subject to categorical PSES, categorical PSNS, or to a local limit in a control mechanism reflecting PSES or PSNS-level treatment, water quality, or pass through, the control mechanism between the indirect discharger and the applicable control authority would have to be modified in order to avoid application of the UTS by rule. EPA is amending § 403.5(c)(1) and § 403.5(c)(2) of the pretreatment rules to specifically authorize control authorities to make such determinations.

The final option is for a facility to obtain a RCRA treatability variance. Thus, the amendment to the treatability variance rules also applies to indirect dischargers properly operating technology identified as the basis for their PSES or their PSNS standard.

4. Zero Dischargers Performing CWA-Equivalent Treatment

The implementation options for zero dischargers performing CWA-equivalent treatment are similar. Some of these facilities may have CWA permits authorizing specified levels of discharge. If these permit limitations apply to underlying hazardous constituents present in the RCRA-prohibited portion of the discharge, the CWA permit limit satisfies RCRA as well. The facility also could seek to amend the CWA permit to add limitations for the hazardous constituent. Enforcement then would be exclusively pursuant to the CWA.

If the zero discharger has no CWA permit, or the permit does not contain limitations for underlying hazardous constituents and is not amended to do so, then the facility would have to meet the RCRA UTS or an alternative standard established by treatability variance either at the point of discharge[4] or at an earlier point of its choosing (assuming, of course, that a valid demonstration of bona fide treatment can be made at an earlier point).

5. Implementation When CWA Standards and Limitations Will Not Be the Exclusive Standard

If the facility treats to UTS and does not modify its CWA permit or control mechanism to include a CWA standard/limitation for an underlying hazardous constituent, EPA is finalizing minimal recordkeeping requirements, under RCRA authority. Generators can use their knowledge to identify the underlying hazardous constituents reasonably expected to be present at the point of generation of the ICRT wastes which are not covered by a CWA limitation or standard and hence must be treated to meet UTS (assuming no permit modification). EPA is requiring that this information be kept on-site in files at the facility. The facility will then monitor compliance with the UTS standard for each of these constituents at the point of ultimate discharge or alternative compliance point, on a quarterly basis, and results of this monitoring must be kept in the facility's on-site files. An exceedence of the RCRA UTS standard must be documented in the facility's on site records.

These same requirements apply to facilities without NPDES permits documenting compliance as zero dischargers with CWA-equivalent treatment who are affected by this rule. The absence of a permit necessitates some alternative means of documenting compliance, and the scheme outlined above seems to be the least burdensome scheme which would still provide a reasonable means of enforcing this rule.

6. RCRA Controls Over Point Source Discharges and Domestic Sewage

Both RCRA and the implementing regulations provide that point source discharges and domestic sewage (including mixtures of domestic sewage with other wastes) are not subject to

[3] EPA is interpreting the language in § 122.62(a)(2) to indicate that the D.C. Circuit's opinion in the Third Third case is new information warranting reopening a permit.

[4] The point of compliance for a zero discharger choosing the point of discharge as a compliance point would be at the point of ultimate disposal. For those zero dischargers who discharge to a dry river bed (common in the western U.S.) not considered a "water of the U.S." under the CWA, the point of compliance would be at the end-of-pipe. For those zero dischargers who spray irrigate, or otherwise place the wastewaters on the land after treatment in the surface impoundment, the point of compliance would be at the point just prior to the land placement. Furthermore, zero dischargers treating wastewaters in a tank system followed by spray irrigation or another form of land placement are also subject to this rule. For those zero dischargers who use evaporation ponds, the point of compliance is before the wastewater enters the surface impoundment, as this is the ultimate disposal point.

would be the trigger level for the LDR prohibition, EPA has recently proposed risk-based hazardous constituent concentration levels which would implement the "minimize threat" requirement in section 3004(m), and would cap the technology-based treatment standards whenever the technology-based standards are lower (60 FR 66344, December 21, 1995). The *de minimis* feature of today's rule further addresses situations where EPA believes that prohibitions need not apply due to the low concentrations and volumes of hazardous constituents in the decharacterized portion of the injectate.

B. Compliance Options for Class I Nonhazardous Wells

In the proposed rule, the Agency indicated that facilities could segregate their hazardous wastes, and treat just that volume of the total waste stream to UTS levels in order to conform to the treatment requirement. A number of commenters maintained that the Agency oversimplified this approach and that such segregation was impractical from both a technical and economic standpoint. EPA acknowledges that many facilities may not practically be able to segregate streams. These facilities may utilize of other LDR compliance options as discussed below.

One option would be to apply for an exemption from treatment standards via the no-migration petition variance. EPA is promulgating a clarifying revision to 40 CFR 148.20 which allows facilities to seek a no-migration variance for their Class I nonhazardous wells, and has long indicated that this compliance option is available (see pp. 25-27, Supplemental Information Report prepared for the Notice of Data Availability, January 19, 1993, 58 FR 4972). If these facilities demonstrate to EPA that their formerly characteristic wastes (including any hazardous constituents) will not migrate out of the injection zone for 10,000 years, or no longer pose a threat to human health and the environment because the wastes are attenuated, transformed, or immobilized by natural processes, then they may continue to inject without further treatment.

A significant number of commenters responded to the proposed rule's discussion on the Agency's position on granting no-migration petitions. Comments included that petitions were a too costly option, took too much time to be processed, generic petitions for Class I non-hazardous wells should be granted, and existing no-migration exemptions should not require modification to include Phase III wastes. These comments, among others, will be discussed in detail in the "Response to Comments" background document for this rule, but basically many had partial merit.

First, although the Agency has estimated earlier that the average petition costs an operator $343,000, several individual petition reviews have far exceeded that amount. The Agency will examine the possibility of revising petition cost data in future LDR rules. Second, although a petition may take up to 3 years to process, the Agency (as noted above) indicated as early as 1992 (after the Third Third opinion) that it would begin review of Class I nonhazardous injection well no-migration petitions if submitted (58 FR 4972, January 19, 1993). Although time and resource restraints on the Agency are real, the Agency will continue to work with affected Class I operators in order to facilitate the no-migration petition review process. Third, although EPA has established a reasonable knowledge base on the review process for Class I hazardous facilities, it cannot automatically infer that all Class I nonhazardous facilities will successfully make a no-migration demonstration. Well site geology, hydrogeology, abandoned well area of review, and the specific characteristics of the injectate and receiving formation are site specific factors which, as a factual matter, must be evaluated individually in order to demonstrate "to a reasonable degree of certainty" (RCRA section 3004(g)(5)) that the no-migration standard has been satisfied. See Supplemental Report to Notice of Data Availability, January 19, 1993, at 25-26 9. It must be remembered that not every Class I injection well applying for the variance has been able to make the demonstration, and that one salutary effect of the no migration process has been to identify certain (albeit a limited number of) wells that would not be capable of adequately containing injectate over the long term.

EPA agrees completely with commenters, however, that wells that already have approved no migration exemptions are not affected by the Third Third opinion and thus are not affected by land disposal restrictions affecting decharacterized wastes. (In fact, EPA does not read the proposal to suggest otherwise.) Absent a change in the waste being injected, there is no reason to reopen no migration determinations that have already evaluated the entire injected waste stream. 57 FR at 31963 (July 20, 1992).

EPA is also promulgating additional means for Class I nonhazardous facilities to comply with the LDR requirements. Revisions to 40 CFR 148.1(c)(1) and 148.4 will allow Class I nonhazardous owners and operators to apply for a case-by-case extension of th capacity variance for up to one year (renewable for up to an additional year) in order to acquire or construct alternative treatment capacity. Based on experience, EPA believes that the availability of the case-by-case extension coupled with national capacity variance(s) should allow operators more than adequate time to acquire alternative treatment or complete the no-migration petition process. Two other options include the pollution prevention option and the de minimis volume exclusion.

C. Pollution Prevention Compliance Option

The final rule provides an alternative means of obtaining the reductions in mass loadings of hazardous constituents mandated by the Third Third opinion. Under this alternative, mass reductions can be achieved by removing hazardous constituents from any of the wastestreams that are going to be injected, and these reductions in mass loadings can be accomplished by means of source reduction (i.e. equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control), recycling, or conventional treatment. As an example, if a facility can make process changes that reduce the mass of cadmium by the same amount that would be removed if the prohibited wastestream was treated to satisfy UTS, the facility would satisfy LDR requirements. The facility could also remove cadmium from any of the streams (prohibited or non-prohibited) which are going to be injected, or could find a means of recycling some portion of the injectate to reduce injected mass loadings of cadmium. In all cases, the result would be that the mass loading of hazardous constituents into the injection unit would be reduced by the same amount as it would be reduced by treatment of the prohibited, characteristic portion of the injectate. 976 F. 2d at 23 n. 8; see also *Specialty Steel Inst.* v. *EPA*, 27 F. 3d 642, 649 (D.C. Cir. 1994) (treatment standards that result in lower volume of waste to be disposed—precisely what the alternative standard here can achieve—are a permissible means of complying with RCRA section 3004 (m)).

Commenters further requested that this alternative be available on a hazardous constituent by hazardous constituent basis. EPA agrees that this is

present in the characteristic wastes at concentrations less than 10 times UTS at the point of generation, then the wastes are not prohibited from injection in a Class I non-hazardous deepwell (assuming the injectate is not hazardous at the point of injection). The Agency continues to believe that under these circumstances, the relatively small decharacterized hazardous waste streams would not appreciably alter the risks posed by the injection practice.

Generally, the proposed approach was well received. Some commenters stated, however, that the *de minimis* volume exemption, as proposed, would allow excessively large volumes of routinely generated characteristic wastes to go untreated to disposal in deep wells, while others believe that the specific quantifying parameters are overly restrictive. The Agency analyzed potential risks associated with concentrations of 5 contaminants detected in Class I facility waste streams at 10, 20, and 50 times UTS. (This analysis was conducted in conjunction with revising the Regulatory Impact Analysis For Underground Injected Wastes for this rule. See 60 FR 11715.) In brief, risk estimates for 4 geologic settings and 2 well malfunction scenarios were found to be below levels of regulatory concern at 10 and 20 times UTS. However, at 50 times UTS, risk estimates for cancer and hazard index were above regulatory concern for a waste stream containing carbon tetrachloride, assuming an abandoned borehole failure within 500 feet of the injection well. Taking into account the statutorily enumerated "long-term uncertainties associated with land disposal" (RCRA section 3004(d)(1)(A)), EPA believes the 10 × UTS level to be well within the zone of reasonable values it could select as *de minimis*. The one percent volumetric requirement is consistent with other longstanding *de minimis* exemptions for wastewater management systems in the subtitle C rules (see § 261.3(a)(2)(iv) (A) and (E)), and would normally cap the total volume of characteristic injectate at approximately 1100 gallons per day, given average Class I UIC non-hazardous injection rates.

At a rate of 1100 gallons per day, 10×UTS for carbon tetrachloride would mean a mass loading of approximately 165 mg of the constituents being injected each day. Mass loadings for the other hazardous constituents would similarly be modest. EPA again believes that these small mass loadings would have *de minimis* effect on the risk potential posed by the injection practice and consequently should be exempted from the prohibition.

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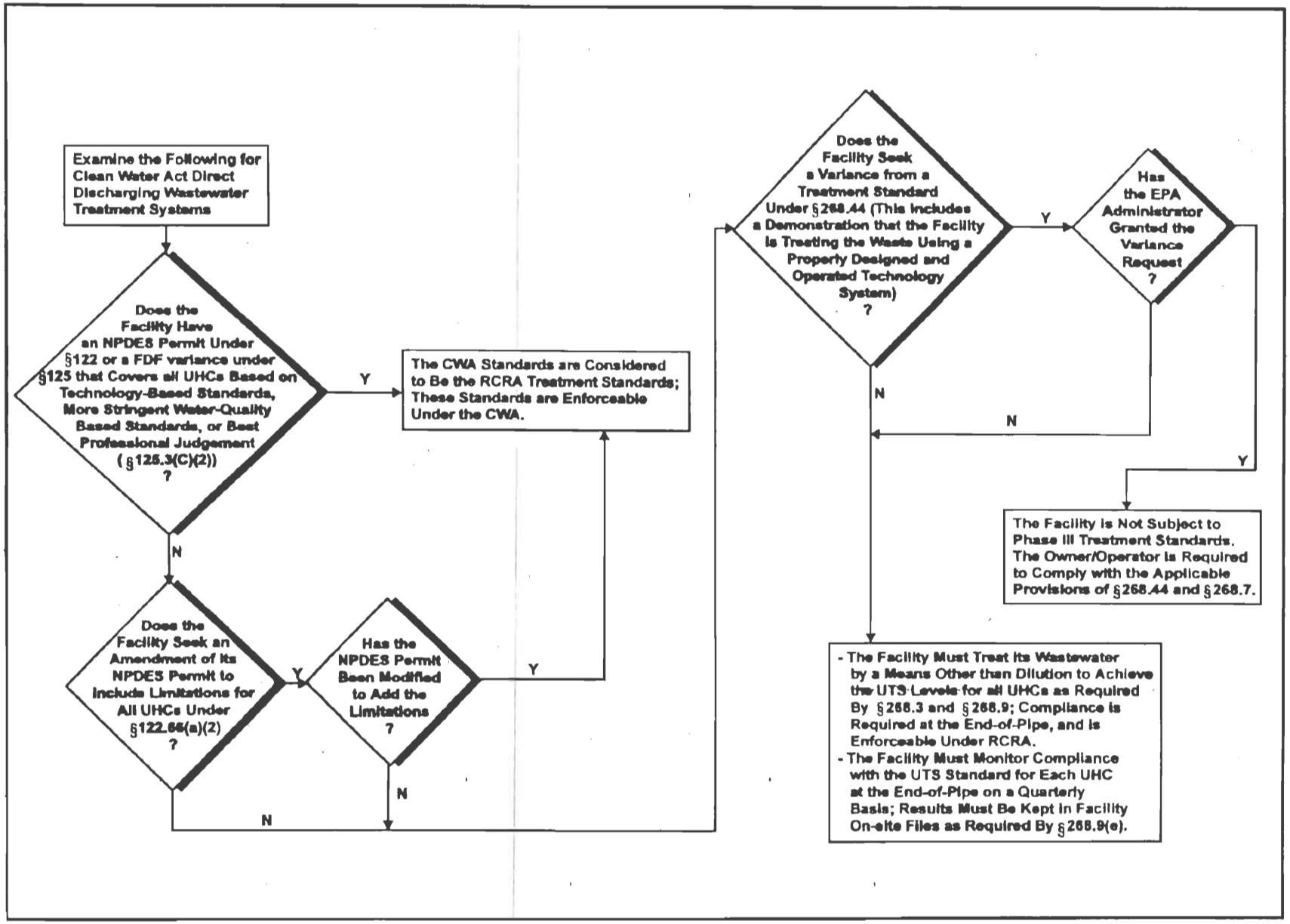


Figure 2. Applicability Criteria and Treatment Standards for Decharacterized Wastes Managed in Clean Water Act Direct Discharging Wastewater Treatment Systems

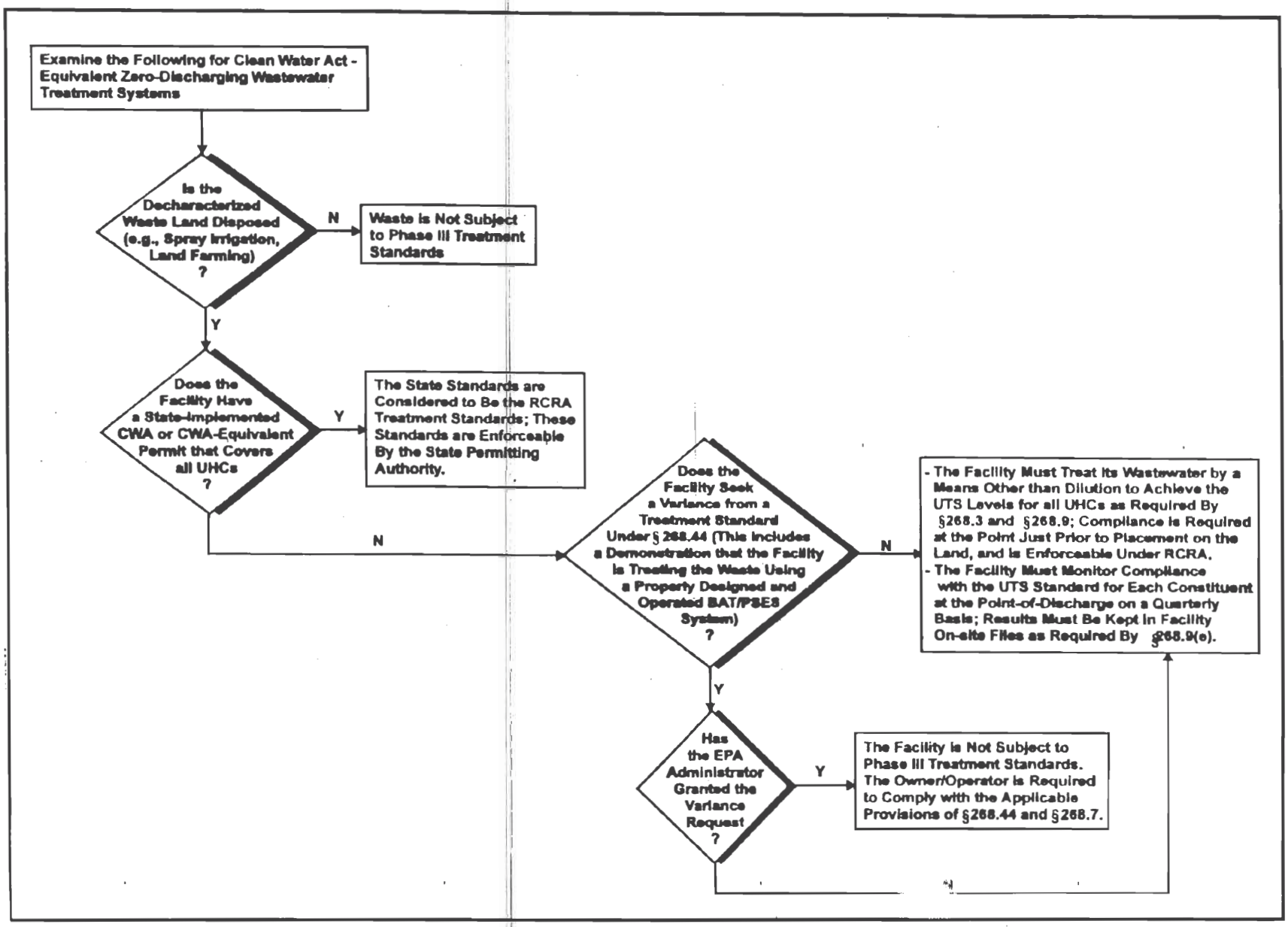


Figure 4. Applicability Criteria and Treatment Standards for Decharacterized Wastes Managed in Clean Water Act - Equivalent Zero-Discharging Wastewater Treatment Systems

V. Treatment Standards for Newly Listed Wastes

A. Carbamates

Hazardous Wastes From Specific Sources (K Waste Codes)

K156—Organic waste (including heavy ends, still bottoms, light ends, spent solvents, filtrates, and decantates) from the production of carbamates and carbamoyl oximes.
K157—Wastewaters (including scrubber waters, condenser waters, washwaters, and separation waters) from the production of carbamates and carbamoyl oximes.
K158—Bag house dust, and filter/separation solids from the production of carbamates and carbamoyl oximes.
K159—Organics from the treatment of thiocarbamate wastes.
K160—Solids (including filter wastes, separation solids, and spent catalysts) from the production of thiocarbamates and solids from the treatment of thiocarbamate wastes.
K161—Purification solids (including filtration, evaporation, and centrifugation solids), baghouse dust, and floor sweepings from the production of dithiocarbamate acids and their salts. (This listing does not include K125 or K126.)

Acute Hazardous Wastes (P Waste Codes)

P203 Aldicarb sulfone
P127 Carbofuran
P189 Carbosulfan
P202 m-Cumenyl methylcarbamate
P191 Dimetilan
P198 Formetanate hydrochloride
P197 Formparanate
P192 Isolan
P196 Manganese dimethyldithiocarbamate
P199 Methiocarb
P190 Metolcarb
P128 Mexacarbate
P194 Oxamyl
P204 Physostigmine
P188 Physostigmine salicylate
P201 Promecarb
P185 Tirpate
P205 Ziram

Toxic Hazardous Wastes

U394 A2213
U280 Barban
U278 Bendiocarb
U364 Bendiocarb phenol
U271 Benomyl
U400 Bis(pentamethylene)thiuram tetrasulfide
U392 Butylate
U279 Carbaryl
U372 Carbendazim
U367 Carbofuran phenol
U393 Copper dimethyldithiocarbamate
U386 Cycloate
U366 Dazomet
U395 Diethylene glycol, dicarbamate
U403 Disulfiram
U390 EPTC
U407 Ethyl Ziram
U396 Ferbam
U375 3-Iodo-2-propynyl n-butylcarbamate
U384 Metam Sodium
U365 Molinate
U391 Pebulate
U383 Potassium dimethyl dithiocarbamate
U378 Potassium n-hydroxymethyl-n-methyldithiocarbamate
U377 Potassium n-methyldithiocarbamate
U373 Propham
U411 Propoxur
U387 Prosulfocarb
U376 Selenium, tetrakis (dimethyldithiocarbamate)
U379 Sodium dibutyldithiocarbamate
U381 Sodium diethyldithiocarbamate
U382 Sodium dimethyldithiocarbamate
U277 Sulfallate
U402 Tetrabutylthiuram disulfide
U401 Tetramethylthiuram monosulfide
U410 Thiodicarb
U409 Thiophanate-methyl
U389 Triallate
U404 Triethylamine
U385 Vernolate

EPA is promulgating the treatment standards that were proposed for wastes from the carbamate industry specified above.

The preamble of the proposed rule described the basis for these treatment standards in greater detail (60 FR 11720). For background information on waste characterization data, data gathering efforts, and applicable technologies, see the Best Demonstrated Available Technology (BDAT) Background Document for Newly Listed or Identified Wastes from the Production of Carbamates.

The concentration-based treatment standards being promulgated today for carbamate wastewaters and nonwastewaters are at UTS levels for certain constituents, and at newly-established levels for other constituents that are today being added to the UTS list. The UTS standards have already been promulgated for 21 of the constituents of concern (16 organic constituents and 5 metals). The Agency is promulgating new UTS for 42 constituents associated with carbamate wastes. Forty of these constituents are chemicals produced by the carbamate industry which may be grouped into the following categories: carbamates and carbamate intermediates, carbamoyl oximes, thiocarbamates, and dithiocarbamates. Please refer to the Background Document for definitions of these chemical groups and the categorization of these 40 chemicals. The other 2 constituents for which new UTS are being promulgated (triethylamine, and o-phenylene diamine) are not carbamate products, but are hazardous constituents present at levels of regulatory concern in carbamate wastes.

One commenter requested clarification on the applicability of the carbamate treatment standards, stating that the summary section of the proposed treatment standards said that treatment standards were being proposed for certain hazardous wastes "including those from the production of carbamate pesticides", whereas the section of the rule that directly addressed carbamate wastes referred to carbamates without the pesticide limitation. EPA points out in response that the final listing rule which defined the new waste codes does not limit the definition to pesticides only. The treatment standards being promulgated apply to all wastes which fit the definitions of the waste codes established in the final listing rule.

One commenter stated that EPA exceeded its authority under RCRA section 3004 and violated the Administrative Procedure Act by preparing the proposed treatment standards and sending this rule to OMB well before the final listing had been promulgated. EPA points out that the proposed treatment standards were actually published after publication of the final listing rule. The proposed treatment standards were modified to conform with the changes that appeared in the final listing; thus, treatment standards were only proposed for those carbamate wastes whose listing had been promulgated in final form. Proposed standards for wastes whose listings were not finalized were eliminated from the proposed treatment standards rule. Given the statutory requirement described above (i.e., the requirement to finalize LDR treatment standards six months after the listing is finalized), Congress must have envisioned that the two rulemaking activities would occur in close proximity.

One commenter had several objections to the proposed standards for thiocarbamate wastes, stating that 1) nonwastewater standards should not have been based on detection limits compiled from sampling and analysis performed as part of the listing process

sources under section 112, but that determination need not be part of the present rulemaking.

2. Comments Received on Regulated Constituents

EPA requested comment on regulating the phthalates: bis (2-ethylhexyl) phthalate, di-n-butyl phthalate and di-n-octyl phthalate. These constituents have seemingly been detected in the untreated potliner and the treated residue; however, EPA believes that their presence may simply be due to lab contamination. Commenters overwhelmingly requested that these phthalates not be regulated. The Agency agrees and is not including any phthalates in the list of regulated constituents for K088.

A number of commenters requested that benzo(a)pyrene be used as a surrogate for analyzing organics. The commenters were concerned that analytical costs for other PAHs would be excessive. EPA is not convinced that analyzing benzo(a)pyrene would be sufficient for determining proper treatment of all organics. The concentration of one constituent does not always reflect the concentration of similar constituents in a waste. Surrogate analyses assume that all PAHs are present at similar concentrations which may or may not be true. Because of the variability of concentrations found in K088 wastes, benzo(a)pyrene may not be present while other PAHs may be present. Analyzing only for benzo(a)pyrene or any other potential surrogate does not ensure the treatment to UTS concentrations of other PAHs. In addition, the Agency believes that since all of the PAHs are analyzed by a single method the cost increase for additional PAHs should not be significant. Therefore, the Agency does not believe the organic constituents monitored in K088 wastes should be limited to a surrogate indicator. EPA is allowing, however, flexibility in the waste analysis plans developed by the companies with their permit writers to analyze only for those constituents expected to be present in the generated K088.

The Agency proposed to regulate fluoride in K088. While fluoride is not a "hazardous constituent", i.e., listed in Appendix VIII of part 261, it is present in very high concentrations in K088 and is capable of causing substantial harm in the form of groundwater degradation, adverse ecological effects and potential adverse human health effects. The Agency's view thus is that, unless fluoride in this waste is treated, the legal standard in section 3004(m) would not be satisfied. That is, treatment would not "substantially diminish the toxicity of the waste * * * so that short-term and long-term threats to human health and the environment are minimized." RCRA section 3004(m)(1). In addition, as discussed in the proposed rule, EPA reads the language in section 3004 (d)(1), (e)(1), and (g)(5) to require that land disposal may still be prohibited after treatment of hazardous constituents if the waste might still pose substantial hazards due to presence of other constituents or properties. 56 FR at 41168 (August 19, 1991); *NRDC* v. *EPA*, 907 F. 2d 1146, 1171–72 (D.C. Cir. 1990) (dissenting opinion). These hazards could be posed due to lack of treatment of other constituents in the waste, in this case, fluoride.

The Agency requested comment on whether fluoride should be added to Appendix VIII, as well. The overwhelming response of the commenters is that fluoride should not be added to Appendix VIII. The Agency agrees that fluoride does not pose the same risks in other wastes because it does not occur in such high concentrations. Furthermore, adding fluoride to Appendix VIII has associated potential analytical costs which would be unwarranted. Therefore, even though the Agency is regulating fluoride in K088, it is not adding it to Appendix VIII at this time.

3. Comments Received on Data

Several comments were received regarding EPA's use of data on K088. One comment in particular suggested that EPA ignored relevant data gathered by the Aluminum Association. The Agency did not ignore these data. They were submitted after the proposal and are currently in the docket for this final rule. The Agency has reviewed these data and found that they do not support any changes to the proposed treatment standards that are being finalized in this rule. This issue is discussed in greater detail in the Response to Comments background document.

4. Comments Received on Technical Basis for BDAT

There were a number of comments submitted on the technical basis for the numerical treatment standards. As described in the preamble to the proposed rule, most of the treatment standards are taken from the universal treatment standards (UTS) (59 FR 47988, September 19, 1994) which were developed for each constituent by evaluating all existing Agency data from various technologies. The exception to the UTS for K088 constituents is the fluoride treatment standard, which was taken from the Reynolds delisting petition. While K088 is a unique waste, available data indicate that these UTS levels can be routinely achieved.

There seemed to be some confusion in that some commenters believed that EPA was proposing a required technology for the treatment of K088. This is not the case. The longstanding position of the Agency is when numerical treatment levels are established under the LDR program, any treatment technology (other than impermissible dilution) can be used to achieve those levels.

Additional K088 comments along with EPA's responses are provided in the Response to Comments Background Document located in the docket for this rule.

VI. Improvements to the Existing Land Disposal Restrictions Program

A. Completion of Universal Treatment Standards

1. Addition of Constituents to Table 268.48

As discussed in the section on carbamate wastes, EPA is today adding 42 new constituents to the table of universal treatment standards (Table 268.48), for which treatment standards are being promulgated today.

2. Wastewater Standard for 1,4-Dioxane

EPA proposed on March 2, 1995 (60 FR 11702), to establish a wastewater treatment standard for 1,4-dioxane. 1,4-Dioxane was the only UTS constituent for which EPA had promulgated a nonwastewater treatment standard but not a wastewater standard. At that time, the Agency proposed a wastewater UTS for 1,4-dioxane of 0.22 mg/l. This proposed standard was based on the maximum daily limit for 1,4-dioxane that had been developed as part of the proposed effluent guidelines for the pharmaceutical industry (60 FR 21592, May 2, 1995). This standard was based on a transfer of distillation performance data from methanol to 1,4-dioxane.

Today, the Agency is promulgating a revised treatment standard for wastewater forms of 1,4-dioxane based on 5 data points. This data was submitted by one of the commenters and represents actual treatment of wastewaters containing 1,4-dioxane. The Agency prefers to use actual treatment data in lieu of a data transfer whenever possible. These data show that wastewaters containing between 2265–7365 mg/l of 1,4-dioxane can be treated by distillation to levels between 3–7 mg/l, representing a 99.9% removal rate for the dioxane. As a result of this data submittal, the Agency is today promulgating a UTS of 12.0 mg/l for 1,4-

a Statement of Policy which clarified this point (59 FR 27546-27547). Today the Agency is codifying and quantifying these principles.

As discussed in the proposed rule, impermissible dilution may occur when wastes not amenable to treatment by a certain method (i.e., treated very ineffectively by that treatment method) are nevertheless 'treated' by that method (55 FR 22666, June 1, 1990; 52 FR at 25778-25779, July 8, 1987). Today's rule provides a general distinction between "adequate treatment" and potential violations of the dilution prohibition.

1. Inorganic Metal-Bearing Wastes

The Agency has evaluated the hazardous wastes and has determined that 43 of the RCRA listed wastes (as set forth in 40 CFR part 261) typically appear to be inorganic hazardous wastes that do not contain organics, or contain only insignificant amounts of organics, and are not regulated for organics. BDAT for these inorganic, metal-bearing listed wastes is metal recovery or stabilization. Thus, impermissible dilution may result when these wastes are combusted. When an inorganic metal-bearing hazardous waste with insignificant concentrations of organics is placed in a combustion unit, legitimate treatment for purposes of LDR ordinarily is not occurring. No treatment of the inorganic component occurs during combustion, and therefore, metals are not destroyed, removed, or immobilized. Since there are no significant concentrations of organic compounds in inorganic metal-bearing hazardous wastes, it cannot be maintained that the waste is being properly or effectively treated via combustion (i.e., thermally treated or otherwise destroyed, removed, or immobilized). For this reason, combustion of inorganic wastes is not a "metho[d] of treatment * * * which substantially diminish[es] the toxicity of the waste or substantially reduce[s] the likelihood of migration of hazardous constituents from the waste * * *" (RCRA § 3004(m)) and so is not a permissible method of treatment under that provision.

In terms of the dilution prohibition, if combustion is allowed as a method to achieve a treatment standard for these wastes, metals in these wastes will be dispersed to the ambient air and will be diluted by being mixed in with combustion ash from other waste streams. Adequate treatment (stabilization or metal recovery to meet LDR treatment standards) has not been performed and dilution has occurred. It is also inappropriate to regard eventual stabilizing of such combustion ash as providing adequate treatment for purposes of the LDRs. Simply meeting the numerical BDAT standards for the ash fails to account for metals in the original waste stream that were emitted to the air and for reductions achieved by dilution with other materials in the ash. (In most cases, of course, the metal-bearing wastes will have been mixed with other wastes before combustion, which mixing itself could be viewed as impermissible dilution).

These inorganic, metal-bearing hazardous wastes should be—and are usually—treated by metal recovery or stabilization technologies. These technologies remove hazardous constituents through recovery in products, or through immobilization, and are therefore permissible BDAT treatment methods.

There are eight characteristic metal wastes; however, only wastes that exhibit the TC as measured by both the TCLP and the EP for D004-D011 are presently prohibited (see 55 FR 22660-22662, June 1, 1990). EPA recently proposed prohibition and treatment standards for wastes identified as hazardous solely because they exhibit the TC (60 FR at 43682, August, 22, 1995). Characteristic wastes, of course, cannot be generically characterized as easily as listed wastes because they can be generated from many different types of processes. For example, although some characteristic metal wastes do not contain organics or cyanide or contain only insignificant amounts, others may have organics or cyanide present which justify combustion, such as a used oil exhibiting the TC characteristic for a metal. Thus, it is difficult to say which D004-D011 wastes would be impermissibly diluted when combusted, beyond stating that as a general matter, impermissible dilution would occur if the D004-D011 waste does not have significant organic or cyanide content but is nevertheless combusted.

An "inorganic metal-bearing waste" is one for which EPA has established treatment standards for metal hazardous constituents, and which does not otherwise contain significant organic or cyanide content. The table being promulgated in 40 CFR part 268, Appendix XI is the list of waste codes for which EPA regulates only metals that are affected by this rule.

2. Inorganic Metal-Bearing Wastes Not Prohibited Under the LDR Dilution Prohibition

Combustion of the following inorganic metal-bearing wastes is not prohibited under the LDR dilution prohibition: (1) wastes that, at the point of generation, or after any bona fide treatment such as cyanide destruction prior to combustion, contain hazardous organic constituents or cyanide at levels exceeding the constituent-specific treatment standard for UTS; (2) organic, debris-like materials (e.g., wood, paper, plastic, or cloth) contaminated with an inorganic metal-bearing hazardous waste; (3) wastes that, at point of generation, have reasonable heating value such as greater than or equal to 5000 Btu/lb (see 48 FR 11157, March 16, 1983); (4) wastes co-generated with wastes that specify combustion as a required method of treatment; (5) wastes, including soil, subject to Federal and/or State requirements necessitating reduction of organics (including biological agents); and (6) wastes with greater than 1% Total Organic Carbon (TOC).

Several commenters want EPA to add additional criteria. One commenter recommended adding a seventh criterion, i.e., combustion that results in a significant reduction in volume. Several commenters recommended adding a seventh criterion to allow combustion of lab packs. The Agency is not persuaded that a seventh criterion is necessary. It has determined that volume reduction is not a sufficient reason to allow the combustion of inorganic metal-bearing wastes because metals are neither destroyed nor immobilized, and it is possible that a significant amount of metal is being transferred to another media. As for lab packs, in the Phase II final rule (59 FR 47982, September 19, 1994), the Agency specifically addressed lab pack issues when it revised 268 Appendix IV to specify those wastes that are prohibited from inclusion in lab packs destined for combustion. Today's dilution prohibition does not supersede the streamlined treatment standards promulgated in the Phase II final rule. Therefore, metal-bearing inorganic wastes may be included in a lab pack unless it is prohibited under the list of wastes in 268 Appendix IV.

3. Cyanide-Bearing Wastes

A commenter questioned why EPA allows the presence of cyanide to justify combustion when there are adequate alternative treatment methods for that waste constituent. This approach was adopted because cyanide is destroyed—i.e., effectively treated and not diluted—by combustion. Existing LDR rules, in many cases, identify combustion as an appropriate BDAT for destruction of cyanide-bearing wastes. See, e.g., treatment standards for F009, F010, and F011. The LDR Phase III proposal solicited comments on whether the

Land Disposal Restrictions Rulemaking, also found in the docket for today's rule.

In general, EPA's capacity analysis methodologies focus on the amount of waste to be restricted from land disposal that is currently managed in land-based units and that will require alternative treatment as a result of the LDRs. The quantity of wastes that are not managed in land-based units (e.g., wastewaters managed only in RCRA exempt tanks, with direct discharge to a POTW) is not included in the quantities requiring alternative treatment as a result of the LDRs. Also, wastes that do not require alternative treatment (e.g., those that are currently treated using an appropriate treatment technology) are not included in these quantity estimates.

EPA's decisions on whether to grant a national capacity variance are based on the availability of alternative treatment or recovery technologies. Consequently, the methodology focuses on deriving estimates of the quantities of waste that will require either commercial treatment or the construction of new on-site treatment systems as a result of the LDRs—quantities of waste that will be treated adequately either on site in existing systems or off site by facilities owned by the same company as the generator (i.e., captive facilities) are omitted from the required capacity estimates.

B. Capacity Analysis Results Summary

For the decharacterized ICR and TC wastes managed in CWA, CWA-equivalent, and Class I injection well systems, EPA estimates that between 85 and 500 million tons per year (estimated at end-of-pipe) will be affected as a result of today's rule. EPA believes that many affected facilities need time to build treatment capacity for these wastes, as wastewater volumes generally make off-site treatment impractical. Thus, EPA has determined that sufficient alternative treatment capacity is not available, and today is granting a two-year national capacity variance for decharacterized wastewaters.

Commenters to the rule generally supported EPA's decision to grant a national capacity variance for decharacterized wastes managed in CWA, CWA-equivalent, and Class I injection well systems. Numerous other comments were received on issues such as those associated with the definition of point of generation for ICR and TC wastewaters and the applicability of today's rule to wastewater management units other than surface impoundments, such as stormwater impoundments, sumps, sewers, and trenches. The Response to Capacity-Related Comments Received on the Phase III Land Disposal Restrictions Rulemaking background document provides a detailed discussion of the capacity-related comments on decharacterized wastewaters and EPA's response to them.

To assess the quantity of D003 wastes that could be affected by the rule other than those wastes managed in CWA and CWA-equivalent systems, EPA extracted information from the 1993 Biennial Reporting System (BRS) on the generation and management of D003 wastes. According to the BRS, approximately 2.2 million tons of D003 wastewaters are currently deepwell injected, 650 tons of D003 nonwastewaters are managed through land application, and 17,600 tons of D003 nonwastewaters are managed in "other" disposal units (not specified in the BRS). These wastes may require additional treatment in order to meet the LDRs. In addition, some D003 waste that may be affected by the rule may not be reported in the BRS, because these wastes may not be considered hazardous by the generator once they have been decharacterized. Although EPA believes that in general there is adequate treatment capacity for these wastes, such capacity may not be immediately available. Therefore, EPA is granting a 90-day capacity variance for D003 wastes that are impacted by the rule and are not managed in CWA and CWA-equivalent systems in order to allow facilities time to determine whether their wastes are affected by this rule, and identify and locate alternative treatment capacity if necessary.

EPA estimates that approximately 105,000—130,000 tons of newly listed wastes included in today's rule will require alternative treatment. In particular, approximately 4,500 tons of carbamate wastes (K156–K161, P127, P128, P185, P188–P192, P194, P196–P199, P201–P205, U271, U277–U280, U364–U367, U372, U373, U375–U379, U381–U387, U389–U396, U400–U404, U407, U409–U411) will require alternative treatment. In addition, 100,000—125,000 tons (not including contaminated media) of spent aluminum potliners (K088) will require alternative treatment capacity.

EPA received a number of comments on its capacity analysis for K088 wastes. Most commenters disagreed with EPA's proposal not to grant a capacity variance for K088 wastes. Specifically, these commenters believe that EPA overestimated the quantity of available capacity and underestimated the quantity of required capacity. In performing the capacity analysis for the final rule, EPA considered all of the issues raised by the commenters and reexamined its estimates of both available and required capacity. EPA found that adequate treatment capacity does exist for K088 wastes, although the amount of treatment capacity appears to be just adequate to accommodate demand. However, some of the facilities capable of treating these wastes may require pretreatment such as grinding or crushing prior to accepting the waste. In order to allow facilities generating K088 adequate time to work out logistics such as transportation, pretreatment capacity, and contracting for treatment capacity, EPA has decided to grant a nine-month national capacity variance for these wastes—the time at which EPA estimates existing treatment capacity will be available as a practical matter. A detailed discussion of the final capacity analysis is provided in the Background Document for Capacity Analysis for Land Disposal Restrictions, Phase III—Decharacterized Wastewaters, Carbamate Wastes, and Spent Potliners and EPA's responses to the individual comments on the K088 capacity analysis are provided in the Response to Capacity-Related Comments Received on the Phase III Land Disposal Restrictions Rulemaking, both of which are in the docket for today's rule.

EPA has determined that there is adequate alternative treatment capacity available for the 4,500 tons of carbamate wastes generated each year and is therefore not granting a national capacity variance for these wastes.

The quantities of radioactive wastes mixed with wastes included in today's rule are generated primarily by the U.S. Department of Energy (DOE). EPA estimates that 820 tons of high-level waste and 360 tons of mixed low-level waste that may be affected by this proposal will be generated annually by DOE. In addition, there are currently 7,000 tons of high-level waste, 10 tons of mixed transuranic waste, and 2,700 tons of mixed low-level waste in storage that may be affected by this rule. DOE currently faces treatment capacity shortfalls for high-level wastes and mixed transuranic wastes. Although DOE does have some available treatment capacity for mixed low-level wastes, most of this capacity is limited to treatment of wastewaters with less than one percent total suspended solids and is not readily adaptable for other waste forms. DOE has indicated that it will generally give treatment priority to mixed wastes that are already restricted under previous LDR rules. Therefore, EPA is granting a two-year national capacity variance to radioactive wastes mixed with the hazardous wastes affected by today's rule. Commenters to the proposed rule supported EPA's

be neither more or less stringent since the technology basis of the standards has not changed. Accordingly, EPA will not implement the amendments to the UTS in today's LDR Phase III rule for those states with LDR authorization.

Because today's rule is promulgated pursuant to HSWA, a State submitting a program modification may apply to receive interim or final authorization under RCRA section 3006(g)(2) or 3006(b), respectively, on the basis of requirements that are substantially equivalent or equivalent to EPA's. The procedures and schedule for State program modifications for final authorization are described in 40 CFR 271.21. It should be noted that all HSWA interim authorizations will expire January 1, 2003. (See § 271.24 and 57 FR 60132, December 18, 1992.)

Section 271.21(e)(2) requires that States with final authorization must modify their programs to reflect Federal program changes and to subsequently submit the modification to EPA for approval. The deadline by which the State would have to modify its program to adopt these regulations is specified in § 271.21(e). This deadline can be extended in certain cases (see § 271.21(e)(3)). Once EPA approves the modification, the State requirements become Subtitle C RCRA requirements.

States with authorized RCRA programs may already have requirements similar to those in today's rule. These State regulations have not been assessed against the Federal regulations being proposed today to determine whether they meet the tests for authorization. Thus, a State is not authorized to implement these requirements in lieu of EPA until the State program modifications are approved. Of course, states with existing standards could continue to administer and enforce their standards as a matter of State law. In implementing the Federal program, EPA will work with States under agreements to minimize duplication of efforts. In most cases, EPA expects that it will be able to defer to the States in their efforts to implement their programs rather than take separate actions under Federal authority.

States that submit official applications for final authorization less than 12 months after the effective date of these regulations are not required to include standards equivalent to these regulations in their application. However, the State must modify its program by the deadline set forth in § 271.21(e). States that submit official applications for final authorization 12 months after the effective date of these regulations must include standards equivalent to these regulations in their application. The requirements a State must meet when submitting its final authorization application are set forth in 40 CFR 271.3.

IX. Regulatory Requirements

A. Regulatory Impact Analysis Pursuant to Executive Order 12866

Executive Order No. 12866 requires agencies to determine whether a regulatory action is "significant." The Order defines a "significant" regulatory action as one that "is likely to result in a rule that may: (1) have an annual effect on the economy of $100 million or more or adversely affect, in a material way, the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities; (2) create serious inconsistency or otherwise interfere with an action taken or planned by another agency; (3) materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of recipients; or (4) raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in the Executive Order."

The Agency estimated the costs of today's rule to determine if it is a significant regulation as defined by the Executive Order. The analysis considers compliance cost and economic impacts for both characteristic wastes and newly listed wastes affected by this rule. For characteristic wastes, the potential cost impacts of this rule depend on whether facilities' current wastewater treatment systems will meet the UTS levels or if additional treatment will be required. If current treatments are adequate, facilities will only incur administrative costs to have their permits revised as well as on-going monitoring costs. In general, the Agency expects that facilities will seek permit modifications, treatability variances, or certification of adequate POTW treatment because these compliance options can be implemented at much lower cost than the option requiring treatment to UTS levels. EPA estimates the total annualized costs of the rule for these wastes would range from approximately $197,000 to $598,000, of which $154,000 to $425,000 would be incurred at the 28 to 73 potentially affected facilities in the organic chemical industry, and approximately $43,000 to $173,000 would be incurred at the 8 to 30 potentially affected facilities in the petroleum refining industry. However, at the high end, if current wastewater treatment systems need to be augmented with additional treatment steps, the incremental compliance costs for today's rule could be as high as $1 million per affected facility. The Agency does not have adequate data to estimate how many, if any, facilities may require modification to their treatment facilities. The Agency did conduct a sensitivity analysis, considering the costs of the rule under two scenarios: (1) Assuming that 80 percent of the facilities comply with the rule by obtaining permit modifications and 20 percent comply by treating their wastes, and, (2) assuming that 60 percent comply by obtaining permit modifications and 40 percent comply by treating their wastes. Based on the first scenario, the estimated annualized costs of the rule would range from $6.6 million to $18.2 million. Based on the second scenario, the estimated annualized costs would range from $12.9 million to $35.7 million. For newly listed wastes, the costs are substantially higher and will be incurred each year. These costs range from approximately $11.9 million to $47.3 million and are attributable to thermal treatment of aluminum potliner wastes (K088). Therefore, today's rule may be considered an economically significant rule. Because today's rule is significant, the Agency analyzed the costs, economic impacts, and benefits.

This section of the preamble for today's rule provides a discussion of the methodology used for estimating the costs, economic impacts and the benefits attributable to today's rule, followed by a presentation of the cost, economic impact and benefit results. More detailed discussions of the methodology and results may be found in the background document, "Regulatory Impact Analysis of the Land Disposal Restrictions Final Rule for the LDR Phase III Newly Listed and Identified Wastes," which has been placed in the docket for today's rule.

1. Methodology Section

In today's rule, the Agency is establishing treatment standards for the following wastes: end-of-pipe standards for ignitable, corrosive, and reactive (ICR) wastewaters managed in CWA, CWA-equivalent systems, and UIC wells; Toxicity Characteristic pesticide (D012–17) and organic (D018–43) wastewaters managed in CWA, CWA-equivalent systems, and UIC wells; and newly listed wastes from two industries—spent aluminum potliners and carbamates.

a. Methodology for Estimating the Affected Universe. In determining the costs, economic impacts, and benefits associated with today's rule, the Agency

newly listed carbamate wastes are expected to be minimal.

i. Estimation of Pollutant Loadings Reductions. An incremental approach was used to estimate reductions in pollutant loadings. For the baseline scenario, contaminant concentrations were based upon data or estimates of current effluent discharge concentration levels. For the post-regulatory scenario, concentration levels were assumed to equal UTS levels.

ii. Estimation of Reductions in Exceedances of Health-Based Levels. The methods used for evaluating the benefits associated with cancer and noncancer risk reductions resulting from the rule entail comparing constituent concentration levels to health-based standards to evaluate whether implementation of the rule reduces concentration levels below levels that pose risk to human health.

To estimate benefits from cancer risk reductions resulting from the rule, a simple screening analysis was performed. This analysis compared contaminant concentrations for the baseline and post-regulatory scenario to health-based levels for carcinogens. Further analysis may be undertaken to quantify benefits associated with facility/ wastestream combinations identified in the contaminant concentration comparisons.

Benefits associated with reductions in non-cancer exceedances are estimated based upon comparisons of contaminant concentration levels in effluent discharges of the affected wastestreams to the reference health levels. These benefits are expressed in terms of the number of exceedances of health-based levels under the baseline scenario compared to the number of exceedances under the rule.

iii. Qualitative Description of the Potential Benefits. A qualitative assessment of potential benefits likely to result from the rule is used where data are limited. The Agency acknowledges limited data availability in developing waste volumes affected, constituents, concentrations, cost estimates, economic impacts, and benefits estimates for the LDR Phase III rulemaking. The Agency continues to request comment from industry regarding constituents, concentrations, waste volumes, and current management practices.

2. Results

a. Volume Results. The Agency has estimated the volumes of formerly characteristic wastes potentially affected by today's rule to total in the range of 33.5 to 500 million metric tons. The Agency requests comment on waste volumes affected by the LDR Phase III rule. For newly listed wastes, the analyses supporting the listing determination showed about 4,500 metric tons of carbamate wastes and 118,000 metric tons of spent aluminum potliners are potentially affected by this rule.

b. Cost Results. For characteristic wastes, the potential cost impacts of this rule depend on whether facilities' current wastewater treatment systems will meet the UTS levels or if additional treatment will be required. If current treatments are adequate, facilities will only incur administrative costs to have their permits revised. EPA estimates the total annualized costs of the rule for these wastes would range from approximately $197,000 to $598,000, of which $154,000 to $425,000 would be incurred at the 28 to 73 potentially affected facilities in the organic chemical industry, and approximately $43,000 to $173,000 would be incurred at the 8 to 30 potentially affected facilities in the petroleum refining industry. However, at the high end, if current wastewater treatment systems need to be augmented with additional treatment steps, the incremental compliance costs could be as high as $1 million per affected facility. The Agency does not have adequate data to estimate how many, if any, facilities may require modification to their treatment facilities. The Agency continues to request comment and data on how often additional treatment may be required. For newly listed wastes, the costs are substantially higher and will be incurred each year. These costs range from approximately $11.9 million to $47.3 million and are attributable to thermal treatment of aluminum potliner wastes (K088). The Agency requests comment on where industry falls within this range.

c. Economic Impact Results. The Agency has estimated the economic impacts of today's rule to represent less than one percent of historic pollution control and operating costs for the organic chemical and petroleum refining industries. However, for those facilities that may need to treat to UTS to comply with today's rule, costs could be more significant. The estimated compliance costs for treating newly listed spent aluminum potliners represents 40 percent of pollution control operating costs for aluminum reducers; however, treatment costs represent only one percent of total historic operating costs.

d. Benefit Estimate Results. The Agency expects facilities to comply with the LDRs through permit modifications. As a result, the Agency has estimated the benefits associated with today's rule to be small. Assuming facilities comply with the rule by treating their affected wastestreams, loadings reductions estimates range between 1,527 to 21,322 metric tons per year at 129 to 291 facilities (direct and indirect dischargers) involving 175 to 647 constituent/wastestream combinations. Ninety-eight percent of the reductions occur at organic chemicals facilities, with the remainder occurring at petroleum refiners. Estimated loadings reductions for direct dischargers range between 36 and 267 tons per year, representing between 0.03 and 0.2 percent of total Toxic Release Inventory (TRI) chemical loadings to surface waters. For indirect dischargers, estimated loadings reductions range between 1,491 and 21,055 metric tons per year, representing between 0.8 and 11.0 percent of total TRI chemical loadings transferred to POTWs. Based upon the results of the screening and more detailed risk assessments, the estimated baseline risks associated with nine to twenty wastestreams (out of the 155 to 404 constituent/wastestream combinations potentially affected by the rule) exceed 10^{-6} under baseline conditions and three to six wastestreams with noncancer risk levels exceeding reference doses. These 12 to 26 wastestreams contain one of five constituents: aniline (9 to 19 wastestreams), acrylamide (0 to 1 wastestream), pyridine (2 waststreams), barium compounds (1 wastestream), and acetonitrile (0 to 2 wastestreams). For these 12 to 26 wastestreams, EPA conducted a more detailed risk assessment, using site-specific data. Results of the more detailed risk assessment indicate that the benefits from the rule are small. EPA identified four wastestreams potentially posing cancer risk exceeding the threshold risk levels. Three wastestreams pose baseline cancer risk ranging from 1×10^{-5} to 1×10^{-4} (due to exposure to aniline) which potentially would be reduced to between 8×10^{-8} and 3×10^{-6} under the LDR Phase III rule. A fourth wastestream containing acrylamide poses baseline cancer risk at a level of 2×10^{-3}. The rule is estimated to reduce this risk to between 2×10^{-4} and 4×10^{-36}. All four of these wastestreams are discharged to POTWs; if POTW treatment removes these constituents from the wastewater prior to discharge to surface water and/or if no drinking water intake is located downstream from the POTW's outfall, baseline risks will be lower. The Agency expects facilities to comply with the LDRs through permit modifications;

from $3.67 million per year for all facilities incurring only petition costs to $132.62 million per year for all facilities incurring both petition and treatment costs. Based on past EPA experience, there is little probability that all facilities will arrive at each of these possible outcomes. However, this indicated range provides an extreme lower and upper bound estimate for national compliance costs purposes.

The benefits to human health and the environment in the RIA are generally defined as reduced human health risk resulting from fewer instances of ground water contamination. In general, potential health risks from Class I injection wells are extremely low.

EPA conducted a quantitative assessment of the potential human health risks associated with two well malfunction scenarios. EPA developed a methodology described in the RIA to measure health risks of five Phase III contaminants: benzene, carbon tetrachloride, chloroform, phenol, and toluene. The results of these analyses show that most of the cancer risks calculated are below the 1×10^{-4} to 1×10^{-6} risk range generally used by EPA to regulate exposure to carcinogens. Virtually all of the non-cancer risks are below a hazard index (HI) of 1, which represents a ratio used to compare the relative health risks posed by contaminants. Therefore, these cancer and non-cancer risks calculated are below any levels of regulatory concern. Only two cancer risk estimates in the high end scenarios, those calculated for benzene and carbon tetrachloride, slightly exceeded the risk range to regulate exposure to carcinogens. Only one hazard index calculated for carbon tetrachloride exceeded EPA's level of concern of a ratio greater than 1. However, these results were derived from a scenario where an abandoned borehole (i.e. the "failure pathway") was in very close proximity to the injection well, substantial pumping of a drinking water well was occurring, and the local geology was typical of the highly transmissive East Gulf Coast Region. The assumptions used in deriving these results were based on conservative, upper-bound estimates, therefore the cancer and non-cancer risks represent worst-case estimates. Considering the limitations imposed by the failure scenarios, and the documented low probability of Class I failures, the overall risks from failure of Class I injection wells would be below regulatory concern.

There also is a potential qualitative benefit to the no-migration process for Class I nonhazardous wells. It is possible that the process would uncover certain wells that cannot satisfy the no-migration standard and indeed may not be suitable for Class I injection in any case. This proved to be true for Class I hazardous wells. However, notwithstanding this potential benefit, as noted in the early part of this preamble, the Agency does not regard this regulatory effort as deserving of the priority afforded it, due to the litigation-driven schedule and the D.C. Circuit's mandate, and would not be undertaking the effort at this time were it not for that mandate and schedule.

The economic analysis of LDR Phase III compliance costs suggests that publicly traded companies probably will not be significantly affected. The limited data available for privately-held companies suggests, however, that they may face significant costs due to the proportionally larger expenses they may face due to the LDR Phase III rule.

C. Regulatory Flexibility Analysis

Pursuant to the Regulatory Flexibility Act of 1980, 5 U.S.C. 601 et seq., when an agency publishes a notice of rulemaking, for a rule that will have a significant effect on a substantial number of small entities, the agency must prepare and make available for public comment a regulatory flexibility analysis that considers the effect of the rule on small entities (i.e.: small businesses, small organizations, and small governmental jurisdictions). Under the Agency's Revised Guidelines for Implementing The Regulatory Flexibility Act, dated May 4, 1992, the Agency committed to considering regulatory alternatives in rulemakings when there were any economic impacts estimated on any small entities. (See RCRA sections 3004 (d), (e), and (g)(5), which apply uniformly to all hazardous wastes.) Previous guidance required regulatory alternatives to be examined only when significant economic effects were estimated on a substantial number of small entities.

In assessing the regulatory approach for dealing with small entities in today's rule, for both surface disposal of wastes, the Agency considered two factors. First, data on potentially affected small entities are unavailable. Second, due to the statutory requirements of the RCRA LDR program, no legal avenues exist for the Agency to provide relief from the LDR's for small entities. The only relief available for small entities is the existing small quantity generator provisions and conditionally exempt small quantity generator exemptions found in 40 CFR 262.11–12, and 261.5, respectively. These exemptions basically prescribe 100 kilograms (kg) per calendar month generation of hazardous waste as the limit below which one is exempted from complying with the RCRA standards.

Given these two factors, the Agency was unable to frame a series of small entity options from which to select the lowest cost approach; rather, the Agency was legally bound to regulate the land disposal of the hazardous wastes covered in today's rule without regard to the size of the entity being regulated.

The Agency has, however, included an exemption covering injection facilities where the decharacterized portion of the injectate is minimal in absolute terms, as a percentage of the total injectate, and in hazardous constituent mass loadings. This *de minimis* exemption provides a measure of relief to both small and larger entities satisfying its terms.

D. Paperwork Reduction Act

The information collection requirements in this rule have been submitted for approval to the Office of Management and Budget (OMB) under the Paperwork Reduction Act, 44 U.S.C. 3501 *et seq.* Four Information Collection Request (ICR) documents have been prepared by EPA, as follows. OSWER ICR No. 1442.12 would amend the existing ICR approved under OMB Control No. 2050–0085. The additional information requirements for the Underground Injection Control (UIC) Program were submitted to OMB under ICR No. 0370.14; this will amend the existing UIC approval under OMB Control No. 2040–0042. OSWER ICR No. 1442.12 and UIC ICR No. 0370.14 have not been approved by OMB and the information collection requirements in those ICRs are not enforceable until OMB approves them. EPA will publish a document in the Federal Register when OMB approves the information collection requirements. Until EPA publishes a document displaying the valid OMB control number, persons are not required to respond to collections of information in these two ICRs. Two amendments to National Pollutant Discharge Elimination System (NPDES) ICRs were approved at proposal. These are ICR 0229.10 for the Discharge Monitoring Report, approved under OMB Control No. 2040–0004, and ICR 0226.11 for NPDES Applications, approved under OMB Control No. 2040–0086.

Copies of these ICRs may be obtained from Sandy Farmer, OPPE Regulatory Information Division; U.S. Environmental Protection Agency (2136); 401 M St., S.W.; Washington, D.C. 20460 or by calling (202) 260–274 Include the ICR numbers in any reques The information requirements for the

constituents as would be removed by treating the characteristic hazardous wastestream pursuant to the treatment standards in 40 CFR 268.48. This mass reduction can come from:

(*1*) Treating nonhazardous portions of the injectate;

(*2*) Recycling before ultimate injection; or

(*3*) Engaging in pollution prevention practices (such as equipment or technology modifications, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control).

(B) The compliance alternative in paragraph (d)(2)(iii)(A) of this section is demonstrated by comparing the injected baseline (determined by multiplying the volume/day of characteristically hazardous waste generated and injected) times the concentration of hazardous constituents before the treatment/recycling/pollution prevention measure, with the mass allowance obtained by multiplying the volume/day of a hazardous constituent generated and injected times the universal treatment standard for that constituent. The baseline cannot include practices initiated before the year 1990. (Recordkeeping requirements for this alternative are found at 40 CFR 268.9(d)(3).)

3. Section 148.3 is revised to read as follows:

§ 148.3 Dilution prohibited as a substitute for treatment.

(a) The provisions of 40 CFR 268.3 shall apply to owners or operators of Class I wells used to inject a waste which is hazardous at the point of generation whether or not the waste is hazardous at the point of injection.

(b) Owners or operators of Class I nonhazardous waste injection wells which inject waste formerly exhibiting a hazardous characteristic which has been removed by dilution, may address underlying hazardous constituents by treating the hazardous waste, obtaining an exemption pursuant to a petition filed under § 148.20, or complying with the provisions set forth in 40 CFR 268.9.

4. Section 148.4 is revised to read as follows:

§ 148.4 Procedures for case-by-case extensions to an effective date.

The owner or operator of a Class I hazardous or nonhazardous waste injection well may submit an application to the Administrator for an extension of the effective date of any applicable prohibition established under subpart B of this part according to the procedures of 40 CFR 268.5.

5. Section 148.18 is added to subpart B to read as follows:

§ 148.18 Waste specific prohibitions—Newly Identified Wastes.

(a) On July 8, 1996, the wastes specified in 40 CFR 261.32 as EPA Hazardous waste numbers K156–K161, P127, P128, P185, P188–P192, P194, P196–P199, P201–P205, U271, U277–U280, U364–U367, U372, U373, U375–U379, U381–387, U389–U396, U400–U404, U407, and U409–U411 are prohibited from underground injection.

(b) On January 8, 1997, the wastes specified in 40 CFR 261.32 as EPA Hazardous waste number K088 is prohibited from underground injection.

(c) On April 8, 1998, the wastes specified in 40 CFR part 261 as EPA Hazardous waste numbers D018–043, and Mixed TC/Radioactive wastes, are prohibited from underground injection.

(d) On April 8, 1998, the wastes specified in 40 CFR part 261 as EPA Hazardous waste numbers D001–D003 are prohibited from underground injection.

6. Section 148.20 is amended by revising paragraph (a) introductory text to read as follows:

§ 148.20 Petitions to allow injection of a waste prohibited under subpart B.

(a) Any person seeking an exemption from a prohibition under subpart B of this part for the injection of a restricted hazardous waste, including a hazardous waste exhibiting a characteristic and containing underlying hazardous constituents at the point of generation, but no longer exhibiting a characteristic when injected into a Class I injection well or wells, shall submit a petition to the Director demonstrating that, to a reasonable degree of certainty, there will be no migration of hazardous constituents from the injection zone for as long as the waste remains hazardous. This demonstration requires a showing that:

* * * * *

PART 268—LAND DISPOSAL RESTRICTIONS

7. The authority citation for part 268 continues to read as follows:

Authority: 42 U.S.C. 6905, 6912(a), 6921, and 6924.

Subpart A—General

8. Section 268.1 is amended in paragraph (e)(3) by removing the period at the end of the paragraph and adding "; or" in its place, by revising paragraph (e)(4) and by removing paragraph (e)(5) to read as follows:

§ 268.1 Purpose, scope and applicability.

* * * * *

(e) * * *

(4) *De minimis* losses of characteristic wastes to wastewaters are not considered to be prohibited wastes and are defined as:

(i) Losses from normal material handling operations (e.g. spills from the unloading or transfer of materials from bins or other containers, leaks from pipes, valves or other devices used to transfer materials); minor leaks of process equipment, storage tanks or containers; leaks from well-maintained pump packings and seals; sample purgings; and relief device discharges; discharges from safety showers and rinsing and cleaning of personal safety equipment; rinsate from empty containers or from containers that are rendered empty by that rinsing; and laboratory wastes not exceeding one per cent of the total flow of wastewater into the facility's headworks on an annual basis, or with a combined annualized average concentration not exceeding one part per million in the headworks of the facility's wastewater treatment or pretreatment facility; or

(ii) Decharacterized wastes which are injected into Class I nonhazardous wells which wastes combined volume is less than one per cent of the total flow at the wellhead on an annualized basis, is no greater than 10,000 gallons per day, and in which any underlying hazardous constituents in the characteristic wastes are present at the point of generation at levels less than ten times the treatment standards found at § 268.48.

* * * * *

9. Section 268.2 is amended by revising paragraphs (f) and (i), and by adding paragraphs (j), (k), and (l) to read as follows:

§ 268.2 Definitions applicable in this part.

* * * * *

(f) *Wastewaters* are wastes that contain less than 1% by weight total organic carbon (TOC) and less than 1% by weight total suspended solids (TSS).

* * * * *

(i) *Underlying hazardous constituent* means any constituent listed in § 268.48, Table UTS—Universal Treatment Standards, except fluoride, vanadium, and zinc, which can reasonably be expected to be present at the point of generation of the hazardous waste, at a concentration above the constituent-specific UTS treatment standards.

(j) *Inorganic metal-bearing waste* is one for which EPA has established treatment standards for metal hazardous constituents, and which does not otherwise contain significant organic or cyanide content as described in § 268.3(b)(1), and is specifically listed in appendix XI of this part.

significant penalties for submitting a false certification, including the possibility of fine and imprisonment.

* * * * *

§ 268.8 [Removed and reserved]

12. Section 268.8 is removed and reserved.

13. Section 268.9 is amended by revising paragraphs (a), (d) introductory text, (d)(1)(i), and (d)(1)(ii), and by adding paragraphs (d)(3), (e), (f), and (g) to read as follows:

§ 268.9 Special rules regarding wastes that exhibit a characteristic.

(a) The initial generator of a solid waste must determine each EPA Hazardous Waste Number (waste code) applicable to the waste in order to determine the applicable treatment standards under subpart D of this part. For purposes of this part 268, the waste will carry the waste code for any applicable listing under 40 CFR part 261, subpart D. In addition, the waste will carry one or more of the waste codes under 40 CFR part 261, subpart C, where the waste exhibits a characteristic, except in the case when the treatment standard for the waste code listed in 40 CFR part 261, subpart D operates in lieu of the standard for the waste code under 40 CFR part 261, subpart C, as specified in paragraph (b) of this section. If the generator determines that his waste displays a hazardous characteristic (and the waste is not a D004—D011 waste, a High TOC D001, or is not treated by CMBST, or RORGS of § 268.42, Table 1), the generator must determine what underlying hazardous constituents (as defined in § 268.2), are reasonably expected to be present above the universal treatment standards found in § 268.48.

* * * * *

(d) Wastes that exhibit a characteristic are also subject to § 268.7 requirements, except that once the waste is no longer hazardous, a one-time notification and certification must be placed in the generators or treaters files and sent to the EPA region or authorized state, except for those facilities discussed in paragraph (f) of this section. The notification and certification that is placed in the generators or treaters files must be updated if the process or operation generating the waste changes and/or if the Subtitle D facility receiving the waste changes. However, the generator or treater need only notify the EPA region or an authorized state on an annual basis if such changes occur. Such notification and certification should be sent to the EPA region or authorized state by the end of the calendar year, but no later than December 31.

(1) * * *

(i) For characteristic wastes other than those managed on site in a wastewater treatment system subject to the Clean Water Act (CWA), zero-dischargers engaged in CWA-equivalent treatment, or Class I nonhazardous injection wells, the name and address of the Subtitle D facility receiving the waste shipment; and

(ii) For all characteristic wastes, a description of the waste as initially generated, including the applicable EPA Hazardous Waste Number(s), treatability group(s), and underlying hazardous constituents.

* * * * *

(3) For characteristic wastes whose ultimate disposal will be into a Class I nonhazardous injection well, and compliance with the treatment standards found in § 268.48 for underlying hazardous constituents is achieved through pollution prevention that meets the criteria set out at 40 CFR 148.1(d), the following information must also be included:

(i) A description of the pollution prevention mechanism and when it was implemented if already complete;

(ii) The mass of each underlying hazardous constituent before pollution prevention;

(iii) The mass of each underlying hazardous constituent that must be removed, adjusted to reflect variations in mass due to normal operating conditions; and

(iv) The mass reduction of each underlying hazardous constituent that is achieved.

(e) For decharacterized wastes managed on-site in a wastewater treatment system subject to the Clean Water Act (CWA) or zero-dischargers engaged in CWA-equivalent treatment, compliance with the treatment standards found at § 268.48 must be monitored quarterly, unless the treatment is aggressive biological treatment, in which case compliance must be monitored annually. Monitoring results must be kept in on-site files for 5 years.

(f) For decharacterized wastes managed on-site in a wastewater treatment system subject to the Clean Water Act (CWA) for which all underlying hazardous constituents (as defined in § 268.2), are addressed by a CWA permit, this compliance must be documented and this documentation must be kept in on-site files.

(g) For characteristic wastes whose ultimate disposal will be into a Class I nonhazardous injection well which qualifies for the *de minimis* exclusion described in § 268.1, information supporting that qualification must be kept in on-site files.

§§ 268.10–268.12 [Removed and Reserved]

14. Sections 268.10 through 268.12 are removed and reserved.

15. Section 268.39 is added to subpart C to read as follows:

§ 268.39 Waste specific prohibitions—End-of-pipe CWA, CWA-equivalent, and Class I nonhazardous injection well treatment standards; spent aluminum potliners; and carbamate wastes.

(a) On July 8, 1996, the wastes specified in 40 CFR 261.32 as EPA Hazardous Waste numbers K156–K161; and in 40 CFR 261.33 as EPA Hazardous Waste numbers P127, P128, P185, P188–P192, P194, P196–P199, P201–P205, U271, U277–U280, U364–U367, U372, U373, U375–U379, U381–U387, U389–U396, U400–U404, U407, and U409–U411 are prohibited from land disposal. In addition, soil and debris contaminated with these wastes are prohibited from land disposal.

(b) On July 8, 1996 the wastes identified in 40 CFR 261.23 as D003 that are managed in systems other than those whose discharge is regulated under the Clean Water Act (CWA), or that inject in Class I deep wells regulated under the Safe Drinking Water Act (SDWA), or that are zero dischargers that engage in CWA-equivalent treatment before ultimate land disposal, are prohibited from land disposal. This prohibition does not apply to unexploded ordnance and other explosive devices which have been the subject of an emergency response (such D003 wastes are prohibited unless they meet the treatment standard of DEACT before land disposal (see § 268.40)).

(c) On July 8, 1996, the wastes specified in 40 CFR 261.32 as EPA Hazardous Waste number K088 are prohibited from land disposal. In addition, soil and debris contaminated with these wastes are prohibited from land disposal.

(d) On April 8, 1998, decharacterized wastes managed in surface impoundments whose discharge is regulated under the Clean Water Act (CWA), or decharacterized wastes managed by zero dischargers in surface impoundments or tanks that engage in CWA-equivalent treatment before ultimate land disposal are prohibited from land disposal. The following are exceptions to this requirement:

(1) Surface impoundments which are permitted under subtitle C of RCRA;

(2) Storm water impoundments as defined in § 268.2;

TREATMENT STANDARDS FOR HAZARDOUS WASTES

(Note: NA means not applicable.)

Waste code	Waste description and treatment/regulatory subcategory[1]	Regulated hazardous constituent		Wastewaters	Nonwastewaters
		Common name	CAS[2] No.	Concentration in mg/l[3]; or technology code[4]	Concentration in mg/kg[5] unless noted as "mg/l TCLP"; or technology code
D001	Ignitable Characteristic Wastes, except for the §261.21(a)(1) High TOC Subcategory.	NA	NA	DEACT and meet §268.48 standards; or RORGS; or CMBST[6]	DEACT and meet §268.48 standards; or RORGS; or CMBST[6]
	High TOC Ignitable Characteristic Liquids Subcategory based on 40 CFR 261.21(a)(1)—Greater than or equal to 10% total organic carbon. (Note: This subcategory consists of nonwastewaters only).	NA	NA	NA	RORGS; or CMBST
D002	Corrosive Characteristic Wastes.	NA	NA	DEACT and meet §268.48 standards[6]	DEACT and meet §268.48 standards[6]
D002, D004, D005, D006, D007, D008, D009, D010, D011.	Radioactive high level wastes generated during the reprocessing of fuel rods. (Note: This subcategory consists of nonwastewaters only).	Corrosivity (pH)	NA	NA	HLVIT
		Arsenic	7440–38–2	NA	HLVIT
		Barium	7440–39–3	NA	HLVIT
		Cadmium	7440–43–9	NA	HLVIT
		Chromium (Total)	7440–47–3	NA	HLVIT
		Lead	7439–92–1	NA	HLVIT
		Mercury	7439–97–6	NA	HLVIT
		Selenium	7782–49–2	NA	HLVIT
		Silver	7440–22–4	NA	HLVIT
D003	Reactive Sulfides Subcategory based on 261.23(a)(5).	NA	NA	DEACT and meet §268.48 standards[6]	DEACT and meet §268.48 standards[6]
	Explosives Subcategory based on 261.23(a) (6), (7) and (8).	NA	NA	DEACT and meet §268.48 standards[6]	DEACT and meet §268.48 standards[6]
	Unexploded ordnance and other explosive devices which have been the subject of an emergency response.	NA	NA	DEACT	DEACT
	Other Reactives Subcategory based on 261.23(a)(1).	NA	NA	DEACT and meet §268.48 standards[6]	DEACT and meet §268.48 standards[6]
	Water Reactive Subcategory based on 261.23(a)(2), (3), and (4). (Note: This subcategory consists of nonwastewaters only).	NA	NA	NA	DEACT and meet §268.48 standards[6]
	Reactive Cyanides Subcategory based on 261.23(a)(5).	Cyanides (Total)[7]	57–12–5	Reserved	590
		Cyanides (Amendable)[7]	57–12–5	0.86	30
D004	Wastes that exhibit, or are expected to exhibit, the characteristic of toxicity for arsenic based on the extraction procedure (EP) in SW846 Methods 1310.	Arsenic	7440–38–2	5.0	5.0 mg/l EP

D009	Nonwastewaters that exhibit, or are expected to exhibit, the characteristic of toxicity for mercury based on the extraction procedure (EP) in SW846 Method 1310; and contain greater than or equal to 260 mg/kg total mercury that also contain organics and are not incinerator residues. (High Mercury-Organic Subcategory.).	Mercury	7439–97–6	NA	IMERC; OR RMERC
	Nonwastewaters that exhibit, or are expected to exhibit, the characteristic of toxicity for mercury based on the extraction procedure (EP) in SW846 Method 1310; and contain greater than or equal to 260 mg/kg total mercury that are inorganic, including incinerator residues and residues from RMERC. (High Mercury-Inorganic Subcategory.).	Mercury	7439–97–6	NA	RMERC
	Nonwastewaters that exhibit, or are expected to exhibit, the characteristic of toxicity for mercury based on the extraction procedure (EP) in SW846 Method 1310; and contain less than 260 mg/kg total mercury. (Low Mercury Subcategory.).	Mercury	7439–97–6	NA	0.20 mg/l TCLP
	All D009 wastewaters	Mercury	7439–97–6	0.20	NA
	Elemental mercury contaminated with radioactive materials. (Note: This subcategory consists of nonwastewaters only.).	Mercury	7439–97–6	NA	AMLGM
	Hydraulic oil contaminated with Mercury Radioactive Materials Subcategory. (Note: This subcategory consists of nonwastewaters only.).	Mercury	7439–97–6	NA	IMERC
D010	Wastes that exhibit, or are expected to exhibit, the characteristic of toxicity for selenium based on the extraction procedure (EP) in SW846 Method 1310.	Selenium	7782–49–2	1.0	5.7 mg/l TCLP
D011	Wastes that exhibit, or are expected to exhibit, the characteristic of toxicity for silver based on the extraction procedure (EP) in SW846 Method 1310.	Silver	7440–22–4	5.0	5.0 mg/l TCLP
D012	Wastes that are TC for Endrin based on the TCLP in SW846 Method 1311.	Endrin	72–20–8	BIODG; or CMBST[a]	0.13 and meet § 268.48 standards[a]
		Endrin aldehyde	7421–93–4	BIODG; or CMBST[a]	0.13 and meet § 268.48 standards[a]
D013	Wastes that are TC for Lindane based on the TCLP in SW846 Method 1311.).	alpha-BHC	319–84–6	CARBN; or CMBST[a]	0.066 and meet § 268.48 standards[a]
		beta–BHC	319–85–7	CARBN; or CMBST[a]	0.066 and meet § 268.48 standards[a]
		delta-BHC	319–86–8	CARBN; or CMBST[a]	0.066 and meet § 268.48 standards[a]
		gamma-BHC (Lindane)	58–89–9	CARBN; or CMBST[a]	0.066 and meet § 268.48 standards[a]
D014	Wastes that are TC for Methoxychlor based on the TCLP in SW846 Method 1311.	Methoxychlor	72–43–5	WETOX or CMBST[a]	0.18 and meet § 268.48 standards[a]

D030	Wastes that are TC for 2,4-Dinitrotoluene based on the TCLP in SW846 Method 1311.	2,4-Dinitrotoluene	121–14–2	0.32 and meet § 268.48 standards [8]	140 and meet § 268.48 standards [8]
D031	Wastes that are TC for Heptachlor based on the TCLP in SW846 Method 1311.	Heptachlor	76–44–8	0.0012 and meet § 268.48 standards [8]	0.066 and meet § 268.48 standards [8]
		Heptachlor epoxide	1024–57–3	0.016 and meet § 268.48 standards [8]	0.066 and meet § 268.48 standards [8]
D032	Wastes that are TC for Hexachlorobenzene based on the TCLP in SW846 Method 1311.	Hexachlorobenzene	118–74–1	0.055 and meet § 268.48 standards [8]	10 and meet § 268.48 standards [8]
D033	Wastes that are TC for Hexachlorobutadiene based on the TCLP in SW846 Method 1311.	Hexachlorobutadiene	87–68–3	0.055 and meet § 268.48 standards [8]	5.6 and meet § 268.48 standards [8]
D034	Wastes that are TC for Hexachloroethane based on the TCLP in SW846 Method 1311.	Hexachloroethane	67–72–1	0.055 and meet § 268.48 standards [8]	30 and meet § 268.48 standards [8]
D035	Wastes that are TC for Methyl ethyl ketone based on the TCLP in SW846 Method 1311.	Methyl ethyl ketone	78–93–3	0.28 and meet § 268.48 standards [8]	36 and meet § 268.48 standards [8]
D036	Wastes that are TC for Nitrobenzene based on the TCLP in SW846 Method 1311.	Nitrobenzene	98–95–3	0.068 and meet § 268.48 standards [8]	14 and meet § 268.48 standards [8]
D037	Wastes that are TC for Pentachlorophenol based on the TCLP in SW846 Method 1311.	Pentachlorophenol	87–86–5	0.089 and meet § 268.48 standards [8]	7.4 and meet § 268.48 standards [8]
D038	Wastes that are TC for Pyridine based on the TCLP in SW846 Method 1311.	Pyridine	110–86–1	0.014 and meet § 268.48 standards [8]	16 and meet § 268.48 standards [8]
D039	Wastes that are TC for Tetrachloroethylene based on the TCLP in SW846 Method 1311.	Tetrachloroethylene	127–18–4	0.056 and meet § 268.48 standards [8]	6.0 and meet § 268.48 standards [8]
D040	Wastes that are TC for Trichloroethylene based on the TCLP in SW846 Method 1311.	Trichloroethylene	79–01–6	0.054 and meet § 268.48 standards [8]	6.0 and meet § 268.48 standards [8]
D041	Wastes that are TC for 2,4,5-Trichlorophenol based on the TCLP in SW846 Method 1311.	2,4,5-Trichlorophenol	95–95–4	0.18 and meet § 268.48 standards [8]	7.4 and meet § 268.48 standards [8]
D042	Wastes that are TC for 2,4,6-Trichlorophenol based on the TCLP in SW846 Method 1311.	2,4,6-Trichlorophenol	88–06–2	0.035 and meet § 268.48 standards [8]	7.4 and meet § 268.48 standards [8]
D043	Wastes that are TC for Vinyl chloride based on the TCLP in SW846 Method 1311.	Vinyl chloride	75–01–4	0.27 and meet § 268.48 standards [8]	6.0 and meet § 268.48 standards [8]

		1,1,2-Trichloro-1,2,2-trifluoroethane.	76–13–1	0.057	30
		Trichloroethylene	79–01–6	0.054	6.0
		Trichloromonofluoromethane	75–69–4	0.020	30
		Xylenes-mixed isomers (sum of o-, m-, and p-xylene concentrations.	1330–20–7	0.32	30
	F003 and/or F005 solvent wastes that contain any combination of one or more of the following three solvents as the only listed F001–5 solvents: carbon disulfide, cyclohexanone, and/or methanol. (formerly 268.41(c)).	Carbon disulfide	75–15–0	3.8	4.8 mg/1 TCLP
		Cyclohexanone	108–94–1	0.36	0.75 mg/l TCLP
		Methanol	67–56–1	5.6	0.75 mg/l TCLP
	F005 solvent waste containing 2-Nitropropane as the only listed F001–5 solvent..	2-Nitropropane	79–46–9	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
	F005 solvent waste containing 2—Ethoxyethanol as the only listed F001–5 solvent..	2-Ethoxyethanol	110–80–5	BIODG; or CMBST	CMBST
F006	Wastewater treatment sludges from electroplating operations except from the following processes: (1) Sulfuric acid anodizing of aluminum; (2) tin plating on carbon steel; (3) zinc plating (segregated basis) on carbon steel; (4) aluminum or zinc-aluminum plating on carbon steel; (5) cleaning/stripping associated with tin, zinc and aluminum plating on carbon steel; and (6) chemical etching and milling of aluminum..	Cadmium	7440–43–9	0.69	0.19 mg/l TCLP
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Cyanides (Total)[7]	57–12–5	1.2	590
		Cyanides (Amendable)[7]	57–12–5	0.86	30
		Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Nickel	7440–02–0	3.98	5.0 mg/l TCLP
		Silver	7440–22–4	0.43	0.30 mg/l TCLP
F007	Spent cyanide plating bath solutions from electroplating operations.	Cadmium	7440–43–9	0.69	0.19 mg/1 TCLP
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Cyanides (Total)[7]	57–12–5	1.2	590
		Cyanides (Amenable)[7]	57–12–5	0.86	30
		Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Nickel	7440–02–0	3.98	5.0 mg/l TCLP
		Silver	7440–22–4	NA	0.30 mg/l TCLP
F008	Plating bath residues from the bottom of plating baths from electroplating operations where cyanides are used in the process.	Cadmium	7440–43–9	NA	0.19 mg/l TCLP
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Cyanides (Total)[7]	57–12–5	1.2	590
		Cyanides (Amenable)[7]	57–12–5	0.86	30
		Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Nickel	7440–02–0	3.98	5.0 mg/l TCLP
		Silver	7440–22–4	NA	0.30 mg/l TCLP
F009	Spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process.	Cadmium	7440–43–9	NA	0.19 mg/l TCLP
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Cyanides (Total)[7]	57–12–5	1.2	590
		Cyanides (Amenable)[7]	57–12–5	0.86	30
		Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Nickel	7440–02–0	3.98	5.0 mg/l TCLP
		Silver	7440–22–4	NA	0.30 mg/l TCLP

F020, F021, F022, F023, F026	Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of: (1) tri- or tetrachlorophenol, or of intermediates used to produce their pesticide derivatives, excluding wastes from the production of Hexachlorophene from highly purified 2,4,5-trichlorophenol (F020); (2) pentachlorophenol, or of intermediates used to produce its derivatives (i.e., F021); (3) tetra-, penta-, or hexachlorobenzenes under alkaline conditions (i.e., F022); and from the production of materials on equipment previously used for the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of: (1) tri- or tetrachlorophenols, excluding wastes from equipment used only for the production of Hexachlorophene from highly purified 2,4,5-trichlorophenol (F023); (2) tetra-, penta-, or hexachlorobenzenes under alkaline conditions (i.e., F026).	HxCDDs (All Hexachlorodibenzo-p-dioxins).	NA	0.000063	0.001
		HxCDFs (All Hexachlorodibenzofurans).	NA	0.000063	0.001
		PeCDDs (All Pentachlorodibenzo-p-dioxins).	NA	0.000063	0.001
		PeCDFs (All Pentachlorodibenzofurans).	NA	0.000035	0.001
		Pentachlorophenol	87–86–5	0.089	7.4
		TCDDs (All Tetrachlorodibenzo-p-dioxins).	NA	0.000063	0.001
		TCDFs (All Tetrachlorodibenzofurans).	NA	0.000063	0.001
		2,4,5-Trichlorophenol	95–95–4	0.18	7.4
		2,4,6-Trichlorophenol	88–06–2	0.035	7.4
		2,3,4,6-Tetrachlorophenol	58–90–2	0.030	7.4
F024	Process wastes, including but not limited to, distillation residues, heavy ends, tars, and reactor clean-out wastes, from the production of certain chlorinated aliphatic hydrocarbons by free radical catalyzed processes. These chlorinated aliphatic hydrocarbons are those having carbon chain lengths ranging from one to and including five, with varying amounts and positions of chlorine substitution. (This listing does not include wastewaters, wastewater treatment sludges, spent catalysts, and wastes listed in § 261.31 or § 261.32.).	All F024 wastes	NA	CMBST	CMBST
		2-Chloro-1,3-butadiene	126–99–8	0.057	0.28
		3-Chloropropylene	107–05–1	0.036	30
		1,1-Dichloroethane	75–34–3	0.059	6.0
		1,2-Dichloroethane	107–06–2	0.21	6.0
		1,2-Dichloropropane	78–87–5	0.85	18
		cis-1,3-Dichloropropylene	10061–01–5	0.036	18
		trans-1,3-Dichloropropylene	10061–02–6	0.036	18
		bis(2-Ethylhexyl) phthalate	117–81–7	0.28	28
		Hexachloroethane	67–72–1	0.055	30
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP

		TCDDs (All Tetrachlorodibenzo-p-dioxins).	NA	0.28	28
		TCDFs (All Tetracholorodibenzofurans).	NA	0.059	3.4
		2,4,5-Trichlorophenol	95–95–4	0.057	28
		2,4,6-Trichlorophenol	88–06–2	0.057	10
		2,3,4,6-Tetrachlorophenol	58–90–2	0.059	NA
F028	Residues resulting from the incineration or thermal treatment of soil contaminated with EPA Hazardous Wastes Nos. F020, F021, F023, F026, and F027.	HxCDDs (All Hexachlorodibenzo-p-dioxins).	NA	0.059	5.6
		HxCDFs (All Hexachlorodibenzofurans).	NA	0.059	5.6
		PeCDDs (All Pentachlorodibenzo-p-dioxins).	NA	0.039	6.2
		PeCDFs (All Pentachlorodibenzofurans).	NA	0.067	8.2
		Pentachlorophenol	87–86–5	0.080	10
		TCDDs (All Tetrachlorodibenzo-p-dioxins).	NA	0.32	30
		TCDFs (All Tetrachlorodibenzofurans).	NA	2.77	0.86 mg/l TCLP
		2,4,5-Trichlorophenol	95–95–4	1.2	590
		2,4,6-Trichlorophenol	88–06–2	0.69	NA
		2,3,4,6-Tetrachlorophenol	58–90–2	3.98	5.0 mg/l TCLP
F037	Petroleum refinery primary oil/water/solids separation sludge—Any sludge generated from the gravitational separation of oil/water/solids during the storage or treatment of process wastewaters and oily cooling wastewaters from petroleum refineries. Such sludges include, but are not limited to, those generated in: oil/water/solids separators; tanks and impoundments; ditches and other conveyances; sumps; and stormwater units receiving dry weather flow. Sludge generated in stormwater units that do not receive dry weather flow, sludges generated from non-contact once-through cooling waters segregated for treatment from other process or oil cooling waters, sludges generated in aggressive biological treatment units as defined in §261.31(b)(2) (including sludges generated in one or more additional units after wastewaters have been treated in aggressive biological treatment units) and K051 wastes are not included in this listing.	Acenaphthene	83–32–9	0.059	NA
		Anthracene	120–12–7	0.059	3.4
		Benzene	71–43–2	0.14	10
		Benz(a)anthracene	56–55–3	0.059	3.4
		Benzo(a)pyrene	50–32–8	0.061	3.4
		bis(2-Ethylhexyl) phthalate	117–81–7	0.28	28
		Chrysene	218–01–9	0.059	3.4
		Di-n-butyl phthalate	84–74–2	0.057	28
		Ethylbenzene	100–41–4	0.057	10
		Fluorene	86–73–7	0.059	NA
		Naphthalene	91–20–3	0.059	5.6
		Phenanthrene	85–01–8	0.059	5.6
		Phenol	108–95–2	0.039	6.2
		Pyrene	129–00–0	0.067	

F039	Leachate (liquids that have percolated through land disposed wastes) resulting from the disposal of more than one restricted waste classified as hazardous under subpart D of this part. (Leachate resulting from the disposal of one or more of the following EPA Hazardous Wastes and no other Hazardous Wastes retains its EPA Hazardous Waste Number(s): F020, F021, F022, F026, F027, and/or F028.).	Acenaphthylene	208–96–8	0.059	3.4
		Acenaphthene	83–32–9	0.059	3.4
		Acetone	67–64–1	0.28	160
		Acetonitrile	75–05–8	5.6	38
		Acetophenone	96–86–2	0.010	9.7
		2-Acetylaminofluorene	53–96–3	0.059	140
		Acrolein	107–02–8	0.29	NA
		Acrylonitrile	107–13–1	0.24	84
		Aldrin	309–00–2	0.021	0.066
		4-Aminobiphenyl	92–67–1	0.13	NA
		Aniline	62–53–3	0.81	14
		Anthracene	120–12–7	0.059	3.4
		Aramite	140–57–8	0.36	NA
		alpha-BHC	319–84–6	0.00014	0.066
		beta-BHC	319–85–7	0.00014	0.066
		delta-BHC	319–86–8	0.023	0.066
		gamma-BHC	58–89–9	0.0017	0.066
		Benzene	71–43–2	0.14	10
		Benz(a)anthracene	56–55–3	0.059	3.4
		Benzo(b)fluoranthene (difficult to distinguish from benzo(k)fluoranthene.	205–99–2	0.11	6.8
		Benzo(b)fluoranthene (difficult to distinguish from benzo(k)fluoranthene.	207–08–9	0.11	6.8
		Benzo(g,h,i)perylene	191–24–2	0.0055	1.8
		Benzo(a)pyrene	50–32–8	0.061	3.4
		Bromodichloromethane	75–27–4	0.35	15
		Methyl bromide (Bromomethane)	74–83–9	0.11	15
		4-Bromophenyl phenyl ether	101–55–3	0.055	15
		n-Butyl alcohol	71–36–3	5.6	2.6
		Butyl benzyl phthalate	85–68–7	0.017	28
		2-sec-Butyl-4,6-dinitrophenol (Dinoseb).	88–85–7	0.066	2.5
		Carbon disulfide	75–15–0	3.8	4.8 mg/l TCLP
		Carbon tetrachloride	56–23–5	0.057	6.0
		Chlordane (alpha and gamma isomers).	57–74–9	0.0033	0.26
		p-Chloroaniline	106–47–8	0.46	16
		Chlorobenzene	108–90–7	0.057	6.0
		Chlorobenzilate	510–15–6	0.10	NA
		2-Chloro-1,3-butadiene	126–99–8	0.057	0.28
		Chlorodibromomethane	124–48–1	0.057	15
		Chloroethane	75–00–3	0.27	6.0
		bis(2-Chloroethoxy)methane	111–91–1	0.036	7.2
		bis(2-Chloroethyl)ether	111–44–4	0.033	6.0
		Chloroform	67–66–3	0.046	6.0
		bis(2-Chloroisopropyl)ether	39638–32–9	0.055	7.2
		p-Chloro-m-cresol	59–50–7	0.018	14
		Chloromethane (Methyl chlorida)	74–87–3	0.19	30
		2-Chloronaphthalene	91–58–7	0.055	5.6

1,4-Dioxane	123–91–1	0.22	170
Diphenylamine (difficult to distinguish from diphenylnitrosamine).	122–39–4	0.92	13
Diphenylnitrosamine (difficult to distinguish from diphenylamine).	86–30–6	0.92	13
1,2-Diphenylhydrazine	122–66–7	0.087	1.5
Disulfoton	298–04–4	0.017	6.2
Endosulfan I	939–98–8	0.023	0.066
Endosulfan II	33213–6–5	0.029	0.13
Endosulfan sulfate	1–31–07–8	0.029	0.13
Endrin	72–20–8	0.0028	0.13
Endrin aldehyde	7421–93–4	0.025	0.13
Ethyl acetate	141–78–6	0.34	33
Ethyl cyanide (Propanenitrile)	107–12–0	0.24	360
Ethyl benzene	100–41–4	0.057	10
Ethyl ether	60–29–7	0.12	160
bis(2-Ethylhexyl) phthalate	117–81–7	0.28	28
Ethyl methacrylate	97–63–2	0.14	160
Ethylene oxide	75–21–8	0.12	NA
Famphur	52–85–7	0.017	15
Fluoranthene	206–44–0	0.068	3.4
Fluorene	86–73–7	0.059	3.4
Heptachlor	76–44–8	0.0012	0.066
Heptachlor epoxide	1024–57–3	0.016	0.066
Hexachlorobenzene	118–74–1	0.055	10
Hexachlorobutadiene	87–68–3	0.055	5.6
Hexachlorocyclopentadiene	77–47–4	0.057	2.4
HxCDDs (All Hexachlorodibenzo-p-dioxins).	NA	0.000063	0.001
HxCDFs (All Hexachlorodibenzofurans).	NA	0.000063	0.001
Hexachloroethane	67–72–1	0.055	30
Hexachloropropylene	1888–71–7	0.035	30
Indeno (1,2,3-c,d) pyrene	193–39–5	0.0055	3.4
Iodomethane	74–88–4	0.19	65
Isobutyl alcohol	78–83–1	5.6	170
Isodrin	465–73–6	0.021	0.066
Isosafrole	120–58–1	0.081	2.6
Kepone	143–50–8	0.0011	0.13
Methacrylonitrile	126–98–7	0.24	84
Methanol	67–56–1	5.6	0.75 mg/l TCLP
Methapyrilene	91–80–5	0.081	1.5
Methoxychlor	72–43–5	0.25	0.18
3-Methylcholanthrene	56–49–5	0.0055	15
4,4-Methylene bis(2-chloroaniline)	101–14–4	0.50	30
Methylene chloride	75–09–2	0.089	30
Methyl ethyl ketone	78–93–3	0.28	36
Methyl isobutyl ketone	108–10–1	0.14	33
Methyl methacrylate	80–62–6	0.14	160
Methyl methansulfonate	66–27–3	0.018	NA
Methyl parathion	298–00–0	0.014	4.6
Naphthalene	91–20–3	0.059	5.6
2-Naphthylamine	91–59–8	0.52	NA
p-Nitroaniline	100–01–6	0.028	28
Nitrobenzene	98–95–3	0.068	14
5-Nitro-o-toluidine	99–55–8	0.32	28
p-Nitrophenol	100–02–7	0.12	29
N-Nitrosodiethylamine	55–18–5	0.40	28
N–Nitrosodimethylamine	62–75–9	0.40	

		tris(2,3-Dibromopropyl) phosphate	126–72–7	0.11	0.10
		Vinyl chloride	75–01–4	0.27	6.0
		Xylenes-mixed isomers (sum of o-, m-, and p-xylene concentrations).	1330–20–7	0.32	30
		Antimony	7440–36–0	1.9	2.1 mg/l TCLP
		Arsenic	7440–38–2	1.4	5.0 mg/l TCLP
		Barium	7440–39–3	1.2	7.6 mg/l TCLP
		Beryllium	7440–41–7	0.82	0.014 mg/l TCLP
		Cadmium	7440–43–9	0.69	0.19 mg/l TCLP
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Cyanides (Total)[7]	57–12–5	1.2	590
		Cyanides (Amenable)[7]	57–12–5	0.86	30
		Fluoride	16964–48–8	35	48
		Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Mercury	7439–97–6	0.15	0.025 mg/l TCLP
		Nickel	7440–02–0	3.98	5.0 mg/l TCLP
		Selenium	7782–49–2	0.82	0.16 mg/l TCLP
		Silver	7440–22–4	0.43	0.30 mg/l TCLP
		Sulfide	8496–25–8	14	NA
		Thallium	7440–28–0	1.4	0.078 mg/l TCLP
		Vanadium	7440–62–2	4.3	0.23
K001	Bottom sediment sludge from the treatment of wastewaters from wood preserving processes that use creosote and/or pentachlorophenol..	Naphthalene	91–20–3	0.059	5.6
		Pentachlorophenol	87–86–5	0.089	7.4
		Phenanthrene	85–01–8	0.059	5.6
		Pyrene	129–00–0	0.067	8.2
		Toluene	108–88–3	0.080	10
		Xylenes-mixed isomers (sum of o-, m-, and p-xylene concentrations).	1330–20–7	0.32	30
K002	Wastewater treatment sludge from the production of chrome yellow and orange pigments.	Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
K003	Wastewater treatment sludge from the production of molybdate orange pigments.	Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
K004	Wastewater treatment sludge from the production of zinc yellow pigments.	Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
K005	Wastewater treatment sludge from the production of chrome green pigments.	Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
K006	Wastewater treatment sludge from the production of chrome oxide green pigments (anhydrous).	Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Cyanides (Total)[7]	57–12–5	1.2	590
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
	Wastewater treatment sludge from the production of chrome oxide green pigments (hydrated).	Lead	7439–92–1	0.69	NA
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
K007	Wastewater treatment sludge from the production of iron blue pigments.	Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
K008	Oven residue from the production of chrome oxide green.	Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Cyanides (Total)[7]	57–12–5	1.2	590
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l
		Lead	7439–92–1	0.69	0.37 mg/l TCLP

K019	Heavy ends from the distillation of ethylene dichloride in ethylene dichloride production..	1,1-Dichloroethane	75–34–3	0.059	6.0
		1,2-Dichloroethane	107–06–2	0.21	6.0
		Hexachlorobenzene	118–74–1	0.055	10
		Hexachlorobutadiene	87–68–3	0.055	5.6
		Hexachloroethane	67–72–1	0.055	30
		Pentachloroethane	76–01–7	NA	6.0
		1,1,1-Trichloroethane	71–55–6	0.054	6.0
		bis(2-Chloroethyl)ether	111–44–4	0.033	6.0
		Chlorobenzene	108–90–7	0.057	6.0
		Chloroform	68–66–3	0.046	6.0
		p-Dichlorobenzene	106–46–7	0.090	NA
		1,2-Dichloroethane	107–06–2	0.21	6.0
		Fluorene	86–73–7	0.059	NA
		Hexachloroethane	67–72–1	0.055	30
		Naphthalene	91–20–3	0.059	5.6
		Phenanthrene	85–01–8	0.059	5.6
		1,2,4,5-Tetrachlorobenzene	95–94–3	0.055	NA
		Tetrachloroethylene	127–18–4	0.056	6.0
		1,2,4-Trichlorobenzene	120–82–1	0.055	19
		1,1,1-Trichloroethane	71–55–6	0.054	6.0
K020	Heavy ends from the distillation of vinyl chloride in vinyl chloride monomer production.	1,2-Dichloroethane	107–06–2	0.21	6.0
		1,1,2,2-Tetrachloroethane	79–34–6	0.057	6.0
		Tetrachloroethylene	127–18–4	0.056	6.0
K021	Aqueous spent antimony catalyst waste from fluoromethanes production.	Carbon tetrachloride	56–23–5	0.057	6.0
		Chloroform	67–66–3	0.046	6.0
		Antimony	7440–36–0	1.9	2.1 mg/l TCLP
K022	Distillation bottom tars from the production of phenol/acetone from cumene.	Toluene	108–88–3	0.080	10
		Acetophenone	96–86–2	0.010	9.7
		Diphenylamine (difficult to distinguish from diphenylnitrosamine).	122–39–4	0.92	13
		Diphenylnitrosamine (difficult to distinguish from diphenylamine).	86–30–6	0.92	13
		Phenol	108–95–2	0.039	6.2
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Nickel	7440–02–0	3.98	5.0 mg/l TCLP
K023	Distillation light ends from the production of phthalic anhydride from naphthalene.	Phthalic anhydride (measured as Phthalic acid or Terephthalic acid).	100–21–0	0.055	28
		Phthalic anhydride (measured as Phthalic acid or Terephthalic acid).	85–44–9	0.055	28
K024	Distillation bottoms from the production of phthalic anhydride from naphthalene.	Phthalic anhydride (measured as Phthalic acid or Terephthalic acid).	100–21–0	0.055	28
		Phthalic anhydride (measured as Phthalic acid or Terephthalic acid).	85–44–9	0.055	28
K025	Distillation bottoms from the production of nitrobenzene by the nitration of benzene.	NA	NA	LLEXT fb SSTRP fb CARBN; or CMBST	CMBST
K026	Stripping still tails from the production of methyl ethyl pyridines.	NA	NA	CMBST	CMBST
K027	Centrifuge and distillation residues from toluene diisocyanate production.	NA	NA	CARBN; or CMBST	CMBST

K035	Wastewater treatment sludges generated in the production of creosote.	Acenaphthene	83–32–9	NA	3.4
		Anthracene	120–12–7	NA	3.4
		Benz(a)anthracene	56–55–3	0.059	3.4
		Benzo(a)pyrene	50–32–8	0.061	3.4
		Chrysene	218–01–9	0.059	3.4
		o-Cresol	95–48–7	0.11	5.6
		m-Cresol (difficult to distinguish from p-cresol).	108–39–4	0.77	5.6
		p-Cresol (difficult to distinguish from m-cresol).	106–44–5	0.77	5.6
		Dibenz(a,h)anthracene	53–70–3	NA	8.2
		Fluoranthene	206–44–0	0.068	3.4
		Fluorene	86–73–7	NA	3.4
		Indeno(1,2,3-cd)pyrene	193–39–5	NA	3.4
		Naphthalene	91–20–3	0.059	5.6
		Phenanthrene	85–01–8	0.059	5.6
		Phenol	108–95–2	0.039	6.2
		Pyrene	129–00–0	0.067	8.2
K036	Still bottoms from toluene reclamation distillation in the production of disulfoton.	Disulfoton	298–04–4	0.017	6.2
K037	Wastewater treatment sludges from the production of disulfoton.	Disulfoton	298–04–4	0.017	6.2
		Toluene	108–88–3	0.080	10
K038	Wastewater from the washing and stripping of phorate production.	Phorate	298–02–2	0.021	4.6
K039	Filter cake from the filtration of diethylphosphorodithioc acid in the production of phorate.	NA	NA	CARBN, or CMBST	CMBST
K040	Wastewater treatment sludge from the production of phorate.	Phorate	298–02–2	0.021	4.6
K041	Wastewater treatment sludge from the production of toxaphene.	Toxaphene	8001–35–2	0.0095	2.6
K042	Heavy ends or distillation residues from the distillation of tetrachlorobenzene in the production of 2,4,5-T.	o-Dichlorobenzene	95–50–1	0.088	6.0
		p-Dichlorobenzene	106–46–7	0.090	6.0
		Pentachlorobenzene	608–93–5	0.055	10
		1,2,4,5-Tetrachlorobenzene	95–94–3	0.055	14
		1,2,4-Trichlorobenzene	120–82–1	0.055	19
K043	2,6-Dichlorophenol waste from the production of 2,4-D.	2,4-Dichlorophenol	120–83–2	0.044	14
		2,6-Dichlorophenol	187–65–0	0.044	14
		2,4,5-Trichlorophenol	95–95–4	0.18	7.4
		2,4,6-Trichlorophenol	88–06–2	0.035	7.4
		2,3,4,6-Tetrachlorophenol	58–90–2	0.030	7.4
		Pentachlorophenol	87–86–5	0.089	7.4
		Tetrachloroethylene	127–18–4	0.056	6.0
		HxCDDs (All Hexachlorodibenzo-p-dioxins).	NA	0.000063	0.001
		HxCDFs (All Hexachlorodibenzofurans).	NA	0.000063	0.001
		PeCDDs (All Pentachlorodibenzo-p-dioxins).	NA	0.000063	0.001
		PeCDFs (All Pentachlorodibenzofurans).	NA	0.000035	0.001
		TCDDs (All Tetrachlorodibenzo-p-dioxins).	NA	0.000063	0.001

		Cyanides (Total)[7]	57–12–5	1.2	590
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Lead	7439–92–1	0.69	NA
		Nickel	7440–02–0	NA	5.0 mg/l TCLP
K050	Heat exchanger bundle cleaning sludge from the petroleum refining industry.	Benzo(a)pyrene	50–32–8	0.061	3.4
		Phenol	108–95–2	0.039	6.2
		Cyanides (Total)[7]	57–12–5	1.2	590
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Lead	7439–92–1	0.69	NA
		Nickel	7440–02–0	NA	5.0 mg/l TCLP
K051	API separator sludge from the petroleum refining industry.	Acenaphthene	83–32–9	0.059	NA
		Anthracene	120–12–7	0.059	3.4
		Benz(a)anthracene	56–55–3	0.059	3.4
		Benzene	71–43–2	0.14	10
		Benzo(a)pyrene	50–32–8	0.061	3.4
		bis(2-Ethylhexyl) phthalate	117–81–7	0.28	28
		Chrysene	2218–01–9	0.059	3.4
		Di-n-butyl phthalate	105–67–9	0.057	28
		Ethylbenzene	100–41–4	0.057	10
		Fluorene	86–73–7	0.059	NA
		Naphthalene	91–20–3	0.059	5.6
		Phenanthrene	85–01–8	0.059	5.6
		Phenol	108–95–2	0.039	6.2
		Pyrene	129–00–0	0.067	8.2
		Toluene	108–88–3	0.08	10
		Xylenes-mixed isomers (sum of o-, m-, and p-xylene concentrations).	1330–20–7	0.32	30
		Cyanides (Total)[7]	57–12–5	1.2	590
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Lead	7439–92–1	0.69	NA
		Nickel	7440–02–0	NA	5.0 mg/l TCLP
K052	Tank bottoms (leaded) from the petroleum refining industry.	Benzene	71–43–2	0.14	10
		Benzo(a)pyrene	50–32–8	0.061	3.4
		o-Cresol	95–48–7	0.11	5.6
		m-Cresol (difficult to distinguish from p-cresol).	108–39–4	0.77	5.6
		p-Cresol (difficult to distinguish from m-cresol).	106–44–5	0.77	5.6
		2,4-Dimethylphenol	105–67–9	0.036	NA
		Ethylbenzene	100–41–4	0.057	10
		Naphthalene	91–20–3	0.059	5.6
		Phenanthrene	85–01–8	0.059	5.6
		Phenol	108–95–2	0.039	6.2
		Toluene	108–88–3	0.08	10
		Xylenes-mixed isomers (sum of o-, m-, and p-xylene concentrations).	1330–20–7	0.32	30
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Cyanides (Total)[7]	57–12–5	1.2	590
		Lead	7439–92–1	0.69	NA
		Nickel	7440–02–0	NA	5.0 mg/l TCLP
K060	Ammonia still lime sludge from coking operations ...	Benzene	71–43–2	0.14	10
		Benzo(a)pyrene	50–32–8	0.061	3.4
		Naphthalene	91–20–3	0.059	5.6
		Phenol	108–95–2	0.039	2

		Diphenylamine (difficult to distinguish from diphenylnitrosamine).	122–39–4	0.92	13
		Diphenylnitrosamine (difficult to distinguish from diphenylamine).	86–30–6	0.92	13
		Nitrobenzene	98–95–3	0.068	14
		Phenol	108–95–2	0.039	6.2
K084	Wastewater treatment sludges generated during the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.	Nickel	7440–02–0	3.98	5.0 mg/l TCLP
		Arsenic	7440–38–2	1.4	5.0 mg/l TCLP
K085	Distillation or fractionation column bottoms from the production of chlorobenzenes.	Benzene	71–43–2	0.14	10
		Chlorobenzene	108–90–7	0.057	6.0
		m-Dichlorobenzene	541–73–1	0.036	6.0
		o-Dichlorobenzene	95–50–1	0.088	6.0
		p-Dichlorobenzene	106–46–7	0.090	6.0
		Hexachlorobenzene	118–74–1	0.055	10
		Total PCBs (sum of all PCB isomers, or all Aroclors).	1336–36–3	0.10	10
		Pentachlorobenzene	608–93–5	0.055	10
		1,2,4,5-Tetrachlorobenzene	95–94–3	0.055	14
		1,2,4-Trichlorobenzene	120–82–1	0.055	19
K086	Solvent wastes and sludges, caustic washes and sludges, or water washes and sludges from cleaning tubs and equipment used in the formulation of ink from pigments, driers, soaps, and stabilizers containing chromium and lead.	Acetone	67–64–1	0.28	160
		Acetophenone	96–86–2	0.010	9.7
		bis(2-Ethylhexyl phthalate	117–81–7	0.28	28
		n-Butyl alcohol	71–36–3	5.6	2.6
		Butylbenzyl phthalate	85–68–7	0.017	28
		Cyclohexanone	108–94–1	0.36	NA
		o-Dichlorobenzene	95–50–1	0.088	6.0
		Diethyl phthalate	84–66–2	0.20	28
		Dimethyl phthalate	131–11–3	0.047	28
		Di-n-butyl phthalate	84–74–2	0.057	28
		Di-n-octyl phthalate	117–84–0	0.017	28
		Ethyl acetate	141–78–6	0.34	33
		Ethylbenzene	100–41–4	0.057	10
		Menthanol	67–56–1	5.6	NA
		Methyl ethyl ketone	78–93–3	0.28	36
		Methyl isobutyl ketone	108–10–1	0.14	33
		Methylene chloride	75–09–2	0.089	30
		Naphthalene	91–20–3	0.059	5.6
		Nitrobenzene	98–95–3	0.068	14
		Toluene	108–88–3	0.080	10
		1,1,1-Trichloroethane	71–55–6	0.054	6.0
		Trichloroethylene	79–01–6	0.054	6.0
		Xylenes-mixed isomers (sum of o-,m-, and p-xylene concentrations).	1330–20–7	0.32	30
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Cyanides (Total) [7]	57–12–5	1.2	590
		Lead	7439–92–1	0.69	0.37 mg/l TCLP
K087	Decanter tank tar sludge from coking operations	Acenaphthylene	208–96–8	0.059	3.4
		Benzene	71–43–2	0.14	10
		Chrysene	218–01–9	0.059	3.4
		Fluoranthene	206–44–0	0.068	3.4
		Indeno(1,2,3-cd)pyrene	193–39–5	0.0055	3.4

K095	Distillation bottoms from the production of 1,1,1-trichloroethane.	Hexachloroethane	67–72–1	0.055	30
		Pentachloroethane	76–01–7	0.055	6.0
		1,1,1,2-Tetrachloroethane	630–20–6	0.057	6.0
		1,1,2,2-Tetrachloroethane	79–34–6	0.057	6.0
		Tetrachloroethylene	127–18–4	0.056	6.0
		1,1,2-Trichloroethane	79–00–5	0.054	6.0
		Trichloroethylene	79–01–6	0.054	6.0
K096	Heavy ends from the heavy ends column from the production of 1,1,1-trichloroethane.	m-Dichlorobenzene	541–73–1	0.036	6.0
		Pentachloroethane	76–01–7	0.055	6.0
		1,1,1,2-Tetrachloroethane	630–20–6	0.057	6.0
		1,1,2,2-Tetrachloroethane	79–34–6	0.057	6.0
		Tetrachloroethylene	127–18–4	0.056	6.0
		1,2,4-Trichlorobenzene	120–82–1	0.055	19
		1,1,2-Trichloroethane	79–00–5	0.054	6.0
		Trichloroethylene	79–01–6	0.054	6.0
K097	Vacuum stripper discharge from the chlordane chlorinator in the production of chlordane.	Chlordane (alpha and gamma isomers).	57–74–9	0.0033	0.26
		Heptachlor	76–44–8	0.0012	0.066
		Heptachlor epoxide	1024–57–3	0.016	0.066
		Hexachlorocyclopentadiene	77–47–4	0.057	2.4
K098	Untreated process wastewater from the production of toxaphene.	Toxaphene	8001–35–2	0.0095	2.6
K099	Untreated wastewater from the production of 2,4-D	2,4-Dichlorophenoxyacetic acid	94–75–7	0.72	10
		HxCDDs (All Hexachlorodibenzo-p-dioxins).	NA	0.000063	0.001
		HxCDFs (All Hexachlorodibenzofurans).	NA	0.000063	0.001
		PeCDDs (All Pentachlorodibenzo-p-dioxins).	NA	0.000063	0.001
		PeCDFs (All Pentachlorodibenzofurans).	NA	0.000035	0.001
		TCDDs (All Tetrachlorodibenzo-p-dioxins).	NA	0.000063	0.001
		TCDFs (All Tetrachlorodibenzofurans).	NA	0.000063	0.001
K100	Waste leaching solution from acid leaching of emission control dust/sludge from secondary lead smelting.	Cadmium	7440–43–9	0.69	0.19 mg/l TCLP
		Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
		Lead	7439–92–1	0.69	0.37 mg/l TCLP
K101	Distillation tar residues from the distillation of aniline-based compounds in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.	o-Nitroaniline	88–74–4	0.27	14
		Arsenic	7440–38–2	1.4	5.0 mg/l TCLP
		Cadmium	7440–43–9	0.69	NA
		Lead	7439–92–1	0.69	NA
		Mercury	7439–97–6	0.15	NA
K102	Residue from the use of activated carbon for decolorization in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.	o-Nitrophenol	88–75–5	0.028	13
		Arsenic	7440–38–2	1.4	5.0 mg/l TCLP
		Cadmium	7440–43–9	0.69	NA
		Lead	7439–92–1	0.69	NA
		Mercury	7439–97–6	0.15	

K110	Condensed column overheads from intermediate separation from the production of 1,1-dimethyhydrazine (UDMH) from carboxylic acid hydrazides.	NA	NA	CMBST; or CHOXD fb CARBN; or BIODG fb CARBN	CMBST
K111	Product washwaters from the production of dinitrotoluene via nitration of toluene.	2,4-Dinitrotoluene	121–1–2	0.32	140
		2,6-Dinitrotoluene	606–20–2	0.55	28
K112	Reaction by-product water from the drying column in the production of toluenediamine via hydrogenation of dinitrotoluene.	NA	NA	CMBST; or CHOXD fb CARBN; or BIODG fb CARBN	CMBST
K113	Condensed liquid light ends from the purification of toluenediamine in the production of toluenediamine via hydrogenation of dinitrotoluene.	NA	NA	CARBN; or CMBST	CMBST
K114	Vicinals from the purification of toluenediamine in the production of toluenediamine via hydrogenation of dinitrotoluene.	NA	NA	CARBN; or CMBST	CMBST
K115	Heavy ends from the purification of toluenediamine in the production of toluenediamine via hydrogenation of dinitrotoluene.	Nickel	7440–02–0	3.98	5.0 mg/l TCLP
		NA	NA	CARBN; or CMBST	CMBST
K116	Organic condensate from the solvent recovery column in the production of toluene diisocyanate via phosgenation of toluenediamine.	NA	NA	CARBN; or CMBST	CMBST
K117	Wastewater from the reactor vent gas scrubber in the production of ethylene dibromide via bromination of ethene.	Methyl bromide (Bromomethane)	74–83–9	0.11	15
		Chloroform	67–66–3	0.046	6.0
		Ethylene dibromide (1,2-Dibromoethane).	106–93–4	0.028	15
K118	Spent absorbent solids from purification of ethylene dibromide in the production of ethylene dibromide via bromination of ethene.	Methyl bromide (Bromomethane)	74–83–9	0.11	15
		Chloroform	67–66–3	0.046	6.0
		Ethylene dibromide (1,2-Dibromoethane).	106–93–4	0.028	15
K123	Process wastewater (including supernates, filtrates, and washwaters) from the production of ethylenebisdithiocarbamic acid and its salts.	NA	NA	CMBST; or CHOXD fb (BIODG or CARBN)	CMBST
K124	Reactor vent scrubber water from the production of ethylenebisdithiocarbamic acid and its salts.	NA	NA	CMBST; or CHOXD fb (BIODG or CARBN)	CMBST
K125	Filtration, evaporation, and centrifugation solids from the production of ethylenebisdithiocarbamic acid and its salts.	NA	NA	CMBST; or CHOXD fb (BIODG or CARBN)	CMBST
K126	Baghouse dust and floor sweepings in milling and packaging operations from the production or formulation of ethylenebisdithiocarbamic acid and its salts.	NA	NA	CMBST; or CHOXD fb (BIODG or CARBN)	CMBST
K131	Wastewater from the reactor and spent sulfuric acid from the acid dryer from the production of methyl bromide.	Methyl bromide (Bromomethane)	74–83–9	0.11	15

		Benzo(a)pyrene	50–32–8	0.061	3.4
		Benzo(b)fluoranthene (difficult to distinguish from benzo(k) fluoranthene).	205–99–2	0.11	6.8
		Benzo(k)fluoranthene (difficult to distinguish from benzo(b)fluoranthene).	207–08–9	0.11	6.8
		Benzene	71–43–2	0.14	10
		Chrysene	218–01–9	0.059	3.4
K144	Wastewater sump residues from light oil refining, including, but not limited to, intercepting or contamination sump sludges from the recovery of coke by-products produced from coal.	Benz(a)anthracene	56–55–3	0.059	3.4
		Benzo(a)pyrene	50–32–8	0.061	3.4
		Benzo(b)fluoranthene (difficult to distinguish from benzo(k)fluoranthene).	205–99–2	0.11	6.8
		Benzo(k)fluoranthene (difficult to distinguish from benzo(b)fluoranthene).	207–08–9	0.11	6.8
		Chrysene	218–01–9	0.059	3.4
		Dibenz(a,h)anthracene	53–70–3	0.055	8.2
K145	Residues from naphthalene collection and recovery operations from the recovery of coke by-products produced from coal.	Benzene	71–43–2	0.14	10
		Benz(a)anthracene	56–55–3	0.059	3.4
		Benzo(a)pyrene	50–32–8	0.061	3.4
		Chrysene	218–01–9	0.059	3.4
		Dibenz(a,h)anthracene	53–70–3	0.055	8.2
		Naphthalene	91–20–3	0.059	5.6
K147	Tar storage tank residues from coal tar refining	Benzene	71–43–2	0.14	10
		Benz(a)anthracene	56–55–3	0.059	3.4
		Benzo(a)pyrene	50–32–8	0.061	3.4
		Benzo(b)fluoranthene (difficult to distinguish from benzo(k)fluoranthene).	205–99–2	0.11	6.8
		Benzo(k)fluoranthene (difficult to distinguish from benzo(b)fluoranthene).	207–08–9	0.11	6.8
		Chrysene	218–01–9	0.059	3.4
		Dibenz(a,h)anthracene	53–70–3	0.055	8.2
		Indeno(1,2,3-cd)pyrene	193–39–5	0.0055	3.4
K148	Residues from coal tar distillation, including, but not limited to, still bottoms.	Benz(a)anthracene	56–55–3	0.059	3.4
		Benzo(a)pyrene	50–32–8	0.061	3.4
		Benzo(b)fluoranthene (difficult to distinguish from benzo(k)fluoranthene).	205–99–2	0.11	6.8
		Benzo(k)fluoranthene (difficult to distinguish from benzo(b)fluoranthene).	207–08–9	0.11	6.8
		Chrysene	218–01–9	0.059	3.4
		Dibenz(a,h)anthracene	53–70–3	0.055	8.2
		Indeno(1,2,3-cd)pyrene	193–39–5	0.0055	3.4

K157..	Wastewaters (including scrubber waters, condenser waters, washwaters, and separation waters) from the production of carbamates and carbamoyl oximes.	Toluene	108–88–3	0.080	10
		Triethylamine	121–44–8	0.081	1.5
		Xylenes (total)	1330–20–7	0.32	30
		Acetone	67–64–1	0.28	160
		Carbon tetrachloride	56–23–5	0.057	6.0
		Chloroform	67–66–3	0.046	6.0
		Chloromethane	74–87–3	0.19	30
		Methanol	67–56–1	5.6	0.75 mg/l TCLP
		Methomyl	16752–77–5	0.028	0.14
		Methylene chloride	75–09–2	0.089	30
		Methyl ethyl ketone	78–93–3	0.28	36
		Methyl isobutyl ketone	108–10–1	0.14	33
		o-Phenylenediamine	95–54–5	0.056	5.6
		Pyridine	110–86–1	0.014	16
		Triethylamine	121–44–8	0.081	1.5
K158..	Bag house dusts and filter/separation solids from the production of carbamates and carbamoyl oximes.	Benomyl	17804–35–2	0.056	1.4
		Benzene	71–43–2	0.14	10
		Carbenzadim	10605–21–7	0.056	1.4
		Carbofuran	1563–66–2	0.006	0.14
		Carbosulfan	55285–14–8	0.028	1.4
		Chloroform	67–66–3	0.046	6.0
		Hexane	110–54–3	0.611	10
		Methanol	67–56–1	5.6	0.75 mg/l TCLP
		Methylene chloride	75–09–2	0.089	30
		Phenol	108–95–2	0.039	6.2
		Xylenes (total)	1330–20–7	0.32	30
K159..	Organics from the treatment of thiocarbamate wastes.	Benzene	71–43–2	0.14	10
		Butylate	2008–41–5	0.003	1.5
		EPTC (Eptam)	759–94–4	0.003	1.4
		Molinate	2212–67–1	0.003	1.4
		Pebulate	1114–71–2	0.003	1.4
		Thiocarbamate, N.O.S.	NA	0.003	1.4
		Vernolate	1929–77–7	0.003	1.4
K160..	Solids (including filter wastes, separation solids, and spent catalysts) from the production of thiocarbamates and solids from the treatment of thiocarbamate wastes.	Butylate	2008–41–5	0.003	1.5
		EPTC (Eptam)	759–94–4	0.003	1.4
		Molinate	2212–67–1	0.003	1.4
		Pebulate	1114–71–2	0.003	1.4
		Thiocarbamate, N.O.S.	NA	0.003	1.4
		Toluene	108–88–3	0.080	10
		Vernolate	1929–77–7	0.003	1.4
		Xylenes (total)	1330–20–7	0.32	30
K161..	Purification solids (including filtration, evaporation, and centrifugation solids), baghouse dust and floor sweepings from the production of dithiocarbamate acids and their salts.	Antimony	7440–36–0	1.9	2.1 mg/l TCLP
		Carbon disulfide	75–15–0	3.8	4.8 mg/l TCLP
		Dithiocarbamates, total	NA	0.028	28
		Lead	7439–92–1	0.69	0.37 mg/l TCLP
		Nickel	7440–02–0	3.98	5.0 mg/l TCLP
		Selenium	7782–49–2	0.82	016 mg/l TCLP
		Xylenes (total)	1330–20–7	0.32	30
P001	Warfarin, & salts, when present at concentrations greater than 0.3%.	Warfarin	81–81–2	(WETOX or CHOXD) fb CARBN; or CBMST	CMBST

P020	2-sec-Butyl-4,6-dinitrophenol (Dinoseb)	2-sec-Butyl-4,6-dinitrophenol (Dinoseb).	88–85–7	0.066	2.5
P021	Calcium cyanide	Cyanides (Total)[7]	57–12–5	1.2	590
		Cyanides (Amenable)[7]	57–12–5	0.86	30
P022	Carbon disulfide	Carbon disulfide	75–15–0	3.8	CMBST
		Carbon disulfide; alternate[6] standard for nonwastewaters only.	75–15–0	NA	4.8 mg/l TCLP
P023	Choloracetaldehyde	Choloracetaldehyde	107–20–0	(WETOX or CHOXD) fb CARBN; or CBMST	CMBST
P024	p-Chloroaniline	p-Chloroaniline	106–47–8	0.46	16
P026	1-(o-Cholorphenyl)thiourea	1-(o-Cholorphenyl)thiourea	5344–82–1	(WETOX or CHOXD) fb CARBN; or CBMST	CMBST
P027	3-Chloropropionitrile	3-Chloropropionitrile	542–76–7	(WETOX or CHOXD) fb CARBN; or CBMST	CMBST
P028	Benzyl chloride	Benzyl chloride	100–44–7	(WETOX or CHOXD) fb CARBN; or CBMST	CMBST
P029	Copper cyanide	Cyanides (Total)[7]	57–12–5	1.2	590
		Cyanides (Amenable)[7]	57–12–5	0.86	30
P030	Cyanides (soluble salts and complexes)	Cyanides (Total)[7]	57–12–5	1.2	590
		Cyanides (Amenable)[7]	57–12–5	0.86	30
P031	Cyanogen	Cyanogen	460–19–5	CHOXD; WETOX; or CMBST	CHOXD; WETOX; or CMBST
P033	Cyanogen chloride	Cyanogen chloride	506–77–4	CHOXD; WETOX; or CMBST	CHOXD; WETOX; or CMBST
P034	2-Cyclohexly-4,6-dinitrophenol	2-Cyclohexly-4,6-dinitrophenol	131–89–5	(WETOX or CHOXD) fb CARBN; or CBMST	CMBST
P036	Dichlorophenylarsine	Arsenic	7440–38–2	1.4	5.0 mg/l TCLP
P037	Dieldrin	Dieldrin	60–57–1	0.017	0.13
P038	Diethylarsine	Arsenic	7440–38–2	1.4	50 mg/l TCLP
P039	Disulfoton	Disulfoton	298–04–4	0.017	6.2
P040	0,0-Diethyl O-pyrazinyl phosphorothioate	0,0-Diethyl O-pyrazinyl phosphorothioate.	297–97–2	CARBN; or CMBST	CMBST
P041	Diethyl-p-nitrophenyl phosphate	Diethyl-p-nitrophenyl phosphate	311–45–5	CARBN; or CMBST	CMBST
P042	Epinephrine	Epinephrine	51–43–4	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
P043	Diisopropylfluorophosphate (DFP)	Diisopropylfluorophosphate (DFP)	55–91–4	CARBN; or CMBST	CMBST
P044	Dimethoate	Dimethoate	60–51–5	CARBN; or CMBST	CMBST
P045	Thiofanox	Thiofanox	39196–18–4	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST

	Mercury fulminate nonwastewaters that are either incinerator residues or are residues from RMERC; and contain greater than or equal to 260 mg/kg total mercury.	Mercury	7339–97–6	NA	RMERC
	Mercury fulminate nonwastewaters that are residues from RMERC and contain less than 260 mg/kg total mercury.	Mercury	7439–97–6	NA	0.20 mg/l TCLP
	Mercury fulminate nonwastewaters that are incinerator residues and contain less than 260 mg/kg total mercury.	Mercury	7439–97–6	NA	0.025 mg/l TCLP
	All mercury fulminate wastewaters	Mercury	7439–97–6	0.15	NA
P066	Methomyl	Methomyl	16752–77–5	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
P067	2-Methyl-aziridine	2-Methyl-aziridine	75–55–8	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
P068	Methyl hydrazine	Methyl hydrazine	60–34–4	CHOXD; CHRED; CARBN; BIODG; or CMBST	CHOXD; CHRED; or CMBST
P069	2-Methyllactonitrile	2-Methyllactonitrile	75–86–5	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
P070	Aldicarb	Aldicarb	116–06–3	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
P071	Methyl parathion	Methyl parathion	298–00–0	0.014	4.6
P072	1-Naphthyl–2–thiourea	1-Naphthyl–2–thiourea	86–88–4	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
P073	Nickel carbonyl	Nickel	7440–02–0	3.98	5.0 mg/l TCLP
P074	Nickel-cyanide	Cyanides (Total)[7]	57–12–5	1.2	590
		Cyanides (Total)[7]	57–12–5	0.86	30
		Nickel	7440–02–0	3.98	5.0 mg/l TCLP
P075	Nicotine and salts	Nicotine and salts	54–11–5	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
P076	Nitric oxide	Nitric oxide	10102–43–9	ADGAS	ADGAS
P077	p-Nitroaniline	p-Nitroaniline	100–01–6	0.028	28
P078	Nitrogen dioxide	Nitrogen dioxide	10102–44–0	ADGAS	ADGAS
P081	Nitroglycerin	Nitroglycerin	55–63–0	CHOXD; CHRED; CARBN; BIODG; or CMBST	CHOXD; CHRED; or CMBST
P082	N-Nitrosodimethylamine	N-Nitrosodimethylamine	62–75–9	0.40	2.3
P084	N-Nitrosomethylvinylamine	N-Nitrosomethylvinylamine	4549–40–0	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
P085	Octamethylpyrophosphoramide	Octamethylpyrophosphoramide	152–16–9	CARBN; OR CMBST	CMBST
P087	Osmium tectroxide	Osmium tectroxide	20816–12–0	RMETL; or RTHRM	RMETL; or RTHRM

P0105	Sodium azide	Sodium azide	26628–22–8	CHOXD; CHRED; CARBN; BIODG; or CMBST	CHOXD; CHRED; or CMBST
P0106	Sodium cyanide	Cyanides (Total)[7]	57–12–5	1.2	590
		Cyanides (Amenable)[7]	57–12–5	0.86	30
P0108	Strychnine and salts	Strychnine and salts	57–24–9	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
P109	Tetraethyldithiopyrophosphate	Tetraethyldithiopyrophosphate	3689–24–5	CARBN; or CMBST	CMBST
P110	Tetraethyl lead	Lead	7439–92–1	0.69	0.37 mg/l TCLP
P111	Tetraethylpyrophosphate	Tetraethylpyrophosphate	107–49–3	CARBN; or CMBST	CMBST
P112	Tetranitromethane	Tetranitromethane	509–14–8	CHOXD; CHRED; CARBN; BIODG; or CMBST	CHOXD; CHRED; or CMBST
P113	Thallic oxide	Thallium (measured in wastewaters only).	7440–28–0	1.4	RTHRM; or STABL
P114	Thallium selenite	Selenium	7782–49–2	0.82	0.16 mg/l TCLP
P115	Thallium (I) sulfate	Thallium (measured in wastewaters only).	7440–28–0	1.4	RTHRM; or STABL
P116	Thiosemicarbazide	Thiosemicarbazide	79–19–6	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
P118	Trichloromethanethiol	Trichloromethanethiol	75–70–7	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
P119	Ammonium vanadate	Vanadium (measured in wastewaters only).	7440–62–2	4.3	STABL
P120	Vandium pentoxide	Vanadium (measured in wastewaters only).	7440–62–2	4.3	STABL
P121	Zinc cyanide	Cyanides (Total)[7]	57–12–5	1.2	590
		Cyanides (Amenable)[7]	57–12–5	0.86	30
P122	Zinc phosphide Zn_3P_2, when present at concentrations greater than 10%.	Zinc Phosphide	1314–84–7	CHOXD; CHRED; or CMBST	CHOXD; CHRED; or CMBST
P123	Toxaphene	Toxaphene	8001–35–2	0.0095	2.6
P127	Carbofuran	Carbofuran	1563–66–2	0.006	0.14
P128	Mexacarbate	Mexacarbate	315–18–4	0.056	1.4
P185	Tirpate	Tirpate	26419–73–8	0.056	0.28
P187	Bendiocarb	Bendiocarb	22781–23–3	0.056	1.4
P188	Physostigimine salicylate	Physostigmine salicylate	57–64–7	0.056	1.4
P189	Carbosulfan	Carbosulfan	55285–14–8	0.028	1.4
P190	Metolcarb	Metolcarb	1129–41–5	0.056	1.4
P191	Dimetilan	Dimetilan	644–64–4	0.056	1.4
P192	Isolan	Isolan	119–38–0	0.056	1.4
P193	Thiophanate-methyl	Thiophanate-methyl	23564–05–8	0.056	1.4
P194	Oxamyl	Oxamyl	23135–22–0	0.056	0.28
P195	Thiodicarb	Thiodicarb	59669–26–0	0.019	1.4
P196	Dithiocarbamates (total)	Dithiocarbamates (total)	NA	0.028	28
P197	Formparanate	Formparanate	17702–57–7	0.056	1.4
P198	Formetanate hydrochloride	Formetanate hydrochloride	23422–53–9	0.056	1.4
P199	Methiocarb	Methiocarb	2032–65–7	0.056	1.4
P200	Propoxur	Propoxur	114–26–1	0.056	1.4
P201	Promecarb	Promecarb	2631–37–0	0.056	1.4
P202	Hercules AC–5727	Hercules AC–5727	64–00–6	0.056	1.4

U017	Benzal chloride	Benzal chloride	98–87–3	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U018	Benz(a)anthracene	Benz(a)anthracene	56–55–3	0.059	3.4
U019	Benzene	Benzene	71–43–2	0.14	10
U020	Benzenesulfonyl chloride	Benzenesulfonyl chloride	98–09–9	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U021	Benzidine	Benzidine	92–87–5	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U022	Benzo(a)pyrene	Benzo(a)pyrene	50–32–8	0.061	3.4
U023	Benzotrichloride	Benzotrichloride	98–07–7	CHOXD; CHRED; CARBN; BIODG; or CMBST	CHOXD; CHRED; or CMBST
U024	bis(2-Chloroethoxy)methane	bis(2-Chloroethoxy)methane	111–91–1	0.036	7.2
U025	bis(2-Chloroethyl)ether	bis(2-Chloroethyl)ether	111–44–4	0.033	6.0
U026	Chlornaphazine	Chlornaphazine	494–03–1	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U027	bis(2-Chloroisopropyl)ether	bis(2-Chloroisopropyl)ether	39638–32–9	(WETOX or CHOXD) fb CARBN; or CMBST	7.2
U028	bis(2-Ethylhexyl) phthalate	bis(2-Ethylhexyl) phthalate	117–81–7	0.28	28
U029	Methyl bromide (Bromomethane)	Methyl bromide (Bromomethane)	74–83–9	0.11	15
U030	4-Bromophenyl phenyl ether	4-Bromophenyl phenyl ether	101–55–3	0.055	15
U031	n-Butyl alcohol	n-Butyl alcohol	71–36–3	5.6	2.6
U032	Calcium chromate	Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
U033	Carbon oxyfluoride	Carbon oxyfluoride	353–50–4	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U034	Trichloroacetaldehyde (Chloral)	Trichloroacetaldehyde (Chloral)	75–87–6	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U035	Chlorambucil	Chlorambucil	305–03–3	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U036	Chlordane	Chlordane (alpha and gamma isomers).	57–74–9	0.0033	0.26
U037	Chlorobenzene	Chlorobenzene	108–90–7	0.057	6.0
U038	Chlorobenzilate	Chlorobenzilate	510–15–6	0.10	CMBEST
U039	p-Chloro-m-cresol	p-Chloro-m-cresol	59–50–7	0.018	14
U041	Epichlorohydrin (1-Chloro-2,3-epoxypropane)	Epichlorohydrin (1-Chloro-2,3-epoxypropane).	106–89–8	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U042	2-Chloroethyl vinyl ether	2-Chloroethyl vinyl ether	110–75–8	0.062	CMBST
U043	Vinyl chloride	Vinyl chloride	75–01–4	0.27	6.0
U044	Chloroform	Chloroform	67–66–3	0.046	6.0
U045	Chloromethane (Methyl chloride)	Chloromethane (Methyl chloride)	74–87–3	0.19	30

U017	Benzal chloride	Benzal chloride	98–87–3	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U018	Benz(a)anthracene	Benz(a)anthracene	56–55–3	0.059	3.4
U019	Benzene	Benzene	71–43–2	0.14	10
U020	Benzenesulfonyl chloride	Benzenesulfonyl chloride	98–09–9	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U021	Benzidine	Benzidine	92–87–5	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U022	Benzo(a)pyrene	Benzo(a)pyrene	50–32–8	0.061	3.4
U023	Benzotrichloride	Benzotrichloride	98–07–7	CHOXD; CHRED; CARBN; BIODG; or CMBST	CHOXD; CHRED; or CMBST
U024	bis(2-Chloroethoxy)methane	bis(2-Chloroethoxy)methane	111–91–1	0.036	7.2
U025	bis(2-Chloroethyl)ether	bis(2-Chloroethyl)ether	111–44–4	0.033	6.0
U026	Chlornaphazine	Chlornaphazine	494–03–1	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U027	bis(2-Chloroisopropyl)ether	bis(2-Chloroisopropyl)ether	39638–32–9	(WETOX or CHOXD) fb CARBN; or CMBST	7.2
U028	bis(2-Ethylhexyl) phthalate	bis(2-Ethylhexyl) phthalate	117–81–7	0.28	28
U029	Methyl bromide (Bromomethane)	Methyl bromide (Bromomethane)	74–83–9	0.11	15
U030	4-Bromophenyl phenyl ether	4-Bromophenyl phenyl ether	101–55–3	0.055	15
U031	n-Butyl alcohol	n-Butyl alcohol	71–36–3	5.6	2.6
U032	Calcium chromate	Chromium (Total)	7440–47–3	2.77	0.86 mg/l TCLP
U033	Carbon oxyfluoride	Carbon oxyfluoride	353–50–4	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U034	Trichloroacetaldehyde (Chloral)	Trichloroacetaldehyde (Chloral)	75–87–6	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U035	Chlorambucil	Chlorambucil	305–03–3	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U036	Chlordane	Chlordane (alpha and gamma isomers).	57–74–9	0.0033	0.26
U037	Chlorobenzene	Chlorobenzene	108–90–7	0.057	6.0
U038	Chlorobenzilate	Chlorobenzilate	510–15–6	0.10	CMBEST
U039	p-Chloro-m-cresol	p-Chloro-m-cresol	59–50–7	0.018	14
U041	Epichlorohydrin (1-Chloro-2,3-epoxypropane)	Epichlorohydrin (1-Chloro-2,3-epoxypropane).	106–89–8	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U042	2-Chloroethyl vinyl ether	2-Chloroethyl vinyl ether	110–75–8	0.062	CMBST
U043	Vinyl chloride	Vinyl chloride	75–01–4	0.27	6.0
U044	Chloroform	Chloroform	67–66–3	0.046	6.0
U045	Chloromethane (Methyl chloride)	Chloromethane (Methyl chloride)	74–87–3	0.19	30

U059	Daunomycin	Daunomycin	20830–81–3	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U060	DDD	o,p'-DDD	53–19–0	0.023	0.087
		p,p'-DDD	72–54–8	0.023	0.087
U061	DDT	o,p'-DDT	789–02–6	0.0039	0.087
		p,p'-DDT	50–29–3	0.0039	0.087
		o,p'-DDD	53–19–0	0.023	0.087
		p,p'-DDD	72–54–8	0.023	0.087
		o,p'-DDE	3424–82–6	0.031	0.087
		p,p'-DDE	72–55–9	0.031	0.087
U062	Diallate	Diallate	2303–16–4	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U063	Dibenz(a,h)anthracene	Dibenz(a,h)anthracene	53–70–3	0.055	8.2
U064	Dibenz(a,i)pyrene	Dibenz(a,i)pyrene	189–55–9	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U066	1,2-Dibromo-3-chloropropane	1,2-Dibromo-3-chloropropane	96–12–8	0.11	15
U067	Ethylene dibromide (1,2-Dibromoethane)	Ethylene dibromide (1,2-Dibromoethane).	106–93–4	0.028	15
U068	Dibromomethane	Dibromomethane	74–95–3	0.11	15
U069	Di-n-butyl phthalate	Di-n-butyl phthalate	84–74–2	0.057	28
U070	o-Dichlorobenzene	o-Dichlorobenzene	95–50–1	0.088	6.0
U071	m-Dichlorobenzene	m-Dichlorobenzene	541–73–1	0.036	6.0
U072	p-Dichlorobenzene	p-Dichlorobenzene	106–46–7	0.090	6.0
U073	3,3'-Dichlorobenzidine	3,3'-Dichlorobenzidine	91–94–1	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U074	1,4-Dichloro-2-butene	cis-1,4-Dichloro-2-butene	1476–11–5	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
		trans-1,4-Dichloro-2-butene	764–41–0	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U075	Dichlorodifluoromethane	Dichlorodifluoromethane	75–71–8	0.23	7.2
U076	1,1-Dichloroethane	1,1-Dichloroethane	75–34–3	0.059	6.0
U077	1,2-Dichloroethane	1,2-Dichloroethane	107–06–2	0.21	6.0
U078	1,1-Dichloroethylene	1,1-Dichloroethylene	75–35–4	0.025	6.0
U079	1,2-Dichloroethylene	trans-1,2-Dichloroethylene	156–60–5	0.054	30
U080	Methylene chloride	Methylene chloride	75–09–2	0.089	30
U081	2,4-Dichlorophenol	2,4-Dichlorophenol	120–83–2	0.044	14
U082	2,6-Dichlorophenol	2,6-Dichlorophenol	87–65–0	0.044	14
U083	1,2-Dichloropropane	1,2-Dichloropropane	78–87–5	0.85	18
U084	1,3-Dichloropropylene	cis-1,3-Dichloropropylene	10061–01–5	0.036	18
		trans-1,3-Dichloropropylene	10061–02–6	0.036	18
U085	1,2:3,4-Diepoxybutane	1,2:3,4-Diepoxybutane	1464–53–5	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST

U099	1,2-Dimethylhydrazine	1,2-Dimethylhydrazine	540–73–8	CHOXD; CHRED; CARBN; BIODG; or CMBST	CHOXD; CHRED; or CMBST CHOXD, CHRED; or CMBST
U101	2,4-Dimethylphenol	2,4-Dimethylphenol	105–67–9	0.036	14
U102	Dimethyl phthalate	Dimethyl phthalate	131–11–3	0.047	28
U103	Dimethyl sulfate	Dimethyl sulfate	77–78–1	CHOXD; CHRED; CARBN; BIODG; or CMBST	CHOXD; CHRED; or CMBST
U105	2,4-Dinitrotoluene	2,4-Dinitrotoluene	121–14–2	0.32	140
U106	2,6-Dinitrotoluene	2,6-Dinitrotoluene	606–20–2	0.55	28
U108	1,4-Dioxane	1,4-Dioxane	123–91–1	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
		1,4-Dioxane; alternate[6] standard for nonwastewaters only.	123–91–1	NA	170
U109	1,2-Diphenylhydrazine	1,2-Diphenylhydrazine	122–66–7	CHOXD; CHRED; CARBN; BIODG; or CMBST	CHOXD; CHRED; or CMBST
		1,2-Diphenylhydrazine; alternate[6] standard for wastewaters only.	122–66–7	0.087	NA
U110	Dipropylamine	Dipropylamine	142–84–7	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U111	Di-n-propylnitrosamine	Di-n-propylnitrosamine	621–64–7	0.40	14
U112	Ethyl acetate	Ethyl acetate	141–78–6	0.34	33
U113	Ethyl acrylate	Ethyl acrylate	140–88–5	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U114	Ethylenebisdithiocarbamic acid salts and esters	Ethylenebisdithiocarbamic acid	111–54–6	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U115	Ethylene oxide	Ethylene oxide	75–21–8	(WETOX or CHOXD) fb CARBN; or CMBST	CHOXD; or CMBST
		Ethylene oxide; alternate[6] standard for wastewaters only.	75–21–8	0.12	NA
U116	Ethylene thiourea	Ethylene thiourea	96–45–7	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U117	Ethyl ether	Ethyl ether	60–29–7	0.12	160
U118	Ethyl methacrylate	Ethyl methacrylate	97–63–2	0.14	160
U119	Ethyl methane sulfonate	Ethyl methane sulfonate	62–50–0	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U120	Fluoranthene	Fluoranthene	206–44–0	0.068	3.4
U121	Trichloromonofluoromethane	Trichloromonofluoromethane	75–69–4	0.020	30

U143	Lasiocarpine	Lasiocarpine	303–34–4	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U144	Lead acetate	Lead	7439–92–1	0.69	0.37 mg/l TCLP
U145	Lead phosphate	Lead	7439–92–1	0.69	0.37 mg/l TCLP
U146	Lead subacetate	Lead	7439–92–1	0.69	0.37 mg/l TCLP
U147	Maleic anhydride	Maleic anhydride	108–31–6	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U148	Maleic hydrazide	Maleic hydrazide	123–33–1	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U149	Malononitrile	Malononitrile	109–77–3	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U150	Melphalan	Melphalan	148–82–3	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U151	U151 (mercury) nonwastewaters that contain greater than or equal to 260 mg/kg total mercury.	Mercury	7439–97–6	NA	RMERC
	U151 (mercury) nonwastewaters that contain less than 260 mg/kg total mercury and that are residues from RMERC only.	Mercury	7439–97–6	NA	0.20 mg/l TCLP
	U151 (mercury) nonwastewaters that contain less than 260 mg/kg total mercury and that are not residues from RMERC.	Mercury	7439–97–6	NA	0.025 mg/l TCLP
	All U151 (mercury) wastewaters	Mercury	7439–97–6	0.15	NA
	Elemental Mercury Contaminated with Radioactive materials.	Mercury	7439–97–6	NA	AMLGM
U152	Methacrylonitrile	Methacrylonitrile	126–98–7	0.24	84
U153	Methanethiol	Methanethiol	74–93–1	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U154	Methanol	Methanol	67–56–1	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
		Methanol, alternate[6] set of standards for both wastewaters and nonwastewaters.	67–56–1	5.6	0.75 mg/l TCLP
U155	Methapyrilene	Methapyrilene	91–80–5	0.081	1.5
U156	Methyl chlorocarbonate	Methyl chlorocarbonate	79–22–1	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U157	3-Methylcholanthrene	3-Methylcholanthrene	56–49–5	0.0055	15
U158	4,4'-Methylene bis(2-chloroaniline)	4,4'-Methylene bis(2-chloroaniline)	101–14–4	0.50	30
U159	Methyl ethyl ketone	Methyl ethyl ketone	78–93–3	0.28	36
U160	Methyl ethyl ketone peroxide	Methyl ethyl ketone peroxide	1338–23–4	CHOXD; CHRED; CARBN; BIODG; OR CMBST	CHOXD; CHRED; OR CMBST

U182	Paraldehyde	Paraldehyde	123–63–7	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U183	Pentachlorobenzene	Pentachlorobenzene	608–93–5	0.055	10
U184	Pentachloroethane	Pentachloroethane	76–01–7	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
		Pentachloroethane; alternate[6] standards for both wastewaters and nonwastewaters.	76–01–7	0.055	6.0
U185	Pentachloronitrobenzene	Pentachloronitrobenzene	82–68–8	0.055	4.8
U186	1,3-Pentadiene	1,3-Pentadiene	504–60–9	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U187	Phenacetin	Phenacetin	62–44–2	0.081	16
U188	Phenol	Phenol	108–95–2	0.039	6.2
U189	Phosphorus sulfide	Phosphorus sulfide	1314–80–3	CHOXD, CHRED, or CMBST	CHOXD, CHRED, or CMBST
U190	Phthalic anhydride (measured as Phthalic acid or Terephthalic acid).	Phthalic anhydride (measured as Phthalic acid or Terephthalic acid).	100–21–0	0.055	28
		Phthalic anhydride	85–44–9	0.055	28
U191	2-Picoline	2-Picoline	109–06–8	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U192	Pronamide	Pronamide	23950–58–5	0.093	1.5
U193	1,3-Propane sultone	1,3-Propane sultone	1120–71–4	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U194	n-Propylamine	n-Propylamine	107–10–8	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U196	Pyridine	Pyridine	110–86–1	0.014	16
U197	p-Benzoquinone	p-Benzoquinone	106–51–4	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U200	Reserpine	Reserpine	50–55–5	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U201	Resorcinol	Resorcinol	108–46–3	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U202	Saccharin and salts	Saccharin	81–07–2	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U203	Safrole	Safrole	94–59–7	0.081	22
U204	Selenium dioxide	Selenium	7782–49–2	0.82	0.16 mg/l TCLP
U205	Selenium sulfide	Selenium	7782–49–2	0.82	0.16 mg/l TCLP

U235	tris-(2,3-Dibromoprophyl)-phosphate	tris-(2,3-Dibromoprophyl)-phosphate.	126–72–7	0.11	0.10
U236	Trypan Blue	Trypan Blue	72–57–1	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U237	Uracil mustard	Uracil mustard	66–75–1	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U238	Urethane (Ethyl carbamate)	Urethane (Ethyl carbamate)	51–79–6	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U239	Xylenes	Xylenes-mixed isomers (sum of o-, m-, and p-xylene concentrations).	1330–20–7	0.32	30
U240	2,4-D (2,4-Dichlorophenoxyacetic acid)	2,4–D (2,4-Dichlorophenoxyacetic acid).	94–75–7	0.72	10
	2,4-D (2,4-Dichlorophenoxyacetic acid) salts and esters.		NA	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U243	Hexachloropropylene	Hexachloropropylene	1888–71–7	0.035	30
U244	Thiram	Thiram	137–26–8	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U246	Cyanogen bromide	Cyanogen bromide	506–68–3	CHOXD; WETOX; or CMBST	CHOXD, WETOX; or CMBST
U247	Methoxychlor	Methoxychlor	72–43–5	0.25	0.18
U248	Warfarin, & salts, when present at concentrations of 0.3% or less.	Warfarin	81–81–2	(WETOX or CHOXD) fb CARBN; or CMBST	CMBST
U249	Zinc phosphide, Zn_3P_2, when present at concentrations of 10% or less.	Zinc Phosphide	1314–84–7	CHOXD; CHRED; or CMBST	CHOXD; CHRED; or CMBST
U271	Benomyl	Benomyl	17804–35–2	0.056	1.4
U277	Sulfallate	Sulfallate	95–06–7	0.056	1.4
U279	Carbaryl	Carbaryl	63–25–2	0.006	0.14
U280	Barban	Barban	101–27–9	0.056	1.4
U328	o-Toluidine	o-Toluidine	95–53–4	CMBST; or CHOXD fb (BIODG or CARBN); or BIODG fb CARBN.	CMBST
U353	p-Toluidine	p-Toluidine	106–49–0	CMBST; or CHOXD fb (BIODG or CARBN); or BIODG fb CARBN.	CMBST
U359	2-Ethoxyethanol	2-Ethoxyethanol	110–80–5	CMBST; or CHOXD fb (BIODG or CARBN); or BIODG fb CARBN	CMBST

U399	Dithiocarbamates (total)	Dithiocarbamates (total)	NA	0.028	28
	Nickel	Nickel	7440–02–0	3.98	5.0 mg/l TCLP
U400	Dithiocarbamates (total)	Dithiocarbamates (total)	NA	0.028	28
U401	Dithiocarbamates (total)	Dithiocarbamates (total)	NA	0.028	28
U402	Dithiocarbamates (total)	Dithiocarbamates (total)	NA	0.028	28
U403	Dithiocarbamates (total)	Dithiocarbamates (total)	NA	0.028	28
U404	Triethylamine	Triethylamine	121–44–8	0.081	1.5
U405	Dithiocarbamates (total)	Dithiocarbamates (total)	NA	0.028	28
U406	Dithiocarbamates (total)	Dithiocarbamates (total)	NA	0.028	28
U407	Dithiocarbamates (total)	Dithiocarbamates (total)	NA	0.028	28
U408	2,4,6-Tribromophenol	2,4,6-Tribromophenol	118–79–6	0.035	7.4

Notes to Table:

[1] The waste descriptions provided in this table do not replace waste descriptions in 40 CFR part 261. Descriptions of Treatment/Regulatory Subcategories are provided, as needed, to distinguish betweenapplicability of different standards.

[2] CAS means Chemical Abstract Services. When the waste code and/or regulated constituents are described as a combination of a chemical with it's salts and/or esters, the CAS number is given for the parent compound only.

[3] Concentration standards for wastewaters are expressed in mg/l and are based on analysis of composite samples.

[4] All treatment standards expressed as a Technology Code or combination of Technology Codes are explained in detail in 40 CFR 268.42 Table 1—Technology Codes and Descriptions of Technology-Based Standards.

[5] Except for Metals (EP or TCLP) and Cyanides (Total and Amenable) the nonwastewater treatment standards expressed as a concentration were established, in part, based upon incineration in units operated in accordance with the technical requirements of 40 CFR Part 264, Subpart O, or Part 265, Subpart O, or based upon combustion in fuel substitution units operating in accordance with applicable technical requirements. A facility may comply with these treatment standards according to provisions in 40 CFR 268.40(d). All concentration standards for nonwastewaters are based on analysis of grab samples.

[6] Where an alternate treatment standard or set of alternate standards has been indicated, a facility may comply with this alternate standard, but only for the Treatment/Regulatory Subcategory or physical form (i.e., wastewater and/or nonwastewater) specified for that alternate standard.

[7] Both Cyanides (Total) and Cyanides (Amenable) for nonwastewaters are to be analyzed using Method 9010 or 9012, found in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods", EPA Publication SW–846, as incorporated by reference in 40 CFR 260.11, with a sample size of 10 grams and a distillation time of one hour and 15 minutes.

[8] As an alternative to these standards, the underlying hazardous constituents in the waste must meet a CWA limitation, which can include a toxic pollutant indicator for the constituent; Pretreatment Standards for Existing Sources; Pretreatment Standards for New Sources; local limitations based upon a pass-through determination; or a Fundamentally Different Factors variance under 40 CFR 125.30–125.32.

UNIVERSAL TREATMENT STANDARDS—Continued

[Note: NA means not applicable.]

Regulated constituent/common name	CAS[1] number	Wastewater standard	Nonwastewater standard
		Concentration in mg/l[2]	Concentration in mg/kg[3] unless noted as "mg/l TCLP"
alpha-BHC	319–84–6	0.00014	0.066
beta-BHC	319–85–7	0.00014	0.066
delta-BHC	319–86–8	0.023	0.066
gamma-BHC	58–89–9	0.0017	0.066
Bromodichloromethane	75–27–4	0.35	15
Bromomethane/Methyl bromide	74–83–9	0.11	15
4-Bromophenyl phenyl ether	101–55–3	0.055	15
n-Butyl alcohol	71–36–3	5.6	2.6
Butyl benzyl phthalate	85–68–7	0.017	28
Butylate	2008–41–5	0.003	1.4
2-sec-Butyl-4,6-dinitrophenol/Dinoseb	88–85–7	0.066	2.5
Carbaryl	63–25–2	0.006	0.14
Carbenzadim	10605–21–7	0.056	1.4
Carbofuran	1563–66–2	0.006	0.14
Carbofuran phenol	1563–38–8	0.056	1.4
Carbon disulfide	75–15–0	3.8	4.8 mg/l TCLP
Carbon tetrachloride	56–23–5	0.057	6.0
Carbosulfan	55285–14–8	0.028	1.4
Chlordane (alpha and gamma isomers)	57–74–9	0.0033	0.26
p-Chloroaniline	106–47–8	0.46	16
Chlorobenzene	108–90–7	0.057	6.0
Chlorobenzilate	510–15–6	0.10	NA
2-Chloro-1,3-butadiene	126–99–8	0.057	0.28
Chlorodibromomethane	124–48–1	0.057	15
Chloroethane	75–00–3	0.27	6.0
bis(2-Chloroethoxy)methane	111–91–1	0.036	7.2
bis(2-Chloroethyl)ether	111–44–4	0.033	6.0
2-Chloroethyl vinyl ether	110–75–8	0.062	NA
Chloroform	67–66–3	0.046	6.0
bis(2-Chloroisopropyl)ether	39638–32–9	0.055	7.2
p-Chloro-m-cresol	59–50–7	0.018	14
Chloromethane/Methyl chloride	74–87–3	0.19	30
2-Chloronaphthalene	91–58–7	0.055	5.6
2-Chlorophenol	95–57–8	0.044	5.7
3-Chloropropylene	107–05–1	0.036	30
Chrysene	218–01–9	0.059	3.4
o-Cresol	95–48–7	0.11	5.6
m-Cresol (difficult to distinguish from p-cresol)	108–39–4	0.77	5.6
p-Cresol (difficult to distinguish from m-cresol)	106–44–5	0.77	5.6
m-Cumenyl methylcarbamate	64–00–6	0.056	1.4
Cycloate	1134–23–2	0.003	1.4
Cyclohexanone	108–94–1	0.36	0.75 mg/l TCLP
o,p'-DDD	53–19–0	0.023	0.087
p,p'-DDD	72–54–8	0.023	0.087
o,p'-DDE	3424–82–6	0.031	0.087
p,p'-DDE	72–55–9	0.031	0.087
o,p'-DDT	789–02–6	0.0039	0.087
p,p'-DDT	50–29–3	0.0039	0.087
Dibenz(a,h)anthracene	53–70–3	0.055	8.2
Dibenz(a,e)pyrene	192–65–4	0.061	NA
1,2-Dibromo-3-chloropropane	96–12–8	0.11	15
1,2-Dibromoethane/Ethylene dibromide	106–93–4	0.028	15
Dibromomethane	74–95–3	0.11	15
m-Dichlorobenzene	541–73–1	0.036	6.0
o-Dichlorobenzene	95–50–1	0.088	6.0
p-Dichlorobenzene	106–46–7	0.090	6.0
Dichlorodifluoromethane	75–71–8	0.23	7.2
1,1-Dichloroethane	75–34–3	0.059	6.0
1,2-Dichloroethane	107–06–2	0.21	6.0
1,1-Dichloroethylene	75–35–4	0.025	6.0
trans-1,2-Dichloroethylene	156–60–5	0.054	30
2,4-Dichlorophenol	120–83–2	0.044	14
2,6-Dichlorophenol	87–65–0	0.044	14
2,4-Dichlorophenoxyacetic acid/2,4-D	94–75–7	0.72	10
1,2-Dichloropropane	78–87–5	0.85	18

UNIVERSAL TREATMENT STANDARDS—Continued

[Note: NA means not applicable.]

Regulated constituent/common name	CAS[1] number	Wastewater standard	Nonwastewater standard
		Concentration in mg/l[2]	Concentration in mg/kg[3] unless noted as "mg/l TCLP"
Methyl isobutyl ketone	108–10–1	0.14	33
Methyl methacrylate	80–62–6	0.14	160
Methyl methansulfonate	66–27–3	0.018	NA
Methyl parathion	298–00–0	0.014	4.6
3-Methylchlolanthrene	56–49–5	0.0055	15
4,4-Methylene bis(2-chloroaniline	101–14–4	0.50	30
Methylene chloride	75–09–2	0.089	30
Metolcarb	1129–41–5	0.056	1.4
Mexacarbate	315–18–4	0.056	1.4
Molinate	2212–67–1	0.003	1.4
Naphthalene	91–20–3	0.059	5.6
2-Naphthylamine	91–59–8	0.52	NA
o-Nitroaniline	88–74–4	0.27	14
p-Nitroaniline	100–01–6	0.028	28
Nitrobenzene	98–95–3	0.068	14
5-Nitro-o-toluidine	99–55–8	0.32	28
o-Nitrophenol	88–75–5	0.028	13
p-Nitrophenol	100–02–7	0.12	29
N-Nitrosodiethylamine	55–18–5	0.40	28
N-Nitrosodimethylamine	62–75–9	0.40	2.3
N-Nitroso-di-n-butylamine	924–16–3	0.40	17
N-Nitrosomethylethylamine	10595–95–6	0.40	2.3
N-Nitrosomorpholine	59–89–2	0.40	2.3
N-Nitrosopiperidine	100–75–4	0.013	35
N-Nitrosopyrrolidine	930–55–2	0.013	35
Oxamyl	23135–22–0	0.056	0.28
Parathion	56–38–2	0.014	4.6
Total PCBs (sum of all PCB isomers, or all Aroclors)	1336–36–3	0.10	10
Pebulate	1114–71–2	0.003	1.4
Pentachlorobenzene	608–93–5	0.055	10
PeCDDs (All Pentachlorodibenzo-p-dioxins)	NA	0.000063	0.001
PeCDFs (All Pentachlorodibenzofurans)	NA	0.000035	0.001
Pentachloroethane	76–01–7	0.055	6.0
Pentachloronitrobenzene	82–68–8	0.055	4.8
Pentachlorophenol	87–86–5	0.089	7.4
Phenacetin	62–44–2	0.081	16
Phenanthrene	85–01–8	0.059	5.6
Phenol	108–95–2	0.039	6.2
o-Phenylenediamine	95–54–5	0.056	5.6
Phorate	298–02–2	0.021	4.6
Phthalic acid	100–21–0	0.055	28
Phthalic anhydride	85–44–9	0.055	28
Physostigmine	57–47–6	0.056	1.4
Physostigmine salicylate	57–64–7	0.056	1.4
Promecarb	2631–37–0	0.056	1.4
Pronamide	23950–58–5	0.093	1.5
Propham	122–42–9	0.056	1.4
Propoxur	114–26–1	0.056	1.4
Prosulfocarb	52888–80–9	0.003	1.4
Pyrene	129–00–0	0.067	8.2
Pyridine	110–86–1	0.014	16
Safrole	94–59–7	0.081	22
Silvex/2,4,5-TP	93–72–1	0.72	7.9
1,2,4,5-Tetrachlorobenzene	95–94–3	0.055	14
TCDDs (All Tetrachlorodibenzo-p-dioxins)	NA	0.000063	0.001
TCDFs (All Tetrachlorodibenzofurans)	NA	0.000063	0.001
1,1,1,2-Tetrachloroethane	630–20–6	0.057	6.0
1,1,2,2-Tetrachloroethane	79–34–5	0.057	6.0
Tetrachloroethylene	127–18–4	0.056	6.0
2,3,4,6-Tetrachlorophenol	58–90–2	0.030	7.4
Thiodicarb	59669–26–0	0.019	1.4
Thiophanate-methyl	23564–05–8	0.056	1.4
Tirpate	26419–73–8	0.056	0.28
Toluene	108–88–3	0.080	10
Toxaphene	8001–35–2	0.0095	2.6

APPENDIX XI TO PART 268—METAL BEARING WASTES PROHIBITED FROM DILUTION IN A COMBUSTION UNIT ACCORDING TO 40 CFR 268.3(C) [1]—Continued

Waste code	Waste description
F006	Wastewater treatment sludges from electroplating operations except from the following processes: (1) sulfuric acid anodizing of aluminum; (2) tin plating carbon steel; (3) zinc plating (segregated basis) on carbon steel; (4) aluminum or zinc-plating on carbon steel; (5) cleaning/stripping associated with tin, zinc and aluminum plating on carbon steel; and (6) chemical etching and milling of aluminum.
F007	Spent cyanide plating bath solutions from electroplating operations.
F008	Plating bath residues from the bottom of plating baths from electroplating operations where cyanides are used in the process.
F009	Spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process.
F010	Quenching bath residues from oil baths from metal treating operations where cyanides are used in the process.
F011	Spent cyanide solutions from salt bath pot cleaning from metal heat treating operations.
F012	Quenching waste water treatment sludges from metal heat treating operations where cyanides are used in the process.
F019	Wastewater treatment sludges from the chemical conversion coating of aluminum except from zirconium phosphating in aluminum car washing when such phosphating is an exclusive conversion coating process.
K002	Wastewater treatment sludge from the production of chrome yellow and orange pigments.
K003	Wastewater treatment sludge from the production of molybdate orange pigments.
K004	Wastewater treatment sludge from the production of zinc yellow pigments.
K005	Wastewater treatment sludge from the production of chrome green pigments.
K006	Wastewater treatment sludge from the production of chrome oxide green pigments (anhydrous and hydrated).
K007	Wastewater treatment sludge from the production of iron blue pigments.
K008	Oven residue from the production of chrome oxide green pigments.
K061	Emission control dust/sludge from the primary production of steel in electric furnaces.
K069	Emission control dust/sludge from secondary lead smelting.
K071	Brine purification muds from the mercury cell processes in chlorine production, where separately prepurified brine is not used.
K100	Waste leaching solution from acid leaching of emission control dust/sludge from secondary lead smelting.
K106	Sludges from the mercury cell processes for making chlorine.
P010	Arsenic acid H_3AsO_4
P011	Arsenic oxide As_2O_5
P012	Arsenic trioxide
P013	Barium cyanide
P015	Beryllium
P029	Copper cyanide Cu(CN)
P074	Nickel cyanide $Ni(CN)_2$
P087	Osmium tetroxide
P099	Potassium silver cyanide
P104	Silver cyanide
P113	Thallic oxide
P114	Thallium (I) selenite
P115	Thallium (I) sulfate
P119	Ammonium vanadate
P120	Vanadium oxide V_2O_5
P121	Zinc cyanide.
U032	Calcium chromate.
U145	Lead phosphate.
U151	Mercury.
U204	Selenious acid.
U205	Selenium disulfide.
U216	Thallium (I) chloride.
U217	Thallium (I) nitrate.

[1] A combustion unit is defined as any thermal technology subject to 40 CFR part 264, subpart O; Part 265, subpart O; and/or 266, subpart H.

PART 271—REQUIREMENTS FOR AUTHORIZATION OF STATE HAZARDOUS WASTE PROGRAMS

21. The authority citation for part 271 continues to read as follows:

Authority: 42 U.S.C. 6905, 6912(a) and 6926.

Subpart A—Requirements for Final Authorization

22. Section 271.1(j) is amended by adding the following entries to Table 1 in chronological order by date of publication in the Federal Register, and by adding the following entries to Table 2 in chronological order by effective date in the Federal Register to read as follows:

§ 271.1 Purpose and scope.

* * * * *

(j) * * *

APPENDIX B

PROCESS DIAGRAMS AND DESCRIPTION

TABLE OF CONTENTS

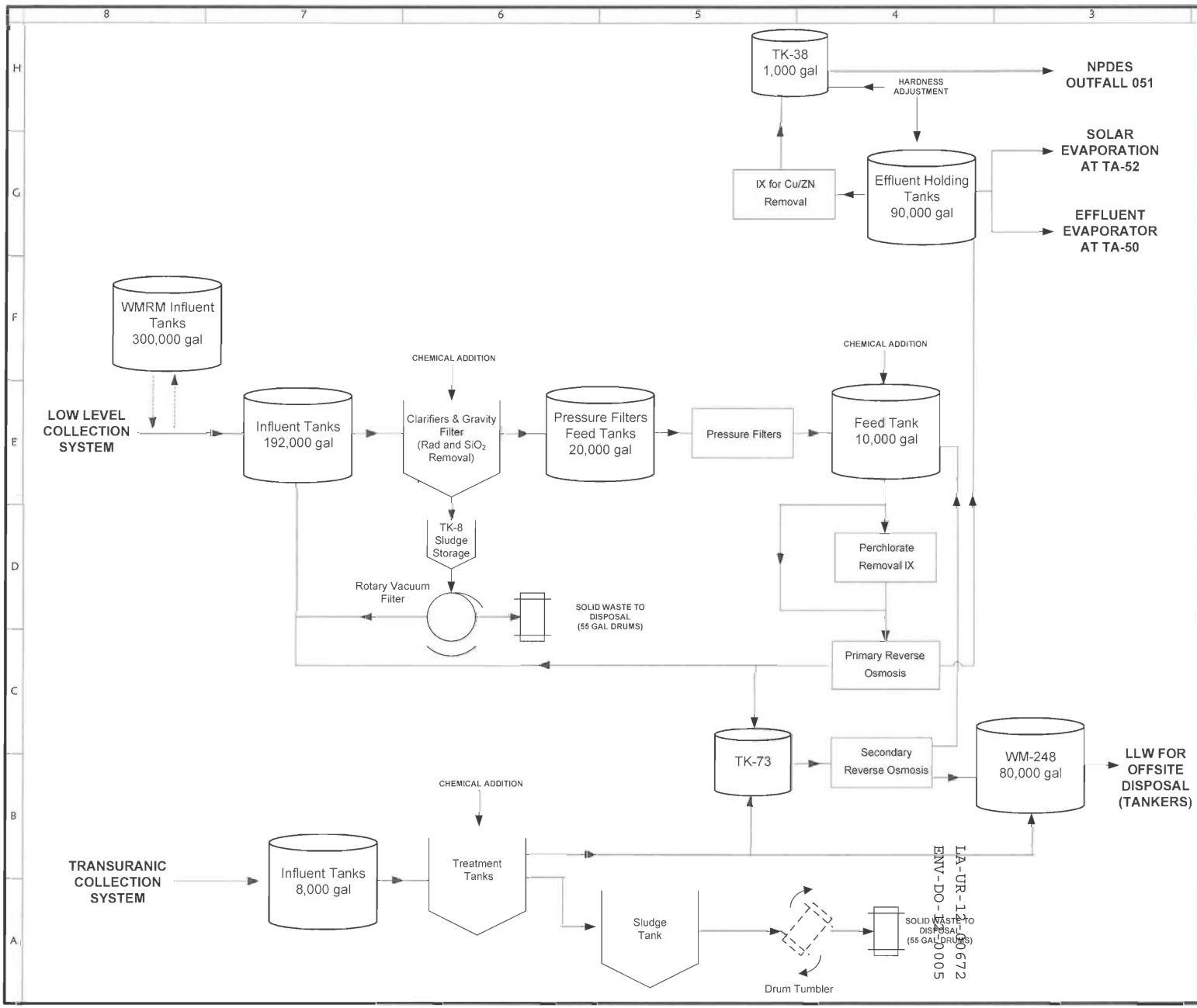
1. PROCESS SCHEMATIC – RLW-SD-PFD-001

2. RLWTF TREATMENT UNITS – SCALED FLOOR PLAN

3. TA-50 RLWTF UNITS AND PROCESSES

PROCESS SCHEMATIC

RLW-SD-PFD-001



General Notes

NOTES:

THIS PROCESS SCHEMATIC DEPICTS TYPICAL FLOW PATHS WHEN TREATING WATER AT THE TA50 RLWTF. ACTUAL TREATMENT MAY VARY DEPENDING UPON WATER QUALITY. FOR EXAMPLE, WATER FROM THE CLARIFIER MAY BE SENT TO EITHER THE GRAVITY FILTER OR THE PRESSURE FILTERS, THUS BYPASSING A SET OF FILTERS. OR PERMEATE FROM THE SECONDARY RO UNIT MAY BE SENT TO EFFLUENT HOLDING TANKS RATHER THAN TO THE PERCHLORATE FEED TANK.

No.	Date	Class Rev	ADC	Description	DFT	CHK	CSE SME	APP
3								
2	01/11/2012	2	U	CHANGES FROM DISCHARGE PERMIT MTNG	JCR	JCDS	RLS	RLS
1	10/31/2011	1	U	CHANGES FROM WQH – RLW MTNG	JCR	JCDS	RLS	RLS

ENGINEERING STANDARDS PROGRAM

Radioactive Liquid Waste Treatment Facility (RLWTF)

PROCESS SCHEMATIC
NPDES OUTFALL 051

DRAFTER	J. Ruiznavarro
CHECKER	J.C Del Signore
CSE / SME	R. Swickley
Date	01/11/2012

SUBMITTED
RLWTF EM: R. Swickley

APPROVED FOR RELEASE
RLWTF DAR: R. Swickley

Los Alamos National Laboratory
Los Alamos, NM 87545

RLWTF-SD-PFD-001

1 OF 1

CLASSIFICATION: UNCLASSIFIED

ADC: JC Del Signore

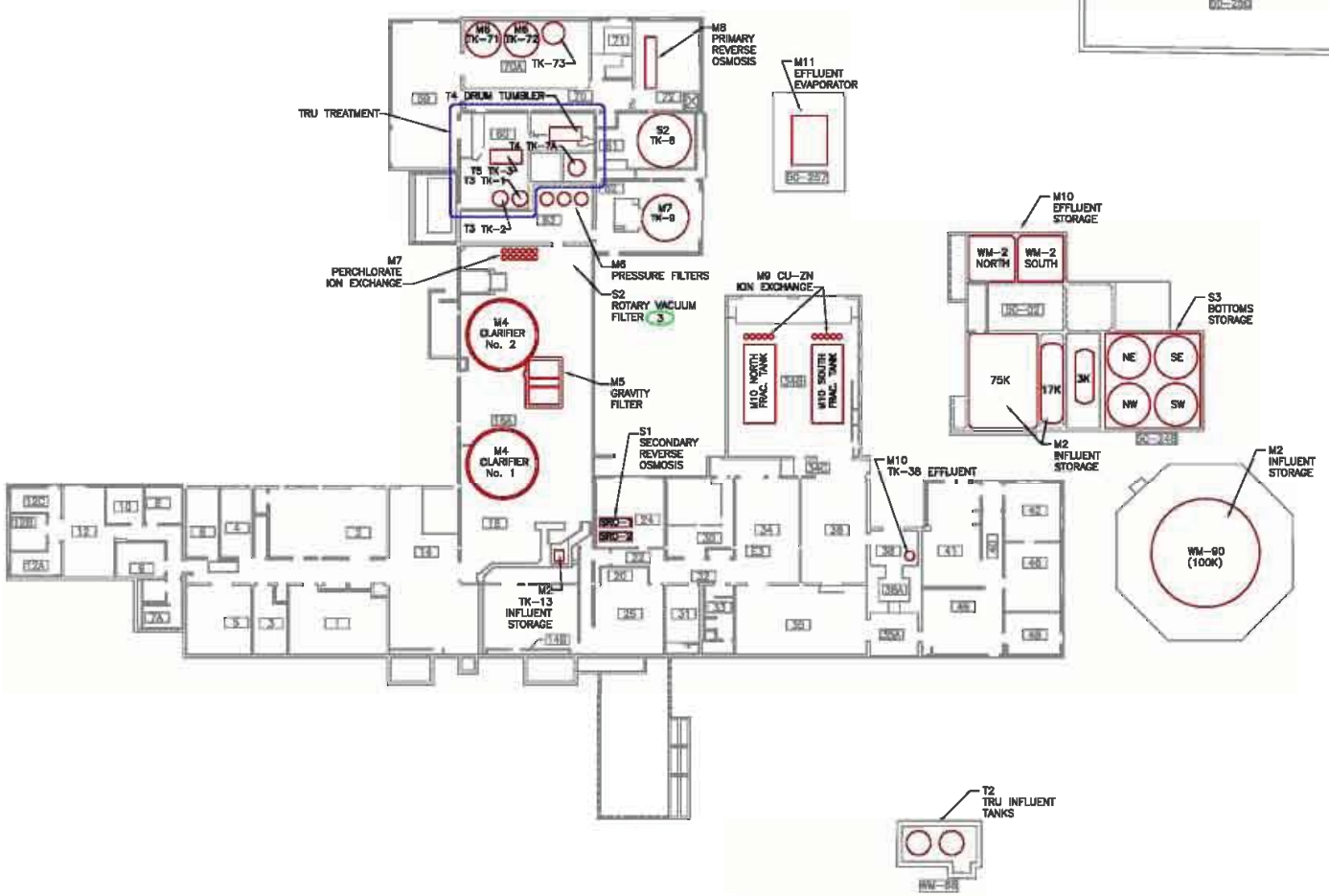
DATE: 1-12-12

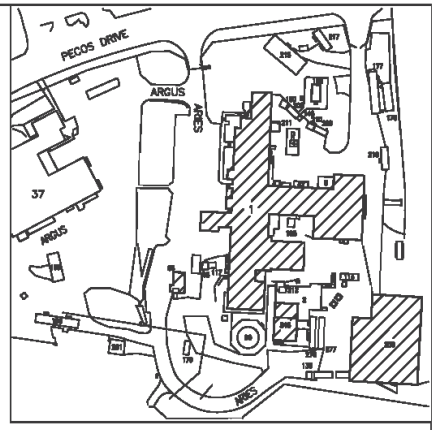
PROJECT ID: N/A

REV: 2

RLWTF TREATMENT UNITS

SCALED FLOOR PLAN





LOCATION PLAN
SCALE: NONE TA-50

GENERAL NOTES

1. IF THIS SHEET IS NOT 11X17, THEN IT IS A REDUCED OR ENLARGED SIZE PLOT. USE INDICATED SCALE ACCORDINGLY.

KEYED NOTES

1. SCALE APPLIES TO BUILDING STRUCTURES AND RELATIVE BUILDING LOCATIONS WITHIN THE SITE. DEPICTED SIZE OF TREATMENT UNITS AND STORAGE TANKS ARE FOR REFERENCE ONLY.
2. TREATMENT UNIT NOT SHOWN ON SKETCH.
3. ROTARY VACUUM FILTER LOCATED THIS AREA SOUTH-EAST CORNER RM. 116A

	RLWTF TREATMENT UNITS	
2	M1	COLLECTION SYSTEM
	M2	INFLUENT STORAGE
	M3	EMERGENCY INFLUENT STORAGE
	M4	CLARIFIERS
	M5	GRAVITY FILTER
	M6	PRESSURE FILTERS
	M7	PERCHLORATE ION EXCHANGE
	M8	PRIMARY REVERSE OSMOSIS
	M9	COPPER ZINC ION EXCHANGE
	M10	EFFLUENT STORAGE
	M11	EFFLUENT EVAPORATOR
2	M11	SOLAR EVAPORATOR AT TA52
2	M11	NPDES OUTFALL #051
2	T1	COLLECTION SYSTEM
	T2	INFLUENT STORAGE
	T3	TREATMENT
	T4	DRUM TUMBLER
	T5	EFFLUENT STORAGE
	S1	SECONDARY REVERSE OSMOSIS
3	S2	ROTARY VACUUM FILTER
	S3	BOTTOMS STORAGE

LA-UR-12-00672
ENV-DO-12-0005

TA-50 RLWTF UNITS AND PROCESSES

The Radioactive Liquid Waste Treatment Facility (RLWTF) consists of: (a) an underground collection system that conveys water to Technical Area (TA) 50 from generators at LANL, (b) structures at TA-50, and (c) the Zero Liquid Discharge Solar Evaporation Tanks at TA-52. At TA- 50, Building 50-01 is the primary structure; it houses treatment equipment, process tanks, analytical laboratories, and offices. Adjacent TA-50 structures primarily provide for additional water storage: 50-02 (influent), 50-66 (influent), 50-90 (influent), 50-248 (secondary waters), and 50-250 (emergency).

The RLWTF receives and treats radioactive liquid waste (RLW) from generators at Los Alamos National Laboratory. RLW includes small volumes, less than one percent of total influent, that are also characteristically hazardous for corrosivity, which are treated using elementary neutralization. The RLWTF has (1) a main treatment process for low-level RLW, (2) a process for treating transuranic RLW, and (3) a secondary treatment process for waste streams from both the low-level and transuranic processes. The units within each of these process lines are summarized in Table 1 and described in the paragraphs that follow. Table 2 provides additional information for each unit operation, including location, treatment and storage vessels, construction materials, and sizes.

Table 1: Summary of RLWTF Treatment Units

Unit Operation		Location
Main Treatment:		
M1	Collection System	TA-03, 35, 48, 50, 55, 59
M2	Influent Storage	50-02, 50-90
M3	Emergency Influent Storage	50-250
M4	Clarifiers	50-01
M5	Gravity Filter	50-01
M6	Pressure Filters	50-01
M7	Perchlorate Ion Exchange	50-01
M8	Primary Reverse Osmosis	50-01
M9	Polishing Ion Exchange	50-01
M10	Effluent Storage	50-01, 50-02
M11	Effluent Evaporator	50-257
M11	Zero Liquid Discharge Solar Evaporation Tanks	TA-52
M11	NPDES Outfall #051	Mortandad Canyon
Transuranic:		
T1	Collection System	TA-50, TA-55
T2	Influent Storage	50-66
T3	Treatment	50-01
T4	Drum Tumbling	50-01
T5	Effluent Storage	50-01
Secondary Treatment:		
S1	Secondary Reverse Osmosis	50-01
S2	Rotary Vacuum Filter	50-01
S3	Bottoms Disposal	50-248

MAIN TREATMENT PROCESS

The main treatment process consists of influent collection and storage, the treatment of low-level RLW, and the discharge of treated water to the environment. Treatment steps include clarification, filtration, ion exchange, and reverse osmosis. Discharge to the environment is via NPDES Outfall #051, solar evaporation at the TA-52 Zero Liquid Discharge (ZLD) Solar Evaporation Tanks, or mechanical evaporation at TA-50-257. Two secondary streams are generated by primary treatment, sludge and reverse osmosis concentrate; they are sent to the secondary treatment process.

M1. Radioactive Liquid Waste Collection System

The majority of RLW is transferred by direct pipeline between generator facilities and the RLWTF. The remaining RLW, typically less than 1,000 gallons per month, is transferred from small generators via truck. The pipeline system, installed in 1982, connects the TA-50 RLWTF to buildings in six TAs using approximately four miles of underground piping. Piping is essentially an underground pipeline within a pipeline. Primary piping is six- or eight-inch-diameter polyethylene encased within 10- or 12-inch polyethylene secondary piping. The primary piping transitions to stainless steel in each of the 62 underground valve stations (also referred to as vaults), then back to polyethylene. Underground vaults are equipped with leak detection sensors that are linked electronically to the RLWTF control room.

M2. Influent Storage

Influent flows from vault 50-72 through the neutralization tank (TK-13) in Room 16 of TA-50-01, and then beneath the RLWTF into the influent tanks at building 50-02. There are two influent tanks, an in-ground concrete vessel with a capacity of 75,000 gallons, and a 17,000-galllon steel vessel set within a below-grade concrete containment vault. Influent may also be stored in Structure 50-90, which is an above-ground steel vessel with secondary containment and a capacity of 100,000 gallons. Low-level influent may be subjected to pH adjustment and/or oxidation. Typically, sodium hydroxide (25% solution) is used to adjust the influent pH; chemicals such as sodium permanganate may be used for oxidation. These two steps may be carried out in the neutralization tank, or the chemicals may be added directly to the influent tanks.

M3. Emergency Influent Storage

Building 50-250, the Waste Management and Risk Mitigation (WMRM) facility, is located about 50 meters southeast of Building 50-01. WMRM houses six emergency influent storage tanks with a capacity of 50,000 gallons each. Low-level influent can be shunted to these fiberglass tanks at vault 50-72, upstream

of the 17K and 75K influent storage tanks. WMRM is a steel frame structure designed to withstand seismic, wind, and snow load criteria. The concrete basement houses the six storage tanks, and acts as secondary containment. Tanks would receive influent by gravity flow from WM-72.

M4. Clarifiers

The clarifier acts as the workhorse of the Main Treatment Plant, removing insoluble constituents, including more than 90% of the radioactivity. There are two concrete clarifiers. Each is 20 feet in diameter with a working volume of about 20,000 gallons, and each is designed to operate at 120 gallons per minute. Influent and chemicals enter from above through a flash mixer into a center well. (Chemicals such as ferric sulfate and magnesium sulfate are added at the clarifier, to promote particle growth and to adjust pH.) Contaminants precipitate as sludge, which settles to the bottom of the clarifier. Treated waters flow to the bottom of the center well, rise in the outer portion of the clarifier, and overflow to the gravity filter. Sludge is periodically removed to TK8 for subsequent treatment in the rotary vacuum filter.

M5. Gravity Filter

The dual media gravity filter is used to remove suspended solids in overflow water from the clarifier. The gravity filter contains two filtration cells of 45 square feet each. The filter bed consists of layers of anthracite, sand, and gravel resting on an underdrain grate. Water flows by gravity into the top and exits at the bottom of the bed. Backwashing is needed periodically to remove solids and to reconstitute the bed. When properly maintained and operated, the gravity filter removes particles down to 10 microns in size. The gravity filter is sized to process up to 250 gallons of water per minute.

M6. Pressure Filters

Three pressure media filters, which operate in parallel or singly, can be used to remove suspended solids in water from either the clarifier or the gravity filter. Water is pumped from two feed tanks, TK71 and TK72, through the media in an enclosed steel vessel at a pressure of about 30 psig. Feed tanks are above-grade, carbon-steel vessels, ~10,000 gallons each. Pressure filters are 30 inches in diameter and ~five feet high, and are constructed of carbon steel lined with plasite (an epoxy). The media in the pressure filter consists of coarse and fine sized particles of sand, garnet, coal, and gravel. Backwashing is needed periodically to remove solids and to reconstitute the bed. Each filter can process up to 50 gallons per minute.

M7. Perchlorate Ion Exchange

Ion-exchange columns located in Room 16 are used to remove perchlorates. Six of the 12 fiberglass reinforced plastic (FRP) ion exchange vessels are typically in service. Vessels range in size to nine cubic feet of ion exchange resin, and can treat up to 60 gallons of water per minute. The columns are installed downstream of TK9, and prior to treatment by the Reverse Osmosis. TK9 is a 9000-gallon, carbon-steel, above-grade vessel located in Room 61. Resins are not re-generated. Instead, columns are drained of water, then disposed as solid radioactive waste.

M8. Primary Reverse Osmosis

The Reverse Osmosis unit removes soluble contaminants, and produces a high quality effluent that approaches and sometimes meets EPA primary drinking water standards. The Reverse Osmosis unit uses commercially available high-rejection membranes, typically rated at nominal NaCl rejection of 90-99%. The unit has three 8-inch-diameter pressure vessels, and operates at pressures of about 400 psig. Each pressure vessel contains four membranes in series; each membrane is 40 inches in length. The Reverse Osmosis is a two-stage membrane unit; the third pressure vessel receives reject from the first two. Feed may first be pH-adjusted at the perchlorate ion exchange feed tank, TK-9. Permeate is sent to storage tanks in Room 34B; concentrate is either recycled to the 75K influent storage tank, or is processed through the secondary Reverse Osmosis unit. The primary Reverse Osmosis has a capacity up to 60 gallons per minute.

M9. Copper-Zinc Ion Exchange

NPDES Permit effluent limits for the discharge of treated water to NPDES Outfall #051 in Mortandad Canyon became more restrictive on 08-01-2010. As a result of acute aquatic life water quality standards being applied to ephemeral streams, discharge limits for copper and zinc were decreased to levels more than 2,000 times lower than EPA's secondary drinking water standards. In order to meet these new effluent limits, an ion exchange system was installed to polish permeate from the primary Reverse Osmosis unit. The system consists of two banks; each bank has five 3.5-cubic foot fiberglass. The ion exchange system draws water from one of the Frac tanks that holds Reverse Osmosis permeate, pumps the water through one, or if needed, both ion exchange banks, and then into TK38. Resins are not re-generated. Instead, columns are drained of water, then disposed as solid radioactive waste.

M10. Effluent Storage

Five tanks are available for the storage of treated water. Two Frac tanks (north tank and south tank) receive permeate from the primary reverse osmosis unit. Frac tanks are horizontal carbon steel tanks located in Room 34B; each has a capacity of ~20,000 gallons. Water that receives post-Reverse Osmosis treatment (i.e., copper-zinc ion exchange) is collected in a 1000-gallon tank, TK38 in Room 38, constructed of high-density polyethylene. Two additional storage tanks (WM2-N and WM2-S) are located in Building 50-02. These are below-grade concrete tanks with a nominal capacity of 25,000 gallons each.

M11. Discharge of Treated Water to the Environment

11a. Discharge Via Mechanical Evaporation at TA-50-257

Treated water may be discharged to the environment via a thermal evaporator located outside Room 34 of Building 50-01. Water is heated using natural gas in a 4.5 million Btu/hr low NOx gas burner that can evaporate up to 400 gallons of water per hour. The unit is constructed of stainless steel, and has received a No Permit Required Determination from the NMED Air Quality Bureau.

11b. Discharge Via Zero Liquid Discharge Solar Evaporation Tanks at TA52

Zero-Liquid-Discharge Solar Evaporation Tanks for solar evaporation of treated water are currently being constructed. The tanks are located on a site of approximately one acre, about two-thirds of a mile from the TA-50 RLWTF within TA-52 at LANL. The Zero Liquid Discharge Solar Evaporation Tanks have concrete walls approximately four feet high, and have a double liner with leak detection; each is approximately 70’ x 250’ in size, with a usable capacity of about 380,000 gallons. The pump house has the capability of returning the contents of the tanks to the TA-50 RLWTF for storage and retreatment, if necessary. Approximately 3500 feet of high-density polyethylene (HDPE) transfer piping connect the Zero Liquid Discharge Solar Evaporation Tanks and the TA-50 RLWTF.

11c. Discharge Via NPDES Outfall #051

Treated water that meets NPDES and DOE discharge standards can be discharged to the environment via NPDES Permitted Outfall #051 in Mortandad Canyon. Water is pumped to the outfall through approximately 1400 feet of three-inch-diameter, carbon steel pipe. NPDES samples are collected at TA-50 while water is discharging to the canyon.

TRANSURANIC TREATMENT PROCESS

Transuranic RLW treatment consists of influent collection and storage, treatment of the transuranic RLW, and sludge treatment. Treated water is not discharged; it either receives additional treatment (secondary reverse osmosis) or is sent to storage tanks in Building 50-248 for disposition as bottoms. Sludge from the treatment process is concentrated, solidified with cement, and shipped to the Waste Isolation Pilot Plant as a solid transuranic waste.

T1. Transuranic Collection System

The transuranic collection system runs from Building 55-04 through below-grade, double-contained transfer lines, through a valve pit and vault at 50-201, and into influent storage tanks at Building 50-66. One transfer line is dedicated for acid waste, and a second for caustic waste. Both are two-inch-diameter pipes. The acid waste lines are constructed of polyvinylidene fluoride (PVDF); the caustic lines are constructed of polypropylene (PP).

TRU wastewater is not freely drained to the RLWTF. Instead, TA55 and RLWTF personnel coordinate batch wastewater transfers in advance. Once a transfer is coordinated, a batch of known volume, typically less than 100 gallons, is discharged through the system by gravity to the TRU influent storage tanks in Building 50-66. Transuranic influent is not trucked.

T2. Transuranic Influent Storage

Two influent storage tanks are located in Building 50-66, one for acid waste (~3900 gallons) and the other for caustic waste (~3000 gallons). Each tank has enough capacity to hold more than two years of transuranic influent. Both tanks are cylindrical, cone-bottomed tanks, and each has a mixer, a HEPA-filtered vent. The sump in Building 50-66 has a leak detector that is linked to the RLWTF control room.

T3. Transuranic Treatment

Acid waste is pumped from Building 50-66 into TK1 in Room 60. The acid waste is neutralized by mixing it with liquid sodium hydroxide (nominal 25%). Chemicals (ferric sulfate or polymer) may be added to promote particle growth. Solids that form in the neutralized waste settle, and are then pumped to the sludge tank, TK-7A. Clear liquid is pumped through a pressure filter into a receiving tank, TK3.

Caustic waste is pumped from Building 50-66 to Tank TK1 in Room 60, and then into the sludge-settling tank, TK-7A. The treated caustic waste is allowed to stand in the tank, which allows most of the solid particles to deposit on the bottom of the tank as sludge. In order to facilitate particle growth, TK-7A may be seeded with sludge left over from the previous treatment campaign. Chemicals (lime, ferric sulfate, or polymer) may also be added to TK-7A for this purpose.

T4. Transuranic Sludge

Sludge collects in TK-7A, a 900-gallon carbon-steel tank in Room 60. Excess water is decanted from TK-7A, then transferred to the effluent storage tank, TK3. The sludge itself is added to cement and sodium silicate, then tumbled and allowed to cure. After curing, drums of cemented sludge are transported to TA-54 to await shipment to and disposal at the Waste Isolation Pilot Plant as a solid transuranic waste.

T5. Transuranic Effluent

Effluent from the transuranic treatment process is collected in TK3 in Room 60, a 1000-gallon, horizontal fiberglass tank. Having been treated, effluent is no longer transuranic waste. The effluent either receives additional treatment (secondary reverse osmosis) or is sent to storage tanks in Building 50-248 for disposition as bottoms.

SECONDARY TREATMENT PROCESSES

The secondary treatment process treats wastes from the primary and transuranic treatment lines. It consists of a rotary vacuum filter to treat sludge from main process, secondary reverse osmosis to treat reverse osmosis concentrate from the main process and/or effluent from the transuranic process, and a bottoms disposal step. Wastes from the secondary treatment process are disposed as low-level radioactive solid waste.

S1. Secondary Reverse Osmosis

These two Reverse Osmosis units, each with a capacity of up to five gallons per minute, recover much of the concentrate from the primary Reverse Osmosis unit, thereby reducing the volume of bottoms that must be disposed of. Effluent from the transuranic process may also be treated. Secondary Reverse Osmosis units use commercially available high-rejection membranes, typically rated at nominal NaCl rejection of 90-99%. The units have two 4-inch-diameter pressure vessels, and operate at pressures of about 300 psig. Each pressure vessel has a single membrane 40 inches in length. They are two-stage membrane units; the second pressure vessel receives reject from the first. Concentrate from the primary Reverse Osmosis unit is collected in TK73 (3700 gallons, lined steel), then fed to a smaller feed tank (300 gallons, polyethylene) in Room 24, adjacent to the secondary Reverse Osmosis units. Permeate is sent to the feed tank for the perchlorate ion exchange system (TK9), for re-treatment through the MTP. Reject is sent to storage tanks in Building 50-248 to await shipment as bottoms.

S2. Rotary Vacuum Filter

Solids that settle to the bottom of the MTP clarifier are separated from water and then disposed as low-level radioactive solid waste. This sludge treatment operation includes the TK8 storage tank (capacity of 8,000 gallons) in Room 61 and the rotary vacuum filter in Room 116. Low-level sludge contains more than 90% of the radioactivity present in low-level influent; it does not contain hazardous chemical constituents above RCRA limits, and is not a mixed waste.

S3. Bottoms Disposal

RLWTF bottoms are shipped to a commercial waste treatment facility using a commercial tanker truck; shipments typically range from 4,000 to 5,000 gallons each. The commercial waste treatment facility processes bottoms to a solid form, and disposes of the solids as low-level radioactive waste at a Department of Energy or commercial disposal site.

Table 2: Vessel Information for RLWTF Treatment Units

Unit Operation	Vessel	Capacity (gallons)	Material	Above (A) Below (B)	Secondary Containment	Note
Main Treatment:						
M1 Collection System	Piping	----	Polyethylene	B	Polyethylene	
	Vaults (62)	----	Concrete	B	----	x
M2 Influent Storage	TK13	400	Stainless Steel	B	Concrete	
	17K tank	17,000	Steel	B	Concrete	
	75K tank	75,000	Concrete	B	----	
	100K tank	100,000	Steel	A	Concrete	
M3 Emergency Influent Storage	WMRM tanks (6)	50,000	Fiberglass	B	Concrete	z
M4 Clarifiers	Clarifiers (2)	26,000	Concrete	A	Concrete	v, z
M5 Gravity Filter	Gravity Filter	7,000	Concrete	A	Concrete	v
M6 Pressure Filters	Filters (3)	100	Lined Steel	A	Concrete-w	z
	TK71, TK72	10,000	Steel	A	Concrete-w	z
M7 Perchlorate Ion Exchange	Ion Exchange Vessels(12)	50	Fiberglass	A	Concrete-w	z
	TK09	10,000	Steel	A	Concrete-w	
M8 Primary Reverse Osmosis	RO Vessel	40	Steel	A	Concrete-w	
M9 Polishing Ion Exchange	Ion Exchange Columns (10)	200	Fiberglass	A	Concrete-w	
M10 Effluent Storage	N. Frac, S. Frac	20,000	Steel	A	Concrete-w	z
	TK-38	1,000	HDPE	A	Concrete-w	
	WM2-N, WM2-S	25,000	Concrete	B	----	z
M11 Effluent Evaporator	----	1,200	Stainless Steel	A	Hypalon, Asphalt	
M11 Solar Evaporation at TA-52	E. Tank, W. Tank	380,000	HDPE	A	HDPE, Concrete	z
M12 NPDES Outfall #051	----	----	----	B	----	y

Notes:

v: Two concrete bottom slabs, with compacted tuff between.

w: Floor of Building 50-01, with floor drains, provides secondary containment.

x: Vaults provide secondary containment.

y: Pipe is below grade; the outfall is at the surface.

z: Capacity is for each vessel.

Table 2: Vessel Information for RLWTF Treatment Units (Continued)

Unit Operation	Vessel	Capacity (gallons)	Material	Above (A) Below (B)	Secondary Containment	Note
Transuranic:						
T1 Collection System	Piping	----	PVDF , PP	B	PVDF, PP	
T2 Influent Storage	Acid Tank	3,900	Steel	B	Concrete	
	Caustic Tank	3,000	Steel	B	Concrete	
T3 Treatment	TK1	900	Steel	A	Concrete-w	
	TK2	800	Fiberglass	A	Concrete-w	
T4 Drum Tumbling	TK-7A	900	Steel	A	Concrete-w	
T5 Effluent Storage	TK3	1,000	Fiberglass	A	Concrete-w	
Secondary Treatment:						
S1 Secondary Reverse Osmosis	RO Vessel	10	Fiberglass	A	Concrete-w	
	TK2401	300	Polyethylene	A	Concrete-w	
	TK73	3,700	Steel	A	Concrete-w	
S2 Rotary Vacuum Filter	Rotary Vacuum Filter	900	Stainless Steel	A	Concrete-w	
	TK8	8,000	Steel	A	Concrete-w	
S3 Bottoms Storage	TK-NE, SE, SW, NW	20,000	Steel	A	Concrete	z

Notes:

w: Floor of Building 50-01, with floor drains, provides secondary containment.

Z: Capacity is for each vessel.

APPENDIX C

NPDES OUTFALL #051

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1. NPDES Permit No. NM0028355, Outfall #051.

NPDES PERMIT No. NM0028355

OUTFALL #051

Region 6
1445 Ross Avenue
Dallas, Texas 75202-2733

NPDES Permit No. **NM0028355**

AUTHORIZATION TO DISCHARGE UNDER THE NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

In compliance with the provisions of the Clean Water Act, as amended, (33 U.S.C. 1251 et. seq; the "Act"),

Los Alamos National Security, LLC Management Contractor for Operations Los Alamos, New Mexico 87544	and	U.S. Department of Energy Los Alamos Area Office Los Alamos, New Mexico 87544

are authorized to discharge from a facility located at Los Alamos,

to receiving waters named: Perennial portion of Sandia Canyon in Waterbody Segment No. 20.6.4.126, and Mortandad Canyon, Canada del Buey, Los Alamos Canyon, ephemeral portion of Sandia Canyon, Ten Site Canyon, Canon de Valle, and Water Canyon, in Waterbody Segment No. 20.6.4.128 of the Rio Grande Basin,

in accordance with this cover page and the effluent limitations, monitoring requirements, and other conditions set forth in Parts I [Requirements for NPDES Permits - 36 pages], II [Other Conditions - 22 pages], III [Standard Conditions for NPDES Permits - 8 pages], and IV [Sewage Sludge Requirements - 18 pages] hereof.

This permit supersedes and replaces NPDES Permit No. NM0028355 issued December 29, 2000.

This permit shall become effective on August 1, 2007

This permit and the authorization to discharge shall expire at midnight, July 31, 2012

Issued on June 8, 2007

Prepared by

Miguel I. Flores
Director
Water Quality Protection Division (6WQ)

Isaac Chen
Environmental Engineer
NPDES Permits Branch (6WQ-P)

OUTFALL 051 - Radioactive Liquid Waste Treatment Facility (TA-50)
Discharge Type: Intermittent
Latitude 35E51'54"N, Longitude 106E17'52"W

During the period beginning the effective date of the permit and lasting through the expiration date of the permit (unless otherwise noted),

the permittee is authorized to discharge treated radioactive liquid waste to Mortandad Canyon in segment number 20.6.4.128 of the Rio Grande Basin.

Such discharges shall be limited and monitored by the permittee as specified below:

PARAMETERS/STORET CODES	DISCHARGE LIMITATIONS/REPORTING REQUIREMENTS			
	QUANTITY/LOADING (LBS/DAY UNLESS STATED)		QUALITY/CONCENTRATION (mg/L UNLESS STATED)	
	MONTHLY AVG	DAILY MAX	MONTHLY AVG	DAILY MAX
Flow STORET: 50050	Report	Report	****	****
Chemical Oxygen Demand STORET: 00340	****	****	125	125
Total Suspended Solids STORET: 00530	****	****	30	45
Total Toxic Organics (*1) STORET: 78141	****	****	1.0	1.0
Ra 226+228 STORET: 11503	****	****	30 pCi/l	30 pCi/l
Total Chromium STORET: 01034	****	****	1.34	2.68
Total Lead STORET: 01051	****	****	0.423	0.524
Total Cadmium (*2) STORET: 01027	****	****	Report	Report
Total Mercury (*2) STORET: 71900	****	****	Report	Report
Total Nickel (*2) STORET: 01067	****	****	Report	Report
Total Copper (*3) STORET: 01042	****	****	Report	Report

Total Copper (*3) STORET: 01042	****	****	0.14 ug/l	0.2 ug/l
Total Zinc (*3) STORET: 01092	****	****	Report	Report
Total Zinc (*3) STORET: 01092	****	****	2.2 ug/l	3.3 ug/l
Total Residual Chlorine (*4) STORET: 50060	****	****	****	0.011
Total Selenium STORET: 01147	****	****	Report	Report
Perchlorate STORET: 61209	****	****	Report	Report
pH (Standard Units) STORET: 00400	Ranges from 6.0 to 9.0			
Total PCBs STORET: 39516	****	****	Report	Report

PARAMETERS/STORET CODES	MONITORING REQUIREMENTS	
	FREQUENCY OF ANALYSIS	SAMPLE TYPE
Flow	Continuous	Record
Chemical Oxygen Demand	1/Month	Grab
Total Suspended Solids	1/Month	Grab
Total Toxic Organics	1/Month	Grab
Tritium	1/Year	Grab
Ra 226+228	1/Year	Grab
Total Chromium	1/Year	Grab
Total Lead	1/Year	Grab
Total Cadmium	1/Year	Grab
Total Mercury	1/Year	Grab
Total Nickel	1/Year	Grab
Total Copper	1/Month	Grab
Total Zinc	1/Month	Grab
Total Residual Chlorine	1/Week	Grab
Total Selenium	1/Year	Grab
Perchlorate	1/Year	Grab
Total PCBs	1/Year	Grab
pH (Standard Units)	1/Week	Grab

EFFLUENT CHARACTERISTIC	DISCHARGE MONITORING	
	30-Day Avg Min.	48-Hr. Min.

Whole Effluent Toxicity Testing (48 Hr. Static Renewal)		
Daphnia pulex	Report	Report

EFFLUENT CHARACTERISTIC	MONITORING REQUIREMENTS	
	Frequency	Type
Whole Effluent Toxicity Testing (48 Hr. Static Renewal)		
Daphnia pulex	1/3 Months (*5)	3-hr Composite

SAMPLING LOCATION(S) AND OTHER REQUIREMENTS

SAMPLING LOCATION(S)
Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): following the final treatment and prior to or at the point of discharge from TA-50-1 treatment plant (approximately at Latitude 35E51'54"N, Longitude 106E17'52"W)

NO DISCHARGE REPORTING
If there is no discharge event at this outfall during the sampling month, place an "X" in the NO DISCHARGE box located in the upper right corner of the preprinted Discharge Monitoring Report.

FLOATING SOLIDS, OIL AND GREASE
There shall be no discharge of oils, scum, grease and other floating materials that would cause the formation of a visible sheen or visible deposits on the bottom or shoreline, or would damage or impair the normal growth, function or reproduction of human, animal, plant or aquatic life.

FLOW MEASUREMENTS
"Estimate" flow measurements shall not be subject to the accuracy provisions established at Part III.C.6. The daily flow value may be estimated using best engineering judgment.

FOOTNOTES

*1 The limits and monitoring for Total Toxic Organics do not include 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD), Pesticides, or Polychlorinated biphenyls

*2 Annual sample shall be taken for five (5) years until the expiration date.

*3 During the period beginning the effective date of the permit and lasting through three (3) years from the effective date, the concentration of total copper and total zinc shall the reported in the DMRs. During the period beginning the three years from the effective date through the expiration date of the permit, the discharge must meet the effluent limitations.

*4 The effluent limitation for TRC is the instantaneous maximum and cannot be averaged for reporting purposes.

*5 Sampling frequency 1/3 Months for the 1st year of the permit. If the test passes, reduce the frequency to 1/6 Months for year 2 through year 5 of the permit. If any test fails, return frequency to 1/3 Months for remainder of the permit. Critical dilution 100%, and the dilution series are 32%, 42%, 56%, 75%, 100%. Also, see Part II, Section I. Whole Effluent Toxicity (48-hour Acute Testing).

Section B. Clean Water Act Requirements

Law: Federal Water Pollution Control Act (Clean Water Act)

As used in this part, the term "total toxic organics" (TTO) means the sum of the concentrations of each of the following toxic organic compounds found in the discharge at a concentration greater than ten (10) micrograms per liter:

- Acenaphthene
- Acrolein
- Acrylonitrile
- Benzene
- Benzidine
- Carbon tetrachloride (tetrachloromethane)
- Chlorobenzene
- 1,2,4-Trichlorobenzene
- Hexachlorobenzene
- 1,2-Dichloroethane
- 1,1,1-Trichloroethane
- Hexachloroethane
- 1,1-Dichloroethane
- 1,1,2-Trichloroethane
- 1,1,2,2-Tetrachlorophenol
- Chloroethane
- Bis (2-chloroethyl) ether
- 2-Chloroethyl vinyl ether (mixed)
- 2-Chloronaphthalene
- 2,4,6-Trichlorophenol
- Parachlorometa cresol
- Chloroform (trichloromethane)
- 2-Chlorophenol
- 1,2-Dichlorobenzene
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- 3,3-Dichlorobenzidine
- 1,1-Dichloroethylene
- 1,2-Trans-dichloroethylene
- 2,4-Dichlorophenol
- 1,2-Dichloropropane
- 1,3-Dichloropropylene (1,3-dichloropropene)
- 2,4-Dimethylphenol
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- 1,2-Diphenylhydrazine
- Ethyl benzene
- Fluoranthene
- 4-Chlorophenyl phenyl ether
- 4-Bromophenyl phenyl ether
- Bis (2-chloroisopropyl) ether

Section B. Clean Water Act Requirements

Law: Federal Water Pollution Control Act (Clean Water Act)

- Bis (2-chloroethoxy) methane
- Methylene chloride (dichloromethane)
- Methyl chloride (chloromethane)
- Methyl bromide (bromomethane)
- Bromoform (tribromomethane)
- Dichlorobromomethane
- Chlorodibromomethane
- Hexachlorobutadiene
- Hexachlorocyclopentadiene
- Isophorone
- Naphthalene
- Nitrobenzene
- 2-Nitrophenol
- 4-Nitrophenol
- 2,4-Dinitrophenol
- 4,6-Dinitro-o-cresol
- N-nitrosodimethylamine
- N-nitrosodiphenylamine
- N-nitrosodi-n-propylamine
- Pentachlorophenol
- Phenol
- Bis (2-ethylhexyl) phthalate
- Butyl Benzyl Phthalate
- Di-n-butyl phthalate
- Di-n-octyl phthalate
- Diethyl phthalate
- Dimethyl phthalate
- 1,2-Benzanthracene (benzo(a)anthracene)
- Benzo(a)pyrene (3,4-benzopyrene)
- 3,4-Benzofluoranthene (benzo(b)fluoranthene)
- 11,12-Benzofluoranthene (benzo(k)fluoranthene)
- Chrysene
- Acenaphthylene
- 1,12-Benzoperylene (benzo(ghi)perylene)
- Fluorene
- Phenanthrene
- 1,2,5,6-Dibenzanthracene (dibenzo(a,h)anthracene)
- Indeno(1,2,3-cd) pyrene (2,3-o-phenylene pyrene)
- Pyrene
- Tetrachloroethylene
- Toluene
- Trichloroethylene
- Vinyl chloride (chloroethylene)
- Aldrin
- Dieldrin

Section B. Clean Water Act Requirements

Law: Federal Water Pollution Control Act (Clean Water Act)

- Chlordane (technical mixture and metabolites)
- 4,4-DDT
- 4,4-DDE (p,p-DDX)
- 4,4-DDD (p,p-TDE)
- Alpha-endosulfan
- Beta-endosulfan
- Endosulfan sulfate
- Endrin
- Endrin aldehyde
- Heptachlor
- Heptachlor epoxide (BHC-hexachlorocyclohexane)
- Alpha-BHC
- Beta-BHC
- Gamma-BHC
- Delta-BHC (PCB-polychlorinated biphenyls)
- PCB-1242 (Arochlor 1242)
- PCB-1254 (Arochlor 1254)
- PCB-1221 (Arochlor 1221)
- PCB-1232 (Arochlor 1232)
- PCB-1248 (Arochlor 1248)
- PCB-1260 (Arochlor 1260)
- PCB-1016 (Arochlor 1016)
- Toxaphene
- 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)

APPENDIX D

GROUNDWATER QUALITY

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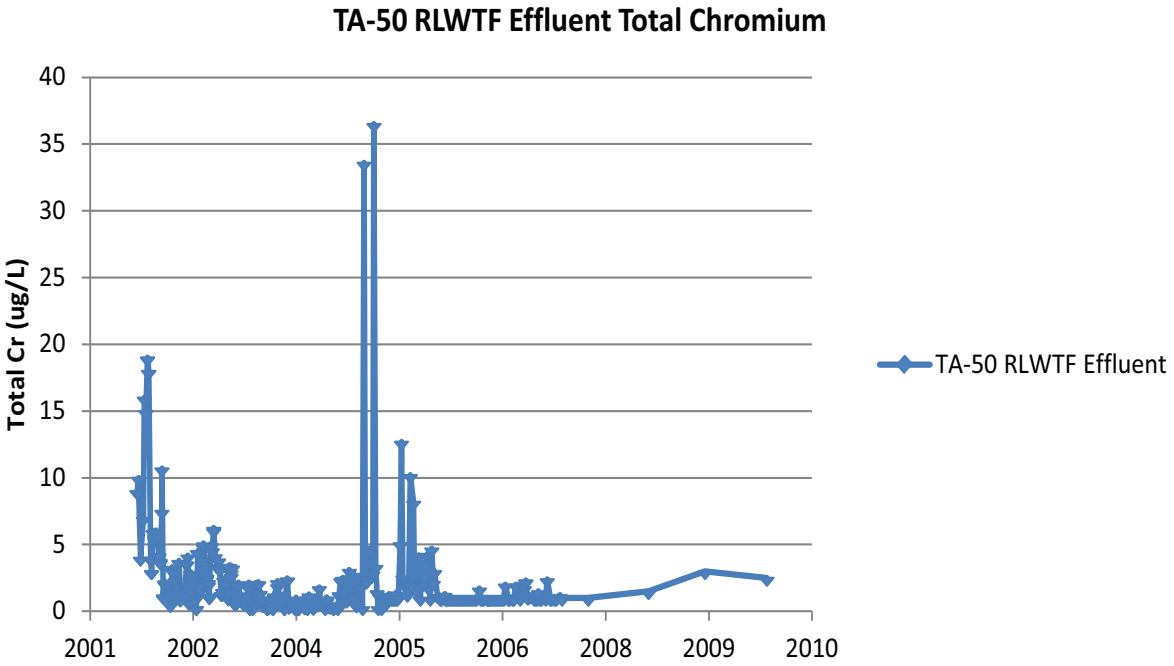
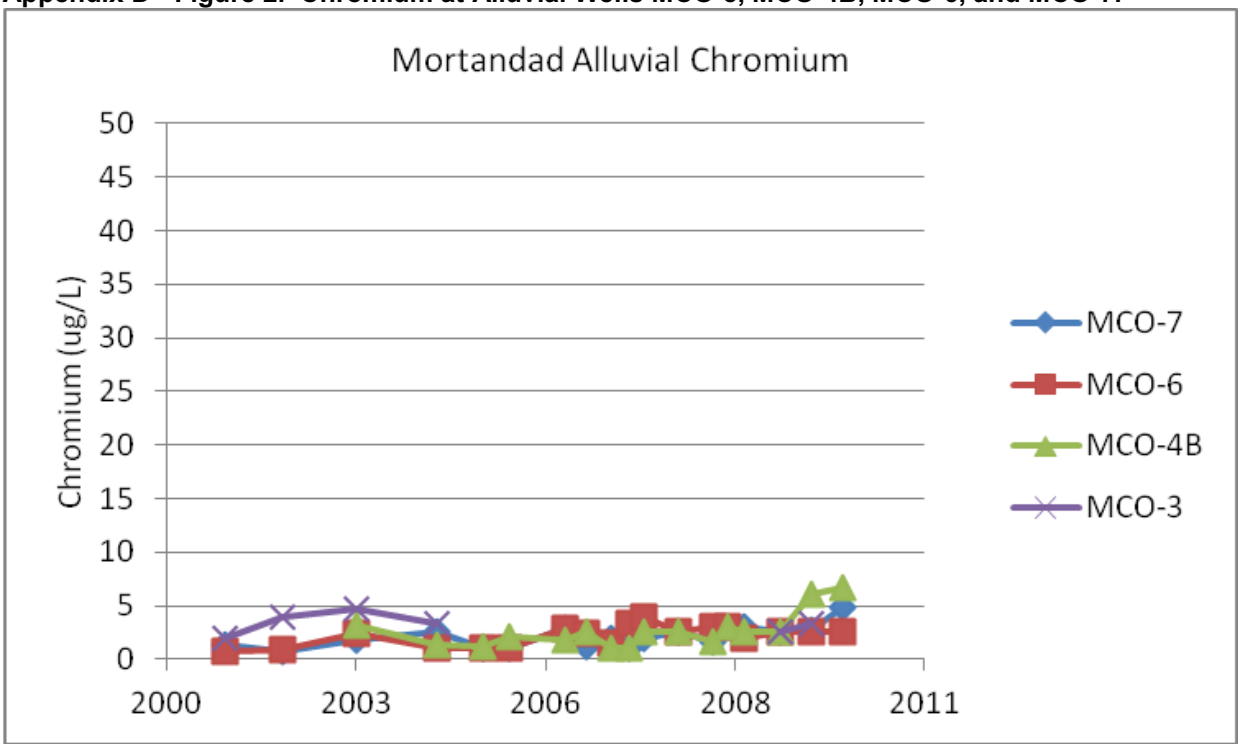
1. GROUNDWATER QUALITY, FIGURES 1-12, PAGES 1-6.

GROUNDWATER QUALITY FIGURES 1 – 12

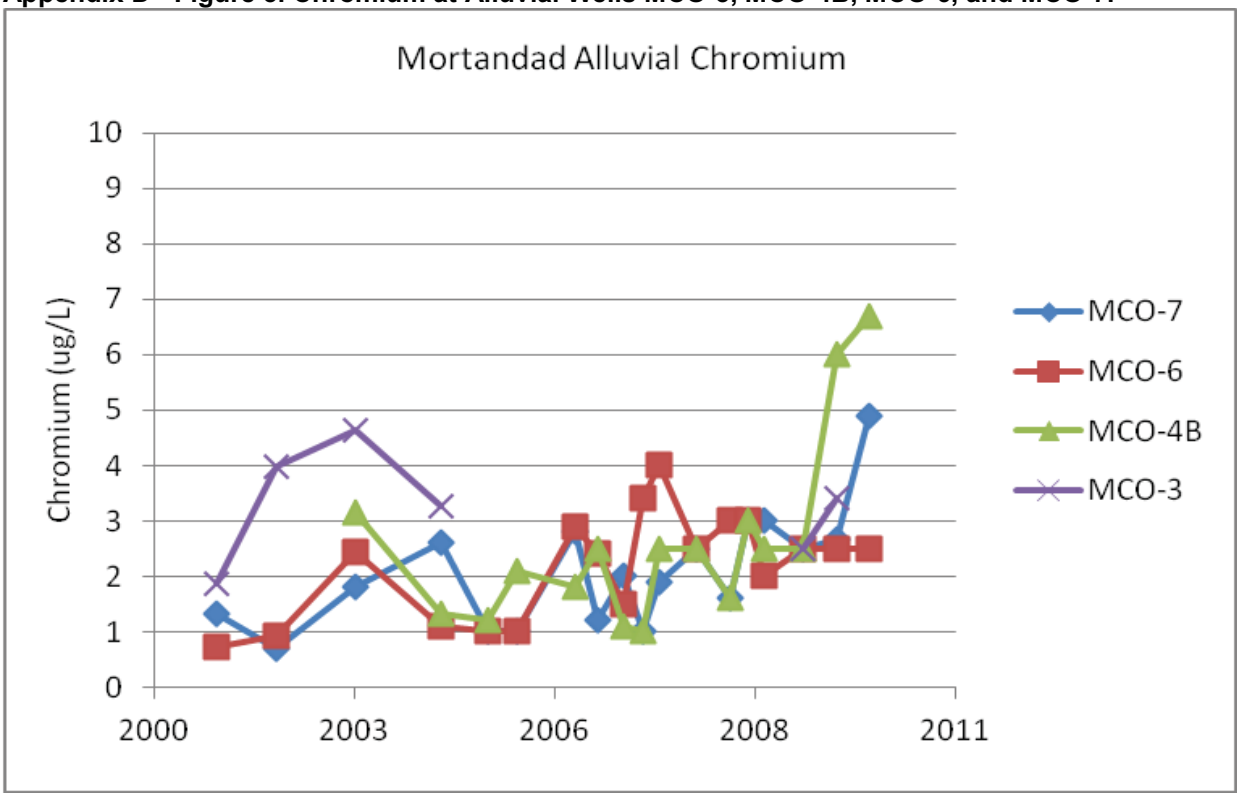
Appendix D - Figure 1. TA-50 RLWTF Effluent Total Chromium from 2001 to 2010.



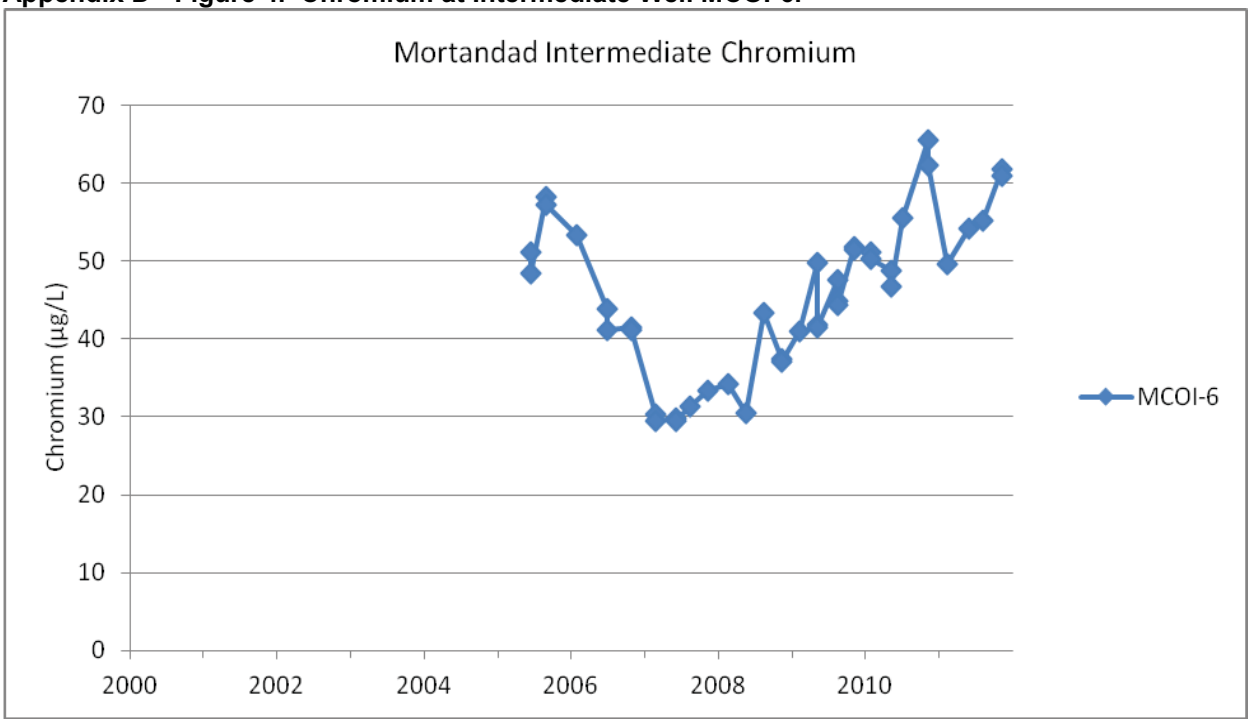
Appendix D - Figure 2. Chromium at Alluvial Wells MCO-3, MCO-4B, MCO-6, and MCO-7.



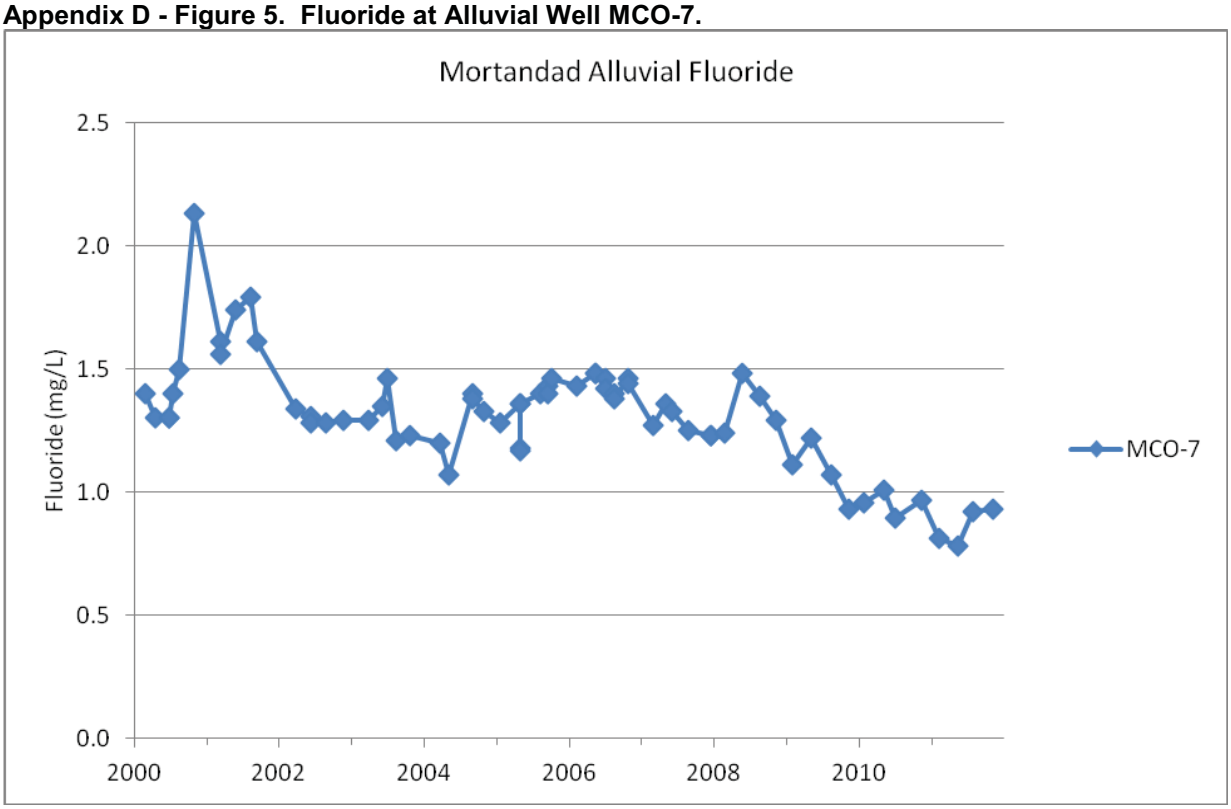
Appendix D - Figure 3. Chromium at Alluvial Wells MCO-3, MCO-4B, MCO-6, and MCO-7.



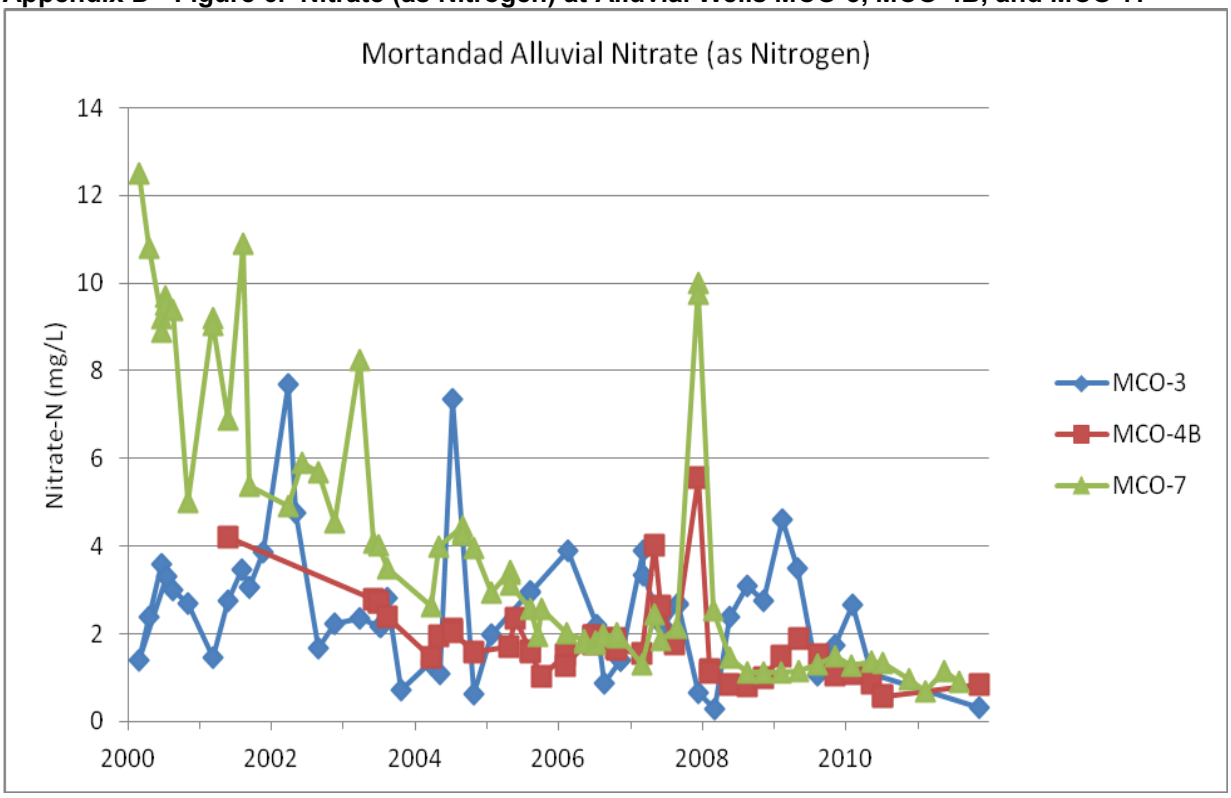
Appendix D - Figure 4. Chromium at Intermediate Well MCOI-6.



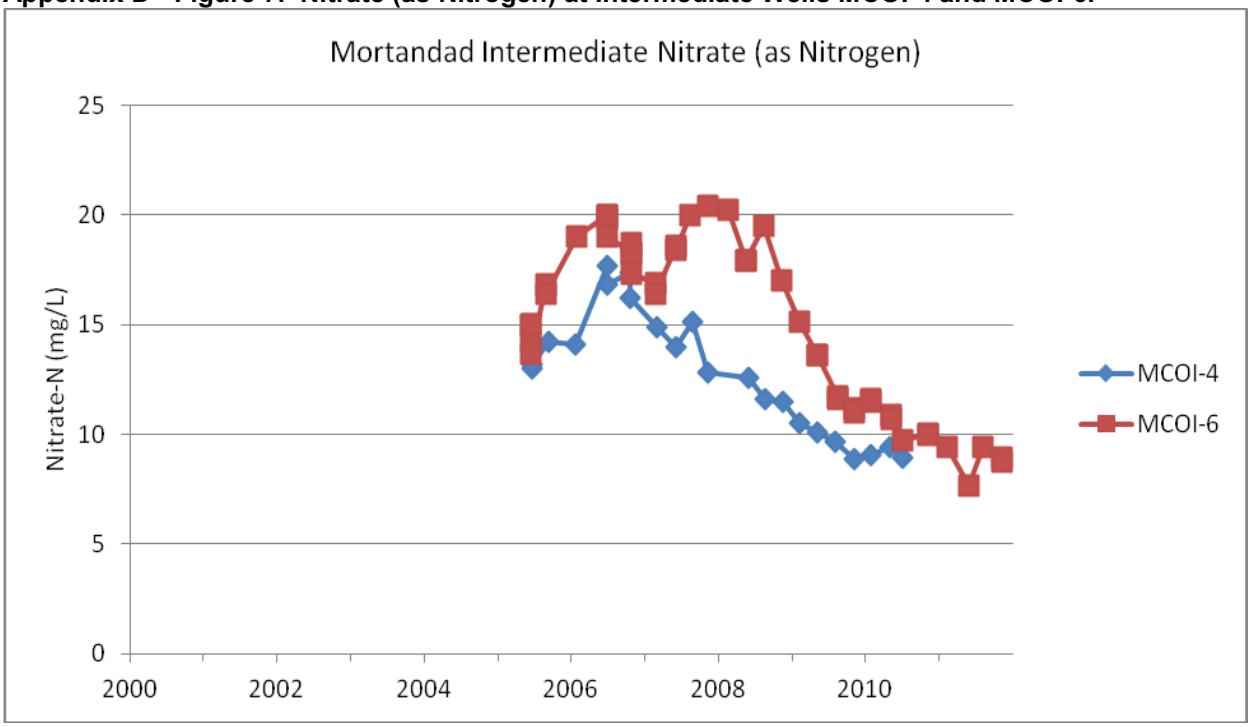
Appendix D - Figure 5. Fluoride at Alluvial Well MCO-7.



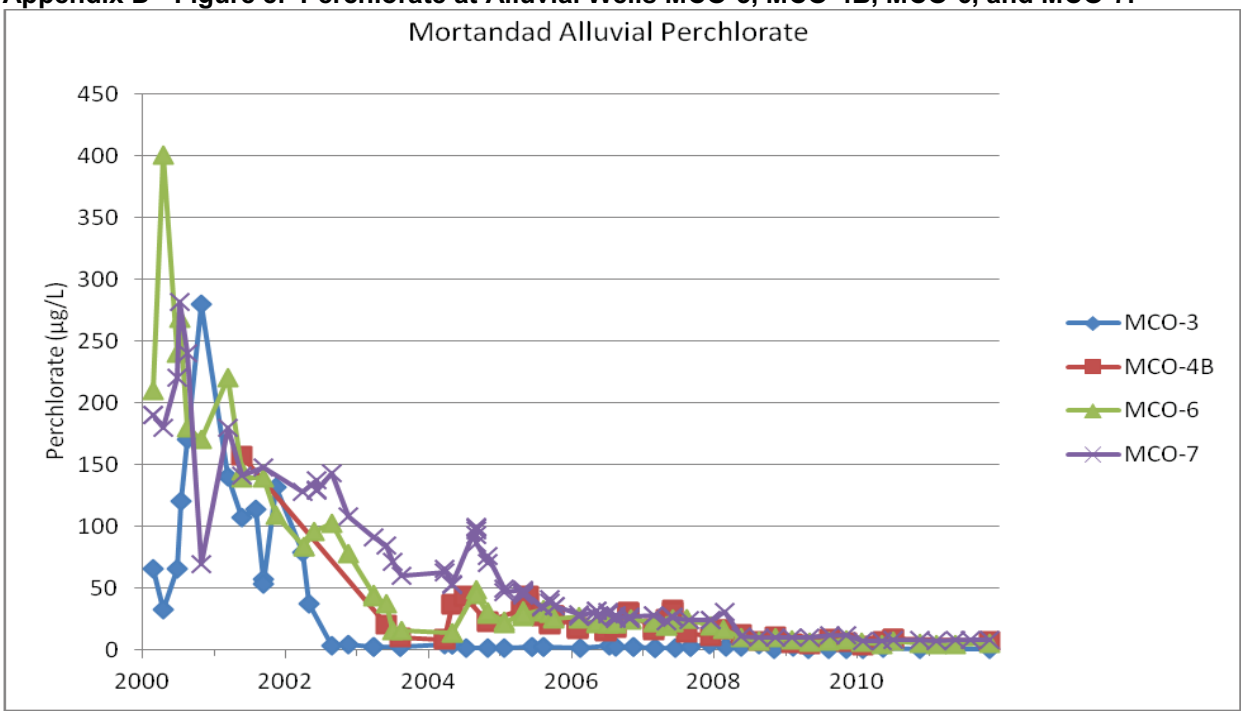
Appendix D - Figure 6. Nitrate (as Nitrogen) at Alluvial Wells MCO-3, MCO-4B, and MCO-7.



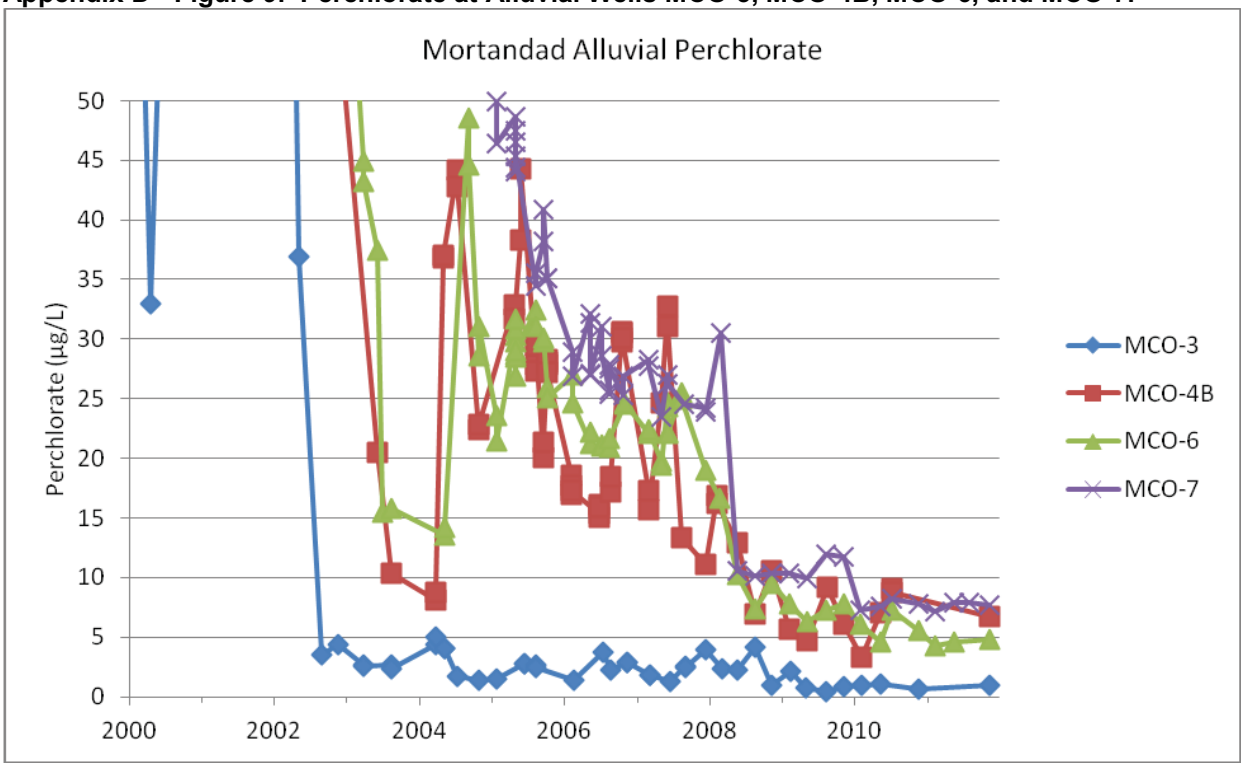
Appendix D - Figure 7. Nitrate (as Nitrogen) at Intermediate Wells MCOI-4 and MCOI-6.



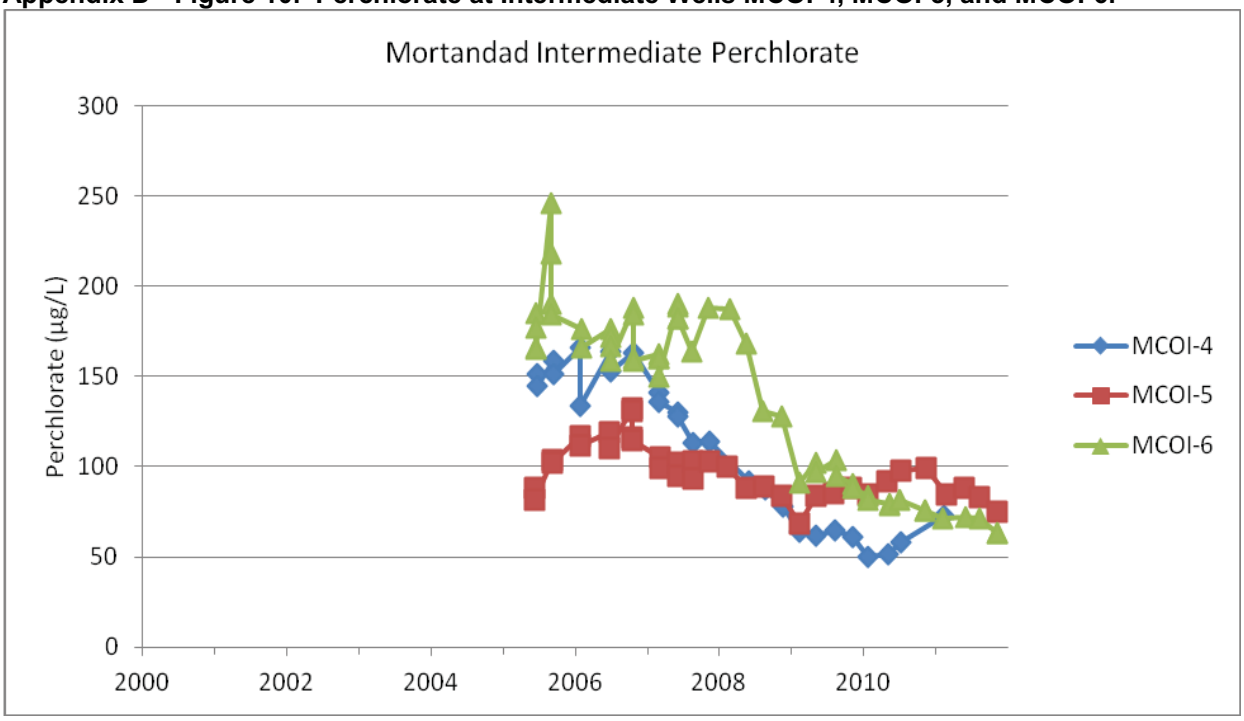
Appendix D - Figure 8. Perchlorate at Alluvial Wells MCO-3, MCO-4B, MCO-6, and MCO-7.



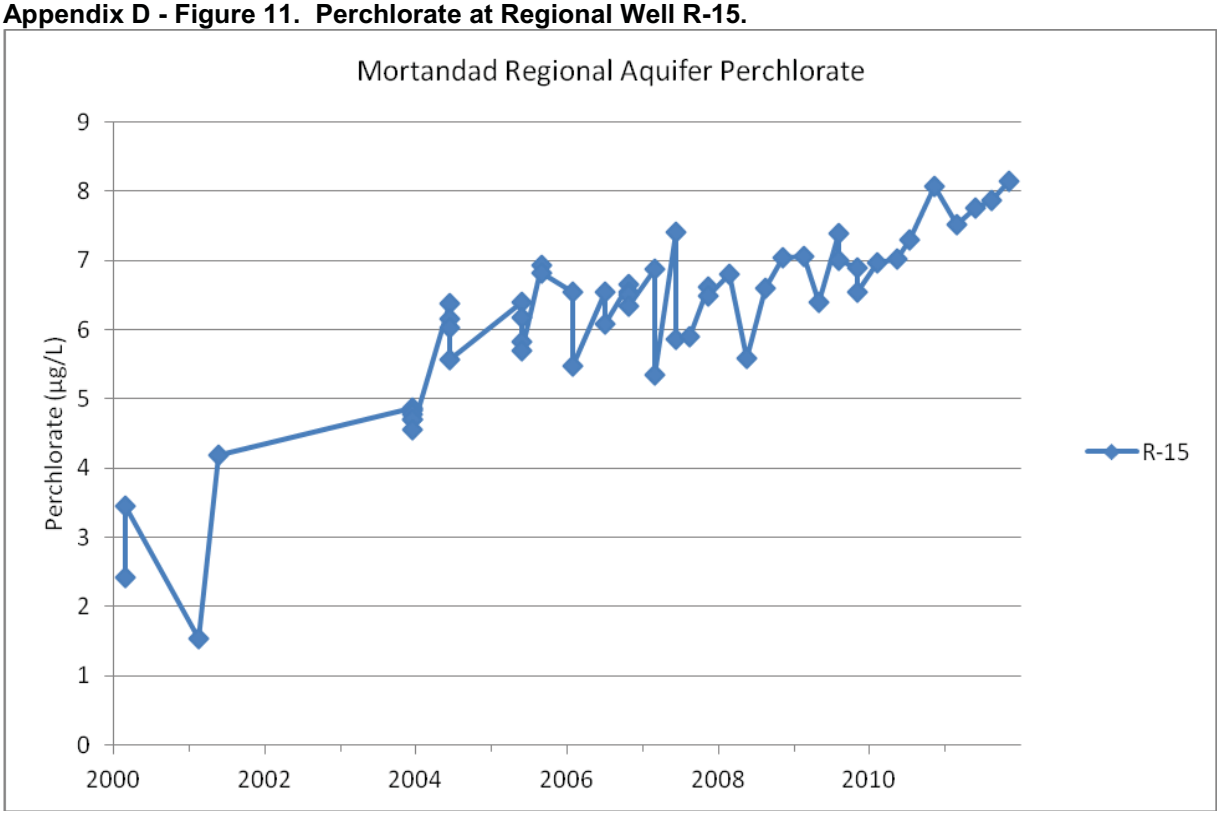
Appendix D - Figure 9. Perchlorate at Alluvial Wells MCO-3, MCO-4B, MCO-6, and MCO-7.



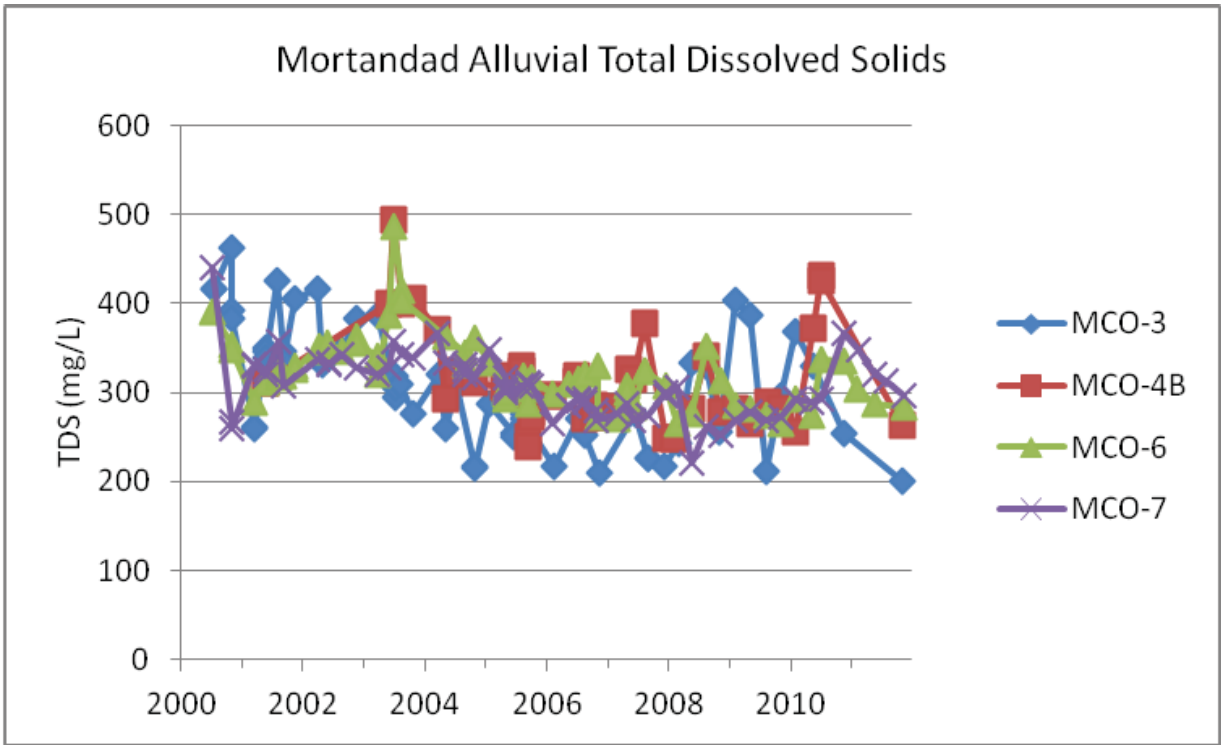
Appendix D - Figure 10. Perchlorate at Intermediate Wells MCOI-4, MCOI-5, and MCOI-6.



Appendix D - Figure 11. Perchlorate at Regional Well R-15.



Appendix D - Figure 12. Total Dissolved Solids at Alluvial Wells MCO-3, MCO-4B, MCO-6, and MCO-7.



APPENDIX E

WELL LOGS

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1. Well logs
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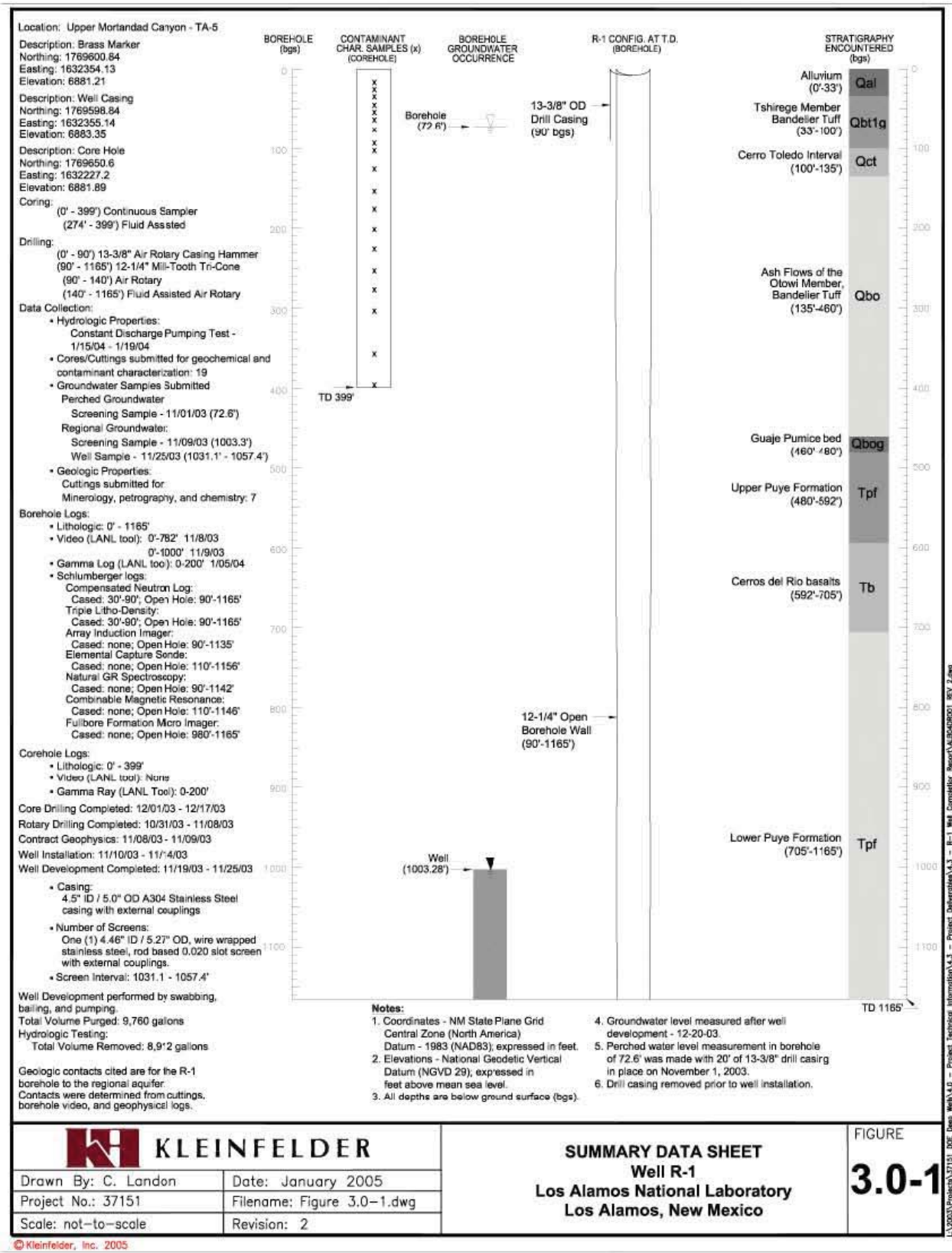
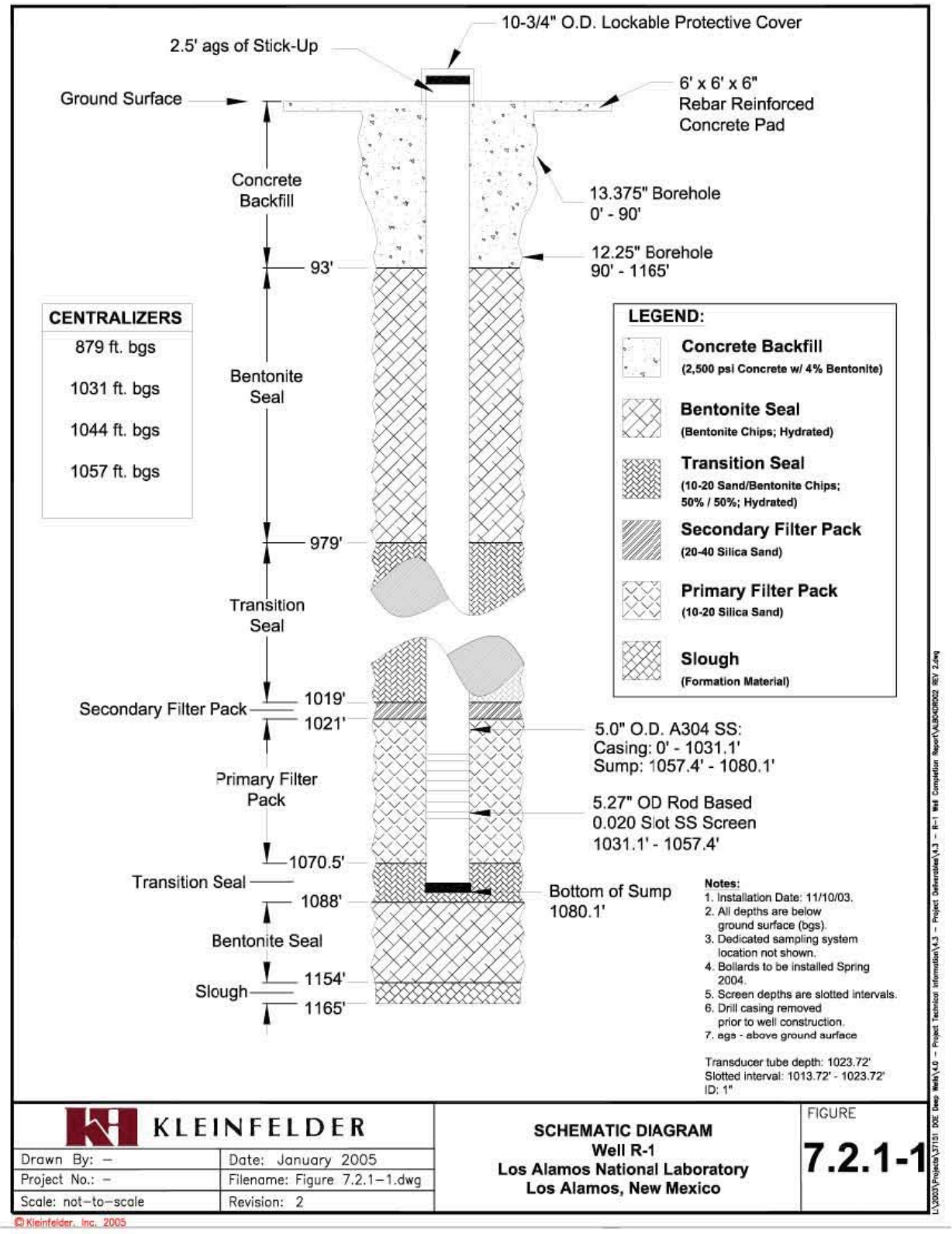
   - R-15
   - MCO-3
   - MCO-4B
   - MCO-6
   - MCO-7
   - MCOI-4
   - MCOI-5
   - MCOI-6

R-1 WELL

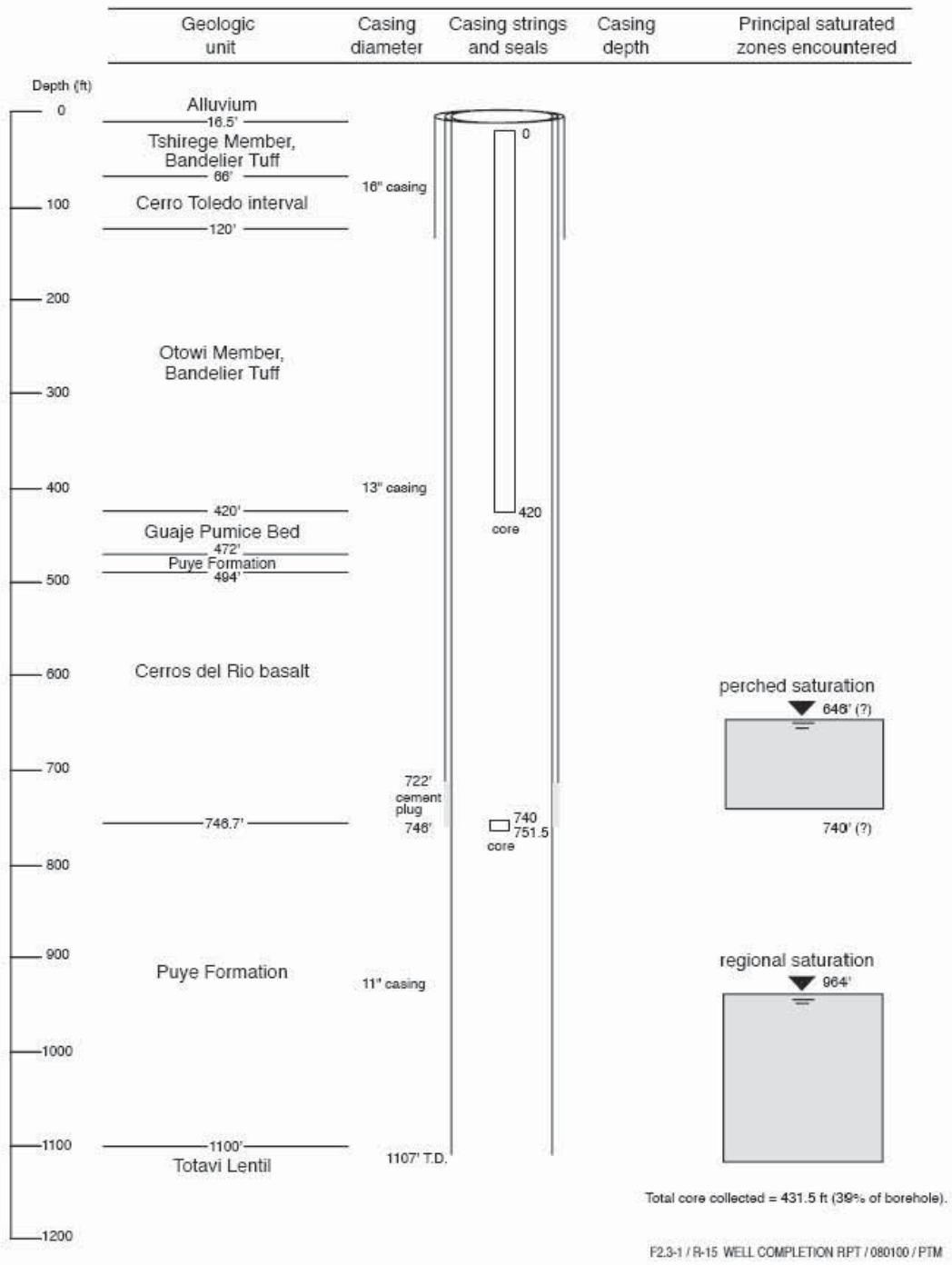


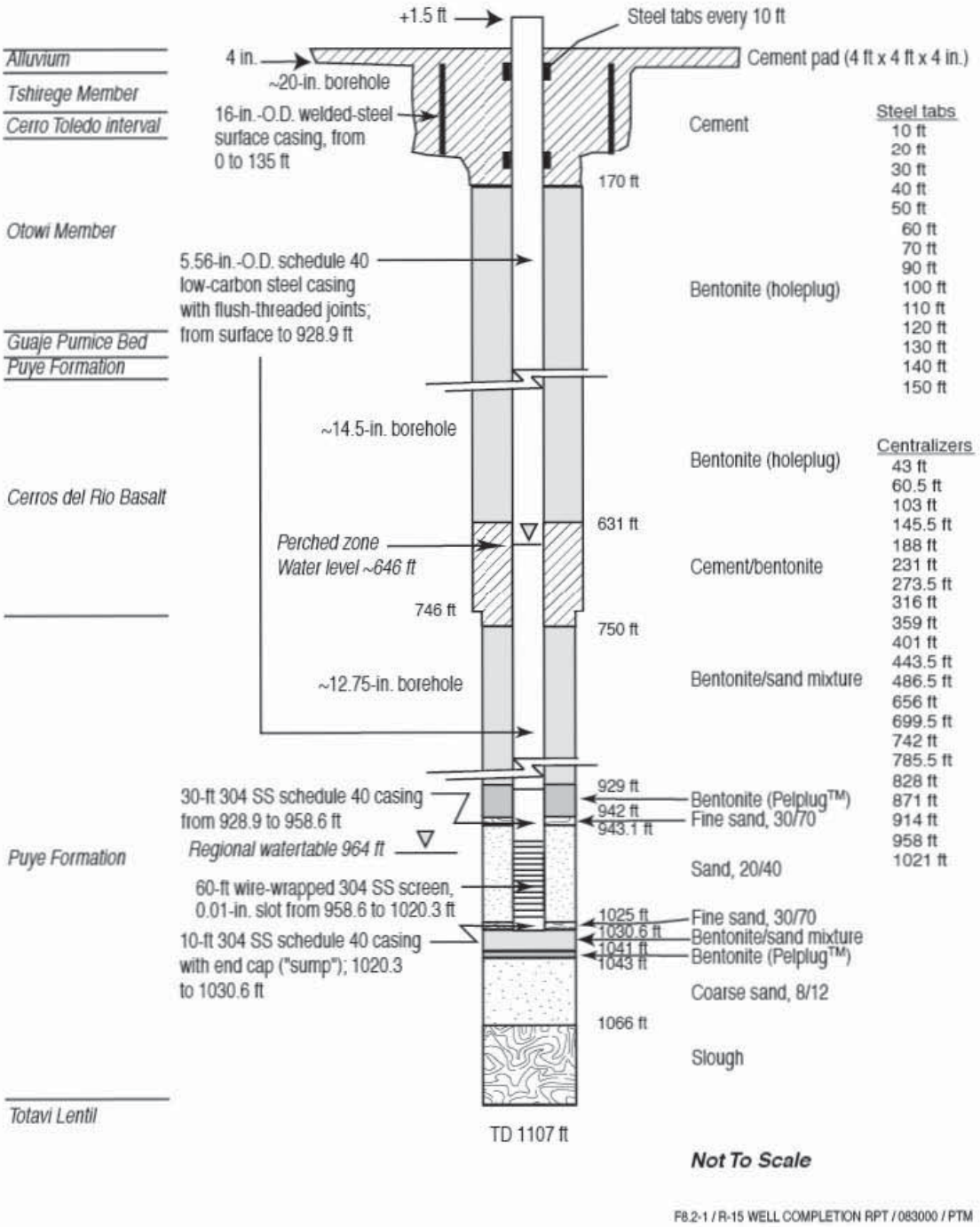
R-1 Well Fact Sheet



R-1 Well Construction Diagram

R-15 WELL


Geologic unit
Casing diameter
Casing strings and seals
Casing depth
Principal saturated zones encountered
Depth (ft)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Alluvium
16.5'
Tshirege Member, Bandelier Tuff
86'
Cerro Toledo interval
120'
Otowi Member, Bandelier Tuff
420'
Guaje Pumice Bed
472'
Puye Formation
494'
Cerros del Rio basalt
746.7'
Puye Formation
1100'
Totavi Lentil
16" casing
13" casing
11" casing
0
420
core
722'
cement plug
746'
740
751.5
core
1107' T.D.
perched saturation
646' (?)
740' (?)
regional saturation
964'
Total core collected = 431.5 ft (39% of borehole).
F2.3-1 / R-15 WELL COMPLETION RPT / 080100 / PTM



F8.2-1 / R-15 WELL COMPLETION RPT / 083000 / PTM

MCO-3 WELL

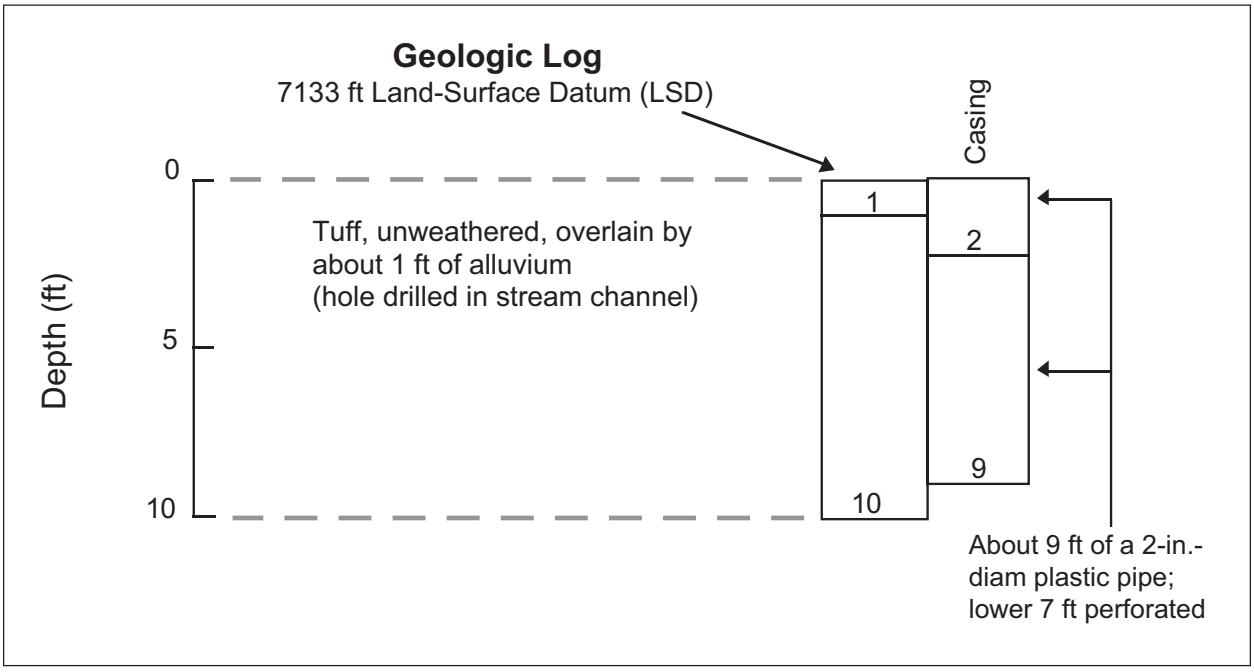


Fig. VI-C. Mortandad Canyon observation well MCO-2, completed November 1960, water level 0.3 ft (Baltz et al. 1963).

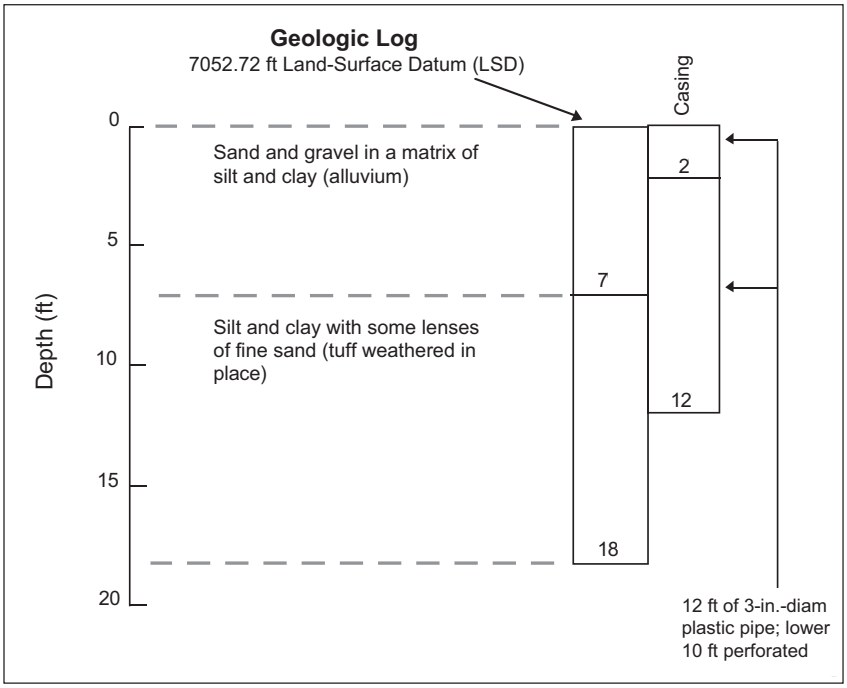


Fig. VI-D. Mortandad Canyon observation well MCO-3, redrilled March 1967 and completed with 3-in.-diam casing, water level 4.4 ft (Baltz et al. 1963; Purtymun 1964).

TABLE VI-B. Geologic Logs and Construction Data for Observation Wells in Mortandad Canyon (20 Obs. Wells)

1. Observation Well MCO-1

Geologic Log	Thickness (ft)	Depth (ft)
Tuff, unweathered, overlain by about 1 ft of silt and sand	8	8

Note: Well abandoned, in stream channel.

2. Observation Well MCO-2

Geologic Log	Thickness (ft)	Depth (ft)
Tuff, unweathered, overlain by about 1 ft of silt and sand	10	10

Note: Well abandoned: in stream channel.

3. Observation Well MCO-3

Geologic Log	Thickness (ft)	Depth (ft)
Alluvium		
Sand and gravel in a matrix of silt and clay	7	7
Tuff (weathered in place)		
Silt and clay with some lenses of sand and gravel	11	18

Construction
12 ft of 3-in.-diam plastic pipe, lower 10 ft perforated.

4. Observation Well MCO-4

Geologic Log	Thickness (ft)	Depth (ft)
Alluvium		
Sand and gravel in a matrix of silt and clay	18	18
Tuff (weathered in place)		
Silt and clay with lenses of sand	6	24

Construction
19 ft of 3-in.-diam plastic pipe, lower 15 ft perforated.

5. Observation Well MCO-4.9

Geologic Log	Thickness (ft)	Depth (ft)
Alluvium		
Sand and gravel in a matrix of silt and clay	27	27
Tuff (weathered in place) silt and clay with gravel	16	43

Construction
30 ft of 3-in.-diam plastic pipe, lower 20 ft perforated.

MCO-4B WELL

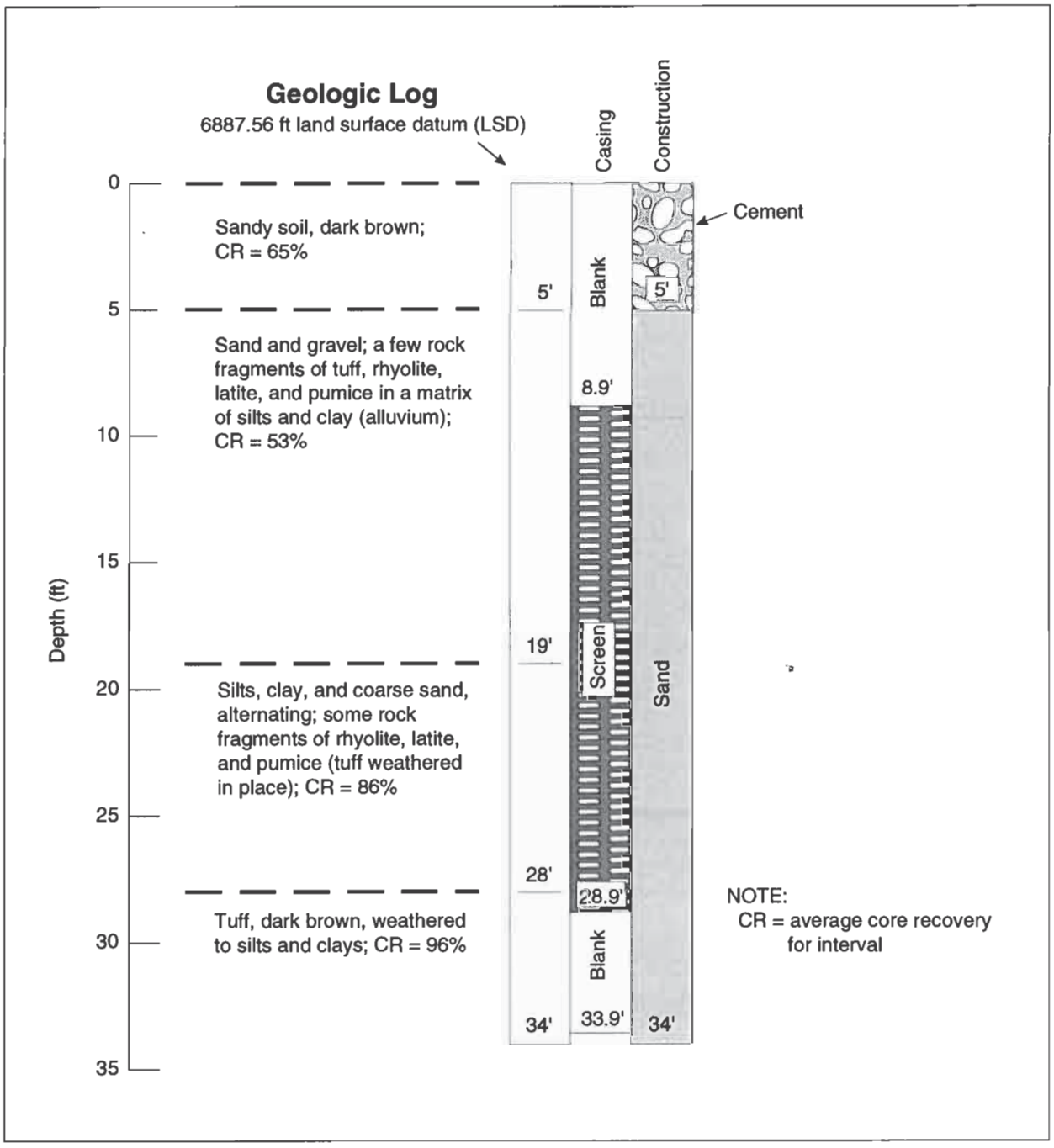


Fig. VIII-L. Mortandad Canyon observation well MCO-4B, completed August 1990, water level 21.7 ft (Purtymun and Stoker 1990).

MCO-6 WELL

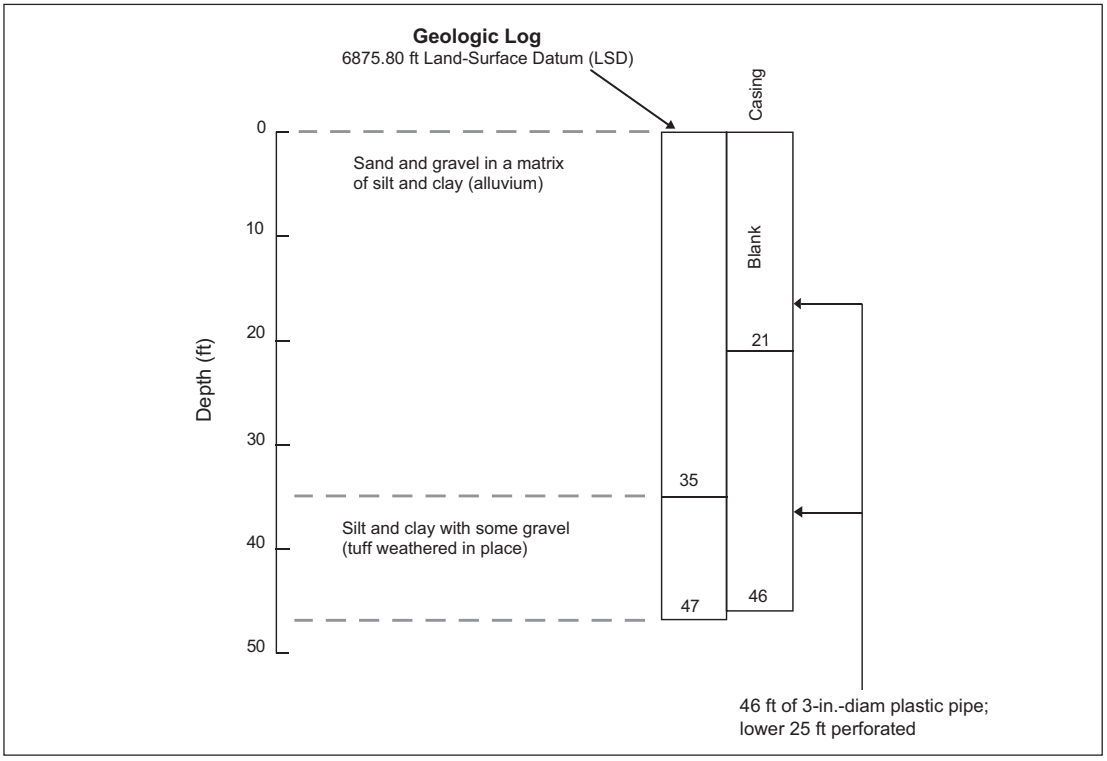


Fig. VI-G. Mortandad Canyon observation well MCO-5, completed October 1960, water level 24.6 ft (Baltz et al. 1963).

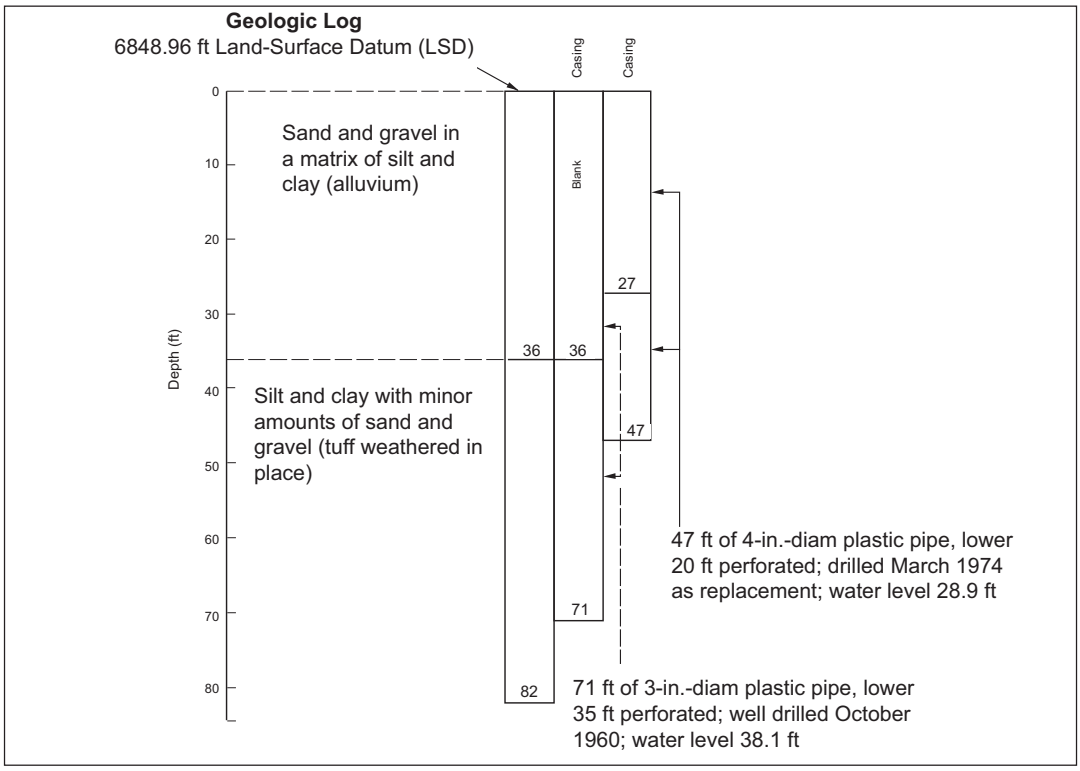


Fig. VI-H. Mortandad Canyon observation well MCO-6, completed October 1960, replaced March 1974 (Baltz et al. 1963, Purtymun 1974).

TABLE VI-B. Geologic Logs and Construction Data for Observation Wells in Mortandad Canyon (20 Obs. Wells)(Continued)

6. Observation Well MCO-5

Geologic Log	Thickness (ft)	Depth (ft)
Alluvium		
Sand and gravel with lenses of silt and clay	35	35
Tuff (weathered in place)		
Silt and clay with some lenses of sand and gravel	12	47

Construction
46 ft of 3-in.-diam plastic pipe, lower 25 ft perforated.

7. Observation Well MCO-6

Geologic Log	Thickness (ft)	Depth (ft)
Alluvium		
Sand, gravel, and occasional cobbles in a matrix of silt and clay	36	36
Tuff (weathered in place)		
Silt and clay with minor amounts of sand and gravel	46	82

Construction
71 ft of 3-in.-diam plastic pipe, lower 35 ft perforated, well drilled October 1960. Well destroyed by flood, summer 1973; redrilled and constructed as a new well about 10 ft to the northeast (March 1974): 47 ft of 4-in.-diam plastic pipe, lower 20 ft perforated.

8. Observation Well MCO-6.5A

Geologic Log	Thickness (ft)	Depth (ft)
Alluvium		
Sand and gravel in a matrix of silt and clay	47	47

Construction
45 ft of 2-in.-diam plastic pipe, lower 20 ft perforated.

9. Observation Well MCO-6.5B

Geologic Log	Thickness (ft)	Depth (ft)
Alluvium		
Sand and gravel in a matrix of silt and clay	42	42

Construction
42 ft of casing, upper 22 ft of 4-in.-diam steel pipe; lower 20 ft of 4-in.-diam plastic pipe, perforated.

MCO-7 WELL

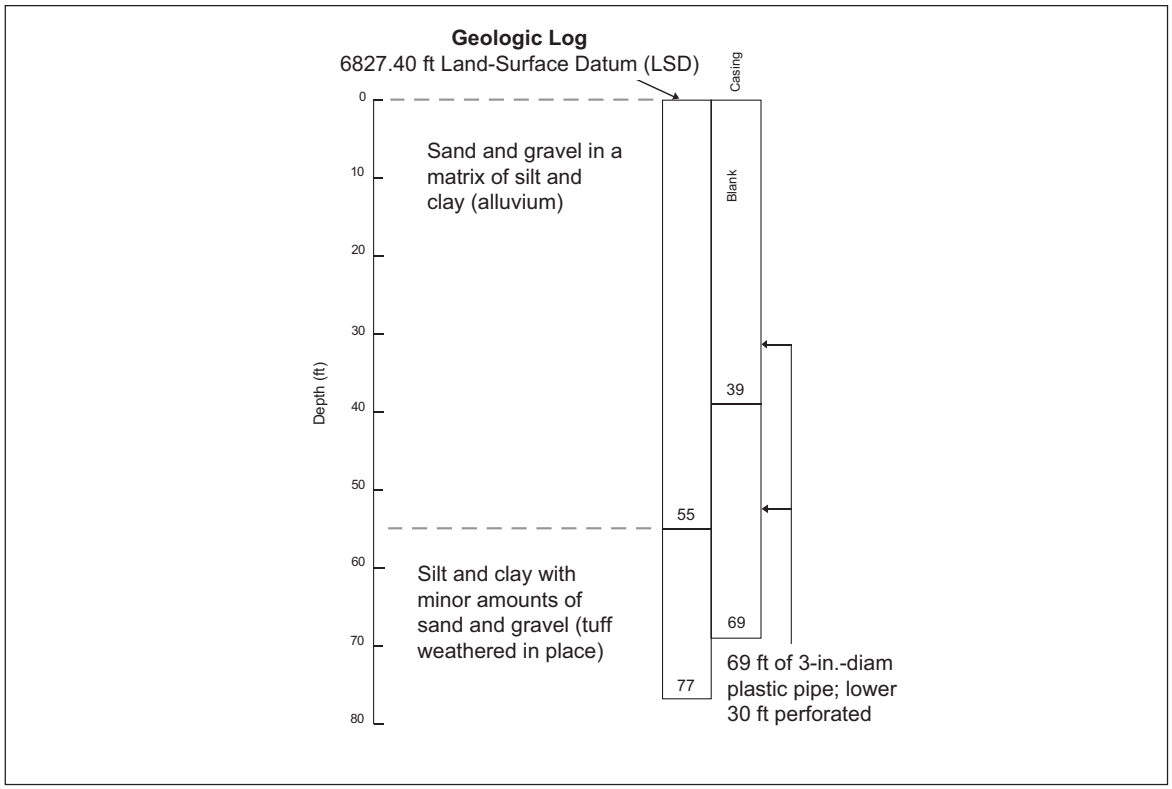


Fig. VI-K. Mortandad Canyon observation well MCO-7, completed October 1960, water level 39.7 ft (Baltz et al. 1963).

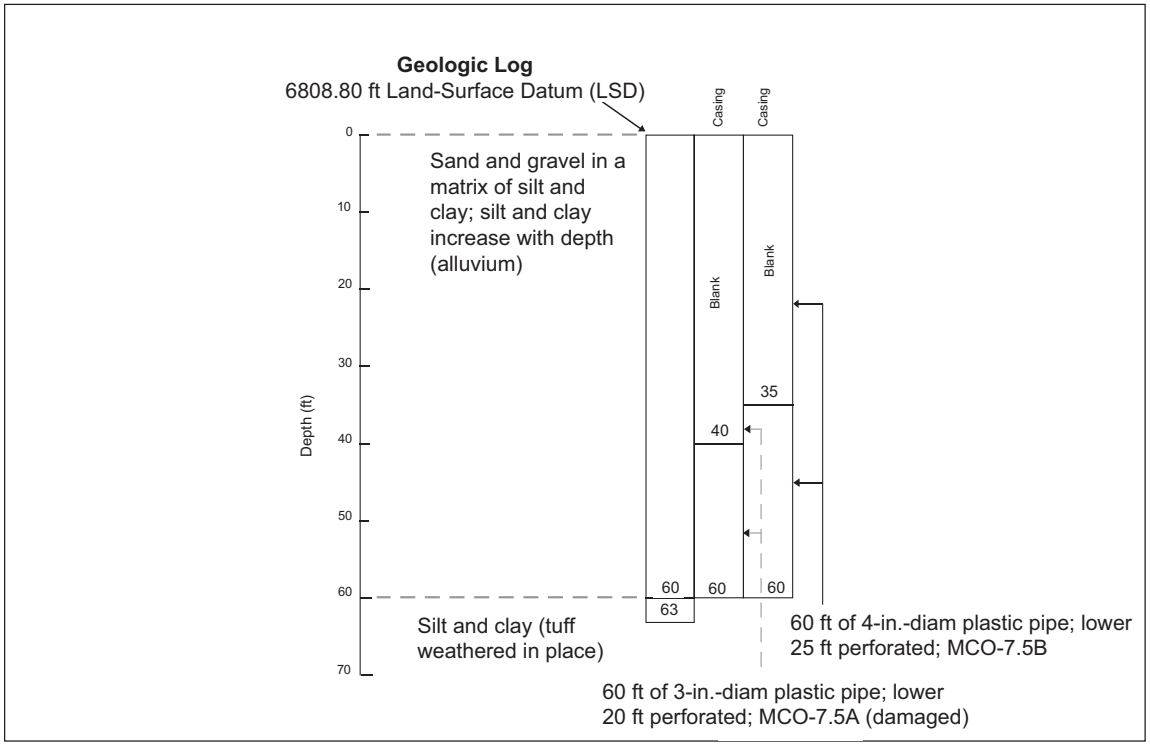


Fig. VI-L. Mortandad Canyon observation well MCO-7.5A (damaged), completed November 1961, water level 41.2 ft; and adjacent well MCO-7.5B, completed April 1974, water level 42.1 ft (Purtymun 1964, 1974).

TABLE VI-B. Geologic Logs and Construction Data for Observation Wells in Mortandad Canyon (20 Obs. Wells)(Continued)

10. Observation Well MCO-7

Geologic Log	Thickness (ft)	Depth (ft)
Alluvium		
Sand and gravel in a silt and clay matrix	55	55
Tuff (weathered in place)		
Silt and clay with lenses of sand and gravel	22	77

Construction
69 ft of 3-in.-diam plastic pipe, lower 30 ft perforated.

11. Observation Well MCO-7.5A/7.5B

Geologic Log	Thickness (ft)	Depth (ft)
Alluvium		
Sand and gravel in a matrix of silt and clay; silt and clay increase with depth	60	60
Tuff (weathered in place) silt and clay	3	63

Construction
November 1961, 60 ft of 3-in.-diam plastic pipe, lower 20 ft perforated; well destroyed by falling tree, replaced April 1974 about 6 ft to the west: 60 ft of 4-in.-diam plastic pipe, lower 25 ft perforated.

12. Observation Well MCO-8

Geologic Log	Thickness (ft)	Depth (ft)
Alluvium		
Sand and gravel in a matrix of silt and clay; silt and clay increase with depth	61	61
Tuff (weathered in place)		
Silt and clay with lenses of fine to coarse sand	31	92

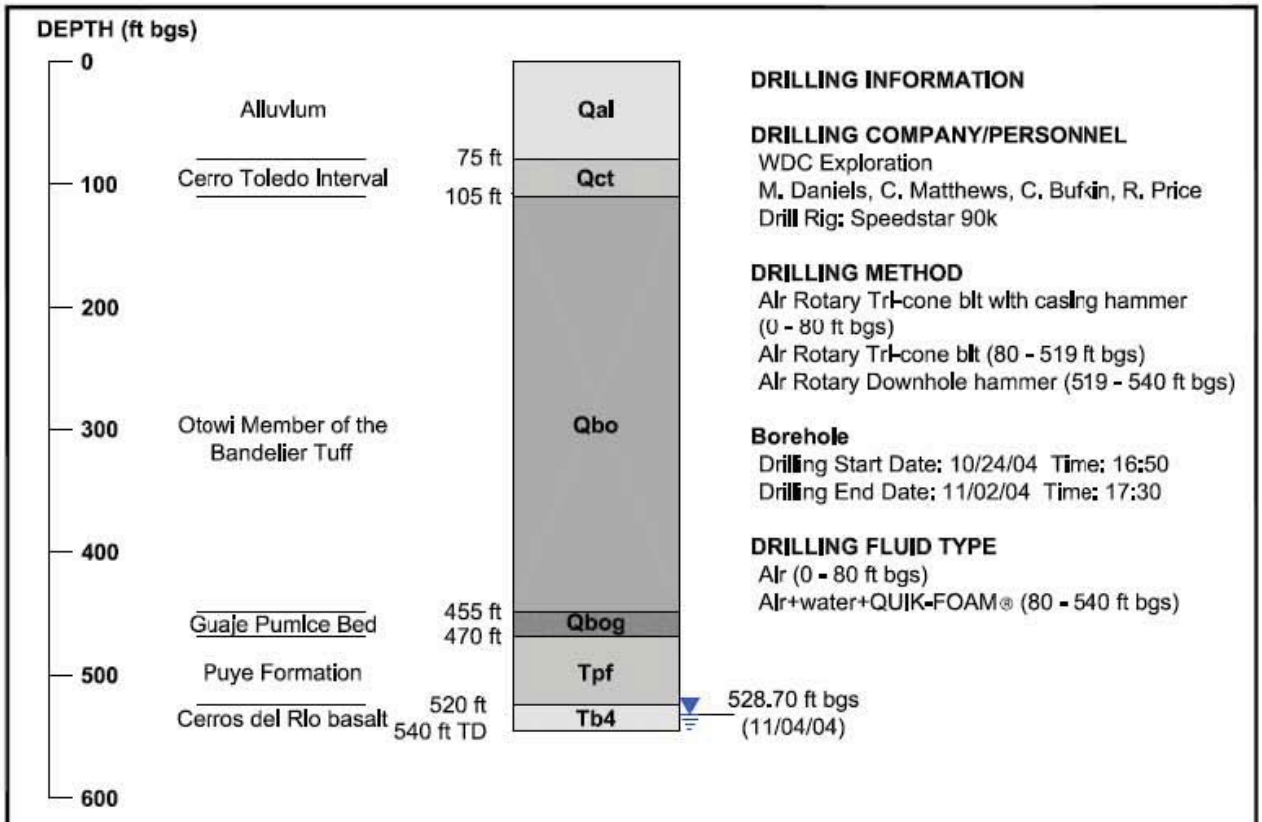
Construction
84 ft of 3-in.-diam plastic pipe, lower 20 ft perforated; well damaged, bailer stuck at about 23 ft.

13. Observation Well MCO-8A

Geologic Log	Thickness (ft)	Depth (ft)
Alluvium		
Sand and gravel in a matrix of silt and clay; silt and clay increase with depth	52	52

Construction
50 ft of 2-in.-diam plastic pipe, lower 10 ft perforated.

MCOI-4 WELL



Notes:
1. Geologic contacts are preliminary and subject to change.
2. Perched water at 59 ft bgs. Zone sealed off by surface casing.
3. Video survey indicated borehole wall moist below 504 ft bgs.
4. Groundwater level at 528.70 ft bgs in open hole after reaching TD of 540 ft bgs

KLEINFELDER		BOREHOLE SUMMARY DATA SHEET I-4 Mortandad Canyon Los Alamos National Laboratory Los Alamos, New Mexico	FIGURE 5.1-1
Drawn By: C. Bhongir	Date: April 2006		
Project No.: 49436	Filename: 49436_01_0.dwg		
Scale: not – to – scale	Revision: –		

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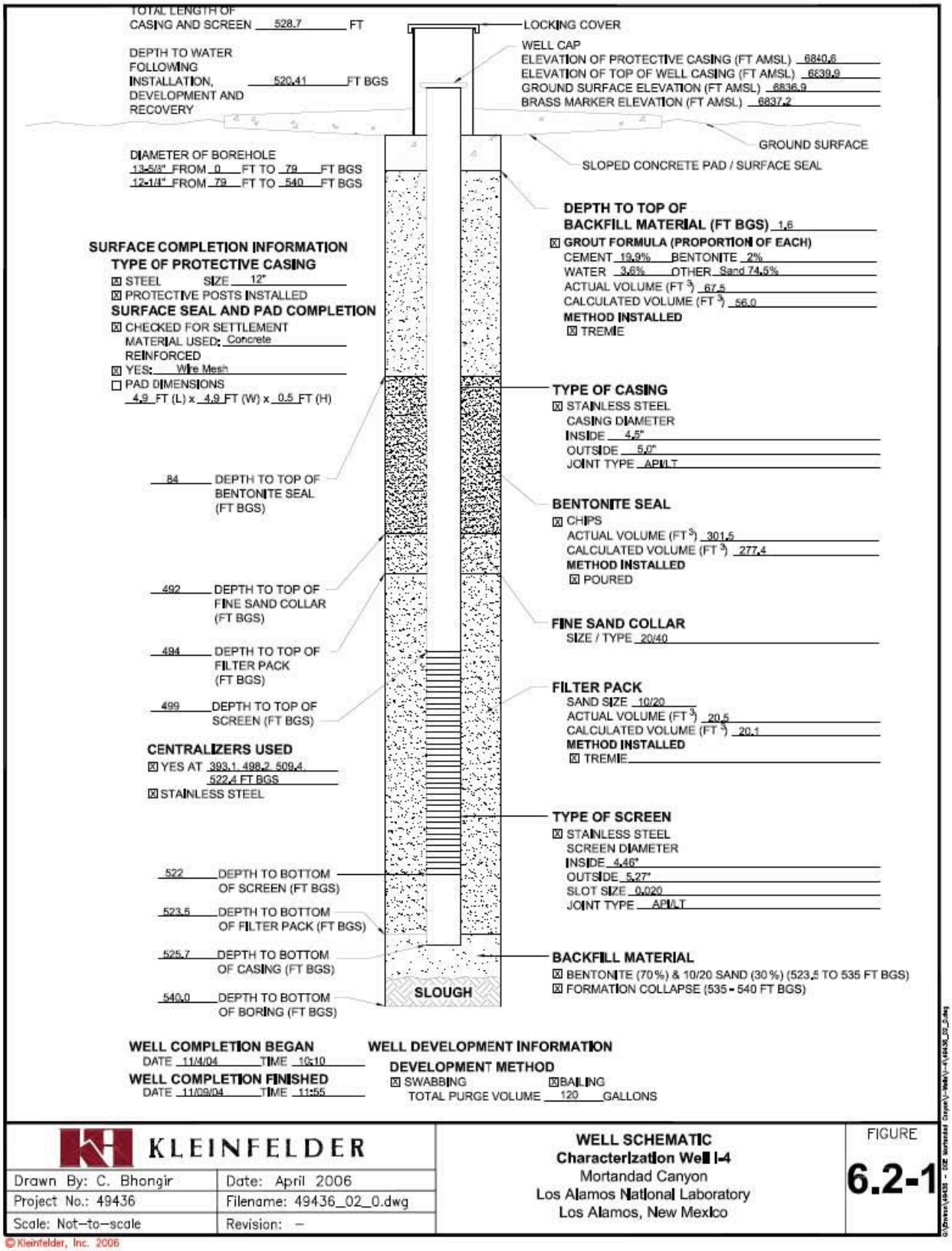

KLEINFELDER

Drawn By: C. Bhongir	Date: April 2006
Project No.: 49436	Filename: 49436_02_0.dwg
Scale: Not-to-scale	Revision: -

WELL SCHEMATIC
Characterization Well I-4
Mortandad Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico

FIGURE
6.2-1

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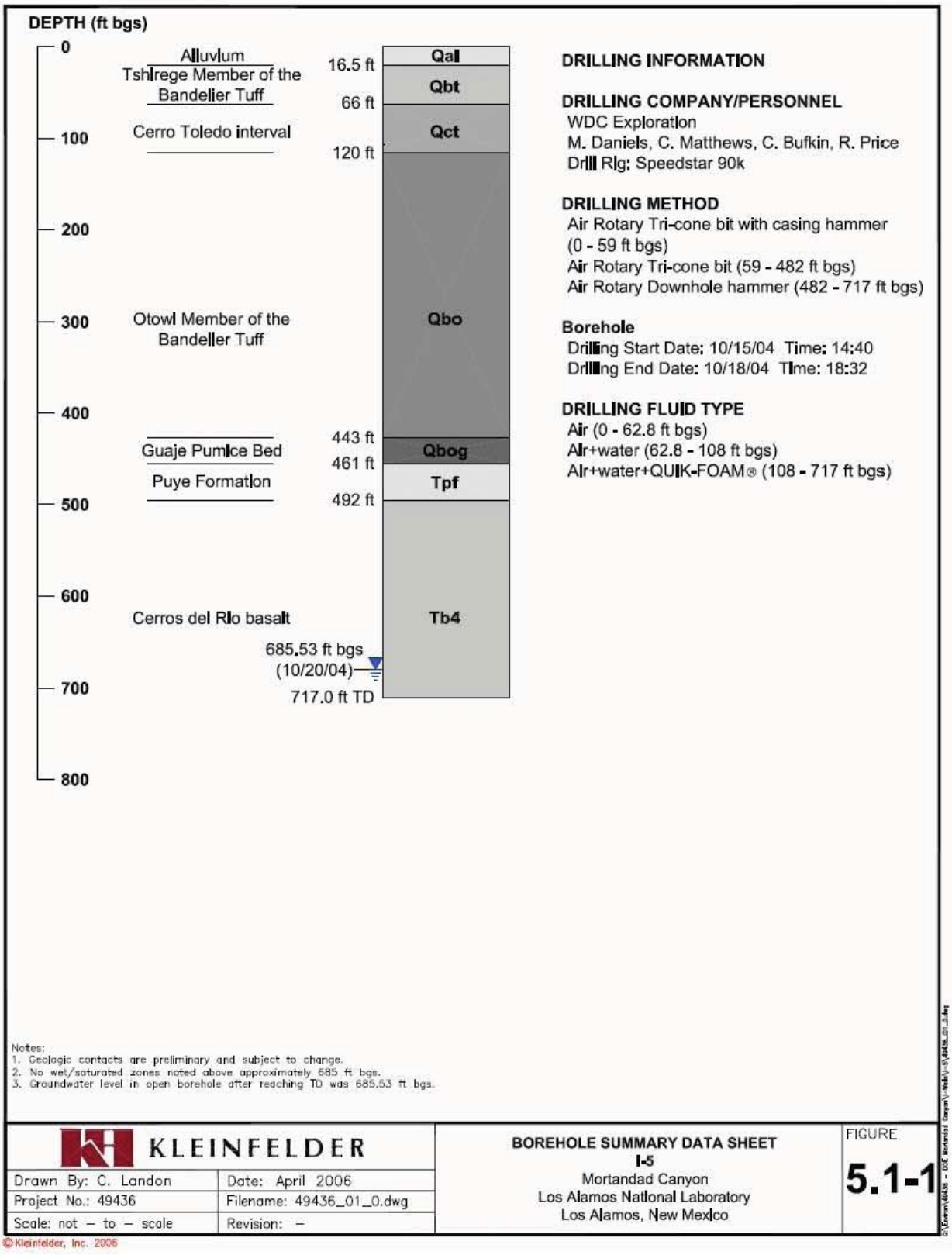
MCOI-5 WELL


DEPTH (ft bgs)
0
100
200
300
400
500
600
700
800
Alluvium
Tshirege Member of the Bandelier Tuff
Cerro Toledo interval
Otowi Member of the Bandelier Tuff
Guaje Pumice Bed
Puye Formation
Cerros del Rio basalt
16.5 ft
66 ft
120 ft
443 ft
461 ft
492 ft
685.53 ft bgs
(10/20/04)
717.0 ft TD
Qal
Qbt
Qct
Qbo
Qbog
Tpf
Tb4
DRILLING INFORMATION
DRILLING COMPANY/PERSONNEL
WDC Exploration
M. Daniels, C. Matthews, C. Bufkin, R. Price
Drill Rig: Speedstar 90k
DRILLING METHOD
Air Rotary Tri-cone bit with casing hammer (0 - 59 ft bgs)
Air Rotary Tri-cone bit (59 - 482 ft bgs)
Air Rotary Downhole hammer (482 - 717 ft bgs)
Borehole
Drilling Start Date: 10/15/04 Time: 14:40
Drilling End Date: 10/18/04 Time: 18:32
DRILLING FLUID TYPE
Air (0 - 62.8 ft bgs)
Air+water (62.8 - 108 ft bgs)
Air+water+QUIK-FOAM® (108 - 717 ft bgs)
Notes:
1. Geologic contacts are preliminary and subject to change.
2. No wet/saturated zones noted above approximately 685 ft bgs.
3. Groundwater level in open borehole after reaching TD was 685.53 ft bgs.
KLEINFELDER
Drawn By: C. Landon
Date: April 2006
Project No.: 49436
Filename: 49436_01_0.dwg
Scale: not – to – scale
Revision: –
BOREHOLE SUMMARY DATA SHEET
I-5
Mortandad Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
5.1-1
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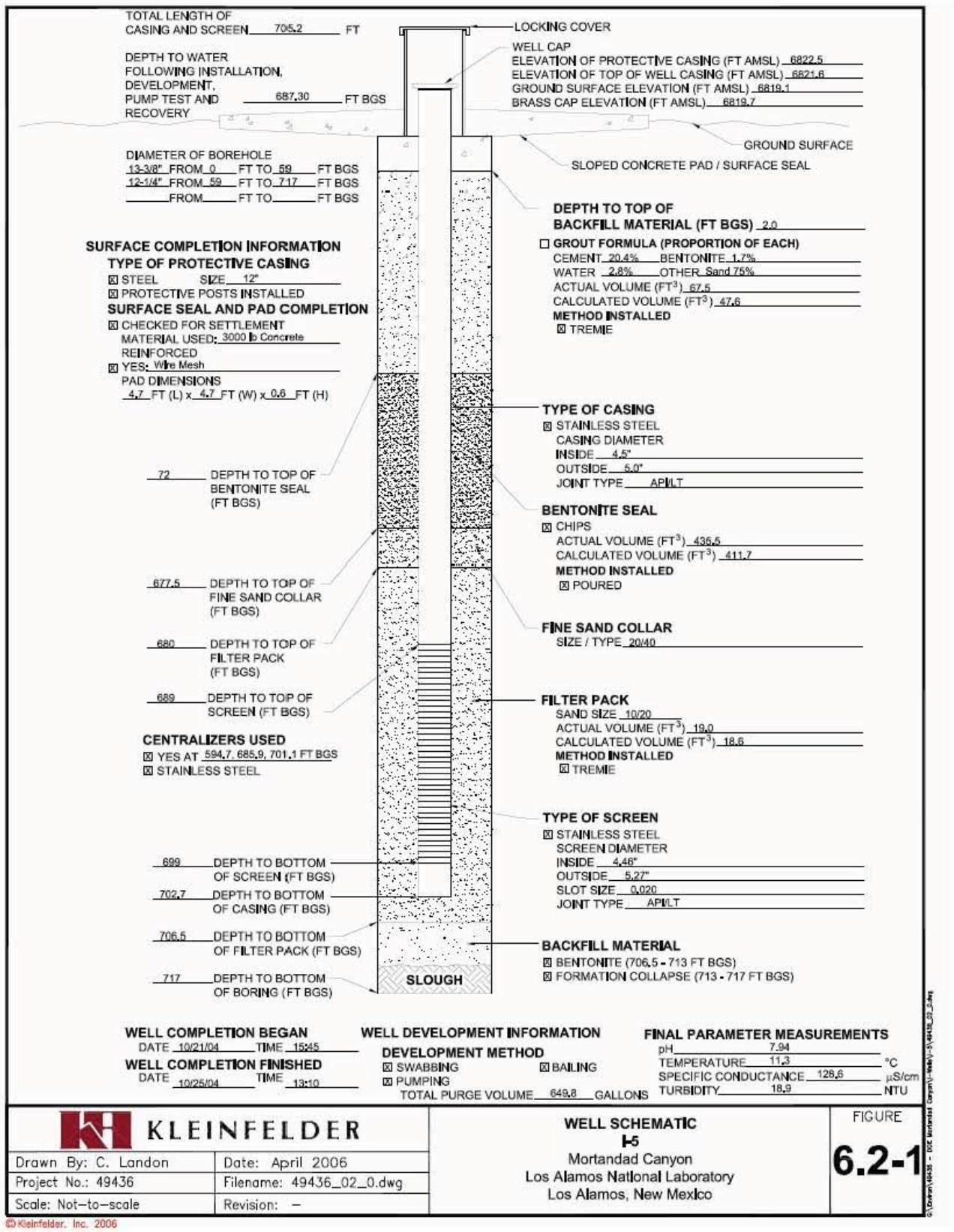
TOTAL LENGTH OF CASING AND SCREEN 705.2 FT
DEPTH TO WATER FOLLOWING INSTALLATION, DEVELOPMENT, PUMP TEST AND RECOVERY 687.30 FT BGS
DIAMETER OF BOREHOLE
13-3/8" FROM 0 FT TO 59 FT BGS
12-1/4" FROM 59 FT TO 717 FT BGS
FROM FT TO FT BGS
SURFACE COMPLETION INFORMATION
TYPE OF PROTECTIVE CASING
☒ STEEL SIZE 12"
☒ PROTECTIVE POSTS INSTALLED
SURFACE SEAL AND PAD COMPLETION
☒ CHECKED FOR SETTLEMENT
MATERIAL USED: 3000 lb Concrete
REINFORCED
☒ YES: Wire Mesh
PAD DIMENSIONS
4.7 FT (L) x 4.7 FT (W) x 0.6 FT (H)
72 DEPTH TO TOP OF BENTONITE SEAL (FT BGS)
677.5 DEPTH TO TOP OF FINE SAND COLLAR (FT BGS)
680 DEPTH TO TOP OF FILTER PACK (FT BGS)
689 DEPTH TO TOP OF SCREEN (FT BGS)
CENTRALIZERS USED
☒ YES AT 594.7, 685.9, 701.1 FT BGS
☒ STAINLESS STEEL
699 DEPTH TO BOTTOM OF SCREEN (FT BGS)
702.7 DEPTH TO BOTTOM OF CASING (FT BGS)
706.5 DEPTH TO BOTTOM OF FILTER PACK (FT BGS)
717 DEPTH TO BOTTOM OF BORING (FT BGS)
SLOUGH
LOCKING COVER
WELL CAP
ELEVATION OF PROTECTIVE CASING (FT AMSL) 6822.5
ELEVATION OF TOP OF WELL CASING (FT AMSL) 6821.6
GROUND SURFACE ELEVATION (FT AMSL) 6819.1
BRASS CAP ELEVATION (FT AMSL) 6819.7
GROUND SURFACE
SLOPED CONCRETE PAD / SURFACE SEAL
DEPTH TO TOP OF BACKFILL MATERIAL (FT BGS) 2.0
☐ GROUT FORMULA (PROPORTION OF EACH)
CEMENT 20.4% BENTONITE 1.7%
WATER 2.8% OTHER Sand 75%
ACTUAL VOLUME (FT3) 67.5
CALCULATED VOLUME (FT3) 47.6
METHOD INSTALLED
☒ TREMIE
TYPE OF CASING
☒ STAINLESS STEEL
CASING DIAMETER
INSIDE 4.5"
OUTSIDE 5.0"
JOINT TYPE API/LT
BENTONITE SEAL
☒ CHIPS
ACTUAL VOLUME (FT3) 435.5
CALCULATED VOLUME (FT3) 411.7
METHOD INSTALLED
☒ POURED
FINE SAND COLLAR
SIZE / TYPE 20/40
FILTER PACK
SAND SIZE 10/20
ACTUAL VOLUME (FT3) 19.0
CALCULATED VOLUME (FT3) 18.6
METHOD INSTALLED
☒ TREMIE
TYPE OF SCREEN
☒ STAINLESS STEEL
SCREEN DIAMETER
INSIDE 4.46"
OUTSIDE 5.27"
SLOT SIZE 0.020
JOINT TYPE API/LT
BACKFILL MATERIAL
☒ BENTONITE (706.5 - 713 FT BGS)
☒ FORMATION COLLAPSE (713 - 717 FT BGS)
WELL COMPLETION BEGAN
DATE 10/21/04 TIME 15:45
WELL COMPLETION FINISHED
DATE 10/25/04 TIME 13:10
WELL DEVELOPMENT INFORMATION
DEVELOPMENT METHOD
☒ SWABBING ☒ BAILING
☒ PUMPING
TOTAL PURGE VOLUME 649.8 GALLONS
FINAL PARAMETER MEASUREMENTS
pH 7.94
TEMPERATURE 11.3 °C
SPECIFIC CONDUCTANCE 128.6 µS/cm
TURBIDITY 18.9 NTU
KLEINFELDER
Drawn By: C. Landon
Date: April 2006
Project No.: 49436
Filename: 49436_02_0.dwg
Scale: Not-to-scale
Revision: –
WELL SCHEMATIC
I-5
Mortandad Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico
FIGURE
6.2-1
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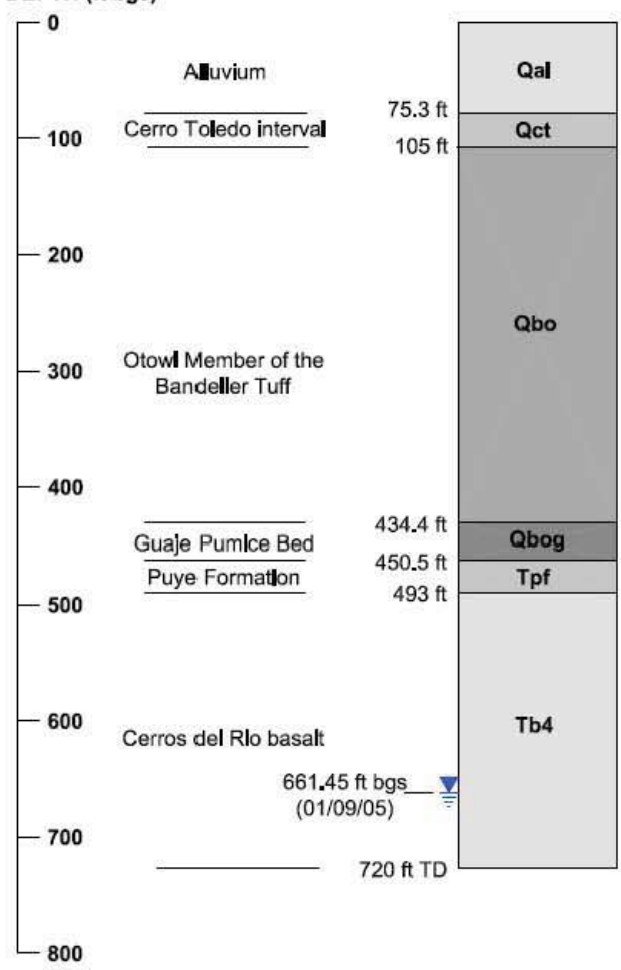
MCOI-6 WELL



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL
WDC Exploration
M. Daniels, C. Matthews, R. Price
Drill Rig: Gefco 50k
Spectrum Exploration
S. Jager
Drill Rig: DB-540

DRILLING METHOD
Corehole
0 - 498.2 ft bgs
Borehole
Air Rotary Tri-cone bit with casing hammer (0 - 60.5 ft bgs)
Air Rotary Tri-cone bit (60.5 - 495 ft bgs)
Air Rotary Downhole hammer (495 - 720 ft bgs)

Corehole
Drilling Start Date: 10/21/04 Time: 15:40
Drilling End Date: 10/28/04 Time: 18:09
Borehole
Drilling Start Date: 01/03/05 Time: 18:05
Drilling End Date: 01/06/05 Time: 17:28

DRILLING FLUID TYPE
Corehole: Air (0 - 498.2 ft bgs)
Borehole: Air, water, QUIK-FOAM®
Air (0-60.5 ft bgs)
Air+water+QUIK-FOAM® (60.5 - 720 ft bgs)

Notes:
1. Geologic contacts are preliminary and subject to change.
2. Wet/saturated zone in Alluvium at approximately 57.5 ft bgs in corehole.
3. Groundwater level in open borehole after reaching TD was 661.45 ft bgs.

KLEINFELDER

Drawn By: C. Landon	Date: April 2006
Project No.: 49436	Filename: 49436_01_0.dwg
Scale: not – to – scale	Revision: –

BOREHOLE SUMMARY DATA SHEET
I-6
Mortandad Canyon
Los Alamos National Laboratory
Los Alamos, New Mexico

FIGURE
5.1-1

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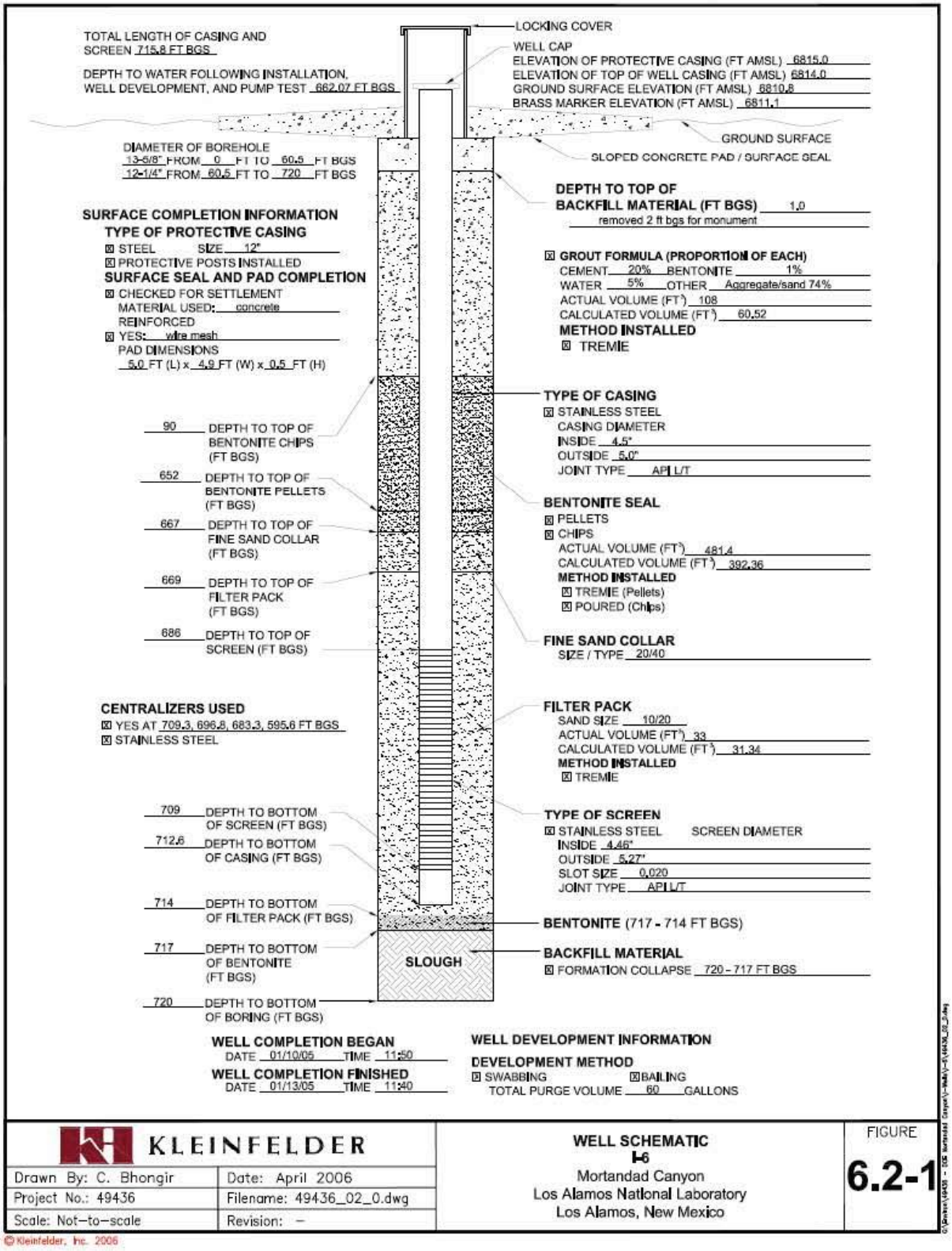

KLEINFELDER		WELL SCHEMATIC I-6 Mortandad Canyon Los Alamos National Laboratory Los Alamos, New Mexico	FIGURE 6.2-1
Drawn By: C. Bhongir	Date: April 2006		
Project No.: 49436	Filename: 49436_02_0.dwg		
Scale: Not-to-scale	Revision: -		

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APPENDIX F

GEOLOGY

TABLE OF CONTENTS

1. SOIL INFORMATION
   - TYPIC EUTROBORALFS, SL - ALANOS
   - LITHIC HAPLUSTALFS, SL - HACKROY

2. GEOTECHNICAL INVESTIGATIONS:
   - TA-50 RADIOACTIVE LIQUID WASTE TREATMENT FACILITY
   - TA-50-0250 WASTE MITIGATION RISK MANAGEMENT (WMRM)
   - TA-52 ZERO LIQUID DISCHARGE SOLAR EVAPORATION TANKS

3. PLAN AND MAP VIEWS OF STRATIGRAPHIC UNITS BENEATH MDA C.

SOIL INFORMATION

TYPIC EUTROBORALFS

AND

LITHIC HAPLUSTALFS

Taxonomic Classification of the Soils

Sandoval County Area, New Mexico, Parts of Los Alamos, Sandoval, and Rio Arriba Counties

[An asterisk by the soil name indicates a taxadjunct to the series]

Soil name	Family or higher taxonomic classification
Alanos	Clayey-skeletal, mixed Typic Eutroboralfs
Hackroy	Clayey, mixed, mesic Lithic Haplustalfs
Mirand	Fine, mixed Mollic Eutroboralfs
Nyjack	Fine-loamy, mixed, mesic Aridic Haplustalfs

Map Unit Description (Brief, Generated)

Sandoval County Area, New Mexico, Parts of Los Alamos, Sandoval, and Rio Arriba Counties

[Minor map unit components are excluded from this report]

Map unit: 162 - Hackroy-Nyjack association, 1 to 5 percent slopes

Component: Hackroy (45%)

The Hackroy component makes up 45 percent of the map unit. Slopes are 1 to 5 percent. This component is on plateaus on uplands. The parent material consists of residuum weathered from tuff. Depth to a root restrictive layer, bedrock, lithic, is 8 to 20 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is very low. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the F036XB133NM Pinus Edulis/rhus Trilobata/bouteloua Gracilis ecological site. Nonirrigated land capability classification is 7s. This soil does not meet hydric criteria.

Component: Nyjack (40%)

The Nyjack component makes up 40 percent of the map unit. Slopes are 1 to 5 percent. This component is on mesas on uplands. The parent material consists of eolian deposits over slope alluvium derived from tuff. Depth to a root restrictive layer, bedrock, paralithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the F048AY011NM Pinus Ponderosa-Juniperus Scopulorum/quercus Gambelii ecological site. Nonirrigated land capability classification is 6c. This soil does not meet hydric criteria.

Map unit: 283 - Mirand-Alanos complex, 5 to 40 percent slopes

Component: Mirand (45%)

The Mirand component makes up 45 percent of the map unit. Slopes are 5 to 30 percent. This component is on mountain slopes on mountains. The parent material consists of colluvium derived from volcanic rock. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is low. Available water to a depth of 60 inches is high. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 65 percent. This component is in the F048AY010NM Pinus Ponderosa/festuca Arizonica-Danthonia Parryi ecological site. Nonirrigated land capability classification is 7c. This soil does not meet hydric criteria.

Component: Alanos (30%)

The Alanos component makes up 30 percent of the map unit. Slopes are 5 to 40 percent. This component is on mountain slopes on mountains. The parent material consists of slope alluvium over colluvium derived from volcanic rock. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately low. Available water to a depth of 60 inches is low. Shrink-swell potential is high. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the F048AY009NM Pseudotsuga Menziesii-Pinus Ponderosa/festuca Arizonica ecological site. Nonirrigated land capability classification is 7c. This soil does not meet hydric criteria.

2C horizon
Hue: 10YR or 7.5YR
Value: 5 to 7 when dry, and 4 to 6 when moist
Chroma: 3 or 4
Texture: sand, loamy sand, gravelly sand, or loamy fine sand
Salinity: from less than 2 to 16 mmhos/cm.

Note: The water table ranges from 4 to 6 feet.

Alanos Series

Map units: 283, 290
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes and hillsides
Parent material: slope alluvium and colluvium derived from tuff and rhyolite
Elevation: 7,800 to 9,500 feet (2,377 to 2,896 meters)
Slope: 5 to 40 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Clayey-skeletal, mixed Typic Eutroboralfs

Typical Pedon

Alanos loam, in an area of mapping unit 290, Alanos-Rock outcrop complex, 20 to 40 percent slopes; Los Alamos County; Frijoles Quadrangle. NAD 83, UTM 13—03 78 360 E—39 67 869 N.

A—0 to 4 inches; grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; weak fine granular structure; soft, very friable, slightly sticky and nonplastic; many fine and medium roots; 10 percent gravel; neutral; abrupt smooth boundary.
E—4 to 9 inches; light gray (10YR 7/2) loam, grayish brown (10YR 5/2) moist; weak fine granular structure; slightly hard, very friable, nonsticky and nonplastic; common fine roots; few fine vesicular pores; 10 percent gravel; neutral; abrupt smooth boundary.
BE—9 to 18 inches; pinkish gray (7.5YR 7/2) and reddish brown (5YR 5/4) very gravelly loam, brown (7.5YR 5/2) and reddish brown (5YR 4/4) moist; weak fine subangular blocky structure; hard, very friable, slightly sticky and slightly plastic; common very fine roots; common fine black (5YR 2/1) iron and manganese concretions; 55 percent gravel; medium acid; clear smooth boundary.
Bt1—18 to 26 inches; reddish brown (5YR 5/4) extremely gravelly clay, reddish brown (5YR 4/4) moist; weak fine subangular blocky structure; hard, firm, sticky and plastic; few fine roots; few fine tubular pores; common fine black (5YR 2/1) iron and manganese concretions; common thin clay films in pores and on gravel; 20 percent cobbles and 55 percent gravel; medium acid; clear smooth boundary.
Bt2—26 to 60 inches; brown (7.5YR 5/4) extremely gravelly clay, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; few fine roots; few fine tubular pores; few thin clay films in pores and on gravel; 20 percent cobbles and 55 percent gravel; medium acid.

Range in Characteristics

Particle-size control section: 35 to 55 percent clay
Other features: Some pedons are slightly alkaline in the lower subhorizons.

A horizon
Hue: 7.5YR or 10YR
Value: 5 or 6 dry, 3 to 5 moist
Chroma: 2 or 3
Texture: loam or cobbly loam

E horizon
Hue: 7.5YR or 10YR
Value: 6 or 7 dry, 4 or 5 moist
Chroma: 2 to 4
Texture: loam, gravelly loam, or cobbly loam

Bt horizon
Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 3 to 6 moist
Chroma: 2 to 6
Texture: extremely gravelly clay loam, extremely gravelly clay, or very gravelly clay
Concretions: fine or medium iron and manganese concretions are in the upper part of the Bt horizon.

Note: C horizons are below 38 inches in some pedons.

Atarque Series

Map units: 324, 396
Depth class: very shallow to shallow
Drainage class: well drained
Landform: breaks; dipslopes of cuestas, hills, mesas, and ridges
Parent material: slope alluvium derived from sandstone and shale
Elevation: 5,700 to 6,600 feet (1,737 to 2,012 meters)
Slope: 5 to 45 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Loamy, mixed, mesic Lithic Haplustalfs

Typical Pedon

Atarque sandy loam, in an area of mapping unit 324, Rock outcrop-Atarque-Menefee complex, 5 to 25 percent slopes; Sandoval County; Ponderosa Quadrangle; about 2 miles northeast of the Jemez Pueblo; 200 feet south and 1,400 feet east of the northwest corner of sec. 11, T 16 N, R 2 E. NAD 27; UTM 13—03 45 805 E—39 44 974 N.

A—0 to 3 inches; light brown (7.5YR 6/4) sandy loam, dark brown (7.5YR 4/4) moist; moderate very thin platy structure; soft, very friable, nonsticky and nonplastic; many very fine roots; neutral; clear smooth boundary.
Bt—3 to 9 inches; reddish brown (5YR 5/4) sandy clay loam, reddish brown (5YR 4/4) moist; moderate fine and medium subangular blocky structure; hard, firm, sticky and plastic; common very fine roots; many very fine tubular pores; many thin clay films on faces of peds and lining pores; neutral; clear smooth boundary.

Bk2—17 to 45 inches; white (N 8/0) and very pale brown (10YR 8/3) extremely gravelly sandy loam, light gray (10YR 7/2) and very pale brown (10YR 7/3) moist; massive; hard, firm, nonsticky and nonplastic; weakly cemented; few fine roots; few fine tubular pores; strongly effervescent; calcium carbonate and siliceous material dominant throughout entire horizon causing 90 percent weak cementation, interrupted only by fractures less than 3 mm wide and less than 4 inches apart; 5 percent cobbles and 60 percent gravel; moderately alkaline; diffuse irregularly boundary.

Bk3—45 to 60 inches; very pale brown (10YR 7/3) very gravelly sandy loam, pale brown (10YR 6/3) moist; massive; soft, very friable, nonsticky and nonplastic; few fine roots; 5 percent cobbles and 50 percent gravel; strongly effervescent; calcium carbonate disseminated throughout and engulfing coarse fragments; moderately alkaline.

Range in Characteristics

Particle-size control section: 5 to 15 percent clay
Depth to the weakly cemented horizon: 12 to 26 inches

A horizon
Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 3 to 5 moist
Chroma: 2 to 4

B horizons
Hue: 7.5YR or 10YR
Value: 5 to 8 dry, 4 to 7 moist
Chroma: 0 to 4
Texture: gravelly, very gravelly, and extremely gravelly sandy loams

Hackroy Series

Map units: 21, 162
Depth class: very shallow to shallow
Drainage class: well drained
Landform: summits of mesas and plateaus
Parent material: residuum from tuff
Elevation: 6,000 to 7,200 feet (1,829 to 2,195 meters)
Slope: 1 to 8 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Clayey, mixed, mesic Lithic Haplustalfs

Typical Pedon

Hackroy sandy loam, in an area of mapping unit 162, Hackroy-Nyjack association, 1 to 5 percent slopes; Los Alamos County; White Rock Quadrangle; on the east end of Ancho Canyon Trail; unsectionized; NAD 83, UTM 13—03 87 647 E—39 61 208 N.

A—0 to 3 inches; brown (10YR 5/3) sandy loam, brown (10YR 4/3) moist; weak fine subangular blocky structure; hard, friable, nonsticky and nonplastic; many fine roots; common fine tubular pores; slightly alkaline; abrupt smooth boundary.

Bt—3 to 13 inches; reddish brown (5YR 4/4) clay, dark reddish brown (5YR 3/4) moist; moderate fine prismatic structure; hard, firm, sticky and plastic; many fine roots; few very fine tubular pores; 3 percent gravel; continuous clay films on faces of peds; slightly alkaline; abrupt smooth boundary.
2R—13 inches; tuff.

Range in Characteristics

Particle-size control section: 35 to 50 percent clay
Depth to lithic contact: 8 to 20 inches

A horizon
Hue: 7.5YR or 10YR
Value: 4 or 6 dry, 2 to 4 moist
Chroma: 2 to 4

Bt1 horizon
Hue: 7.5YR or 5YR
Value: 3 to 6 dry, 3 or 4 moist
Chroma: 4 or 6, dry or moist

Hagerman Series

Map units: 227, 240
Depth class: moderately deep
Drainage class: well drained
Landform: hills, mesas and ridges
Parent material: eolian material and alluvium derived from sandstone
Elevation: 5,700 to 6,400 feet (1,737 to 1,951 meters)
Slope: 1 to 5 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine-loamy, mixed, mesic Ustollic Haplargids

Typical Pedon

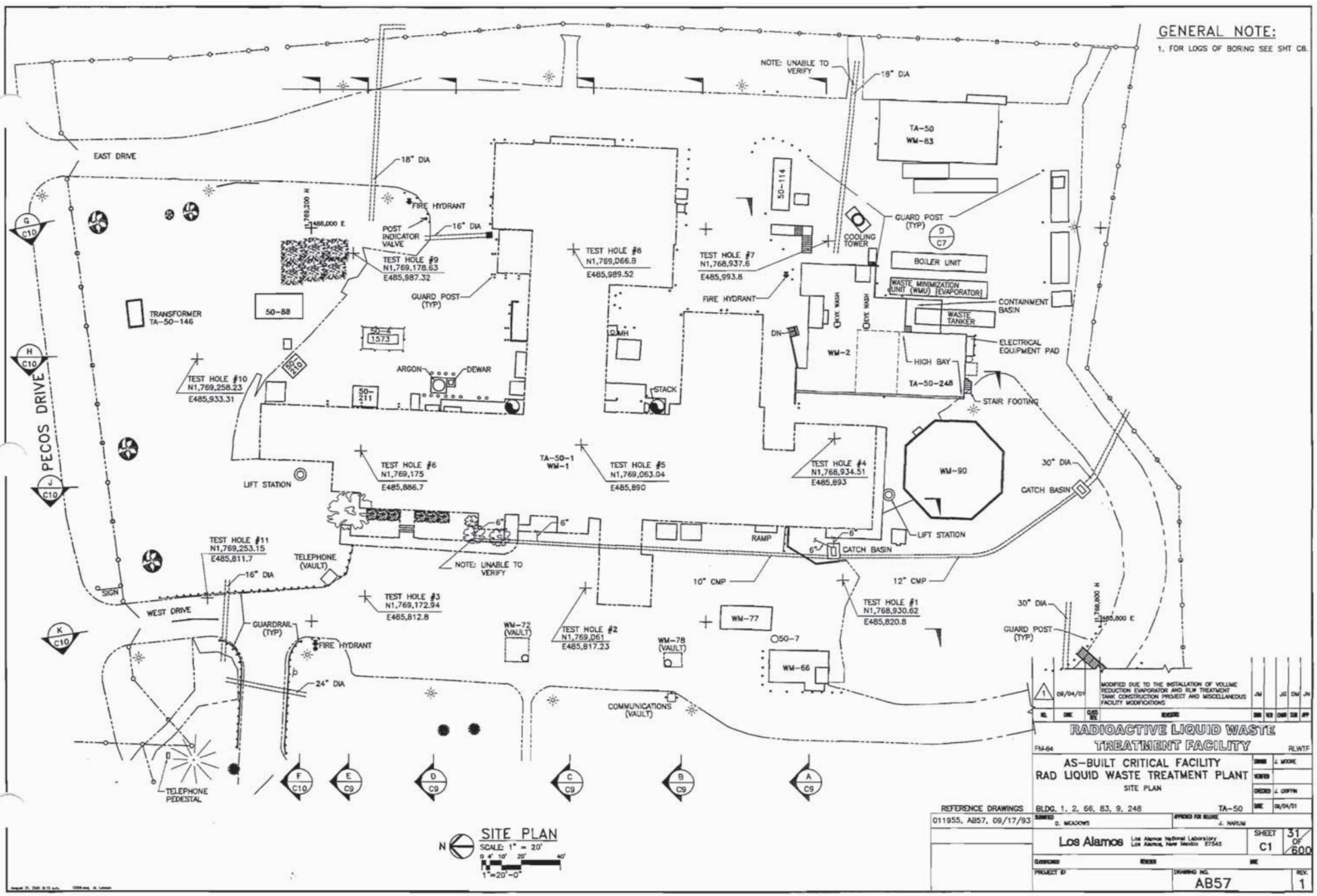
Hagerman fine sandy loam, in an area of mapping unit 240, Penistaja-Hagerman association, 1 to 5 percent slopes; Sandoval County; Cabezon Peak Quadrangle; about 1.5 miles southeast of the Rio Puerco along the Gas Company of New Mexico pipeline; unsectionized; NAD 83, UTM 13—03 13 428 E—39 43 499 N.

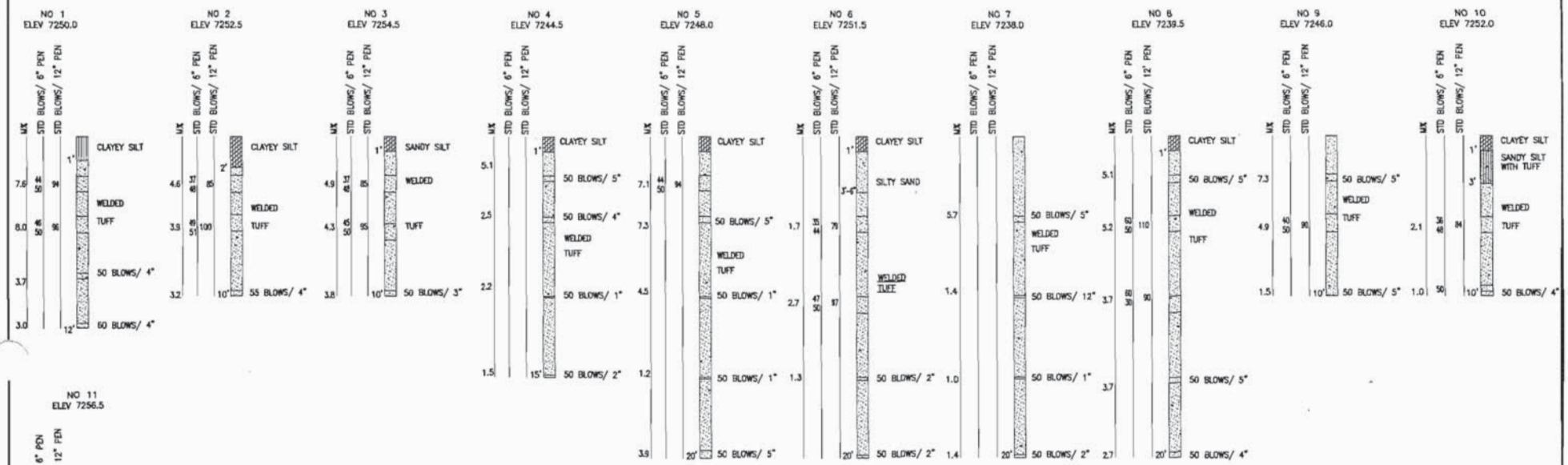
A—0 to 2 inches; brown (7.5YR 5/4) fine sandy loam, dark brown (7.5YR 4/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; common medium and many fine roots; moderately alkaline; clear smooth boundary.
Bt—2 to 9 inches; brown (7.5YR 4/4) clay loam, dark brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, firm, sticky and plastic; common medium and many fine roots; thin continuous clay films on faces of peds; moderately alkaline; clear smooth boundary.
Btk—9 to 24 inches; light brown (7.5YR 6/4) clay loam, brown (7.5YR 5/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; few medium and many fine roots; few thin clay films on faces of peds; strongly effervescent; few fine accumulations of calcium carbonate; moderately alkaline; clear smooth boundary.
2R—24 inches; sandstone.

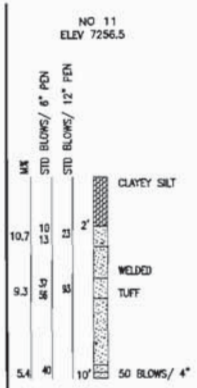
TA-50 RLWTF

GEOTECHNICAL INVESTIGATION

SITE MAP AND BORE LOGS


GENERAL NOTE:
1. FOR LOGS OF BORING SEE SHT C8.
EAST DRIVE
PECOS DRIVE
WEST DRIVE
NOTE: UNABLE TO VERIFY
18" DIA
16" DIA
24" DIA
30" DIA
FIRE HYDRANT
POST INDICATOR VALVE
TEST HOLE #9 N1,769,178.63 E485,987.32
TEST HOLE #8 N1,769,066.8 E485,989.52
TEST HOLE #7 N1,768,937.6 E485,993.8
TEST HOLE #10 N1,769,258.23 E485,933.31
TEST HOLE #6 N1,769,175 E485,886.7
TEST HOLE #5 N1,769,063.04 E485,890
TEST HOLE #4 N1,768,934.51 E485,893
TEST HOLE #11 N1,769,253.15 E485,811.7
TEST HOLE #3 N1,769,172.94 E485,812.8
TEST HOLE #2 N1,769,061 E485,817.23
TEST HOLE #1 N1,768,930.62 E485,820.8
TRANSFORMER TA-50-146
50-88
50-4 1573
50-210
50-211
50-114
50-7
ARGON
DEWAR
STACK
LIFT STATION
TELEPHONE (VAULT)
TELEPHONE PEDESTAL
GUARDRAIL (TYP)
GUARD POST (TYP)
COOLING TOWER
BOILER UNIT
WASTE MINIMIZATION UNIT (WMU) EVAPORATOR
CONTAINMENT BASIN
WASTE TANKER
ELECTRICAL EQUIPMENT PAD
HIGH BAY
TA-50-248
STAIR FOOTING
TA-50 WM-83
WM-2
WM-90
WM-77
WM-66
WM-72 (VAULT)
WM-78 (VAULT)
TA-50-1 WM-1
RAMP
CATCH BASIN
10" CMP
12" CMP
COMMUNICATIONS (VAULT)
SIGN
SITE PLAN
SCALE: 1" = 20'
1"=20'-0"
REFERENCE DRAWINGS
011955, AB57, 09/17/93
1 09/04/01 MODIFIED DUE TO THE INSTALLATION OF VOLUME REDUCTION EVAPORATOR AND RLW TREATMENT TANK CONSTRUCTION PROJECT AND MISCELLANEOUS FACILITY MODIFICATIONS
RADIOACTIVE LIQUID WASTE TREATMENT FACILITY
FM-64
RLWTF
AS-BUILT CRITICAL FACILITY
RAD LIQUID WASTE TREATMENT PLANT
SITE PLAN
BLDG. 1, 2, 66, 83, 9, 248
TA-50
J. MOORE
J. GRIFFIN
09/04/01
D. MEADOWS
J. NARUM
Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545
SHEET C1
31 OF 600
PROJECT ID
DRAWING NO. AB57
REV. 1





LOGS OF BORING

STD BLOWS/ 12" PEN	THE NUMBER OF BLOWS REQUIRED TO DRIVE A 2 INCH OUTSIDE DIAMETER, 1.3750 INCH INSIDE DIAMETER STANDARD SPLIT SPOON SAMPLER THRU A VERTICAL DISTANCE OF 1-FOOT, USING A 140# HAMMER WITH A FREE FALL OF 30 INCHES, UNLESS OTHERWISE NOTED.
STD BLOWS/ 6" PEN	PENETRATION COUNT AT 6 INCH VERTICAL INTERVALS
M%	MOISTURE CONTENT IN PER CENT

GENERAL NOTES:

1. WATER TABLE NOT ENCOUNTERED IN ANY TEST HOLE
2. TEST HOLE BORINGS WERE MADE DURING APRIL, 1961 WITH 4 INCH POWER AUGER
3. FOR LOCATION OF TEST HOLES, SEE SHEET C1
4. NOT AS-BUILT VERIFIED

NO.	DATE	CLASS REV.	REVISION	DRN	VER	CHKD	SUB	APP
1	09/04/01		GENERAL REVISIONS	JM		JG	DM	JN

RADIOACTIVE LIQUID WASTE TREATMENT FACILITY

FM-84 RLWTF

AS-BUILT CRITICAL FACILITY
RAD LIQUID WASTE TREATMENT PLANT
LOGS OF BORING

DRAWN: C. BINKLEY
VERIFIED:
CHECKED: J. GRIFFIN
DATE: 09/04/01

REFERENCE DRAWINGS
011955, AB57, 09/17/93

BLDG. 1 TA-50

SUBMITTED: D. MEADOWS
APPROVED FOR RELEASE: J. NARUM

Los Alamos — Los Alamos National Laboratory, Los Alamos, New Mexico 87545

SHEET C8 38 OF 600

CLASSIFICATION REVIEWED NAME

PROJECT ID

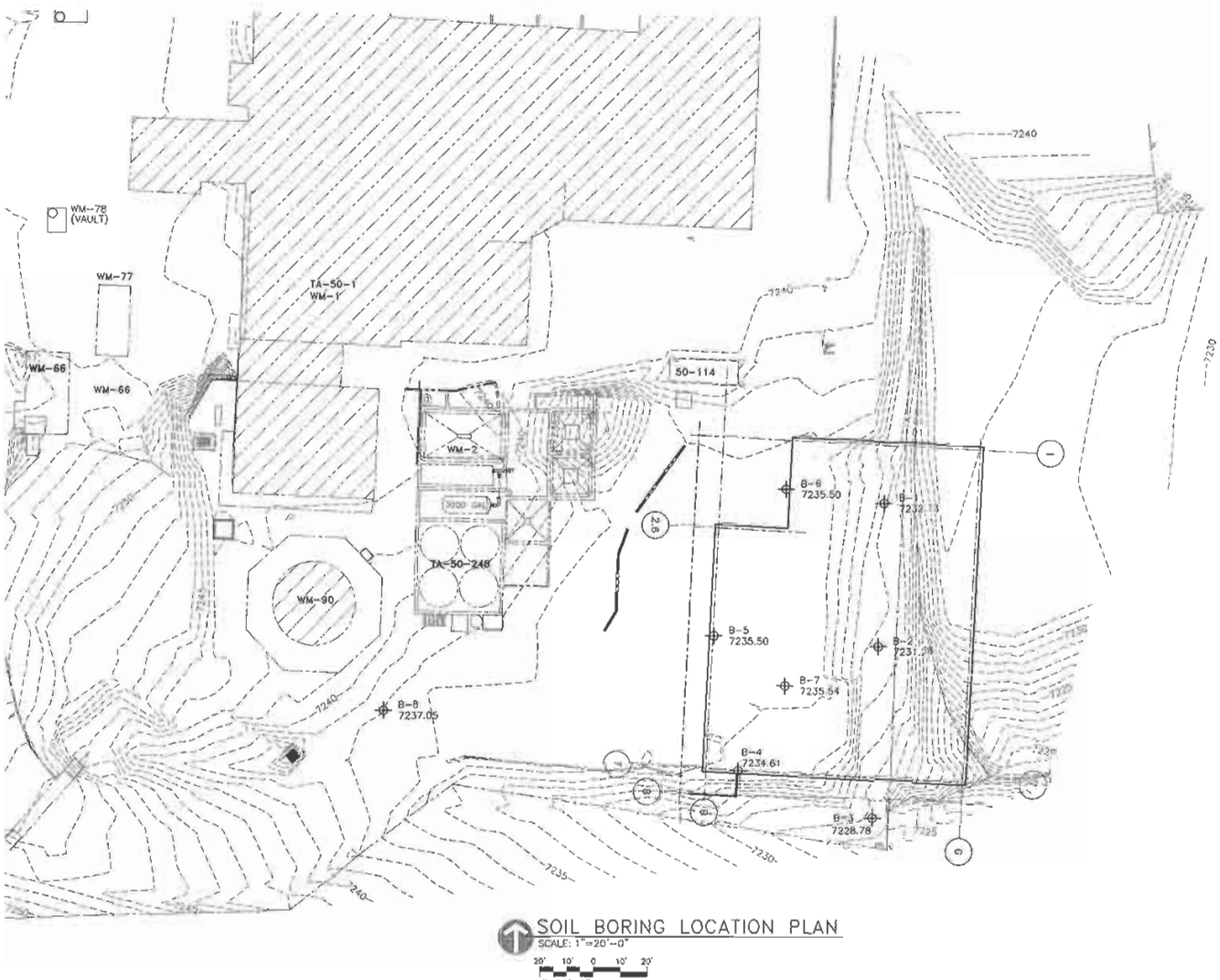
DRAWING NO. AB57

REV. 1

TA-50-250 WMRM

GEOTECHNICAL INVESTIGATION

SITE MAP AND BORE LOGS



SOIL BORING LOCATION PLAN
SCALE: 1"=20'-0"
20' 10' 0 10' 20'
1"=20'-0"

GENERAL NOTES

1. SOIL BORINGS WERE DRILLED BY KLEINFELDER, INC. INFORMATION SHOWN HERE IS REPORTED IN GREATER DETAIL IN THE SOILS REPORT PREPARED BY KLEINFELDER, INC. JOB No 59-0010145.001 AND DATED JANUARY 15, 2001, WHICH IS REPRODUCED IN THE SPECIFICATIONS OF THIS CONTRACT.
2. SUCH INFORMATION IS NOT A WARRANTY OF SUBSURFACE CONDITIONS AND MAY NOT REFLECT SUBSURFACE CONDITIONS OVER THE ENTIRE PROPOSED CONSTRUCTION AREA. THE CONTRACTOR SHALL BE RESPONSIBLE FOR HIS/HER INTERPRETATIONS AND USE OF THE INFORMATION. ALSO NOTE GENERAL PROVISIONS "SITE INVESTIGATION AND CONDITIONS AFFECTING THE WORK".
3. THE AVAILABILITY OR USE OF THE SOILS INVESTIGATION REPORT AND LOGS OF TEST BORINGS SHALL NOT BE CONSTRUED AS A WAVER OF THE CONTRACTORS DUTY TO EXAMINE THE SITE AND THE CONDITIONS AFFECTING THE WORK, AND DOES NOT RELIEVE THE CONTRACTOR FROM THE RISK OF SOIL OR SUBSURFACE CONDITIONS WHICH COULD REASONABLY BE ANTICIPATED OR FROM PROPERLY FULFILLING THE TERMS OF THE CONTRACT.
4. IF THIS SHEET IS NOT 24 X 36, THEN IT IS A REDUCED SIZE PLOT. USE GRAPHIC SCALE ACCORDINGLY.

NO	DATE	CLASS REV	DESCRIPTION	DWN	DES	CHKD	SUB	APP
0	10/07/04	U	ISSUED FOR CONSTRUCTION	SS	HC	DJM	DJW	JJ

THE AUSTIN COMPANY
CONSULTANTS • DESIGNERS • ENGINEERS • CONSTRUCTORS

TA-50 PUMP HOUSE AND INFLUENT STORAGE FACILITY

SOIL BORING LOCATION PLAN

BLDG. 250 TA-50

DRAWN	S SHARP
DESIGN	D McGREGOR
CHECKED	H COLBURN
DATE	10/07/04

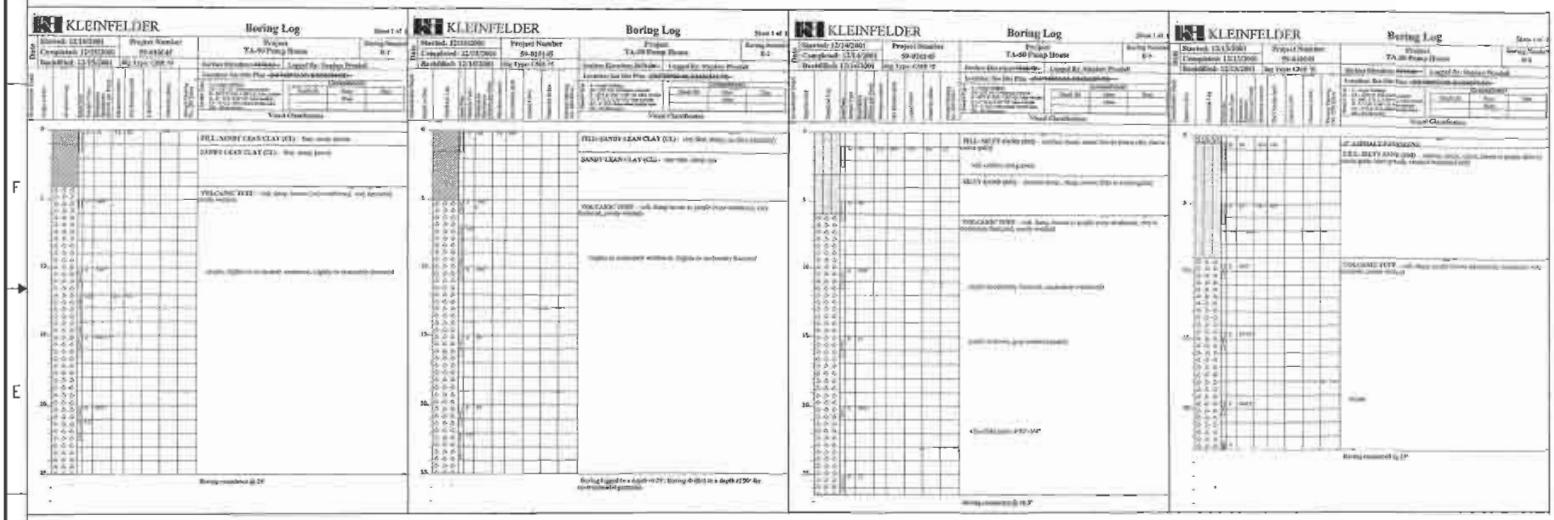
SUBMITTED AUTHORITY TO RELEASE DATE RECORDS
APPROVED FOR RELEASE PROJECT TEAM LEADER JIM JONES

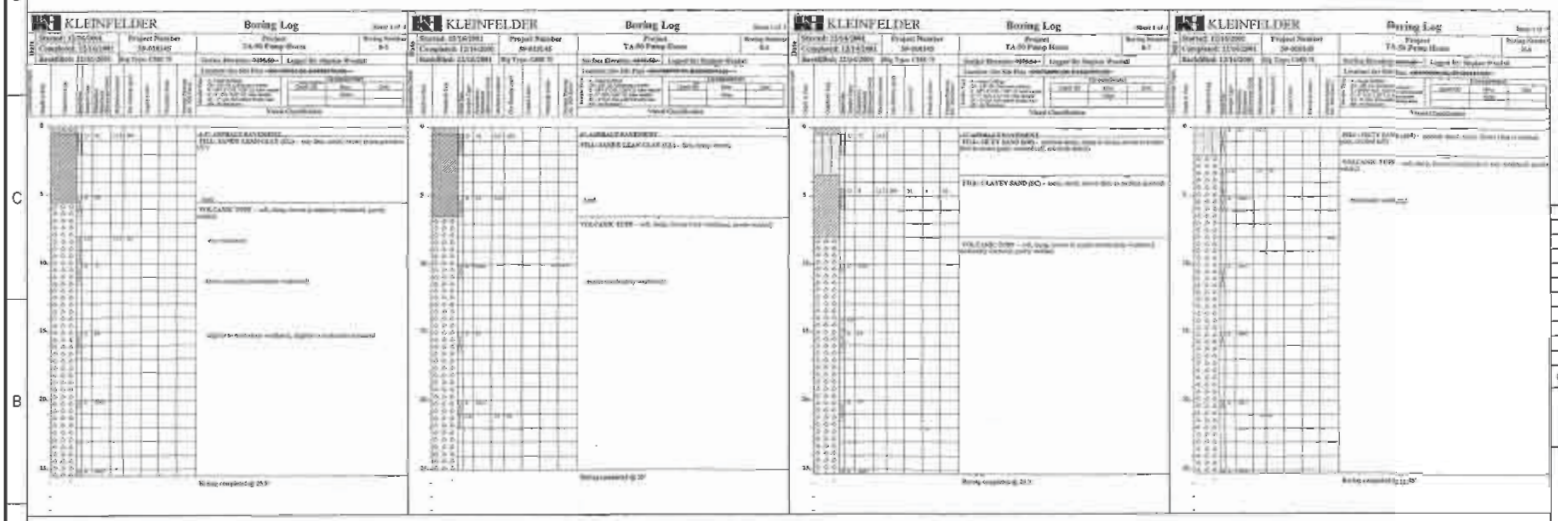
Los Alamos NATIONAL LABORATORY PO Box 1663 Los Alamos, New Mexico 87545

SHEET C-1000
7 OF 194

CLASSIFICATION U
REVIEWER
DATE 10/13/04
PROJECT ID 100145
DRAWING NO C53029
REV 0

10-8-04





GENERAL NOTES

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2. SUCH INFORMATION IS NOT A WARRANTY OF SUBSURFACE CONDITIONS AND MAY NOT REFLECT SUBSURFACE CONDITIONS OVER THE ENTIRE PROPOSED CONSTRUCTION AREA. THE CONTRACTOR SHALL BE RESPONSIBLE FOR HIS/HER INTERPRETATIONS AND USE OF THE INFORMATION. ALSO NOTE GENERAL PROVISIONS "SITE INVESTIGATION AND CONDITIONS AFFECTING THE WORK".
3. THE AVAILABILITY OR USE OF THE SOILS INVESTIGATION REPORT AND LOGS OF TEST BORINGS SHALL NOT BE CONSTRUED AS A WAVER OF THE CONTRACTORS DUTY TO EXAMINE THE SITE AND THE CONDITIONS AFFECTING THE WORK, AND DOES NOT RELIEVE THE CONTRACTOR FROM THE RISK OF SOIL OR SUBSURFACE CONDITIONS WHICH COULD REASONABLY BE ANTICIPATED OR FROM PROPERLY FULFILLING THE TERMS OF THE CONTRACT.
4. BORING LOGS SHOWN HERE ARE ALSO INCLUDED IN VOL. 1 of 3 OF DESIGN SUBSTANTIATION DOCUMENTS UNDER SECTION #1.

REVISED BORING LOG COORDINATES AND ELEVATIONS

Exploratory Boring	Northing (ft)	Easting (ft)	Elevation (ft)
B-1	1769765.74719568	1627282.35742702	7232.13
B-2	1769712.59331194	1627060.12842683	7231.28
B-3	1769648.29452926	1627057.62530023	7228.78
B-4	1769666.15252320	1627007.67294656	7234.91
B-5	1769716.47604956	1626888.48893146	7235.99
B-6	1769771.00946131	1627005.72100762	7236.96
B-7	1769697.86871073	1627025.44090222	7235.54
B-8	1769688.84288021	1626875.27309144	7237.05

NO	DATE	CLASS REV	DESCRIPTION	DWN	DES	CHKD	SUB	APP
0	10/07/04	U	ISSUED FOR CONSTRUCTION	SS	HC	DJM	BJW	JJ

THE AUSTIN COMPANY
CONSULTANTS • DESIGNERS • ENGINEERS • CONSTRUCTORS

TA-50 PUMP HOUSE AND INFLUENT STORAGE FACILITY

SOIL BORING LOGS

BLDG. 250 TA-50

DRAWN	S SHARP
DESIGN	D McGREGOR
CHECKED	H COLBURN
DATE	10/07/04

SUBMITTED
AUTHORITY TO RELEASE DAN WIEGANDT
APPROVED FOR RELEASE
PROJECT TEAM LEADER JIM JONES

Los Alamos NATIONAL LABORATORY PO Box 1663 Los Alamos, New Mexico 87545

SHEET C-1001
8 OF 194

CLASSIFICATION U
REVIEWER
DATE 10/13/04

PROJECT ID 100145
DRAWING NO C53029
REV 0

10-8-04

TA-52 ZERO LIQUID DISCHARGE (ZLD) SOLAR EVAPORATION TANKS

GEOTECHNICAL INVESTIGATION

BORE LOGS

DATE DRILLED: 6-13-11
LOCATION: See Location Diagram
ELEVATION: Not Determined

BORING NO. 1

EQUIPMENT TYPE: CME-75
DRILLING TYPE: 7"HSA
FIELD ENGINEER: S. DeWeese

MOISTURE CONTENT (% OF DRY WT.)	DRY DENSITY (LBS/CU FT)	SAMPLE TYPE	SAMPLE	BLOW COUNTS	DEPTH (FEET)	USCS	GRAPHIC	SOIL DESCRIPTION
4.2		N		23		SM		SILTY SAND; slightly clayey, very fine, light brown, medium dense, dry
3.0		N		65				TUFF; slightly weathered, light gray with some light brown, intensely fractured, thinly bedded, moderately hard, dry
3.9		N		88	5			
0.6		N		61				fresh, light gray, thickly bedded, hard
0.7		N		64	10			slightly weathered, some brown, thinly bedded, moderately hard
0.5		N		71	15			fresh, light gray, thickly bedded
1.2		N		50/4"	20			slightly weathered, some brown, very fractured, thinly bedded, hard
1.0		N		48	25			intensely fractured, moderately hard
								BORING TERMINATED AT 26.5 FEET

THIS SUMMARY APPLIES ONLY AT THIS LOCATION AND AT THE TIME OF LOGGING. CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH TIME. DATA PRESENTED IS A SIMPLIFICATION.

N- STANDARD PENETRATION TEST
R- RING SAMPLE
NR- NO SAMPLE RECOVERY
G- GRAB SAMPLE
B- BUCKET SAMPLE

NOTES: **Groundwater Not Encountered**

WESTERN TECHNOLOGIES INC.

PROJECT: ZERO LIQUID DISCHARGE PROJECT - LANL
REF. NO.: 3221JJ103

PLATE
A - 4

BORING LOG

DATE DRILLED: 6-13-11
LOCATION: See Location Diagram
ELEVATION: Not Determined

BORING NO. 2

EQUIPMENT TYPE: CME-75
DRILLING TYPE: 7"HSA
FIELD ENGINEER: S. DeWeese

MOISTURE CONTENT (% OF DRY WT.)	DRY DENSITY (LBS/CU FT)	SAMPLE TYPE	SAMPLE	BLOW COUNTS	DEPTH (FEET)	USCS	GRAPHIC	SOIL DESCRIPTION
4.9		N		29		SM		SILTY SAND; slightly clayey, very fine, brown, medium dense, dry to slightly damp
3.7		G						
2.3		N		62				TUFF; fresh, light gray, intensely fractured, thickly bedded, moderately hard, dry
2.4		N		66	5			slightly weathered, hard
1.4		N		74				fresh
1.3		N		75	10			moderately hard
0.7		N		71	15			
0.3		N		47	20			
0.3		N		35	25			
								BORING TERMINATED AT 26.5 FEET

THIS SUMMARY APPLIES ONLY AT THIS LOCATION AND AT THE TIME OF LOGGING. CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH TIME. DATA PRESENTED IS A SIMPLIFICATION.

N- STANDARD PENETRATION TEST
R- RING SAMPLE
NR- NO SAMPLE RECOVERY
G- GRAB SAMPLE
B- BUCKET SAMPLE

NOTES: **Groundwater Not Encountered**

WESTERN TECHNOLOGIES INC.

PROJECT: ZERO LIQUID DISCHARGE PROJECT - LANL
REF. NO.: 3221JJ103

PLATE
A - 5

BORING LOG

DATE DRILLED: 6-13-11
LOCATION: See Location Diagram
ELEVATION: Not Determined

BORING NO. 3

EQUIPMENT TYPE: CME-75
DRILLING TYPE: 7"HSA
FIELD ENGINEER: S. DeWeese

MOISTURE CONTENT (% OF DRY WT.)	DRY DENSITY (LBS/CU FT)	SAMPLE TYPE	SAMPLE	BLOW COUNTS	DEPTH (FEET)	USCS	GRAPHIC	SOIL DESCRIPTION
12.7		N		13		SM		SILTY SAND; with some clay, brown, loose, slightly damp
5.4		G						
13.6	89	R		50/5.5"				some tuff, brown with light gray, very dense
0.4		N		60	5			TUFF; fresh, light gray, intensely fractured, thinly bedded, moderately hard, dry
0.8		N		56				
1.5		N		43	10			
0.9		N		34	15			
13.6		N		20	20			slightly weathered, with clay interbedded, light gray with brown
27.2		N		14	25	CL		CLAY; with caliche, brown and tan, medium dense, damp
								BORING TERMINATED AT 26.5 FEET

N- STANDARD PENETRATION TEST
R- RING SAMPLE
NR- NO SAMPLE RECOVERY
G- GRAB SAMPLE
B- BUCKET SAMPLE

NOTES: **Groundwater Not Encountered**

THIS SUMMARY APPLIES ONLY AT THIS LOCATION AND AT THE TIME OF LOGGING. CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH TIME. DATA PRESENTED IS A SIMPLIFICATION.

WESTERN TECHNOLOGIES INC.

PROJECT: ZERO LIQUID DISCHARGE PROJECT - LANL
REF. NO.: 3221JJ103

BORING LOG

PLATE
A - 6

DATE DRILLED: 6-13-11
LOCATION: See Location Diagram
ELEVATION: Not Determined

BORING NO. 4

EQUIPMENT TYPE: CME-75
DRILLING TYPE: 7"HSA
FIELD ENGINEER: S. DeWeese

MOISTURE CONTENT (% OF DRY WT.)	DRY DENSITY (LBS/CU FT)	SAMPLE TYPE	SAMPLE	BLOW COUNTS	DEPTH (FEET)	USCS	GRAPHIC	SOIL DESCRIPTION
7.0		N		32		SM		SILTY SAND; with some clay and caliche, brown and tan, dense, dry to slightly damp
3.9		G						
4.3		N		49				TUFF; fresh, light gray, intensely fractured, thinly bedded, moderately hard, dry
1.4		N		55	5			
1.5		N		80				
2.8		N		67	10			
0.1		N		50/6"	15			
0.3		N		76	20			
0.1		N		44	25			
								BORING TERMINATED AT 26.5 FEET

THIS SUMMARY APPLIES ONLY AT THIS LOCATION AND AT THE TIME OF LOGGING. CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH TIME. DATA PRESENTED IS A SIMPLIFICATION.

N- STANDARD PENETRATION TEST
R- RING SAMPLE
NR- NO SAMPLE RECOVERY
G- GRAB SAMPLE
B- BUCKET SAMPLE

NOTES: **Groundwater Not Encountered**

WESTERN TECHNOLOGIES INC.

PROJECT: ZERO LIQUID DISCHARGE PROJECT - LANL
REF. NO.: 3221JJ103

PLATE
A - 7

BORING LOG

DATE DRILLED: 6-13-11
LOCATION: See Location Diagram
ELEVATION: Not Determined

BORING NO. 5

EQUIPMENT TYPE: CME-75
DRILLING TYPE: 7"HSA
FIELD ENGINEER: S. DeWeese

MOISTURE CONTENT (% OF DRY WT.)	DRY DENSITY (LBS/CU FT)	SAMPLE TYPE	SAMPLE	BLOW COUNTS	DEPTH (FEET)	USCS	GRAPHIC	SOIL DESCRIPTION
4.9		N		32		SM		SILTY SAND; with some clay, brown, dense, slightly damp
5.0		G						
2.8		N		45				TUFF; fresh, light gray, intensely fractured, thinly bedded, moderately hard, dry
0.9		N		51	5			
1.0		N		49				
0.9		N		57	10			
1.4		N		72	15			
1.7		N		50/6"	20			
1.6		N		71	25			
								BORING TERMINATED AT 26.5 FEET

N- STANDARD PENETRATION TEST
R- RING SAMPLE
NR- NO SAMPLE RECOVERY
G- GRAB SAMPLE
B- BUCKET SAMPLE

NOTES: **Groundwater Not Encountered**

THIS SUMMARY APPLIES ONLY AT THIS LOCATION AND AT THE TIME OF LOGGING. CONDITIONS MAY DIFFER AT OTHER LOCATIONS AND MAY CHANGE AT THIS LOCATION WITH TIME. DATA PRESENTED IS A SIMPLIFICATION.

WESTERN TECHNOLOGIES INC.

PROJECT: ZERO LIQUID DISCHARGE PROJECT - LANL
REF. NO.: 3221JJ103

BORING LOG

PLATE
A - 8

PLAN AND MAP VIEWS

STRATIGRAPHIC UNITS BENEATH MDA C

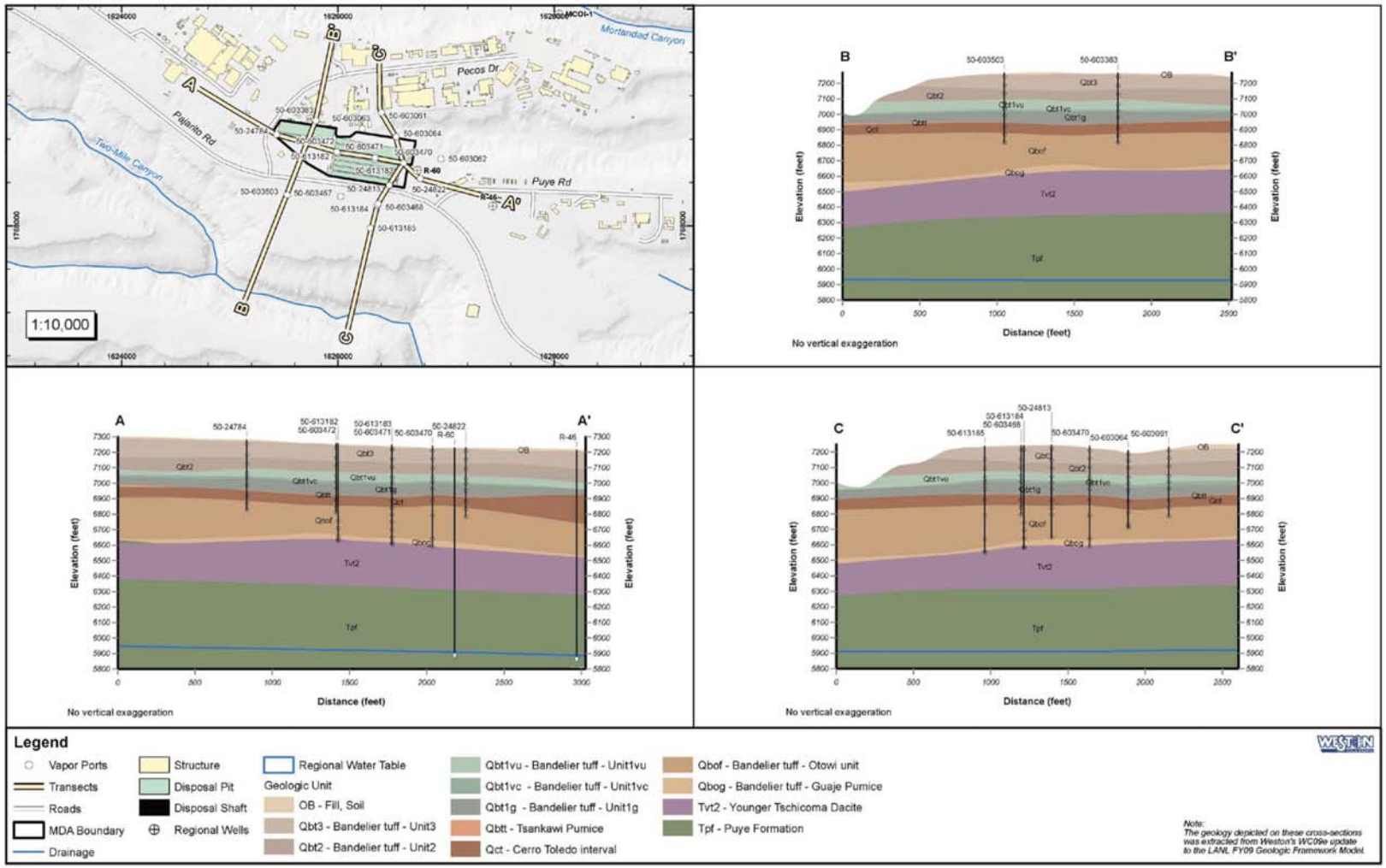

Figure 4.3-2 Plan and map views of stratigraphic units beneath MDA C. Also included are the locations of vapor-monitoring wells and ports as well as regional wells R-60 and R-46 and their well screen locations

APPENDIX G

CONTIGENCY PLAN

TA-50 RLWTF CONTINGENCY PLAN – DP-1132

PER THE JANUARY 27, 2012 NMED LETTER

(SEE APPENDIX A) GRANTING A 45-DAY EXTENSION,

THIS ITEM WILL BE ADDRESSED AND INFORMATION WILL BE SUBMITTED TO NMED UNDER SEPARATE COVER BY APRIL 2, 2012.

APPENDIX H

CLOSURE PLAN

TA-50 Radioactive Liquid Waste Treatment Facility (RLWTF)

Groundwater Discharge Permit Application (DP-1132)

Closure Plan and Post-Closure Monitoring

I. Closure

In the event that operations at the RLWTF should cease, and the facility is proposed to be permanently closed, the Permittees shall perform the following closure measures for systems of treatment and control associated with the facility:

- The collection system shall be decontaminated, and removed or plugged so that a discharge to the RLWTF can no longer occur.
- Wastewater shall be drained from the system components and disposed of in accordance with all local, state, and federal regulations.
- Disconnect and/or plug piping, tanks, and treatment units that could allow a discharge or leak of liquid wastewater.
- Solids shall be disposed of from treatment units and tanks, including, influent tanks, feed tanks, clarifiers, effluent tanks, wastewater storage tanks and other units. Removed solids shall be contained, transported, and disposed of in accordance with all local, state, and federal regulations. The Permittees shall maintain a record of all solids transported for off-site disposal.
- Tanks and components shall be removed and disposed of according to applicable local, state, and federal laws. Provided such tanks and components are not required to meet other local, state, or federal requirements. Re-grade the area with suitable fill to blend with surface topography and promote positive drainage to prevent ponding.
- In the event that evidence of leakage from piping, tanks, or treatment units is discovered during closure activities, the Permittees shall implement the contingency plan required by this Discharge Permit.

II. Post-Closure

1. Permittees shall continue to monitor groundwater wells as identified in the Discharge Permit, and at the same frequency required by the Discharge Permit for at least five years after closure.
2. If monitoring results show that a groundwater quality standard in Section 20.6.2.3103 NMAC are being exceeded; the Permittee shall implement the contingency plan required by this Discharge Permit.
3. Following notification from NMED that post-closure monitoring may cease, the Permittees may plug and abandon the monitoring well(s) provided that such monitoring wells are not required to meet another regulatory program, including the 2005 Order on Consent.
4. When all closure and post-closure requirements have been met, the Permittees may submit a written request for termination of the Discharge Permit to NMED.

[NMSA 1978, § 74-6-5.D, Subsection B of 20.6.2.3109 NMAC, Subsection A of 20.6.2.3107.

III. Reporting and Record-Keeping

1. After closure activities, the Permittees shall submit a Closure Report containing the following:
   a) Verification (photographic or narrative) that lines leading to the tanks and other units have been plugged or removed so that a discharge can no longer occur.
   b) A description of the volume and mass (dry weight) of residual solids removed from the tanks and other units and the ultimate disposal of the solids.
2. Permittees shall submit records of activities required for closure and post-closure as set forth in this Permit.

[NMSA 1978, § 74-6-5.D, Subsection B of 20.6.2.3109 NMAC, Subsection A of 20.6.2.3107 NMAC]

APPENDIX I

REFERENCED DOCUMENTS

TABLE OF CONTENTS

1. COMPACT DISC (CD) CONTAINING THE FOLLOWING DOCUMENTS:

   - LOS ALAMOS NATIONAL LABORATORY'S HYDROGEOLOGIC STUDIES OF THE PAJARITO PLATEAU: A SYNTHESIS OF HYDROGEOLOGIC WORKPLAN ACTIVITIES (1994-2004). LA-14263-MS.
   - 2009 HYDROGEOLOGIC SITE ATLAS. LAUR-09-3763.
   - GROUNDWATER LEVEL STATUS REPORT FOR 2010 LOS ALAMOS NATIONAL LABORATORY. LA-14437-PR.
   - CONCEPTUAL MODELS OF VADOSE ZONE FLOW AND TRANSPORT BENEATH THE PAJARITO PLATEAU, LOS ALAMOS, NEW MEXICO. VADOSE ZONE JOURNAL, VOL. 4, AUGUST 2005.
   - NRCS SOIL SURVEY OF SANDOVAL COUNTY AREA, NEW MEXICO, PARTS OF LOS ALAMOS, SANDOVAL, AND RIO ARRIBA COUNTIES.
   - 2006 MORTANDAD CANYON INVESTIGATION REPORT. LA-UR-06-6752
   - 2011 INTERIM FACILITY-WIDE GROUNDWATER MONITORING PLAN, REVISION 1. LA-UR-11-6958.

2. COMPACT DISC (CD) CONTAINING THE FOLLOWING DOCUMENT:
   - ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 2010. LA-14445-ENV.

APPENDIX J

MAPS

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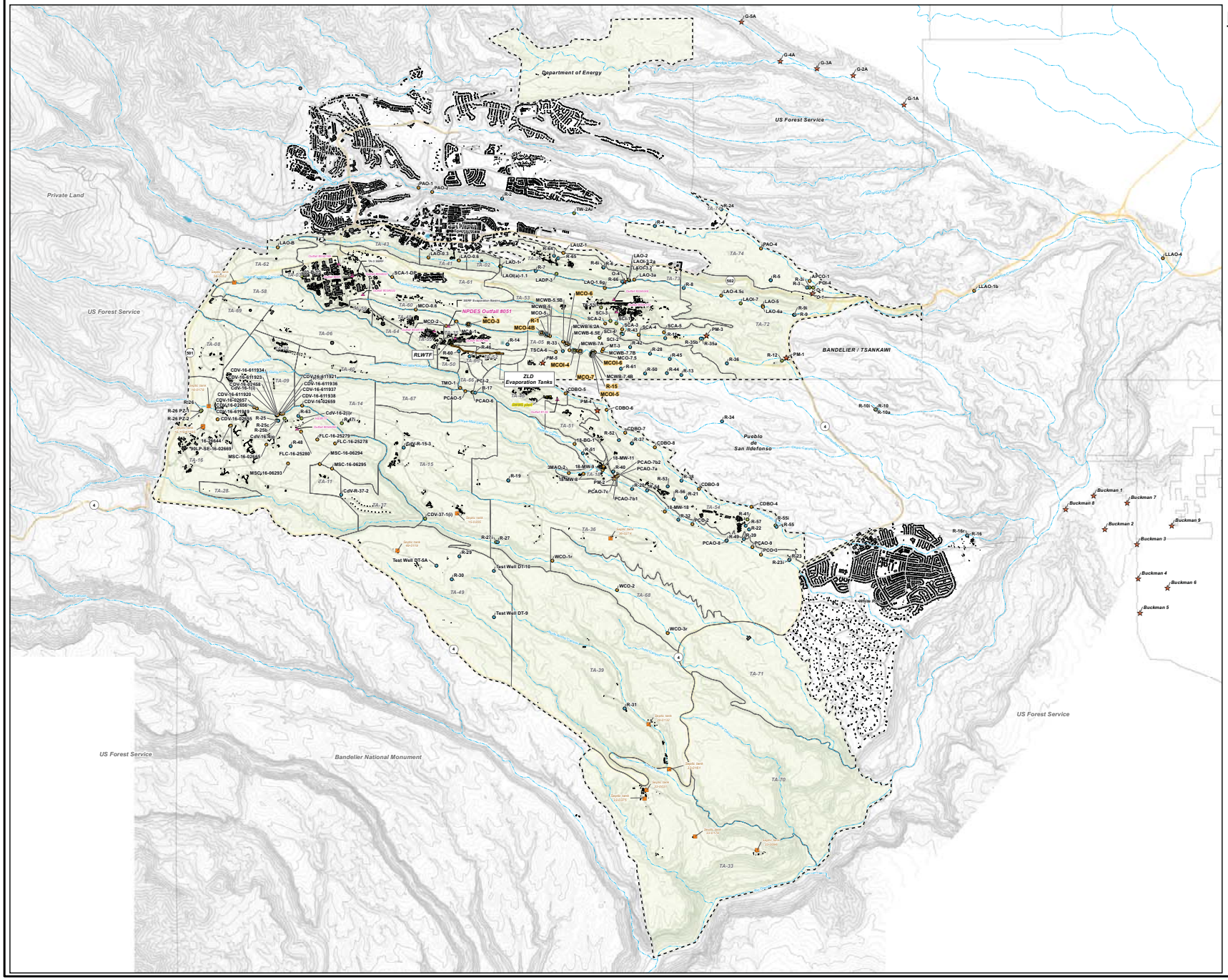
1. MAP #1 - LOCATION MAP WITH TREATMENT UNITS, LAGOONS, TANKS, ROADS, BUILDINGS, SUPPLY WELLS, MONITORING WELLS, CANYONS, WATER BODIES, PROPERTY BOUNDARIES, OTHER PERMITTED DISCHARGES, AND NORTH ARROW.

2. MAP #2 - TA-50 RLWTF, RLW COLLECTION SYSTEM, NPDES OUTFALL #051, TA-52 ZLD SOLAR EVAPORATION TANKS, AND 100-YEAR FLOOD PLAIN

3. MAP #3 - LANL SOILS MAP

4. MAP #4 - TA-50 RADIOACTIVE LIQUID WASTE TREATMENT FACILITY (RLWTF), STORM DRAIN SYSTEM MAP



Los Alamos National Laboratory

MAP #1
LA-UR-12-00672
ENV-DO-12-0005

- Proposed discharge permit monitoring wells
- NPDES outfall
- Septic tank
- Supply well
- Alluvial well
- Intermediate well
- Regional well
- Major roadway
- ZLD Line
- LANL boundary
- Technical boundary
- Ownership boundaries
- Structures
- SWWS Plant
- RLWTF
- HEWTF
- ZLD Evaporations Tanks

N

0 0.5 1 2 Miles
0 0.5 1 2 Kilometers

1:29,000

New Mexico State Plane Coordinates
Central Zone US Ft
North American Datum 1983
National Geodetic Datum 1929

Created by Winters Red Star, 18 October 2012,
Map # 12-009-05

DATA SOURCE:

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.

Technical Area Boundaries; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; September 2007; as published 04 December 2008.

Ownership Boundaries Around LANL Area; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; 19 September 2007; as published 04 December 2008.

WQH Drainage_arc; Los Alamos National Laboratory, ENV Water Quality and Hydrology Group; 1:24,000 Scale Data; 03 June 2003.

Ponds; County of Los Alamos, Information Services; as published 16 May 2006.

Sewer Line System; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.

Primary Industrial Waste Lines; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 15 January 2009.

Hypsography, 100, 20 Foot Contour Interval; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program; 1991.

LANL Areas Used and Occupied ; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; 19 September 2007; as published 04 December 2008.

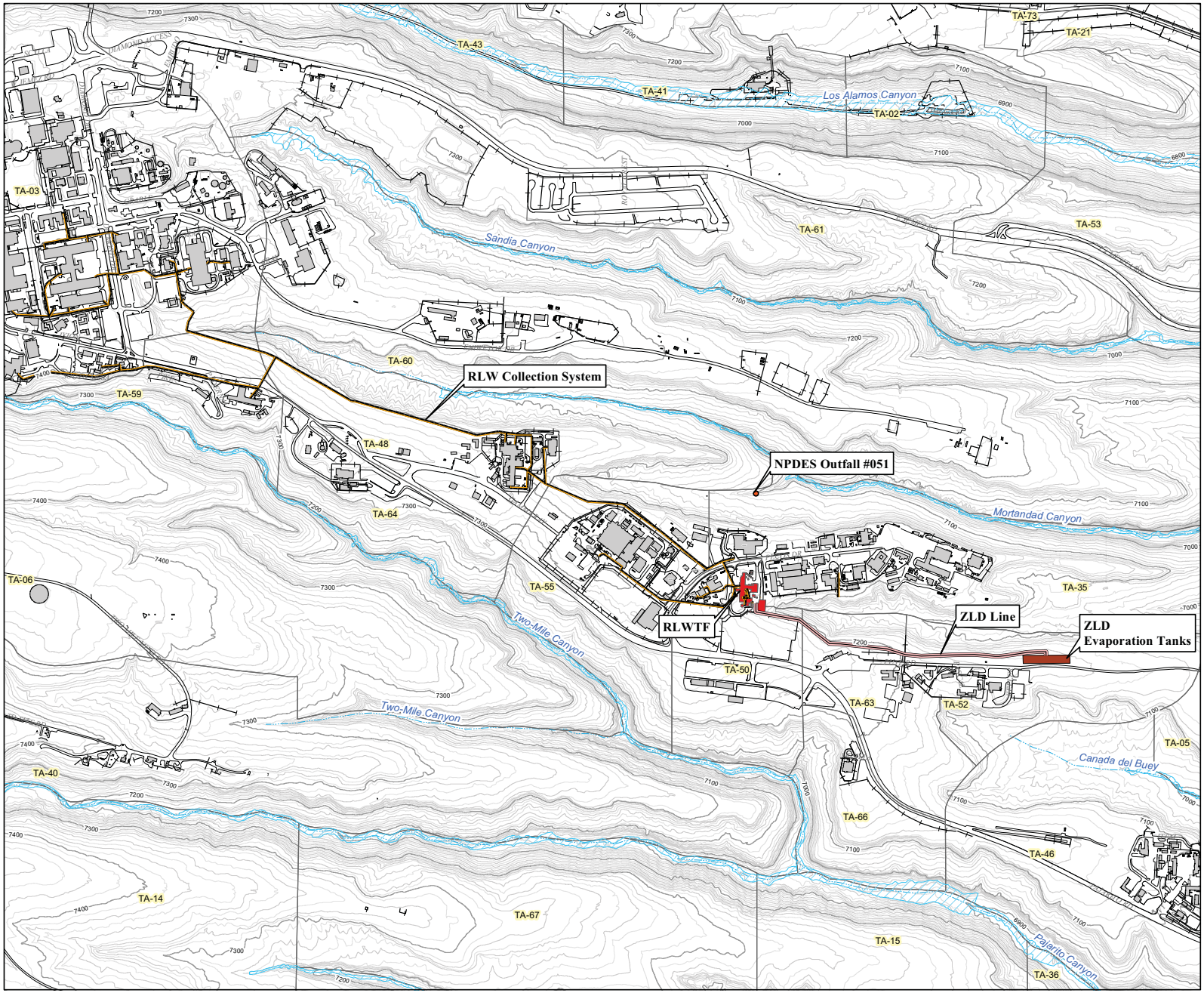
Point Feature Locations of the Environmental Restoration Project Database; Los Alamos National Laboratory, Waste and Environmental Services Division, EP2009-0283; 04 June 2009.

Structures; County of Los Alamos, Information Services; as published 29 October 2007.

Septic tanks: Los Alamos National Laboratory;X:\Projects\09-Projects\09-0092\DATA\Stanks. Taken from Map project # 07-0015. October 12, 2009.
WQH NPDES Outfalls; Los Alamos National Laboratory, ENV Water Quality and Hydrology Group; Edition 2002.01; 01 September 2003.

ZLD line and tank; Los Alamos National Laboratory,ENV DATA AND ANALYSIS Group ; X:\Projects\11-Projects\11-0096\DATA\Digitized VLD_LINES_01112012\ VLD_TANK.shp; 11 January 2012

This map was created for work processes associated with the Water Quality & RCRA(CAP) . All other uses for this map should be confirmed with LANL ENV-RCRA staff.



TA-50 RLWTF, RLW Collection System, NPDES Outfall 051, ZLD Evaporation Tanks, and the 100-Yr Floodplain

- NPDES Outfall 051051
- Fences
- Drainages
- Paved roads
- RLW Collection system
- ZLD line
- ZLD Evaporation tanks
- RLWTF buildings
- Structures
- Technical areas
- 100-year floddplain

N

Feet
0 312.5 625 1,250 1,875 2,500

0 120 240 480 720 960
Meters

1:12,000

State Plane Coordinate System
New Mexico, Central Zone, US Feet
NAD 1983 Datum, NGVD 1929

Map Created By: Winters Red Star
Map #12-0009-03 17 JANUARY 2012

MAP #2
LA-UR-12-00672
ENV-DO-12-0005

DATA SOURCE:

ER Project Locations; Los Alamos National Laboratory, ESH&Q Waste and Environmental Services Division, erPL4-20110821; 1:2,500 Scale Data; 04 August 2011.

Hypsography, 100, 20,10 Foot Contour Interval; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program; 1991.

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

Security and Industrial Fences and Gates; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

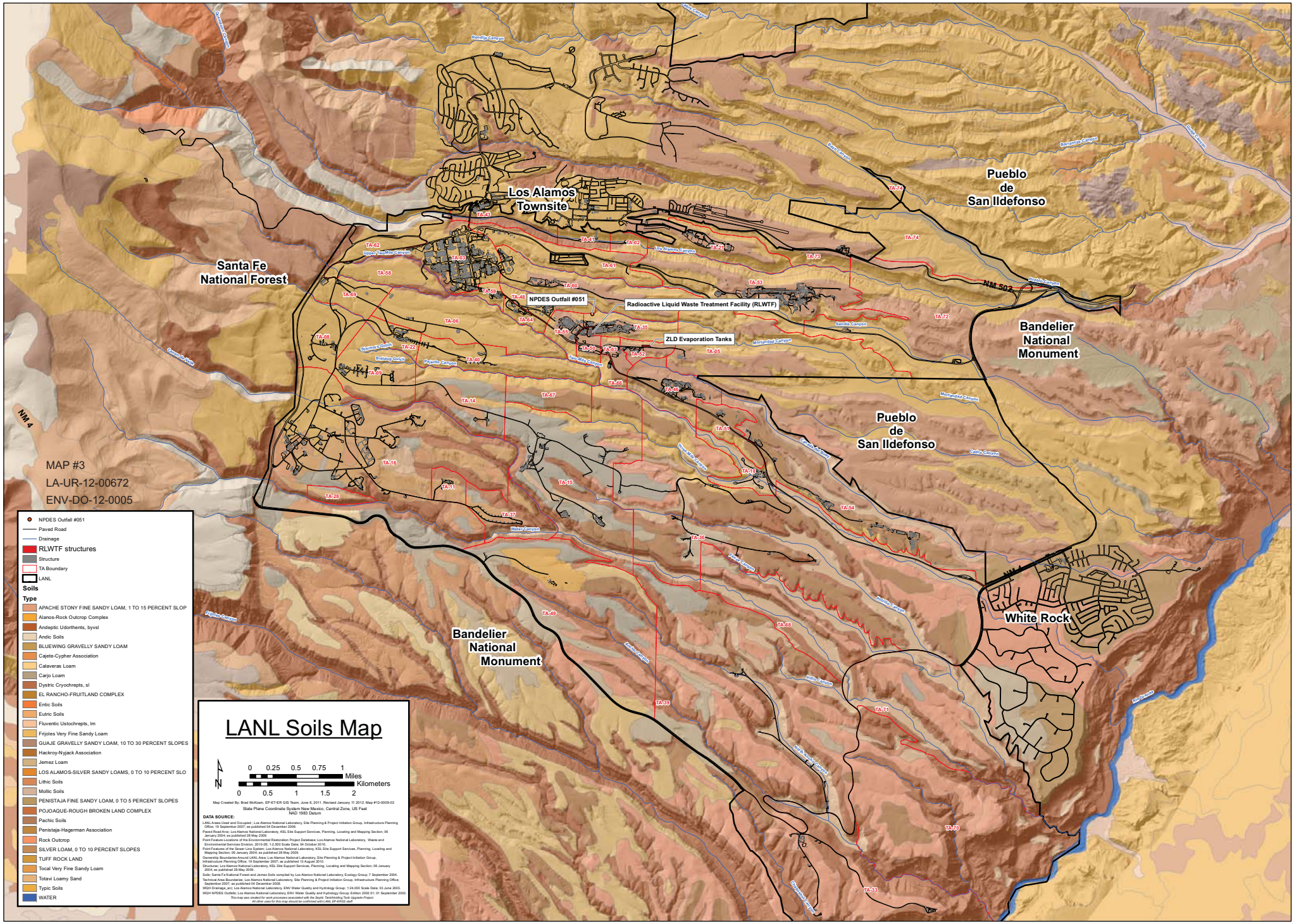
Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

Technical Area Boundaries; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; September 2007; as published 13 August 2010.

WQH Drainage_arc; Los Alamos National Laboratory, ENV Water Quality and Hydrology Group; 1:24,000 Scale Data; 03 June 2003.

ZLD line and tank; Los Alamos National Laboratory,ENV DATA AND ANALYSIS Group; X:\Projects\11-Projects\11-0096\DATA\Digitized VLD_LINES_01112012\VLD_TANK.shp; 11 January 2012

Disclaimer: This map was created for work processes associated with the Water Quality & RCRA. All other uses for this map should be confirmed with LANL ENV-RCRA staff.


Los Alamos Townsite
Pueblo de San Ildefonso
Santa Fe National Forest
Bandelier National Monument
White Rock
NPDES Outfall #051
Radioactive Liquid Waste Treatment Facility (RLWTF)
ZLD Evaporation Tanks
NM 502
NM 4
MAP #3
LA-UR-12-00672
ENV-DO-12-0005
NPDES Outfall #051
Paved Road
Drainage
RLWTF structures
Structure
TA Boundary
LANL
Soils
Type
APACHE STONY FINE SANDY LOAM, 1 TO 15 PERCENT SLOP
Alanos-Rock Outcrop Complex
Andeptic Udorthents, byvsl
Andic Soils
BLUEWING GRAVELLY SANDY LOAM
Cajete-Cypher Association
Calaveras Loam
Carjo Loam
Dystric Cryochrepts, sl
EL RANCHO-FRUITLAND COMPLEX
Entic Soils
Eutric Soils
Fluventic Ustochrepts, lm
Frijoles Very Fine Sandy Loam
GUAJE GRAVELLY SANDY LOAM, 10 TO 30 PERCENT SLOPES
Hackroy-Nyjack Association
Jemez Loam
LOS ALAMOS-SILVER SANDY LOAMS, 0 TO 10 PERCENT SLO
Lithic Soils
Mollic Soils
PENISTAJA FINE SANDY LOAM, 0 TO 5 PERCENT SLOPES
POJOAQUE-ROUGH BROKEN LAND COMPLEX
Pachic Soils
Penistaja-Hagerman Association
Rock Outcrop
SILVER LOAM, 0 TO 10 PERCENT SLOPES
TUFF ROCK LAND
Tocal Very Fine Sandy Loam
Totavi Loamy Sand
Typic Soils
WATER
LANL Soils Map
N
0 0.25 0.5 0.75 1 Miles
0 0.5 1 1.5 2 Kilometers
Map Created By: Brad McKeen, EP-ET-EIR GIS Team, June 6, 2011. Revised January 11 2012. Map #12-0009-02
State Plane Coordinate System New Mexico, Central Zone, US Feet
NAD 1983 Datum
DATA SOURCE:
LANL Areas Used and Occupied ; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; 19 September 2007; as published 04 December 2008.
Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.
Point Feature Locations of the Environmental Restoration Project Database; Los Alamos National Laboratory, Waste and Environmental Services Division; 2010-26; 1:2,500 Scale Data; 04 October 2010.
Point Features of the Sewer Line System; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.
Ownership Boundaries Around LANL Area; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; 19 September 2007; as published 13 August 2010.
Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.
Soils; Santa Fe National Forest and Jemez Soils compiled by Los Alamos National Laboratory, Ecology Group; 7 September 2004.
Technical Area Boundaries; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; September 2007; as published 04 December 2008.
WQH Drainage_arc; Los Alamos National Laboratory, ENV Water Quality and Hydrology Group; 1:24,000 Scale Data; 03 June 2003.
WQH NPDES Outfalls; Los Alamos National Laboratory, ENV Water Quality and Hydrology Group; Edition 2002.01; 01 September 2003.
This map was created for work processes associated with the Septic Tank/Aerating Tank Upgrade Project
All other uses for this map should be confirmed with LANL EP-ERSS staff.



TA-50
Radioactive Liquid Waste Treatment Facility (RLWTF), Storm Drain System

Storm drain
Fences
Paved Roads
Structures

N

Feet
0 25 50 100 150 200

0 5 10 20 30 40
Meters

1:800

Map Created By: Winters Red Star
Map #12-0009-01 11 JANUARY 2012

State Plane Coordinate System
New Mexico, Central Zone, US Feet
NAD 1983 Datum

MAP #4
LA-UR-12-00672
ENV-DO-12-0005

DATA SOURCE:

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

Orthophotography, 2011 Los Alamos National Laboratory Aerial Photography, Site Planning and Project Initiation Group, APRIL 2011.

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Storm Drain Line Distribution System; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

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(505) 606-2337/FAX (505) 665-1812

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JUN 2009
Hazardous
Waste Bureau

National Nuclear Security Administration
Los Alamos Site Office, MS A316
Environmental Restoration Program
Los Alamos, New Mexico 87544
(505) 667-4255/FAX (505) 606-2132

Date: June 30, 2009
Refer To: EP2009-0191

James P. Bearzi, Bureau Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6303

Subject: Submittal of the General Facility Information Component #9 - 2009 Hydrogeologic Site Atlas

References: (1) Letter, Messrs. Gregory and Graham to Bearzi, dated February 13, 2009
(2) Letter, Bearzi to Messrs. Gregory and McInroy, dated February 26, 2009

Dear Mr. Bearzi:

Enclosed please find two hard copies with electronic files of the 2009 Hydrogeologic Site Atlas (Atlas). This fulfills the submittal of component #9 of the 2009 General Facility Information Report according to the schedule in Reference 2. As stated in Reference 1, the Atlas map surfaces were prepared from the significantly updated 2009 Geologic Framework Model (GFM) which captures geologic contact data from wells logged as recently as early March 2009.

If you have any questions or if you and your staff would like a briefing on the 2009 GFM and Atlas, please contact Ardyth Simmons at (505) 665-3935 (asimmons@lanl.gov) or Hai Shen at (505) 665-5046 (hshen@doeal.gov).

Sincerely,

Michael J. Graham, Associate Director
Environmental Programs
Los Alamos National Laboratory

Sincerely,

David R. Gregory, Project Director
Environmental Operations
Los Alamos Site Office

MG/DG/PH/AS:sm

Enclosures: 1) Two hard copies with electronic files – 2009 Hydrogeologic Site Atlas (LA-UR-09-3763)

Cy: (w/enc.)
Neil Weber, San Ildefonso Pueblo
Ardyth Simmons, EP-LWSP, MS M992 (20 extra copies)
Greg Cole, EES-16, MS D462
Bob King, EP-LWSP, MS M992
Hai Shen, DOE-LASO, MS A316
RPF, MS M707 (with two CDs)
Public Reading Room, MS M992

Cy: (Letter and CD and/or DVD only)
Laurie King, EPA Region 6, Dallas, TX
Steve Yanicak, NMED-OB, White Rock, NM
Jeff Heikoop, EES-14, MS D462
Kristine Smeltz, EP-WES, MS M992
EP-LWSP File, MS M992

Cy: (w/o enc.)
Tom Skibitski, NMED-OB, Santa Fe, NM
Keyana DeAguero, DOE-LASO (date-stamped letter emailed)
Michael J. Graham, ADEP, MS M991
Alison M. Dorries, EP-WES, MS M992
Paul R. Huber, EP-LWSP, MS M992
IRM-RMMSO, MS A150 (date-stamped letter emailed)

Los Alamos
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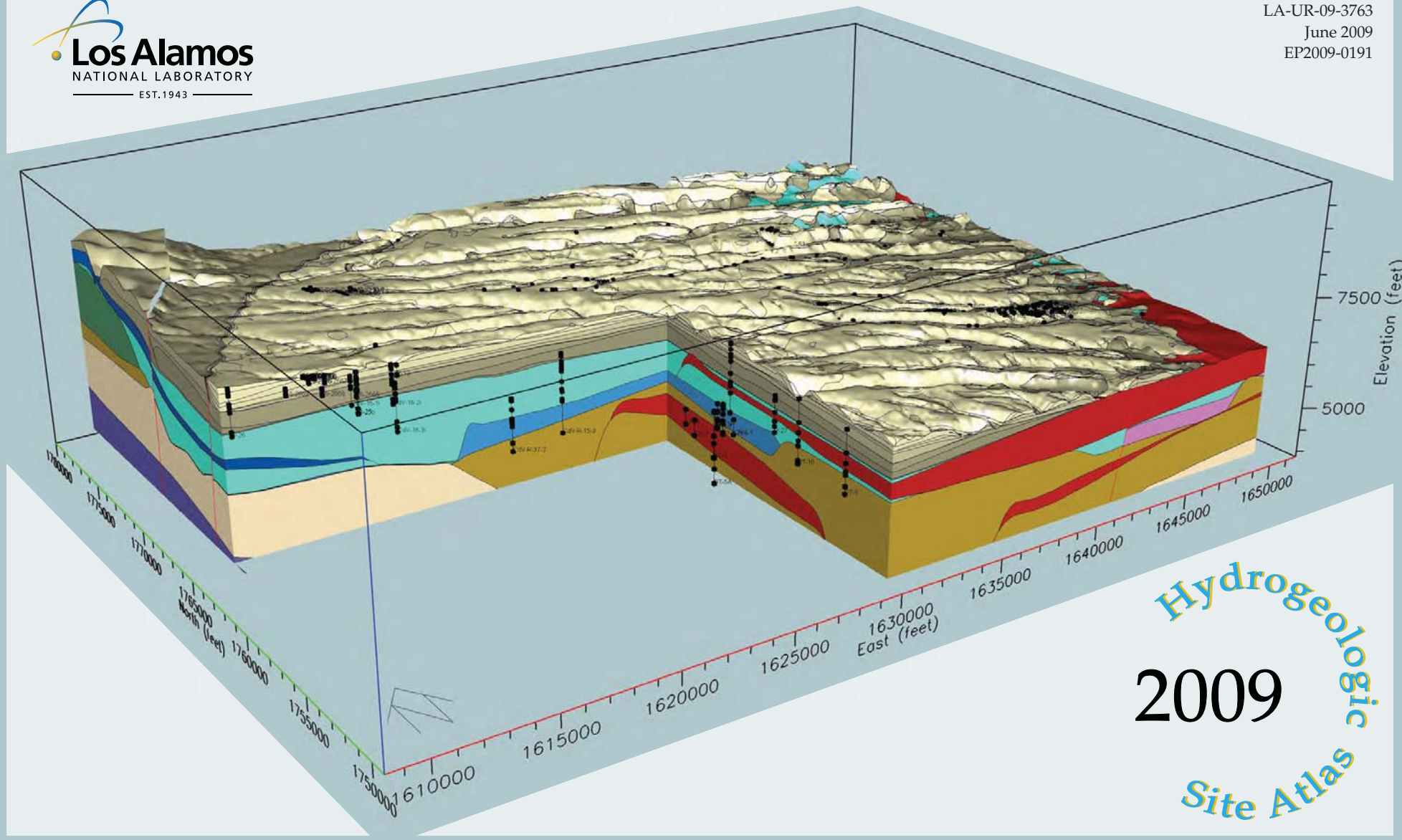
EST. 1943

LA-UR-09-3763
June 2009
EP2009-0191



Hydrogeologic 2009 Site Atlas

The cover shows a three-dimensional geologic framework model of the region near Technical Area 03, depicting the geology down to a depth of 4000 feet above sea level. The stratigraphic units in the area wells are also shown. For illustrative purposes, a modified color palette was used for this model that differs from that used for illustrations in the rest of the atlas to highlight the large-scale character of the Quaternary tuffs (tan colors), older flows (blues), and the basalt flows (red).

Prepared by the Environmental Programs Directorate–LANL Water Stewardship Project

The primary author of the 2009 Hydrogeologic Site Atlas text and creator of the map plates was Greg Cole. David Broxton and Dan Koning provided figures and text describing the geologic units in Section 2, and Velimir (Monty) Vesselinov provided the text, tables, and water-table data for the plates of Section 3. David Coblentz used Earth Vision software to create the cross-section, three-dimensional views of the geologic framework model, and the atlas cover. Susan Rhyne provided editing support. Pamela Maestas provided graphics and editing support and created the cover using images generated by David Coblentz.

Greg Cole led the development of the 2009 geologic framework model. Other contributors included David Coblentz and Elaine Jacobs, who assisted in the model development; and Dan Koning, David Broxton, David Vaniman, and Fraser Goff, who provided structure contours and/or cross-sections for many of the model units.

Los Alamos National Laboratory, operated by Los Alamos National Security, LLC, for the U.S. Department of Energy under Contract No. DE-AC52-06NA25396, has prepared this document pursuant to the Compliance Order on Consent, signed March 1, 2005. The Compliance Order on Consent contains requirements for the investigation and cleanup, including corrective action, of contamination at Los Alamos National Laboratory. The U.S. government has rights to use, reproduce, and distribute this document. The public may copy and use this document without charge, provided that this notice and any statement of authorship are reproduced on all copies.

LA-UR-09-3763
EP2009-0191

2009 Hydrogeologic Site Atlas

June 2009

Responsible project leader:

Printed Name	Signature	Title	Organization	Date
Ardyth M. Simmons	Ardyth M. Simmons	Program Manager	Environmental Programs	6-29-09

Responsible LANS representative:

Printed Name	Signature	Title	Organization	Date
Michael J. Graham	B. G. Schoppelt for MJG	Associate Director	Environmental Programs	6-29-09

Responsible DOE representative:

Printed Name	Signature	Title	Organization	Date
David R. Gregory	David R. Gregory	Project Director	DOE-LASO	6/30/09

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ABSTRACT

The “2009 Hydrogeologic Site Atlas” describes those portions of the 2009 geologic framework model (GFM) that encompass Los Alamos National Laboratory (the Laboratory) and surrounding area. This atlas is extracted from the 2009 GFM, a major revision and expansion of the previous 2005 GFM, and incorporates a large amount of new subsurface data from an expanded drilling program. The 2009 GFM is a set of three models: the site model (SITE), the southern Española Basin (SEB) model and the Española Basin (EB) model, which provide computational grids for increasingly larger portions of the EB at decreasing resolutions. The 2009 GFM has also been extended to greater depths beneath the Pajarito Plateau through a projection of modeled EB geology to the east and southeast and utilization of new geologic map data from the Valles Caldera to the west and the Cochiti Pueblo region to the south. The atlas incorporates enhanced stratigraphic control to identify additional details of the deeper Santa Fe Group sediments beneath the Laboratory and provides new and/or updated geologic maps, structure contour and thickness maps, and water-table maps, as well as cross-sections and three-dimensional (3-D) visualizations of the geology.

1.0 INTRODUCTION

The Laboratory has produced a series of hydrologic site atlases that document updated models for the Laboratory site (Stone et al. 1999, 064039; Stone et al. 2001, 069830; Cole et al. 2006, 095079). This current document is the latest addition to the atlas series. This document satisfies component 9 as indicated in the 2009 General Facility Information (LANL 2009, 105632).

1.1 Background

The earliest 3-D geologic model for the Laboratory site was produced in the mid-1990s to support compliance with the Laboratory’s Hazardous Waste Facility permit(s), required under the Resource Conservation and Recovery Act. The 1995 site geologic model (Vaniman et al. 1996, 106129) used early-version, ArcInfo software for building the model, and IBM DX-Explorer software for 3-D visualizations. The model consisted of 14 surfaces that were derived from the contouring of triangular integrated networks (TINs) created from limited sets of surface and drill hole control points. The model surfaces did not extend to the Laboratory boundaries and were limited to units/subunits of the Bandelier Tuff, portions of the Cerro Toledo and Puye and Totavi units, and a small piece of the Santa Fe Group. Figures 1-1a and b provide samples of the surfaces and visualizations from this early model of the 3-D geology and the Laboratory site.

Through the ensuing years, there has been an ongoing effort to accelerate the characterization and remediation of the hazardous (release) sites at the Laboratory. This effort has resulted in the installation of many new characterization and monitoring wells and additional surface geologic mapping. The effort has also resulted in the need to extend geologic-based groundwater flow and contaminant transport models past Laboratory boundaries into the surrounding communities. The Laboratory has continued to support the development of 3-D geologic models with updated models produced for 1997 (Cole et al. 1997, 106127), 1998 (Cole et al. 1998, 106128), 1999 (Carey et al. 1999, 066782), 2002 (no report produced), 2003 (partial model, including Area G and Mortandad and Sandia Canyons [Stauffer et al. 2005, 097432]), and 2006 (Cole et al. 2006, 095079). These newer models were developed mainly to support the numerical analysis of groundwater flow and transport.

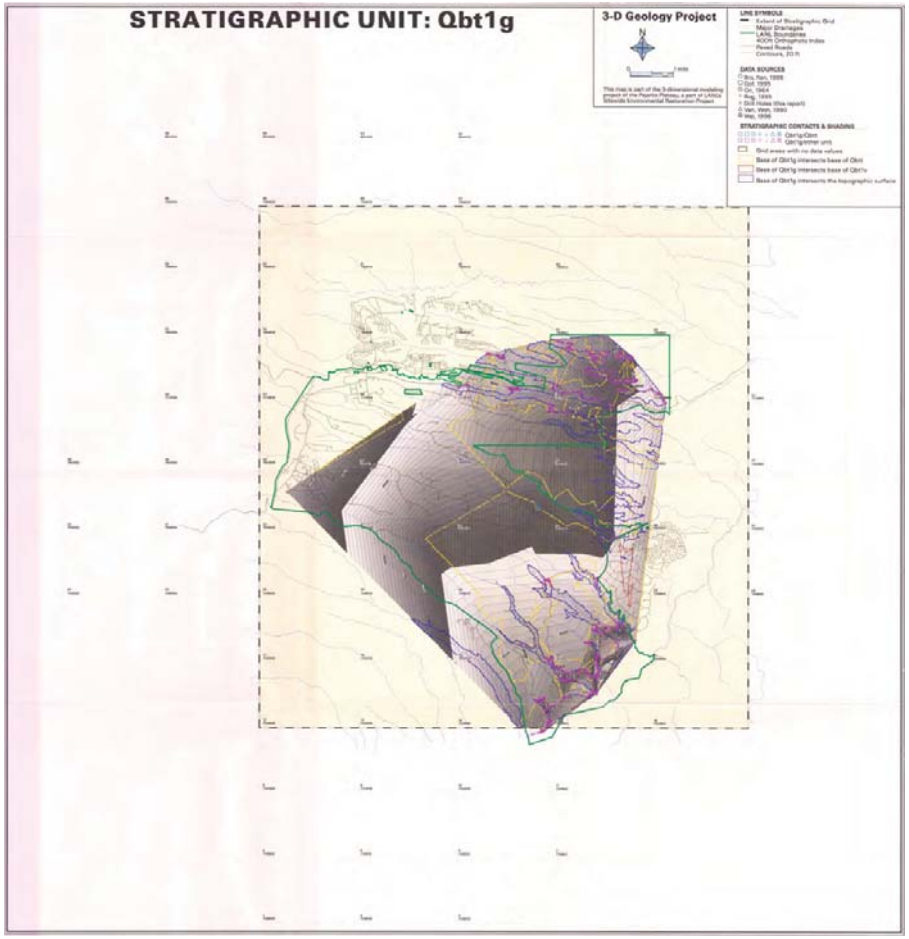
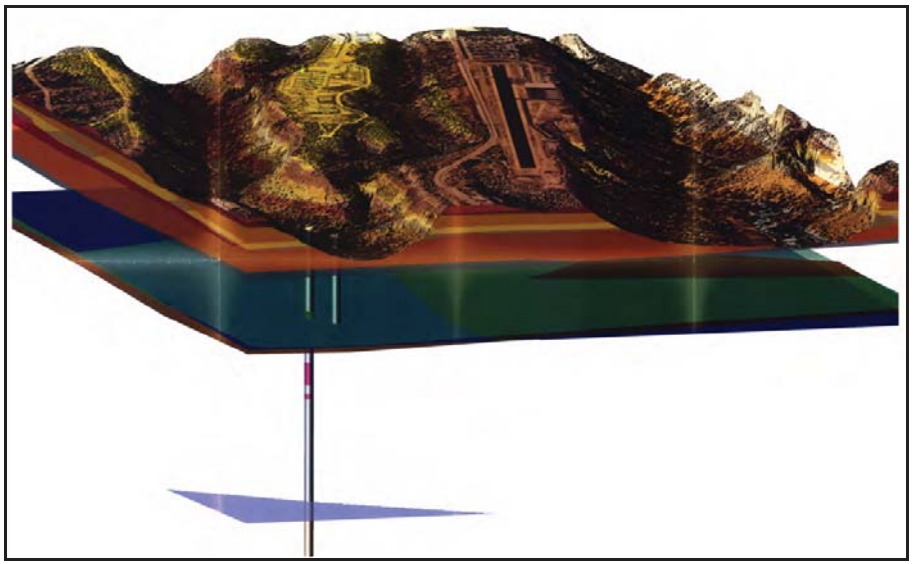


Figure 1-1a. Example of a geologic unit surface (Qbt1g) from the 1995 site geologic model



Source: Vaniman et al. 1996, 106129.

Figure 1-1b. Visualization at TA-21, utilizing the 1995 site geologic model

The earlier geologic models have been expanded in geographical extent to address issues of possible contaminant transport past Laboratory boundaries. The 2002 geologic model was expanded to include the full extent of all four 7.5-min quadrangle maps intersected by the Laboratory boundary. This model was called the "Pajarito Plateau" model in Cole et al. (2006, 095079). The model presented in this atlas includes the SITE model and a portion of the SEB model of the 2009 GFM. Table 1-1 provides a measure of the data support used to create each of the past and present GFMs. The fiscal year (FY) 2003 model provided only a partial coverage of the site and is therefore not included in the comparison.

Table 1-1.
Quantities of Contact Points Available for Past and Present GFMs

Model Year	FY96	FY97	FY98	FY99	FY02	FY06	FY09
Total Number of Data Points	34,989	40,991	43,369	31,624	76,638	121,284	>200,000
Number of Drill Hole Data Points	615	615	703	866	1042	1398	2228

Subsets of the total set of data points, augmented by outcrop maps, are used to develop structure contours. Final digital grids for the unit surfaces are created from the structure contours and "hard" data points reflecting the actual preerosional position of unit surfaces. Increased point counts at the FY02, FY06, and FY09 GFM dates reflect the combined increase in data density, as well as the increased geographical extent of these models.

1.2 Scope

In addition to the Laboratory, a number of government entities have been involved in the development of digital geologic data and geologic-based groundwater models for the region surrounding Los Alamos, including the New Mexico Bureau of Geology and Mineral Resources, the U.S. Geological Survey (USGS), and the City and County of Santa Fe. Development of the 2009 expanded Laboratory GFM incorporates the following:

- voluminous new subsurface (drill hole) data collected to support current characterization and remediation projects at the Laboratory
- new regional geologic information for development of accurate models of deeper, hydrologically significant units beneath the Laboratory (Grauch et. al. 2009, available at http://pubs.usgs.gov/pp/1761/)
- new models by other government agencies, reflecting a communal redefinition of many of the hydrogeologic units for the region (INTERA Incorporated 2006, 106106; Pantea et al. 2009 personal communication)
- revision of many of the geologic quadrangle maps within and along the boundaries of previous Laboratory GFMs
- revision of a large percentage of the geologic quadrangle maps within the EB that provide "boundary constraints" for the numerical flow and transport modeling at the Laboratory

The 2009 GFM was developed at three extents, with two resolutions (cell size) for each extent. The extents of the 2009 3-D geologic model(s) are shown in Figure 1-2. The areal extent of the EB model intersects more than 60 7.5-min quadrangle maps, that of the SEB model incorporates 12 quadrangle maps, and that of the site model consists of the four quadrangle maps encompassing the Laboratory site. The lower resolution for each model version is half the higher resolution and is limited to be no more than a million cells per grid surface. The SITE model has the highest resolution of the three model extents, with the model developed at 50-ft cell center spacing. Additional models of limited extent, including the model presented in this atlas, as well as a local model for Area G at the Laboratory site, represent extraction of data from these larger models and not a regeneration of model surfaces.

The map extent of this atlas encompasses the Laboratory and surrounding area. This region lies mainly within the SITE model but extends into the western portions of the Española and Horcado Ranch quadrangle maps, the northern edges of the Cochiti Dam, Montoso Peak quadrangle maps, and the northwest corner of the Agua Fria quadrangle map. Because the atlas surfaces extend past the SITE model boundary, surfaces were extracted from the lower-resolution (100-ft) SEB model.

The atlas presents a set of maps/plates that provide

1. land ownership and the location of wells that provide constraints for the 3-D geologic model,
2. mapped and modeled surface geology with mapped faults,
3. structure contours for the top of each unit and subunit of the model present within the atlas extent,
4. isochors (vertical thickness contours) for each unit and subunit of the model present within the atlas extent,
5. structure contours for the bottom of each unit of the model present within the atlas extent,
6. elevations of the regional water table produced for this atlas from the currently available data,
7. the geology at the water table,
8. cross-sections of the geology with the water-table position, and
9. locations of the cross-sections.

Basic information for the atlas, including land ownership, roads, and well locations with descriptions is provided in Plates 1-1, 1-2, and 1-3.

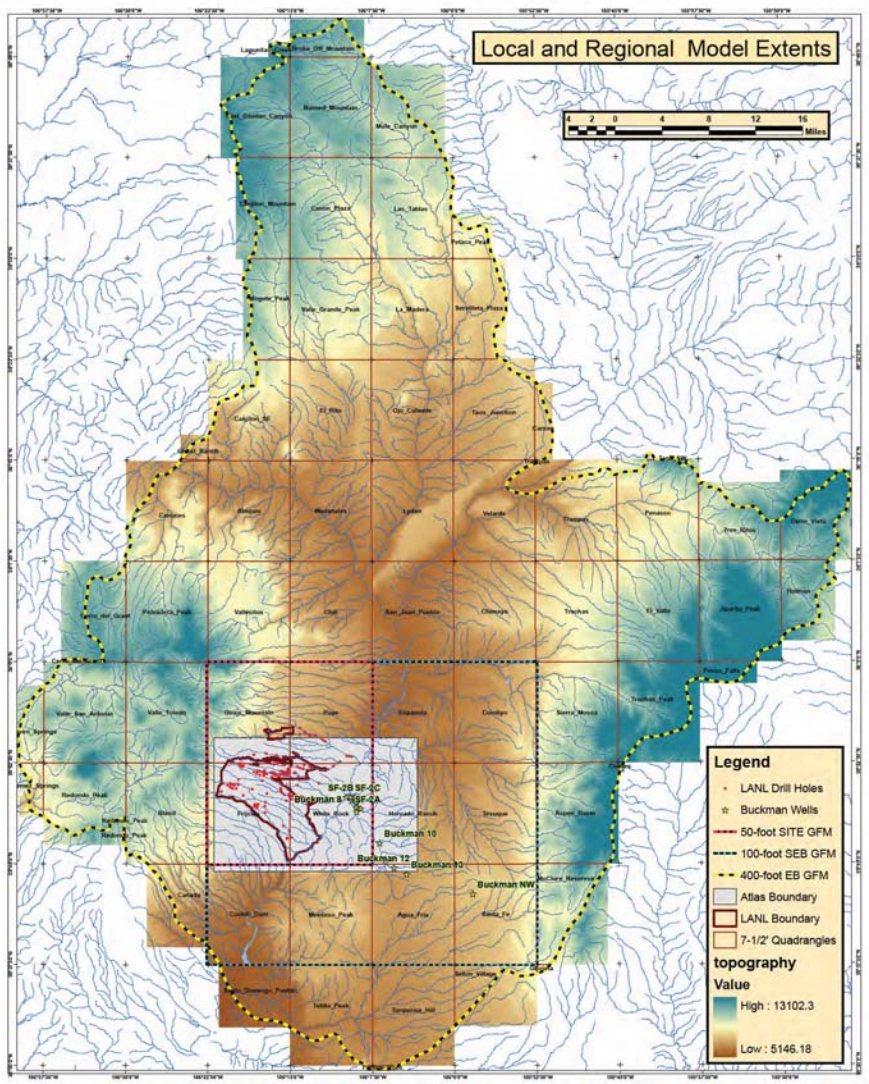


Figure 1-2. Location of the SITE, SEB, and EB models of the 2009 GFM

1.3 Data Sets

Data used to develop the SEB model that encompasses the atlas extent include the following:

- mapped surface geology and associated cross-sections for the following 7.5-min geologic quadrangle maps:
  - Guaje Mountain (Kempter et al. 2007, 106111)
  - Puye (Dethier 2003, 106113)
  - Española (Koning 2002, 105710)
  - Cundiyo (Koning 2002, 105710)
  - Frijoles (Goff et al. 2002, 088776)
  - White Rock (Dethier 1997, 049843)
- professional papers and open file reports for the following 7.5-min geologic quadrangle maps:
  - Horcado Ranch (Read et al. 2005, 105709)
  - Tesuque (Read et al. 2005, 105709)
  - Cochiti Dam (Sawyer et al. 2007, 106130)
  - Montoso Peak (Sawyer et al. 2007, 106130)
  - Agua Fria (Read et al. 2005, 105709)
  - Santa Fe (Read et al. 2005, 105709)
- mapping of subunits of the Bandelier Tuff by Laboratory scientists (Rogers 1995, 054419; Lewis et al. 2002, 073785; Lavine et al. 2003, 092527)
- subsurface geologic contacts from the current Laboratory database (Cole et al. 2006, 095079)

Source data were obtained from digital and analog (paper map) sources and converted to digital contact control points. All geologic unit data were preprocessed to convert (field) mapped units to the set of "regional" units of the model in the appropriate coordinate system. The preprocessed surface geologic map data for the 12-quadrangle map area of the SEB model are shown in "model" units as Figure 1-3.

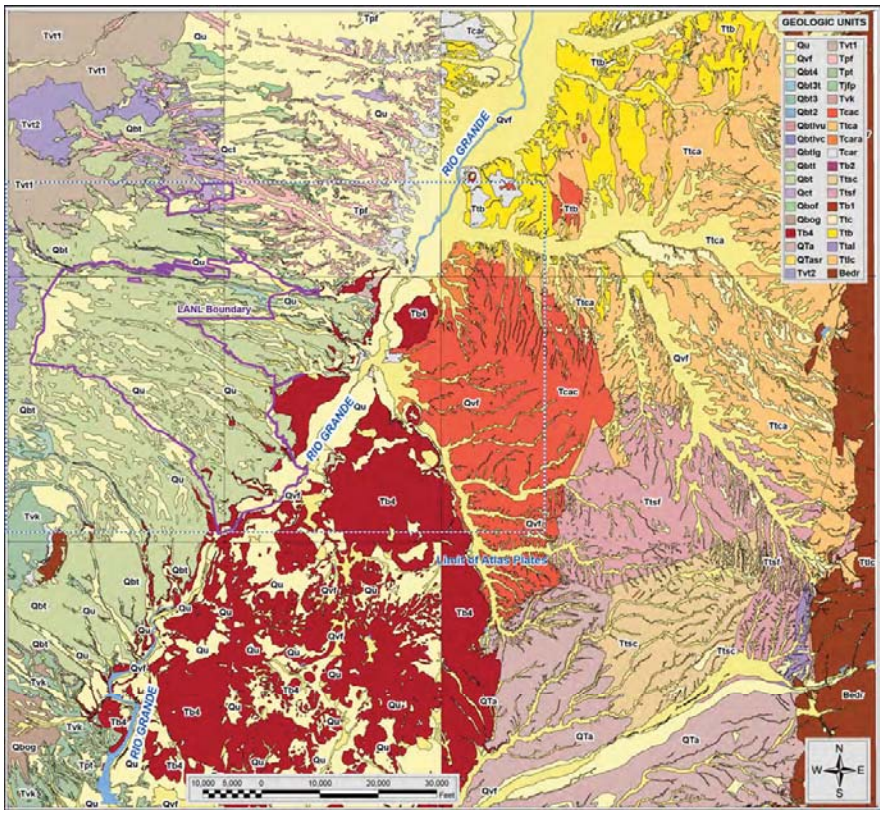
The analog-to-digital conversion process includes

- scanning of contacts from cross-sections and geologic maps,
- extracting points at constant horizontal and/or vertical distances along the lines, and
- obtaining the "third" part of the spatial coordinate through a digital elevation model (for surface maps) or from geometric calculations (for cross-sections).

The conversion process was performed using the R2V digitizing software (Able Software), ArcInfo Geographical Information System (GIS) software and scripts, and utility FORTRAN programs.

2.0 THE 2009 GFM

The 2009 GFM is the latest of a series of 3-D geologic models that have been developed to support environmental cleanup and waste management programs at the Laboratory. This new GFM is unique in that it comprises multiple overlapping models of differing resolutions that allow the highest-resolution model centered on the Laboratory site to be seamlessly joined with lower resolution models at successive distances outside of the Laboratory boundary, with an ultimate model extent of the entire EB. Model resolution, defined by the distance between cell centers on a rectilinear grid, can range from 50 to 800 ft, with possible cell center increments of 50, 100, 200, 400, and 800 ft.



Note: The atlas extent is indicated by the dashed blue-and-white line.

Figure 1-3. Map of geologic unit polygons obtained from the surface geologic maps of the SEB region

The GFM reflects current ideas about the geologic evolution of the model area and depositional processes within the EB, embracing the voluminous amounts of new geologic mapping by the joint USGS and State mapping project, as well as the results of associated geological and geophysical studies. The GFM incorporates a large amount of new, subsurface data, including contact data from borehole logs of more than 100 new wells (through February 2009) that result in a 50% increase of subsurface contact control points. In addition, repositioning of well locations through global positioning system (GPS) techniques and reanalysis of existing geological and geophysical logs have resulted in many changes in the preexisting drill hole database. The locations of wells that provide new or updated contact control data are shown in Plate 1-1.

The 2009 GFM also provides a completely revised definition for the Santa Fe Group units that comprise most of the saturated zone stratigraphy. The GFM incorporates the breakout of geologic units used in the recent geologic remapping of most of the quadrangle maps within the model area.

Surfaces of the new GFM were developed with the ArcInfo software. Digital data sets were obtained from a variety of sources, including

- existing digital grids or digital line data from USGS and the New Mexico Bureau of Geology and Mineral Resources,
- published geologic maps and cross-sections (scanned and digitized),
- "open-source" topographic grids and digital line graphs of the USGS,
- structure contours for unit surfaces developed by the Laboratory, and
- well logs from the Laboratory database as well as off-site logs from other sources, where available.

Quality assurance was provided through comparison of the modeled and actual 3-D position of the input data with emphasis on the fit of subsurface data. USGS topographic data were used rather than the higher-quality, light detection and ranging (LIDAR) elevation data available at the Laboratory (Carey and Cole 2002, 073784). A single-source data set was desired for the GFM, and the LIDAR data do not extend into the SEB and EB portions of the model. Topographic maps (7.5 min) are usually the basis for placement of geologic contacts by field geologists and are the source of the digital line graph (DLG) contour data that are used as the elevation model for the GFM. The subsurface contacts at drill holes are normally positioned relative to high-resolution surface measurements obtained from LIDAR or GPS elevation data and not from the DLG data.

2.1 Geologic Overview

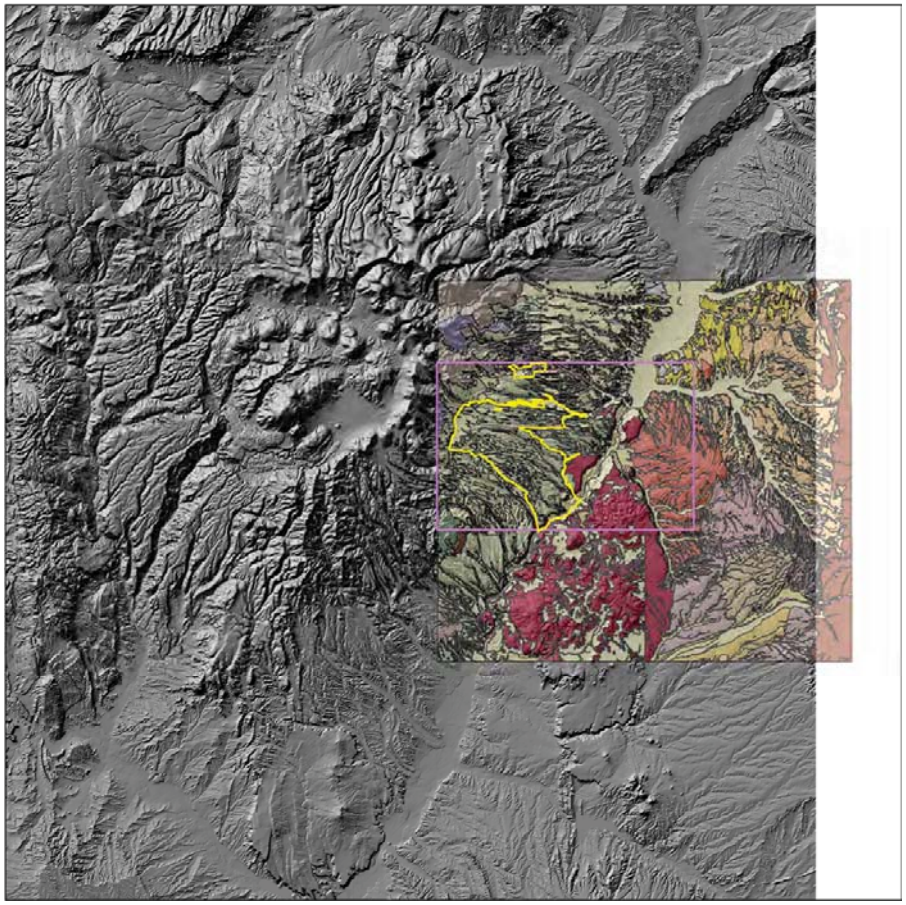
The Laboratory is located on the Pajarito Plateau within the eastern area of the Jemez volcanic field (JVF), along the east-southeastern slope of the Valles Caldera at the western edge of the EB (Figure 2-1).

The stratigraphy of the modeled area reflects the interplay of tectonic and depositional processes within the developing EB, which at the model latitude, is hinged at its eastern edge with major, predominantly downward, displacements at its western margin. This geometry is schematically shown in Figure 2-2.

The tectonically active portion of the western edge of the EB is present within the far western portion of the GFM, at the Pajarito fault system, which exhibits both discrete offsets and distributed strain. Other, poorly defined, north-south faults with major offsets occur west of the model area, within the eastern portion of the Valles Caldera. The volcanic activity began approximately 14 million years ago (Ma) (Goff 2009, 106105), with the most recent major eruptive events creating the Pajarito Plateau. The origin of the upper (above water table) geologic units of the plateau is predominantly volcanic, and these geologic units include dacitic and rhyolitic flows, ash-flow tuffs, and their erosional derivatives. Basaltic flows from sources within and to the east and southeast of the Laboratory are intermixed with this Jemez volcanic material. The units generally tilt to the east and southeast, although downward displacements to the west may offset or reverse the original depositional dips of units, depending on their age.

The JVF material lies on top of EB sedimentary units and extends almost to the currently active position of the Rio Grande, with some intermixing with basin sediments to the east. The EB sedimentary units exposed further east, reflect the erosion of the uplifting Sangre de Cristo Mountains, which form the eastern boundary of the basin, as well as sediment sources farther to the north. The units tilt regionally to the west, reflecting both the depositional attitude as well as their increased downward displacement to the west, along poorly defined north-south trending faults within the basin. Older basin sedimentary units underlie the JVF volcanic material to the west. Figures 2-3 and 2-4 show relationships between the stratigraphic units in the east-west direction between the JVF volcanic and fanglomerate material and the river gravels and other sedimentary material in the EB.

Plates 2-1 and 2-2 show the mapped and modeled geology in greater detail within its extent identified in Figure 2-1. Plate 2-3 provides the observed and inferred geologic structure for this region. Plates 2-84 through 2-91 provide cross-section information for the GFM, which add some reality to the schematic views provided by Figures 2-3 and 2-4. Plates 2-93 and 2-94 provide 3-D views for cutouts of the atlas and SEB model.



Notes: The Laboratory site is outlined in yellow. The purple boundary identifies the geologic extent of this atlas. Geologic units are colored for the extent of the SEB model. The flat, pale-green area running from the north-central to southwest corners of the SEB model identifies the alluvial units of the Rio Grande that approximate the eastern extent of volcanic material of the JVF.

Figure 2-1. The Laboratory setting along the eastern flank of the Valles Caldera

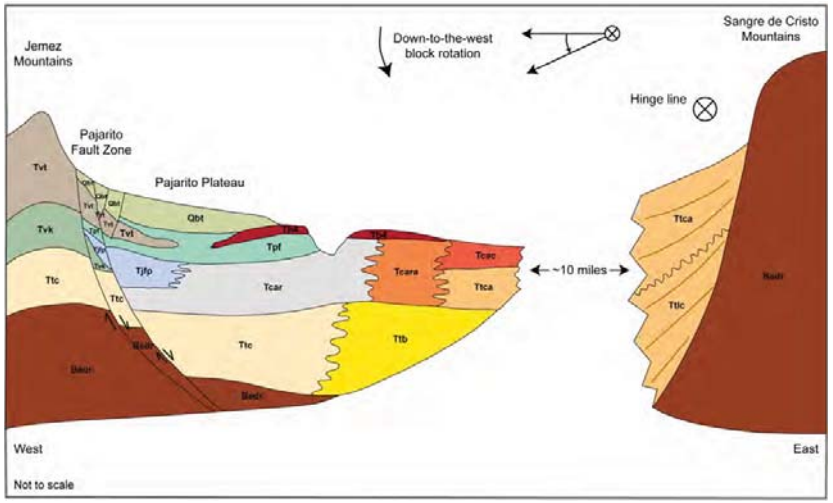
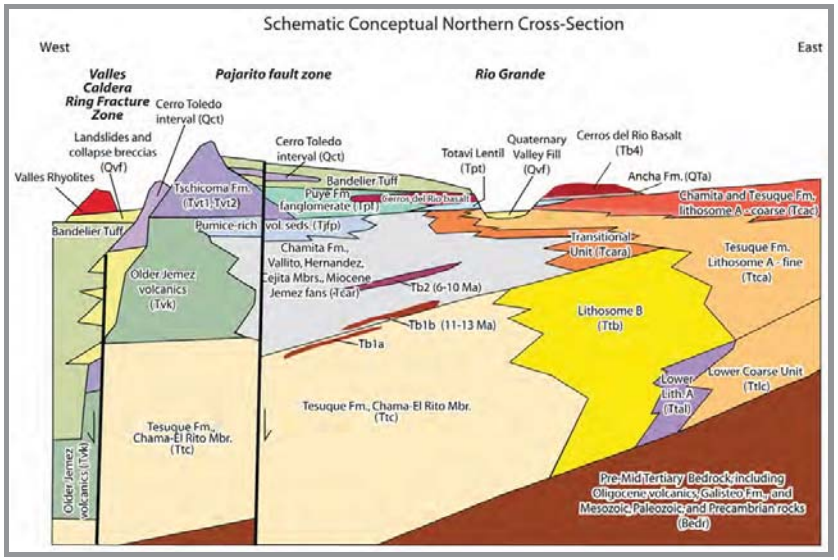
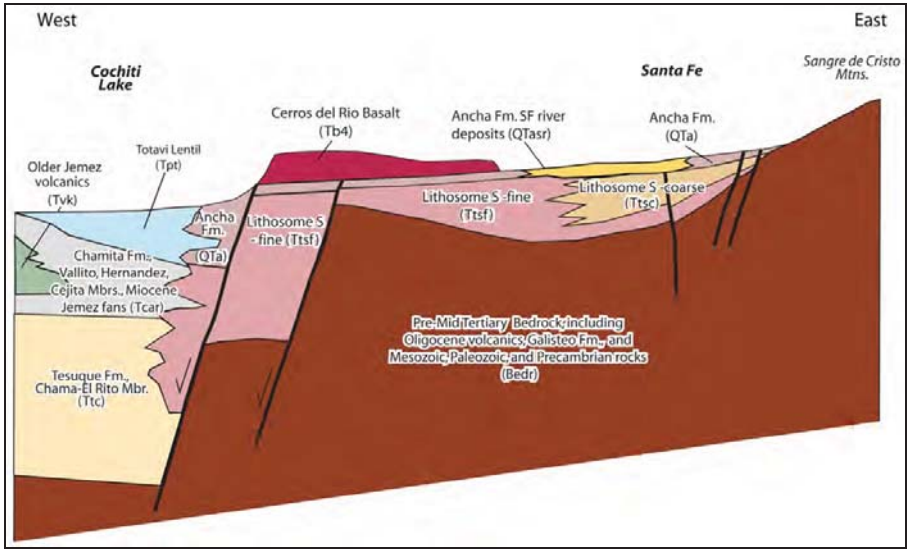


Figure 2-2. Schematic cross-section across the EB



Note: Volcanic material of the JVF dominates the upper portions of the section to the west.

Figure 2-3. Units of the northern portion of the SEB model



Note: The Cerros del Rio Basalts and ancestral Santa Fe River sediments encroach on Jemez volcanic fans to the west.

Figure 2-4. Units of the southern portion of the SEB model

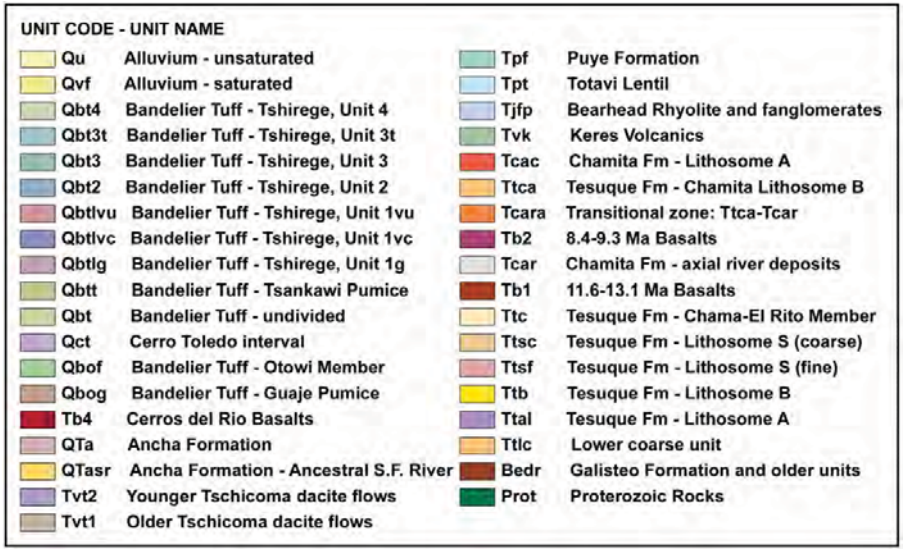


Figure 2-5. Codes and colors used for the GFM units

2.2 Stratigraphic/Geologic Units

The following section describes the modeled geologic units, which include both sedimentary and volcanic units. Figure 2-5 provides the colors and codes that are used in the GFM and on the plates provided in this atlas. Also included are descriptions (and colors) for several units within the SEB that do not extend into the reduced extent of the atlas. Plates showing the top structure and vertical thickness of each unit and the bottom structure of all units, except for the units/subunits of the Tshirege Member of the Bandelier Tuff, are provided as Plates 2-5 through 2-83. The alluvial units are not included in any of the models.

2.2.1 Tshirege Member, Bandelier Tuff (Qbt)

The Tshirege Member is the youngest member of the Bandelier Tuff, a multiple-flow ash-and-pumice unit that erupted from the Valles Caldera at approximately 1.22 Ma (Izett and Obradovich 1994, 048817; Spell et al. 1996, 055542). This is the most widely exposed bedrock unit of the Pajarito Plateau. The Tshirege Member tends to be more strongly welded than the Otowi Member, especially toward the western side of the plateau, closer to the Valles Caldera. Time breaks between the successive emplacements of ash-flow units caused the tuff to cool as several distinct cooling units, resulting in a complex internal stratigraphy that varies laterally as a function of distance from the caldera source. The stratigraphic nomenclature for the subunits of the Tshirege Member has evolved significantly through time (Broxton and Eller 1995, 058207; Broxton and Reneau 1995, 049726; Broxton and Vaniman 2005, 090038). The 2009 GFM follows the Tshirege subdivisions of the 2005 3-D GFM. The Tshirege Member is broken into a basal pumice layer and four overlying cooling units. Two of the cooling units are further subdivided, based on lithologic differences (Cole et al. 2006, 095079).

2.2.1.1 Unit 4 (Qbt4)

Unit 4 is a complex unit consisting of nonwelded to densely welded ash-flow tuffs that crop out in the western part of the Laboratory. Lewis et al. (2002, 073785) divide Qbt4 into local subunits and provide detailed descriptions of this heterogeneous unit. However, for the 3-D GFM, Qbt4 is not subdivided.

2.2.1.2 Unit 3t (Qbt3t)

Unit 3t is a moderately to densely welded ash-flow tuff that has petrographic and geochemical characteristics transitional between unit 3 and unit 4. Unit 3t is present in the western part of the Laboratory (Broxton and Vaniman 2005, 090038) and can impede the downward flow of surface water, creating seasonal springs along canyon walls.

2.2.1.3 Unit 3 (Qbt3)

Unit 3 is a nonwelded to partially welded tuff that forms the cap rock of mesas in the central part of the Pajarito Plateau. This unit and the overlying units Qbt3t and Qbt4 are absent from large areas in the eastern part of the Laboratory where they have been removed by erosion (Broxton and Eller 1995, 058207; Broxton and Reneau 1995, 049726; Broxton and Vaniman 2005, 090038).

2.2.1.4 Unit 2 (Qbt2)

Unit 2 is typically the most strongly welded tuff in the Tshirege Member and is characterized by lower porosity and higher density than the other units. It forms a distinctive medium-brown, vertical cliff that stands out in marked contrast

to the slope-forming, lighter-colored tuffs above and below. Unit 2 contains numerous well-developed, near-vertical fractures (Broxton and Reneau 1995, 049726; Broxton et al. 1995, 058207; Broxton and Vaniman 2005, 090038).

2.2.1.5 Unit 1

Cooling unit 1 of the Tshirege Member is a thick succession of ash-flow tuffs that dips gently east-southeast. This unit is characterized by a lack of welding and has been subdivided into a glassy lower tuff and an upper devitrified, vapor-phase crystallized tuff. The vapor-phase tuff is further divided into a colonnade portion and an upper portion (Broxton and Reneau 1995, 049726; Broxton and Vaniman 2005, 090038).

2.2.1.5.1 Unit 1vu (Qbt1vu)

The upper part of the vapor-phase unit (Qbt1vu) forms a distinctive grayish-white band between the darker colored colonnade tuff (Qbt1vc) below and unit 2 above. The upper vapor-phase unit is generally nonwelded and slope-forming, but in some localities it forms weakly developed cliffs and benches due to slight variations in welding (Broxton and Reneau 1995, 049726; Broxton and Vaniman 2005, 090038).

2.2.1.5.2 Unit 1, Colonnade (Qbt1vc)

The base of this altered vapor-phase unit (Qbt1vc) is a thin, horizontal zone of preferential weathering that forms a marker horizon, often called the vapor-phase notch, which marks the transition from glassy tuffs below to vapor-phase crystallized tuffs above. In some places, the vapor-phase notch grades laterally into a prominent bench developed on top of the glassy tuff. This colonnade vapor-phase tuff has distinctive columnar cooling joints and is a resistant, cliff-forming unit that may be slightly welded (Broxton and Reneau 1995, 049726; Broxton and Vaniman 2005, 090038).

2.2.1.5.3 Unit 1, Glassy (Qbt1g)

The lower part of unit 1 (Qbt1g) is not vapor-phase altered, retaining primary glass in both pumice and ash. Vapor-phase alteration is absent in this and all lower units of the Bandelier Tuff.

2.2.1.5.4 Unit 1 Tsankawi Pumice (Qbtt)

The Tsankawi Pumice Bed is the basal pumice fall of the Tshirege Member. This unit is typically 20 to 100 cm thick. Pumices in the Tsankawi Pumice Bed are mostly of rhyolitic composition, but there is a small (<5%) amount of dacitic pumice as well (Broxton and Reneau 1995, 049726). This pumice fall is vitric and unaltered by vapor-phase processes.

2.2.2 Cerro Toledo Interval (Qct)

The Cerro Toledo interval comprises a stratified sequence of volcaniclastic sediments and tephra and occurs between the two tuff members of the Bandelier Tuff. It is not considered as an integral part of the Bandelier Tuff (Broxton and Eller 1995, 058207; Broxton and Reneau 1995, 049726; Goff 1995, 049682; Broxton and Vaniman 2005, 090038). Structure contours for the base of the Cerro Toledo indicate that this unit fills a broad southeast-draining valley fed by one or more canyons exiting the Sierra de los Valles. The rhyolitic tuffaceous sandstone and tephra within this interval represent the reworked equivalents of Cerro Toledo rhyolitic tephra erupted from the Cerro Toledo and Rabbit Mountain dome complexes located northeast and southeast of the Valles Caldera, respectively. Clast-supported gravel, cobble, and boulder deposits derived from the Tschicoma Formation are interbedded with the tuffaceous rocks. In the western part of the Plateau, the interval also contains tuffaceous sediments that represent reworked Otowi Member of the Bandelier Tuff (Broxton and Vaniman 2005, 090038).

2.2.3 Otowi Member (Qbo)

The Otowi Member includes both the ash-flow (Qbof) and the basal pumice (Qbog).

2.2.3.1 Otowi Member, Bandelier Tuff (Qbof)

The Otowi Member consists of moderately consolidated, porous, nonwelded ash-flow tuffs. The ash-flow tuffs are vitric and contain light gray-to-orange pumice supported in a white to tan ashy matrix of glass shards, broken pumice, crystals, and rock fragments (Broxton et al. 1995, 058207; Goff 1995, 049682). Structure contours indicate that the Otowi Member ash-flow tuffs filled a broad south-draining paleovalley west of the Cerros del Rio basaltic highland and east of the Sierra de los Valles (Broxton and Vaniman 2005, 090038).

2.2.3.2 Guaje Pumice Bed, Otowi Member, Bandelier Tuff (Qbog)

The Guaje Pumice Bed forms the base of the Otowi Member of the Bandelier Tuff, which erupted from the Toledo Caldera at approximately 1.61 Ma (Izett and Obradovich 1994, 048817, Spell et al. 1996, 055542). The Guaje Pumice Bed contains layers of sorted vitric pumice fragments whose mean size varies between 2 and 4 cm. It has an average thickness of ~9 m over much of the Plateau. Geophysical logs show that the Guaje Pumice Bed has a higher porosity than overlying Otowi Member ash-flow tuffs and the underlying Puye Formation (Broxton and Vaniman 2005, 090038).

2.2.4 Puye Formation

The Puye Formation is a large apron of overlapping alluvial and pyroclastic fans that were shed eastward from the JVF into the western EB (Griggs and Hem 1964, 092516; Bailey et al. 1969, 021498). This unit consists of highly stratified, poorly cemented gravels and conglomerates, consisting of subrounded dacitic and andesitic lava clasts in a poorly sorted, sandy to silty matrix. Debris flows, ash beds, pumiceous volcaniclastic sediments, and beds of fluvial sand and silt are interbedded with the gravels and conglomerates. Because its primary source area was volcanic domes in the Sierra de los Valles, the Puye Formation overlaps and postdates the Tschicoma Formation (Broxton and Vaniman 2005, 090038).

2.2.5 Tschicoma Formation

The Tschicoma Formation includes dacitic to low-silica rhyolitic flows.

2.2.5.1 Tschicoma Formation, Pajarito and Caballo Mountains, Cerro Grande (Tvt2)

The Tschicoma Formation of the Polvadera Group consists of thick dacitic to low-silica rhyolitic lava flows that make up the rugged Sierra de los Valles highlands west of Los Alamos. The flows erupted from large overlapping dome complexes. The upper portion of this unit (Tvt2) includes the Pajarito Mountain, Cerro Grande, and Caballo Mountain lobes of the Tschicoma Formation, as well as fine-grained dacites encountered in the subsurface of an unknown source. Lavas from the Pajarito Mountain, Cerro Grande, and Caballo Mountain centers are predominantly dacite, aged between 2.93 and 3.35 Ma (Broxton and Vaniman 2005, 090038).

2.2.5.2 Tschicoma Formation, Rendija Canyon Lobe (Tvt1)

The lower portion of the Tschicoma Formation (Tvt1) consists of the Rendija Canyon lobe and includes low-silica rhyolite erupted from a deeply eroded dome complex in the Rendija Canyon and Guaje Mountain area that has yielded ages between 4.98 and 5.36 Ma (Broxton et al. 2007, 106121).

2.2.6 Cerros del Rio Basalt (Tb4)

The Cerros del Rio volcanic field was active from approximately 4.5 to 2.0 Ma (WoldeGabriel et al. 2001, 092523). These rocks are mostly basalts and basaltic andesites, but subordinate dacite is also present. The Cerros del Rio Basalt is generally composed of thick sequences of stacked lava flows separated by interflow breccia, scoria, sediment, and ash. Outcrops of the Cerros del Rio Basalt cap the Tesuque Formation east of the Rio Grande and the Puye Formation in the vicinity of White Rock. These basalts are buried to increasing depths below the Plateau in the

central portions of the model and may lap onto or interfinger with the Tschicoma flows at isolated locations to the west (Cole et al. 2006, 095079).

2.2.7 Ancha Formation

The Ancha Formation was deposited on an alluvial slope in the Santa Fe area by west-flowing, ephemeral streams (Koning et al. 2002, 105711). It overlies older strata across an angular unconformity. The Ancha Formation contains a coarse-grained and a fine-grained part (Koning et al. 2002, 105711).

2.2.7.1 Ancha Formation (QTa)

Found near the base of the deposit and the mountain front to the east, the coarse-grained part is commonly reddish and consists of sandy pebbles to cobbles. The coarse-grained deposit laterally grades westward into a finer-grained deposit consisting of light yellowish brown to brownish yellow, silty-clayey sand (mostly very fine- to medium-grained). In many places, the Ancha Formation is not saturated. Where it is saturated, groundwater is found near the base of the deposit where the deposit is relatively thick (50–90 m thick). Most of the deposition occurred in the late Pliocene, with aggradation continuing near the mountain-front during the early Pleistocene (Koning et al. 2002, 105711).

2.2.7.2 Ancha Formation, Santa Fe River (QTasr)

An ancestral Santa Fe River was present during Ancha Formation deposition (primarily late Pliocene). The river deposited relatively coarse-grained sediment that interfingers southward and northward into alluvial slope deposits of unit QTa. The sediment of this unit contains sandy gravel (typically cobbles and pebbles) that interfinger with overbank facies of clayey-silty sand. Colors are generally reddish. Near Santa Fe, the unit is inset into lithosome S of the Tesuque Formation (Ttsc).

2.2.8 Totavi Lentil (Tpt)

This unit includes the Totavi Lentil as well as older river gravels. Based on new well data, it appears that the Totavi Lentil river gravels may form lenticular deposits of limited lateral extent and that ancient river deposits in the Pajarito Plateau area are coeval with a variety of stratigraphic units that span a longer time interval than previously recognized (Broxton and Vaniman 2005, 090038). The river gravels probably represent channel deposits of the ancestral Rio Chama/Rio Grande drainages and contain Precambrian and younger cobbles from northern source areas, indicating through-going, north-to-south fluvial systems dating to at least approximately 7.9 Ma (Broxton and Vaniman 2005, 090038; Broxton et al. 2006, 092520).

2.2.9 Bearhead Rhyolite and Fanglomerates (Tjfp)

This unit incorporates the pumiceous Bearhead Rhyolite, vitric pumiceous deposits related to the Peralta Tuff, and older fanglomerate material derived predominantly from erosion of the Keres Group volcanic highlands. These fanglomerates interfinger with Santa Fe Group sands within a north-south trending, troughlike structure in the central portion of the Plateau. This unit does not crop out; its existence and modeled geometry are based solely on well logs and cuttings and surrounding geologic controls. The geometry of this unit suggests deposition within a fault-controlled basin with associated episodic basaltic volcanism (Cole et al. 2006, 095079). This unit tends to be part of the most productive aquifer beneath the Pajarito Plateau (Purtymun 1995, 045344).

2.2.10 Keres Group Volcanics (Tvk)

The Keres Group includes basaltic and rhyolitic rocks that erupted as the JVF began to develop (Gardner et al. 1986, 059104; Goff and Gardner 2004, 092526). These rocks intrude and cover Santa Fe Group rocks along the western edge of the EB (Cole et al. 2006, 095079).

2.2.11 Chamita Formation

The Chamita Formation forms the upper part of the Santa Fe Group.

2.2.11.1 Chamita Formation, Lithosome A (Tcac)

Lithosome A of the Chamita Formation is used to designate strata containing arkosic sand and granite-bearing gravel that were deposited on an alluvial slope by streams draining the west flank of the Sangre de Cristo Mountains south of Truchas Peaks (Cavazza 1986, 105708). Technically, lithosome A extends into the Tesuque Formation east of the Rio Grande (Koning and Aby 2005, 106162).

Lithosome A that is younger than 13.2 Ma is relatively coarser grained (Koning 2002, 105710; Koning et al. 2002, 105711; Koning et al. 2005, 106120), and consists of slightly orange-tan, coarse channel-fill of sandy conglomerate and conglomeratic sandstone, interbedded with subordinate clayey-silty sandstone. Unit Tcac reflects this coarse-grained lithosome A, excluding relatively fine-grained, distal alluvial slope strata. These relatively coarse strata correlate with the Cuarteles Member of the Chamita and Tesuque Formations (Koning and Aby 2005, 106162; Koning et al. 2005, 106120). The Cuarteles Member is considered part of the Tesuque Formation east of the Rio Grande and part of the Chamita Formation west of the Rio Grande. This unit interfingers westward with unit Ttca and gradationally overlies unit Ttca.

2.2.11.2 Chamita and Tesuque Formations, Lithosome A (Ttca)

Unit Ttca includes relatively fine-grained, distal alluvial slope strata that postdates the 13.2 Ma coarsening of Tcac (Koning et al. 2007, 106122). The sediment is a slightly orange-tan to tan, clayey-silty sandstone intercalated with subordinate coarse channel-fills of sandy conglomerate and conglomeratic sandstone. Gravel includes granite with minor, yellowish Paleozoic limestone and siltstone. Minor quartzite clasts are also present. The unit correlates with the fine-grained, distal Cuarteles Member of the Chamita and Tesuque Formations (Koning and Aby 2005, 106162; Koning et al. 2005, 106120) and also correlates with lithosome A sediment of the Pojoaque, Skull Ridge, and Nambe Members of the Tesuque Formation (Cavazza 1986, 105708). This unit grades laterally westward into lithosome B (Ttb) and laterally southward into deposits of the ancestral Santa Fe River (units Ttsc and Ttsf).

2.2.11.3 Transition Zone between Ttca and Tcar (Tcara)

This unit reflects a zone of interfingering and mixing between coarse-grained lithosome A and the axial river deposits of the Chamita Formation. Lithosome A in this zone is typically a slightly orange-tan, silty-clayey sand, interbedded with minor pebbly channel-fills. The axial river deposits include floodplain deposits of claystone, siltstone, and very fine- to medium-grained sandstone that are subequal in proportion to coarse channel-fills of fine- to very coarse-grained sand, pebbly sand, and sandy pebbles-cobbles. Colors of the axial river deposits are generally tannish. This unit interfingers eastward with unit Ttca, and interfingers westward with unit Tcar. It gradationally overlies lithosome B of the Tesuque Formation (Ttb).

2.2.11.4 Chamita Formation, Axial River Deposits (Tcar)

Sediments deposited by the river system flowing south along the basin floor of the EB coarsened after ~13.2 Ma (Koning et al. 2005, 106120; Koning et al. 2007, 106122). This coarser sediment consists primarily of channel-fills of sandstone, gravelly sandstone, and sandy conglomerate. Floodplain deposits of claystone, siltstone, and very fine- to medium-grained sandstone are subequal in proportion to the coarse channel-fills. The gravel of the axial river deposits contains felsic to intermediate volcanic clasts, with lesser quartzite and Paleozoic sedimentary clasts. Tannish colors generally typify the unit. The unit correlates to the Vallito, Hernandez, and Cejita Members of the Chamita Formation (Koning and Aby 2005, 106162). The unit includes sandy channel-fills from a drainage that flowed southeastward in the region that is now the Jemez Mountains. This unit interfingers eastward with unit Tcara and overlies units Ttb and Ttc.

2.2.12 8.4–9.3 Ma Basalts (Tb2)

The Bayo Canyon Basalt is a rift basalt and consists of local, episodic, Miocene basalt to latitic flows that are 8.4 to 9.3 Ma (WoldeGabriel et al. 1996, 054427; WoldeGabriel et al. 2001, 092523) that are interbedded with basin sediments. The flows are intermixed with both Keres Group and Santa Fe Group sedimentary units in a zone that extends from the central plateau east to Bayo Canyon, and south to Ancho Canyon (Cole et al. 2006, 095079). Model boundaries for this unit extend from the bottom of the oldest flow to the top of the youngest flow. Thus, the volume of this unit includes any intercalated sediments.

2.2.13 11.6–13.1 Ma Basalts (Tb1)

The Guaje Canyon Basalt (Tb1) is a thick sequence of basalt flows contained within the Tesuque Formation in the vicinity of Guaje Canyon. The basalts range from 11.55 to 13.1 Ma (WoldeGabriel et al. 1996, 054427; WoldeGabriel et al. 2001, 092523). The Tb1 unit crosses the stratigraphic boundary between the Chamita Formation (Tcar) and the Chama–El Rito Member of the Tesuque Formation (Ttc). The portion of this flow unit within Ttc is designated as Tb1a. The portion of this flow unit within Tcar is designated as Tb1b.

2.2.14 Tesuque Formation

The Tesuque Formation forms the lower part of the Santa Fe Group.

2.2.14.1 Tesuque Formation, Chama–El Rito Member (Ttc)

In the study area, strata assigned to the Chama–El Rito Member are light orange-tan. Sediment consists primarily of very fine- to medium-grained sand, siltstone, and claystone. Pebble beds are very sparse. The unit was deposited on a southward-southeastward alluvial slope environment in the west part of the EB during the early to middle Miocene epoch. The unit includes quartz-rich sand from a southeast-flowing, tributary drainage. This unit gradationally underlies unit Tcar and interfingers eastward with lithosome B of the Tesuque Formation (Ttb).

2.2.14.2 Tesuque Formation, Lithosome S, Coarse-Grained Part (Ttsc)

An ancestral equivalent of the Santa Fe River deposited relatively coarse-grained sediment in the Santa Fe area during the early to middle Miocene epoch. This sediment was named lithosome S by Koning et al. (2004, 106104). Generally reddish, this sediment consists mostly of pebbly sand and sandy pebble channel-fills. Overbank deposits of clay, siltstone, and clayey very fine- to fine-grained sandstone are subordinate. Gravel includes granite with minor, yellowish Paleozoic limestone and siltstone. Minor quartzite clasts are also present. The unit grades northward into lithosomes A and B (units Ttca and Ttb) and westward into finer-grained lithosome S (Ttsf). The unit gradationally overlies the finer-grained part of lithosome S (Ttsf).

2.2.14.3 Tesuque Formation, Lithosome S, Fine-Grained Part (Ttsf)

This unit is also identified as a part of lithosome S by Koning et al. (2004, 106104). Although finer grained than the coarse-grained part of lithosome S (Ttsc), the finer-grained part of lithosome S is still, in an overall sense, coarser grained than lithosomes B and A to the north (units TTb and Ttca). This unit contains relatively abundant, reddish clay, silt, and very fine- to medium-grained sand deposits, which are intercalated with subordinate coarse-grained channel-fills of pebbly sand and sandy pebbles-cobbles. The finer-grained part of lithosome S grades northward into lithosomes A and B (units Ttca and Ttb) and westward into lithosome B (Ttb). The unit gradationally underlies the coarser-grained part of lithosome S (Ttsc).

2.2.14.4 Tesuque Formation, Lithosome B (Ttb)

Lithosome B was deposited on a wide basin floor between approximately 25 and 13 Ma by a drainage system flowing south southwest from the San Luis Basin and Peñasco embayment (Cavazza 1986, 105708; Koning et al. 2005, 106120). Relatively fine-grained, overbank deposits predominate in the SEB model area (Koning 2002, 105710; Koning and Maldonado 2003, 106112). These consist of light gray to light greenish gray clay, silt, and very fine- to medium-grained sand. Subordinate coarse-grained channels contain medium- to very coarse-grained sand, pebbly sand, and sandy pebbles. Gravel includes clasts of Paleozoic sedimentary rocks (limestone, sandstone, and siltstone), in addition to minor quartzite and felsic-intermediate volcanic clasts. This unit grades southward into ancestral Santa Fe River deposits (units Ttsc and Ttsf) and eastward into alluvial slope deposits of lithosome A (Ttca).

2.2.14.5 Tesuque Formation, Lower Lithosome A, Fine Grained (Ttal)

In the Santa Fe area, adjacent to the Sangre de Cristo Mountain front, lies tannish to pinkish sand, clayey sand, and pebbly-cobbly sand. Gravel contains primarily granite clasts, although locally, yellowish Paleozoic limestone-siltstone clasts are present. This unit is well-consolidated and underlies fine-grained lithosome S. It grades northward into the lower, coarse-grained unit (Ttlc).

2.2.14.6 Tesuque Formation, Lower Coarse Unit (Ttlc)

At the base of the Santa Fe Group in the eastern E, lies relatively coarse-grained, alluvial slope deposits. This sediment is tannish to pinkish and contains channel-fills of sandy pebbles-cobbles, pebbly sand, and very fine- to very coarse-grained sand. Overbank beds of clay, silt, and very fine- to fine-grained sand are minor. Gravel contains primarily granite clasts, although the proportion of Paleozoic limestone clasts increases to the south. Near the Rio Tesuque drainage, the proportion of Paleozoic limestone clasts increases down section. This unit grades laterally southward into unit Ttal and is gradationally overlain by unit Ttca. This unit grades laterally westward into lithosome B (unit Ttb).

2.2.15 Bedrock (Bedr)

Underlying the Santa Fe Group are various, typically well-cemented or indurated, formations that we have combined into one unit called “bedrock,” or the Pre-Miocene-Tertiary bedrock. This surface represents the base of the Santa Fe Group, as defined by Grauch et al. (available at http://pubs.usgs.gov/pp/1761/). The combined formations of this unit are described from top to bottom (youngest to oldest). At the top of this unit are lava flows and intercalated, mafic volcaniclastic deposits of the Cieneguilla basanite; this unit is typically dark gray. The Espinaso Formation consists of alluvial fan deposits that were shed away from a volcanic edifice centered near the Cerrillos Hills–La Cienega area. The sediment is composed of latitic to andesitic detritus. There are minor latitic flows intercalated in the well-cemented, light gray to gray alluvial fan deposits. The Galisteo Formation includes red sandstone, pebbly sandstone, and mudstone deposited in a depression formed during the Laramide orogeny. Sand and clasts in the study area are primarily of arkosic and granitic composition, with minor Paleozoic limestone detritus. Mesozoic–Paleozoic strata in the study area mostly consist of interbedded limestone, shale, and sandstone.

The EB model includes an older/deeper unit of Proterozoic rocks that includes pink to red granite and gneiss to the southwest of the model (Goff 2009, 106105), and metasedimentary, metavolcanic, and granitic rocks to the east (Daniel 1995, 106123). This unit is not shown in the atlas because it will be added to the model at a later date when the full basin model is completed. Within the extent of the atlas, this unit is probably located at depths below sea level.

3.0 MAPPING OF THE REGIONAL WATER-TABLE ELEVATION

The regional aquifer beneath the Laboratory is a complex hydrogeological system. The top of the aquifer is predominantly under phreatic (water-table) conditions. However, there are also areas of local confinement that are caused by local hydrogeological conditions. In general, the top of the regional aquifer is defined by the elevation of the regional water table. In the areas of local confinement, there is a regional piezometric surface that represents the elevation of hydraulic heads in the confined zones. In general, the regional piezometric surface can be considered to represent a spatial continuation of the water table in the confined areas. Because the aquifer is predominantly under

phreatic conditions, in the text below, the term “regional water table” is used even though in some areas of the aquifer the term “regional piezometric surface” is more appropriate.

The general shape of the regional water table is predominantly controlled by the areas of regional recharge to the west (flanks of Sierra de los Valles) and discharge to the east (the Rio Grande and the White Rock Canyon Springs). The structure of regional phreatic flow is also expected to be impacted by (1) local infiltration zones (e.g., beneath wet canyons), (2) aquifer properties heterogeneity, and (3) discharge zones (water supply wells and springs).

Information about the elevation of the regional water table is provided by existing data from monitoring wells (water levels) and selected springs (discharge elevations). Well data are predominantly applied to map the elevation of the regional water table; spring discharge elevations are used only in the vicinity of White Rock Canyon to provide additional constraints on the water-table elevation.

Water-table elevations vary in time due to transient effects that include pumping of the water supply wells, and large- and small-scale variability in aquifer recharge. Therefore, water-level maps represent specific periods of time. Based on analysis of 2008 water-level data (Koch and Schmeer 2009, 105181), it has been observed that water levels generally reached recent maxima in March 2008. The March 2008 data are likely to be the least affected by pumping and thus are potentially most representative of ambient flow conditions. Therefore, these data are used, in part, to construct the water-table map.

Monthly averaged water levels for March 2008 are computed for 36 regional aquifer wells and presented in Table 3-1. For the wells, R-7, R-14, R-33, and R-36, water-level data are not available for March 2008 (Table 3-1), and alternative periods of representative measurements have been selected. For five wells, H-19, TW-1, TW-2, TW-3 and TW-4 (Table 3-1), historic water-level data considered to be less certain but important for constraining the water-table map in the northern portion of the Laboratory site are used. New water-level data are also available from a series of recently drilled wells (R-38, R-39, R-40, R-41, R-42, R-43, R-44, R-45, and R-46), but the measurements are difficult to interpret because they are preliminary and for a different time period. Future analysis will address how these data will be incorporated in the water-table mapping. The available preliminary water-level measurements for these wells are listed in Table 3-1 but are not applied in the mapping process.

Inclusion of water-level data that do not represent the March 2008 time period is a source of uncertainty in the mapping process. Differences in the screen placements and local hydrogeologic conditions also complicate the interpretation of the water-level data for the following reasons.

1. Some screens are substantially below the top of regional saturation (more than 60 ft); as a result, the collected water-level data may not be representative of the actual water-table elevations (TW-1, R-10a, R-13, R-18, R-20, R-21, R-24, R-26, R-32, and R-34; 10 wells in total).
2. Some screens are long (more than 50 ft) and may represent composite water levels within the aquifer (DT-5A, DT-9, DT-10, R-8, R-13, and R-15; 6 wells in total).
3. Some screens are potentially under confined conditions and may represent piezometric surface elevations (R-4 and R-24; 2 wells).
4. R-25 is drilled in a complicated hydrogeological setting, and it is uncertain which of the R-25 screens (screen 4 or 5) provides information about the water-table elevation.
5. R-9 is screened in a zone (basalts within Santa Fe Group, Tb2) that is potentially disconnected from the regional aquifer. The regional aquifer screen R-12 is in a similar setting, but this screen has been plugged and abandoned. Water-table screens are located in various hydrostratigraphic units, including sedimentary and volcanic rocks with contrasting hydrogeologic properties (Table 3-1). The structure of the regional water table is probably impacted by groundwater flow within hydrostratigraphic units with contrasting properties. For example, low permeability lava flows may divert the phreatic groundwater flow. Lavas occur at or near the regional water table at R-5, R-9, and R-12 (Miocene basalts [Tb2], and at R-32, R-20, and R-22 [Cerros del Rio Basalts, Tb4]).

Related to issue 5 above, the regional water levels observed at R-9 and at the former R-12 regional screen are substantially lower than water levels observed at nearby wells. (Since December 2007, the regional screen at R-12, screen 3, is abandoned and not monitored; the regional screen of R-12 is replaced by R-36.) The regional screens in both wells are in Miocene basalt (Tb2). R-9 and R-12 monitoring wells are located near water supply wells PM-1 and O-1, and their low water levels might define cones of drawdown around the production wells. However, water levels at R-9 and R-12 do not respond to daily or seasonal changes in municipal water production, suggesting that their low heads are not caused by the water supply pumping. Alternatively, the regional screens at R-9 and R-12 may represent a deep compartmentalized zone within the Santa Fe Group basalt that is in poor hydraulic connection with the rest of the aquifer.

Because of the uncertainties described above, we evaluated a series of alternative conceptual-model assumptions pertaining to the regional groundwater flow and chose the model presented in Plate 3-1.

The process of water-table contouring is theoretically constrained by the following conformity rules (Freeze and Cherry 1979, 088742): (1) the contour lines should be perpendicular to the flow paths and (2) the length and the width of the flow net cells formed by the contour lines between two adjacent flow paths should have the same ratios. These rules are theoretically valid only for the case of a uniform isotropic aquifer with no recharge/discharge sources within flow net cells. Deviations from the conformity rules are caused by aquifer heterogeneity and anisotropy as well as recharge/discharge sources within flow net cells.

The regional water table is contoured by attempting to satisfy three goals simultaneously: (1) to match the water-level data at the monitoring wells, (2) to account for issues of data representativeness, and (3) to preserve flow net conformity. Plate 3-1 is a contour map of the regional water table that attempts to satisfy those three goals. The actual contouring is performed using a combination of manual and automated techniques. (The automated contouring is performed using the standard splining methods.) Table 3-1 lists the deviations between observed and predicted (based on the contoured water-table map) water levels.

The water-level data and the contoured map (Plate 3-1) suggest potential mounding of the regional water table near TW-1, R-8, and R-36 (the water level at R-36 is slightly higher than the water levels of R-28 and R-11). The mounding may result from local recharge of the regional aquifer along Los Alamos, Pueblo, and Sandia Canyons.

The water-level data represented by the contour map indicate that thick lavas near R-32 and R-22 may be the cause of the increased phreatic hydraulic gradients in this area. This may be the result of lower transmissive properties of lava flows compared with the more transmissive Puye Formation and Santa Fe Group sediments. The hydrogeologic properties associated with the lava flows may be also responsible for diverting the flow of phreatic groundwater to the north. The increased hydraulic gradients in the area of R-32 and R-22 may also be an indication of recharge in the lower Pajarito Canyon area that causes local mounding in the lavas, which are expected to be of low storativity when compared with the Puye Formation fanglomerates and Santa Fe Group sediments.

Table 3-1 also lists the differences between observed and contoured water-level elevations displayed in Plate 3-1. Most of the discrepancies are minor and within 3 ft. Substantial deviations are calculated for locations at which the water-level data are uncertain: TW-1, R-5, R-9, R-8, R-10a, and R-25. The table also compares the predicted water levels with recently collected water-level data not included in the mapping. Substantial differences are observed only at R-41 and R-46 where static water-level conditions may not have been achieved. Future analysis will incorporate the water-level data from recently installed monitoring wells.

Plate 3-2 identifies the modeled geologic units present at the regional water table model.

Table 3-1.
Summary of Well-Screen Positions, Water-Level Observations, and Differences between Observed and Contoured Water Levels

Well/Screen Name	Geologic Unit	Surface Elevation (ft)	Screen Top (ft bgs)	Screen Bottom (ft bgs)	Screen Length (ft)	Observed Water-Level Elevation (ft)	Representative Measurement Period	Top of the Screen from the Water Level (ft)	Comments	Differences between Observed and Contoured Water-Level Elevation (ft)
H-19	Tpf	7172	—*	—	—	6228.00	Jan-51	—	Historic observation applied to constrain water-levels in the NW section of LANL site. The data are uncertain	1.47
TW-1	Tcar	6369.19	632.00	642.00	10.00	5855.50	Feb-06	118.31	Historic observation applied to constrain water-levels in the NE section of LANL site. The data are uncertain and potentially affected by well construction problems	35.53
TW-2	Tcar	6648.06	768.00	824.00	56.00	5845.70	Oct-00	-34.36	Historic observation applied to constrain water-levels in the N section of LANL site. The data are uncertain	0.09
TW-3	Tcar	6626.90	805.00	815.00	10.00	5840.10	Feb-06	18.20	Historic observation applied to constrain water-levels in the N section of LANL site. The data are uncertain	0.74
TW-4	Tvt1	7244.56	1195.00	1205.00	10.00	6071.50	Feb-06	21.94	Historic observation applied to constrain water-levels in the NW corner of LANL site. The data are uncertain	1.79
CdV-16-3i	Tvt2	7486.40	—	—	—	6136.75	Oct-05	—	Open borehole. The data are uncertain	2.17
CdV-R-15-3#4	Tpf	7258.90	1235.10	1278.90	43.80	6019.50	Mar-08	-4.30	No comment	-1.17
CdV-R-37-2#2	Tvt2	7330.60	1188.70	1213.80	25.10	6137.00	Mar-08	-4.90	No comment	0.62
DT-10	Tb4/Tpf/Tcar	7019.00	1080.00	1408.00	328.00	5918.70	Mar-08	-20.30	Long screen; Composite water-level expected	1.31
DT-5A	Tb4/Tpf/Tcar	7144.20	1172.00	1821.00	649.00	5958.08	Mar-08	-14.12	Long screen; Composite water-level expected	0.10
DT-9	Tb4/Tpf/Tcar	6936.00	1040.00	1501.00	461.00	5915.12	Mar-08	19.12	Long screen; Composite water-level expected	0.71
R-1	Tjfp	6881.21	1031.12	1057.42	26.30	5878.27	Mar-08	28.18	No comment	-0.44
R-2	Tcar	6770.38	906.45	929.57	23.12	5870.65	Mar-08	6.72	No comment	-0.46
R-4	Tcar	6577.49	792.90	816.00	23.10	5830.83	Mar-08	46.24	Hydrogeologic data suggest confined conditions	-0.84
R-5#3	Tcar	6472.60	676.90	720.30	43.40	5766.75	Mar-08	-28.95	No comment	-42.83
R-6	Tcar	6995.80	1205.00	1228.00	23.00	5838.44	Mar-08	47.64	Screen significantly below water table	-0.82
R-7#3	Tjfp	6779.20	895.50	937.40	41.90	5877.25	Apr-08	-6.45	Water-level data missing for Mar 2008	-0.91
R-8#1	Tcar	6544.74	705.31	755.70	50.39	5853.22	Mar-08	13.79	Long screen below water table	7.29
R-9	Tb2	6382.80	683.00	748.50	65.50	5691.52	Mar-08	-8.28	Water-level may be not representative of the regional water-table due to local aquifer heterogeneities	-108.48
R-10a	Tcar	6363.74	690.00	700.00	10.00	5740.49	Mar-08	66.75	Screen significantly below water table	-3.65
R-11	Tjfp	6673.72	855.00	877.90	22.90	5837.78	Mar-08	19.06	No comment	0.19
R-13	Tpf/Tjfp	6673.05	958.33	1018.72	60.39	5836.08	Mar-08	121.36	Long screen significantly below water table	0.18
R-14#1	Tpf/Tjfp	7062.08	1200.60	1233.20	32.60	5880.19	Feb-08	18.71	Water-level data missing for Mar 2008	0.00
R-15	Tpf/Tjfp	6820.00	958.60	1020.30	61.70	5850.65	Mar-08	-10.75	Long screen; Compsite water-level expected	-0.41
R-16r	Tpt	6256.97	600.00	617.60	17.60	5692.58	Mar-08	35.61	No comment	-0.08
R-17#1	Tpf	6921.51	1057	1080	23.00	5884.77	Mar-08	20.26	No comment	-0.05
R-18	Tpf	7404.83	1358.00	1381.00	23.00	6117.11	Mar-08	70.28	Screen significantly below water table	-0.93
R-19#3	Tpf	7066.30	1171.40	1215.40	44.00	5887.40	Mar-08	-7.50	No comment	-0.73
R-20#1	Tb4	6694.35	904.60	912.20	7.60	5864.60	Mar-08	74.85	Screen significantly below water table	1.26
R-21	Tpf	6656.24	888.80	906.80	18.00	5854.53	Mar-08	87.09	Screen significantly below water table	0.19
R-22#1	Tb4	6650.50	872.30	914.20	41.90	5755.00	Mar-08	-23.20	No comment	0.28

Table 3-1. (continued)

Well/Screen Name	Geologic Unit	Surface Elevation (ft)	Screen Top (ft bgs)	Screen Bottom (ft bgs)	Screen Length (ft)	Observed Water-Level Elevation (ft)	Representative Measurement Period	Top of the Screen from the Water Level (ft)	Comments	Differences between Observed and Contoured Water-Level Elevation (ft)
R-23	Tcar	6527.75	816.00	873.20	57.20	5697.41	Mar-08	-14.34	No comment	0.09
R-24	Tcar	6547.38	825.00	848.00	23.00	5830.04	Mar-08	107.66	Hydrogeologic data suggest confined conditions	-1.17
R-25#5	Tpf	7516.10	1294.70	1304.70	10.00	6234.27	Mar-08	12.87	Uncertain which of the R-25 screens characterizes water-table elevation (4 or 5)	-4.15
R-26#2	Tpf	7641.69	1422.00	1445.00	23.00	6538.00	Mar-08	318.31	Screen significantly below water table	-2.20
R-27	Tpf	6713.72	852	875	23.00	5898.21	Mar-08	36.49	No comment	-0.79
R-28	Tpf/Tjfp	6728.61	934.30	958.10	23.80	5838.31	Mar-08	44.00	Screen significantly below water table	1.13
R-31#2	Tb4	6362.50	515.00	545.70	30.70	5827.44	Mar-08	-20.06	No comment	0.29
R-32#1	Tb4/Tpt	6637.63	867.50	875.20	7.70	5852.74	Mar-08	82.61	Hydrogeologic data suggest confined conditions	0.19
R-33#1	Tjfp	6853.33	995.50	1018.50	23.00	5871.20	Jun-08	13.37	Water-level data missing for Mar 2008	-0.34
R-34	Tcar	6629.99	883.70	906.60	22.90	5834.47	Mar-08	88.18	Screen significantly below water table	0.51
R-35b	Tpf	6625.21	825.40	848.50	23.10	5837.00	Mar-08	37.19	No comment	-0.66
R-36	Tcar	6591.37	766.90	789.90	23.00	5839.47	Apr-08	15.00	Water-level data not available for Mar 2008	1.49
R-38	Tpf	6668.58	821.20	831.20	10.00	5858.73	Jan-09	11.35	Recently installed well. Insufficient water-level record; Hydrogeologic data suggest confined conditions	1.43
R-39	Tb4/Tpf	6580.86	859.00	869.00	10.00	5754.16	Jan-09	32.30	Recently installed well. Insufficient water-level record; Hydrogeologic data suggest confined conditions	-2.85
R-40 # 2	Tpf	6718.00	849.30	870.00	20.70	5864.10	Oct-08	-4.60	Recently installed well. Insufficient water-level record	-2.78
R-41	Tpt	6650.50	965.00	975.00	10.00	5690.37	Mar-09	4.87	Recently installed well. Insufficient water-level record	-72.26
R-42	Tjfp	6759.02	931.80	952.90	21.10	5839.22	Nov-08	12.00	Recently installed well. Insufficient water-level record	0.49
R-43#1	Tcar	6732.65	903.90	924.60	20.70	5839.65	Jan-09	10.90	Recently installed well. Insufficient water-level record	-1.88
R-44#1	Tpf	6714.91	895.00	905.00	10.00	5835.91	Jan-09	16.00	Recently installed well. Insufficient water-level record	-1.25
R-45#1	Tpf	6704.02	880.00	890.00	10.00	5836.12	Jan-09	12.10	Recently installed well. Insufficient water-level record	0.45
R-46	Tpf	7213.33	1340.00	1360.00	20.00	5885.33	Jan-09	12.00	Recently installed well. Insufficient water-level record	-12.17

*— = No data.

4.0 MAP SPECIFICATIONS

All maps are presented in 11- × 17-in. format at a scale of 1:80,000. All map plates include the boundary of the Laboratory and major roads for reference. Unit codes and colors, as defined in Figure 2-5, are consistent for all plates, cross-sections, and 3-D views. The map indices for wells are consistent throughout the set of plates.

Plates mapping the unit surfaces provide well locations only for those wells that contribute exact data to the surface that is mapped. “Exact” is used to mean “hard” data that provide an elevation value. Other wells contain “soft” data that provide “greater than,” “less than,” or “absent” constraints. While this “soft” information is used in the development of the surfaces, well locations for these data are not shown. In some cases, the density of the data prevents identification of all wells with “hard” constraints.

The principal component of an atlas is the set of maps or plates. The maps of this atlas provide the identification and/or definition of surface and subsurface features for the region encompassing the Laboratory and the town of Los Alamos (including White Rock), extending west past the Pajarito Fault zone into the Sierra de los Valles, and east approximately 8 mi past the eastern extent of the Laboratory boundary. The maps are presented using New Mexico state plane (NAD 83) coordinates (in feet). The mapped area, and the reference grid with labels outside of the map area, are extended to the full page size. Placement of map labels, legends, scale, north arrow, and descriptive text are therefore restricted to within the map area, resulting in the masking of some of the map data.

The Laboratory site and most of the volcanic, geologic units are located within the western portion of the map area. For this reason, the sets of tabular data are normally placed within the upper-right (eastern) portions of the map plates. The caption is always located at the lower-right corner, the legend and data credits are normally placed in the lower-left corner, and the map scale and north arrow are usually at the upper-left corner of the plate. Many of the older units are defined only within the eastern portions of the map area.

4.1 Base Map

The base map (Plate 1-1) shows the extent of the Hydrogeologic Site Atlas as well as the locations of R-wells, water supply wells, and other wells or boreholes important in constraining the GFM. The base map also shows the location of the major roads and outlines of Laboratory properties. This map also depicts the surrounding land ownership. Plates 1-2 and 1-3 identify all wells that provide data to the geologic models of the Laboratory. Plate 1-2 identifies the vintage of the well data, highlighting the large amounts of new data that were used in this current GFM.

Plate 1-3 provides a table that lists all wells that contributed to the 2009 GFM, including wells outside of the atlas extent but within the SEB. Where wells on a plate are completely within the extent of Laboratory SITE model, the wells are identified in the legend as Laboratory wells. If the set of wells for a plate consists only of wells outside of the Laboratory boundaries and within the SEB model, they are identified in the legend as SEB wells. The Buckman wells are within the Laboratory SITE model but provide minimal “exact” geologic contact information. These wells are displayed separately as the Buckman wells on selected sets of unit maps where they may be of interest.

4.2 Geology

The geology of the atlas region is presented in a series of plates. Plates 2-1 and 2-2 provide a comparison of the mapped geologic quadrangles, and the surface geology predicted by the modeled geologic unit surfaces. Plate 2-3 provides a compilation of mapped fault trace data within the atlas extent, much of which is inferred. Plates 2-4 through 2-83 provide structure contour maps of the unit surface elevations and isochors (vertical thickness). And finally, Plates 2-93 and 2-94 present a 3-D view for the atlas and that of the encompassing SEB model.

4.2.1 Surface Geology

There are two plates that provide maps of the surface geology. Plate 2-1 provides the merged geologic quadrangle maps identified and referenced in Section 1.3. The unit names have been adjusted to reflect the mapping of source unit names to model unit names. Plate 2-2 provides the surface geologic map defined by the GFM and includes a breakout of the subunits of the Tshirege and Otowi members of the Bandelier Tuff not provided in the geologic quadrangle maps. Plate 2-3 provides fault trace data for the atlas area. The structural block model of the 2005 GFM is shown in the western portion of this plate. The faults to the west (in red) were mapped by the seismic hazards team at the Laboratory. Many of the other fault traces are inferred and/or poorly constrained. The inferred faults are older and do not intersect the Bandelier Tuff. Many of these are inferred based on apparent stratigraphic discontinuities in widely spaced well data. Some of these discontinuities may actually represent paleotopography.

The fault traces can be extruded vertically or with a given dip to provide 3-D structural controls for flow models.

4.2.2 Geologic Unit Morphology

The 3-D morphology and geometry of the geologic units are presented in a series of plates: Plate 2-3 through Plate 2-83. Structure contours of the unit surfaces provide a 3-D definition of the units. Such maps are commonly defined as 2.5-D maps. Maps for the tops, isochors, and bottoms of all units are presented in top-to-bottom order through the set of units. Maps for the top and isochors of the Tshirege subunits are also provided.

Each of these plates also identifies the position of all wells that contributed to the definition of the mapped surface. The number at the well position on the map provides an index to the included map table which shows the well name and the elevation or thickness of the unit at the well. The well numbers also correlate to those of Plates 1-2 and 1-3. For Plate 2-4, there were too many wells to place in a map table, so the user must refer to Plate 1-3 for top elevation values at the wells.

The geologic outcrops can provide critical elevation control points for the surfaces. The geologic contacts are often exposed best in the canyons or regions of rugged topography, while wells intersecting these exposed units are usually located some distance within the Pajarito Plateau. The locations of unit outcrops are therefore identified on all plates, using the modeled color of the units. As these outcrops are often of limited geographical extent, e.g., when on the canyon walls, the structure contours for the top of the unit are clipped at the outcrop/topography so that the outcrop is visible to the map reader. For the Cerros del Rio Basalt, which outcrops over a broad surface area in the south-central portion, these top contours have been reinserted into the plate.

4.3 Cross-Sections

Geologic cross-sections of the GFM are provided for the atlas extent at 10,000-ft intervals in both the north-south and east-west directions. These sections identify both the geologic units and the water table. with a 1.75x vertical exaggeration. The modeled water table is not defined throughout the atlas extent, so the water table may be absent from some lines and represented for only parts of other cross-section lines. The locations of the cross-section lines are shown in Plate 2-84. Plate 2-84 also provides the location of “source” geologic cross-sections that were used in the development of the GFM.

4.4 3-D Views of the GFM

The 3-D views of the GFM, with the southeast quadrant removed, are provided for the atlas extent as Plate 2-93 and for the SEB as Plate 2-94.

4.5 Water-Table Elevation and Geology

Plate 3-1 shows the elevations of the regional water table, highlighting the 100-ft contour interval. Fainter contours at 10- or 20-ft intervals are provided for finer resolution, especially in the central portion of the laboratory. The location of springs and major drainages are also indicated. Topographic contours are provided to allow visual determination of the depth to the water table. Plate 3-2 shows the modeled geology at the water-table surface.

5.0 REFERENCES

The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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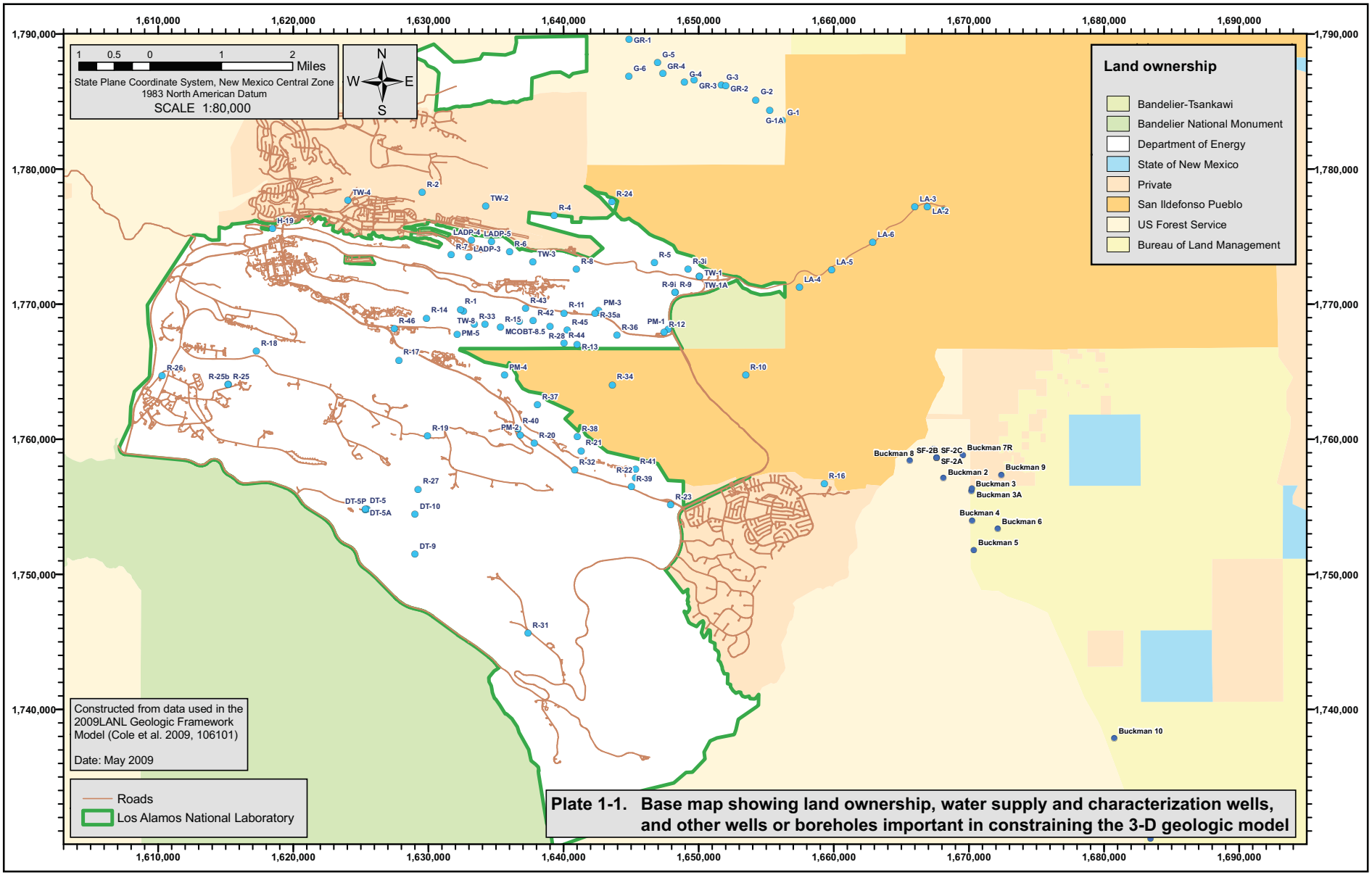
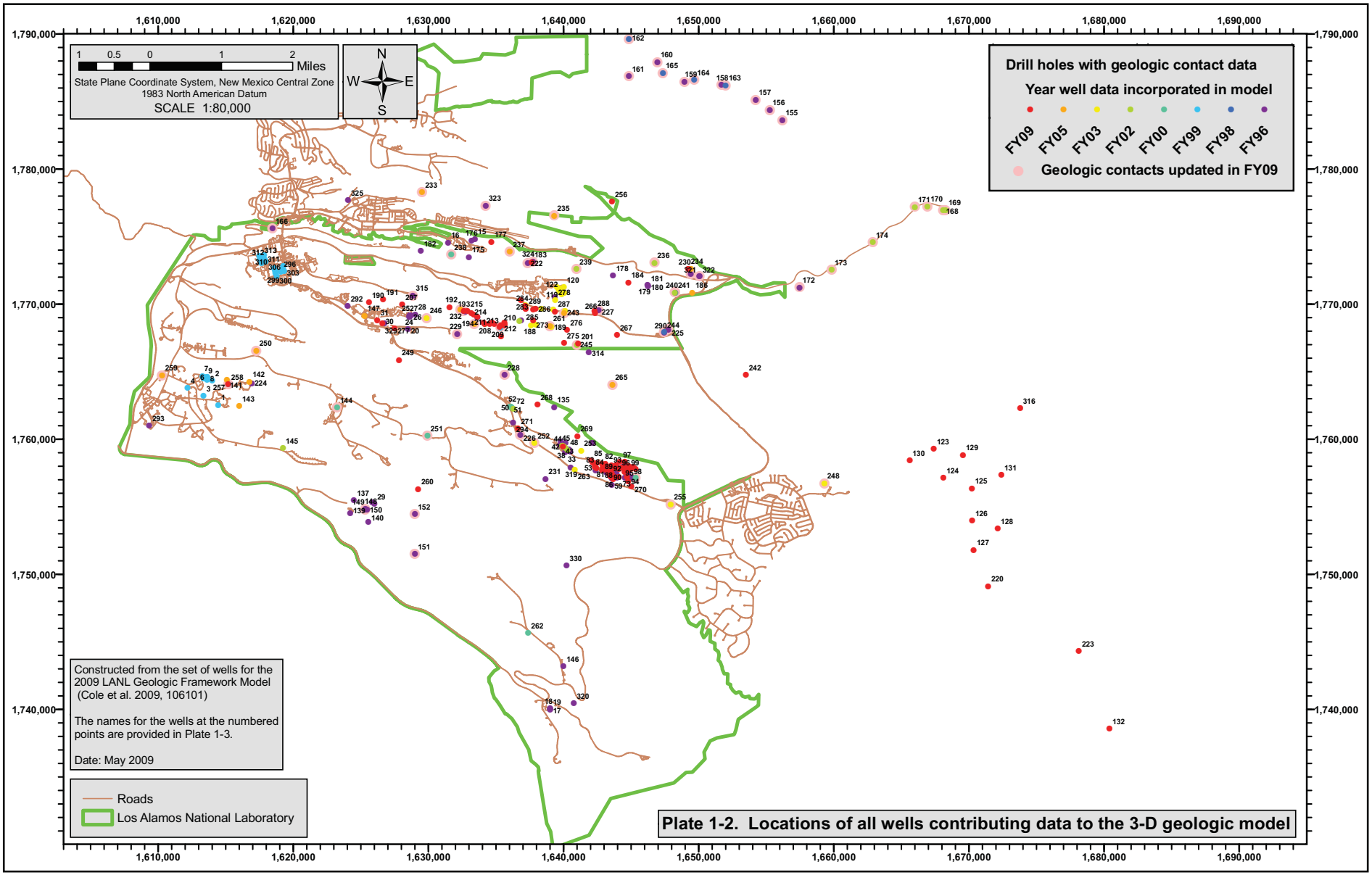


Plate 1-1. Base map showing land ownership, water supply and characterization wells, and other wells or boreholes important in constraining the 3-D geologic model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N
W E
S
Drill holes with geologic contact data
Year well data incorporated in model
FY09 FY05 FY03 FY02 FY00 FY99 FY98 FY96
Geologic contacts updated in FY09
Constructed from the set of wells for the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
The names for the wells at the numbered points are provided in Plate 1-3.
Date: May 2009
Roads
Los Alamos National Laboratory
Plate 1-2. Locations of all wells contributing data to the 3-D geologic model

ID	Well name	Top elev.	Bot elev.
1	16-2665	7517.4	7392.4
2	16-2667	7532.0	7325.0
3	16-2668	7556.0	7368.5
4	16-2669	7584.3	7419.3
5	16-2701	7547.0	7462.0
6	16-2702	7535.0	7466.0
7	16-2703	7549.6	7480.0
8	16-2704	7538.9	7469.0
9	16-2706	7530.0	7440.0
10	16-2708	7543.9	7429.5
11	16-2709	7519.8	7486.0
12	16-2711	7521.0	7453.0
13	16-2712	7522.4	7422.0
14	16-2735	7536.5	7446.0
15	21-1811	7032.5	6772.5
16	21-2523	7159.0	6839.0
17	33-1230	6514.0	6284.0
18	33-1231	6516.0	6201.0
19	33-1232	6517.0	6271.0
20	35-2004	7180.2	7080.2
21	35-2005	7170.7	7070.7
22	35-2006	7179.9	7079.9
23	35-2007	7175.5	7082.5
24	35-2008	7172.0	7072.0
25	35-2009	7165.3	7065.3
26	35-2011	7166.8	7066.8
27	35-2013	7171.1	7071.1
28	35-2028	7103.4	6803.4
29	49-2-700-1	7133.9	6433.9
30	50-24769	7240.7	6540.7
31	50-24818	7239.7	6619.7
32	54-1001	6781.7	6499.8
33	54-1002	6789.3	6499.9
34	54-1003	6791.7	6492.7
35	54-1004	6788.2	6448.2
36	54-1005	6778.5	6506.8
37	54-1006	6790.3	6500.3
38	54-1007	6790.3	6640.3
39	54-1008	6796.6	6646.6
40	54-1009	6792.0	6642.0
41	54-1010	6790.6	6748.2
42	54-1011	6792.2	6751.2
43	54-1012	6793.1	6752.1
44	54-1013	6793.6	6752.6
45	54-1014	6793.8	6752.8
46	54-1015	6708.2	6242.4
47	54-1016	6700.4	6177.4
48	54-1018	6787.7	6459.7
49	54-1023	6884.0	6624.3
50	54-1024	6885.0	6795.0
51	54-1025	6889.5	6799.5
52	54-1026	6889.6	6799.6
53	54-1102	6720.6	6656.2
54	54-1105	6710.5	6662.4
55	54-1106	6700.4	6648.4
56	54-1107	6718.1	6588.1
57	54-1108	6701.1	6649.1
58	54-1110(G-3)	6691.2	6588.2
59	54-1111(G-4)	6674.6	6521.6
60	54-1112	6693.2	6632.7
61	54-1114	6667.2	6625.5
62	54-1115	6672.0	6600.5
63	54-1116	6683.0	6593.5
64	54-1117	6679.7	6587.2
65	54-1120	6688.3	6638.8
66	54-1121	6673.5	6525.5
67	54-1123	6665.3	6565.3
68	54-1124	6636.1	6597.6
69	54-1125	6669.4	6605.9
70	54-1126	6655.8	6604.8

ID	Well name	Top elev.	Bot elev.
71	54-1128	6653.2	6612.0
72	54-15462	6880.0	6580.0
73	54-24360	6670.6	6470.6
74	54-24361/27436	6695.1	6503.6
75	54-24362	6681.6	6492.6
76	54-24363	6692.0	6442.0
77	54-24364	6704.7	6504.7
78	54-24366	6680.7	6430.7
79	54-24367	6692.1	6492.1
80	54-24368	6715.6	6430.6
81	54-24369	6725.0	6475.0
82	54-24370	6726.4	6476.9
83	54-12371	6728.4	6528.4
84	54-24372	6748.5	6498.5
85	54-24373	6746.0	6496.0
86	54-24374	6677.2	6477.2
87	54-243751	6708.9	6703.9
88	54-24375	6638.9	6507.9
89	54-24376	6693.5	6493.5
90	54-24377	6684.0	6484.0
91	54-24378	6684.8	6502.3
92	54-24379	6675.6	6475.6
93	54-24380	6697.6	6501.6
94	54-24381	6660.1	6460.1
95	54-24382	6672.4	6525.4
96	54-24383	6653.7	6506.2
97	54-24384	6605.5	6537.5
98	54-24385	6677.4	6500.4
99	54-24386	6676.8	6475.8
100	54-24387	6616.0	6535.0
101	54-24388	6684.8	6503.8
102	54-24389	6698.2	6498.2
103	54-24390	6704.0	6518.0
104	54-24391	6711.0	6511.0
105	54-24392	6666.4	6466.4
106	54-24393	6717.8	6511.8
107	54-24394	6726.1	6419.6
108	54-24395	6729.3	6529.3
109	54-24396	6684.0	6484.0
110	54-24397	6671.9	6427.6
111	54-24399	6793.0	6133.0
112	54-25105	6709.0	6007.7
113	54-G-2	6694.1	6592.1
114	54-G-5	6699.1	6586.1
115	Archery	7185.0	6032.0
116	BH1	6915.8	6865.8
117	BH2	6914.4	6866.4
118	BH3	6896.4	6846.4
119	BH4	6929.2	6729.2
120	BH5	6913.8	6713.8
121	BH6	6911.9	6711.9
122	BH7	6910.0	6611.0
123	Buckman_1	5510.0	4406.0
124	Buckman_2	5539.0	4066.0
125	Buckman_3A	5619.0	4169.0
126	Buckman_4	5646.0	4211.0
127	Buckman_5	5690.0	4255.0
128	Buckman_6	5718.0	4330.0
129	Buckman_7R	5606.0	4143.0
130	Buckman_8	5514.0	4582.0
131	Buckman_9	5738.0	4303.0
132	Buckman_10	6045.0	4035.0
133	Buckman_11	6155.0	4152.0
134	Buckman_12	6250.0	4318.0
135	CDBM-1	6721.6	6532.6
136	CDBM-2	6634.1	6535.1
137	CH-1	7170.6	6669.6
138	CH-2	7141.3	6634.3
139	CH-3	7169.9	6869.9
140	CH-4	7118.2	6815.2

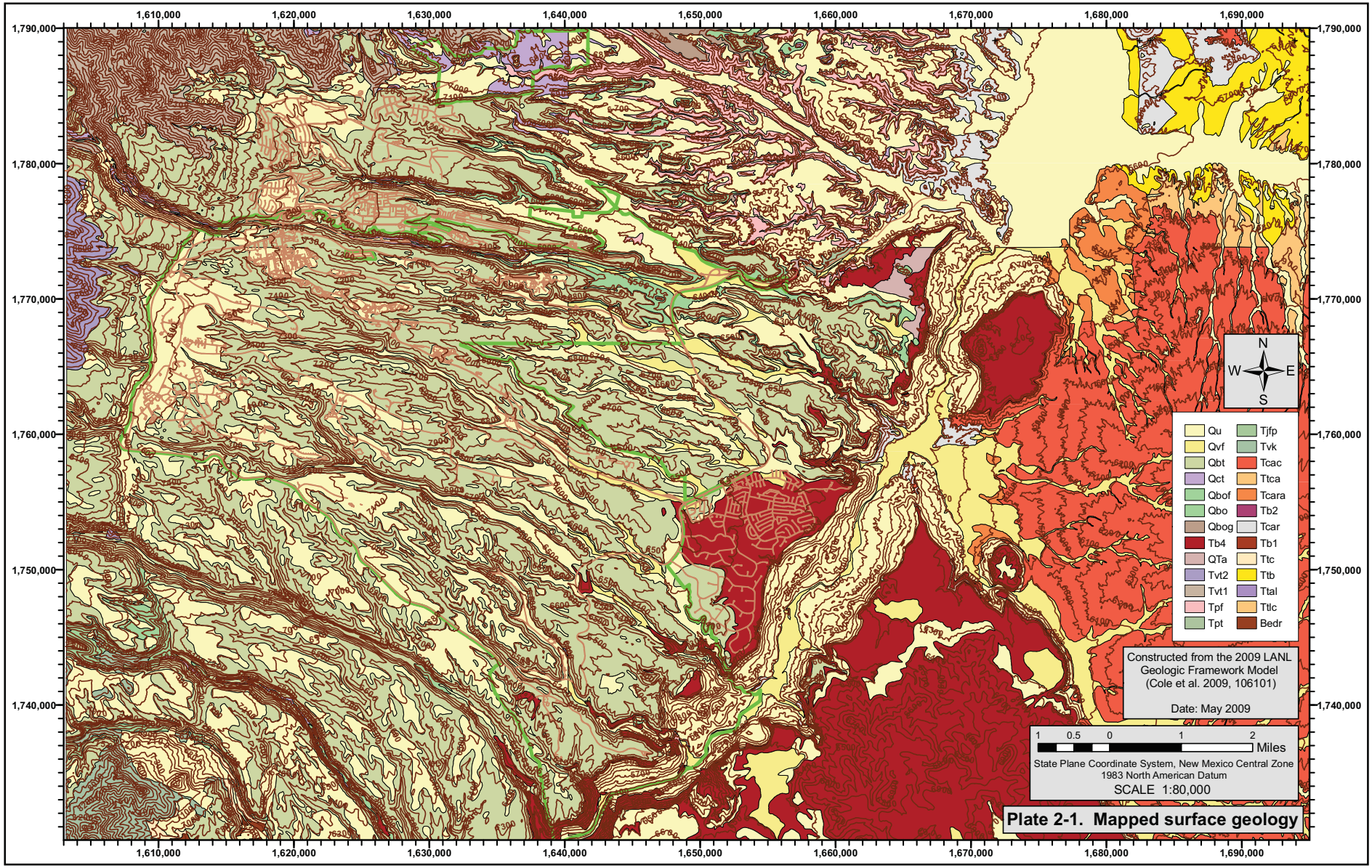
ID	Well name	Top elev.	Bot elev.
141	CdV-16-1i	7382.2	6699.2
142	CdV-16-2i	7457.1	6394.1
143	CdV-16-3i	7486.8	6081.8
144	CdV-R-15-3	7258.9	5536.9
145	CdV-R-37-2	7330.6	5666.6
146	DMB-1	6276.1	6152.1
147	DSC-2	7285.0	6880.0
148	DT-5	7144.5	6182.5
149	DT-5A	7144.2	5323.2
150	DT-5P	7136.8	6651.9
151	DT-9	6936.0	5435.0
152	DT-10	7019.0	5610.0
153	EB-35	6930.0	5120.0
154	EB-47	7140.0	5580.0
155	G-1	5978.9	3958.9
156	G-1A	6015.9	3944.9
157	G-2	6057.8	4051.8
158	G-3	6138.8	4142.8
159	G-4	6235.0	4233.0
160	G-5	6309.6	4312.6
161	G-6	6424.4	4419.4
162	GR-1	6416.2	4386.2
163	GR-2	6140.2	4096.2
164	GR-3	6212.2	4202.2
165	GR-4	6299.2	4371.2
166	H-19	7172.0	5172.0
167	Kelly_Fed	6035.0	3332.0
168	LA-1	5624.0	4623.0
169	LA-1B	5622.0	3366.0
170	LA-2	5651.0	4769.0
171	LA-3	5672.0	4762.0
172	LA-4	5970.9	3951.9
173	LA-5	5840.0	3816.0
174	LA-6	5770.0	3740.0
175	LADP-3	6755.6	6406.6
176	LADP-4	7049.7	6249.7
177	LADP-5	7018.1	6298.1
178	LAO-4.5	6479.8	6417.9
179	LAO-5	6427.1	6400.1
180	LAO-6	6423.5	6397.6
181	LAO-6A	6423.8	6408.8
182	LAOI(A)-1.1	6833.2	6510.2
183	LAOI-3.2a	6624.4	6357.5
184	LAOI-7	6458.4	6076.1
185	Las_Campanas	6400.0	4395.0
186	LAWS-01	6304.8	6023.3
187	MC1	6764.6	6580.0
188	MC2	6751.9	6580.0
189	MC3	6726.6	6582.5
190	MCB-1	7150.2	7045.2
191	MCB-2	7076.4	6971.9
192	MCB-5	6895.3	6791.3
193	MCB-6	6875.5	6786.5
194	MCB-7	6852.4	6751.4
195	MCB-8	6824.4	6719.9
196	MCB-9	6824.1	6721.1
197	MCB-10	6805.7	6701.7
198	MCB-11	6805.4	6701.4
199	MCB-12	6805.2	6700.7
200	MCB-14	6827.1	6543.1
201	MCB-16	6670.7	6570.7
202	MCC-8.2	6775.2	6591.2
203	MCM-5.1	6870.8	6759.3
204	MCM-5.9A	6850.2	6656.2
205	MCOBT-4.4	6836.2	6069.2
206	MCOBT-8.5	6780.5	6040.5
207	MCOI-1	7106.2	6263.0
208	MCOI-4	6837.2	6297.2
209	MCOI-5	6819.7	6102.7
210	MCOI-6	6811.1	6091.1

ID	Well name	Top elev.	Bot elev.
211	MCOI-8	6859.2	6114.2
212	MCOI-10	7034.5	5984.5
213	MCRES-2	6838.2	6638.0
214	MCRES-3	6862.6	6662.6
215	MCRES-4	6870.6	6645.6
216	NAD-64	6635.0	5635.0
217	NAD-63	6415.0	5455.0
218	NAD-60	6225.0	5205.0
219	Northwest	7100.0	5100.0
220	Nuc_Dynamics_34	5683.0	5120.0
221	O-1	6400.9	3791.9
222	O-4	6639.0	3833.0
223	OSE_Devils_Throne	5985.0	3485.0
224	P-12	7451.6	7251.6
225	PM-1	6513.2	4012.2
226	PM-2	6712.0	4112.0
227	PM-3	6610.9	4058.9
228	PM-4	6920.0	4000.0
229	PM-5	7094.0	3974.0
230	POI-4	6372.3	6191.3
231	POTO-4A	6622.0	6448.0
232	R-1	6881.2	5716.2
233	R-2	6770.4	5827.4
234	R-3i	6390.1	6121.9
235	R-4	6577.5	5732.5
236	R-5	6472.6	5570.6
237	R-6	6995.8	5692.8
238	R-7	6779.2	5682.2
239	R-8	6542.9	5520.9
240	R-9	6382.8	5611.8
241	R-9i	6382.8	6060.8
242	R-10	6362.3	5197.3
243	R-11	6672.4	5745.4
244	R-12	6499.6	5613.6
245	R-13	6673.1	5540.1
246	R-14	7062.1	5735.1
247	R-15	6820.0	5713.0
248	R-16	6256.9	4969.9
249	R-17	6921.5	5754.5
250	R-18	7404.8	5974.8
251	R-19	7066.3	5163.8
252	R-20	6694.3	5329.3
253	R-21	6656.2	5661.2
254	R-22	6650.5	5161.5
255	R-23	6527.8	5601.8
256	R-24	6547.4	5666.4
257	R-25	7516.1	5574.1
258	R-25b	7516.0	6376.0
259	R-26	7641.6	6151.1
260	R-27	6713.7	5726.7
261	R-28	6728.5	5723.5
262	R-31	6362.5	5259.5
263	R-32	6637.6	5629.6
264	R-33	6853.3	5723.3
265	R-34	6630.0	5565.0
266	R-35a	6623.1	5481.1
267	R-36	6593.0	5728.0
268	R-37	6860.0	5780.0
269	R-38	6670.0	5760.0
270	R-39	6580.0	5684.0
271	R-40	6718.0	5905.0
272	R-41	6650.0	6650.0
273	R-42	6759.1	5731.1
274	R-43	6730.0	5795.0
275	R-44	6718.0	5624.0
276	R-45	6699.0	5642.0
277	R-46	7212.0	5797.0
278	SC1	6691.5	6578.5
279	SC2	6722.8	6580.0
280	SC3	6701.7	6578.5

ID	Well name	Top elev.	Bot elev.
281	SC4	6682.1	6578.5
282	SC5	6661.8	6580.0
283	SCC-1	6738.3	6338.3
284	SCC-2	6723.7	6335.1
285	SCC-3	6713.0	6369.0
286	SCC-4	6709.2	6386.2
287	SCC-5	6683.6	6393.6
288	SCC-6	6619.3	6359.8
289	SCI-2	6730.0	5840.0
290	SCOI-3	6499.0	6367.0
291	SF_River	6365.0	4365.0
292	SHB-1	7315.9	6615.9
293	SHB-3	7607.7	6747.7
294	SHB-4	6708.7	6547.7
295	SHB-CMR-1	7402.2	7334.7
296	SHB-CMR-10	7398.4	7338.4
297	SHB-CMR-2	7399.8	7337.3
298	SHB-CMR-3	7398.6	7343.6
299	SHB-CMR-4	7398.4	7346.0
300	SHB-CMR-5	7397.5	7345.0
301	SHB-CMR-6	7392.2	7334.7
302	SHB-CMR-7	7394.9	7337.4
303	SHB-CMR-8	7392.7	7340.2
304	SHB-NISC-1	7439.2	7356.7
305	SHB-NISC-2	7428.1	7345.6
306	SHB-NISC-3	7427.8	7352.8
307	SHB-NISC-4	7439.3	7356.8
308	SHB-NISC-5	7432.5	7347.5
309	SHB-SCC-1	7440.2	7342.7
310	SHB-SCC-2	7430.5	7345.5
311	SHB-SCC-3	7428.1	7343.1
312	SHB-SCC-4	7441.9	7351.9
313	SHB-SCC-5	7435.7	7353.2
314	SIMO	6655.4	6551.4
315	Sigma_Mesa	7209.5	4917.5
316	Skillet	5850.0	3946.0
317	St_Michael	6870.0	4850.0
318	TH-5	6590.7	6327.8
319	TH-6	6642.4	6342.5
320	TH-7	6223.5	6168.5
321	TW-1	6369.9	5727.9
322	TW-1A	6369.8	6144.8
323	TW-2	6646.4	5812.4
324	TW-3	6626.9	5811.9
325	TW-4	7242.7	6037.7
326	TW-8	6875.1	5810.1
327	TestHole6-53	6921.2	6771.2
328	TestHole7-53	6701.0	6621.0
329	USGS-TH	7227.4	7017.4
330	WCO-3	6433.9	6420.0
331	Yates_2	6605.0	2634.0

Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101) Date: May 2009

Plate 1-3. Identification of all wells contributing data to the 3-D geologic model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Tb4
QTa
Tvt2
Tvt1
Tpf
Tpt
Tjfp
Tvk
Tcac
Ttca
Tcara
Tb2
Tcar
Tb1
Ttc
Ttb
Ttal
Ttlc
Bedr
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Date: May 2009
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Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
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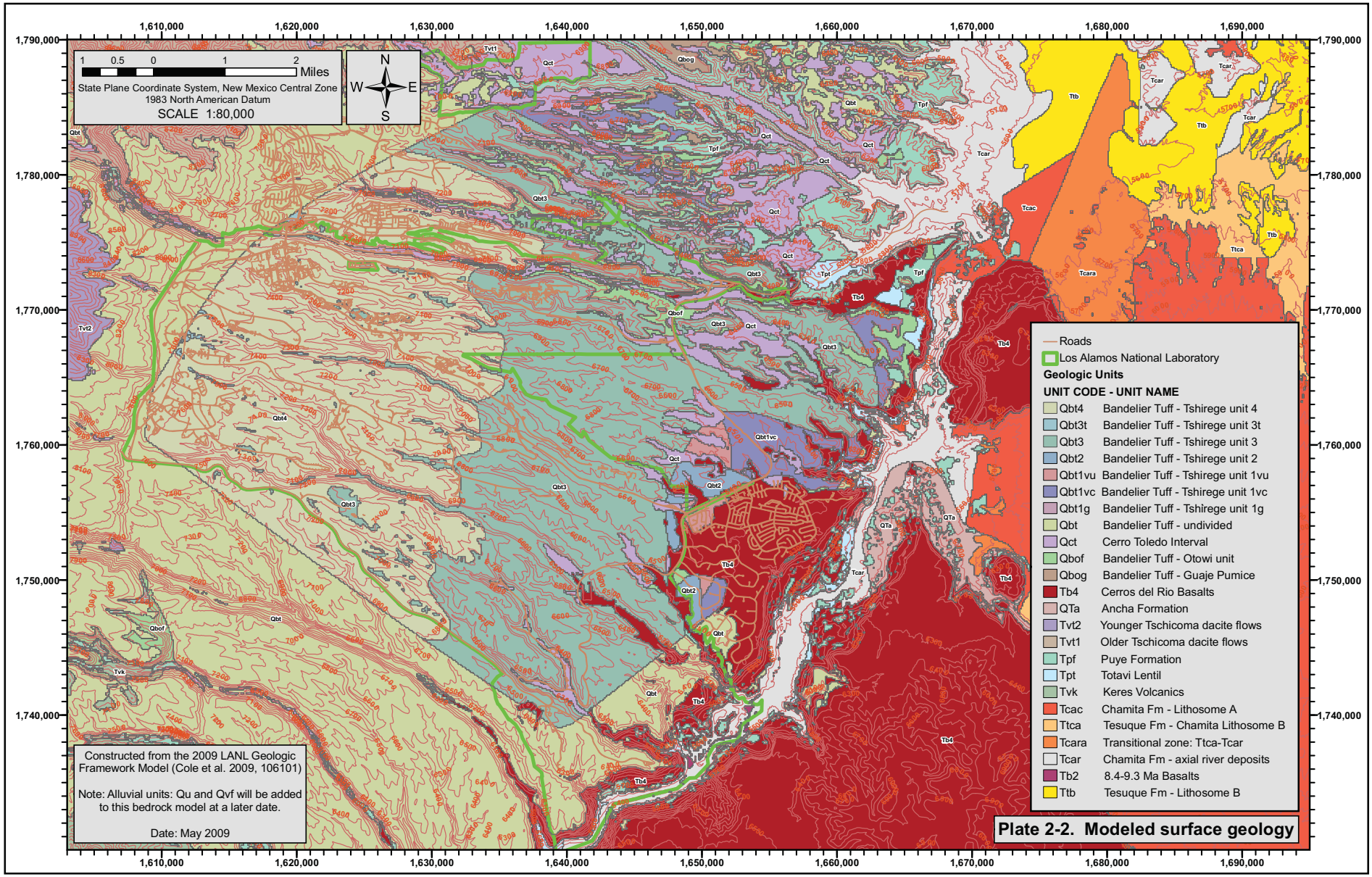
Plate 2-1. Mapped surface geology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State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
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Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Note: Alluvial units: Qu and Qvf will be added to this bedrock model at a later date.
Date: May 2009
Roads
Los Alamos National Laboratory
Geologic Units
UNIT CODE - UNIT NAME
Qbt4 Bandelier Tuff - Tshirege unit 4
Qbt3t Bandelier Tuff - Tshirege unit 3t
Qbt3 Bandelier Tuff - Tshirege unit 3
Qbt2 Bandelier Tuff - Tshirege unit 2
Qbt1vu Bandelier Tuff - Tshirege unit 1vu
Qbt1vc Bandelier Tuff - Tshirege unit 1vc
Qbt1g Bandelier Tuff - Tshirege unit 1g
Qbt Bandelier Tuff - undivided
Qct Cerro Toledo Interval
Qbof Bandelier Tuff - Otowi unit
Qbog Bandelier Tuff - Guaje Pumice
Tb4 Cerros del Rio Basalts
QTa Ancha Formation
Tvt2 Younger Tschicoma dacite flows
Tvt1 Older Tschicoma dacite flows
Tpf Puye Formation
Tpt Totavi Lentil
Tvk Keres Volcanics
Tcac Chamita Fm - Lithosome A
Ttca Tesuque Fm - Chamita Lithosome B
Tcara Transitional zone: Ttca-Tcar
Tcar Chamita Fm - axial river deposits
Tb2 8.4-9.3 Ma Basalts
Ttb Tesuque Fm - Lithosome B
Plate 2-2. Modeled surface geology

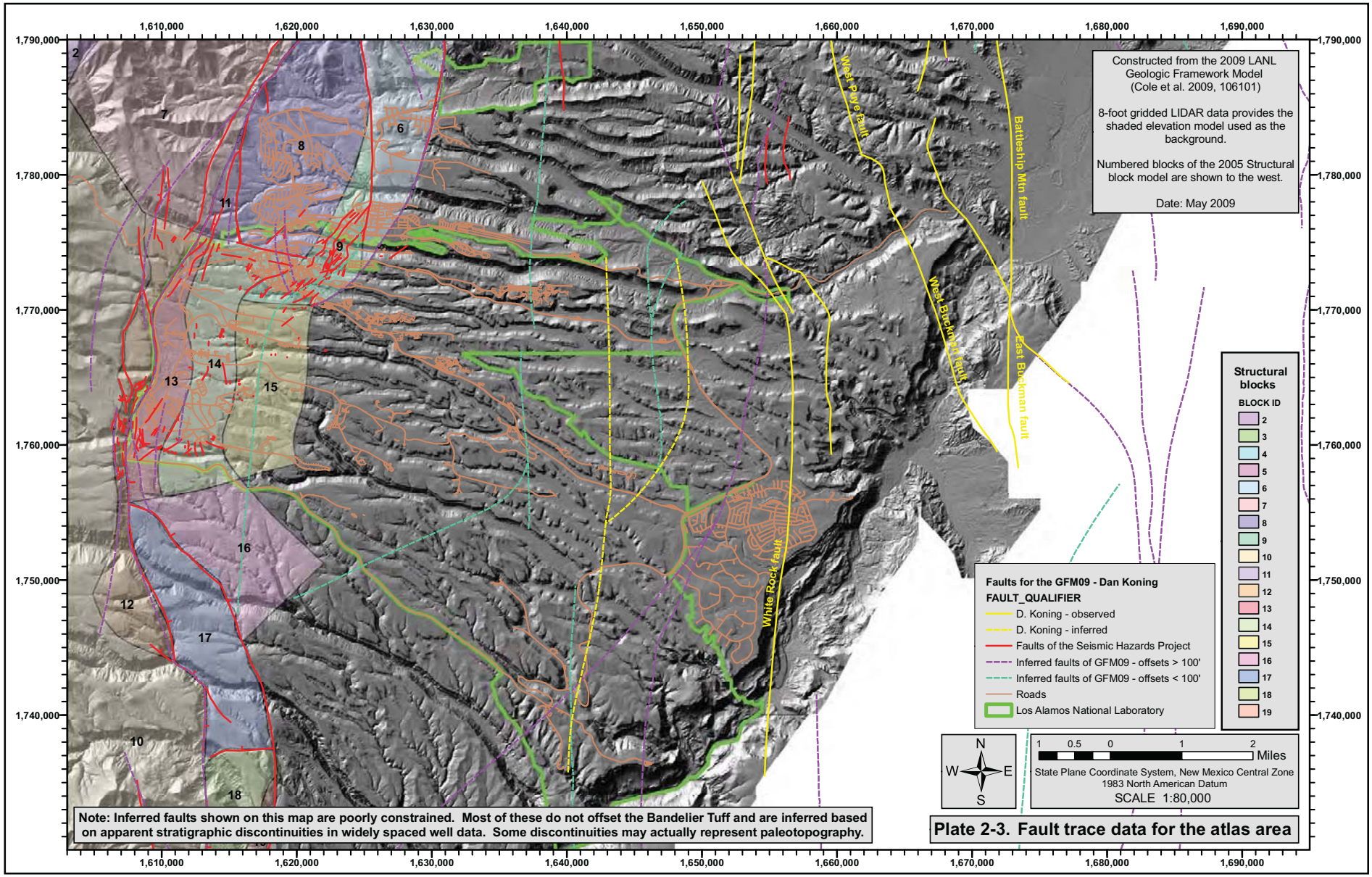
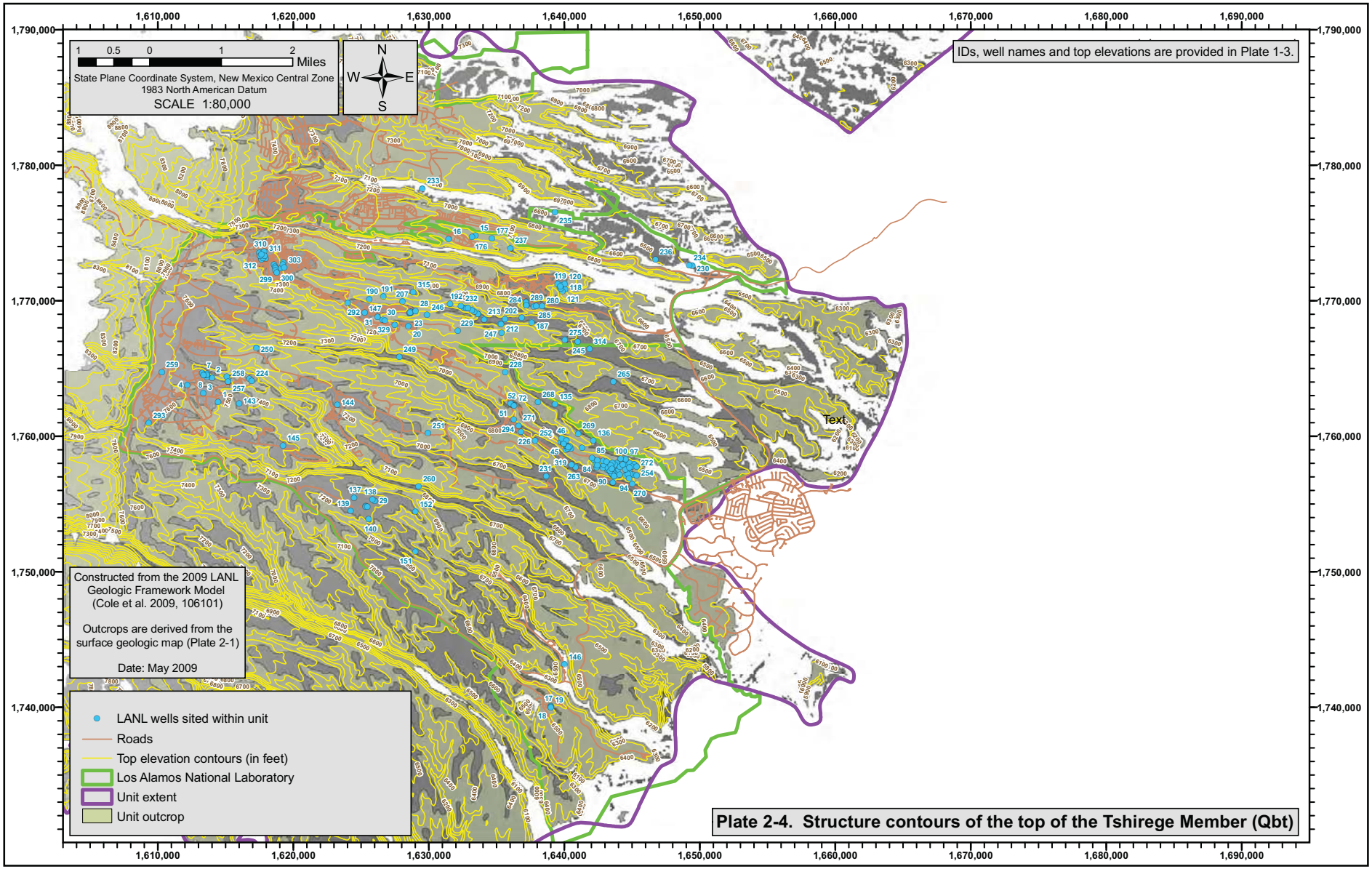


Plate 2-3. Fault trace data for the atlas area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1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
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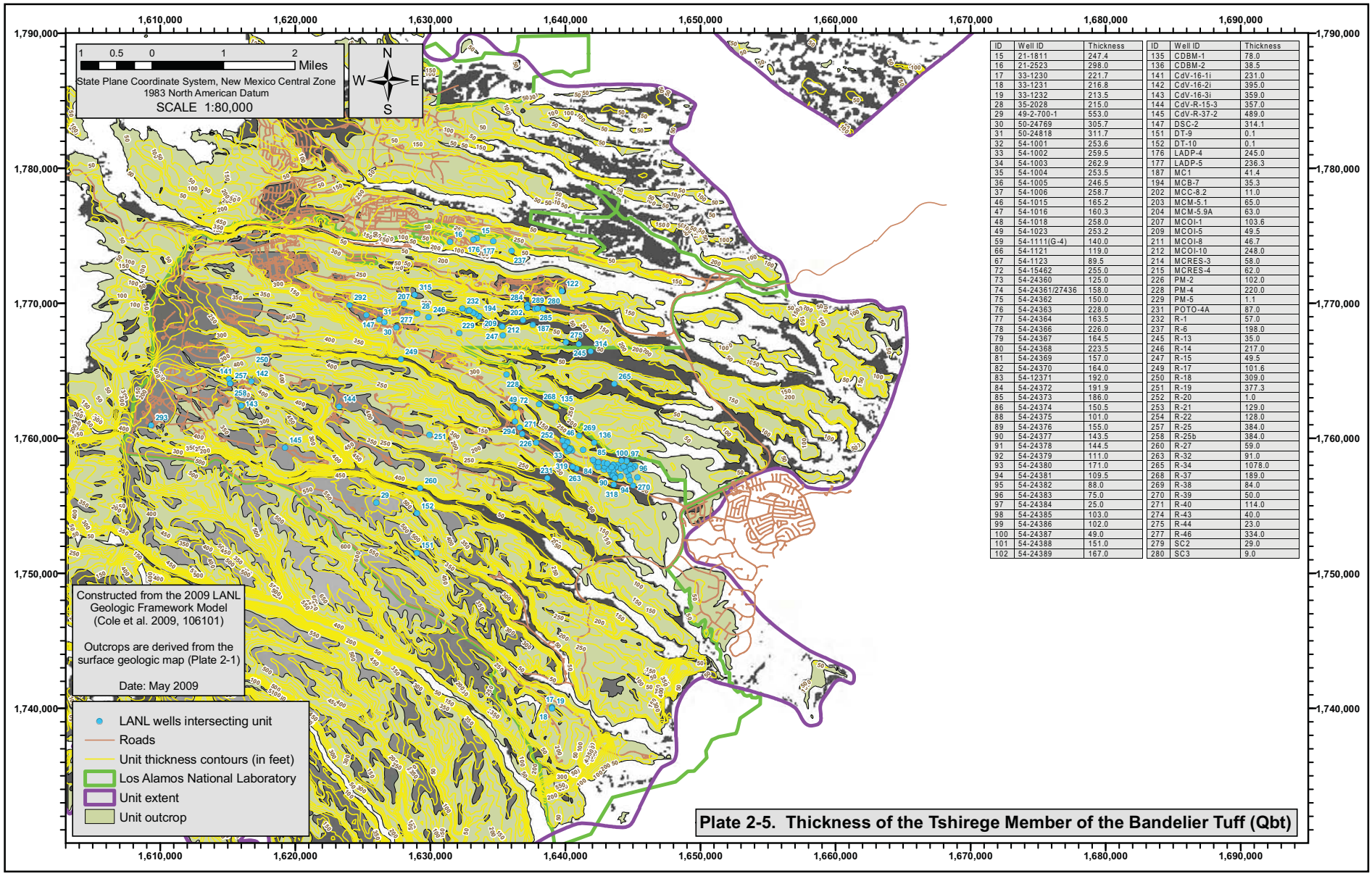
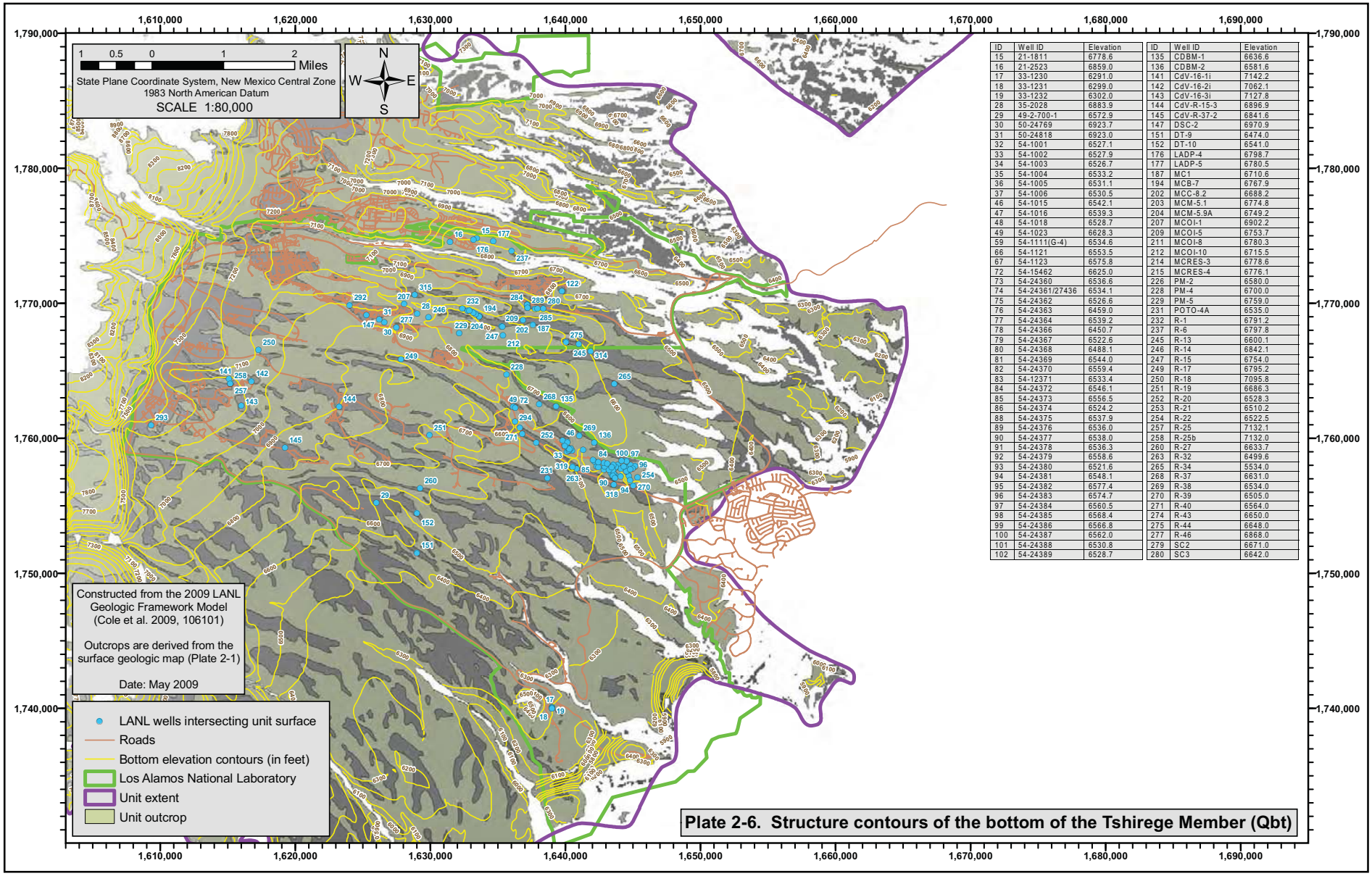
W E
S
IDs, well names and top elevations are provided in Plate 1-3.
Text
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
LANL wells sited within unit
Roads
Top elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-4. Structure contours of the top of the Tshirege Member (Qbt)



ID	Well ID	Thickness
15	21-1811	247.4
16	21-2523	298.0
17	33-1230	221.7
18	33-1231	216.8
19	33-1232	213.5
28	35-2028	215.0
29	49-2-700-1	553.0
30	50-24769	305.7
31	50-24818	311.7
32	54-1001	253.6
33	54-1002	259.5
34	54-1003	262.9
35	54-1004	253.5
36	54-1005	246.5
37	54-1006	258.7
46	54-1015	165.2
47	54-1016	160.3
48	54-1018	258.0
49	54-1023	253.2
59	54-1111(G-4)	140.0
66	54-1121	119.0
67	54-1123	89.5
72	54-15462	255.0
73	54-24360	125.0
74	54-24361/27436	158.0
75	54-24362	150.0
76	54-24363	228.0
77	54-24364	163.5
78	54-24366	226.0
79	54-24367	164.5
80	54-24368	223.5
81	54-24369	157.0
82	54-24370	164.0
83	54-12371	192.0
84	54-24372	191.9
85	54-24373	186.0
86	54-24374	150.5
88	54-24375	101.0
89	54-24376	155.0
90	54-24377	143.5
91	54-24378	144.5
92	54-24379	111.0
93	54-24380	171.0
94	54-24381	109.5
95	54-24382	88.0
96	54-24383	75.0
97	54-24384	25.0
98	54-24385	103.0
99	54-24386	102.0
100	54-24387	49.0
101	54-24388	151.0
102	54-24389	167.0

ID	Well ID	Thickness
135	CDBM-1	78.0
136	CDBM-2	38.5
141	CdV-16-1i	231.0
142	CdV-16-2i	395.0
143	CdV-16-3i	359.0
144	CdV-R-15-3	357.0
145	CdV-R-37-2	489.0
147	DSC-2	314.1
151	DT-9	0.1
152	DT-10	0.1
176	LADP-4	245.0
177	LADP-5	236.3
187	MC1	41.4
194	MCB-7	35.3
202	MCC-8.2	11.0
203	MCM-5.1	65.0
204	MCM-5.9A	63.0
207	MCOI-1	103.6
209	MCOI-5	49.5
211	MCOI-8	46.7
212	MCOI-10	248.0
214	MCRES-3	58.0
215	MCRES-4	62.0
226	PM-2	102.0
228	PM-4	220.0
229	PM-5	1.1
231	POTO-4A	87.0
232	R-1	57.0
237	R-6	198.0
245	R-13	35.0
246	R-14	217.0
247	R-15	49.5
249	R-17	101.6
250	R-18	309.0
251	R-19	377.3
252	R-20	1.0
253	R-21	129.0
254	R-22	128.0
257	R-25	384.0
258	R-25b	384.0
260	R-27	59.0
263	R-32	91.0
265	R-34	1078.0
268	R-37	189.0
269	R-38	84.0
270	R-39	50.0
271	R-40	114.0
274	R-43	40.0
275	R-44	23.0
277	R-46	334.0
279	SC2	29.0
280	SC3	9.0

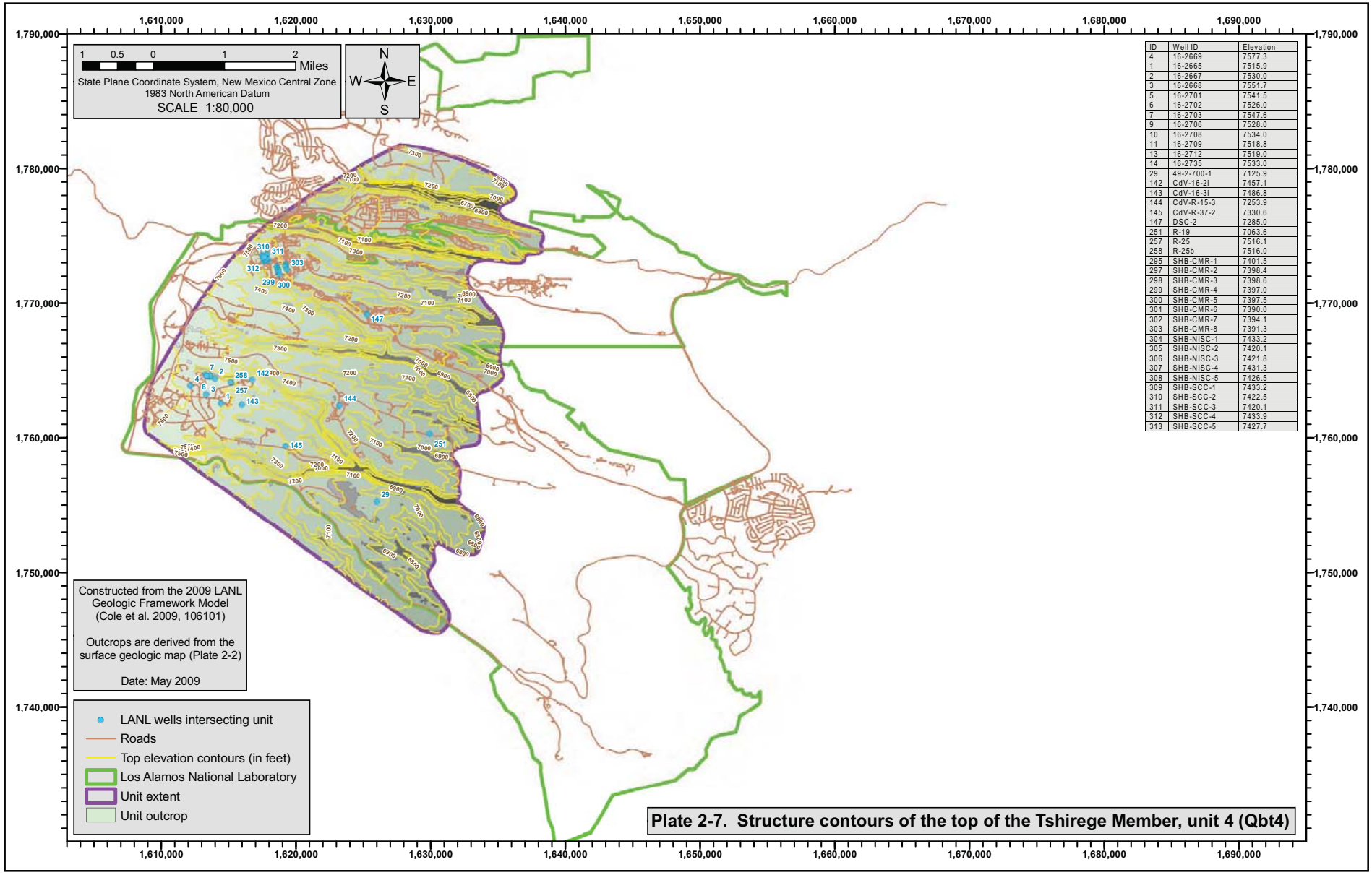
Plate 2-5. Thickness of the Tshirege Member of the Bandelier Tuff (Qbt)



ID	Well ID	Elevation
15	21-1811	6778.6
16	21-2523	6859.0
17	33-1230	6291.0
18	33-1231	6299.0
19	33-1232	6302.0
28	35-2028	6883.9
29	49-2-700-1	6572.9
30	50-24769	6923.7
31	50-24818	6923.0
32	54-1001	6527.1
33	54-1002	6527.9
34	54-1003	6526.7
35	54-1004	6533.2
36	54-1005	6531.1
37	54-1006	6530.5
46	54-1015	6542.1
47	54-1016	6539.3
48	54-1018	6528.7
49	54-1023	6628.3
59	54-1111(G-4)	6534.6
66	54-1121	6553.5
67	54-1123	6575.8
72	54-15462	6625.0
73	54-24360	6536.6
74	54-24361/27436	6534.1
75	54-24362	6526.6
76	54-24363	6459.0
77	54-24364	6539.2
78	54-24366	6450.7
79	54-24367	6522.6
80	54-24368	6488.1
81	54-24369	6544.0
82	54-24370	6559.4
83	54-12371	6533.4
84	54-24372	6546.1
85	54-24373	6556.5
86	54-24374	6524.2
88	54-24375	6537.9
89	54-24376	6536.0
90	54-24377	6538.0
91	54-24378	6536.3
92	54-24379	6558.6
93	54-24380	6521.6
94	54-24381	6548.1
95	54-24382	6577.4
96	54-24383	6574.7
97	54-24384	6560.5
98	54-24385	6568.4
99	54-24386	6566.8
100	54-24387	6562.0
101	54-24388	6530.8
102	54-24389	6528.7

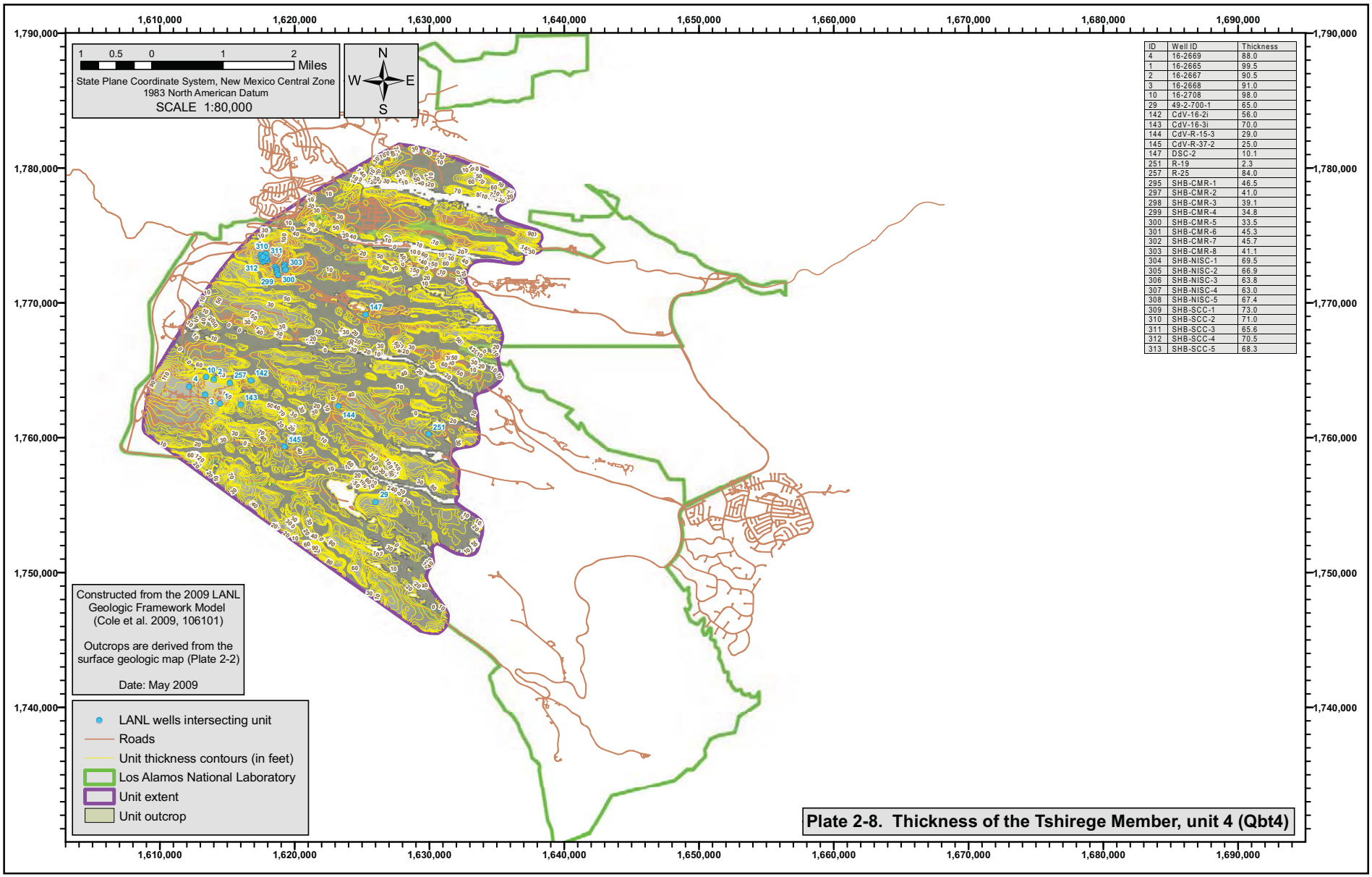
ID	Well ID	Elevation
135	CDBM-1	6636.6
136	CDBM-2	6581.6
141	CdV-16-1i	7142.2
142	CdV-16-2i	7062.1
143	CdV-16-3i	7127.8
144	CdV-R-15-3	6896.9
145	CdV-R-37-2	6841.6
147	DSC-2	6970.9
151	DT-9	6474.0
152	DT-10	6541.0
176	LADP-4	6798.7
177	LADP-5	6780.5
187	MC1	6710.6
194	MCB-7	6767.9
202	MCC-8.2	6688.2
203	MCM-5.1	6774.8
204	MCM-5.9A	6749.2
207	MCOI-1	6902.2
209	MCOI-5	6753.7
211	MCOI-8	6780.3
212	MCOI-10	6715.5
214	MCRES-3	6778.6
215	MCRES-4	6776.1
226	PM-2	6580.0
228	PM-4	6700.0
229	PM-5	6759.0
231	POTO-4A	6535.0
232	R-1	6791.2
237	R-6	6797.8
245	R-13	6600.1
246	R-14	6842.1
247	R-15	6754.0
249	R-17	6795.2
250	R-18	7095.8
251	R-19	6686.3
252	R-20	6528.3
253	R-21	6510.2
254	R-22	6522.5
257	R-25	7132.1
258	R-25b	7132.0
260	R-27	6633.7
263	R-32	6499.6
265	R-34	5534.0
268	R-37	6631.0
269	R-38	6534.0
270	R-39	6505.0
271	R-40	6564.0
274	R-43	6650.0
275	R-44	6648.0
277	R-46	6868.0
279	SC2	6671.0
280	SC3	6642.0

Plate 2-6. Structure contours of the bottom of the Tshirege Member (Qbt)



ID	Well ID	Elevation
4	16-2669	7577.3
1	16-2665	7515.9
2	16-2667	7530.0
3	16-2668	7551.7
5	16-2701	7541.5
6	16-2702	7526.0
7	16-2703	7547.6
9	16-2706	7528.0
10	16-2708	7534.0
11	16-2709	7518.8
13	16-2712	7519.0
14	16-2735	7533.0
29	49-2-700-1	7125.9
142	CdV-16-2i	7457.1
143	CdV-16-3i	7486.8
144	CdV-R-15-3	7253.9
145	CdV-R-37-2	7330.6
147	DSC-2	7285.0
251	R-19	7063.6
257	R-25	7516.1
258	R-25b	7516.0
295	SHB-CMR-1	7401.5
297	SHB-CMR-2	7398.4
298	SHB-CMR-3	7398.6
299	SHB-CMR-4	7397.0
300	SHB-CMR-5	7397.5
301	SHB-CMR-6	7390.0
302	SHB-CMR-7	7394.1
303	SHB-CMR-8	7391.3
304	SHB-NISC-1	7433.2
305	SHB-NISC-2	7420.1
306	SHB-NISC-3	7421.8
307	SHB-NISC-4	7431.3
308	SHB-NISC-5	7426.5
309	SHB-SCC-1	7433.2
310	SHB-SCC-2	7422.5
311	SHB-SCC-3	7420.1
312	SHB-SCC-4	7433.9
313	SHB-SCC-5	7427.7

Plate 2-7. Structure contours of the top of the Tshirege Member, unit 4 (Qbt4)



ID	Well ID	Thickness
4	16-2669	88.0
1	16-2665	99.5
2	16-2667	90.5
3	16-2668	91.0
10	16-2708	98.0
29	49-2-700-1	65.0
142	CdV-16-2i	56.0
143	CdV-16-3i	70.0
144	CdV-R-15-3	29.0
145	CdV-R-37-2	25.0
147	DSC-2	10.1
251	R-19	2.3
257	R-25	84.0
295	SHB-CMR-1	46.5
297	SHB-CMR-2	41.0
298	SHB-CMR-3	39.1
299	SHB-CMR-4	34.8
300	SHB-CMR-5	33.5
301	SHB-CMR-6	45.3
302	SHB-CMR-7	45.7
303	SHB-CMR-8	41.1
304	SHB-NISC-1	69.5
305	SHB-NISC-2	66.9
306	SHB-NISC-3	63.8
307	SHB-NISC-4	63.0
308	SHB-NISC-5	67.4
309	SHB-SCC-1	73.0
310	SHB-SCC-2	71.0
311	SHB-SCC-3	65.6
312	SHB-SCC-4	70.5
313	SHB-SCC-5	68.3

Plate 2-8. Thickness of the Tshirege Member, unit 4 (Qbt4)

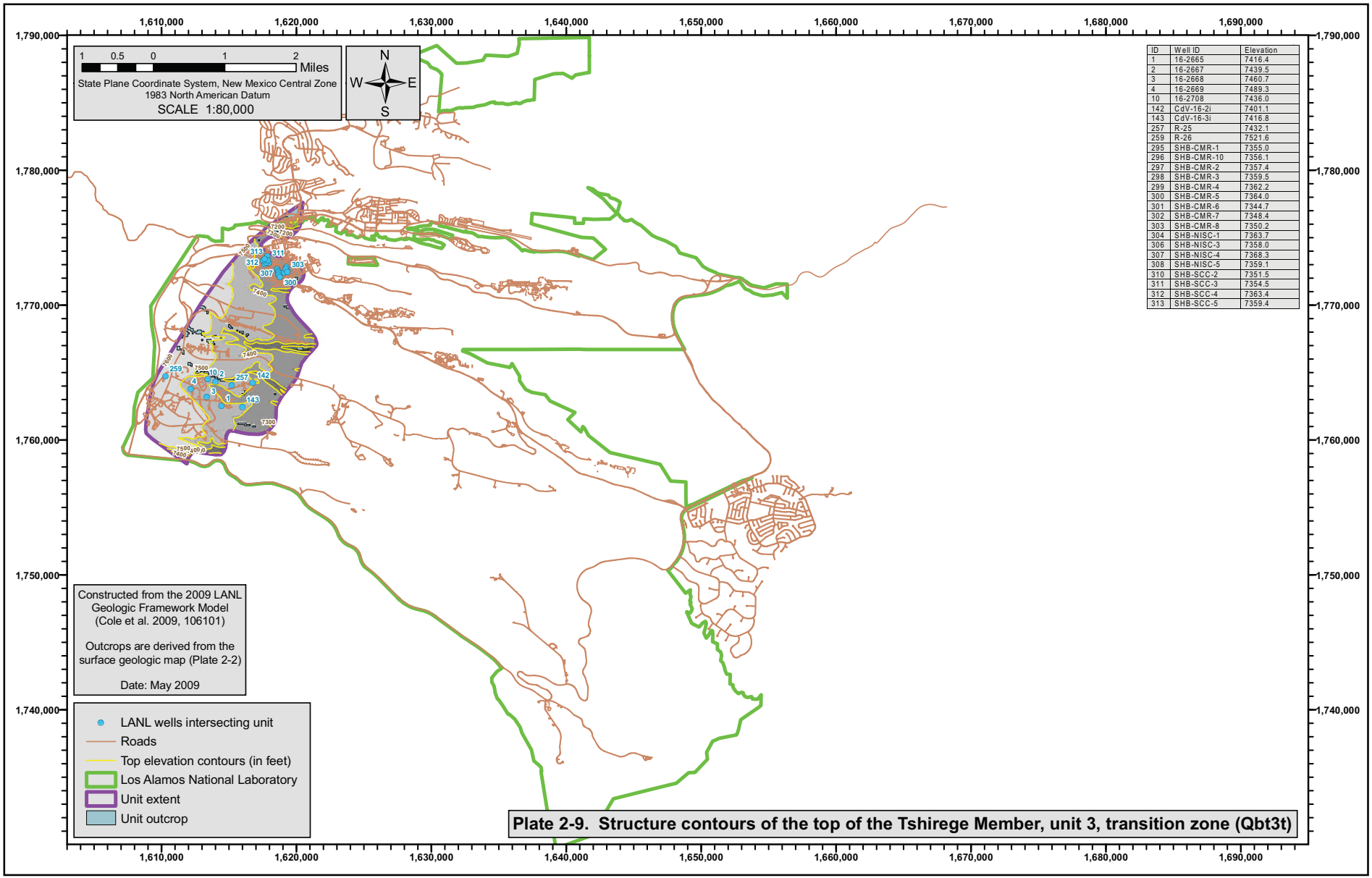
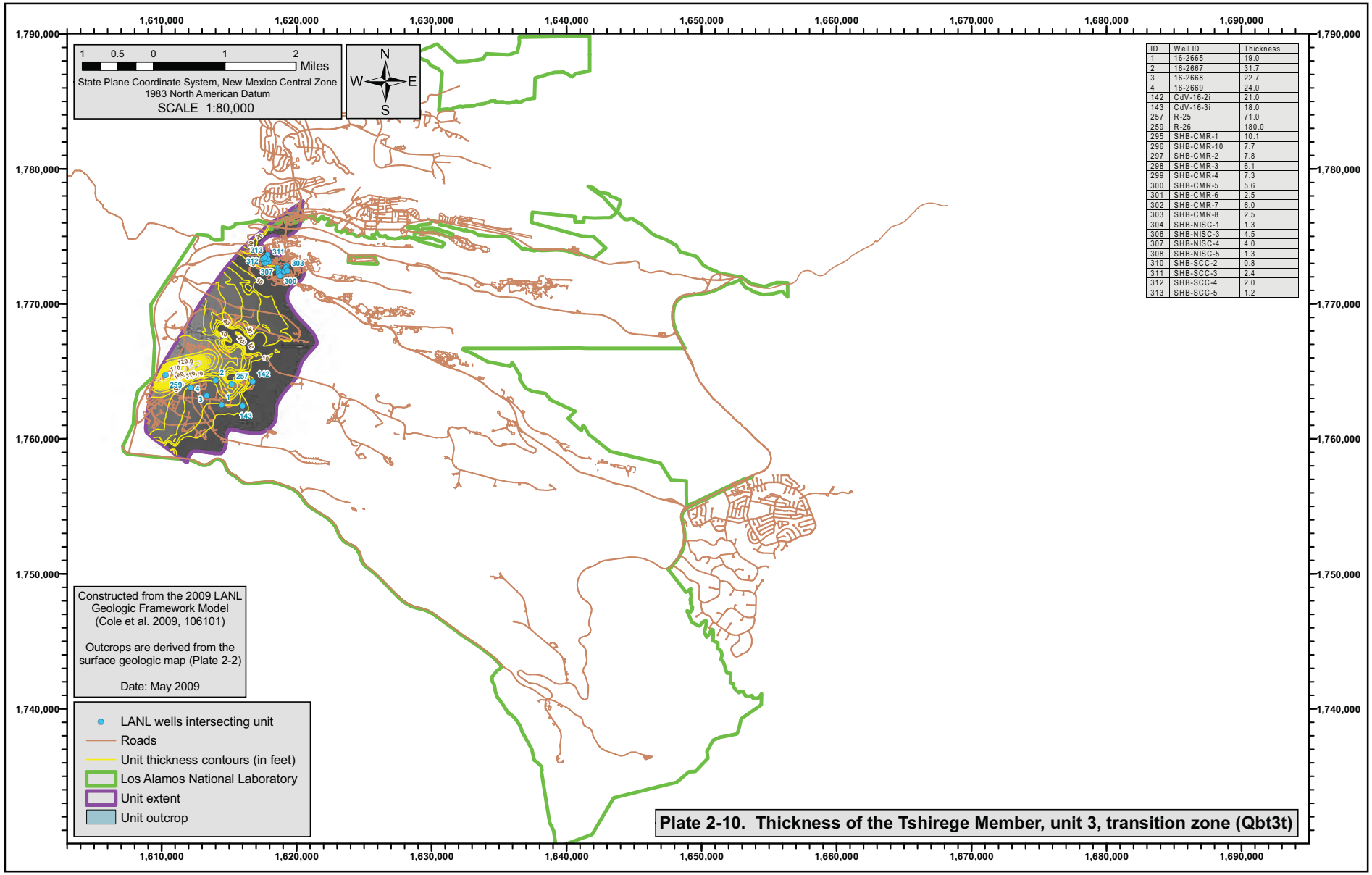


Plate 2-9. Structure contours of the top of the Tshirege Member, unit 3, transition zone (Qbt3t)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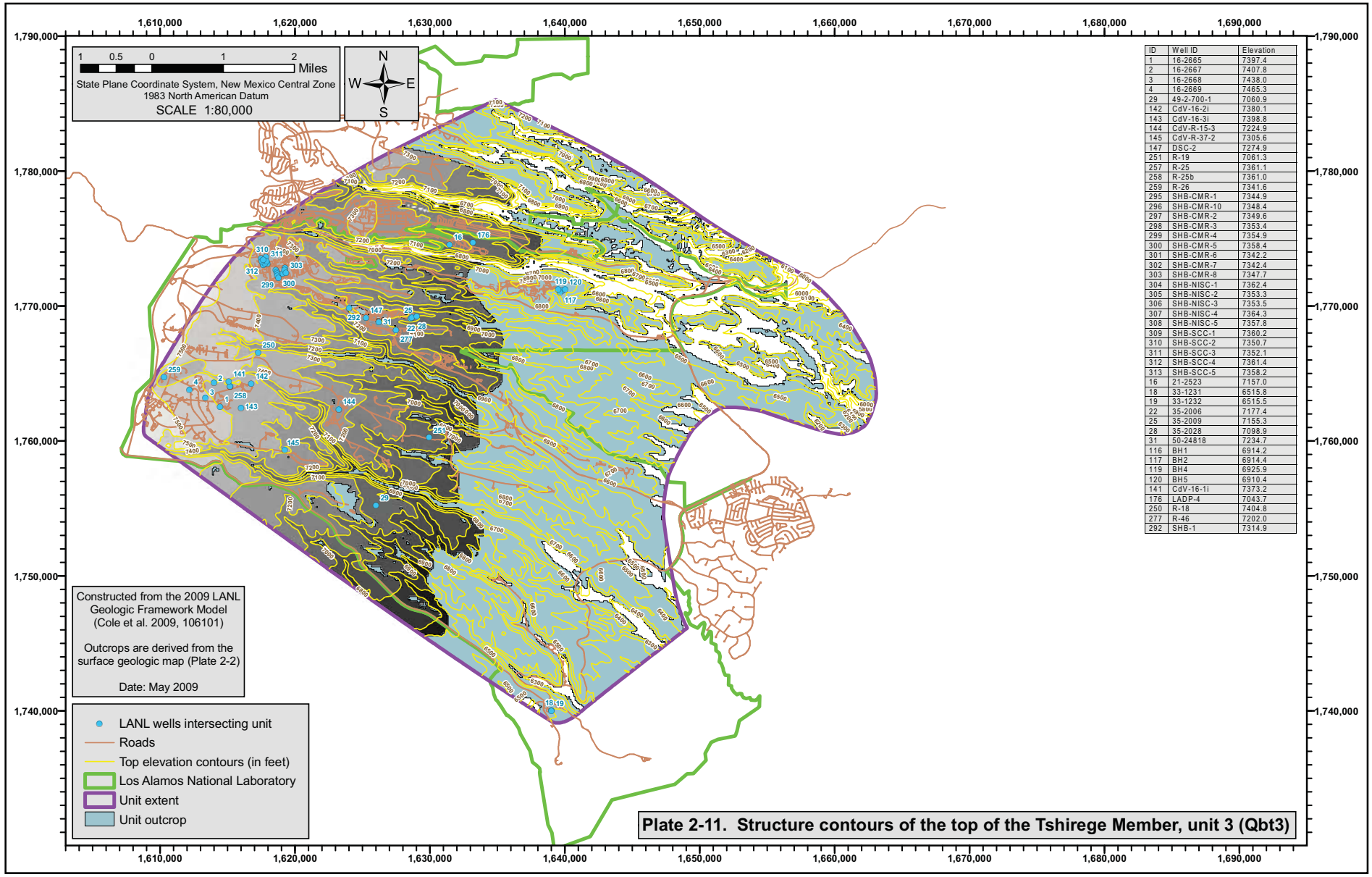
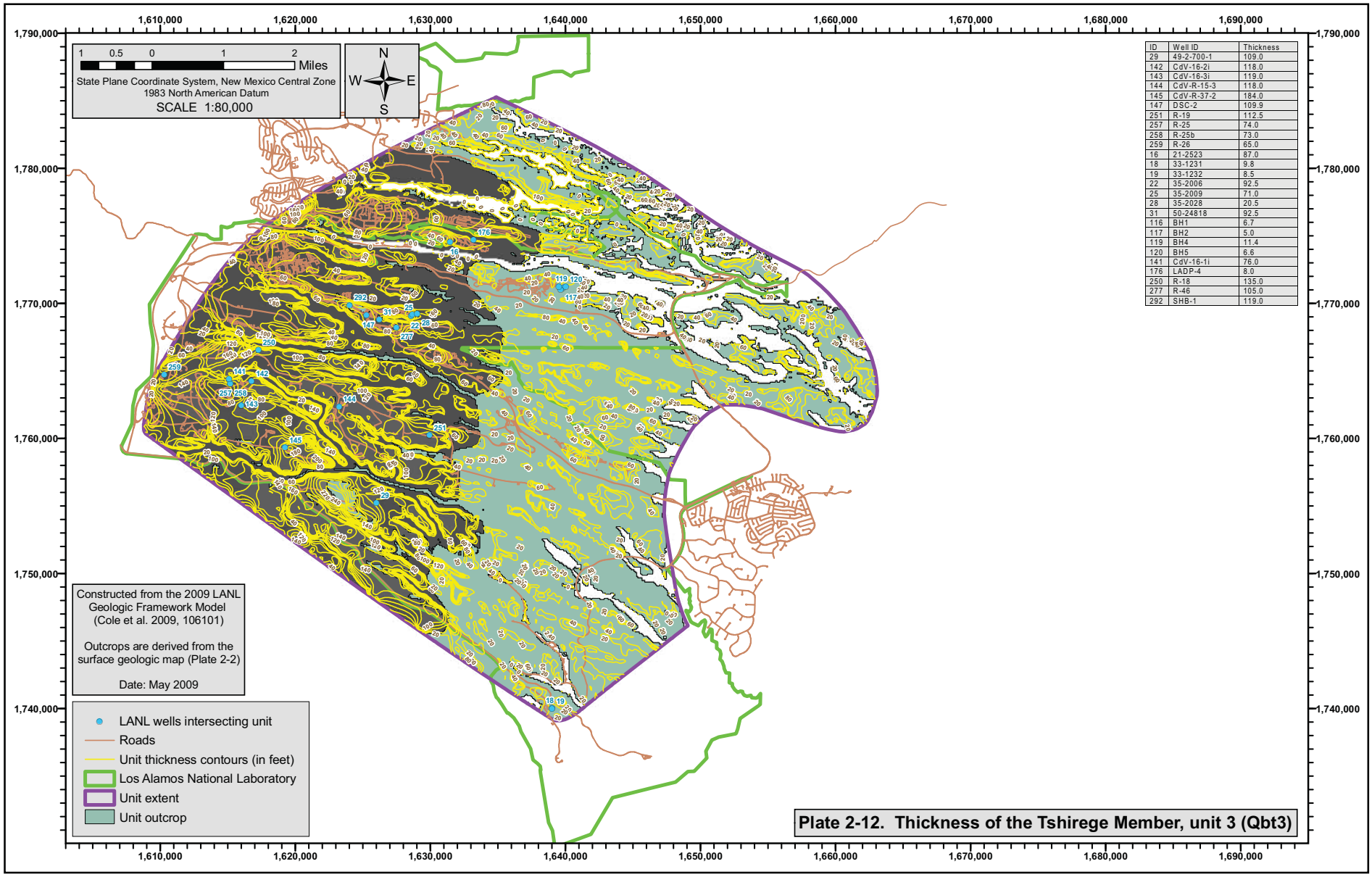
1,790,000
1,780,000
1,770,000
1,760,000
1,750,000
1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Thickness
1 | 16-2665 | 19.0
2 | 16-2667 | 31.7
3 | 16-2668 | 22.7
4 | 16-2669 | 24.0
142 | CdV-16-2i | 21.0
143 | CdV-16-3i | 18.0
257 | R-25 | 71.0
259 | R-26 | 180.0
295 | SHB-CMR-1 | 10.1
296 | SHB-CMR-10 | 7.7
297 | SHB-CMR-2 | 7.8
298 | SHB-CMR-3 | 6.1
299 | SHB-CMR-4 | 7.3
300 | SHB-CMR-5 | 5.6
301 | SHB-CMR-6 | 2.5
302 | SHB-CMR-7 | 6.0
303 | SHB-CMR-8 | 2.5
304 | SHB-NISC-1 | 1.3
306 | SHB-NISC-3 | 4.5
307 | SHB-NISC-4 | 4.0
308 | SHB-NISC-5 | 1.3
310 | SHB-SCC-2 | 0.8
311 | SHB-SCC-3 | 2.4
312 | SHB-SCC-4 | 2.0
313 | SHB-SCC-5 | 1.2
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-2)
Date: May 2009
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-10. Thickness of the Tshirege Member, unit 3, transition zone (Qbt3t)



ID	Well ID	Elevation
1	16-2665	7397.4
2	16-2667	7407.8
3	16-2668	7438.0
4	16-2669	7465.3
29	49-2-700-1	7060.9
142	CdV-16-2i	7380.1
143	CdV-16-3i	7398.8
144	CdV-R-15-3	7224.9
145	CdV-R-37-2	7305.6
147	DSC-2	7274.9
251	R-19	7061.3
257	R-25	7361.1
258	R-25b	7361.0
259	R-26	7341.6
295	SHB-CMR-1	7344.9
296	SHB-CMR-10	7348.4
297	SHB-CMR-2	7349.6
298	SHB-CMR-3	7353.4
299	SHB-CMR-4	7354.9
300	SHB-CMR-5	7358.4
301	SHB-CMR-6	7342.2
302	SHB-CMR-7	7342.4
303	SHB-CMR-8	7347.7
304	SHB-NISC-1	7362.4
305	SHB-NISC-2	7353.3
306	SHB-NISC-3	7353.5
307	SHB-NISC-4	7364.3
308	SHB-NISC-5	7357.8
309	SHB-SCC-1	7360.2
310	SHB-SCC-2	7350.7
311	SHB-SCC-3	7352.1
312	SHB-SCC-4	7361.4
313	SHB-SCC-5	7358.2
16	21-2523	7157.0
18	33-1231	6515.8
19	33-1232	6515.5
22	35-2006	7177.4
25	35-2009	7155.3
28	35-2028	7098.9
31	50-24818	7234.7
116	BH1	6914.2
117	BH2	6914.4
119	BH4	6925.9
120	BH5	6910.4
141	CdV-16-1i	7373.2
176	LADP-4	7043.7
250	R-18	7404.8
277	R-46	7202.0
292	SHB-1	7314.9

Plate 2-11. Structure contours of the top of the Tshirege Member, unit 3 (Qbt3)


1,610,000
1,620,000
1,630,000
1,640,000
1,650,000
1,660,000
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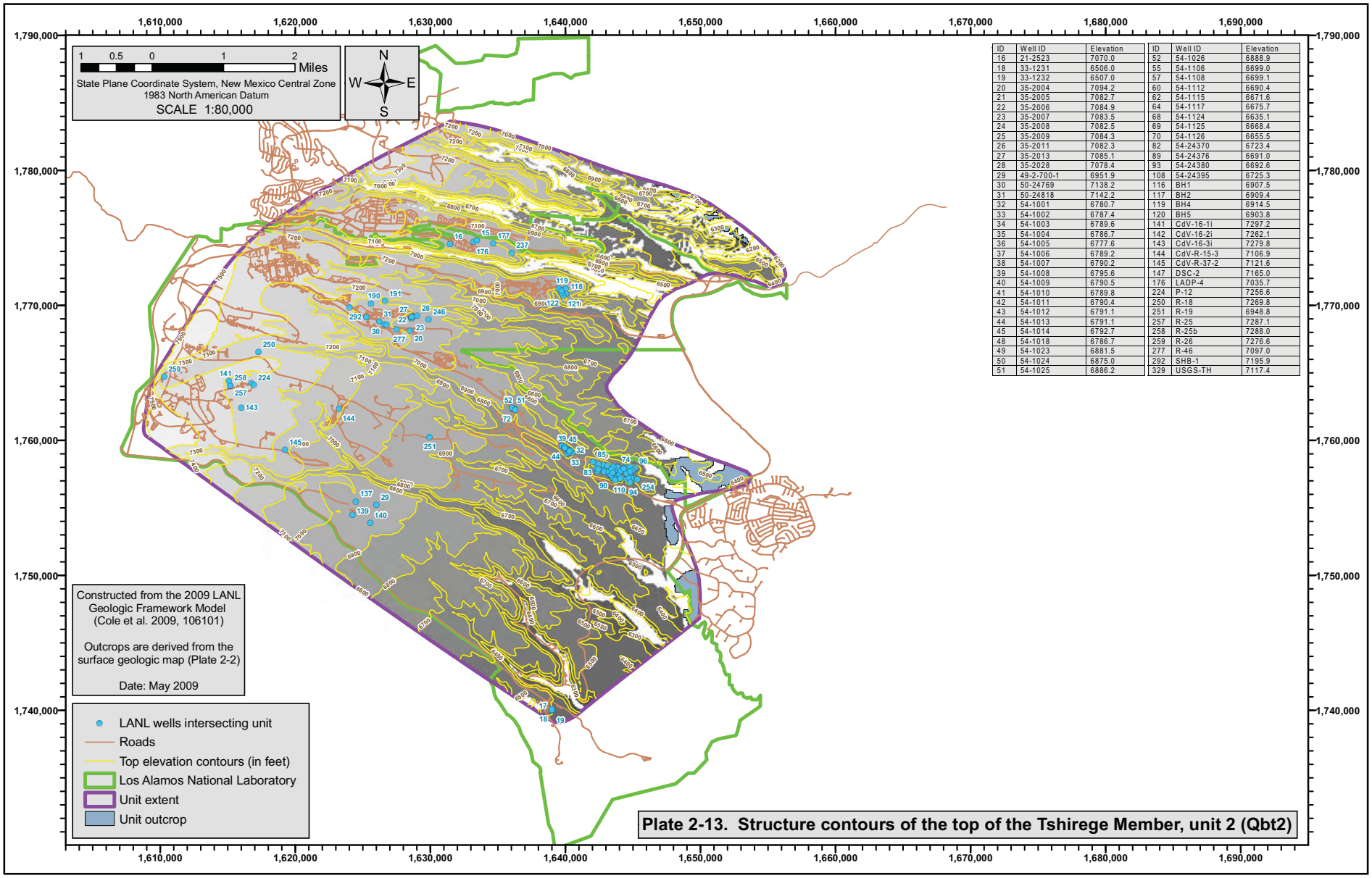
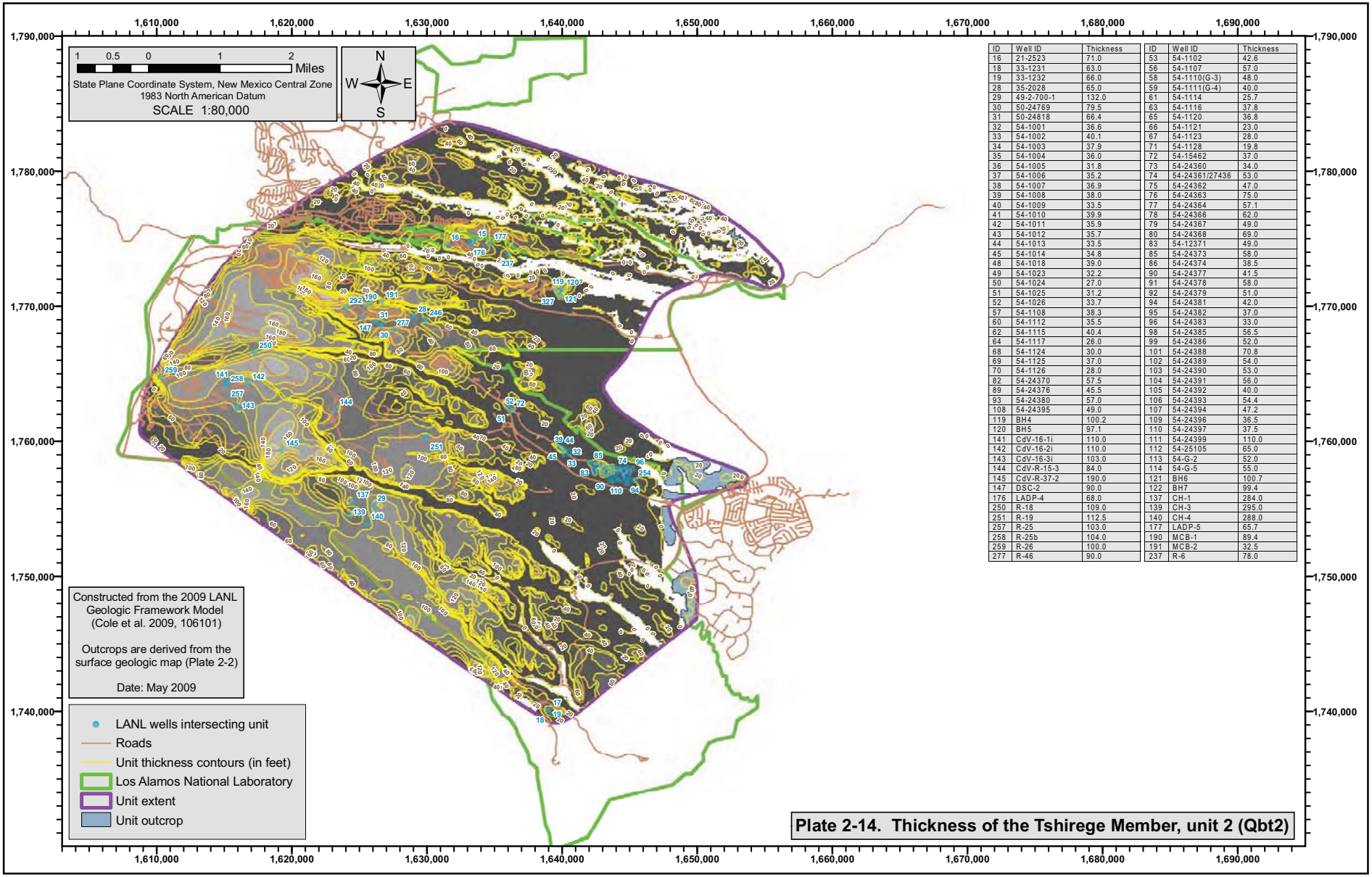
1,790,000
1,780,000
1,770,000
1,760,000
1,750,000
1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Thickness
29 | 49-2-700-1 | 109.0
142 | CdV-16-2i | 118.0
143 | CdV-16-3i | 119.0
144 | CdV-R-15-3 | 118.0
145 | CdV-R-37-2 | 184.0
147 | DSC-2 | 109.9
251 | R-19 | 112.5
257 | R-25 | 74.0
258 | R-25b | 73.0
259 | R-26 | 65.0
16 | 21-2523 | 87.0
18 | 33-1231 | 9.8
19 | 33-1232 | 8.5
22 | 35-2006 | 92.5
25 | 35-2009 | 71.0
28 | 35-2028 | 20.5
31 | 50-24818 | 92.5
116 | BH1 | 6.7
117 | BH2 | 5.0
119 | BH4 | 11.4
120 | BH5 | 6.6
141 | CdV-16-1i | 76.0
176 | LADP-4 | 8.0
250 | R-18 | 135.0
277 | R-46 | 105.0
292 | SHB-1 | 119.0
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-2)
Date: May 2009
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-12. Thickness of the Tshirege Member, unit 3 (Qbt3)



ID	Well ID	Elevation
16	21-2523	7070.0
18	33-1231	6506.0
19	33-1232	6507.0
20	35-2004	7094.2
21	35-2005	7082.7
22	35-2006	7084.9
23	35-2007	7083.5
24	35-2008	7082.5
25	35-2009	7084.3
26	35-2011	7082.3
27	35-2013	7085.1
28	35-2028	7078.4
29	49-2-700-1	6951.9
30	50-24769	7138.2
31	50-24818	7142.2
32	54-1001	6780.7
33	54-1002	6787.4
34	54-1003	6789.6
35	54-1004	6786.7
36	54-1005	6777.6
37	54-1006	6789.2
38	54-1007	6790.2
39	54-1008	6795.6
40	54-1009	6790.5
41	54-1010	6789.8
42	54-1011	6790.4
43	54-1012	6791.1
44	54-1013	6791.1
45	54-1014	6792.7
48	54-1018	6786.7
49	54-1023	6881.5
50	54-1024	6875.0
51	54-1025	6886.2

ID	Well ID	Elevation
52	54-1026	6888.9
55	54-1106	6699.0
57	54-1108	6699.1
60	54-1112	6690.4
62	54-1115	6671.6
64	54-1117	6675.7
68	54-1124	6635.1
69	54-1125	6668.4
70	54-1126	6655.5
82	54-24370	6723.4
89	54-24376	6691.0
93	54-24380	6692.6
108	54-24395	6725.3
116	BH1	6907.5
117	BH2	6909.4
119	BH4	6914.5
120	BH5	6903.8
141	CdV-16-1i	7297.2
142	CdV-16-2i	7262.1
143	CdV-16-3i	7279.8
144	CdV-R-15-3	7106.9
145	CdV-R-37-2	7121.6
147	DSC-2	7165.0
176	LADP-4	7035.7
224	P-12	7256.6
250	R-18	7269.8
251	R-19	6948.8
257	R-25	7287.1
258	R-25b	7288.0
259	R-26	7276.6
277	R-46	7097.0
292	SHB-1	7195.9
329	USGS-TH	7117.4

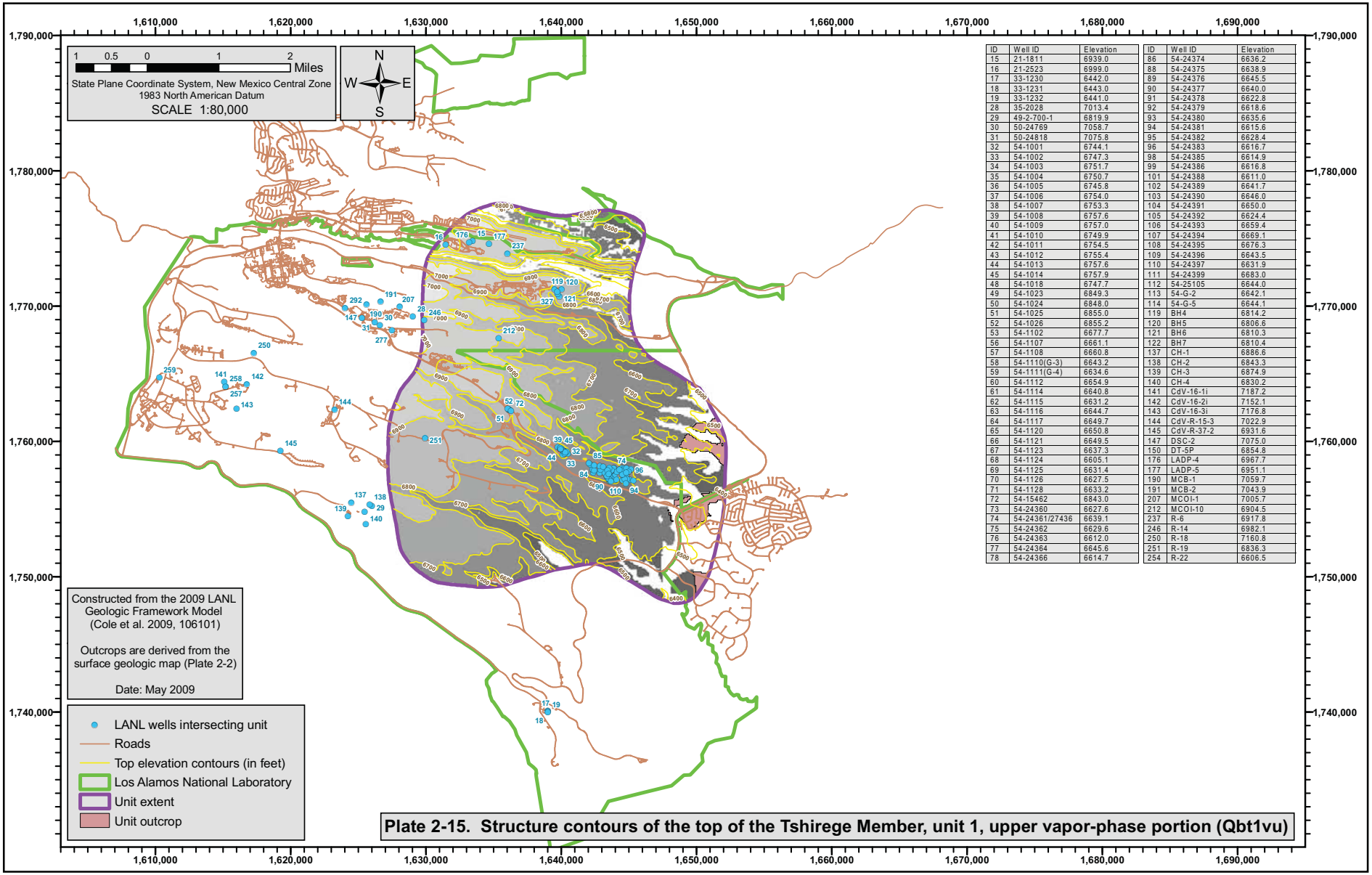
Plate 2-13. Structure contours of the top of the Tshirege Member, unit 2 (Qbt2)



ID	Well ID	Thickness
16	21-2523	71.0
18	33-1231	63.0
19	33-1232	66.0
28	35-2028	65.0
29	49-2-700-1	132.0
30	50-24769	79.5
31	50-24818	66.4
32	54-1001	36.6
33	54-1002	40.1
34	54-1003	37.9
35	54-1004	36.0
36	54-1005	31.8
37	54-1006	35.2
38	54-1007	36.9
39	54-1008	38.0
40	54-1009	33.5
41	54-1010	39.9
42	54-1011	35.9
43	54-1012	35.7
44	54-1013	33.5
45	54-1014	34.8
48	54-1018	39.0
49	54-1023	32.2
50	54-1024	27.0
51	54-1025	31.2
52	54-1026	33.7
57	54-1108	38.3
60	54-1112	35.5
62	54-1115	40.4
64	54-1117	26.0
68	54-1124	30.0
69	54-1125	37.0
70	54-1126	28.0
82	54-24370	57.5
89	54-24376	45.5
93	54-24380	57.0
108	54-24395	49.0
119	BH4	100.2
120	BH5	97.1
141	CdV-16-1i	110.0
142	CdV-16-2i	110.0
143	CdV-16-3i	103.0
144	CdV-R-15-3	84.0
145	CdV-R-37-2	190.0
147	DSC-2	90.0
176	LADP-4	68.0
250	R-18	109.0
251	R-19	112.5
257	R-25	103.0
258	R-25b	104.0
259	R-26	100.0
277	R-46	90.0

ID	Well ID	Thickness
53	54-1102	42.6
56	54-1107	57.0
58	54-1110(G-3)	48.0
59	54-1111(G-4)	40.0
61	54-1114	25.7
63	54-1116	37.8
65	54-1120	36.8
66	54-1121	23.0
67	54-1123	28.0
71	54-1128	19.8
72	54-15462	37.0
73	54-24360	34.0
74	54-24361/27436	53.0
75	54-24362	47.0
76	54-24363	75.0
77	54-24364	57.1
78	54-24366	62.0
79	54-24367	49.0
80	54-24368	69.0
83	54-12371	49.0
85	54-24373	58.0
86	54-24374	38.5
90	54-24377	41.5
91	54-24378	58.0
92	54-24379	51.0
94	54-24381	42.0
95	54-24382	37.0
96	54-24383	33.0
98	54-24385	56.5
99	54-24386	52.0
101	54-24388	70.8
102	54-24389	54.0
103	54-24390	53.0
104	54-24391	56.0
105	54-24392	40.0
106	54-24393	54.4
107	54-24394	47.2
109	54-24396	36.5
110	54-24397	37.5
111	54-24399	110.0
112	54-25105	65.0
113	54-G-2	52.0
114	54-G-5	55.0
121	BH6	100.7
122	BH7	99.4
137	CH-1	284.0
139	CH-3	295.0
140	CH-4	288.0
177	LADP-5	65.7
190	MCB-1	89.4
191	MCB-2	32.5
237	R-6	78.0

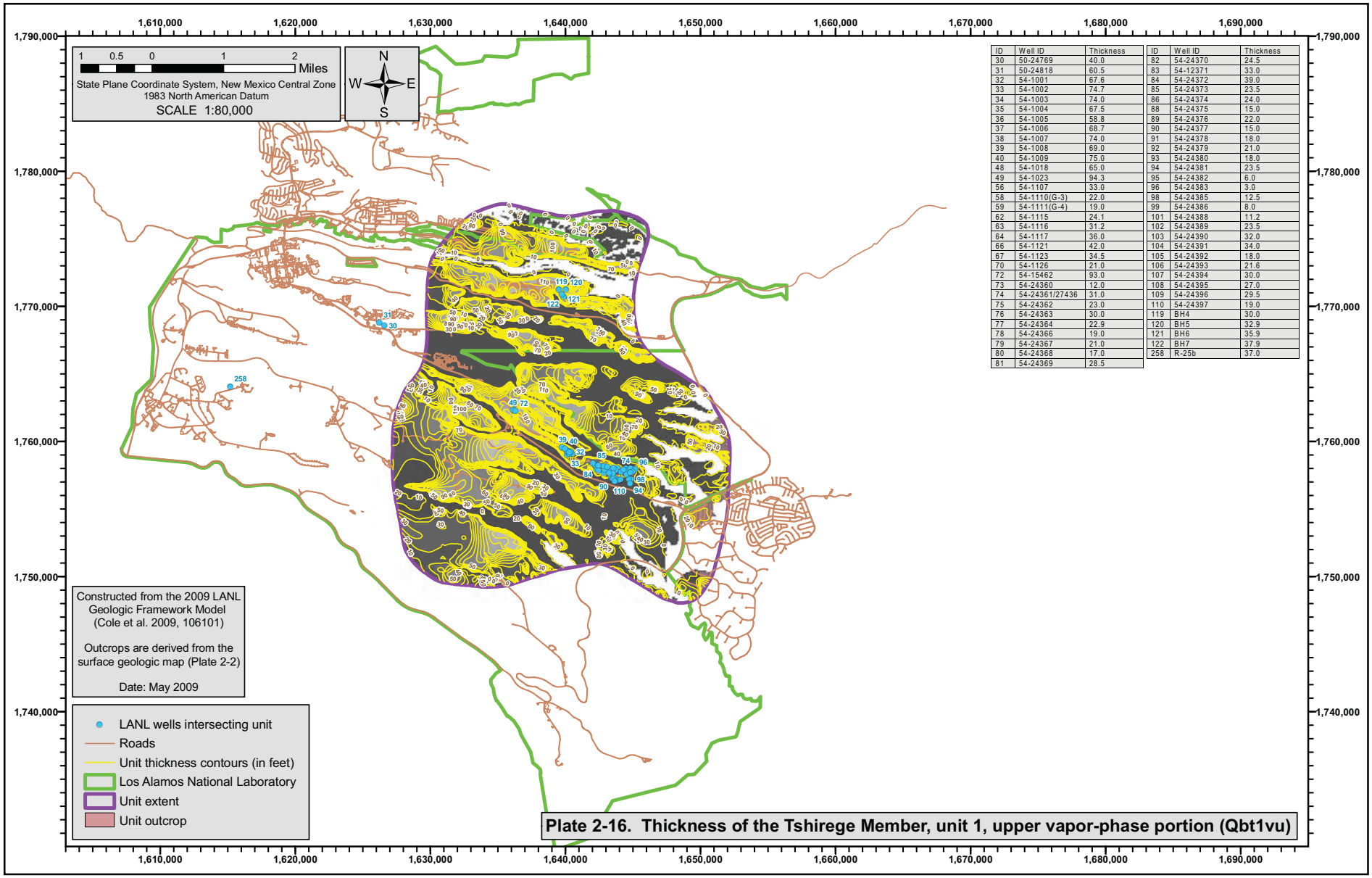
Plate 2-14. Thickness of the Tshirege Member, unit 2 (Qbt2)



ID	Well ID	Elevation
15	21-1811	6939.0
16	21-2523	6999.0
17	33-1230	6442.0
18	33-1231	6443.0
19	33-1232	6441.0
28	35-2028	7013.4
29	49-2-700-1	6819.9
30	50-24769	7058.7
31	50-24818	7075.8
32	54-1001	6744.1
33	54-1002	6747.3
34	54-1003	6751.7
35	54-1004	6750.7
36	54-1005	6745.8
37	54-1006	6754.0
38	54-1007	6753.3
39	54-1008	6757.6
40	54-1009	6757.0
41	54-1010	6749.9
42	54-1011	6754.5
43	54-1012	6755.4
44	54-1013	6757.6
45	54-1014	6757.9
48	54-1018	6747.7
49	54-1023	6849.3
50	54-1024	6848.0
51	54-1025	6855.0
52	54-1026	6855.2
53	54-1102	6677.7
56	54-1107	6661.1
57	54-1108	6660.8
58	54-1110(G-3)	6643.2
59	54-1111(G-4)	6634.6
60	54-1112	6654.9
61	54-1114	6640.8
62	54-1115	6631.2
63	54-1116	6644.7
64	54-1117	6649.7
65	54-1120	6650.8
66	54-1121	6649.5
67	54-1123	6637.3
68	54-1124	6605.1
69	54-1125	6631.4
70	54-1126	6627.5
71	54-1128	6633.2
72	54-15462	6843.0
73	54-24360	6627.6
74	54-24361/27436	6639.1
75	54-24362	6629.6
76	54-24363	6612.0
77	54-24364	6645.6
78	54-24366	6614.7

ID	Well ID	Elevation
86	54-24374	6636.2
88	54-24375	6638.9
89	54-24376	6645.5
90	54-24377	6640.0
91	54-24378	6622.8
92	54-24379	6618.6
93	54-24380	6635.6
94	54-24381	6615.6
95	54-24382	6628.4
96	54-24383	6616.7
98	54-24385	6614.9
99	54-24386	6616.8
101	54-24388	6611.0
102	54-24389	6641.7
103	54-24390	6646.0
104	54-24391	6650.0
105	54-24392	6624.4
106	54-24393	6659.4
107	54-24394	6669.1
108	54-24395	6676.3
109	54-24396	6643.5
110	54-24397	6631.9
111	54-24399	6683.0
112	54-25105	6644.0
113	54-G-2	6642.1
114	54-G-5	6644.1
119	BH4	6814.2
120	BH5	6806.6
121	BH6	6810.3
122	BH7	6810.4
137	CH-1	6886.6
138	CH-2	6843.3
139	CH-3	6874.9
140	CH-4	6830.2
141	CdV-16-1i	7187.2
142	CdV-16-2i	7152.1
143	CdV-16-3i	7176.8
144	CdV-R-15-3	7022.9
145	CdV-R-37-2	6931.6
147	DSC-2	7075.0
150	DT-5P	6854.8
176	LADP-4	6967.7
177	LADP-5	6951.1
190	MCB-1	7059.7
191	MCB-2	7043.9
207	MCOI-1	7005.7
212	MCOI-10	6904.5
237	R-6	6917.8
246	R-14	6982.1
250	R-18	7160.8
251	R-19	6836.3
254	R-22	6606.5

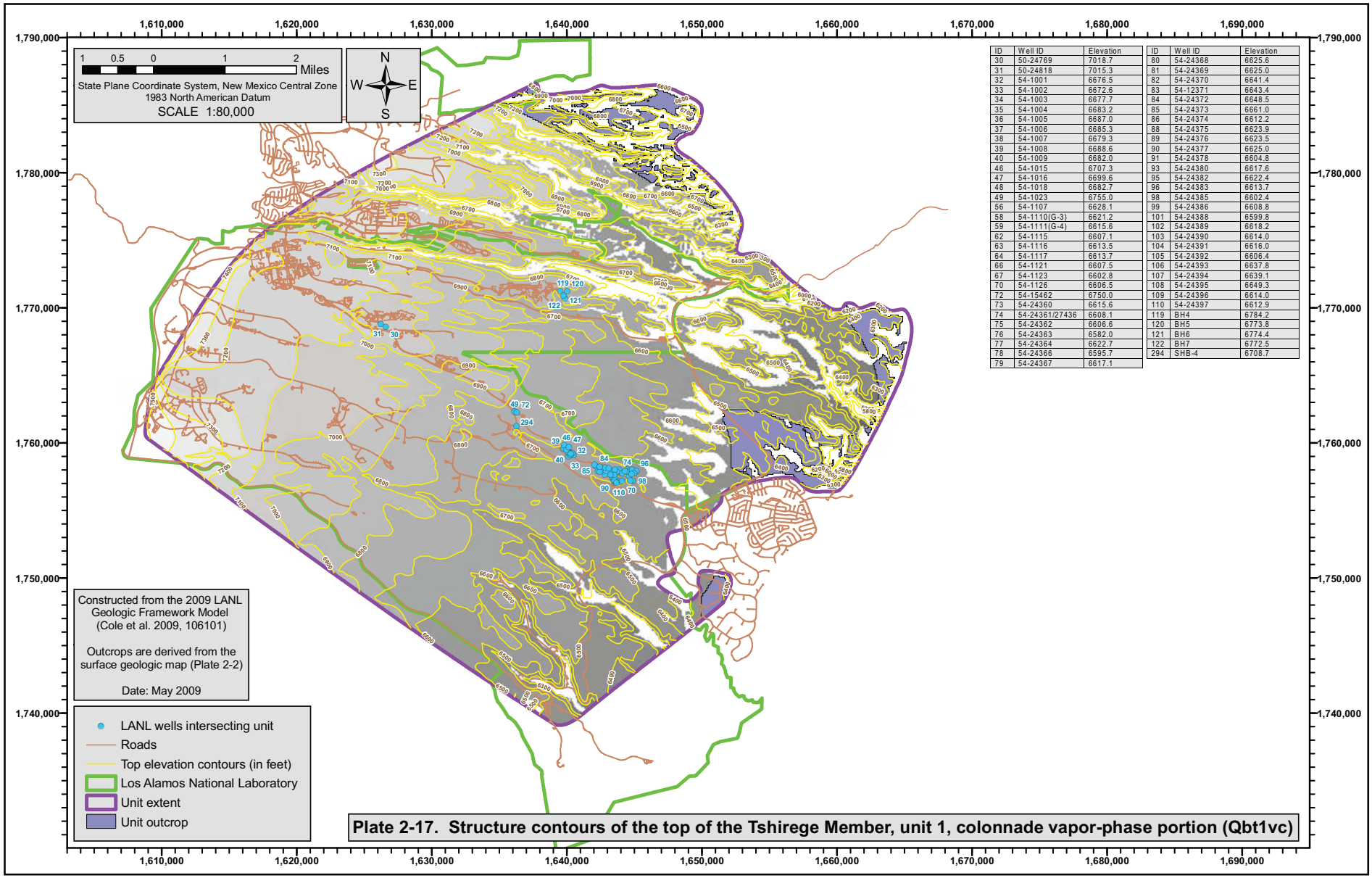
Plate 2-15. Structure contours of the top of the Tshirege Member, unit 1, upper vapor-phase portion (Qbt1vu)



ID	Well ID	Thickness
30	50-24769	40.0
31	50-24818	60.5
32	54-1001	67.6
33	54-1002	74.7
34	54-1003	74.0
35	54-1004	67.5
36	54-1005	58.8
37	54-1006	68.7
38	54-1007	74.0
39	54-1008	69.0
40	54-1009	75.0
48	54-1018	65.0
49	54-1023	94.3
56	54-1107	33.0
58	54-1110(G-3)	22.0
59	54-1111(G-4)	19.0
62	54-1115	24.1
63	54-1116	31.2
64	54-1117	36.0
66	54-1121	42.0
67	54-1123	34.5
70	54-1126	21.0
72	54-15462	93.0
73	54-24360	12.0
74	54-24361/27436	31.0
75	54-24362	23.0
76	54-24363	30.0
77	54-24364	22.9
78	54-24366	19.0
79	54-24367	21.0
80	54-24368	17.0
81	54-24369	28.5

ID	Well ID	Thickness
82	54-24370	24.5
83	54-12371	33.0
84	54-24372	39.0
85	54-24373	23.5
86	54-24374	24.0
88	54-24375	15.0
89	54-24376	22.0
90	54-24377	15.0
91	54-24378	18.0
92	54-24379	21.0
93	54-24380	18.0
94	54-24381	23.5
95	54-24382	6.0
96	54-24383	3.0
98	54-24385	12.5
99	54-24386	8.0
101	54-24388	11.2
102	54-24389	23.5
103	54-24390	32.0
104	54-24391	34.0
105	54-24392	18.0
106	54-24393	21.6
107	54-24394	30.0
108	54-24395	27.0
109	54-24396	29.5
110	54-24397	19.0
119	BH4	30.0
120	BH5	32.9
121	BH6	35.9
122	BH7	37.9
258	R-25b	37.0

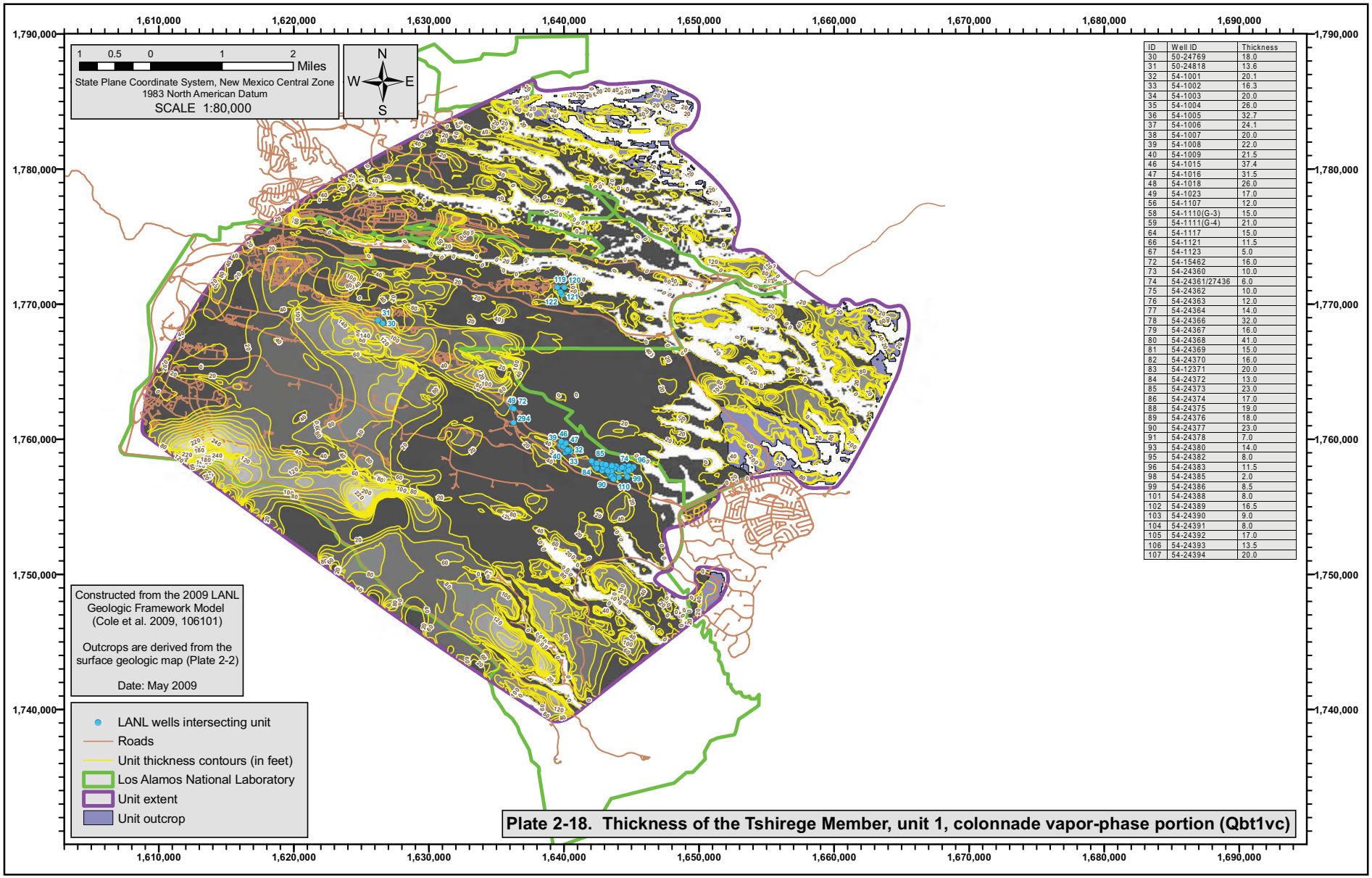
Plate 2-16. Thickness of the Tshirege Member, unit 1, upper vapor-phase portion (Qbt1vu)



ID	Well ID	Elevation
30	50-24769	7018.7
31	50-24818	7015.3
32	54-1001	6676.5
33	54-1002	6672.6
34	54-1003	6677.7
35	54-1004	6683.2
36	54-1005	6687.0
37	54-1006	6685.3
38	54-1007	6679.3
39	54-1008	6688.6
40	54-1009	6682.0
46	54-1015	6707.3
47	54-1016	6699.6
48	54-1018	6682.7
49	54-1023	6755.0
56	54-1107	6628.1
58	54-1110(G-3)	6621.2
59	54-1111(G-4)	6615.6
62	54-1115	6607.1
63	54-1116	6613.5
64	54-1117	6613.7
66	54-1121	6607.5
67	54-1123	6602.8
70	54-1126	6606.5
72	54-15462	6750.0
73	54-24360	6615.6
74	54-24361/27436	6608.1
75	54-24362	6606.6
76	54-24363	6582.0
77	54-24364	6622.7
78	54-24366	6595.7
79	54-24367	6617.1

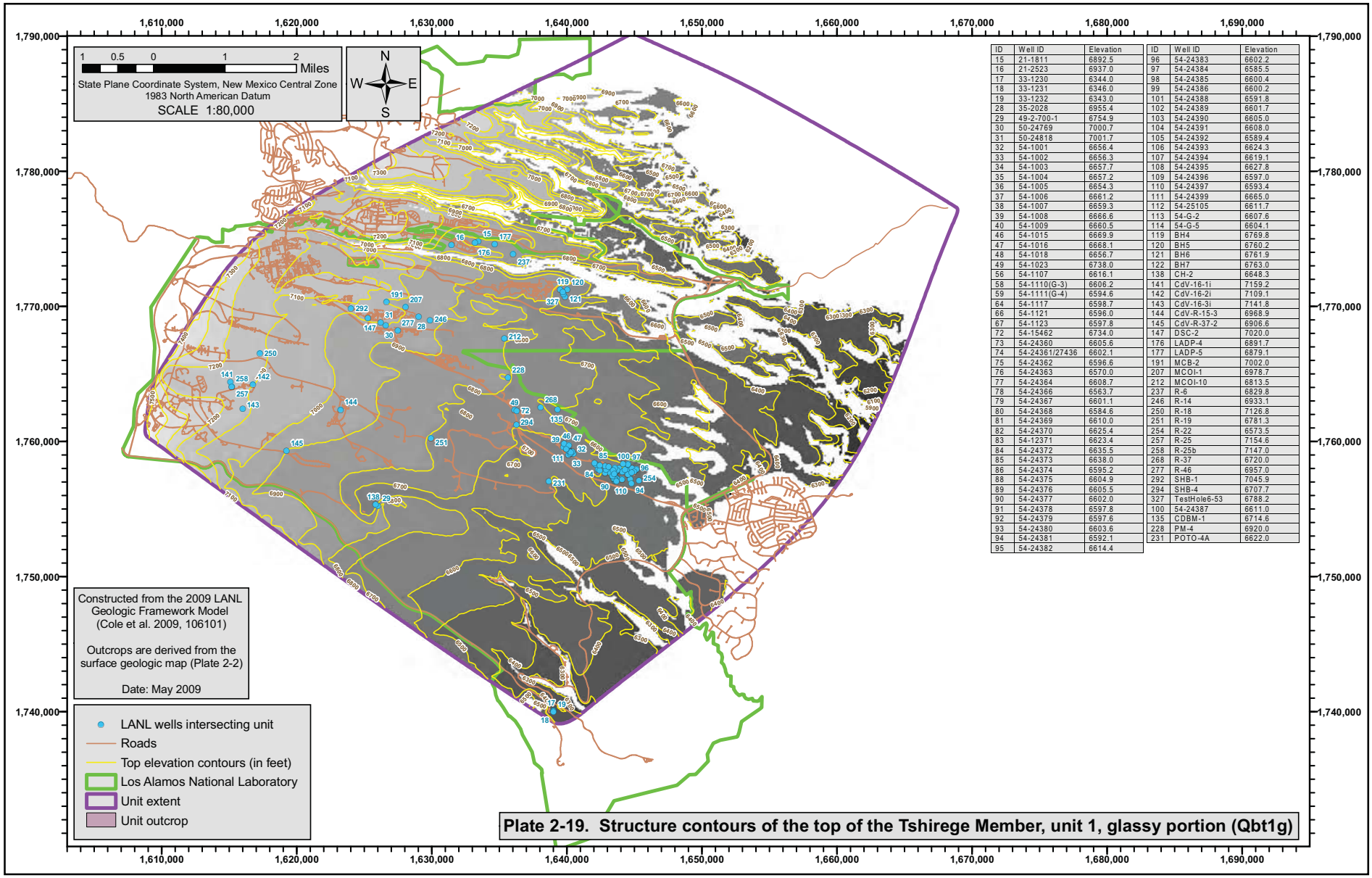
ID	Well ID	Elevation
80	54-24368	6625.6
81	54-24369	6625.0
82	54-24370	6641.4
83	54-12371	6643.4
84	54-24372	6648.5
85	54-24373	6661.0
86	54-24374	6612.2
88	54-24375	6623.9
89	54-24376	6623.5
90	54-24377	6625.0
91	54-24378	6604.8
93	54-24380	6617.6
95	54-24382	6622.4
96	54-24383	6613.7
98	54-24385	6602.4
99	54-24386	6608.8
101	54-24388	6599.8
102	54-24389	6618.2
103	54-24390	6614.0
104	54-24391	6616.0
105	54-24392	6606.4
106	54-24393	6637.8
107	54-24394	6639.1
108	54-24395	6649.3
109	54-24396	6614.0
110	54-24397	6612.9
119	BH4	6784.2
120	BH5	6773.8
121	BH6	6774.4
122	BH7	6772.5
294	SHB-4	6708.7

Plate 2-17. Structure contours of the top of the Tshirege Member, unit 1, colonnade vapor-phase portion (Qbt1vc)



ID	Well ID	Thickness
30	50-24769	18.0
31	50-24818	13.6
32	54-1001	20.1
33	54-1002	16.3
34	54-1003	20.0
35	54-1004	26.0
36	54-1005	32.7
37	54-1006	24.1
38	54-1007	20.0
39	54-1008	22.0
40	54-1009	21.5
46	54-1015	37.4
47	54-1016	31.5
48	54-1018	26.0
49	54-1023	17.0
56	54-1107	12.0
58	54-1110(G-3)	15.0
59	54-1111(G-4)	21.0
64	54-1117	15.0
66	54-1121	11.5
67	54-1123	5.0
72	54-15462	16.0
73	54-24360	10.0
74	54-24361/27436	6.0
75	54-24362	10.0
76	54-24363	12.0
77	54-24364	14.0
78	54-24366	32.0
79	54-24367	16.0
80	54-24368	41.0
81	54-24369	15.0
82	54-24370	16.0
83	54-12371	20.0
84	54-24372	13.0
85	54-24373	23.0
86	54-24374	17.0
88	54-24375	19.0
89	54-24376	18.0
90	54-24377	23.0
91	54-24378	7.0
93	54-24380	14.0
95	54-24382	8.0
96	54-24383	11.5
98	54-24385	2.0
99	54-24386	8.5
101	54-24388	8.0
102	54-24389	16.5
103	54-24390	9.0
104	54-24391	8.0
105	54-24392	17.0
106	54-24393	13.5
107	54-24394	20.0

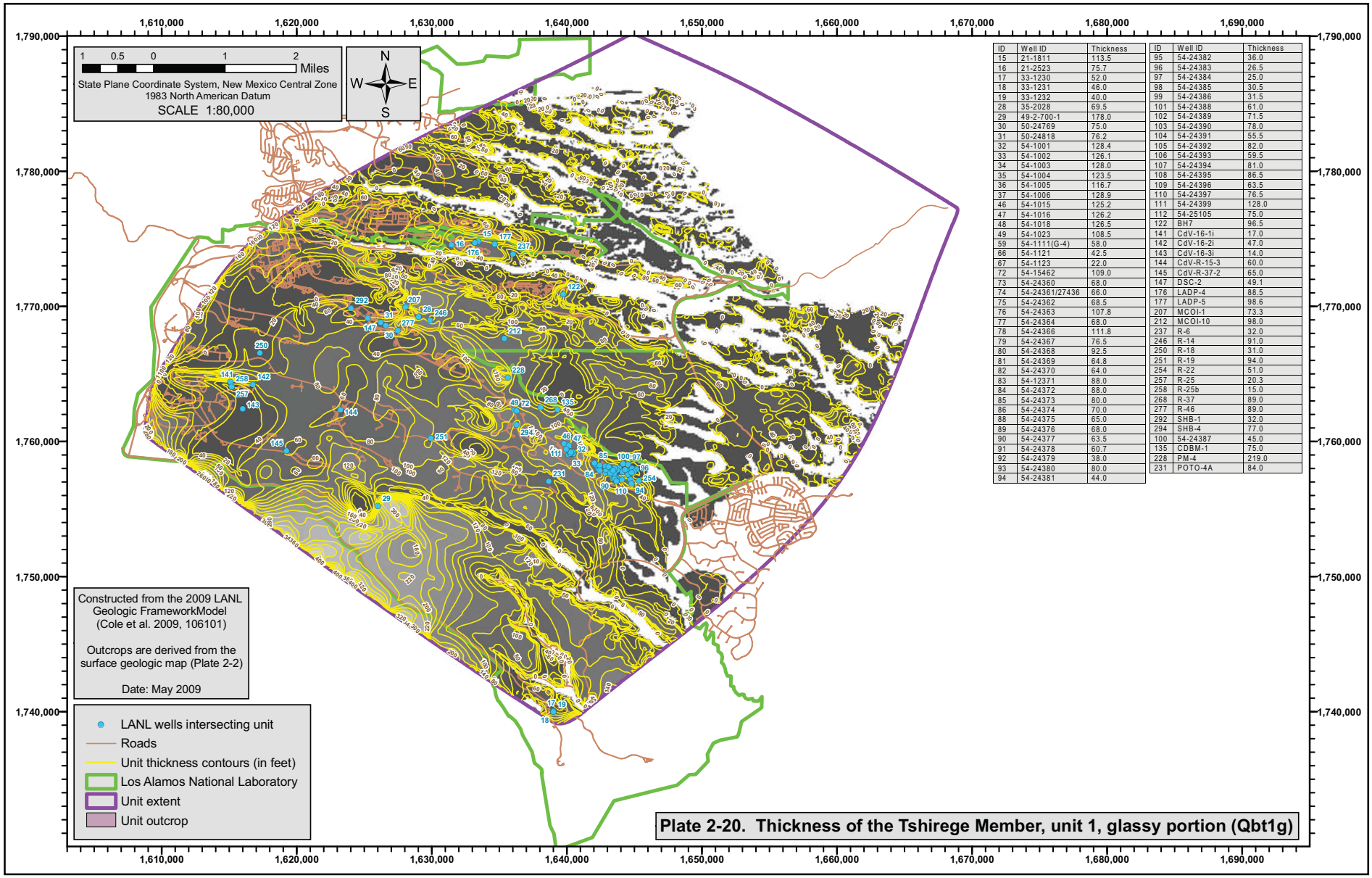
Plate 2-18. Thickness of the Tshirege Member, unit 1, colonnade vapor-phase portion (Qbt1vc)



ID	Well ID	Elevation
15	21-1811	6892.5
16	21-2523	6937.0
17	33-1230	6344.0
18	33-1231	6346.0
19	33-1232	6343.0
28	35-2028	6955.4
29	49-2-700-1	6754.9
30	50-24769	7000.7
31	50-24818	7001.7
32	54-1001	6656.4
33	54-1002	6656.3
34	54-1003	6657.7
35	54-1004	6657.2
36	54-1005	6654.3
37	54-1006	6661.2
38	54-1007	6659.3
39	54-1008	6666.6
40	54-1009	6660.5
46	54-1015	6669.9
47	54-1016	6668.1
48	54-1018	6656.7
49	54-1023	6738.0
56	54-1107	6616.1
58	54-1110(G-3)	6606.2
59	54-1111(G-4)	6594.6
64	54-1117	6598.7
66	54-1121	6596.0
67	54-1123	6597.8
72	54-15462	6734.0
73	54-24360	6605.6
74	54-24361/27436	6602.1
75	54-24362	6596.6
76	54-24363	6570.0
77	54-24364	6608.7
78	54-24366	6563.7
79	54-24367	6601.1
80	54-24368	6584.6
81	54-24369	6610.0
82	54-24370	6625.4
83	54-12371	6623.4
84	54-24372	6635.5
85	54-24373	6638.0
86	54-24374	6595.2
88	54-24375	6604.9
89	54-24376	6605.5
90	54-24377	6602.0
91	54-24378	6597.8
92	54-24379	6597.6
93	54-24380	6603.6
94	54-24381	6592.1
95	54-24382	6614.4

ID	Well ID	Elevation
96	54-24383	6602.2
97	54-24384	6585.5
98	54-24385	6600.4
99	54-24386	6600.2
101	54-24388	6591.8
102	54-24389	6601.7
103	54-24390	6605.0
104	54-24391	6608.0
105	54-24392	6589.4
106	54-24393	6624.3
107	54-24394	6619.1
108	54-24395	6627.8
109	54-24396	6597.0
110	54-24397	6593.4
111	54-24399	6665.0
112	54-25105	6611.7
113	54-G-2	6607.6
114	54-G-5	6604.1
119	BH4	6769.8
120	BH5	6760.2
121	BH6	6761.9
122	BH7	6763.0
138	CH-2	6648.3
141	CdV-16-1i	7159.2
142	CdV-16-2i	7109.1
143	CdV-16-3i	7141.8
144	CdV-R-15-3	6968.9
145	CdV-R-37-2	6906.6
147	DSC-2	7020.0
176	LADP-4	6891.7
177	LADP-5	6879.1
191	MCB-2	7002.0
207	MCOI-1	6978.7
212	MCOI-10	6813.5
237	R-6	6829.8
246	R-14	6933.1
250	R-18	7126.8
251	R-19	6781.3
254	R-22	6573.5
257	R-25	7154.6
258	R-25b	7147.0
268	R-37	6720.0
277	R-46	6957.0
292	SHB-1	7045.9
294	SHB-4	6707.7
327	TestHole6-53	6788.2
100	54-24387	6611.0
135	CDBM-1	6714.6
228	PM-4	6920.0
231	POTO-4A	6622.0

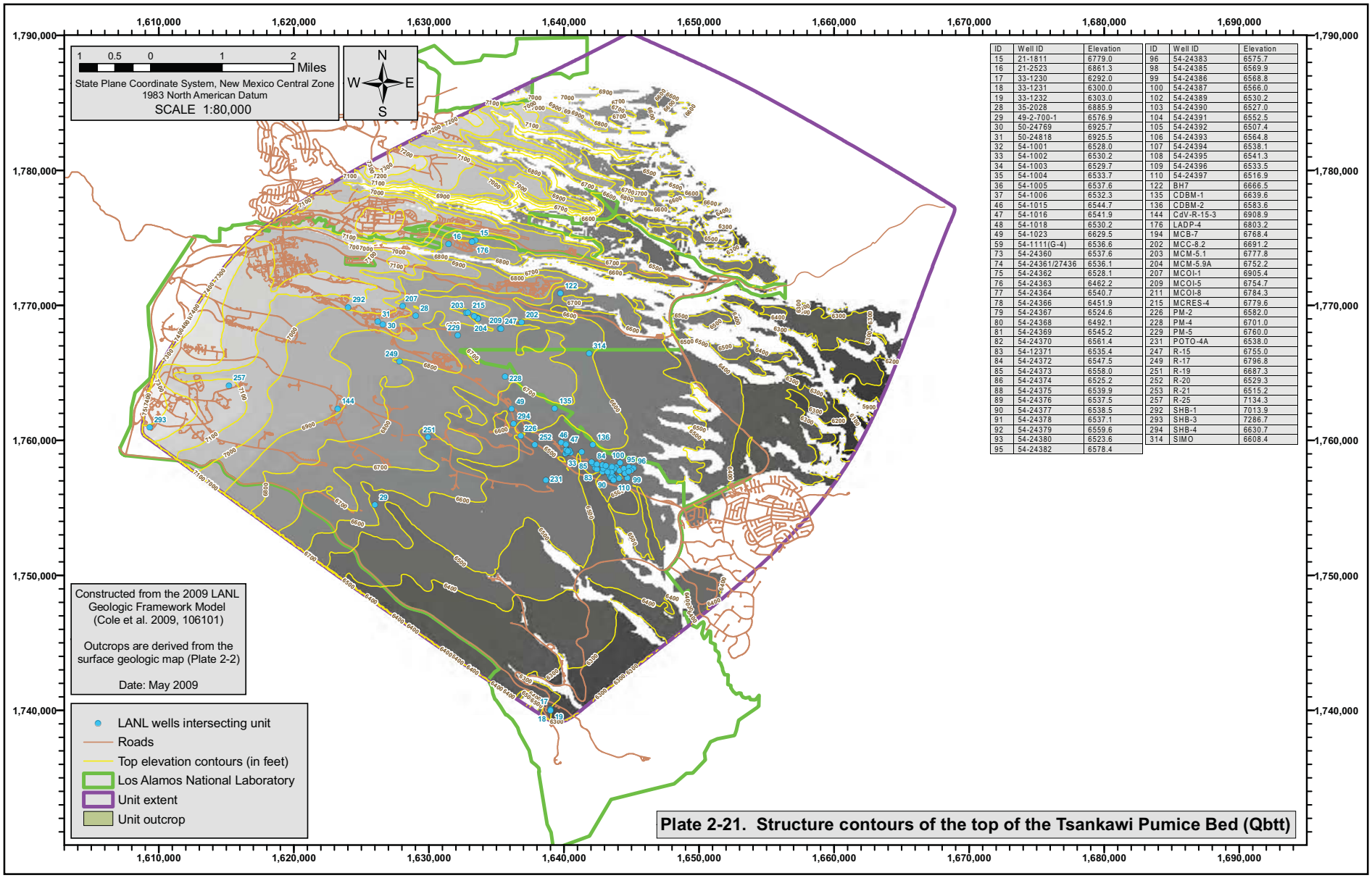
Plate 2-19. Structure contours of the top of the Tshirege Member, unit 1, glassy portion (Qbt1g)



ID	Well ID	Thickness
15	21-1811	113.5
16	21-2523	75.7
17	33-1230	52.0
18	33-1231	46.0
19	33-1232	40.0
28	35-2028	69.5
29	49-2-700-1	178.0
30	50-24769	75.0
31	50-24818	76.2
32	54-1001	128.4
33	54-1002	126.1
34	54-1003	128.0
35	54-1004	123.5
36	54-1005	116.7
37	54-1006	128.9
46	54-1015	125.2
47	54-1016	126.2
48	54-1018	126.5
49	54-1023	108.5
59	54-1111(G-4)	58.0
66	54-1121	42.5
67	54-1123	22.0
72	54-15462	109.0
73	54-24360	68.0
74	54-24361/27436	66.0
75	54-24362	68.5
76	54-24363	107.8
77	54-24364	68.0
78	54-24366	111.8
79	54-24367	76.5
80	54-24368	92.5
81	54-24369	64.8
82	54-24370	64.0
83	54-12371	88.0
84	54-24372	88.0
85	54-24373	80.0
86	54-24374	70.0
88	54-24375	65.0
89	54-24376	68.0
90	54-24377	63.5
91	54-24378	60.7
92	54-24379	38.0
93	54-24380	80.0
94	54-24381	44.0

ID	Well ID	Thickness
95	54-24382	36.0
96	54-24383	26.5
97	54-24384	25.0
98	54-24385	30.5
99	54-24386	31.5
101	54-24388	61.0
102	54-24389	71.5
103	54-24390	78.0
104	54-24391	55.5
105	54-24392	82.0
106	54-24393	59.5
107	54-24394	81.0
108	54-24395	86.5
109	54-24396	63.5
110	54-24397	76.5
111	54-24399	128.0
112	54-25105	75.0
122	BH7	96.5
141	CdV-16-1i	17.0
142	CdV-16-2i	47.0
143	CdV-16-3i	14.0
144	CdV-R-15-3	60.0
145	CdV-R-37-2	65.0
147	DSC-2	49.1
176	LADP-4	88.5
177	LADP-5	98.6
207	MCOI-1	73.3
212	MCOI-10	98.0
237	R-6	32.0
246	R-14	91.0
250	R-18	31.0
251	R-19	94.0
254	R-22	51.0
257	R-25	20.3
258	R-25b	15.0
268	R-37	89.0
277	R-46	89.0
292	SHB-1	32.0
294	SHB-4	77.0
100	54-24387	45.0
135	CDBM-1	75.0
228	PM-4	219.0
231	POTO-4A	84.0

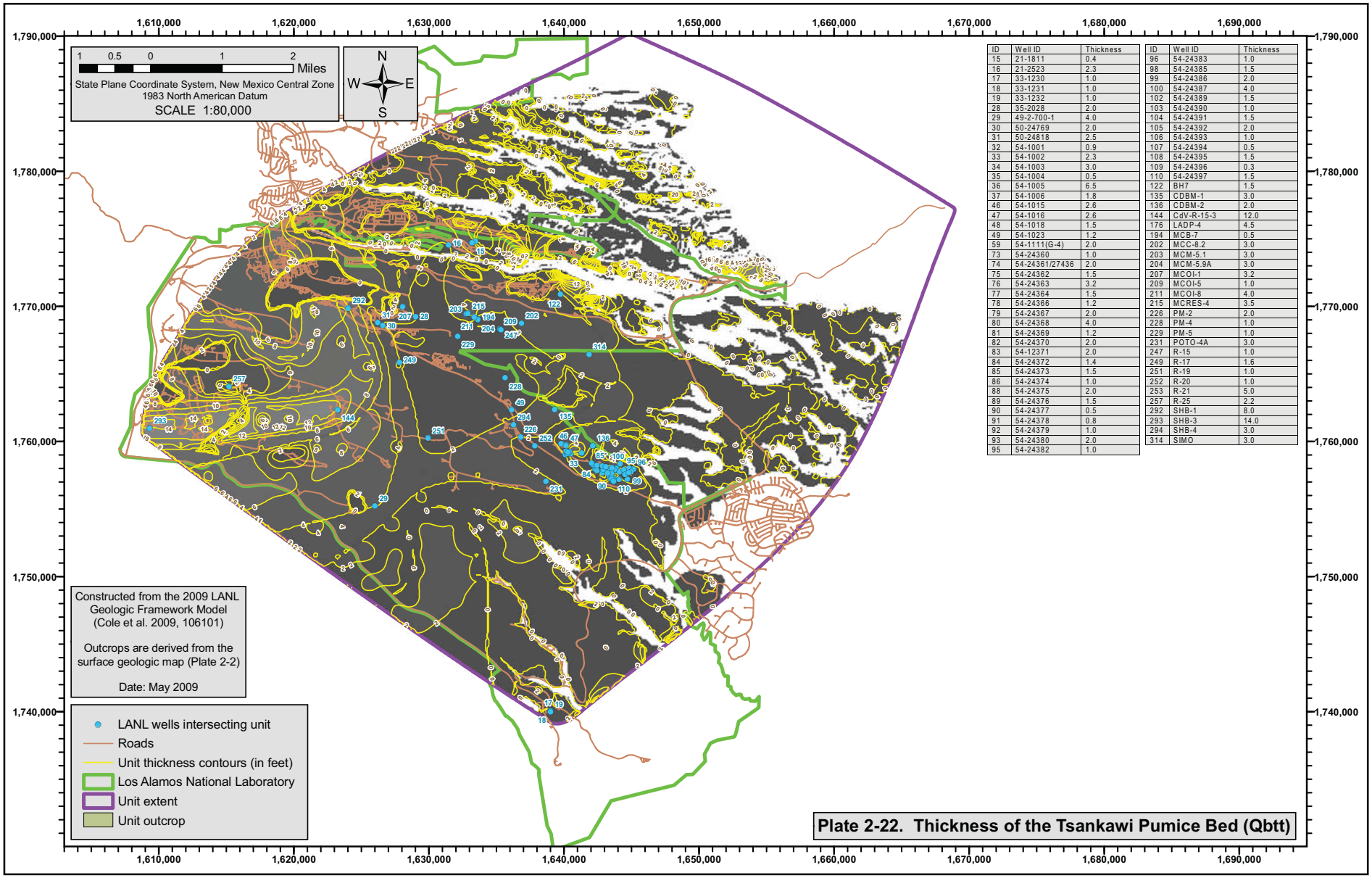
Plate 2-20. Thickness of the Tshirege Member, unit 1, glassy portion (Qbt1g)



ID	Well ID	Elevation
15	21-1811	6779.0
16	21-2523	6861.3
17	33-1230	6292.0
18	33-1231	6300.0
19	33-1232	6303.0
28	35-2028	6885.9
29	49-2-700-1	6576.9
30	50-24769	6925.7
31	50-24818	6925.5
32	54-1001	6528.0
33	54-1002	6530.2
34	54-1003	6529.7
35	54-1004	6533.7
36	54-1005	6537.6
37	54-1006	6532.3
46	54-1015	6544.7
47	54-1016	6541.9
48	54-1018	6530.2
49	54-1023	6629.5
59	54-1111(G-4)	6536.6
73	54-24360	6537.6
74	54-24361/27436	6536.1
75	54-24362	6528.1
76	54-24363	6462.2
77	54-24364	6540.7
78	54-24366	6451.9
79	54-24367	6524.6
80	54-24368	6492.1
81	54-24369	6545.2
82	54-24370	6561.4
83	54-12371	6535.4
84	54-24372	6547.5
85	54-24373	6558.0
86	54-24374	6525.2
88	54-24375	6539.9
89	54-24376	6537.5
90	54-24377	6538.5
91	54-24378	6537.1
92	54-24379	6559.6
93	54-24380	6523.6
95	54-24382	6578.4

ID	Well ID	Elevation
96	54-24383	6575.7
98	54-24385	6569.9
99	54-24386	6568.8
100	54-24387	6566.0
102	54-24389	6530.2
103	54-24390	6527.0
104	54-24391	6552.5
105	54-24392	6507.4
106	54-24393	6564.8
107	54-24394	6538.1
108	54-24395	6541.3
109	54-24396	6533.5
110	54-24397	6516.9
122	BH7	6666.5
135	CDBM-1	6639.6
136	CDBM-2	6583.6
144	CdV-R-15-3	6908.9
176	LADP-4	6803.2
194	MCB-7	6768.4
202	MCC-8.2	6691.2
203	MCM-5.1	6777.8
204	MCM-5.9A	6752.2
207	MCOI-1	6905.4
209	MCOI-5	6754.7
211	MCOI-8	6784.3
215	MCRES-4	6779.6
226	PM-2	6582.0
228	PM-4	6701.0
229	PM-5	6760.0
231	POTO-4A	6538.0
247	R-15	6755.0
249	R-17	6796.8
251	R-19	6687.3
252	R-20	6529.3
253	R-21	6515.2
257	R-25	7134.3
292	SHB-1	7013.9
293	SHB-3	7286.7
294	SHB-4	6630.7
314	SIMO	6608.4

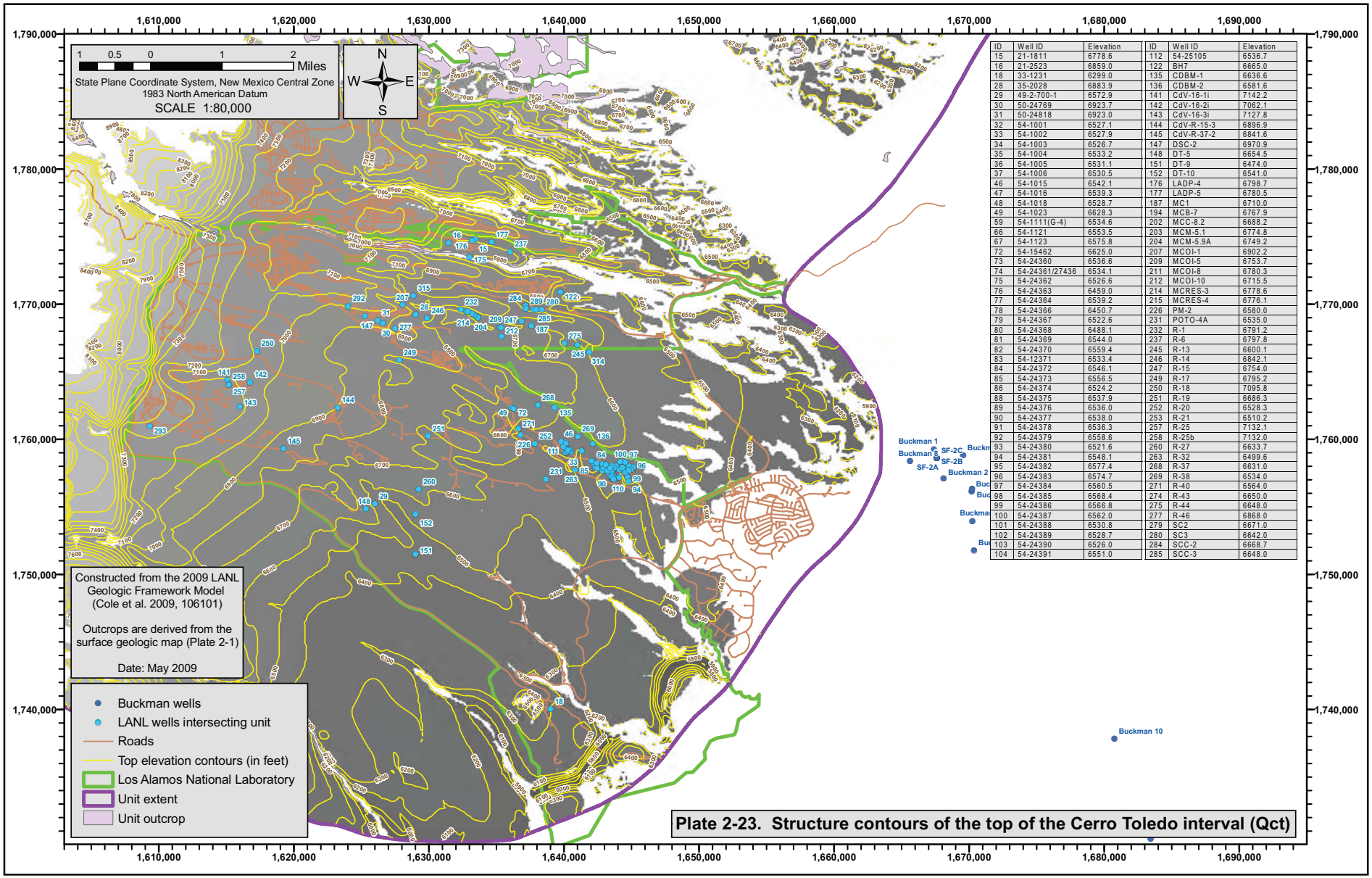
Plate 2-21. Structure contours of the top of the Tsankawi Pumice Bed (Qbtt)



ID	Well ID	Thickness
15	21-1811	0.4
16	21-2523	2.3
17	33-1230	1.0
18	33-1231	1.0
19	33-1232	1.0
28	35-2028	2.0
29	49-2-700-1	4.0
30	50-24769	2.0
31	50-24818	2.5
32	54-1001	0.9
33	54-1002	2.3
34	54-1003	3.0
35	54-1004	0.5
36	54-1005	6.5
37	54-1006	1.8
46	54-1015	2.6
47	54-1016	2.6
48	54-1018	1.5
49	54-1023	1.2
59	54-1111(G-4)	2.0
73	54-24360	1.0
74	54-24361/27436	2.0
75	54-24362	1.5
76	54-24363	3.2
77	54-24364	1.5
78	54-24366	1.2
79	54-24367	2.0
80	54-24368	4.0
81	54-24369	1.2
82	54-24370	2.0
83	54-12371	2.0
84	54-24372	1.4
85	54-24373	1.5
86	54-24374	1.0
88	54-24375	2.0
89	54-24376	1.5
90	54-24377	0.5
91	54-24378	0.8
92	54-24379	1.0
93	54-24380	2.0
95	54-24382	1.0

ID	Well ID	Thickness
96	54-24383	1.0
98	54-24385	1.5
99	54-24386	2.0
100	54-24387	4.0
102	54-24389	1.5
103	54-24390	1.0
104	54-24391	1.5
105	54-24392	2.0
106	54-24393	1.0
107	54-24394	0.5
108	54-24395	1.5
109	54-24396	0.3
110	54-24397	1.5
122	BH7	1.5
135	CDBM-1	3.0
136	CDBM-2	2.0
144	CdV-R-15-3	12.0
176	LADP-4	4.5
194	MCB-7	0.5
202	MCC-8.2	3.0
203	MCM-5.1	3.0
204	MCM-5.9A	3.0
207	MCOI-1	3.2
209	MCOI-5	1.0
211	MCOI-8	4.0
215	MCRES-4	3.5
226	PM-2	2.0
228	PM-4	1.0
229	PM-5	1.0
231	POTO-4A	3.0
247	R-15	1.0
249	R-17	1.6
251	R-19	1.0
252	R-20	1.0
253	R-21	5.0
257	R-25	2.2
292	SHB-1	8.0
293	SHB-3	14.0
294	SHB-4	3.0
314	SIMO	3.0

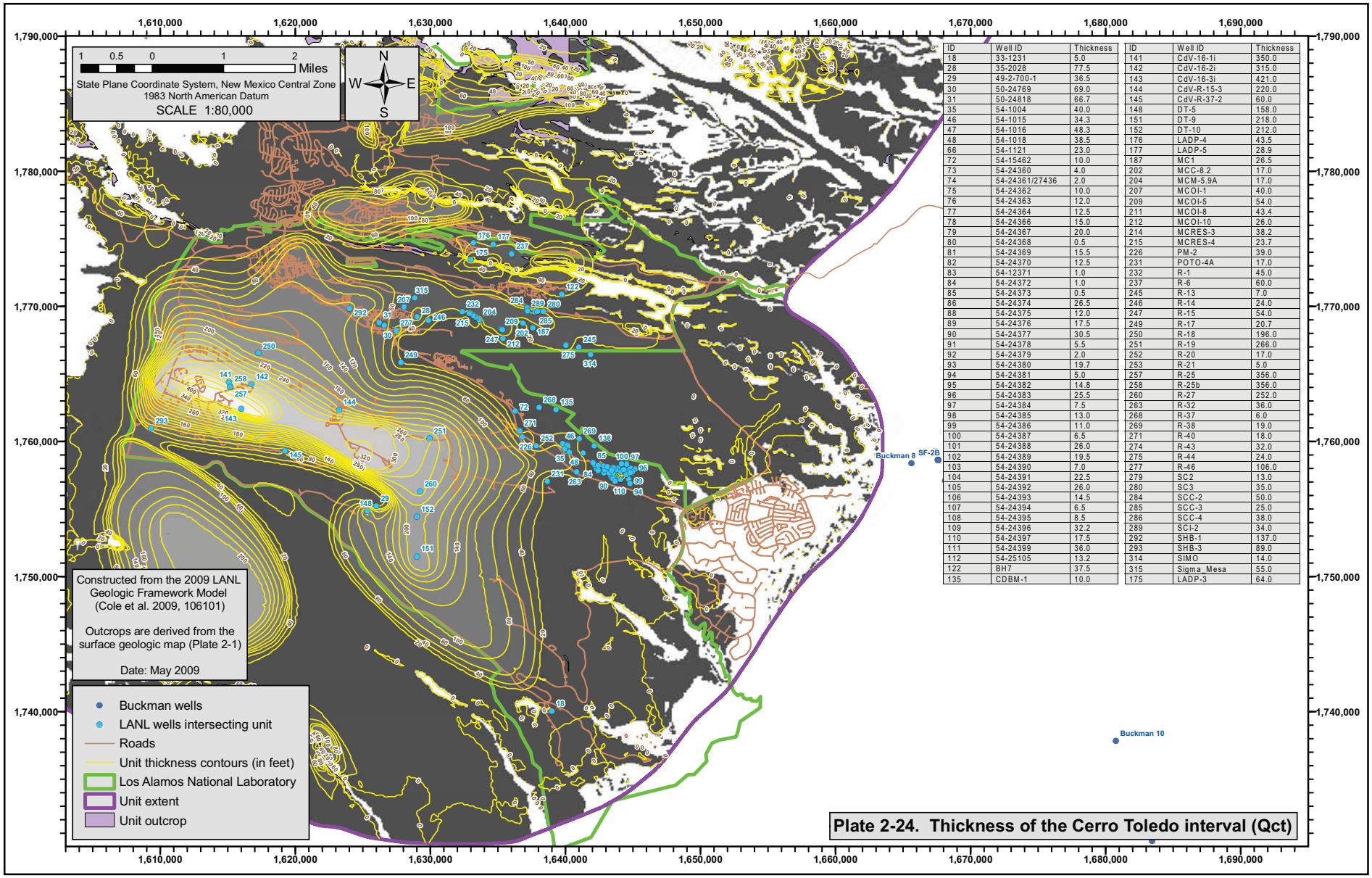
Plate 2-22. Thickness of the Tsankawi Pumice Bed (Qbtt)



ID	Well ID	Elevation
15	21-1811	6778.6
16	21-2523	6859.0
18	33-1231	6299.0
28	35-2028	6883.9
29	49-2-700-1	6572.9
30	50-24769	6923.7
31	50-24818	6923.0
32	54-1001	6527.1
33	54-1002	6527.9
34	54-1003	6526.7
35	54-1004	6533.2
36	54-1005	6531.1
37	54-1006	6530.5
46	54-1015	6542.1
47	54-1016	6539.3
48	54-1018	6528.7
49	54-1023	6628.3
59	54-1111(G-4)	6534.6
66	54-1121	6553.5
67	54-1123	6575.8
72	54-15462	6625.0
73	54-24360	6536.6
74	54-24361/27436	6534.1
75	54-24362	6526.6
76	54-24363	6459.0
77	54-24364	6539.2
78	54-24366	6450.7
79	54-24367	6522.6
80	54-24368	6488.1
81	54-24369	6544.0
82	54-24370	6559.4
83	54-12371	6533.4
84	54-24372	6546.1
85	54-24373	6556.5
86	54-24374	6524.2
88	54-24375	6537.9
89	54-24376	6536.0
90	54-24377	6538.0
91	54-24378	6536.3
92	54-24379	6558.6
93	54-24380	6521.6
94	54-24381	6548.1
95	54-24382	6577.4
96	54-24383	6574.7
97	54-24384	6560.5
98	54-24385	6568.4
99	54-24386	6566.8
100	54-24387	6562.0
101	54-24388	6530.8
102	54-24389	6528.7
103	54-24390	6526.0
104	54-24391	6551.0

ID	Well ID	Elevation
112	54-25105	6536.7
122	BH7	6665.0
135	CDBM-1	6636.6
136	CDBM-2	6581.6
141	CdV-16-1i	7142.2
142	CdV-16-2i	7062.1
143	CdV-16-3i	7127.8
144	CdV-R-15-3	6896.9
145	CdV-R-37-2	6841.6
147	DSC-2	6970.9
148	DT-5	6654.5
151	DT-9	6474.0
152	DT-10	6541.0
176	LADP-4	6798.7
177	LADP-5	6780.5
187	MC1	6710.0
194	MCB-7	6767.9
202	MCC-8.2	6688.2
203	MCM-5.1	6774.8
204	MCM-5.9A	6749.2
207	MCOI-1	6902.2
209	MCOI-5	6753.7
211	MCOI-8	6780.3
212	MCOI-10	6715.5
214	MCRES-3	6778.6
215	MCRES-4	6776.1
226	PM-2	6580.0
231	POTO-4A	6535.0
232	R-1	6791.2
237	R-6	6797.8
245	R-13	6600.1
246	R-14	6842.1
247	R-15	6754.0
249	R-17	6795.2
250	R-18	7095.8
251	R-19	6686.3
252	R-20	6528.3
253	R-21	6510.2
257	R-25	7132.1
258	R-25b	7132.0
260	R-27	6633.7
263	R-32	6499.6
268	R-37	6631.0
269	R-38	6534.0
271	R-40	6564.0
274	R-43	6650.0
275	R-44	6648.0
277	R-46	6868.0
279	SC2	6671.0
280	SC3	6642.0
284	SCC-2	6668.7
285	SCC-3	6648.0

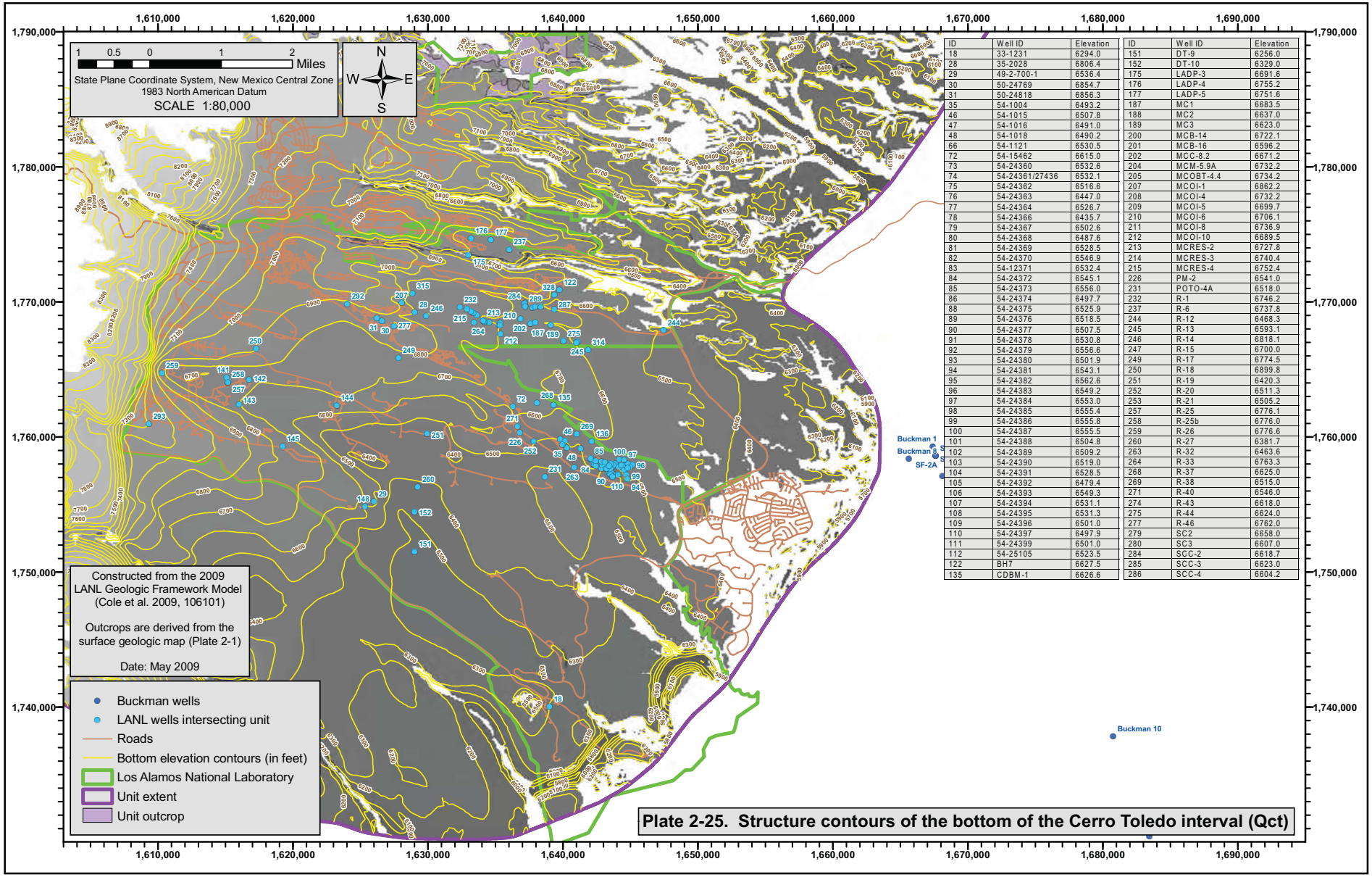
Plate 2-23. Structure contours of the top of the Cerro Toledo interval (Qct)



ID	Well ID	Thickness
18	33-1231	5.0
28	35-2028	77.5
29	49-2-700-1	36.5
30	50-24769	69.0
31	50-24818	66.7
35	54-1004	40.0
46	54-1015	34.3
47	54-1016	48.3
48	54-1018	38.5
66	54-1121	23.0
72	54-15462	10.0
73	54-24360	4.0
74	54-24361/27436	2.0
75	54-24362	10.0
76	54-24363	12.0
77	54-24364	12.5
78	54-24366	15.0
79	54-24367	20.0
80	54-24368	0.5
81	54-24369	15.5
82	54-24370	12.5
83	54-12371	1.0
84	54-24372	1.0
85	54-24373	0.5
86	54-24374	26.5
88	54-24375	12.0
89	54-24376	17.5
90	54-24377	30.5
91	54-24378	5.5
92	54-24379	2.0
93	54-24380	19.7
94	54-24381	5.0
95	54-24382	14.8
96	54-24383	25.5
97	54-24384	7.5
98	54-24385	13.0
99	54-24386	11.0
100	54-24387	6.5
101	54-24388	26.0
102	54-24389	19.5
103	54-24390	7.0
104	54-24391	22.5
105	54-24392	26.0
106	54-24393	14.5
107	54-24394	6.5
108	54-24395	8.5
109	54-24396	32.2
110	54-24397	17.5
111	54-24399	36.0
112	54-25105	13.2
122	BH7	37.5
135	CDBM-1	10.0

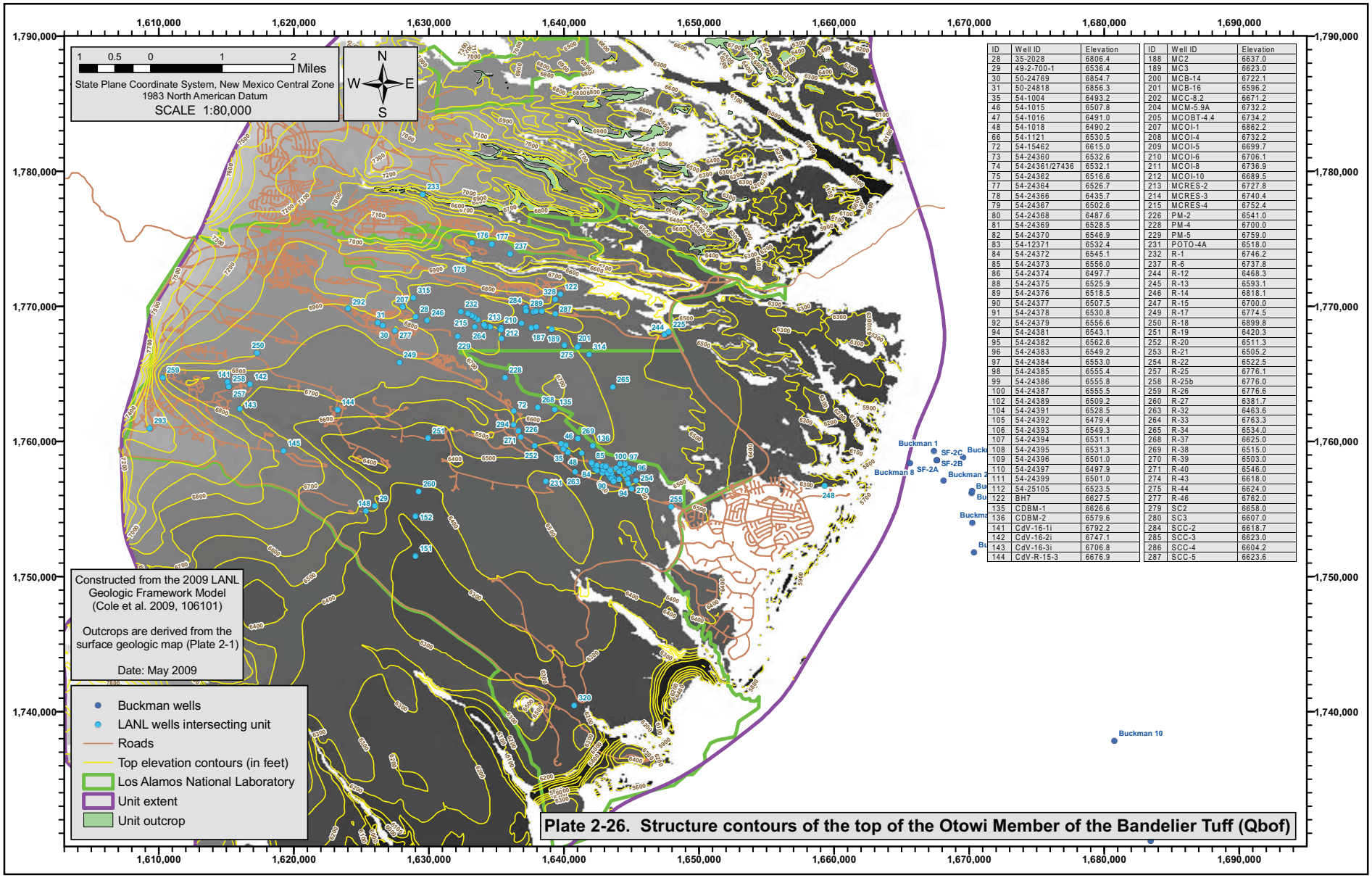
ID	Well ID	Thickness
141	CdV-16-1i	350.0
142	CdV-16-2i	315.0
143	CdV-16-3i	421.0
144	CdV-R-15-3	220.0
145	CdV-R-37-2	60.0
148	DT-5	158.0
151	DT-9	218.0
152	DT-10	212.0
176	LADP-4	43.5
177	LADP-5	28.9
187	MC1	26.5
202	MCC-8.2	17.0
204	MCM-5.9A	17.0
207	MCOI-1	40.0
209	MCOI-5	54.0
211	MCOI-8	43.4
212	MCOI-10	26.0
214	MCRES-3	38.2
215	MCRES-4	23.7
226	PM-2	39.0
231	POTO-4A	17.0
232	R-1	45.0
237	R-6	60.0
245	R-13	7.0
246	R-14	24.0
247	R-15	54.0
249	R-17	20.7
250	R-18	196.0
251	R-19	266.0
252	R-20	17.0
253	R-21	5.0
257	R-25	356.0
258	R-25b	356.0
260	R-27	252.0
263	R-32	36.0
268	R-37	6.0
269	R-38	19.0
271	R-40	18.0
274	R-43	32.0
275	R-44	24.0
277	R-46	106.0
279	SC2	13.0
280	SC3	35.0
284	SCC-2	50.0
285	SCC-3	25.0
286	SCC-4	38.0
289	SCI-2	34.0
292	SHB-1	137.0
293	SHB-3	89.0
314	SIMO	14.0
315	Sigma_Mesa	55.0
175	LADP-3	64.0

Plate 2-24. Thickness of the Cerro Toledo interval (Qct)



ID	Well ID	Elevation	ID	Well ID	Elevation
18	33-1231	6294.0	151	DT-9	6256.0
28	35-2028	6806.4	152	DT-10	6329.0
29	49-2-700-1	6536.4	175	LADP-3	6691.6
30	50-24769	6854.7	176	LADP-4	6755.2
31	50-24818	6856.3	177	LADP-5	6751.6
35	54-1004	6493.2	187	MC1	6683.5
46	54-1015	6507.8	188	MC2	6637.0
47	54-1016	6491.0	189	MC3	6623.0
48	54-1018	6490.2	200	MCB-14	6722.1
66	54-1121	6530.5	201	MCB-16	6596.2
72	54-15462	6615.0	202	MCC-8.2	6671.2
73	54-24360	6532.6	204	MCM-5.9A	6732.2
74	54-24361/27436	6532.1	205	MCOBT-4.4	6734.2
75	54-24362	6516.6	207	MCOI-1	6862.2
76	54-24363	6447.0	208	MCOI-4	6732.2
77	54-24364	6526.7	209	MCOI-5	6699.7
78	54-24366	6435.7	210	MCOI-6	6706.1
79	54-24367	6502.6	211	MCOI-8	6736.9
80	54-24368	6487.6	212	MCOI-10	6689.5
81	54-24369	6528.5	213	MCRES-2	6727.8
82	54-24370	6546.9	214	MCRES-3	6740.4
83	54-12371	6532.4	215	MCRES-4	6752.4
84	54-24372	6545.1	226	PM-2	6541.0
85	54-24373	6556.0	231	POTO-4A	6518.0
86	54-24374	6497.7	232	R-1	6746.2
88	54-24375	6525.9	237	R-6	6737.8
89	54-24376	6518.5	244	R-12	6468.3
90	54-24377	6507.5	245	R-13	6593.1
91	54-24378	6530.8	246	R-14	6818.1
92	54-24379	6556.6	247	R-15	6700.0
93	54-24380	6501.9	249	R-17	6774.5
94	54-24381	6543.1	250	R-18	6899.8
95	54-24382	6562.6	251	R-19	6420.3
96	54-24383	6549.2	252	R-20	6511.3
97	54-24384	6553.0	253	R-21	6505.2
98	54-24385	6555.4	257	R-25	6776.1
99	54-24386	6555.8	258	R-25b	6776.0
100	54-24387	6555.5	259	R-26	6776.6
101	54-24388	6504.8	260	R-27	6381.7
102	54-24389	6509.2	263	R-32	6463.6
103	54-24390	6519.0	264	R-33	6763.3
104	54-24391	6528.5	268	R-37	6625.0
105	54-24392	6479.4	269	R-38	6515.0
106	54-24393	6549.3	271	R-40	6546.0
107	54-24394	6531.1	274	R-43	6618.0
108	54-24395	6531.3	275	R-44	6624.0
109	54-24396	6501.0	277	R-46	6762.0
110	54-24397	6497.9	279	SC2	6658.0
111	54-24399	6501.0	280	SC3	6607.0
112	54-25105	6523.5	284	SCC-2	6618.7
122	BH7	6627.5	285	SCC-3	6623.0
135	CDBM-1	6626.6	286	SCC-4	6604.2

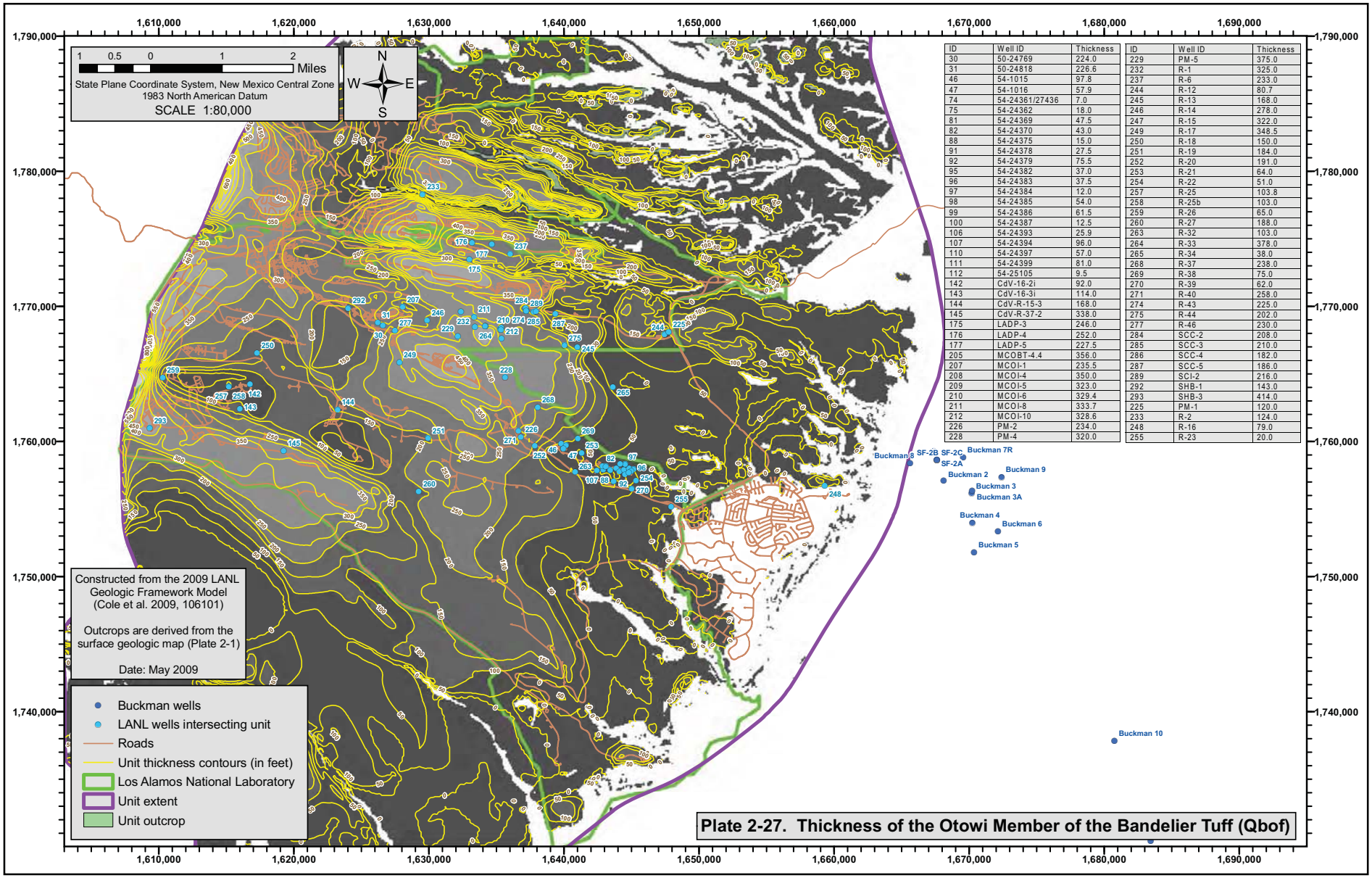
Plate 2-25. Structure contours of the bottom of the Cerro Toledo interval (Qct)



ID	Well ID	Elevation
28	35-2028	6806.4
29	49-2-700-1	6536.4
30	50-24769	6854.7
31	50-24818	6856.3
35	54-1004	6493.2
46	54-1015	6507.8
47	54-1016	6491.0
48	54-1018	6490.2
66	54-1121	6530.5
72	54-15462	6615.0
73	54-24360	6532.6
74	54-24361/27436	6532.1
75	54-24362	6516.6
77	54-24364	6526.7
78	54-24366	6435.7
79	54-24367	6502.6
80	54-24368	6487.6
81	54-24369	6528.5
82	54-24370	6546.9
83	54-12371	6532.4
84	54-24372	6545.1
85	54-24373	6556.0
86	54-24374	6497.7
88	54-24375	6525.9
89	54-24376	6518.5
90	54-24377	6507.5
91	54-24378	6530.8
92	54-24379	6556.6
94	54-24381	6543.1
95	54-24382	6562.6
96	54-24383	6549.2
97	54-24384	6553.0
98	54-24385	6555.4
99	54-24386	6555.8
100	54-24387	6555.5
102	54-24389	6509.2
104	54-24391	6528.5
105	54-24392	6479.4
106	54-24393	6549.3
107	54-24394	6531.1
108	54-24395	6531.3
109	54-24396	6501.0
110	54-24397	6497.9
111	54-24399	6501.0
112	54-25105	6523.5
122	BH7	6627.5
135	CDBM-1	6626.6
136	CDBM-2	6579.6
141	CdV-16-1i	6792.2
142	CdV-16-2i	6747.1
143	CdV-16-3i	6706.8
144	CdV-R-15-3	6676.9

ID	Well ID	Elevation
188	MC2	6637.0
189	MC3	6623.0
200	MCB-14	6722.1
201	MCB-16	6596.2
202	MCC-8.2	6671.2
204	MCM-5.9A	6732.2
205	MCOBT-4.4	6734.2
207	MCOI-1	6862.2
208	MCOI-4	6732.2
209	MCOI-5	6699.7
210	MCOI-6	6706.1
211	MCOI-8	6736.9
212	MCOI-10	6689.5
213	MCRES-2	6727.8
214	MCRES-3	6740.4
215	MCRES-4	6752.4
226	PM-2	6541.0
228	PM-4	6700.0
229	PM-5	6759.0
231	POTO-4A	6518.0
232	R-1	6746.2
237	R-6	6737.8
244	R-12	6468.3
245	R-13	6593.1
246	R-14	6818.1
247	R-15	6700.0
249	R-17	6774.5
250	R-18	6899.8
251	R-19	6420.3
252	R-20	6511.3
253	R-21	6505.2
254	R-22	6522.5
257	R-25	6776.1
258	R-25b	6776.0
259	R-26	6776.6
260	R-27	6381.7
263	R-32	6463.6
264	R-33	6763.3
265	R-34	6534.0
268	R-37	6625.0
269	R-38	6515.0
270	R-39	6503.0
271	R-40	6546.0
274	R-43	6618.0
275	R-44	6624.0
277	R-46	6762.0
279	SC2	6658.0
280	SC3	6607.0
284	SCC-2	6618.7
285	SCC-3	6623.0
286	SCC-4	6604.2
287	SCC-5	6623.6

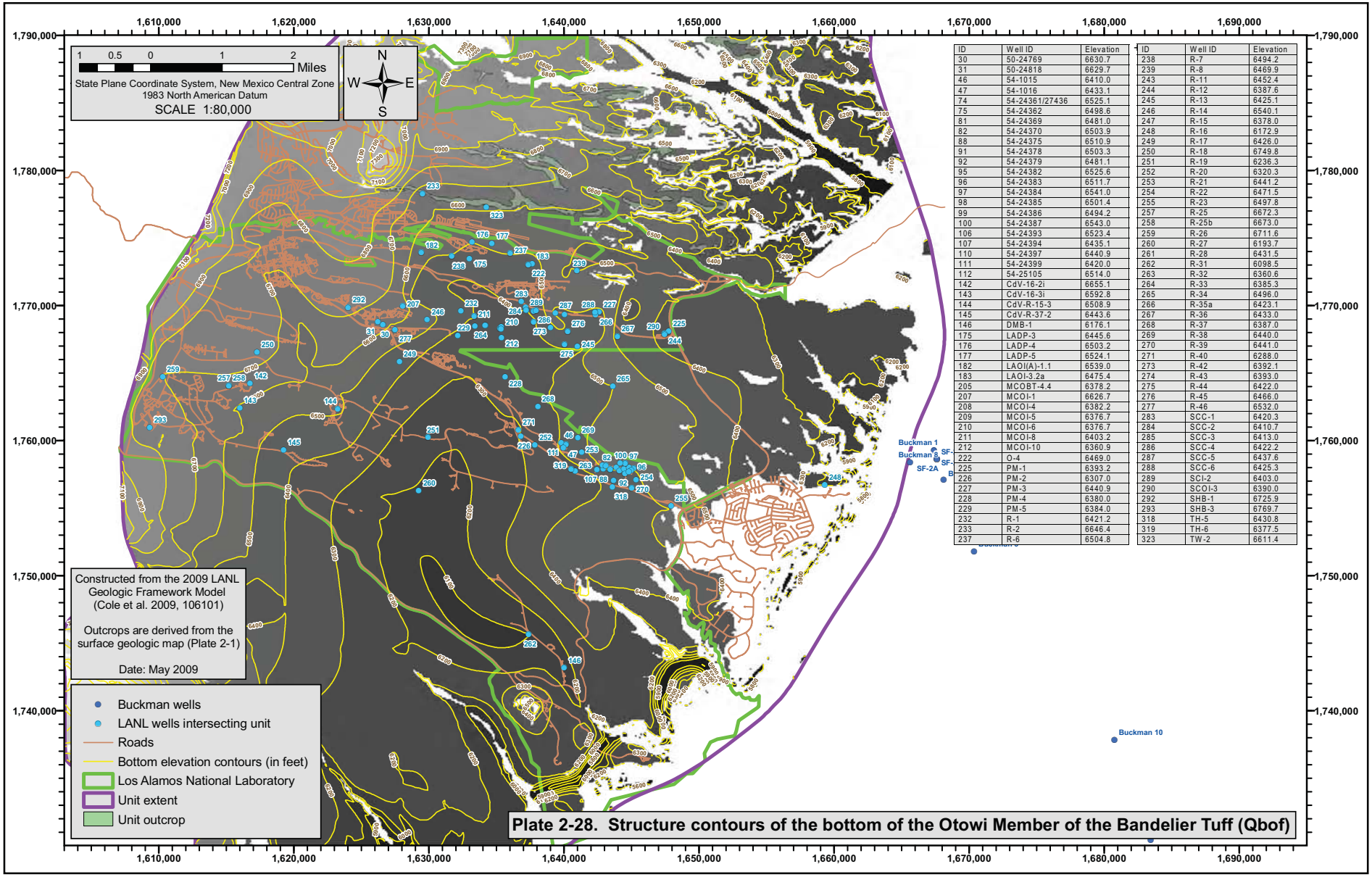
Plate 2-26. Structure contours of the top of the Otowi Member of the Bandelier Tuff (Qbof)



ID	Well ID	Thickness
30	50-24769	224.0
31	50-24818	226.6
46	54-1015	97.8
47	54-1016	57.9
74	54-24361/27436	7.0
75	54-24362	18.0
81	54-24369	47.5
82	54-24370	43.0
88	54-24375	15.0
91	54-24378	27.5
92	54-24379	75.5
95	54-24382	37.0
96	54-24383	37.5
97	54-24384	12.0
98	54-24385	54.0
99	54-24386	61.5
100	54-24387	12.5
106	54-24393	25.9
107	54-24394	96.0
110	54-24397	57.0
111	54-24399	81.0
112	54-25105	9.5
142	CdV-16-2i	92.0
143	CdV-16-3i	114.0
144	CdV-R-15-3	168.0
145	CdV-R-37-2	338.0
175	LADP-3	246.0
176	LADP-4	252.0
177	LADP-5	227.5
205	MCOBT-4.4	356.0
207	MCOI-1	235.5
208	MCOI-4	350.0
209	MCOI-5	323.0
210	MCOI-6	329.4
211	MCOI-8	333.7
212	MCOI-10	328.6
226	PM-2	234.0
228	PM-4	320.0

ID	Well ID	Thickness
229	PM-5	375.0
232	R-1	325.0
237	R-6	233.0
244	R-12	80.7
245	R-13	168.0
246	R-14	278.0
247	R-15	322.0
249	R-17	348.5
250	R-18	150.0
251	R-19	184.0
252	R-20	191.0
253	R-21	64.0
254	R-22	51.0
257	R-25	103.8
258	R-25b	103.0
259	R-26	65.0
260	R-27	188.0
263	R-32	103.0
264	R-33	378.0
265	R-34	38.0
268	R-37	238.0
269	R-38	75.0
270	R-39	62.0
271	R-40	258.0
274	R-43	225.0
275	R-44	202.0
277	R-46	230.0
284	SCC-2	208.0
285	SCC-3	210.0
286	SCC-4	182.0
287	SCC-5	186.0
289	SCI-2	216.0
292	SHB-1	143.0
293	SHB-3	414.0
225	PM-1	120.0
233	R-2	124.0
248	R-16	79.0
255	R-23	20.0

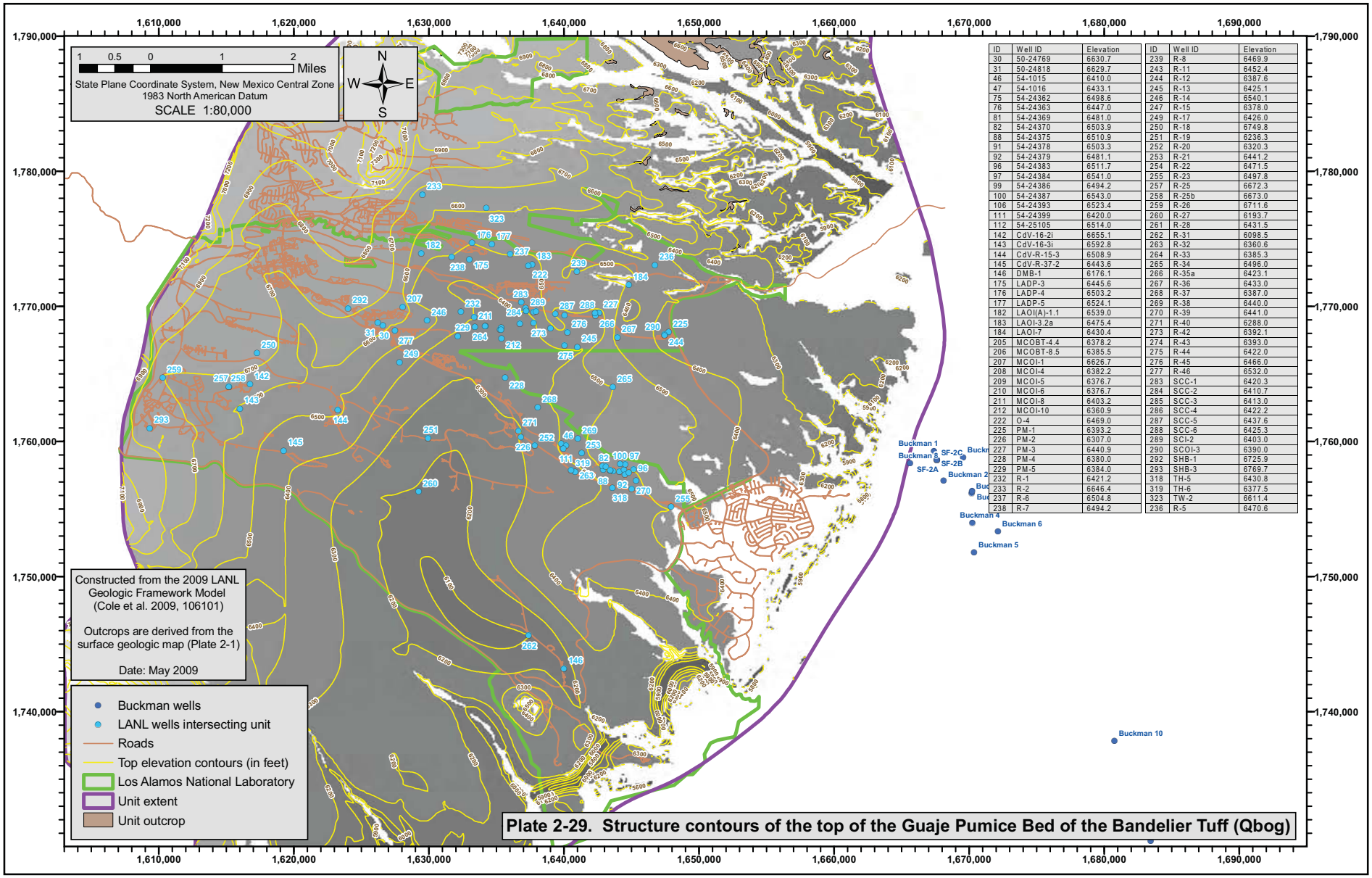
Plate 2-27. Thickness of the Otowi Member of the Bandelier Tuff (Qbof)



ID	Well ID	Elevation
30	50-24769	6630.7
31	50-24818	6629.7
46	54-1015	6410.0
47	54-1016	6433.1
74	54-24361/27436	6525.1
75	54-24362	6498.6
81	54-24369	6481.0
82	54-24370	6503.9
88	54-24375	6510.9
91	54-24378	6503.3
92	54-24379	6481.1
95	54-24382	6525.6
96	54-24383	6511.7
97	54-24384	6541.0
98	54-24385	6501.4
99	54-24386	6494.2
100	54-24387	6543.0
106	54-24393	6523.4
107	54-24394	6435.1
110	54-24397	6440.9
111	54-24399	6420.0
112	54-25105	6514.0
142	CdV-16-2i	6655.1
143	CdV-16-3i	6592.8
144	CdV-R-15-3	6508.9
145	CdV-R-37-2	6443.6
146	DMB-1	6176.1
175	LADP-3	6445.6
176	LADP-4	6503.2
177	LADP-5	6524.1
182	LAOI(A)-1.1	6539.0
183	LAOI-3.2a	6475.4
205	MCOBT-4.4	6378.2
207	MCOI-1	6626.7
208	MCOI-4	6382.2
209	MCOI-5	6376.7
210	MCOI-6	6376.7
211	MCOI-8	6403.2
212	MCOI-10	6360.9
222	O-4	6469.0
225	PM-1	6393.2
226	PM-2	6307.0
227	PM-3	6440.9
228	PM-4	6380.0
229	PM-5	6384.0
232	R-1	6421.2
233	R-2	6646.4
237	R-6	6504.8

ID	Well ID	Elevation
238	R-7	6494.2
239	R-8	6469.9
243	R-11	6452.4
244	R-12	6387.6
245	R-13	6425.1
246	R-14	6540.1
247	R-15	6378.0
248	R-16	6172.9
249	R-17	6426.0
250	R-18	6749.8
251	R-19	6236.3
252	R-20	6320.3
253	R-21	6441.2
254	R-22	6471.5
255	R-23	6497.8
257	R-25	6672.3
258	R-25b	6673.0
259	R-26	6711.6
260	R-27	6193.7
261	R-28	6431.5
262	R-31	6098.5
263	R-32	6360.6
264	R-33	6385.3
265	R-34	6496.0
266	R-35a	6423.1
267	R-36	6433.0
268	R-37	6387.0
269	R-38	6440.0
270	R-39	6441.0
271	R-40	6288.0
273	R-42	6392.1
274	R-43	6393.0
275	R-44	6422.0
276	R-45	6466.0
277	R-46	6532.0
283	SCC-1	6420.3
284	SCC-2	6410.7
285	SCC-3	6413.0
286	SCC-4	6422.2
287	SCC-5	6437.6
288	SCC-6	6425.3
289	SCI-2	6403.0
290	SCOI-3	6390.0
292	SHB-1	6725.9
293	SHB-3	6769.7
318	TH-5	6430.8
319	TH-6	6377.5
323	TW-2	6611.4

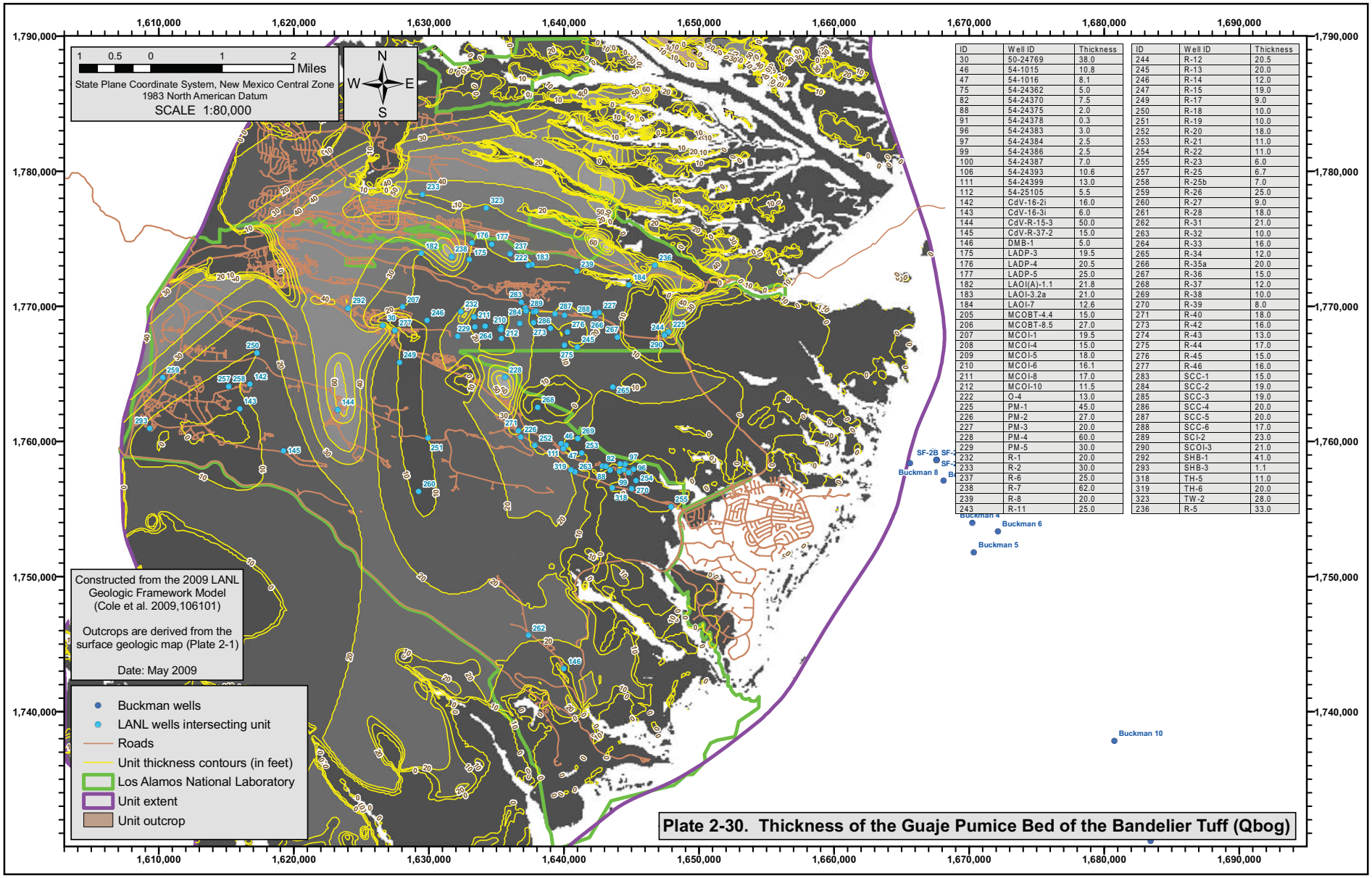
Plate 2-28. Structure contours of the bottom of the Otowi Member of the Bandelier Tuff (Qbof)



ID	Well ID	Elevation
30	50-24769	6630.7
31	50-24818	6629.7
46	54-1015	6410.0
47	54-1016	6433.1
75	54-24362	6498.6
76	54-24363	6447.0
81	54-24369	6481.0
82	54-24370	6503.9
88	54-24375	6510.9
91	54-24378	6503.3
92	54-24379	6481.1
96	54-24383	6511.7
97	54-24384	6541.0
99	54-24386	6494.2
100	54-24387	6543.0
106	54-24393	6523.4
111	54-24399	6420.0
112	54-25105	6514.0
142	CdV-16-2i	6655.1
143	CdV-16-3i	6592.8
144	CdV-R-15-3	6508.9
145	CdV-R-37-2	6443.6
146	DMB-1	6176.1
175	LADP-3	6445.6
176	LADP-4	6503.2
177	LADP-5	6524.1
182	LAOI(A)-1.1	6539.0
183	LAOI-3.2a	6475.4
184	LAOI-7	6430.4
205	MCOBT-4.4	6378.2
206	MCOBT-8.5	6385.5
207	MCOI-1	6626.7
208	MCOI-4	6382.2
209	MCOI-5	6376.7
210	MCOI-6	6376.7
211	MCOI-8	6403.2
212	MCOI-10	6360.9
222	O-4	6469.0
225	PM-1	6393.2
226	PM-2	6307.0
227	PM-3	6440.9
228	PM-4	6380.0
229	PM-5	6384.0
232	R-1	6421.2
233	R-2	6646.4
237	R-6	6504.8
238	R-7	6494.2

ID	Well ID	Elevation
239	R-8	6469.9
243	R-11	6452.4
244	R-12	6387.6
245	R-13	6425.1
246	R-14	6540.1
247	R-15	6378.0
249	R-17	6426.0
250	R-18	6749.8
251	R-19	6236.3
252	R-20	6320.3
253	R-21	6441.2
254	R-22	6471.5
255	R-23	6497.8
257	R-25	6672.3
258	R-25b	6673.0
259	R-26	6711.6
260	R-27	6193.7
261	R-28	6431.5
262	R-31	6098.5
263	R-32	6360.6
264	R-33	6385.3
265	R-34	6496.0
266	R-35a	6423.1
267	R-36	6433.0
268	R-37	6387.0
269	R-38	6440.0
270	R-39	6441.0
271	R-40	6288.0
273	R-42	6392.1
274	R-43	6393.0
275	R-44	6422.0
276	R-45	6466.0
277	R-46	6532.0
283	SCC-1	6420.3
284	SCC-2	6410.7
285	SCC-3	6413.0
286	SCC-4	6422.2
287	SCC-5	6437.6
288	SCC-6	6425.3
289	SCI-2	6403.0
290	SCOI-3	6390.0
292	SHB-1	6725.9
293	SHB-3	6769.7
318	TH-5	6430.8
319	TH-6	6377.5
323	TW-2	6611.4
236	R-5	6470.6

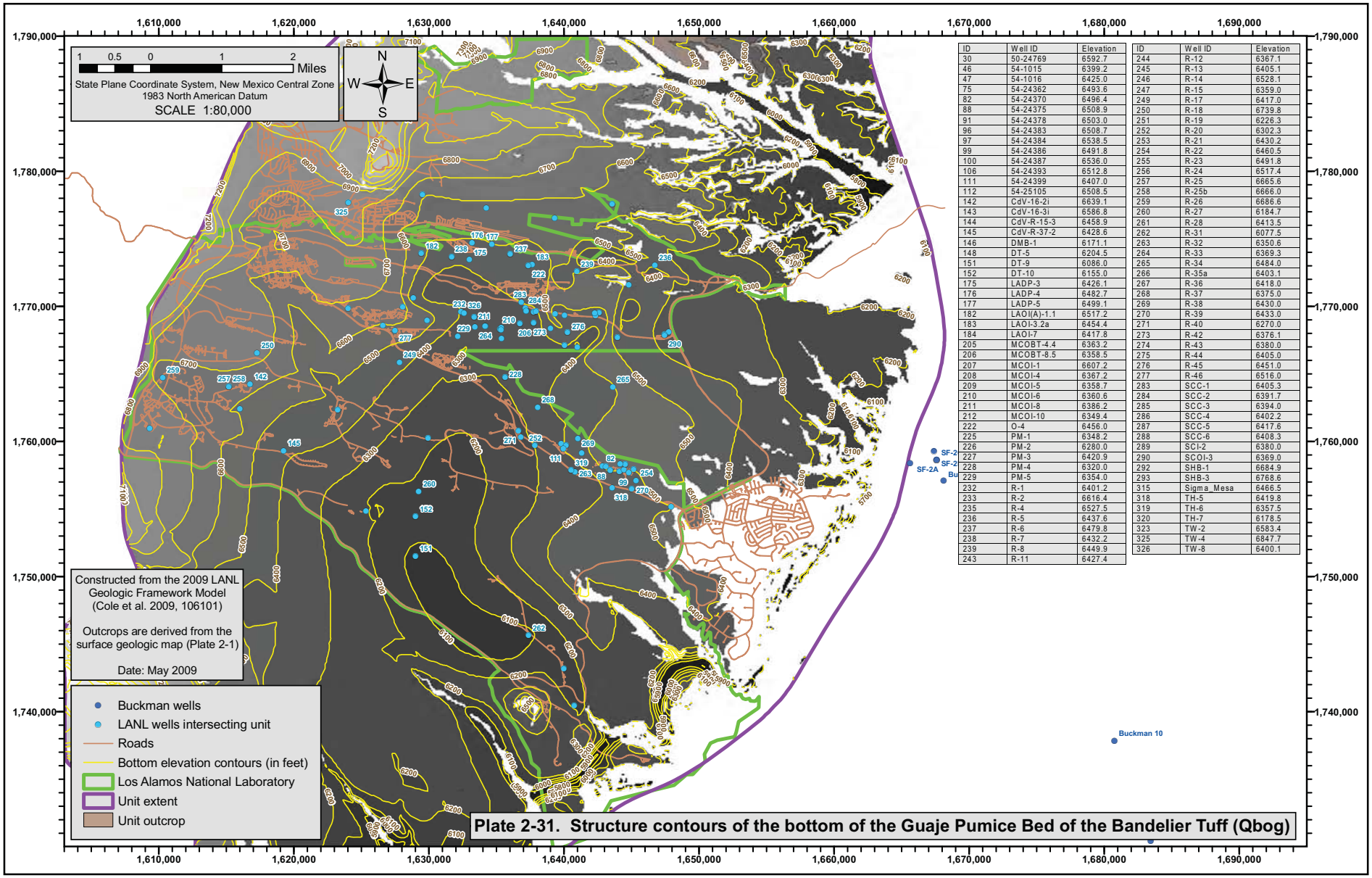
Plate 2-29. Structure contours of the top of the Guaje Pumice Bed of the Bandelier Tuff (Qbog)



ID	Well ID	Thickness
30	50-24769	38.0
46	54-1015	10.8
47	54-1016	8.1
75	54-24362	5.0
82	54-24370	7.5
88	54-24375	2.0
91	54-24378	0.3
96	54-24383	3.0
97	54-24384	2.5
99	54-24386	2.5
100	54-24387	7.0
106	54-24393	10.6
111	54-24399	13.0
112	54-25105	5.5
142	CdV-16-2i	16.0
143	CdV-16-3i	6.0
144	CdV-R-15-3	50.0
145	CdV-R-37-2	15.0
146	DMB-1	5.0
175	LADP-3	19.5
176	LADP-4	20.5
177	LADP-5	25.0
182	LAOI(A)-1.1	21.8
183	LAOI-3.2a	21.0
184	LAOI-7	12.6
205	MCOBT-4.4	15.0
206	MCOBT-8.5	27.0
207	MCOI-1	19.5
208	MCOI-4	15.0
209	MCOI-5	18.0
210	MCOI-6	16.1
211	MCOI-8	17.0
212	MCOI-10	11.5
222	O-4	13.0
225	PM-1	45.0
226	PM-2	27.0
227	PM-3	20.0
228	PM-4	60.0
229	PM-5	30.0
232	R-1	20.0
233	R-2	30.0
237	R-6	25.0
238	R-7	62.0
239	R-8	20.0
243	R-11	25.0

ID	Well ID	Thickness
244	R-12	20.5
245	R-13	20.0
246	R-14	12.0
247	R-15	19.0
249	R-17	9.0
250	R-18	10.0
251	R-19	10.0
252	R-20	18.0
253	R-21	11.0
254	R-22	11.0
255	R-23	6.0
257	R-25	6.7
258	R-25b	7.0
259	R-26	25.0
260	R-27	9.0
261	R-28	18.0
262	R-31	21.0
263	R-32	10.0
264	R-33	16.0
265	R-34	12.0
266	R-35a	20.0
267	R-36	15.0
268	R-37	12.0
269	R-38	10.0
270	R-39	8.0
271	R-40	18.0
273	R-42	16.0
274	R-43	13.0
275	R-44	17.0
276	R-45	15.0
277	R-46	16.0
283	SCC-1	15.0
284	SCC-2	19.0
285	SCC-3	19.0
286	SCC-4	20.0
287	SCC-5	20.0
288	SCC-6	17.0
289	SCI-2	23.0
290	SCOI-3	21.0
292	SHB-1	41.0
293	SHB-3	1.1
318	TH-5	11.0
319	TH-6	20.0
323	TW-2	28.0
236	R-5	33.0

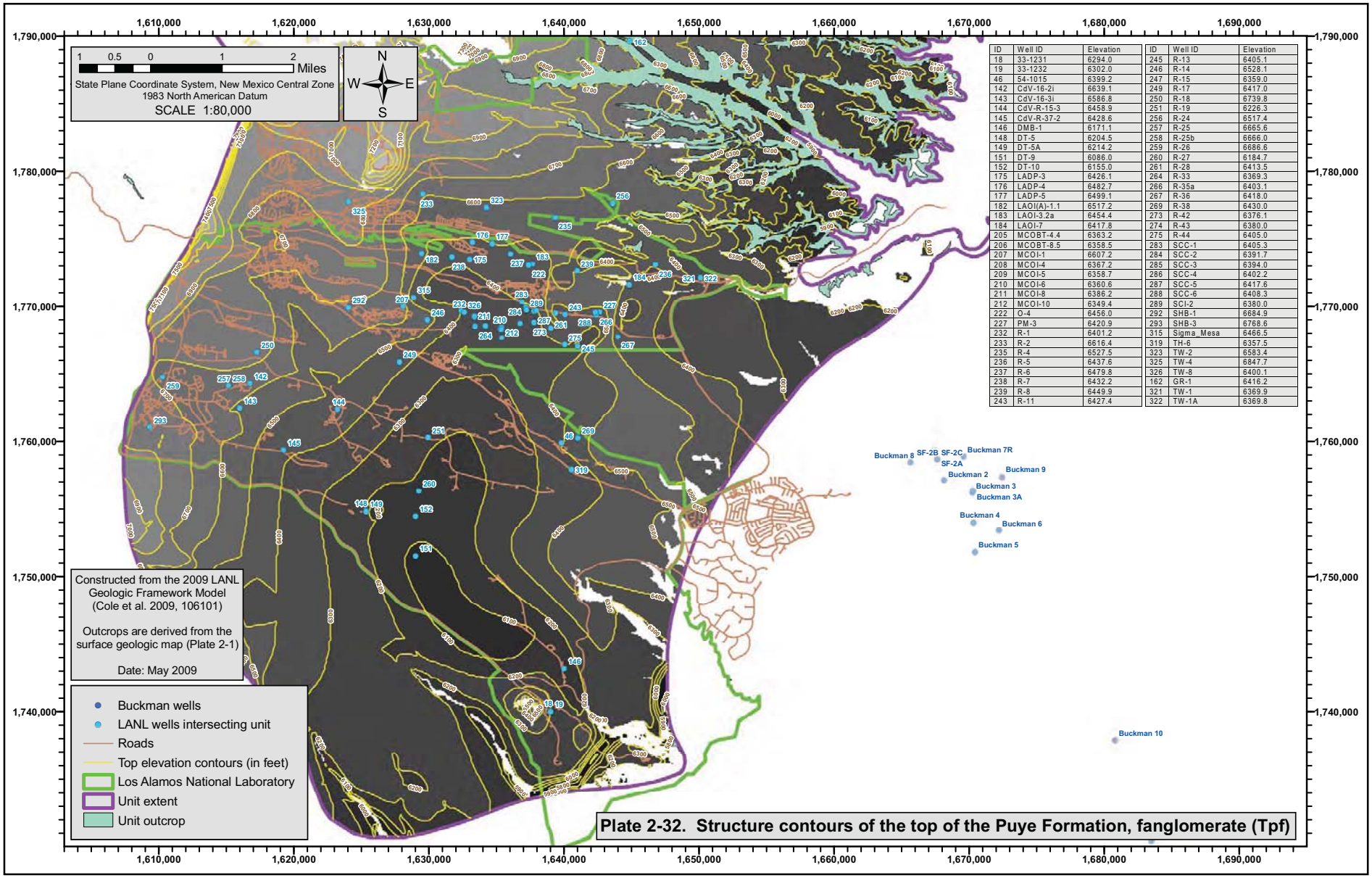
Plate 2-30. Thickness of the Guaje Pumice Bed of the Bandelier Tuff (Qbog)



ID	Well ID	Elevation
30	50-24769	6592.7
46	54-1015	6399.2
47	54-1016	6425.0
75	54-24362	6493.6
82	54-24370	6496.4
88	54-24375	6508.9
91	54-24378	6503.0
96	54-24383	6508.7
97	54-24384	6538.5
99	54-24386	6491.8
100	54-24387	6536.0
106	54-24393	6512.8
111	54-24399	6407.0
112	54-25105	6508.5
142	CdV-16-2i	6639.1
143	CdV-16-3i	6586.8
144	CdV-R-15-3	6458.9
145	CdV-R-37-2	6428.6
146	DMB-1	6171.1
148	DT-5	6204.5
151	DT-9	6086.0
152	DT-10	6155.0
175	LADP-3	6426.1
176	LADP-4	6482.7
177	LADP-5	6499.1
182	LAOI(A)-1.1	6517.2
183	LAOI-3.2a	6454.4
184	LAOI-7	6417.8
205	MCOBT-4.4	6363.2
206	MCOBT-8.5	6358.5
207	MCOI-1	6607.2
208	MCOI-4	6367.2
209	MCOI-5	6358.7
210	MCOI-6	6360.6
211	MCOI-8	6386.2
212	MCOI-10	6349.4
222	O-4	6456.0
225	PM-1	6348.2
226	PM-2	6280.0
227	PM-3	6420.9
228	PM-4	6320.0
229	PM-5	6354.0
232	R-1	6401.2
233	R-2	6616.4
235	R-4	6527.5
236	R-5	6437.6
237	R-6	6479.8
238	R-7	6432.2
239	R-8	6449.9
243	R-11	6427.4

ID	Well ID	Elevation
244	R-12	6367.1
245	R-13	6405.1
246	R-14	6528.1
247	R-15	6359.0
249	R-17	6417.0
250	R-18	6739.8
251	R-19	6226.3
252	R-20	6302.3
253	R-21	6430.2
254	R-22	6460.5
255	R-23	6491.8
256	R-24	6517.4
257	R-25	6665.6
258	R-25b	6666.0
259	R-26	6686.6
260	R-27	6184.7
261	R-28	6413.5
262	R-31	6077.5
263	R-32	6350.6
264	R-33	6369.3
265	R-34	6484.0
266	R-35a	6403.1
267	R-36	6418.0
268	R-37	6375.0
269	R-38	6430.0
270	R-39	6433.0
271	R-40	6270.0
273	R-42	6376.1
274	R-43	6380.0
275	R-44	6405.0
276	R-45	6451.0
277	R-46	6516.0
283	SCC-1	6405.3
284	SCC-2	6391.7
285	SCC-3	6394.0
286	SCC-4	6402.2
287	SCC-5	6417.6
288	SCC-6	6408.3
289	SCI-2	6380.0
290	SCOI-3	6369.0
292	SHB-1	6684.9
293	SHB-3	6768.6
315	Sigma_Mesa	6466.5
318	TH-5	6419.8
319	TH-6	6357.5
320	TH-7	6178.5
323	TW-2	6583.4
325	TW-4	6847.7
326	TW-8	6400.1

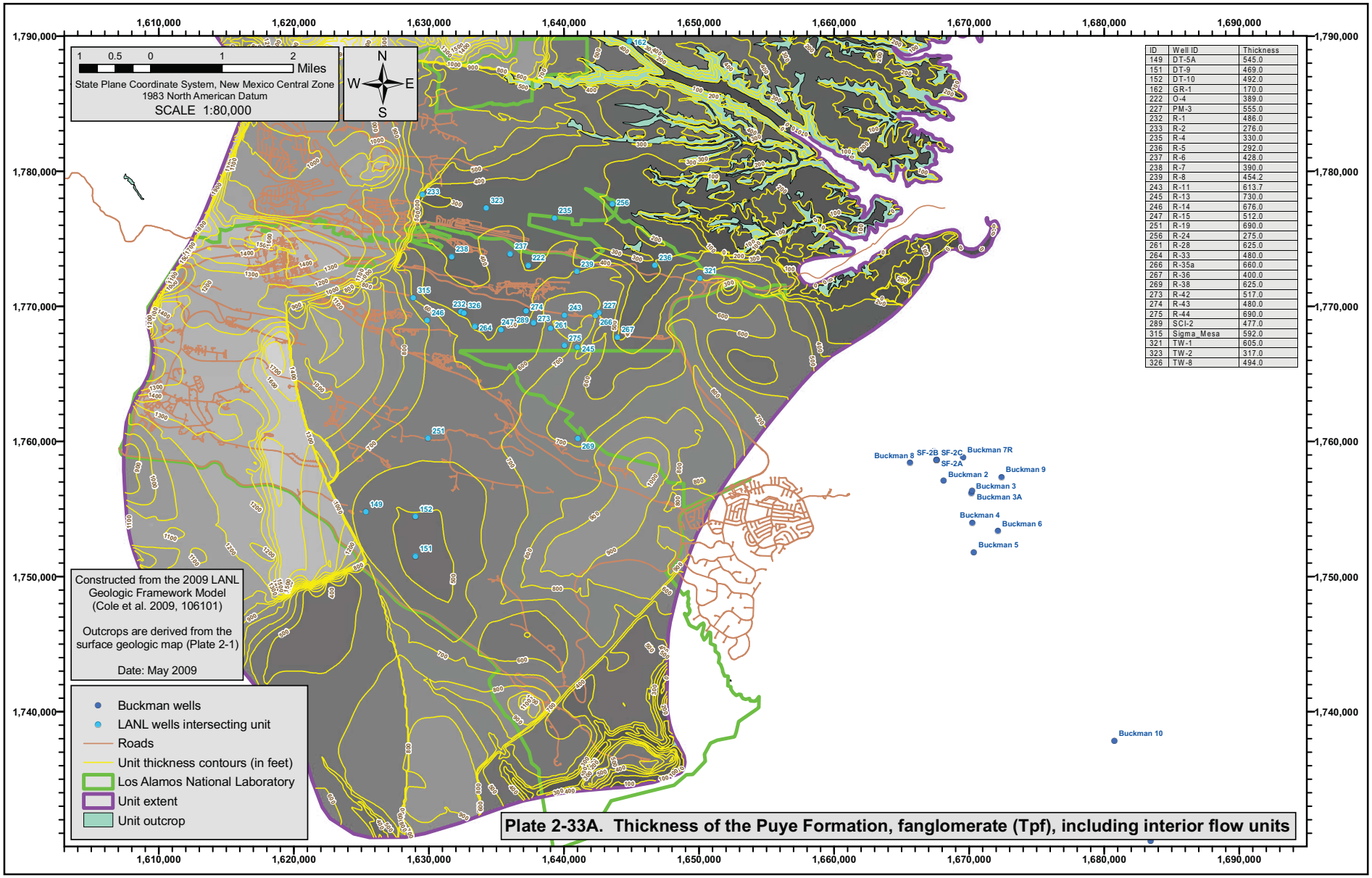
Plate 2-31. Structure contours of the bottom of the Guaje Pumice Bed of the Bandelier Tuff (Qbog)



ID	Well ID	Elevation
18	33-1231	6294.0
19	33-1232	6302.0
46	54-1015	6399.2
142	CdV-16-2i	6639.1
143	CdV-16-3i	6586.8
144	CdV-R-15-3	6458.9
145	CdV-R-37-2	6428.6
146	DMB-1	6171.1
148	DT-5	6204.5
149	DT-5A	6214.2
151	DT-9	6086.0
152	DT-10	6155.0
175	LADP-3	6426.1
176	LADP-4	6482.7
177	LADP-5	6499.1
182	LAOI(A)-1.1	6517.2
183	LAOI-3.2a	6454.4
184	LAOI-7	6417.8
205	MCOBT-4.4	6363.2
206	MCOBT-8.5	6358.5
207	MCOI-1	6607.2
208	MCOI-4	6367.2
209	MCOI-5	6358.7
210	MCOI-6	6360.6
211	MCOI-8	6386.2
212	MCOI-10	6349.4
222	O-4	6456.0
227	PM-3	6420.9
232	R-1	6401.2
233	R-2	6616.4
235	R-4	6527.5
236	R-5	6437.6
237	R-6	6479.8
238	R-7	6432.2
239	R-8	6449.9
243	R-11	6427.4

ID	Well ID	Elevation
245	R-13	6405.1
246	R-14	6528.1
247	R-15	6359.0
249	R-17	6417.0
250	R-18	6739.8
251	R-19	6226.3
256	R-24	6517.4
257	R-25	6665.6
258	R-25b	6666.0
259	R-26	6686.6
260	R-27	6184.7
261	R-28	6413.5
264	R-33	6369.3
266	R-35a	6403.1
267	R-36	6418.0
269	R-38	6430.0
273	R-42	6376.1
274	R-43	6380.0
275	R-44	6405.0
283	SCC-1	6405.3
284	SCC-2	6391.7
285	SCC-3	6394.0
286	SCC-4	6402.2
287	SCC-5	6417.6
288	SCC-6	6408.3
289	SCI-2	6380.0
292	SHB-1	6684.9
293	SHB-3	6768.6
315	Sigma_Mesa	6466.5
319	TH-6	6357.5
323	TW-2	6583.4
325	TW-4	6847.7
326	TW-8	6400.1
162	GR-1	6416.2
321	TW-1	6369.9
322	TW-1A	6369.8

Plate 2-32. Structure contours of the top of the Puye Formation, fanglomerate (Tpf)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1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
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ID Well ID Thickness
149 DT-5A 545.0
151 DT-9 469.0
152 DT-10 492.0
162 GR-1 170.0
222 O-4 389.0
227 PM-3 555.0
232 R-1 486.0
233 R-2 276.0
235 R-4 330.0
236 R-5 292.0
237 R-6 428.0
238 R-7 390.0
239 R-8 454.2
243 R-11 613.7
245 R-13 730.0
246 R-14 676.0
247 R-15 512.0
251 R-19 690.0
256 R-24 275.0
261 R-28 625.0
264 R-33 480.0
266 R-35a 660.0
267 R-36 400.0
269 R-38 625.0
273 R-42 517.0
274 R-43 480.0
275 R-44 690.0
289 SCI-2 477.0
315 Sigma Mesa 592.0
321 TW-1 605.0
323 TW-2 317.0
326 TW-8 494.0
Buckman 8
SF-2B
SF-2C
Buckman 7R
SF-2A
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-33A. Thickness of the Puye Formation, fanglomerate (Tpf), including interior flow units

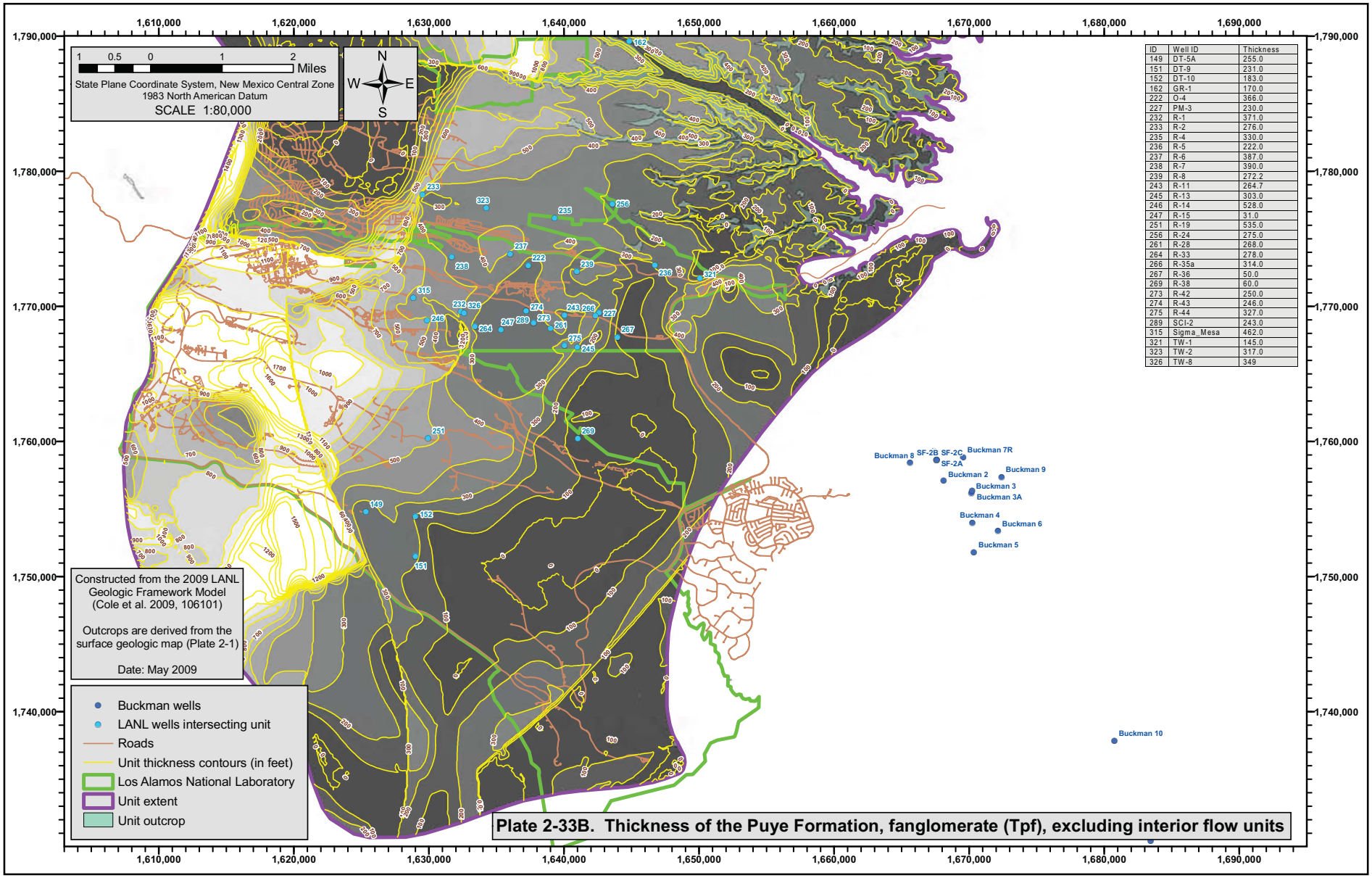
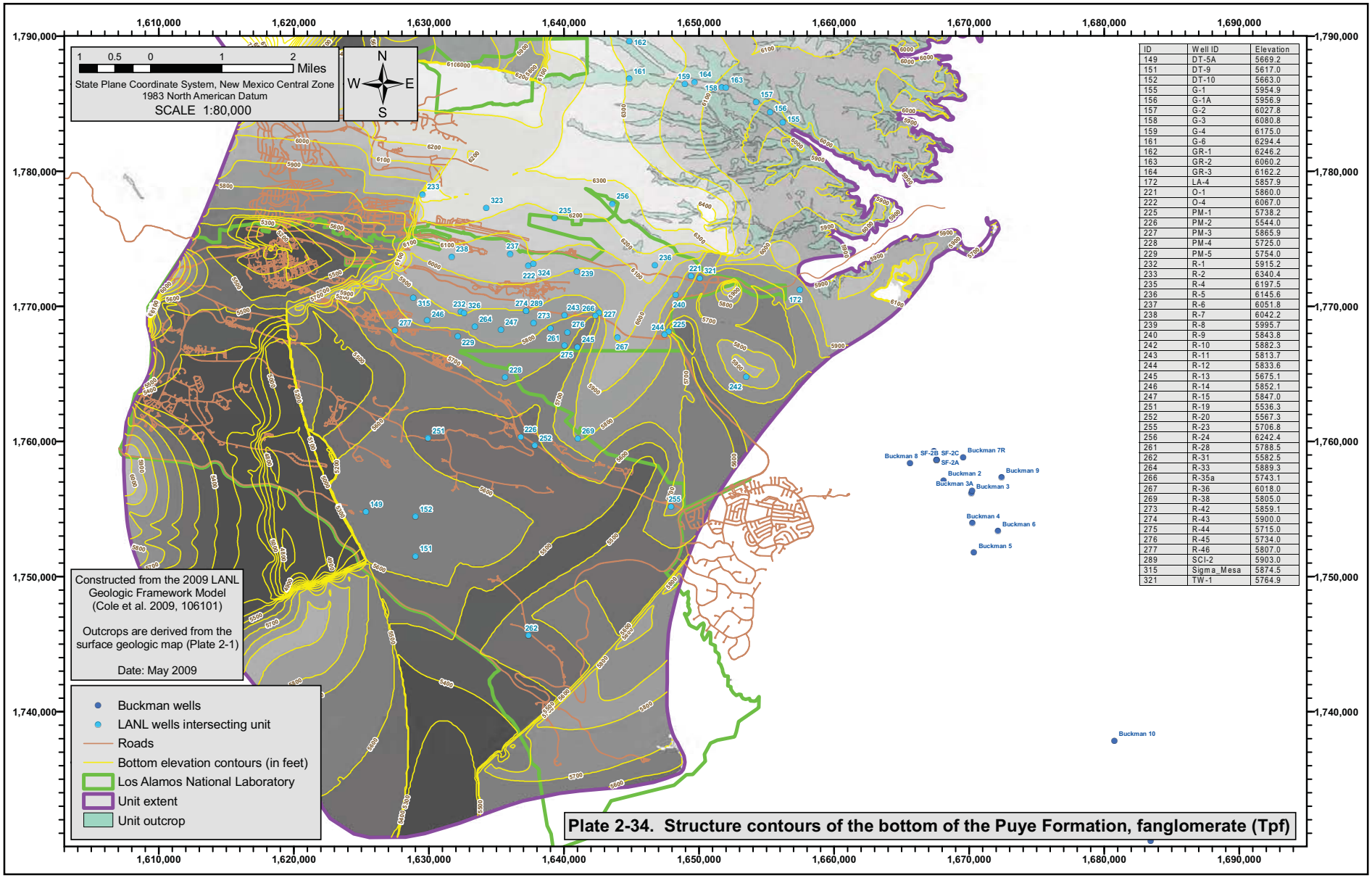
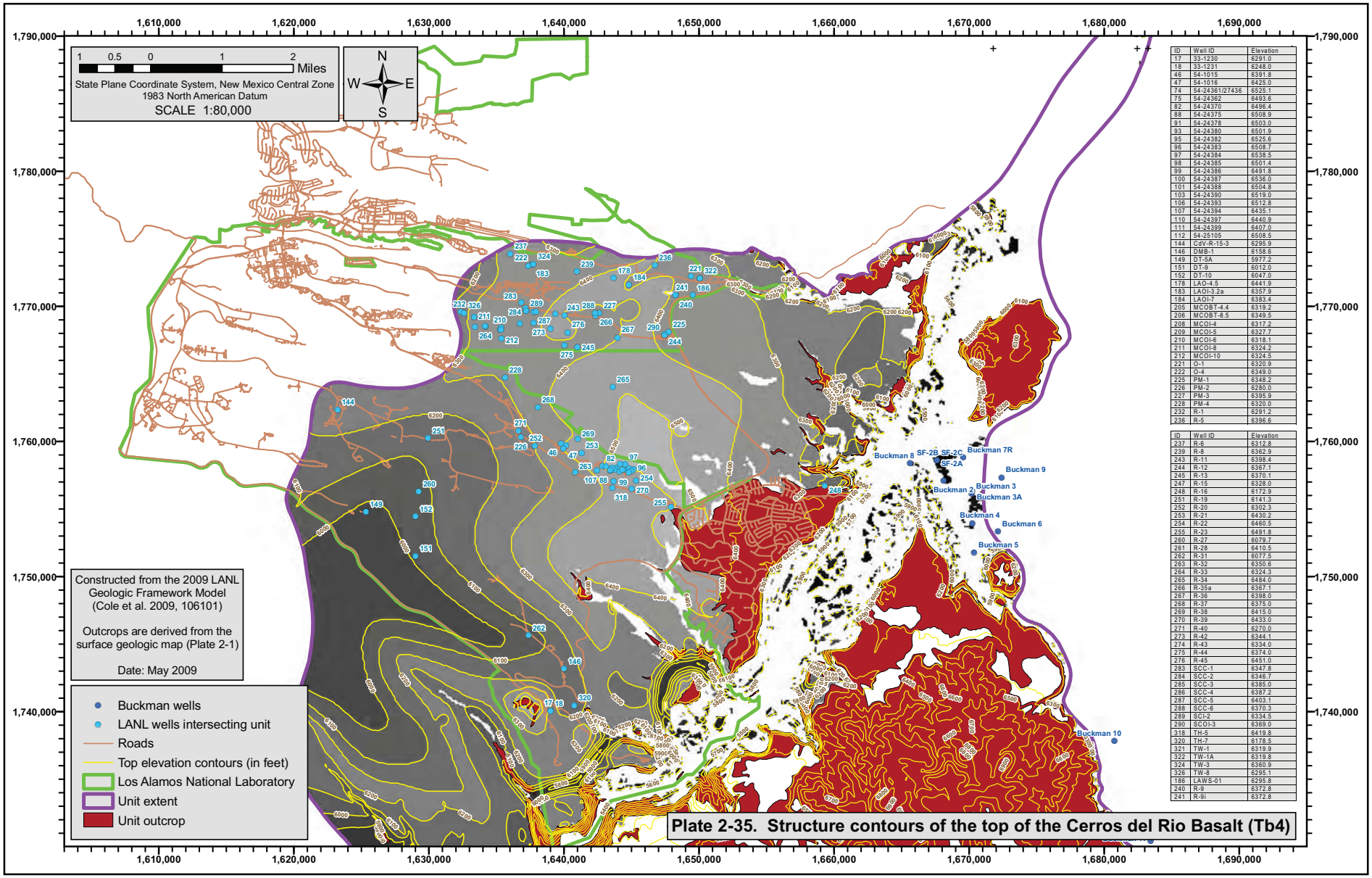


Plate 2-33B. Thickness of the Puye Formation, fanglomerate (Tpf), excluding interior flow units



ID	Well ID	Elevation
149	DT-5A	5669.2
151	DT-9	5617.0
152	DT-10	5663.0
155	G-1	5954.9
156	G-1A	5956.9
157	G-2	6027.8
158	G-3	6080.8
159	G-4	6175.0
161	G-6	6294.4
162	GR-1	6246.2
163	GR-2	6060.2
164	GR-3	6162.2
172	LA-4	5857.9
221	O-1	5860.0
222	O-4	6067.0
225	PM-1	5738.2
226	PM-2	5544.0
227	PM-3	5865.9
228	PM-4	5725.0
229	PM-5	5754.0
232	R-1	5915.2
233	R-2	6340.4
235	R-4	6197.5
236	R-5	6145.6
237	R-6	6051.8
238	R-7	6042.2
239	R-8	5995.7
240	R-9	5843.8
242	R-10	5882.3
243	R-11	5813.7
244	R-12	5833.6
245	R-13	5675.1
246	R-14	5852.1
247	R-15	5847.0
251	R-19	5536.3
252	R-20	5567.3
255	R-23	5706.8
256	R-24	6242.4
261	R-28	5788.5
262	R-31	5582.5
264	R-33	5889.3
266	R-35a	5743.1
267	R-36	6018.0
269	R-38	5805.0
273	R-42	5859.1
274	R-43	5900.0
275	R-44	5715.0
276	R-45	5734.0
277	R-46	5807.0
289	SCI-2	5903.0
315	Sigma_Mesa	5874.5
321	TW-1	5764.9

Plate 2-34. Structure contours of the bottom of the Puye Formation, fanglomerate (Tpf)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State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
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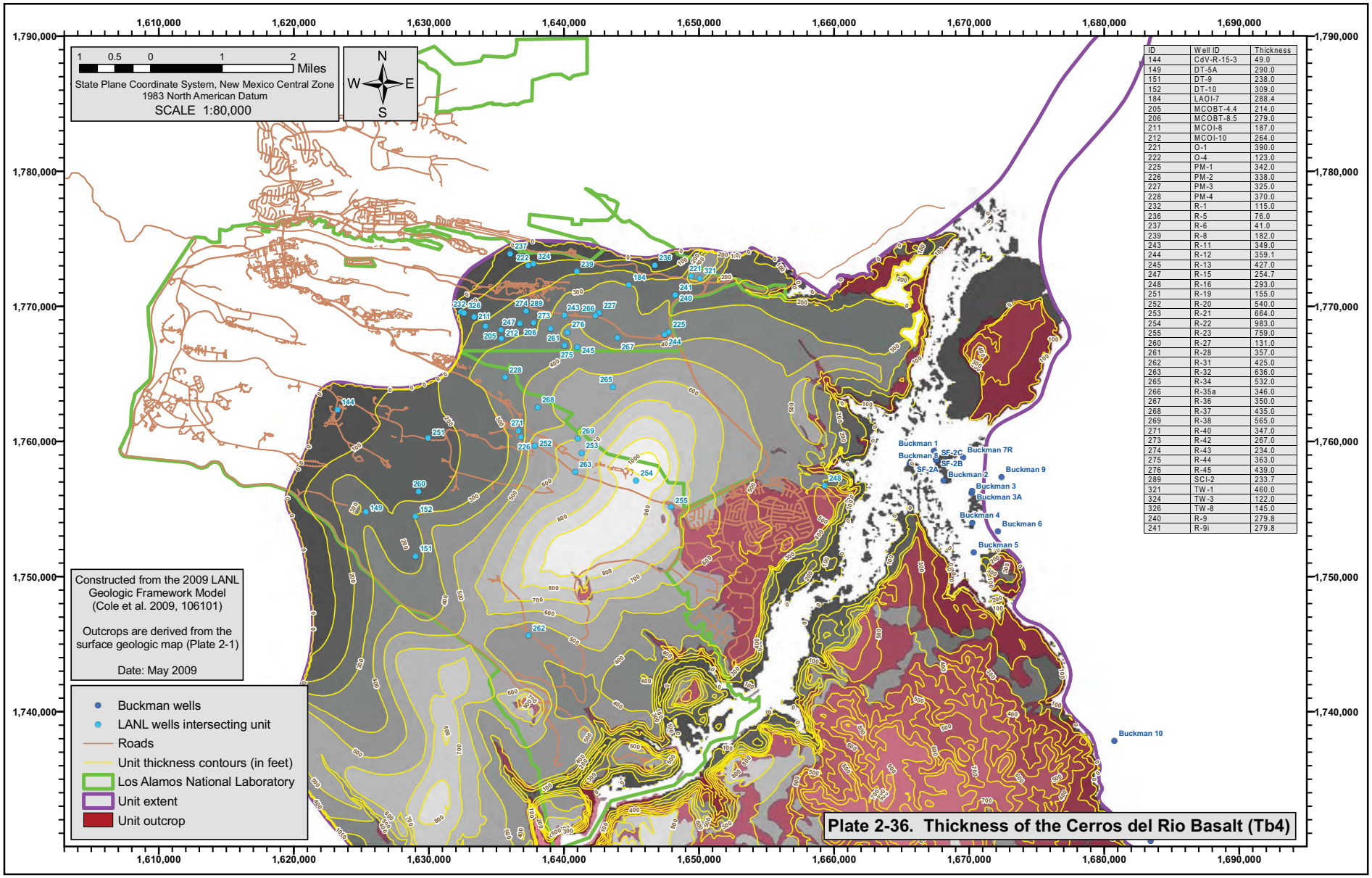
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Top elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Buckman 8
SF-2B
SF-2C
SF-2A
Buckman 7R
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
ID Well ID Elevation
17 33-1230 6291.0
18 33-1231 6248.0
46 54-1015 6391.8
47 54-1016 6425.0
74 54-24361/27436 6525.1
75 54-24362 6493.6
82 54-24370 6496.4
88 54-24375 6508.9
91 54-24378 6503.0
93 54-24380 6501.9
95 54-24382 6525.6
96 54-24383 6508.7
97 54-24384 6538.5
98 54-24385 6501.4
99 54-24386 6491.8
100 54-24387 6536.0
101 54-24388 6504.8
103 54-24390 6519.0
106 54-24393 6512.8
107 54-24394 6435.1
110 54-24397 6440.9
111 54-24399 6407.0
112 54-25105 6508.5
144 CdV-R-15-3 6295.9
146 DMB-1 6158.6
149 DT-5A 5977.2
151 DT-9 6012.0
152 DT-10 6047.0
178 LAO-4.5 6441.9
183 LAOI-3.2a 6357.9
184 LAOI-7 6383.4
205 MCOBT-4.4 6319.2
206 MCOBT-8.5 6349.5
208 MCOI-4 6317.2
209 MCOI-5 6327.7
210 MCOI-6 6318.1
211 MCOI-8 6324.2
212 MCOI-10 6324.5
221 O-1 6320.9
222 O-4 6349.0
225 PM-1 6348.2
226 PM-2 6280.0
227 PM-3 6395.9
228 PM-4 6320.0
232 R-1 6291.2
236 R-5 6396.6
ID Well ID Elevation
237 R-6 6312.8
239 R-8 6362.9
243 R-11 6398.4
244 R-12 6367.1
245 R-13 6370.1
247 R-15 6328.0
248 R-16 6172.9
251 R-19 6141.3
252 R-20 6302.3
253 R-21 6430.2
254 R-22 6460.5
255 R-23 6491.8
260 R-27 6079.7
261 R-28 6410.5
262 R-31 6077.5
263 R-32 6350.6
264 R-33 6324.3
265 R-34 6484.0
266 R-35a 6367.1
267 R-36 6398.0
268 R-37 6375.0
269 R-38 6415.0
270 R-39 6433.0
271 R-40 6270.0
273 R-42 6344.1
274 R-43 6334.0
275 R-44 6374.0
276 R-45 6451.0
283 SCC-1 6347.8
284 SCC-2 6346.7
285 SCC-3 6385.0
286 SCC-4 6387.2
287 SCC-5 6403.1
288 SCC-6 6370.3
289 SCI-2 6334.5
290 SCOI-3 6369.0
318 TH-5 6419.8
320 TH-7 6178.5
321 TW-1 6319.9
322 TW-1A 6319.8
324 TW-3 6360.9
326 TW-8 6295.1
186 LAWS-01 6295.8
240 R-9 6372.8
241 R-9i 6372.8
Plate 2-35. Structure contours of the top of the Cerros del Rio Basalt (Tb4)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State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
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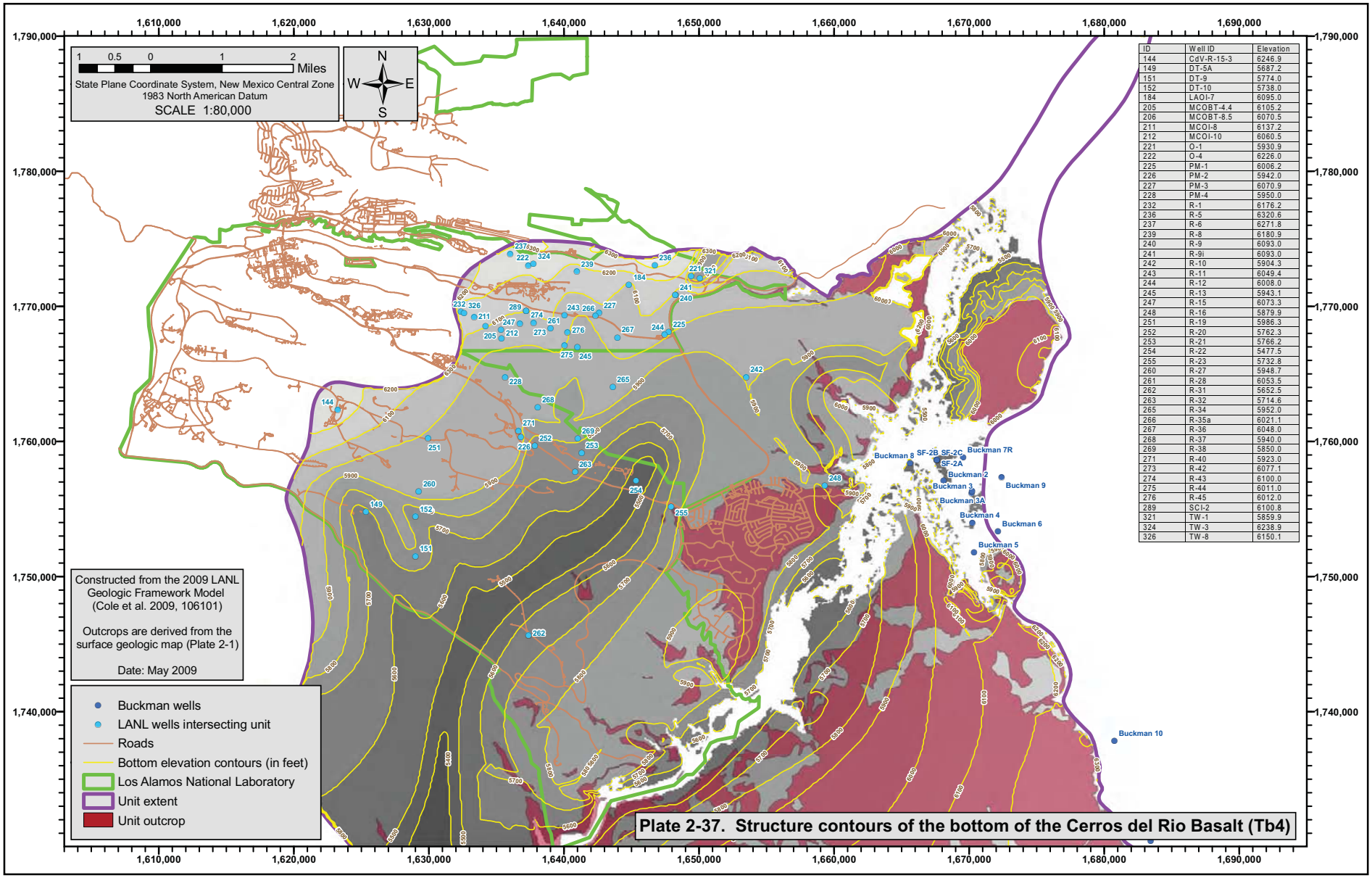
ID | Well ID | Thickness
144 | CdV-R-15-3 | 49.0
149 | DT-5A | 290.0
151 | DT-9 | 238.0
152 | DT-10 | 309.0
184 | LAOI-7 | 288.4
205 | MCOBT-4.4 | 214.0
206 | MCOBT-8.5 | 279.0
211 | MCOI-8 | 187.0
212 | MCOI-10 | 264.0
221 | O-1 | 390.0
222 | O-4 | 123.0
225 | PM-1 | 342.0
226 | PM-2 | 338.0
227 | PM-3 | 325.0
228 | PM-4 | 370.0
232 | R-1 | 115.0
236 | R-5 | 76.0
237 | R-6 | 41.0
239 | R-8 | 182.0
243 | R-11 | 349.0
244 | R-12 | 359.1
245 | R-13 | 427.0
247 | R-15 | 254.7
248 | R-16 | 293.0
251 | R-19 | 155.0
252 | R-20 | 540.0
253 | R-21 | 664.0
254 | R-22 | 983.0
255 | R-23 | 759.0
260 | R-27 | 131.0
261 | R-28 | 357.0
262 | R-31 | 425.0
263 | R-32 | 636.0
265 | R-34 | 532.0
266 | R-35a | 346.0
267 | R-36 | 350.0
268 | R-37 | 435.0
269 | R-38 | 565.0
271 | R-40 | 347.0
273 | R-42 | 267.0
274 | R-43 | 234.0
275 | R-44 | 363.0
276 | R-45 | 439.0
289 | SCI-2 | 233.7
321 | TW-1 | 460.0
324 | TW-3 | 122.0
326 | TW-8 | 145.0
240 | R-9 | 279.8
241 | R-9i | 279.8
Buckman 1
Buckman 8
SF-2C
Buckman 7R
SF-2B
SF-2A
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-36. Thickness of the Cerros del Rio Basalt (Tb4)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1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Elevation
144 | CdV-R-15-3 | 6246.9
149 | DT-5A | 5687.2
151 | DT-9 | 5774.0
152 | DT-10 | 5738.0
184 | LAOI-7 | 6095.0
205 | MCOBT-4.4 | 6105.2
206 | MCOBT-8.5 | 6070.5
211 | MCOI-8 | 6137.2
212 | MCOI-10 | 6060.5
221 | O-1 | 5930.9
222 | O-4 | 6226.0
225 | PM-1 | 6006.2
226 | PM-2 | 5942.0
227 | PM-3 | 6070.9
228 | PM-4 | 5950.0
232 | R-1 | 6176.2
236 | R-5 | 6320.6
237 | R-6 | 6271.8
239 | R-8 | 6180.9
240 | R-9 | 6093.0
241 | R-9i | 6093.0
242 | R-10 | 5904.3
243 | R-11 | 6049.4
244 | R-12 | 6008.0
245 | R-13 | 5943.1
247 | R-15 | 6073.3
248 | R-16 | 5879.9
251 | R-19 | 5986.3
252 | R-20 | 5762.3
253 | R-21 | 5766.2
254 | R-22 | 5477.5
255 | R-23 | 5732.8
260 | R-27 | 5948.7
261 | R-28 | 6053.5
262 | R-31 | 5652.5
263 | R-32 | 5714.6
265 | R-34 | 5952.0
266 | R-35a | 6021.1
267 | R-36 | 6048.0
268 | R-37 | 5940.0
269 | R-38 | 5850.0
271 | R-40 | 5923.0
273 | R-42 | 6077.1
274 | R-43 | 6100.0
275 | R-44 | 6011.0
276 | R-45 | 6012.0
289 | SCI-2 | 6100.8
321 | TW-1 | 5859.9
324 | TW-3 | 6238.9
326 | TW-8 | 6150.1
Buckman 8
SF-2B
SF-2C
Buckman 7R
SF-2A
Buckman 2
Buckman 3
Buckman 9
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Bottom elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-37. Structure contours of the bottom of the Cerros del Rio Basalt (Tb4)

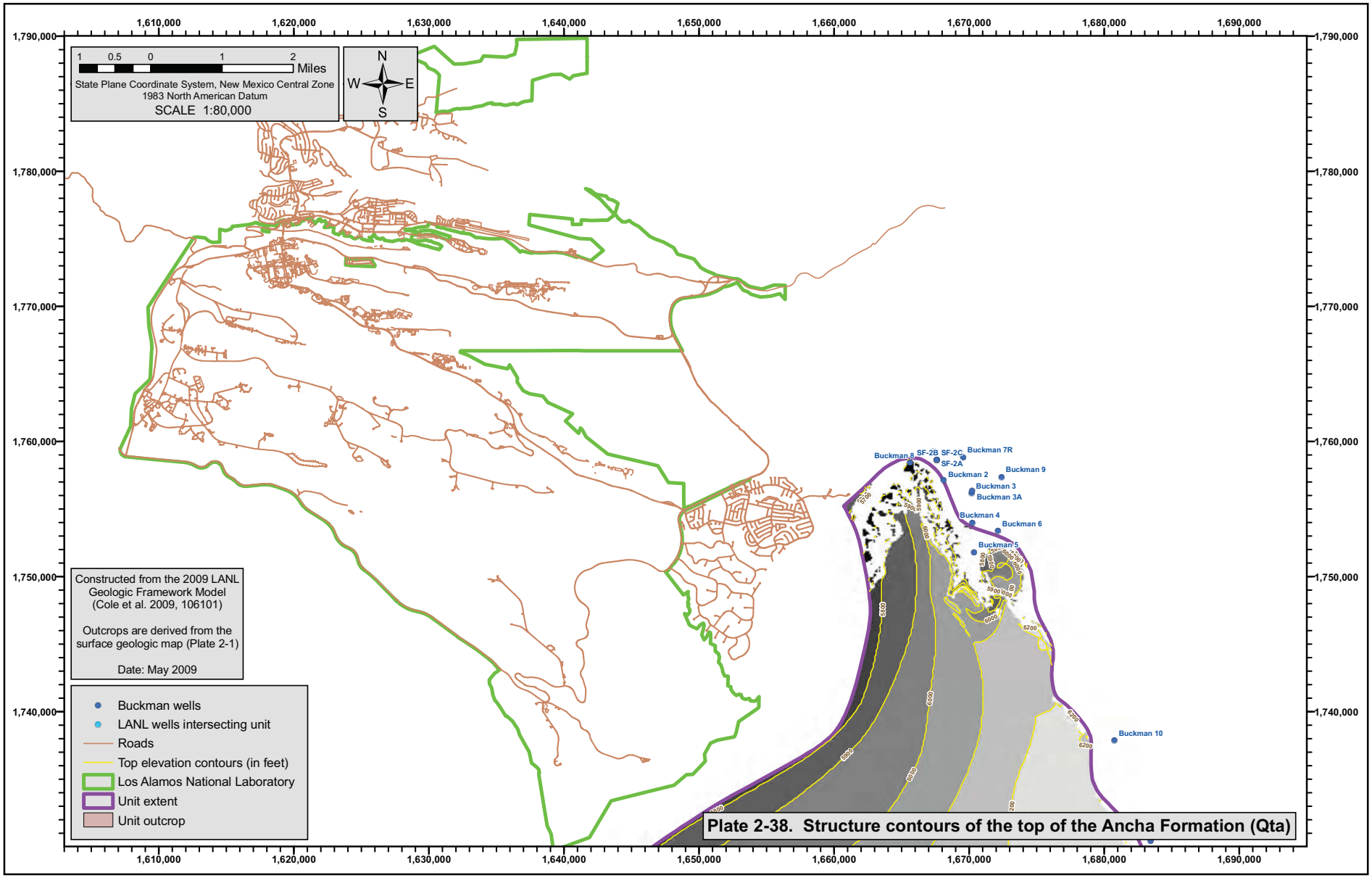
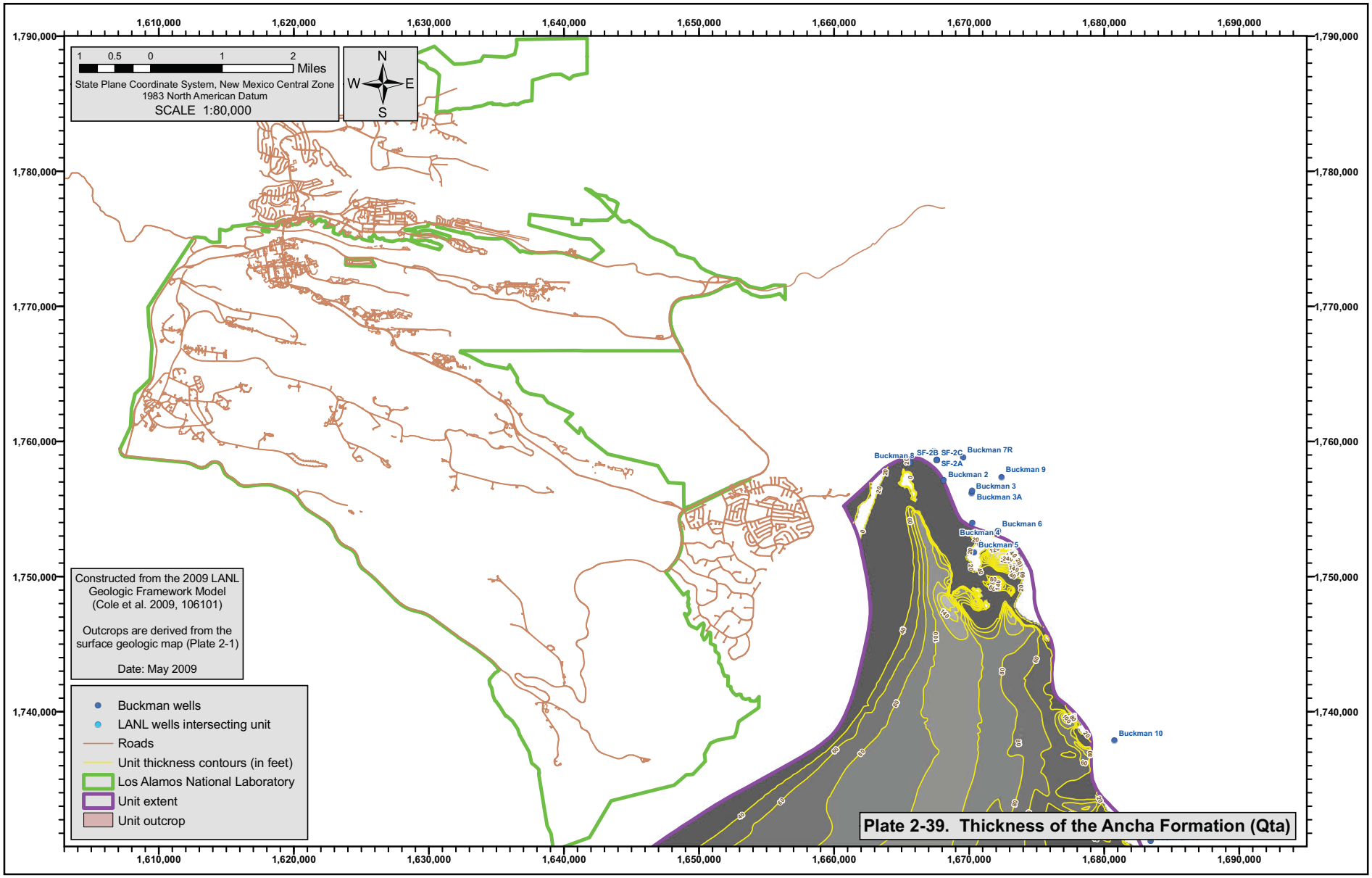


Plate 2-38. Structure contours of the top of the Ancha Formation (Qta)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1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
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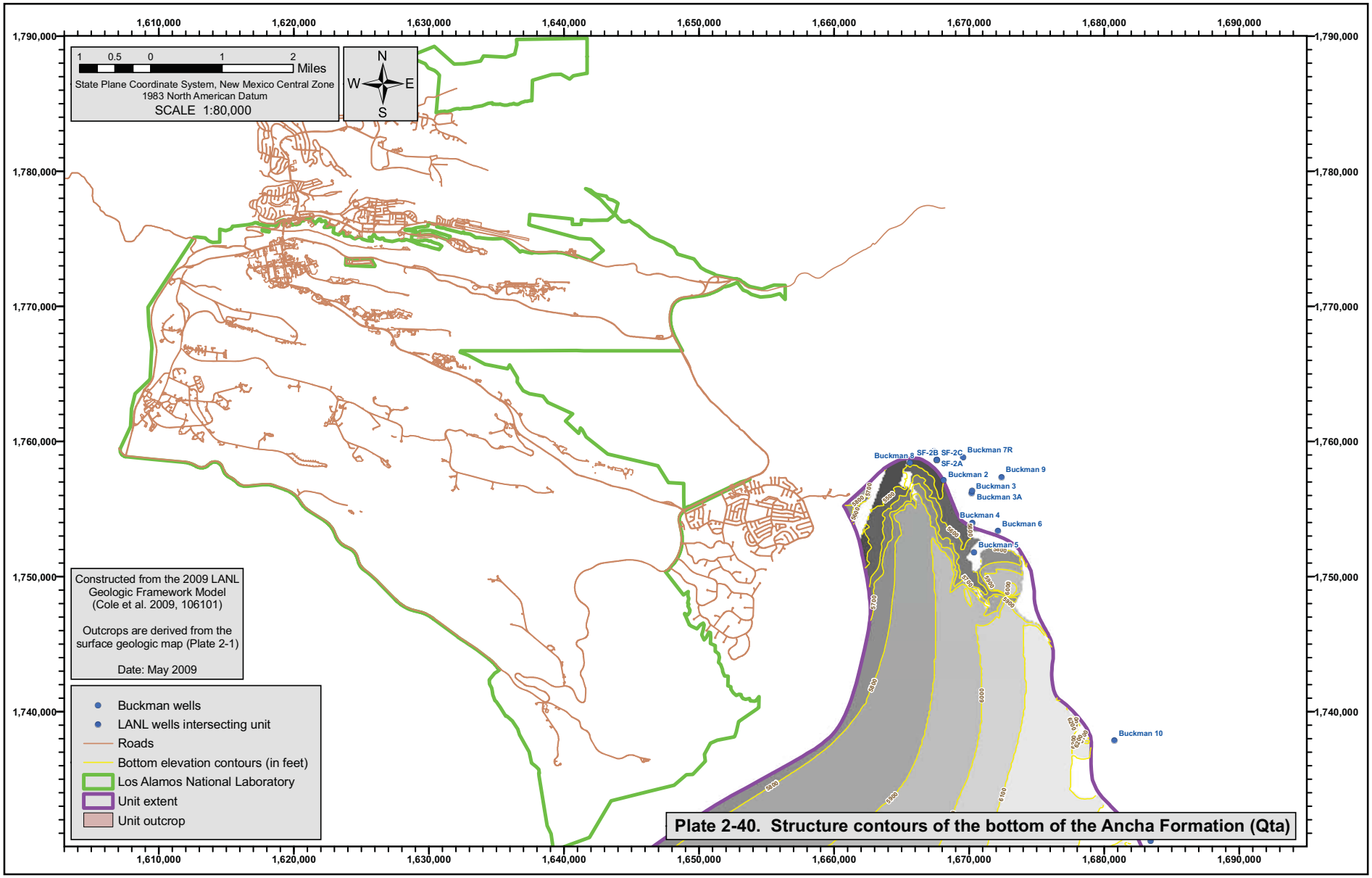
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Buckman 8
SF-2B
SF-2C
SF-2A
Buckman 7R
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 6
Buckman 4
Buckman 5
Buckman 10
Plate 2-39. Thickness of the Ancha Formation (Qta)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State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
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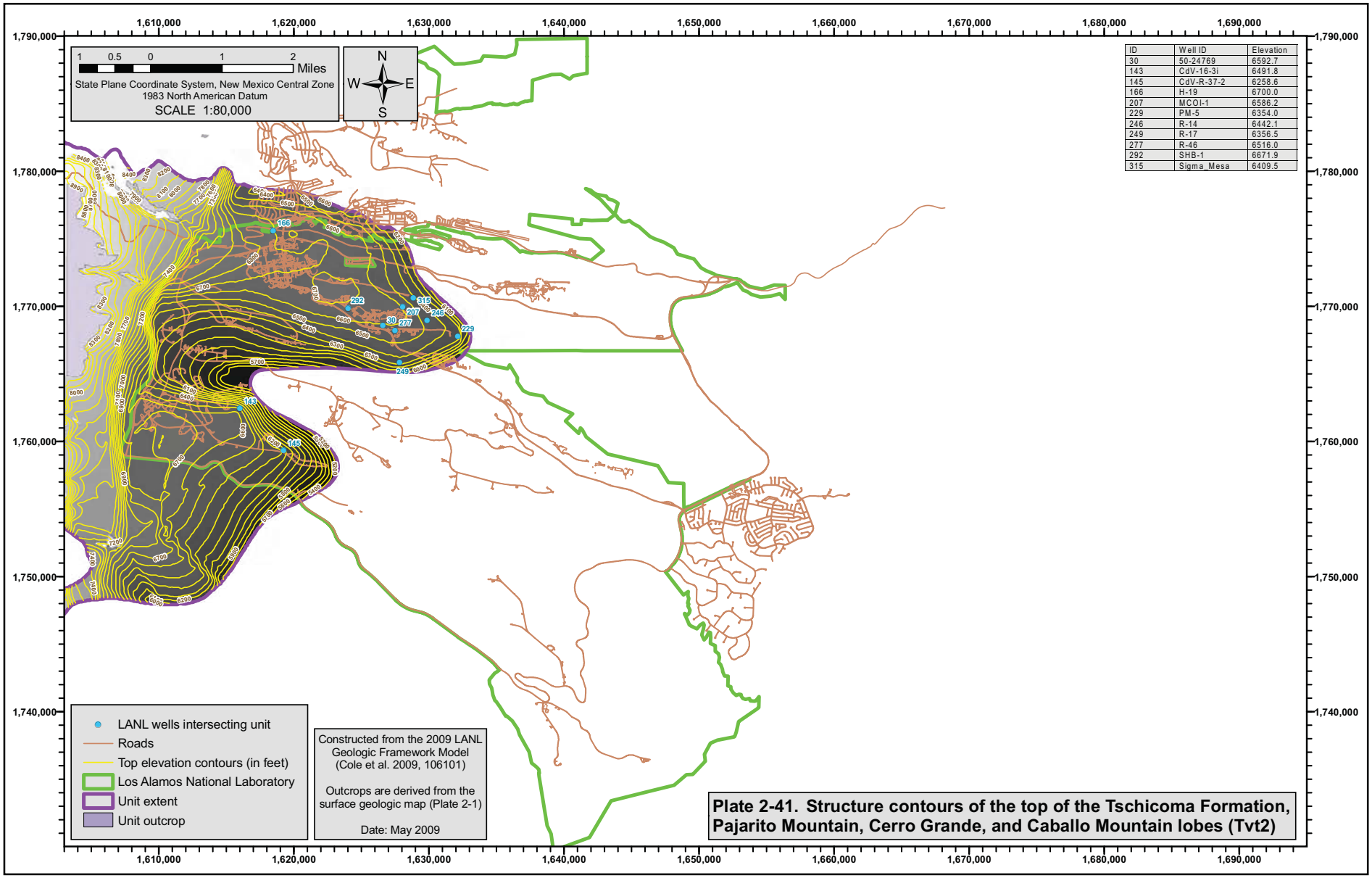
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Bottom elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Buckman 8
SF-2B
SF-2C
SF-2A
Buckman 7R
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
Plate 2-40. Structure contours of the bottom of the Ancha Formation (Qta)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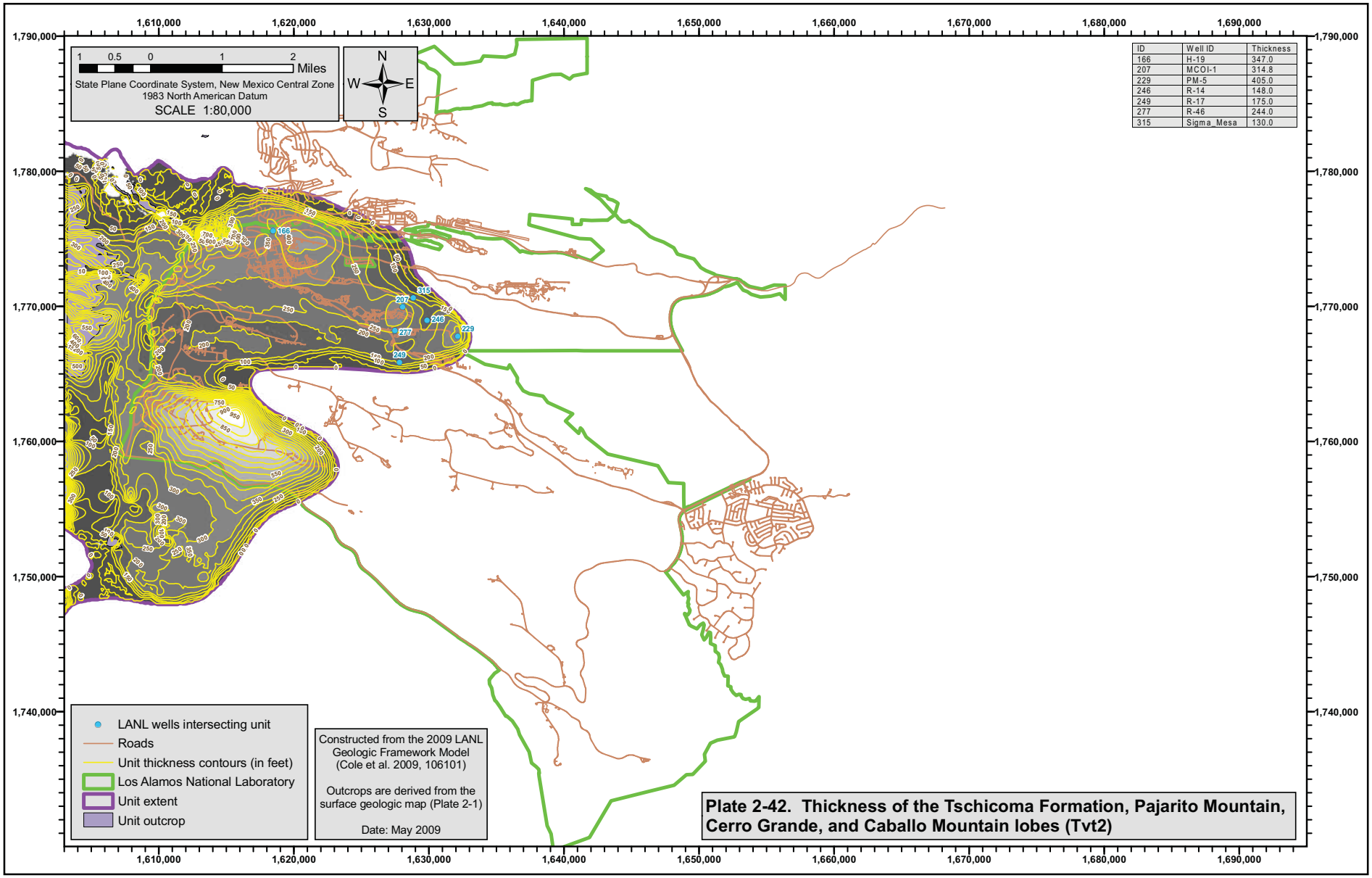
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Elevation
30 | 50-24769 | 6592.7
143 | CdV-16-3i | 6491.8
145 | CdV-R-37-2 | 6258.6
166 | H-19 | 6700.0
207 | MCOI-1 | 6586.2
229 | PM-5 | 6354.0
246 | R-14 | 6442.1
249 | R-17 | 6356.5
277 | R-46 | 6516.0
292 | SHB-1 | 6671.9
315 | Sigma_Mesa | 6409.5
LANL wells intersecting unit
Roads
Top elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Plate 2-41. Structure contours of the top of the Tschicoma Formation, Pajarito Mountain, Cerro Grande, and Caballo Mountain lobes (Tvt2)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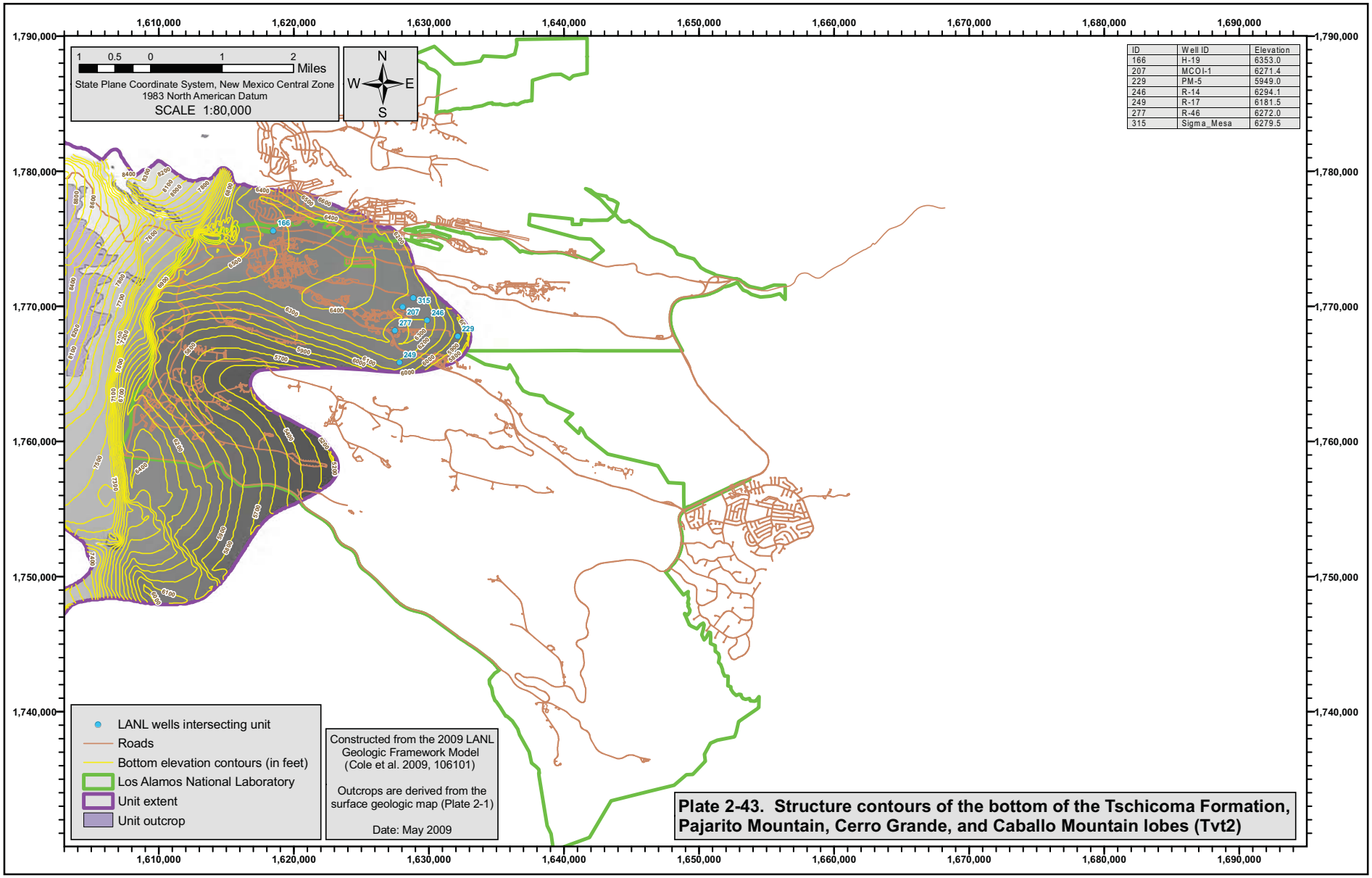
1,750,000
1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Thickness
166 | H-19 | 347.0
207 | MCOI-1 | 314.8
229 | PM-5 | 405.0
246 | R-14 | 148.0
249 | R-17 | 175.0
277 | R-46 | 244.0
315 | Sigma_Mesa | 130.0
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Plate 2-42. Thickness of the Tschicoma Formation, Pajarito Mountain, Cerro Grande, and Caballo Mountain lobes (Tvt2)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1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Elevation
166 | H-19 | 6353.0
207 | MCOI-1 | 6271.4
229 | PM-5 | 5949.0
246 | R-14 | 6294.1
249 | R-17 | 6181.5
277 | R-46 | 6272.0
315 | Sigma_Mesa | 6279.5
LANL wells intersecting unit
Roads
Bottom elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Plate 2-43. Structure contours of the bottom of the Tschicoma Formation, Pajarito Mountain, Cerro Grande, and Caballo Mountain lobes (Tvt2)

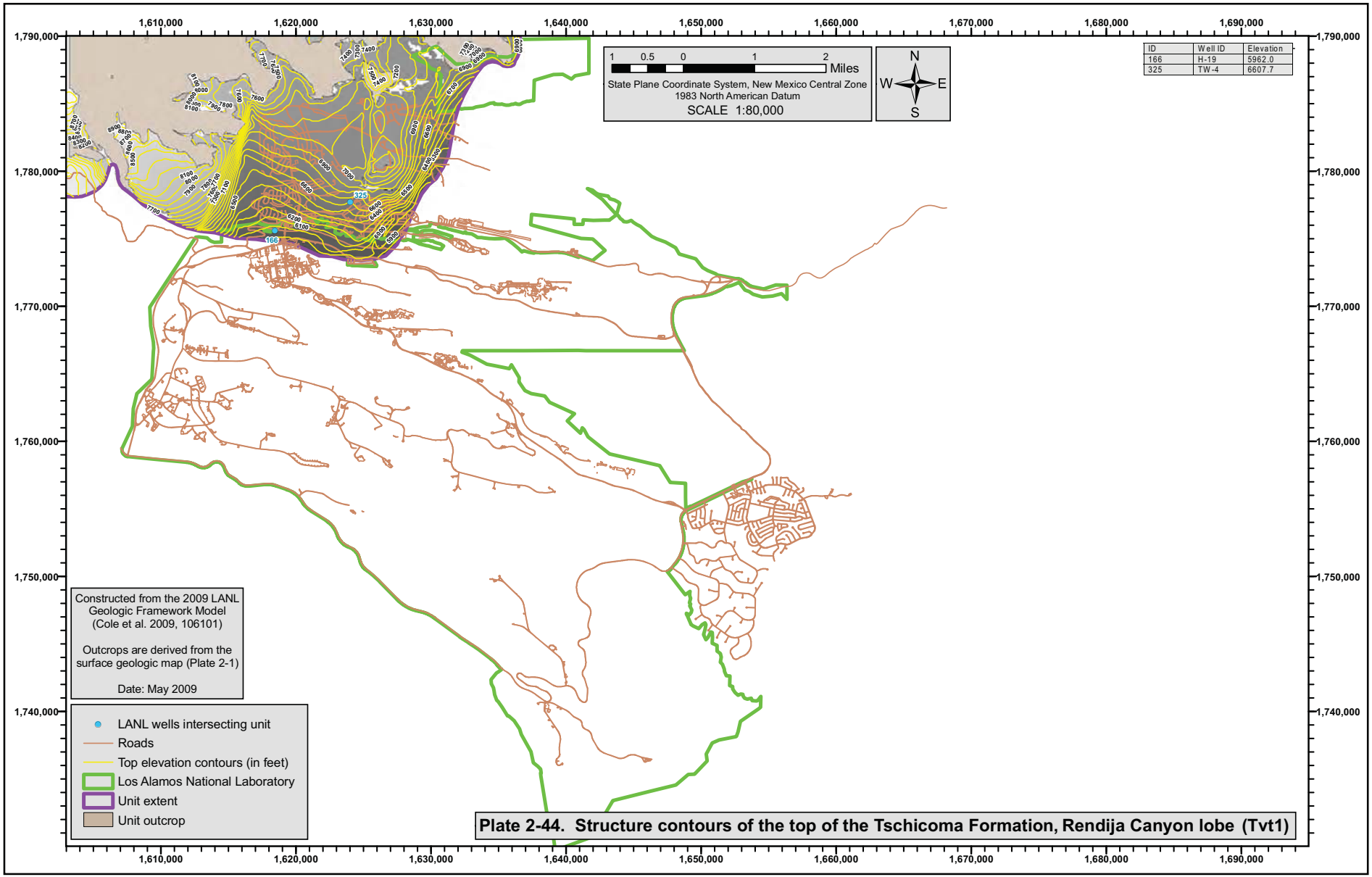
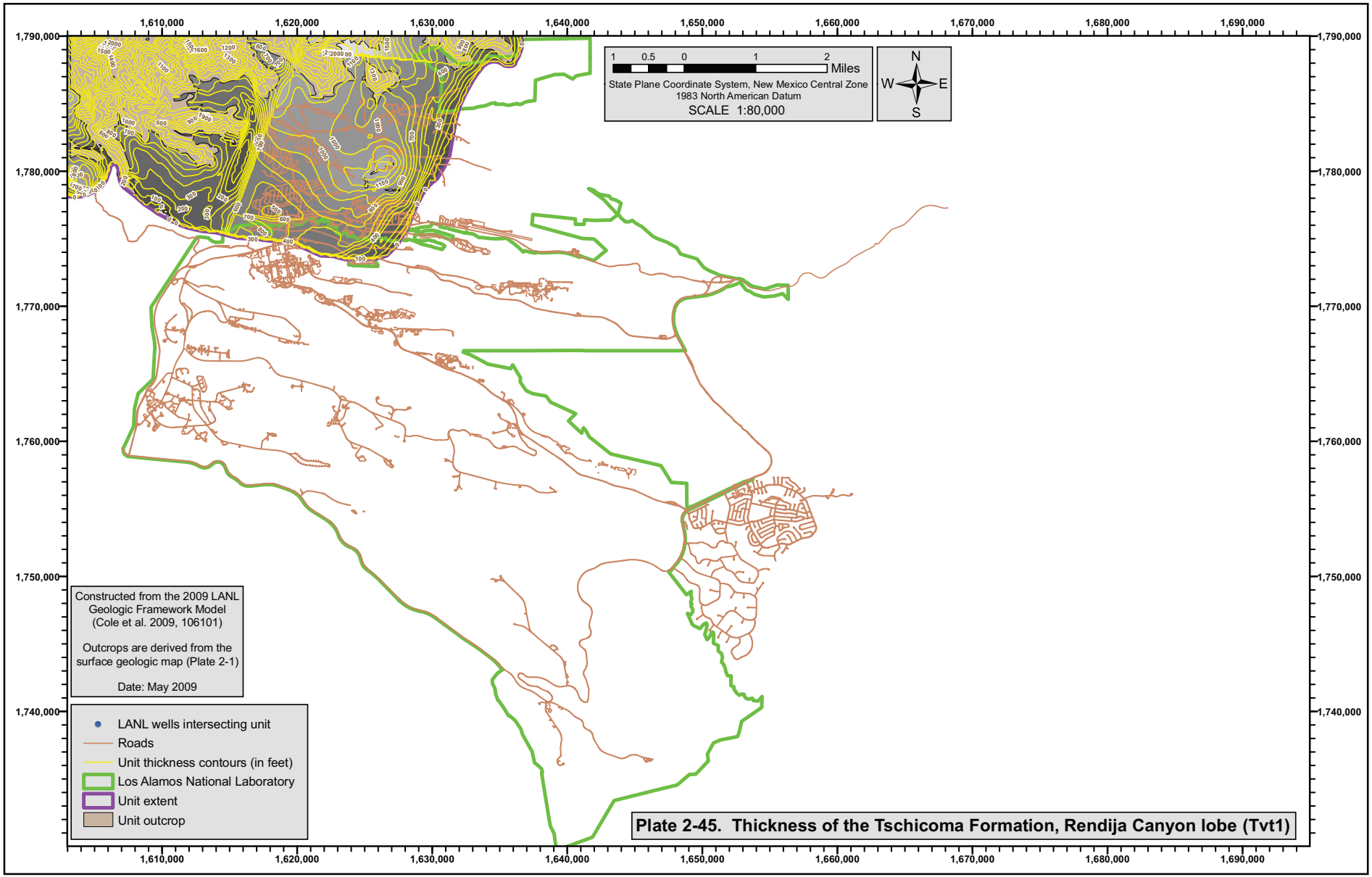


Plate 2-44. Structure contours of the top of the Tschicoma Formation, Rendija Canyon lobe (Tvt1)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1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-45. Thickness of the Tschicoma Formation, Rendija Canyon lobe (Tvt1)

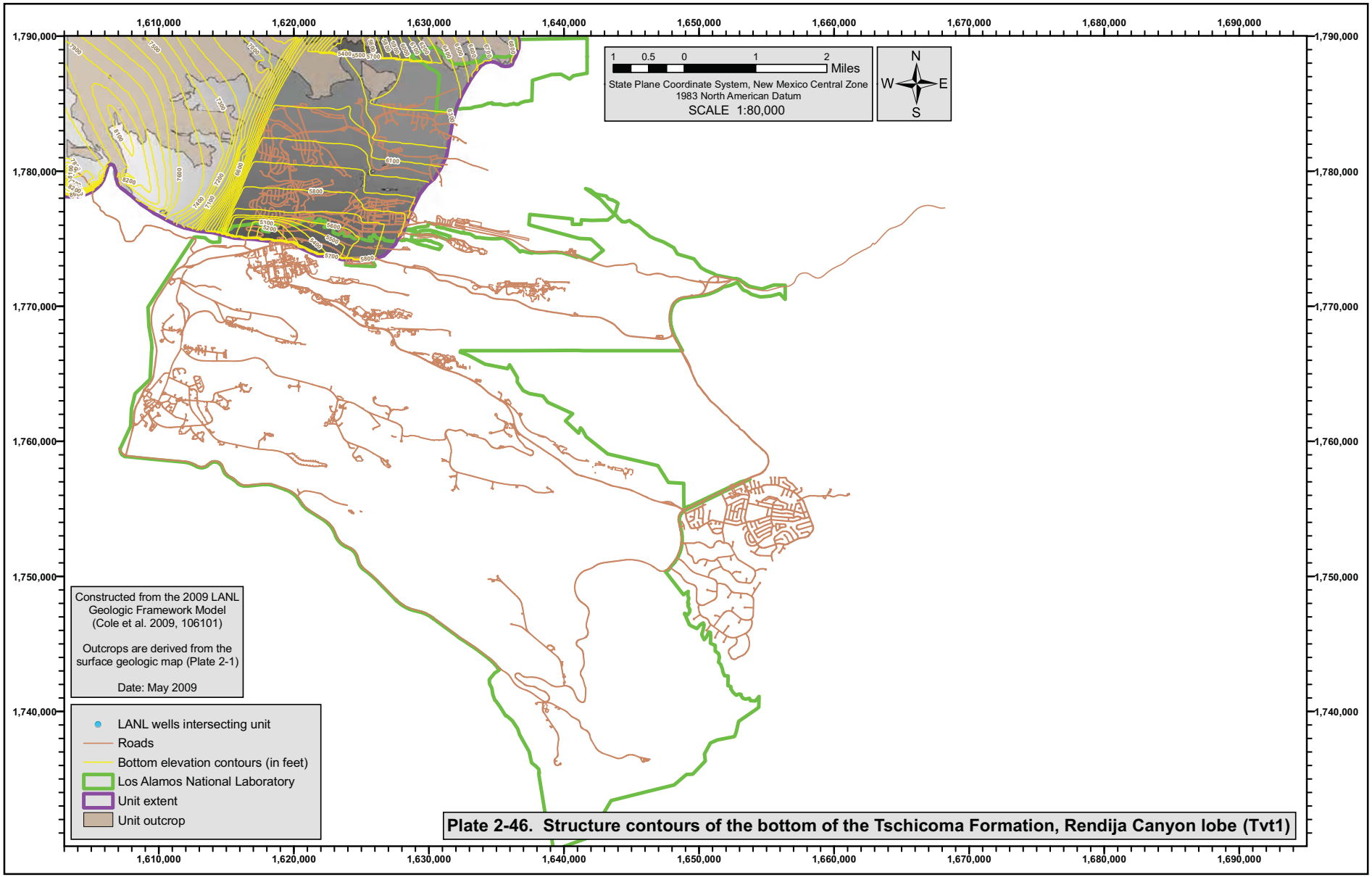
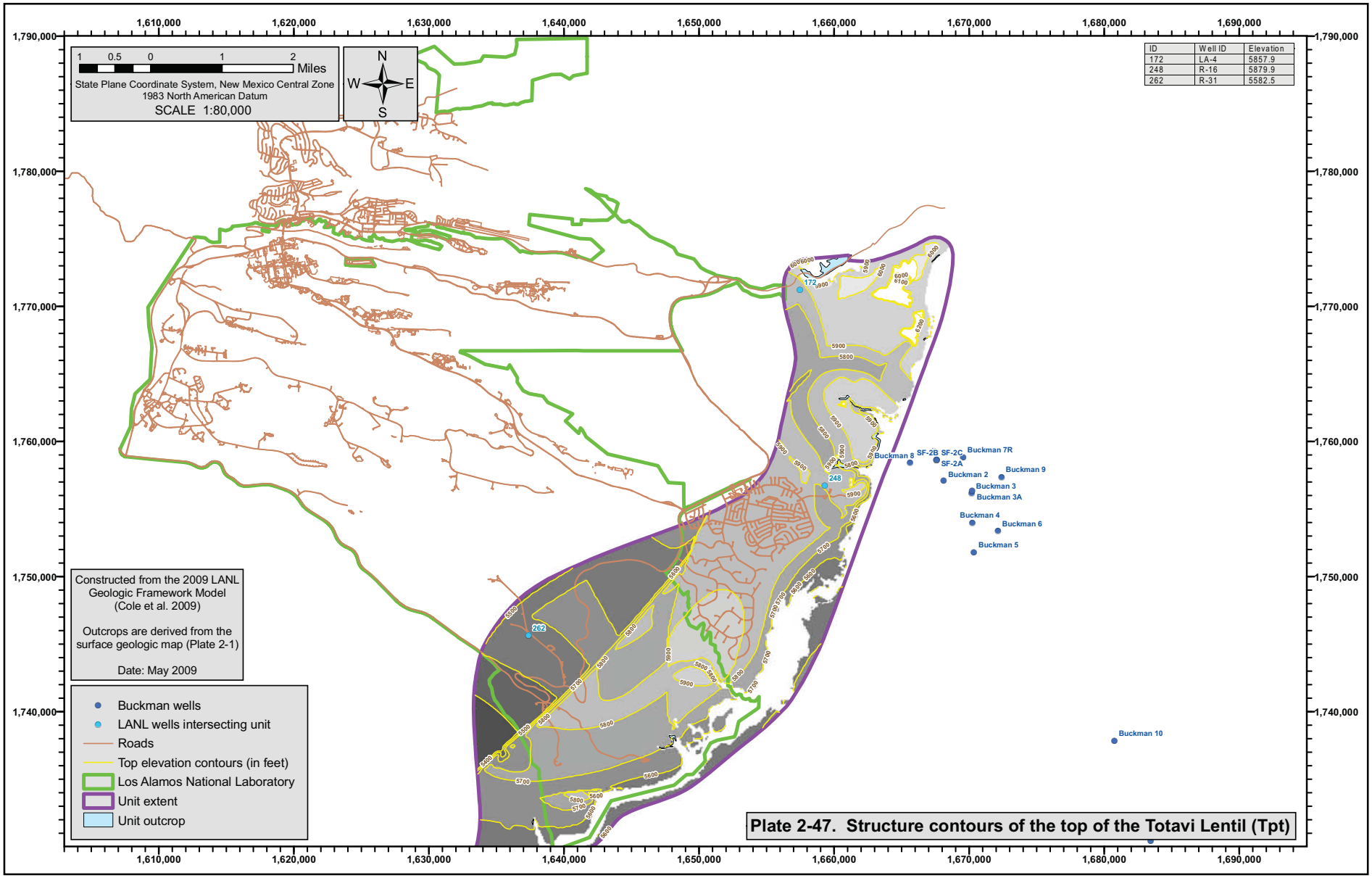


Plate 2-46. Structure contours of the bottom of the Tschicoma Formation, Rendija Canyon lobe (Tvt1)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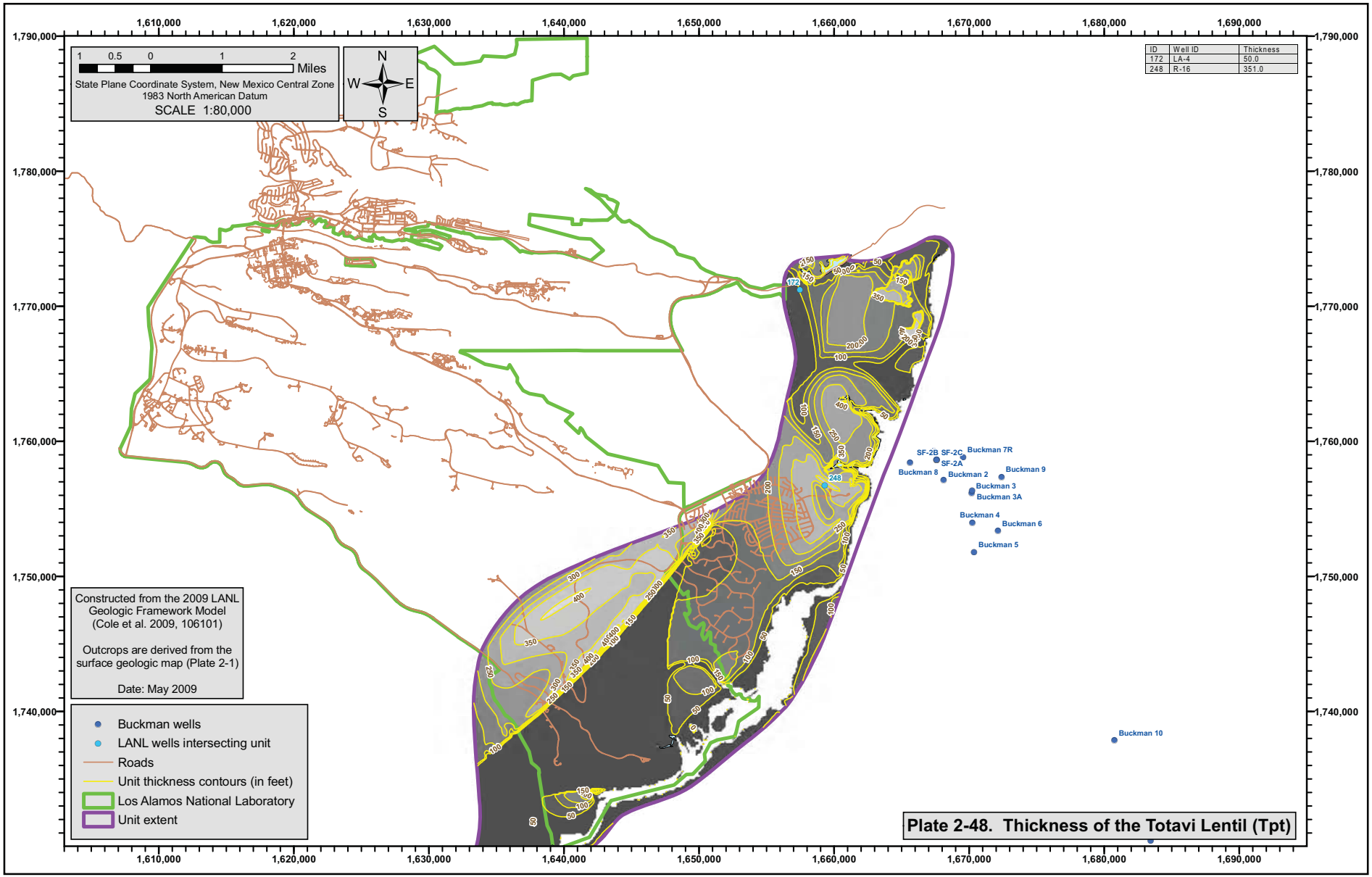
1,770,000
1,760,000
1,750,000
1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Elevation
172 | LA-4 | 5857.9
248 | R-16 | 5879.9
262 | R-31 | 5582.5
Buckman 8
SF-2B
SF-2C
SF-2A
Buckman 7R
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Top elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-47. Structure contours of the top of the Totavi Lentil (Tpt)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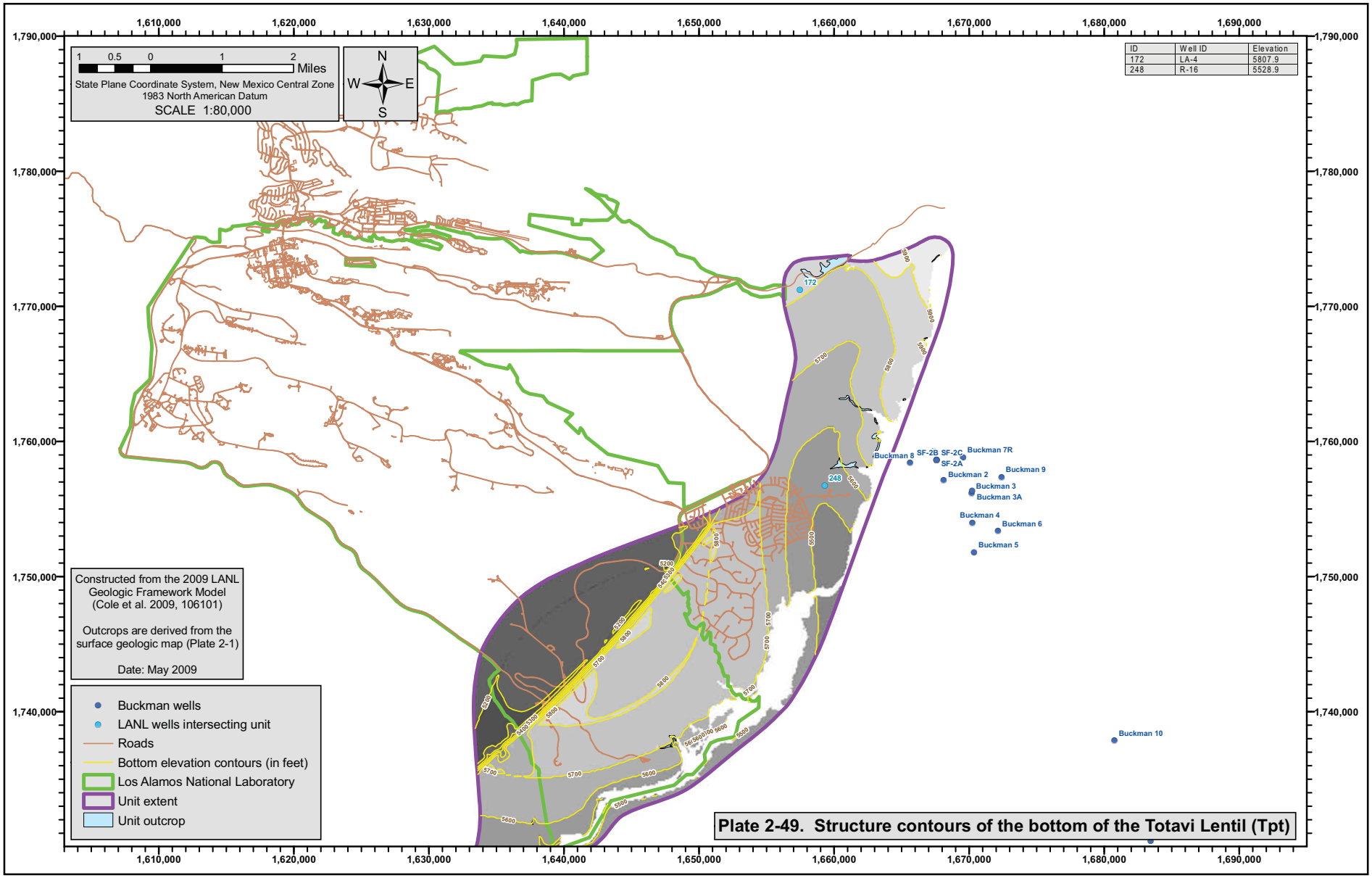
1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Thickness
172 | LA-4 | 50.0
248 | R-16 | 351.0
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
SF-2B
SF-2C
Buckman 7R
SF-2A
Buckman 8
Buckman 2
Buckman 9
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
Plate 2-48. Thickness of the Totavi Lentil (Tpt)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1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Elevation
172 | LA-4 | 5807.9
248 | R-16 | 5528.9
Buckman 8
SF-2B
SF-2C
Buckman 7R
SF-2A
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Bottom elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-49. Structure contours of the bottom of the Totavi Lentil (Tpt)

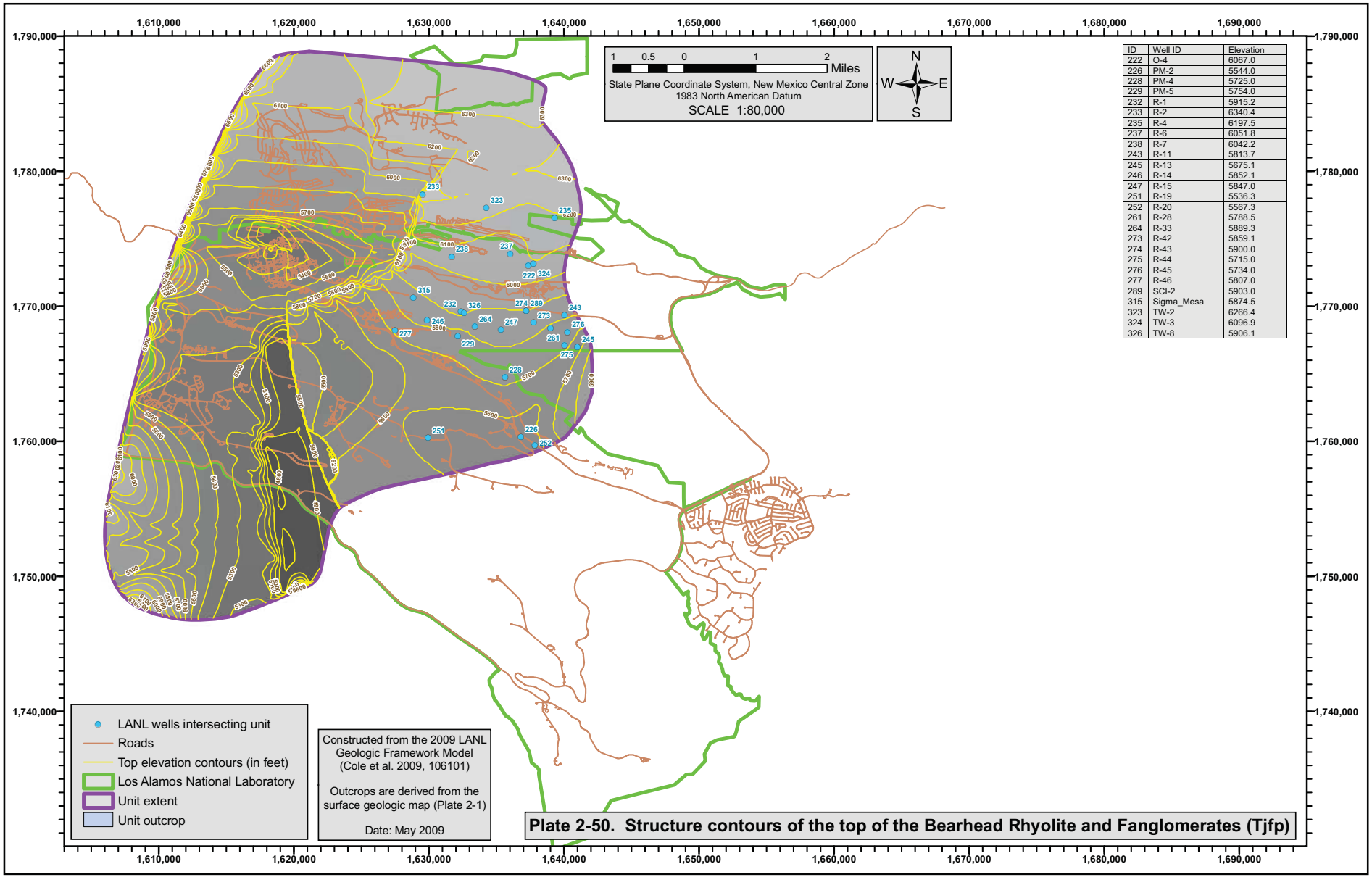
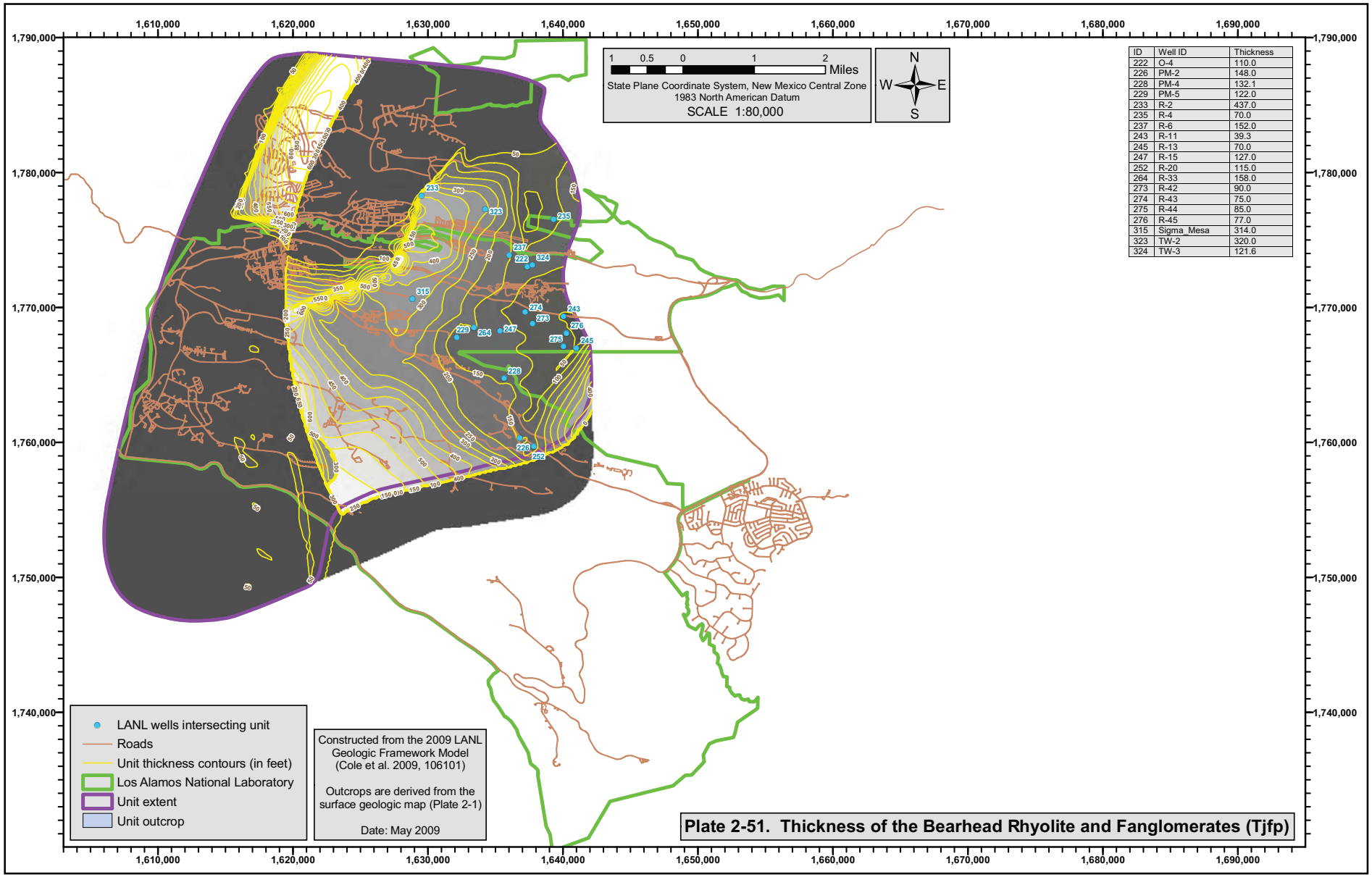


Plate 2-50. Structure contours of the top of the Bearhead Rhyolite and Fanglomerates (Tjfp)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1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Thickness
222 | O-4 | 110.0
226 | PM-2 | 148.0
228 | PM-4 | 132.1
229 | PM-5 | 122.0
233 | R-2 | 437.0
235 | R-4 | 70.0
237 | R-6 | 152.0
243 | R-11 | 39.3
245 | R-13 | 70.0
247 | R-15 | 127.0
252 | R-20 | 115.0
264 | R-33 | 158.0
273 | R-42 | 90.0
274 | R-43 | 75.0
275 | R-44 | 85.0
276 | R-45 | 77.0
315 | Sigma_Mesa | 314.0
323 | TW-2 | 320.0
324 | TW-3 | 121.6
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Plate 2-51. Thickness of the Bearhead Rhyolite and Fanglomerates (Tjfp)

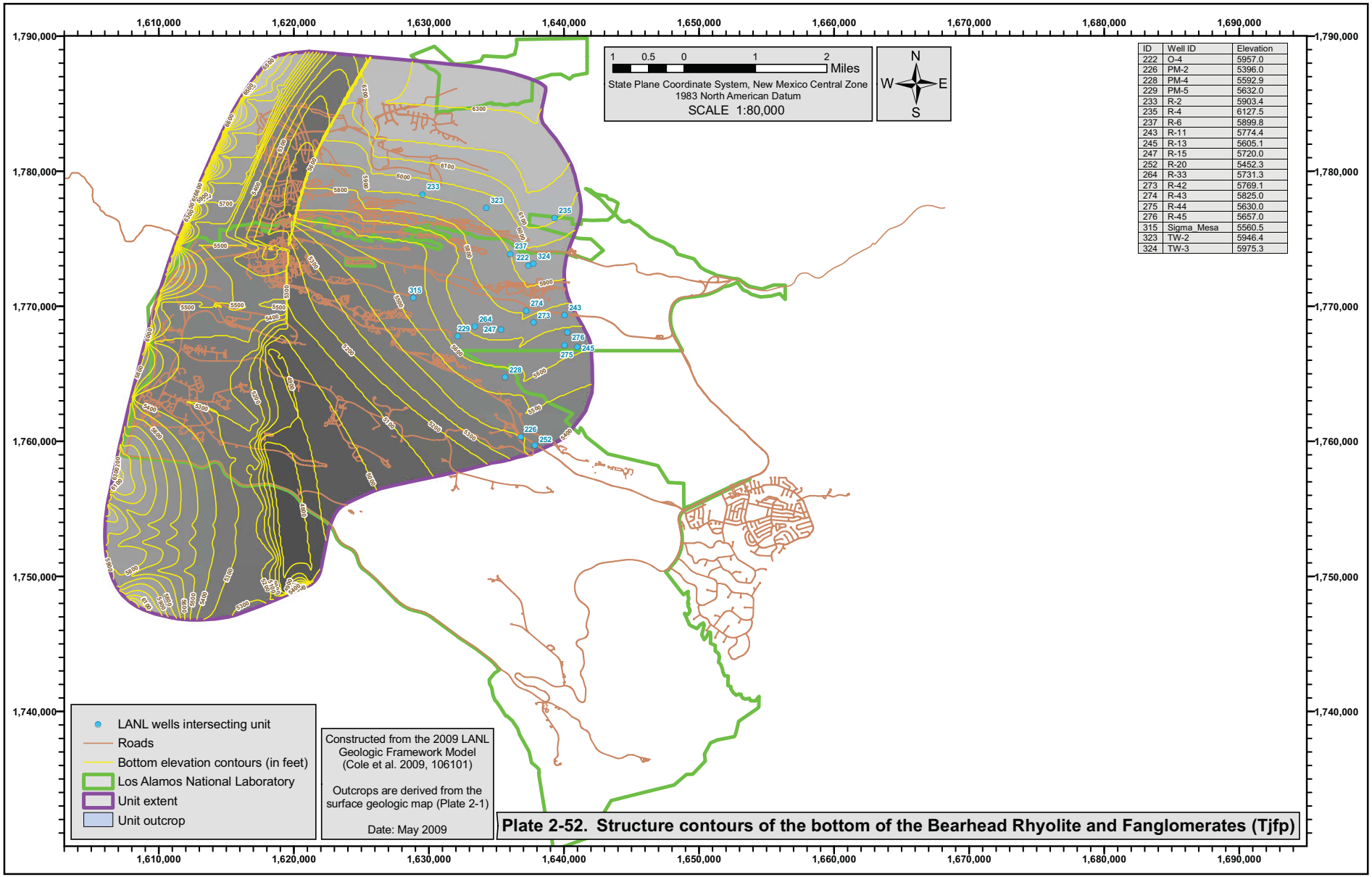


Plate 2-52. Structure contours of the bottom of the Bearhead Rhyolite and Fanglomerates (Tjfp)

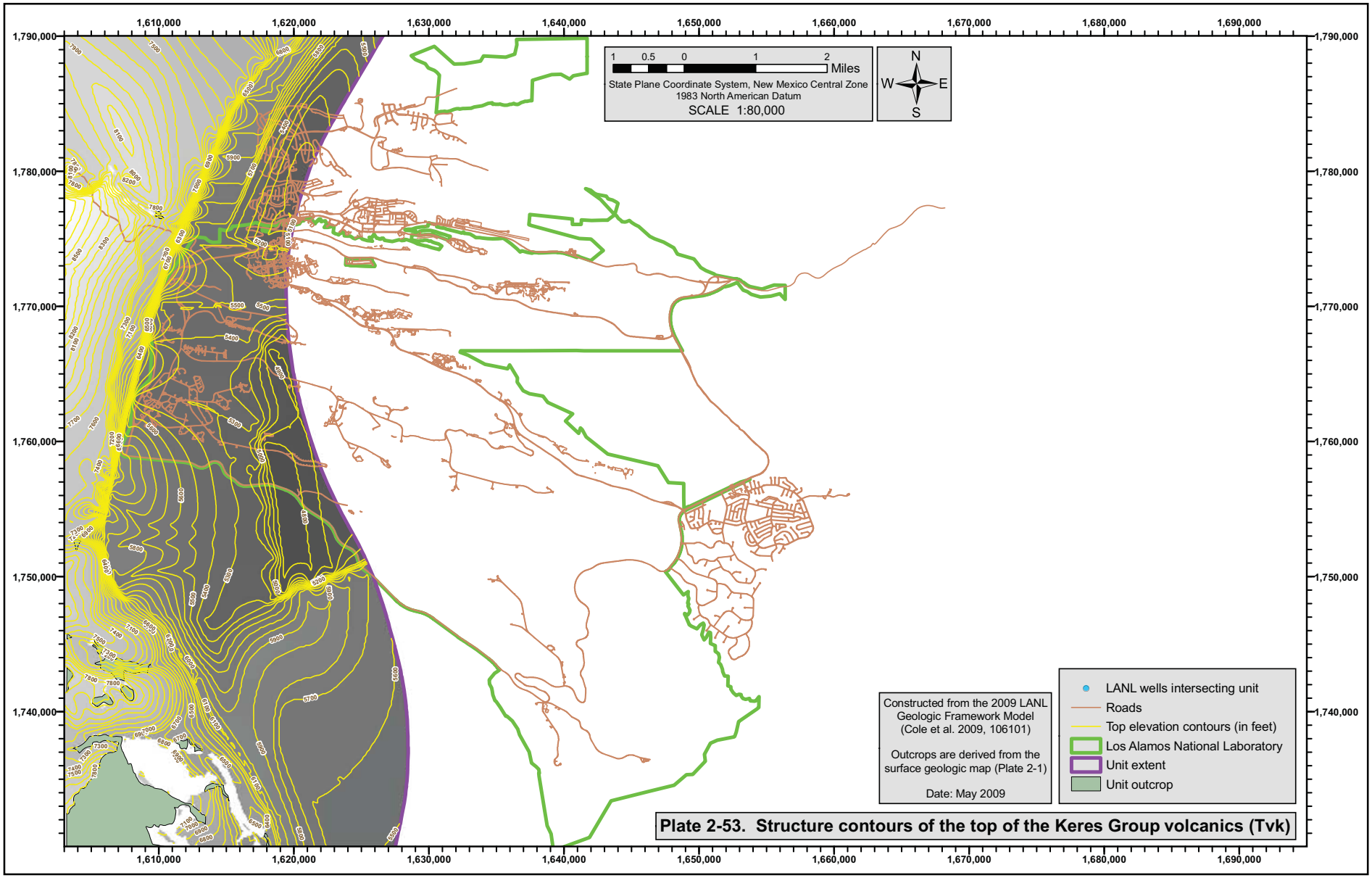
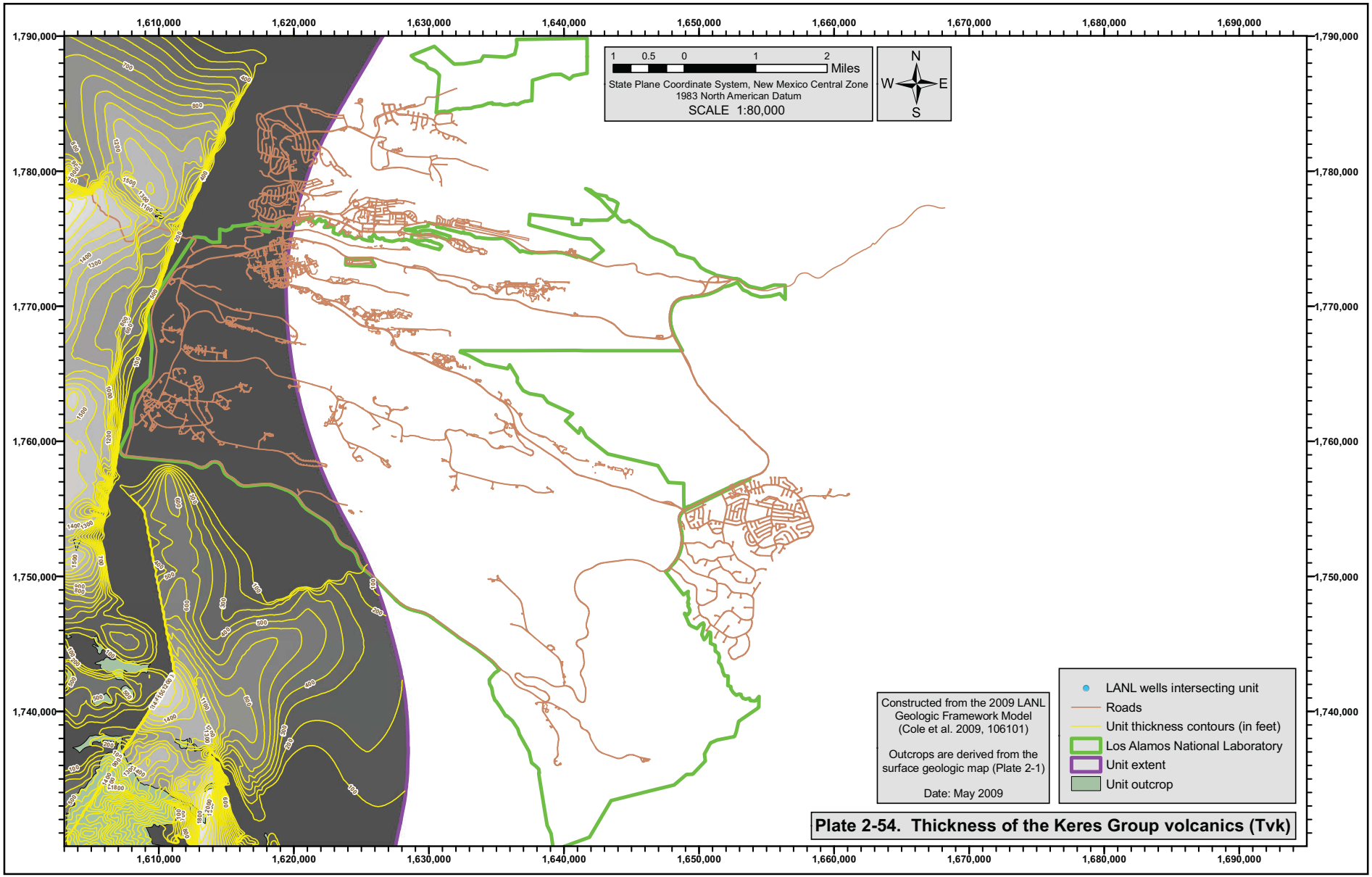


Plate 2-53. Structure contours of the top of the Keres Group volcanics (Tvk)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1,750,000
1,740,000
1 0.5 0 1 2
Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
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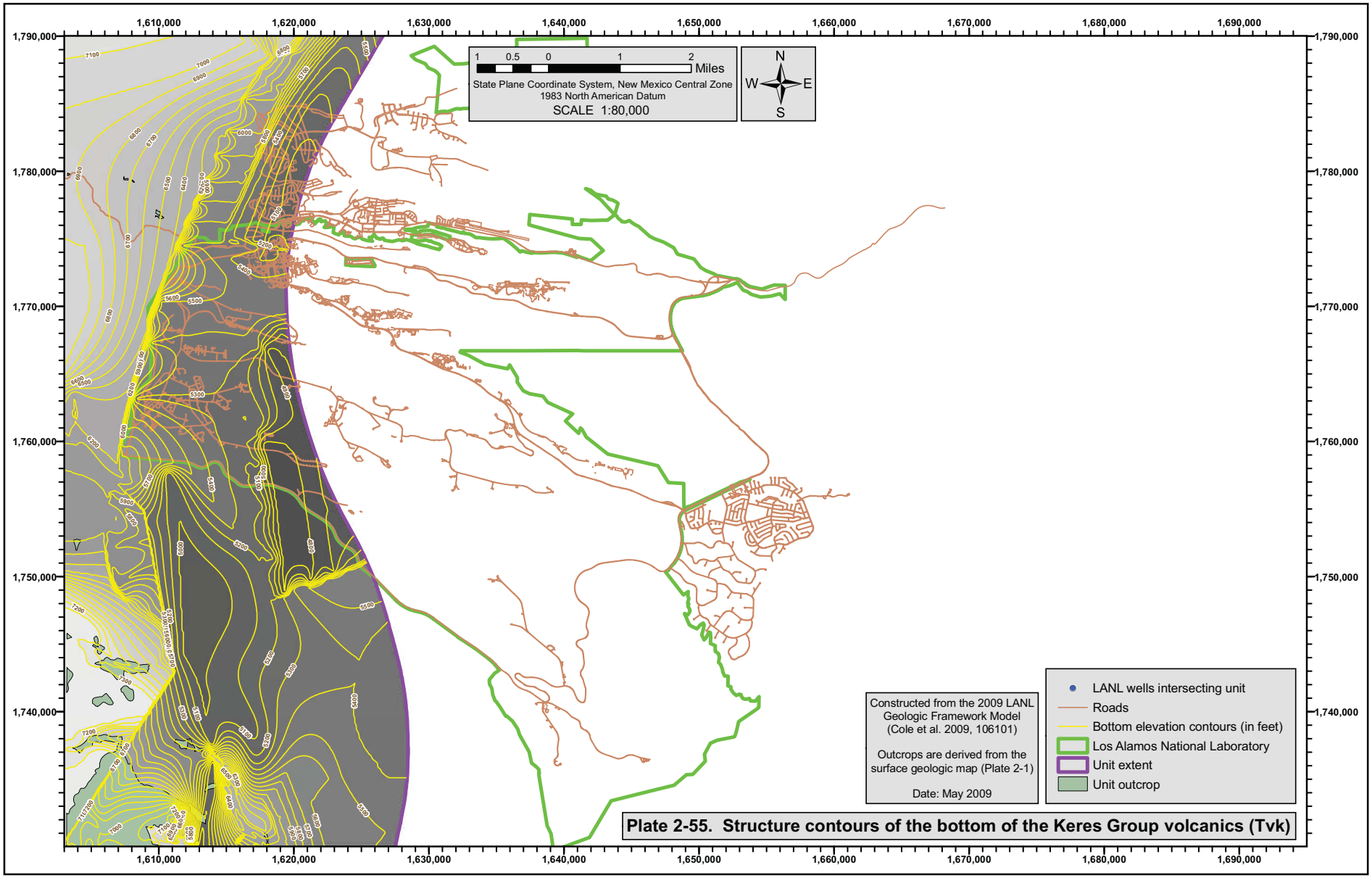
S
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-54. Thickness of the Keres Group volcanics (Tvk)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1,770,000
1,760,000
1,750,000
1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
LANL wells intersecting unit
Roads
Bottom elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-55. Structure contours of the bottom of the Keres Group volcanics (Tvk)

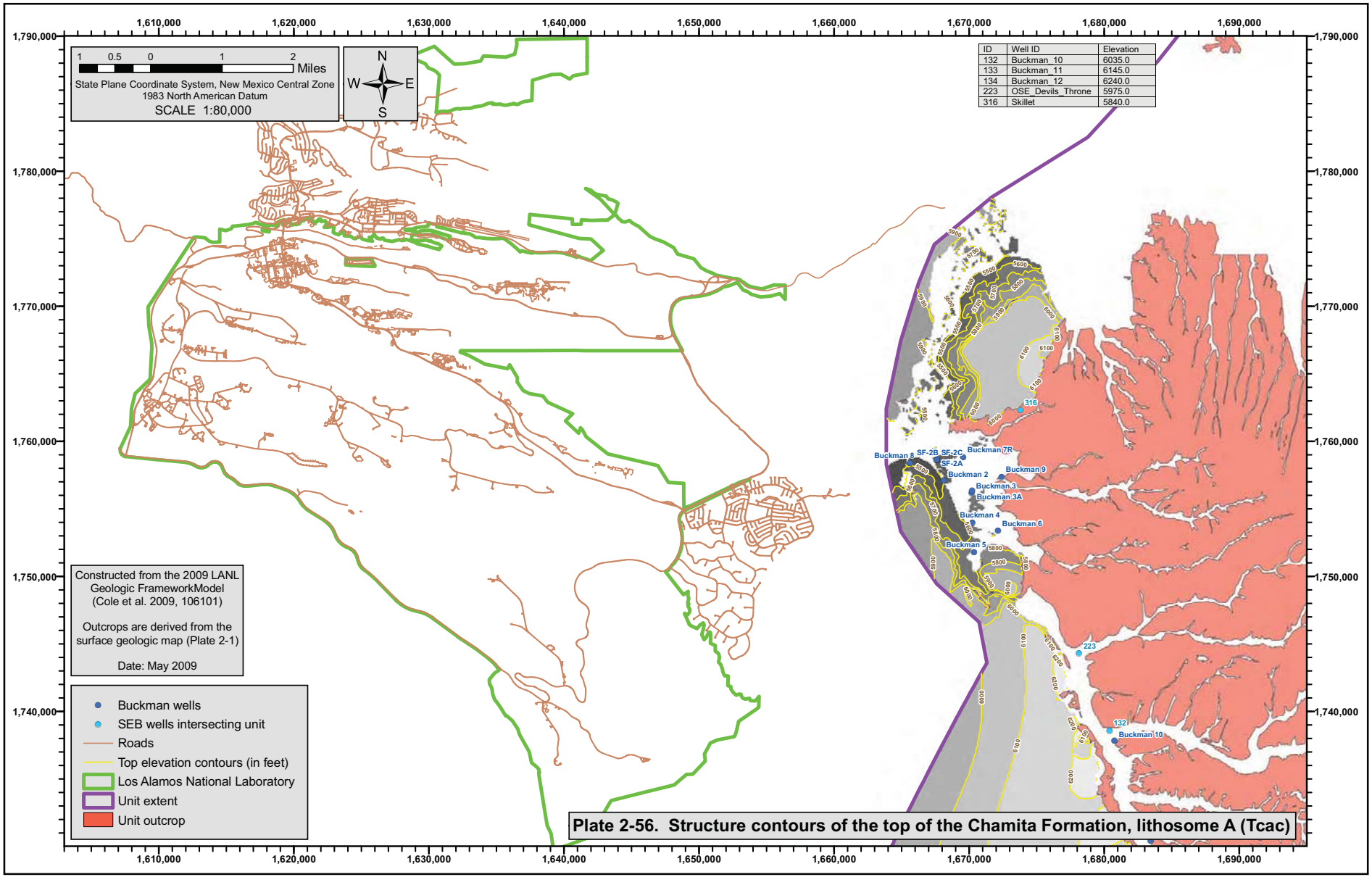
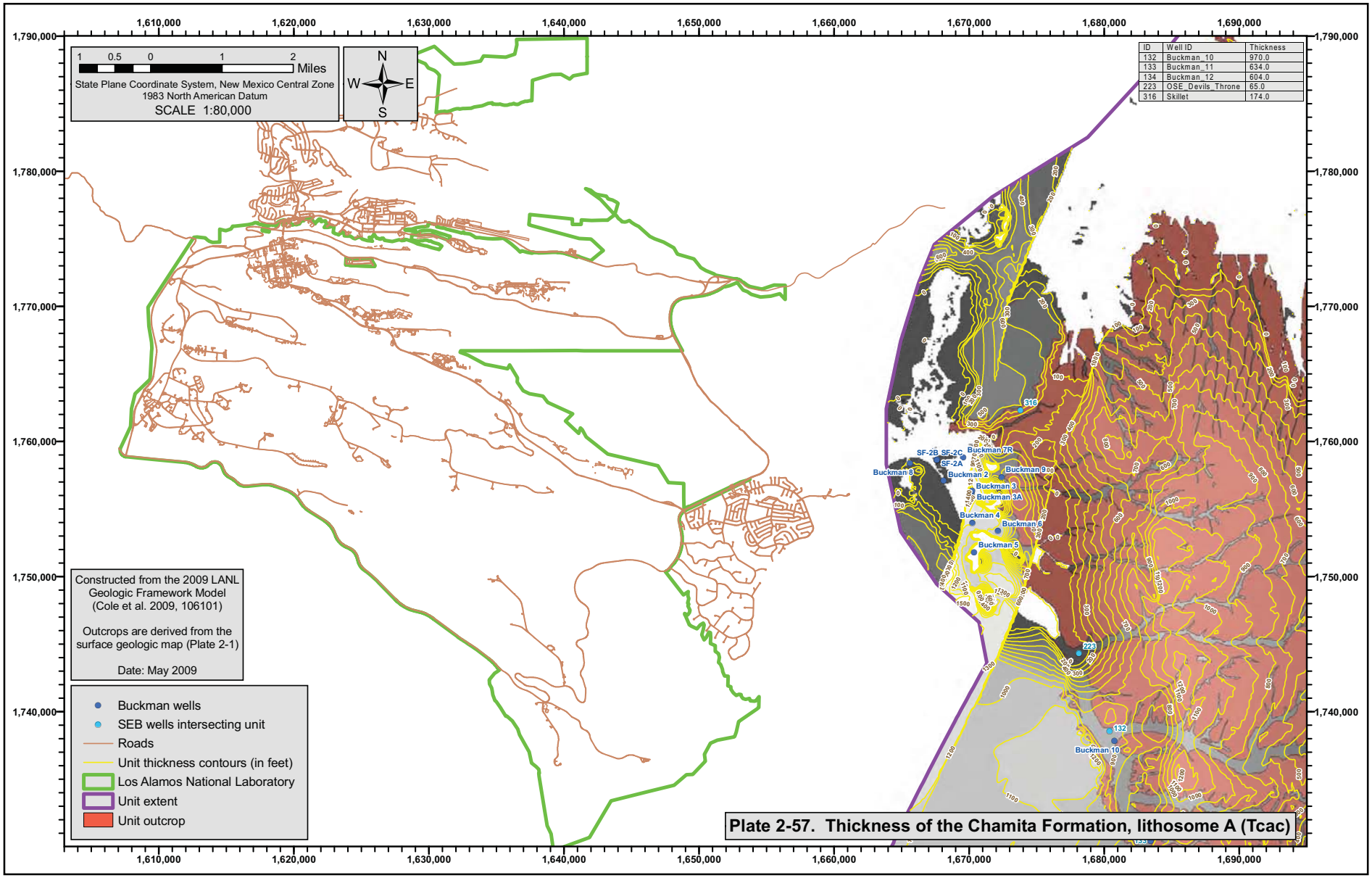


Plate 2-56. Structure contours of the top of the Chamita Formation, lithosome A (Tcac)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1,760,000
1,750,000
1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Thickness
132 | Buckman_10 | 970.0
133 | Buckman_11 | 634.0
134 | Buckman_12 | 604.0
223 | OSE_Devils_Throne | 65.0
316 | Skillet | 174.0
316
SF-2B SF-2C
SF-2A
Buckman 7R
Buckman 8
Buckman 2
Buckman 9
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
223
132
Buckman 10
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
SEB wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-57. Thickness of the Chamita Formation, lithosome A (Tcac)

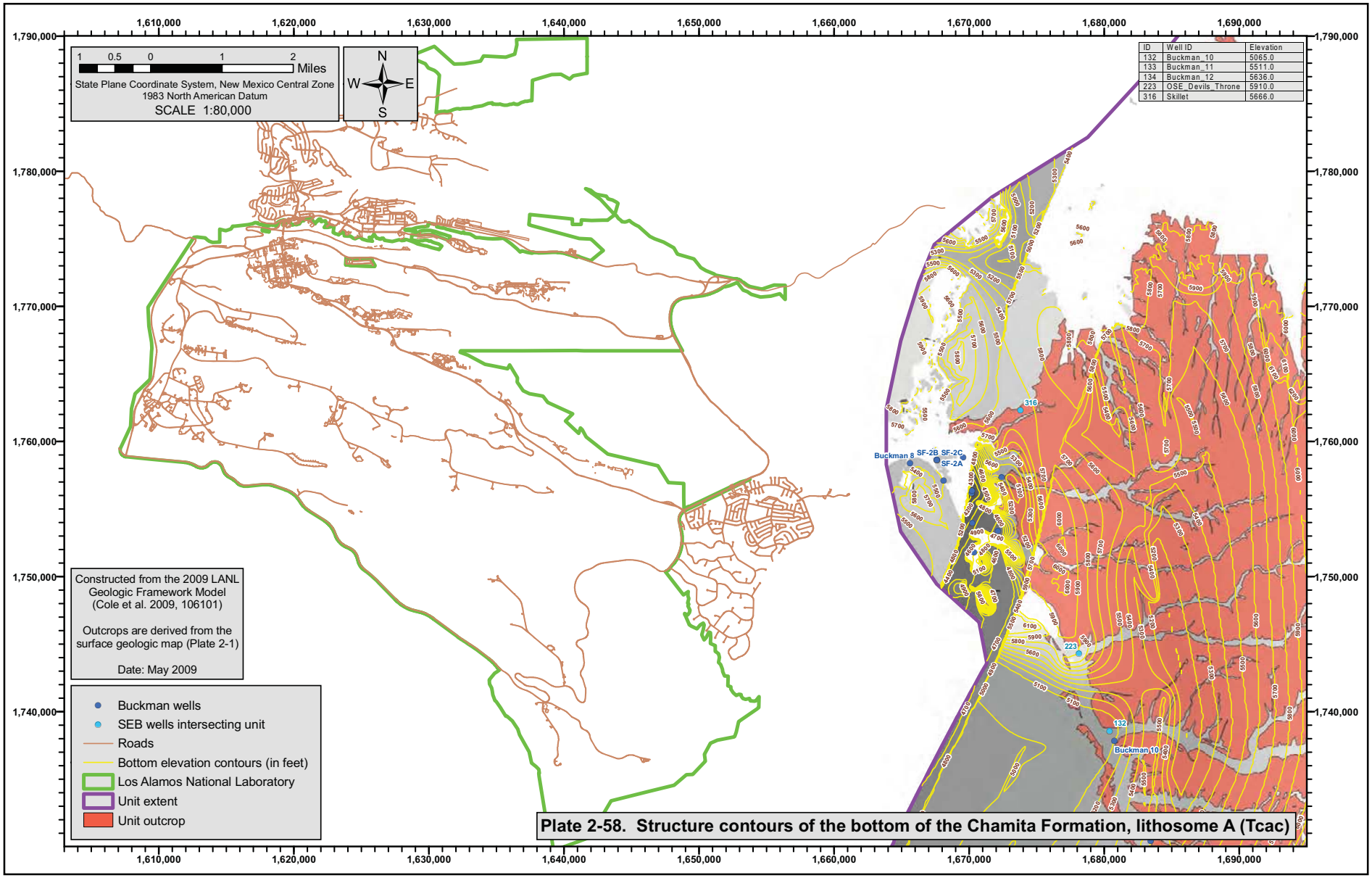


Plate 2-58. Structure contours of the bottom of the Chamita Formation, lithosome A (Tcac)

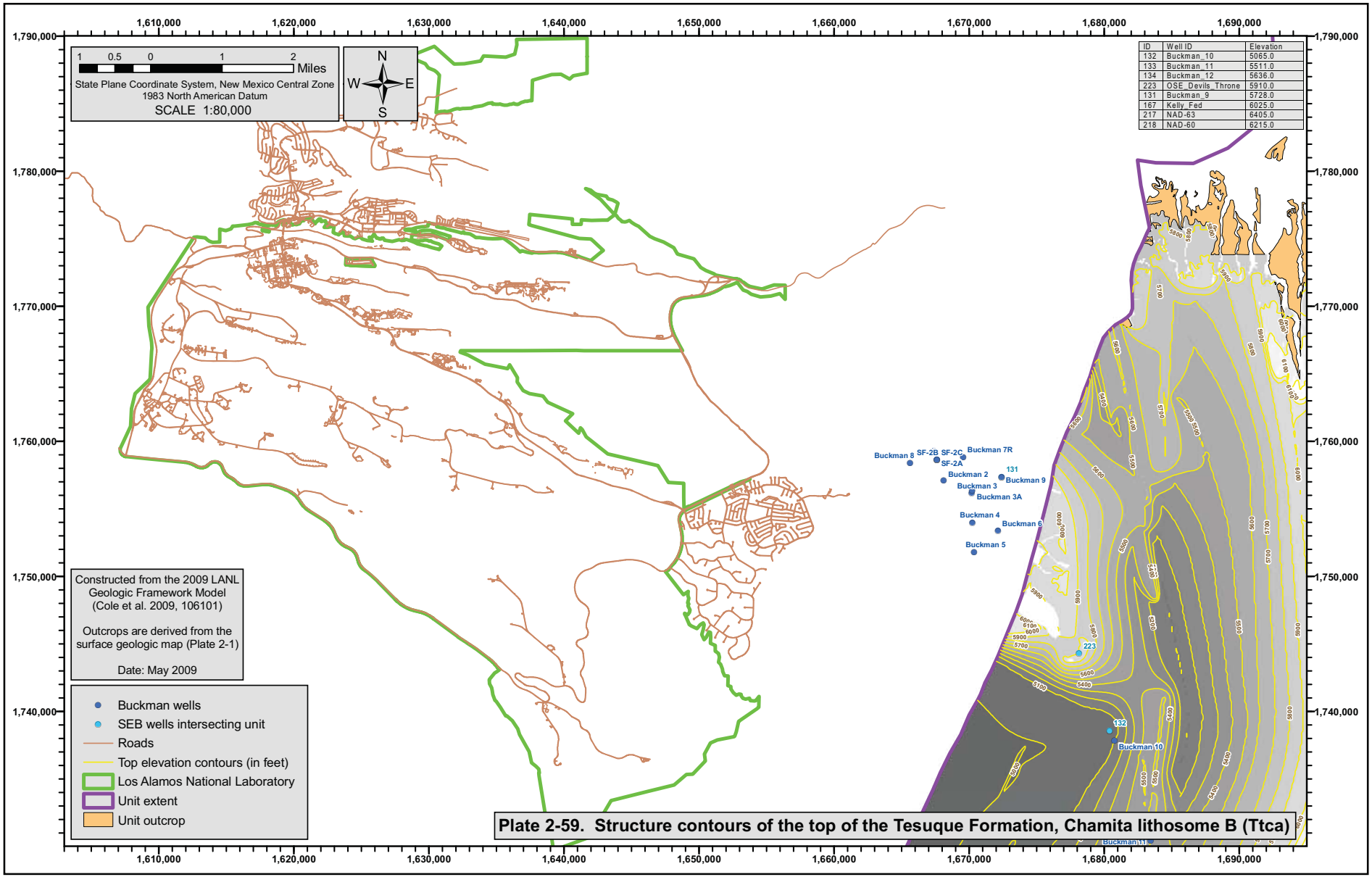
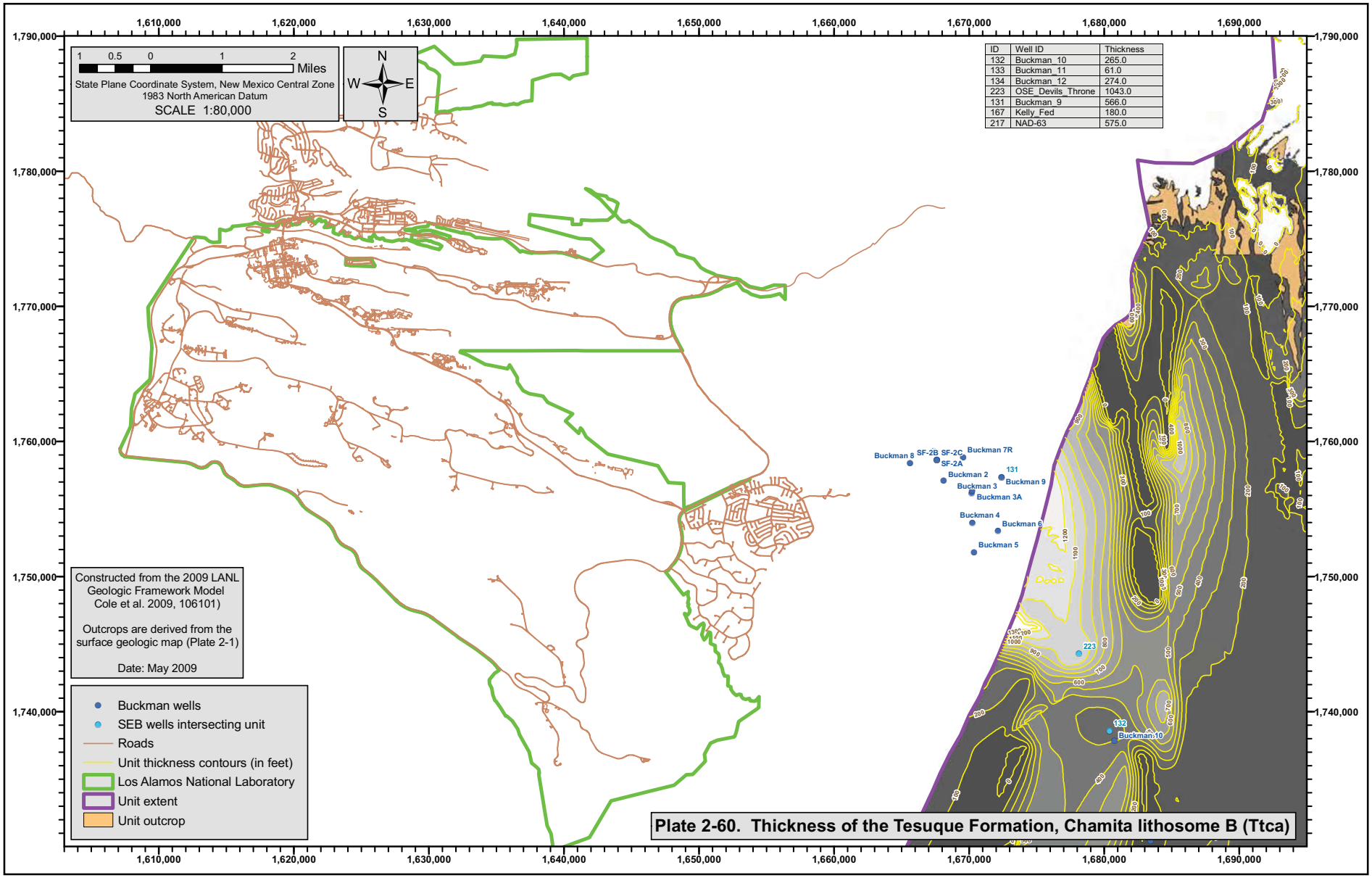


Plate 2-59. Structure contours of the top of the Tesuque Formation, Chamita lithosome B (Ttca)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1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Thickness
132 | Buckman_10 | 265.0
133 | Buckman_11 | 61.0
134 | Buckman_12 | 274.0
223 | OSE_Devils_Throne | 1043.0
131 | Buckman_9 | 566.0
167 | Kelly_Fed | 180.0
217 | NAD-63 | 575.0
Buckman 8
SF-2B
SF-2C
Buckman 7R
SF-2A
Buckman 2
131
Buckman 9
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
223
132
Buckman 10
Constructed from the 2009 LANL Geologic Framework Model Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
SEB wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-60. Thickness of the Tesuque Formation, Chamita lithosome B (Ttca)

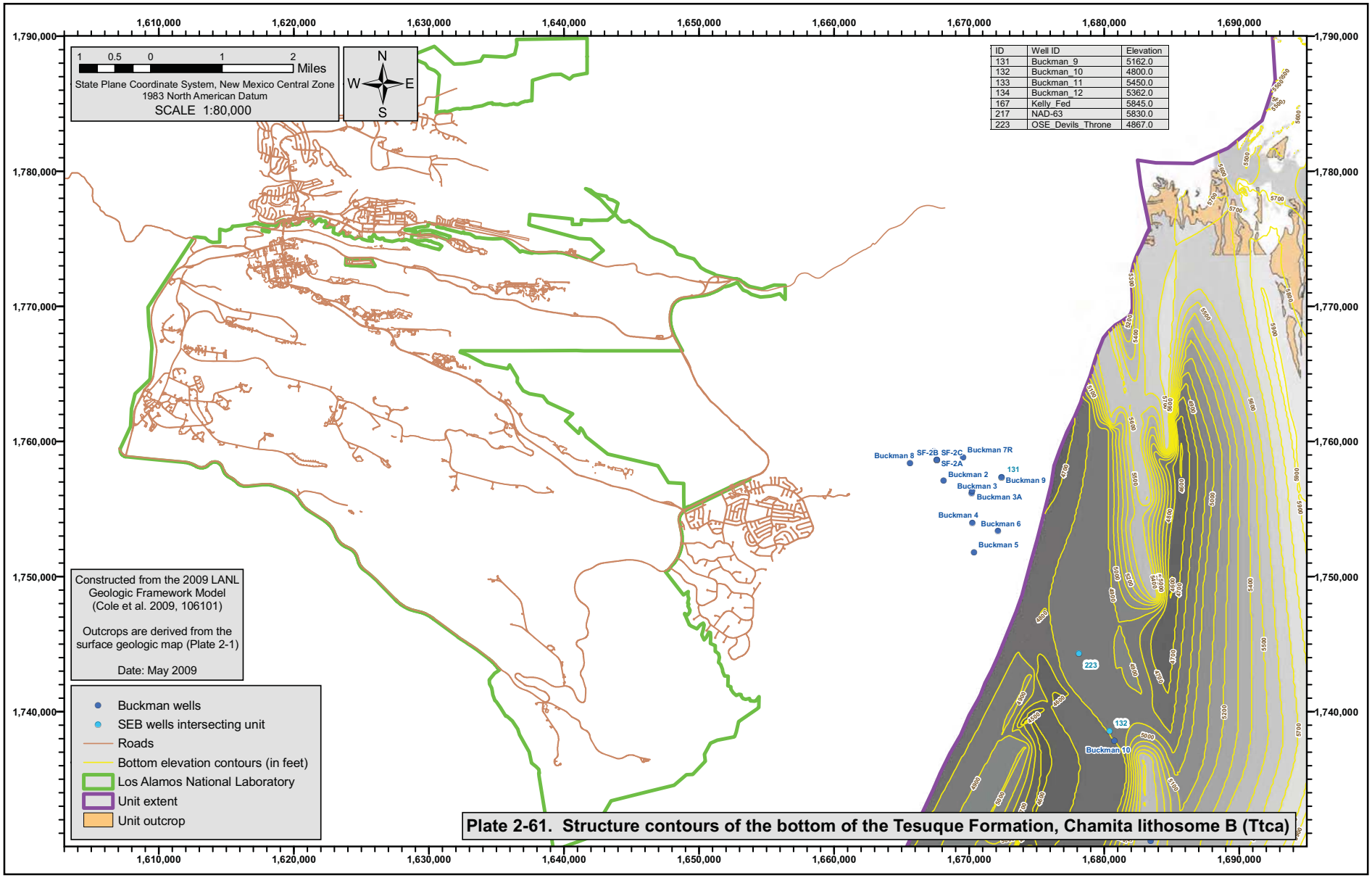


Plate 2-61. Structure contours of the bottom of the Tesuque Formation, Chamita lithosome B (Ttca)

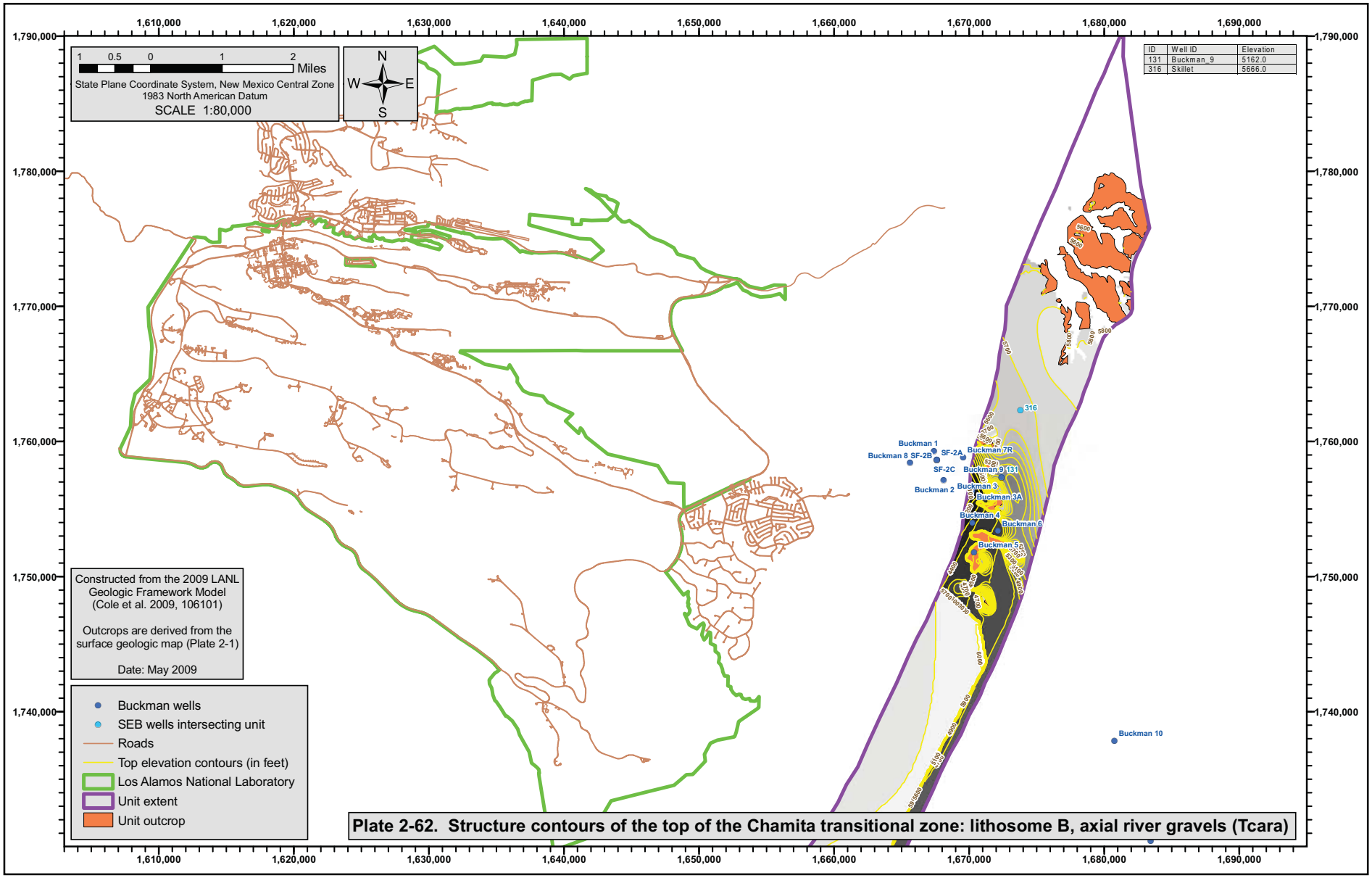


Plate 2-62. Structure contours of the top of the Chamita transitional zone: lithosome B, axial river gravels (Tcara)

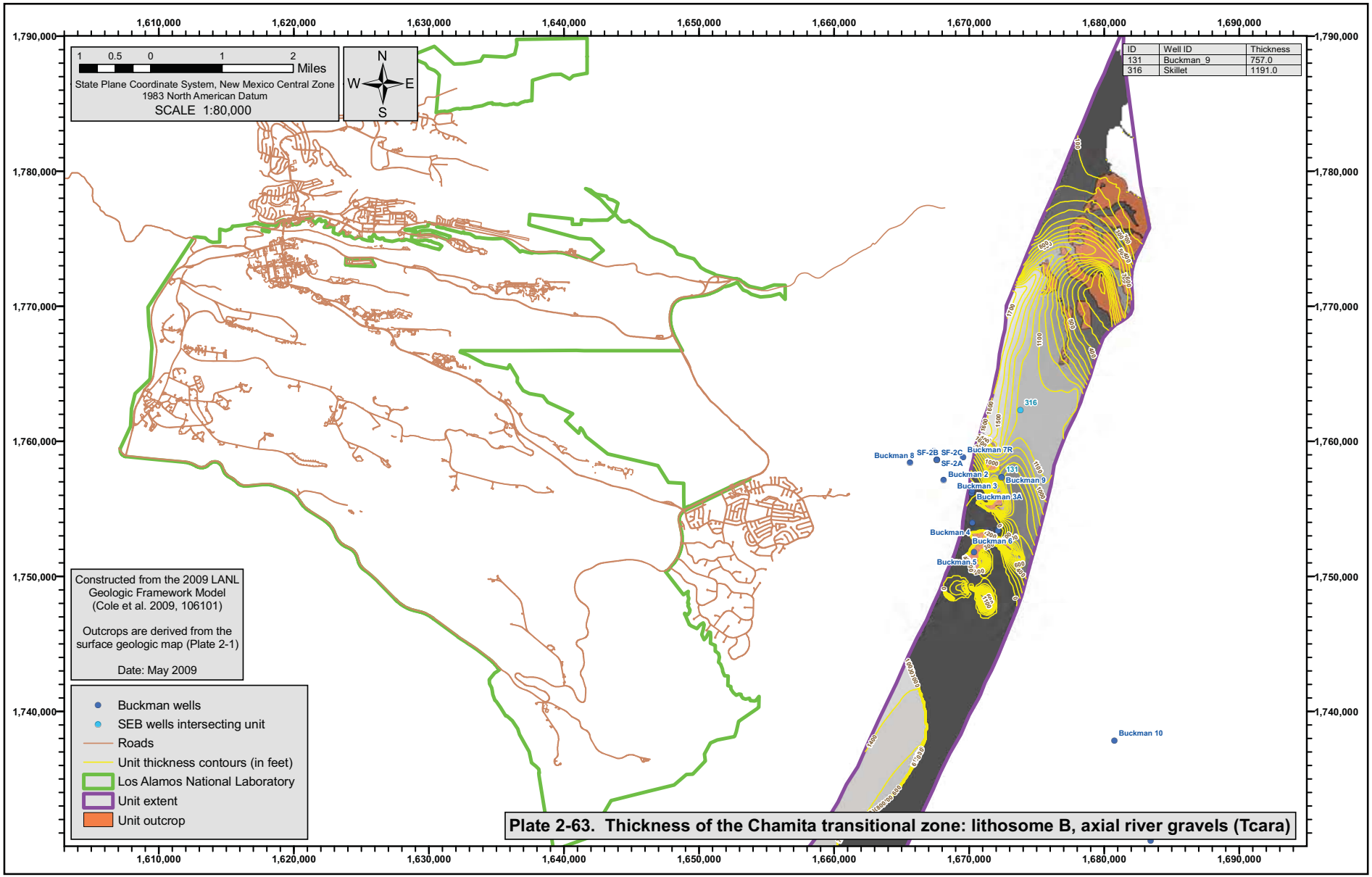


Plate 2-63. Thickness of the Chamita transitional zone: lithosome B, axial river gravels (Tcara)

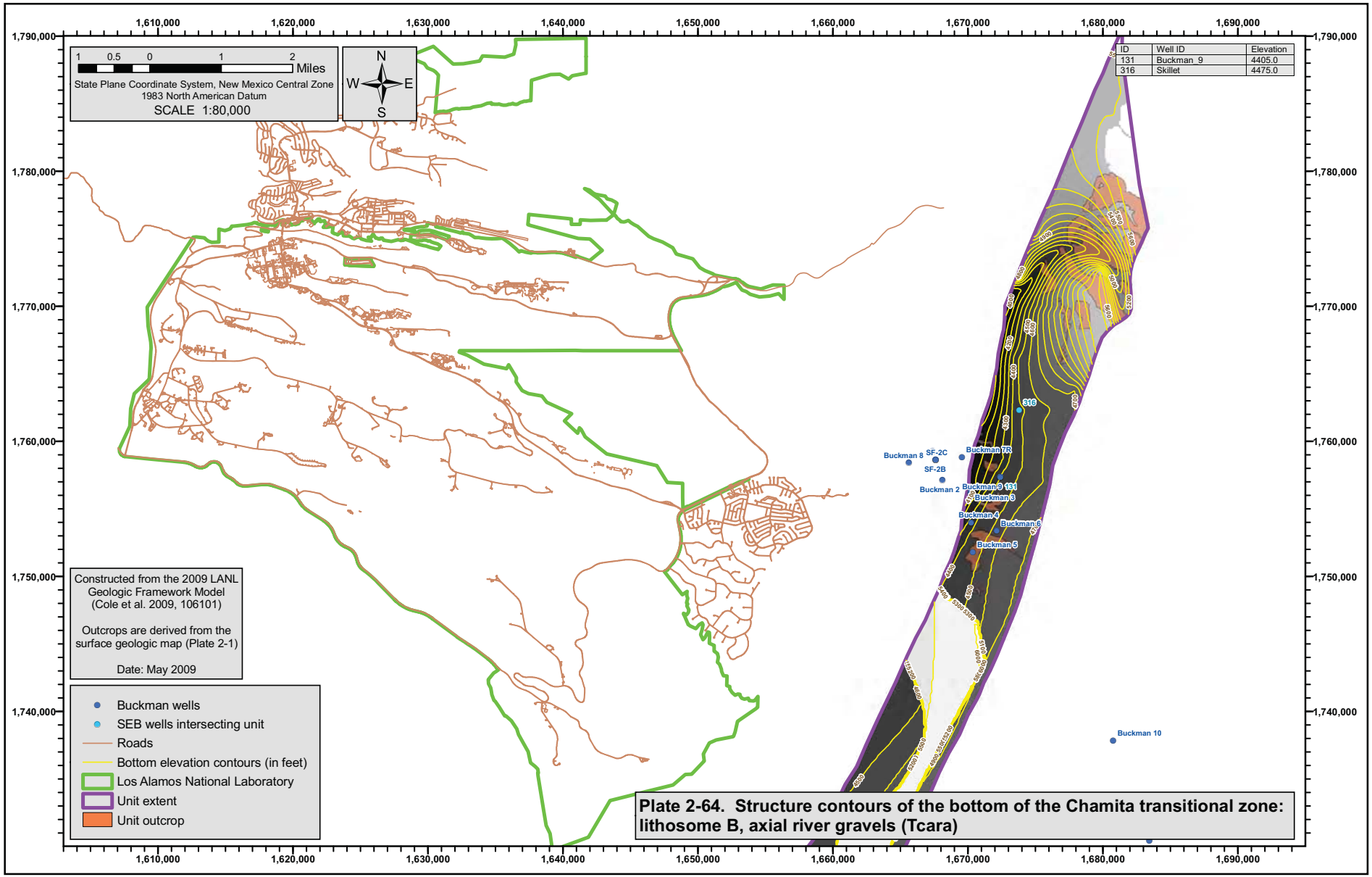


Plate 2-64. Structure contours of the bottom of the Chamita transitional zone: lithosome B, axial river gravels (Tcara)

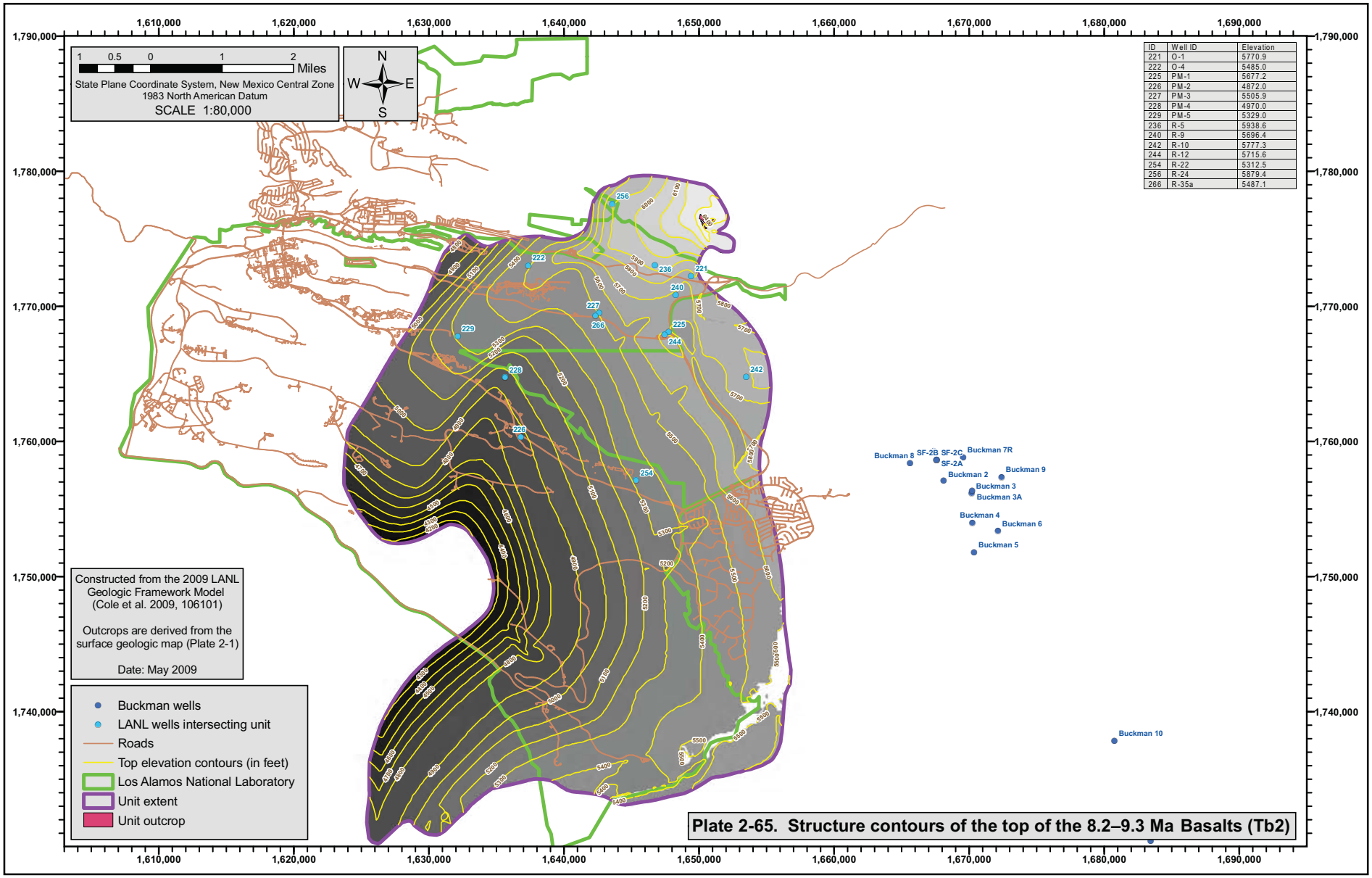
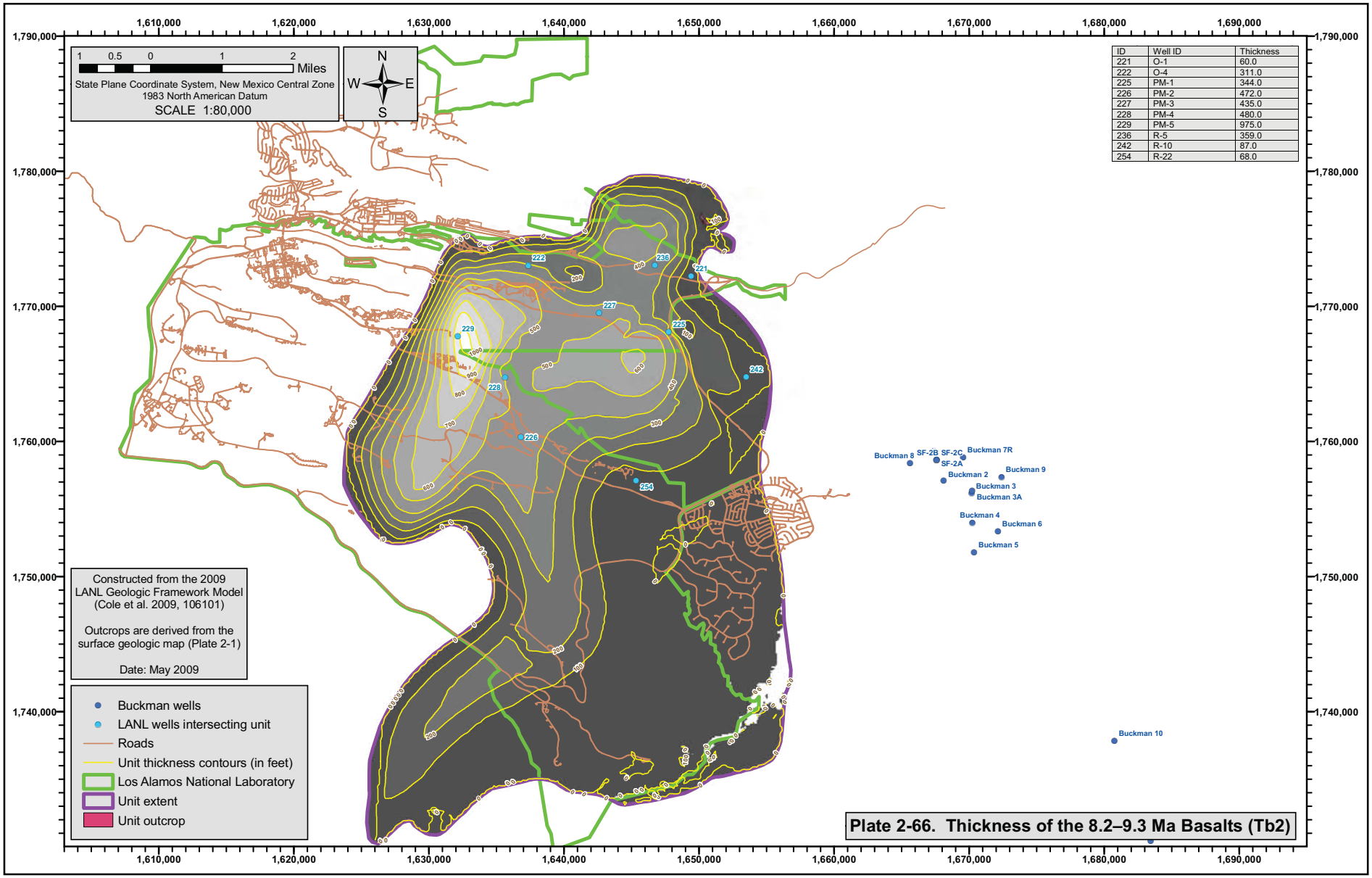


Plate 2-65. Structure contours of the top of the 8.2–9.3 Ma Basalts (Tb2)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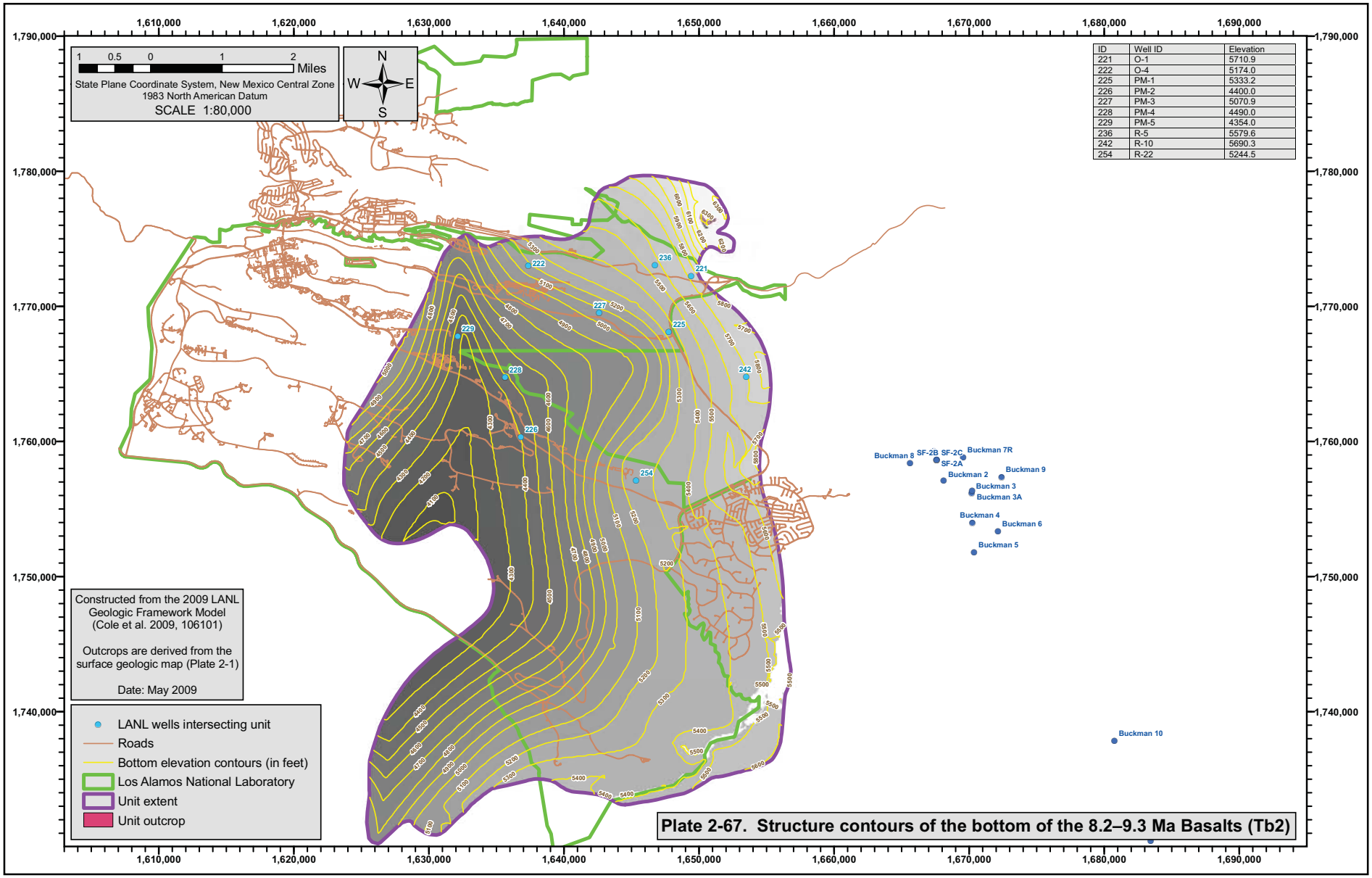
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Thickness
221 | O-1 | 60.0
222 | O-4 | 311.0
225 | PM-1 | 344.0
226 | PM-2 | 472.0
227 | PM-3 | 435.0
228 | PM-4 | 480.0
229 | PM-5 | 975.0
236 | R-5 | 359.0
242 | R-10 | 87.0
254 | R-22 | 68.0
Buckman 8
SF-2B
SF-2C
SF-2A
Buckman 7R
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-66. Thickness of the 8.2–9.3 Ma Basalts (Tb2)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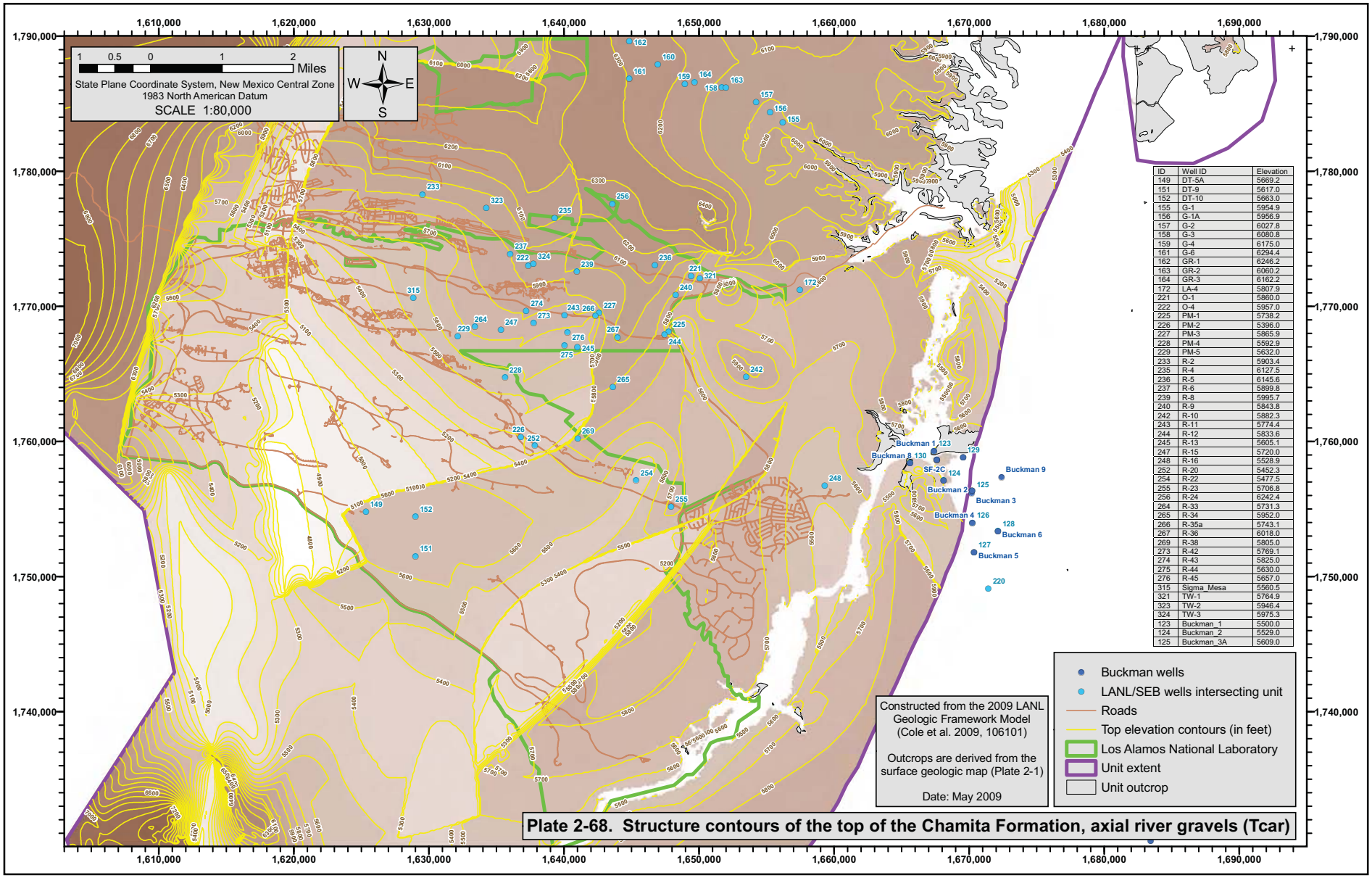
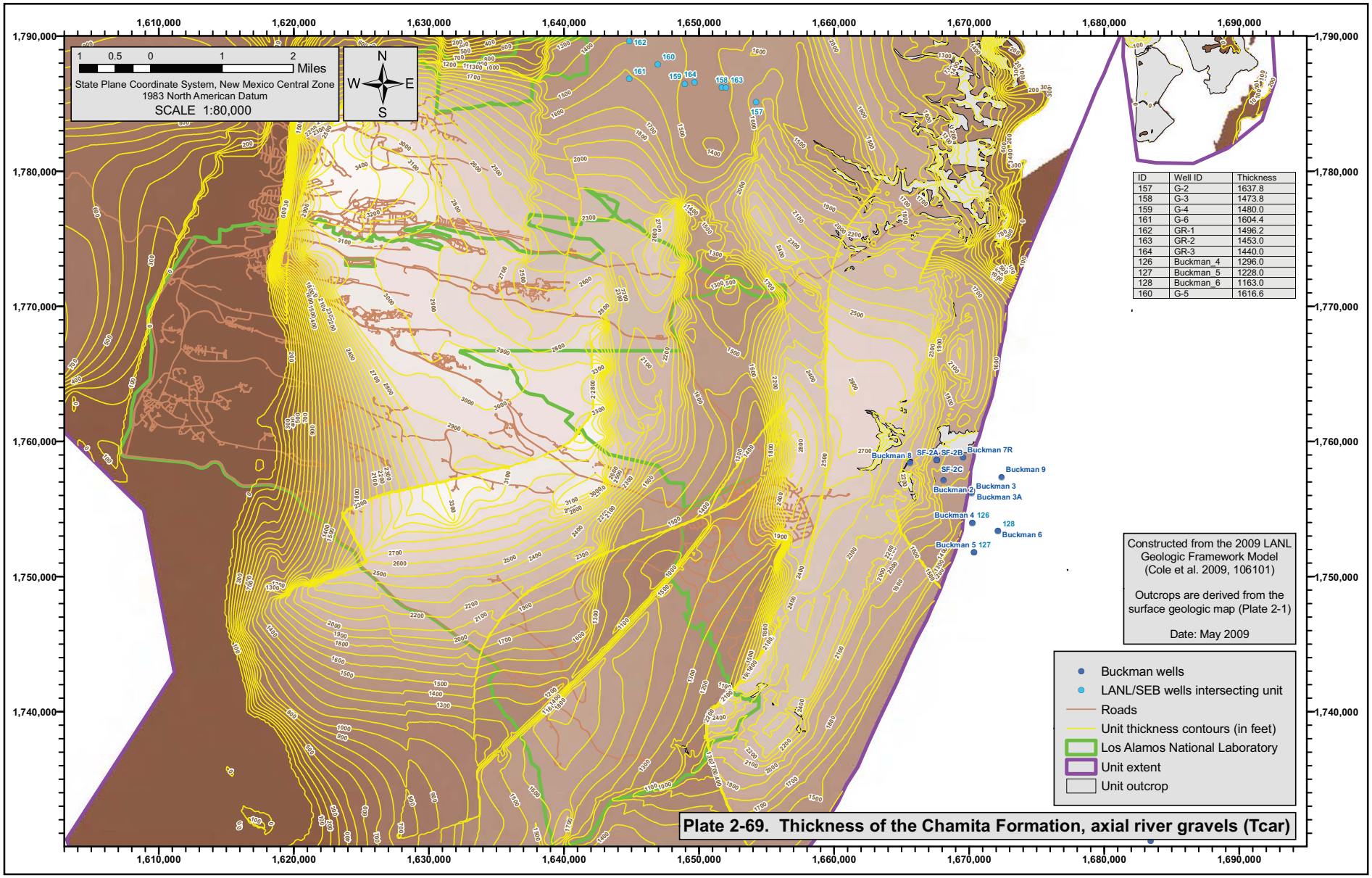
1,740,000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
W E
S
ID | Well ID | Elevation
221 | O-1 | 5710.9
222 | O-4 | 5174.0
225 | PM-1 | 5333.2
226 | PM-2 | 4400.0
227 | PM-3 | 5070.9
228 | PM-4 | 4490.0
229 | PM-5 | 4354.0
236 | R-5 | 5579.6
242 | R-10 | 5690.3
254 | R-22 | 5244.5
Buckman 8
SF-2B
SF-2C
SF-2A
Buckman 7R
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
LANL wells intersecting unit
Roads
Bottom elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-67. Structure contours of the bottom of the 8.2–9.3 Ma Basalts (Tb2)



ID	Well ID	Elevation
149	DT-5A	5669.2
151	DT-9	5617.0
152	DT-10	5663.0
155	G-1	5954.9
156	G-1A	5956.9
157	G-2	6027.8
158	G-3	6080.8
159	G-4	6175.0
161	G-6	6294.4
162	GR-1	6246.2
163	GR-2	6060.2
164	GR-3	6162.2
172	LA-4	5807.9
221	O-1	5860.0
222	O-4	5957.0
225	PM-1	5738.2
226	PM-2	5396.0
227	PM-3	5865.9
228	PM-4	5592.9
229	PM-5	5632.0
233	R-2	5903.4
235	R-4	6127.5
236	R-5	6145.6
237	R-6	5899.8
239	R-8	5995.7
240	R-9	5843.8
242	R-10	5882.3
243	R-11	5774.4
244	R-12	5833.6
245	R-13	5605.1
247	R-15	5720.0
248	R-16	5528.9
252	R-20	5452.3
254	R-22	5477.5
255	R-23	5706.8
256	R-24	6242.4
264	R-33	5731.3
265	R-34	5952.0
266	R-35a	5743.1
267	R-36	6018.0
269	R-38	5805.0
273	R-42	5769.1
274	R-43	5825.0
275	R-44	5630.0
276	R-45	5657.0
315	Sigma_Mesa	5560.5
321	TW-1	5764.9
323	TW-2	5946.4
324	TW-3	5975.3
123	Buckman_1	5500.0
124	Buckman_2	5529.0
125	Buckman_3A	5609.0

Plate 2-68. Structure contours of the top of the Chamita Formation, axial river gravels (Tcar)


1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
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1,770,000
1,760,000
1,750,000
1,740,000
Buckman 8
SF-2A
SF-2B
Buckman 7R
SF-2C
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 4
126
128
Buckman 6
Buckman 5
127
ID | Well ID | Thickness
157 | G-2 | 1637.8
158 | G-3 | 1473.8
159 | G-4 | 1480.0
161 | G-6 | 1604.4
162 | GR-1 | 1496.2
163 | GR-2 | 1453.0
164 | GR-3 | 1440.0
126 | Buckman_4 | 1296.0
127 | Buckman_5 | 1228.0
128 | Buckman_6 | 1163.0
160 | G-5 | 1616.6
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL/SEB wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-69. Thickness of the Chamita Formation, axial river gravels (Tcar)

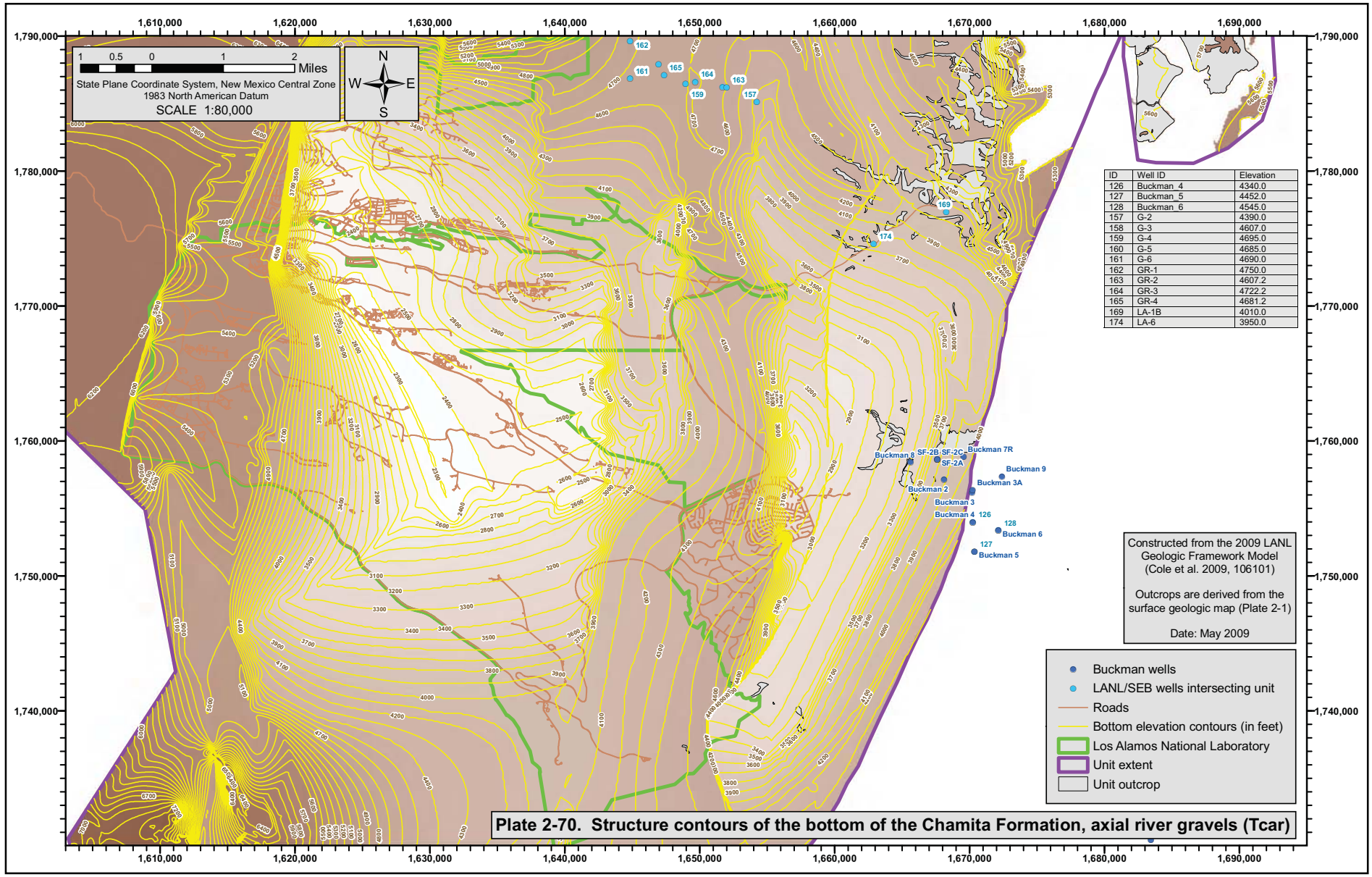


Plate 2-70. Structure contours of the bottom of the Chamita Formation, axial river gravels (Tcar)

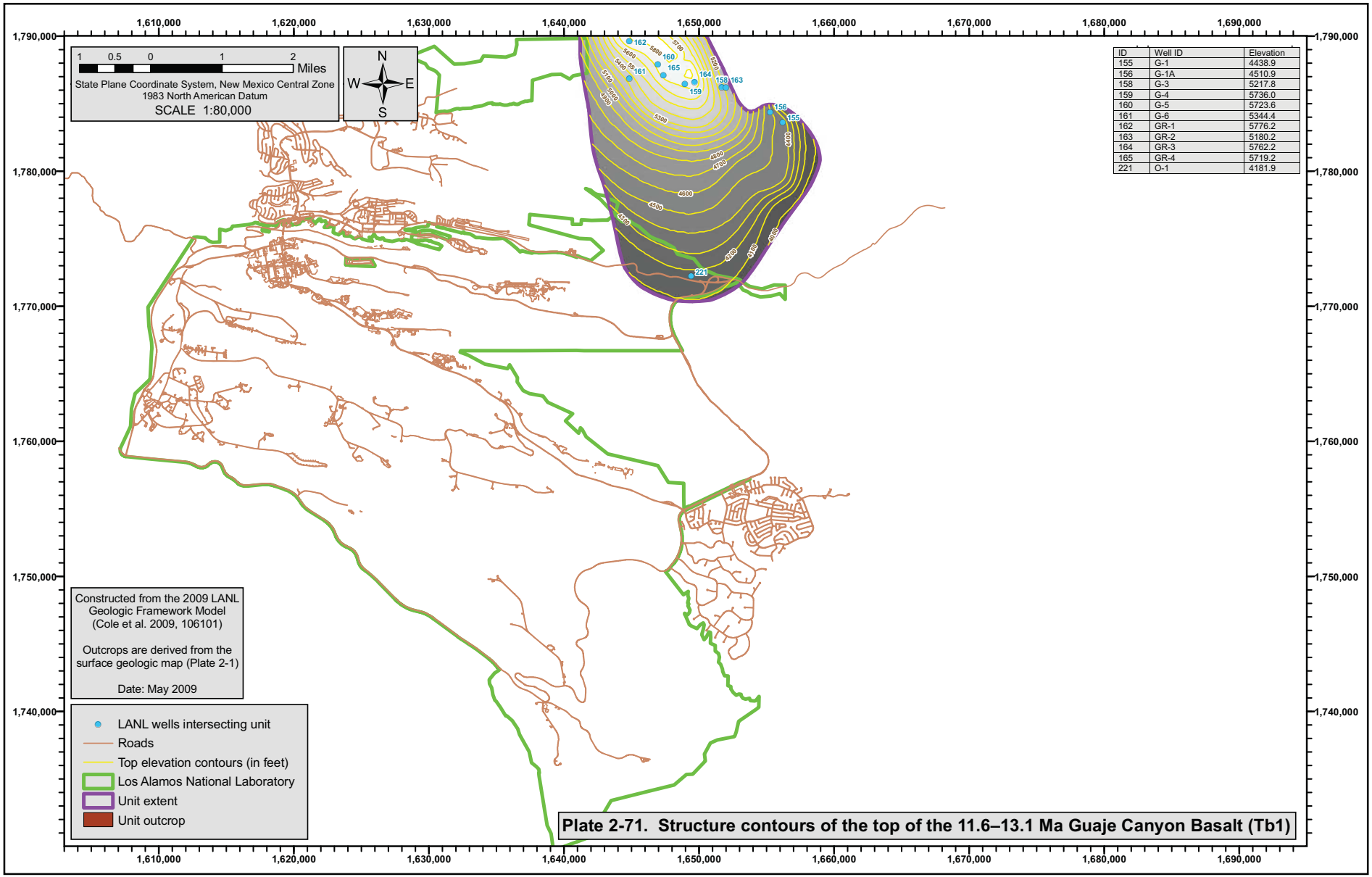


Plate 2-71. Structure contours of the top of the 11.6–13.1 Ma Guaje Canyon Basalt (Tb1)

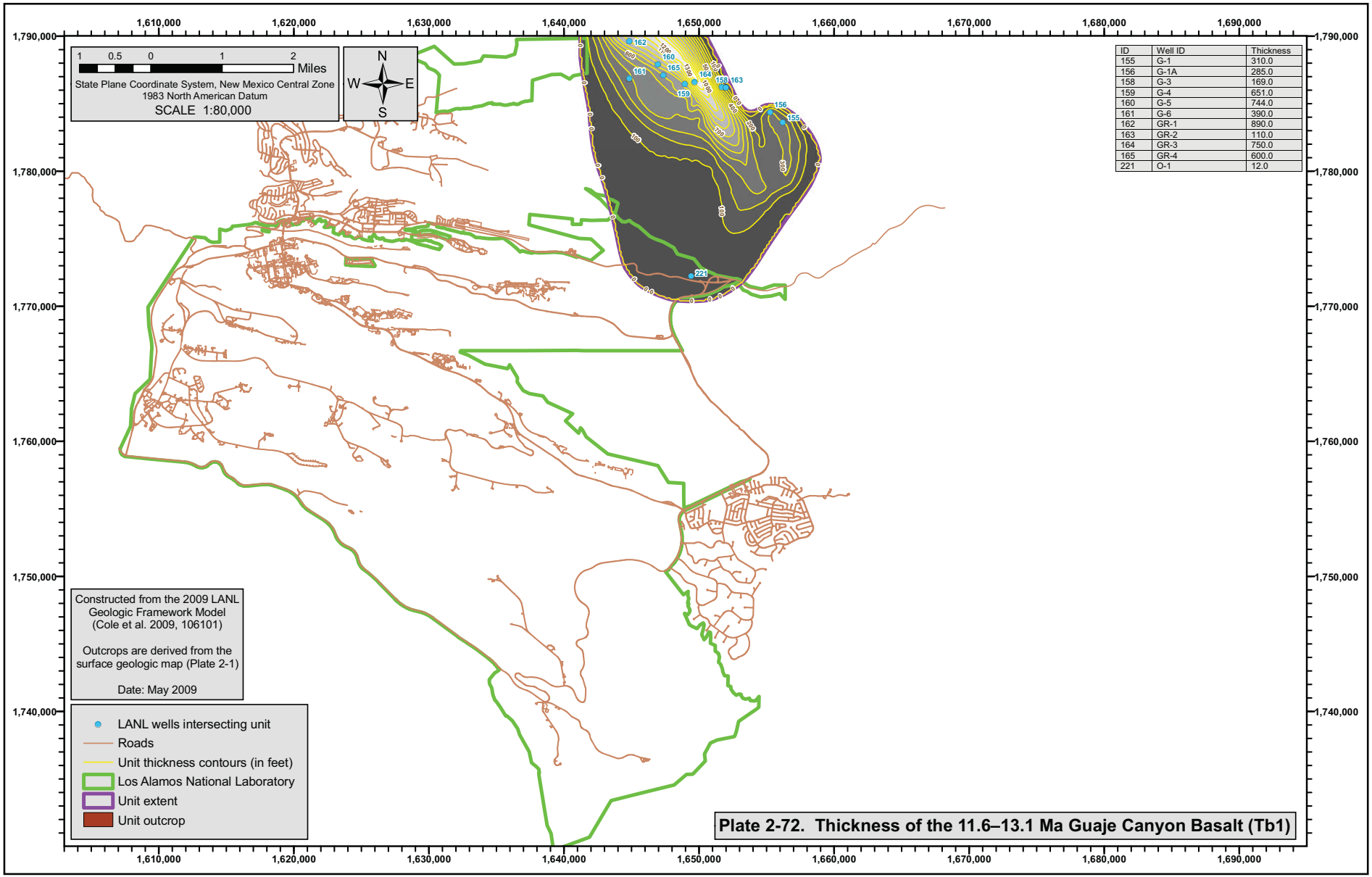


Plate 2-72. Thickness of the 11.6–13.1 Ma Guaje Canyon Basalt (Tb1)

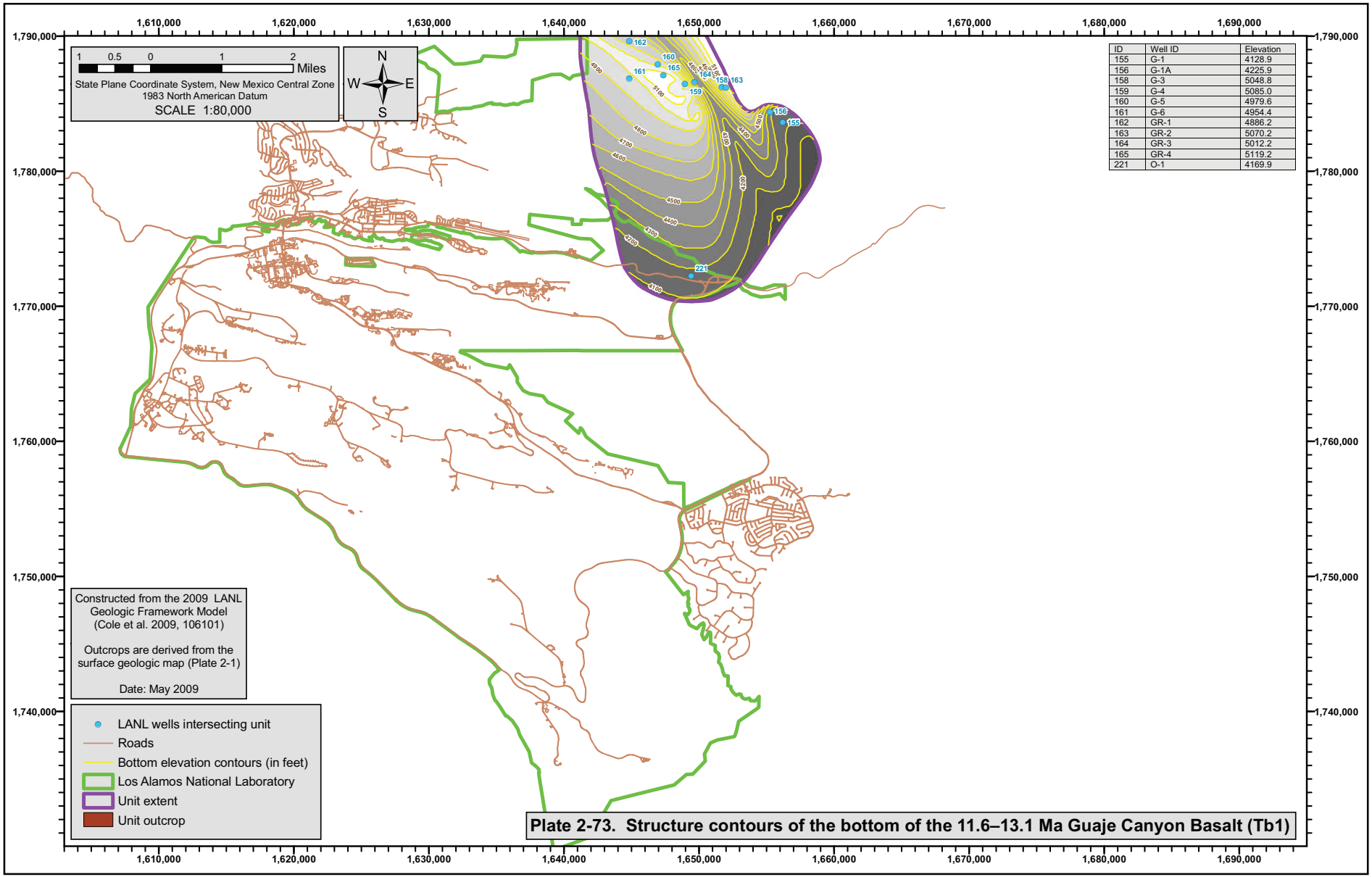


Plate 2-73. Structure contours of the bottom of the 11.6–13.1 Ma Guaje Canyon Basalt (Tb1)

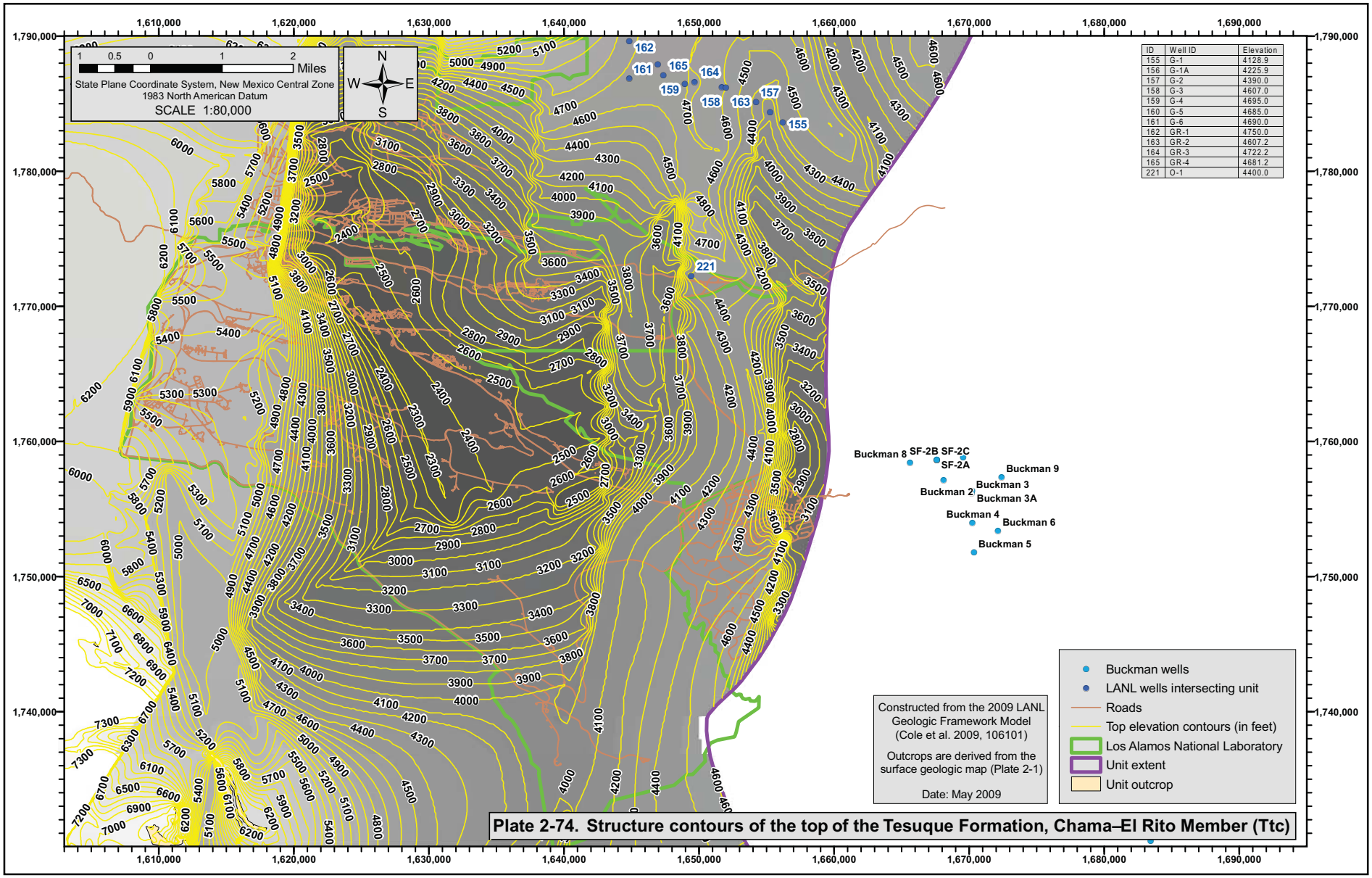
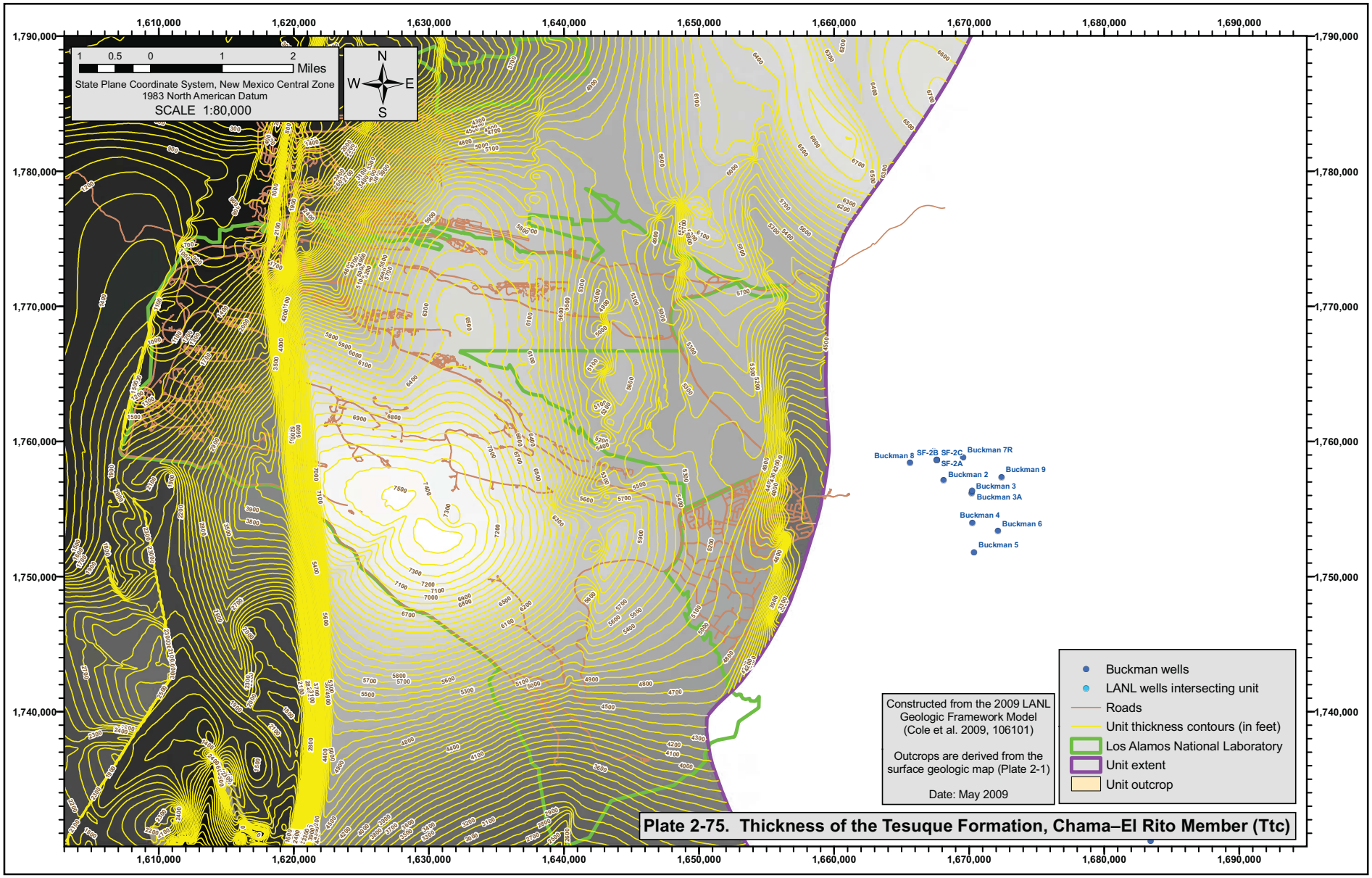


Plate 2-74. Structure contours of the top of the Tesuque Formation, Chama–El Rito Member (Ttc)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1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
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Buckman 8
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SF-2C
Buckman 7R
SF-2A
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Unit thickness contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
Plate 2-75. Thickness of the Tesuque Formation, Chama–El Rito Member (Ttc)

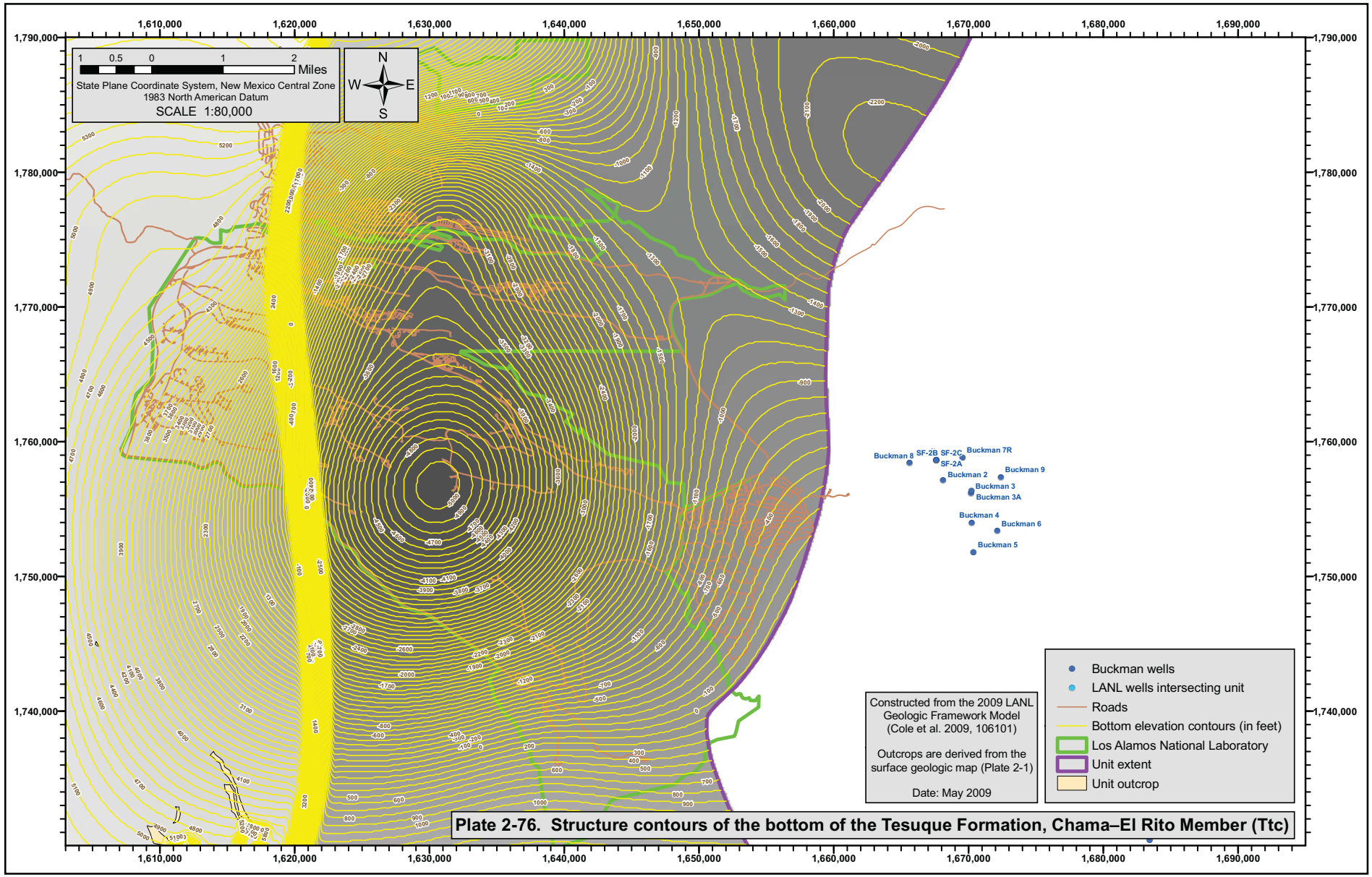


Plate 2-76. Structure contours of the bottom of the Tesuque Formation, Chama–El Rito Member (Ttc)

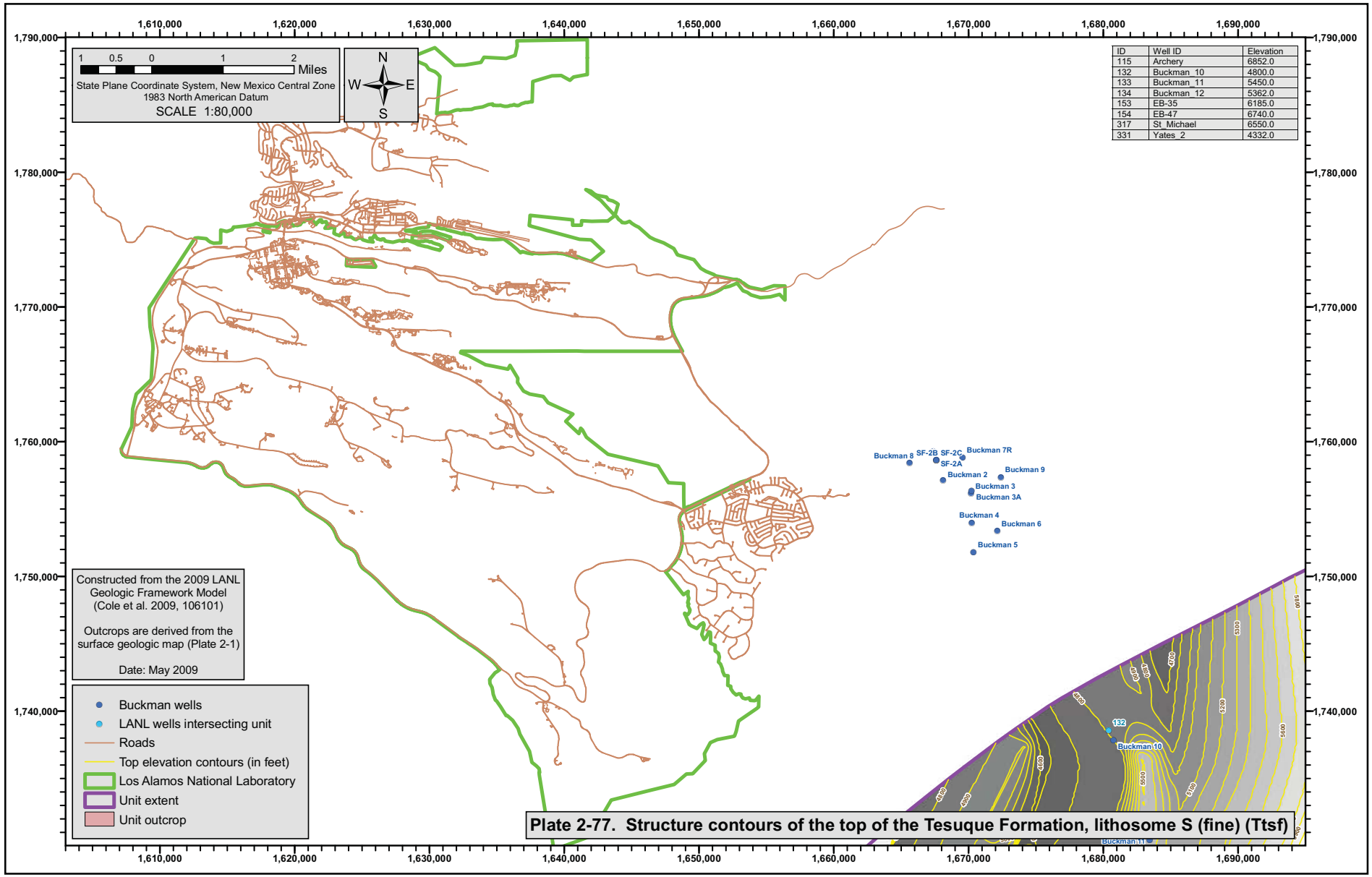


Plate 2-77. Structure contours of the top of the Tesuque Formation, lithosome S (fine) (Ttsf)

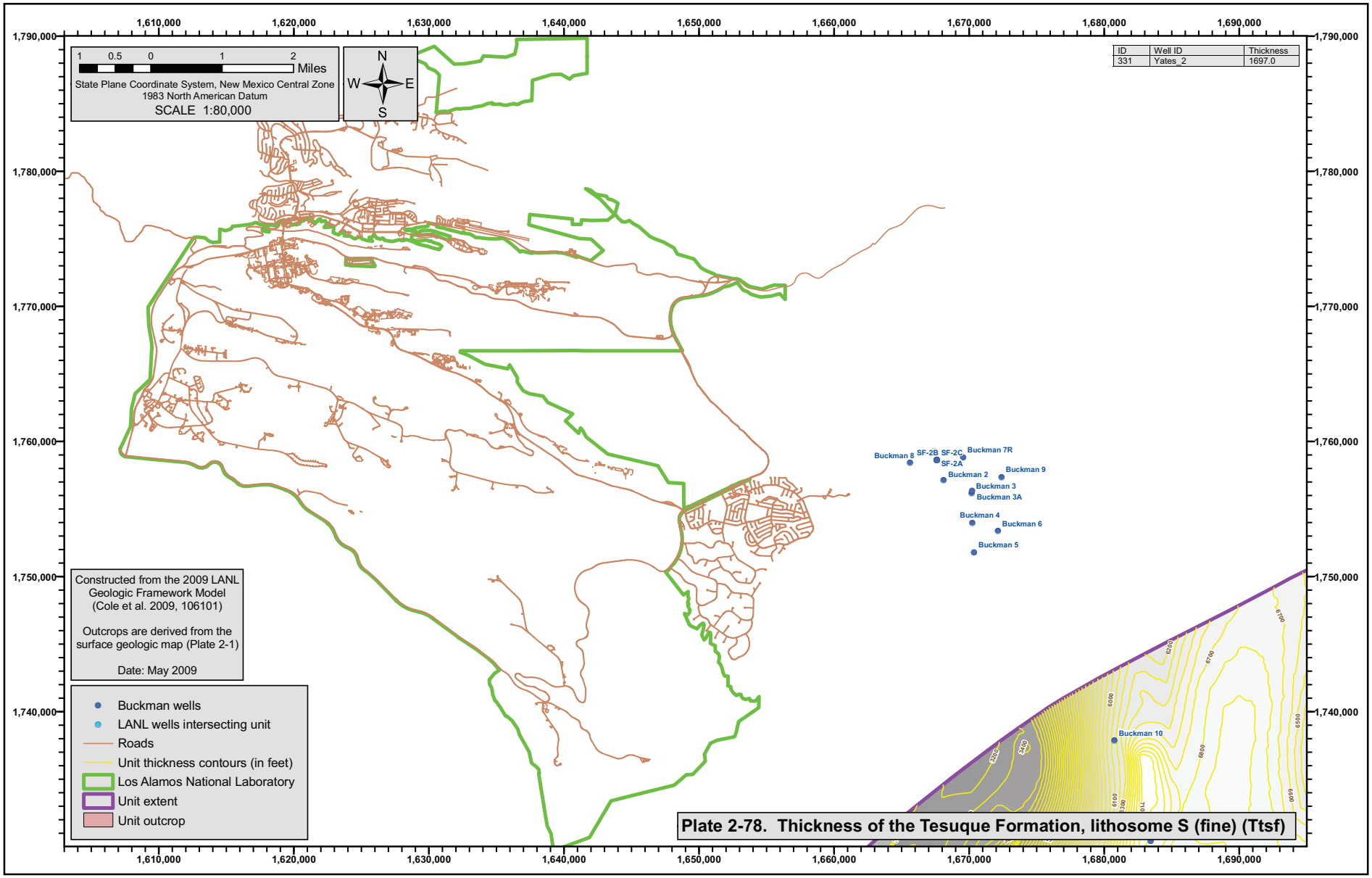


Plate 2-78. Thickness of the Tesuque Formation, lithosome S (fine) (Ttsf)

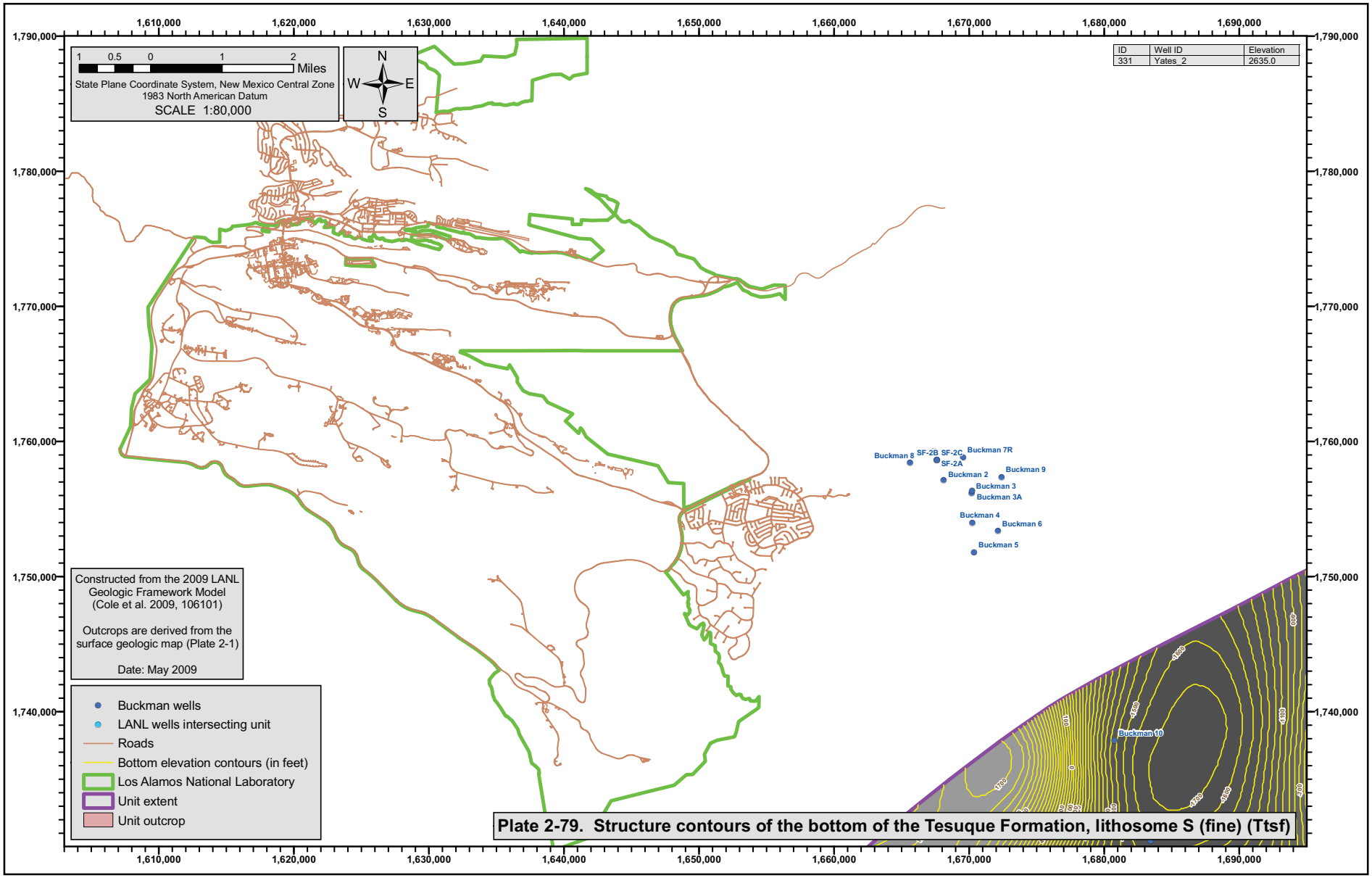
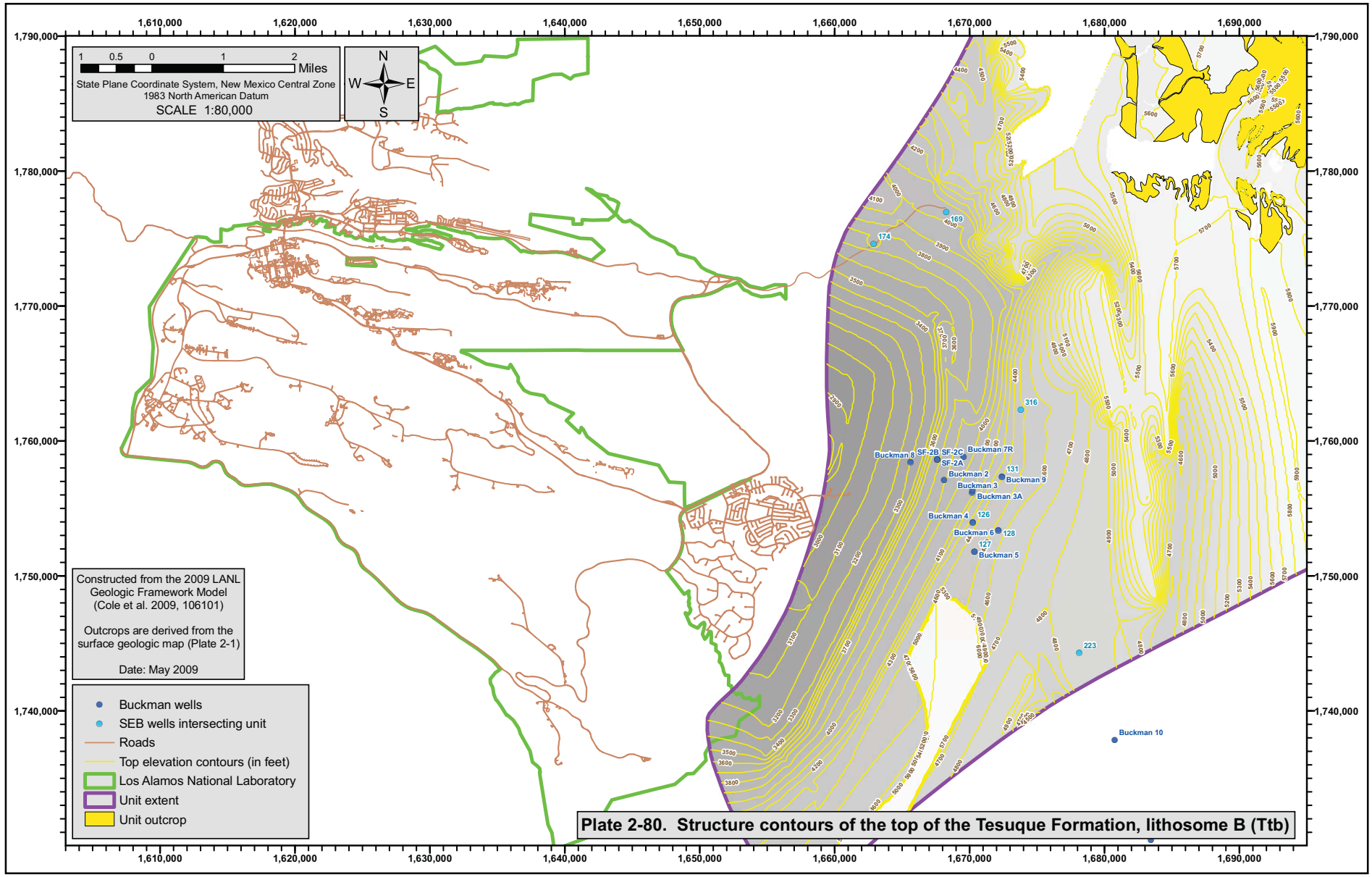


Plate 2-79. Structure contours of the bottom of the Tesuque Formation, lithosome S (fine) (Ttsf)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1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
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Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
SEB wells intersecting unit
Roads
Top elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
169
174
316
131
126
128
127
223
Buckman 8
SF-2B
SF-2C
SF-2A
Buckman 7R
Buckman 2
Buckman 9
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
Plate 2-80. Structure contours of the top of the Tesuque Formation, lithosome B (Ttb)

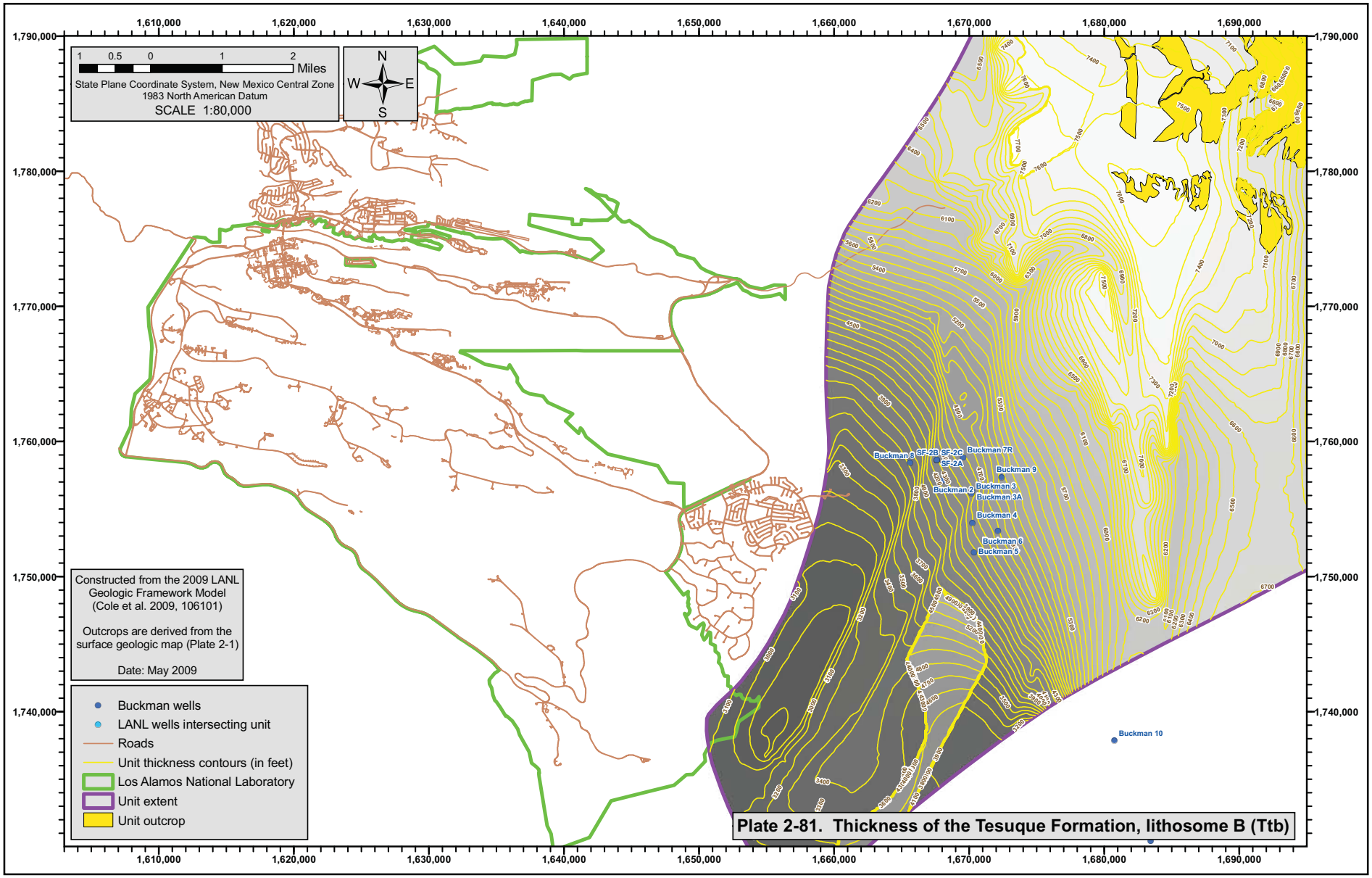


Plate 2-81. Thickness of the Tesuque Formation, lithosome B (Ttb)

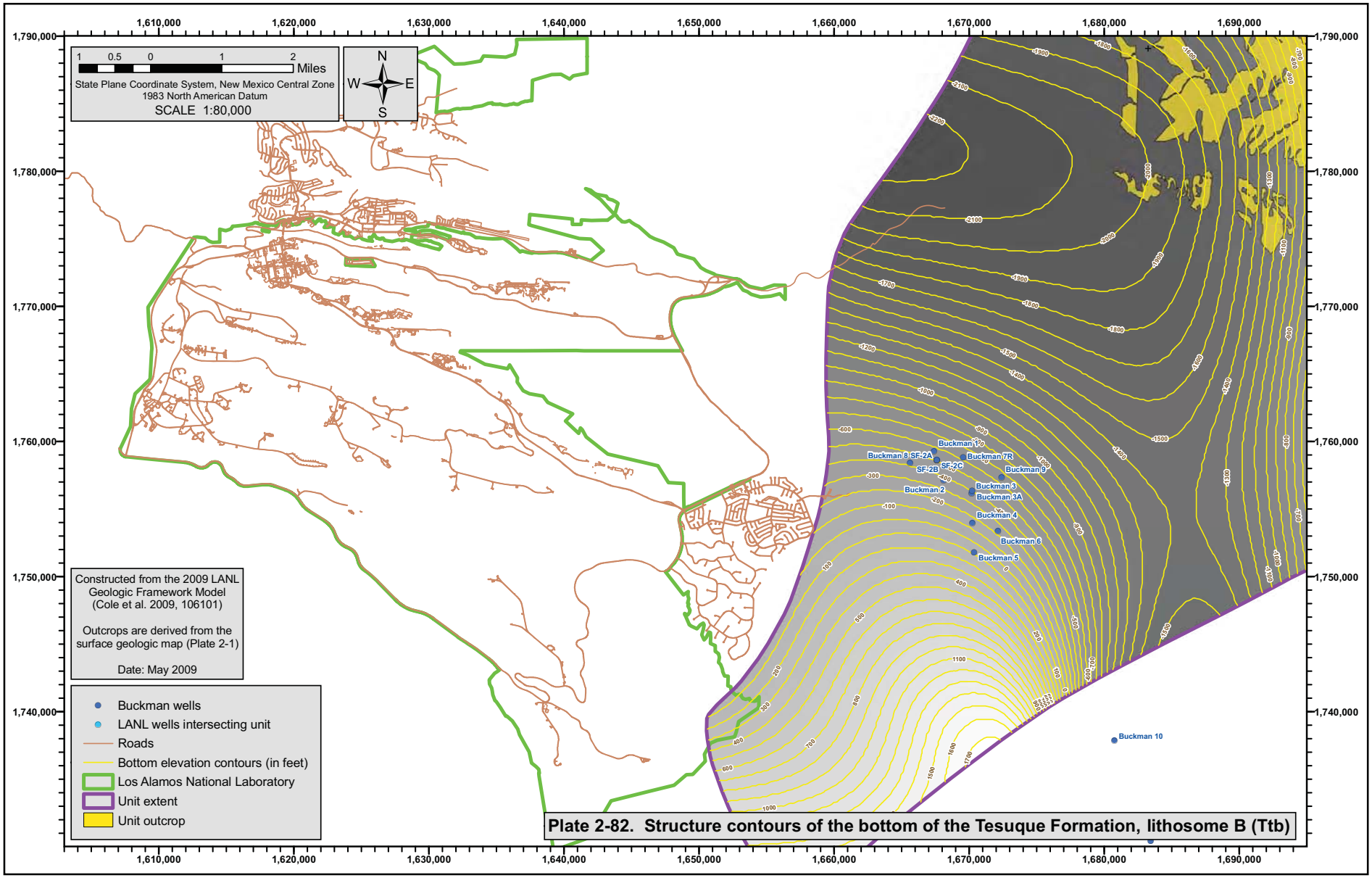
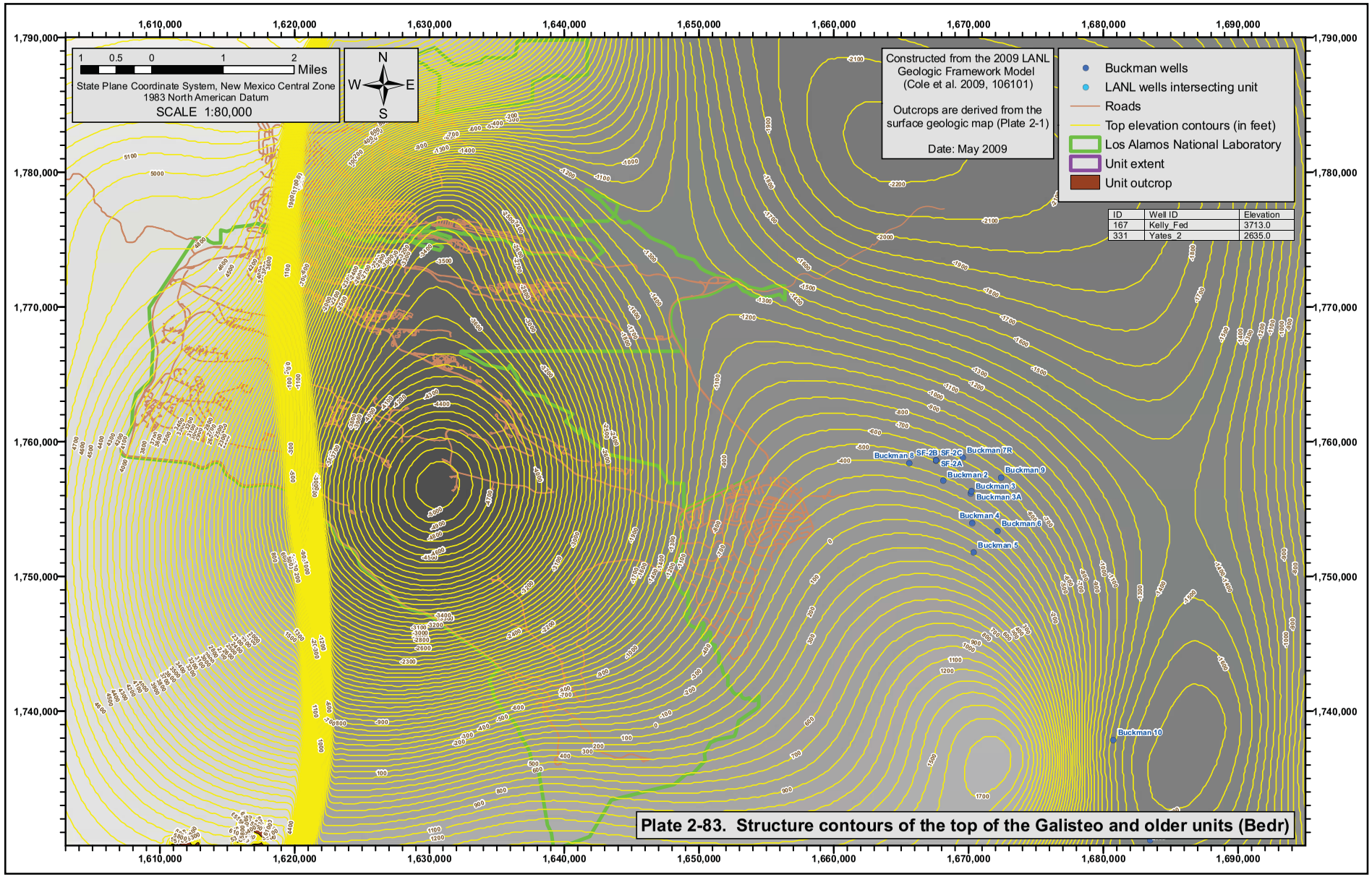


Plate 2-82. Structure contours of the bottom of the Tesuque Formation, lithosome B (Ttb)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State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
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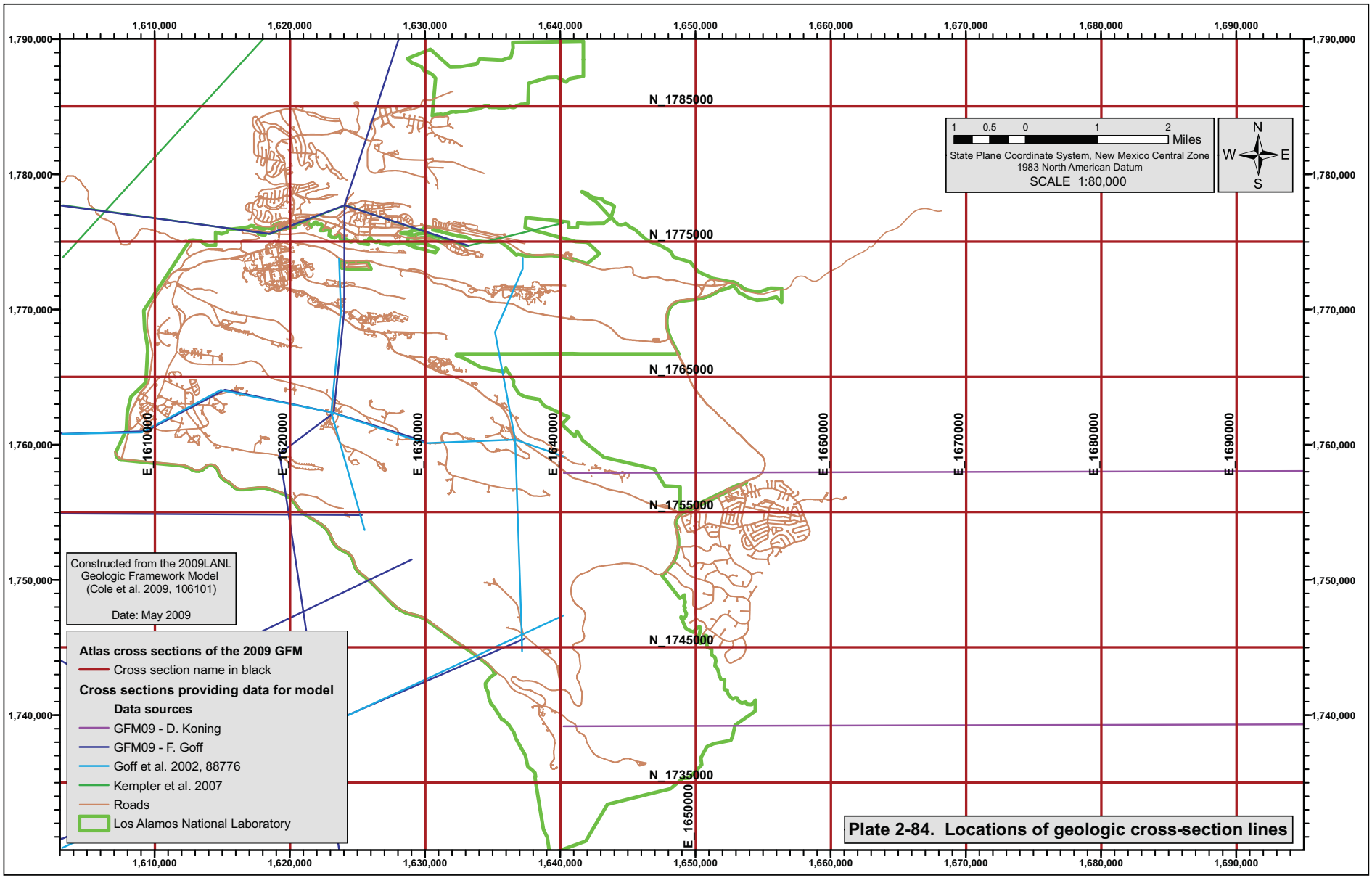
S
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Outcrops are derived from the surface geologic map (Plate 2-1)
Date: May 2009
Buckman wells
LANL wells intersecting unit
Roads
Top elevation contours (in feet)
Los Alamos National Laboratory
Unit extent
Unit outcrop
ID | Well ID | Elevation
167 | Kelly_Fed | 3713.0
331 | Yates_2 | 2635.0
Buckman 8
SF-2B
SF-2C
Buckman 7R
SF-2A
Buckman 9
Buckman 2
Buckman 3
Buckman 3A
Buckman 4
Buckman 6
Buckman 5
Buckman 10
Plate 2-83. Structure contours of the top of the Galisteo and older units (Bedr)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1,750,000
1,740,000
N_1785000
N_1775000
N_1765000
N_1755000
N_1745000
N_1735000
E_1610000
E_1620000
E_1630000
E_1640000
E_1650000
E_1660000
E_1670000
E_1680000
E_1690000
1 0.5 0 1 2 Miles
State Plane Coordinate System, New Mexico Central Zone
1983 North American Datum
SCALE 1:80,000
N
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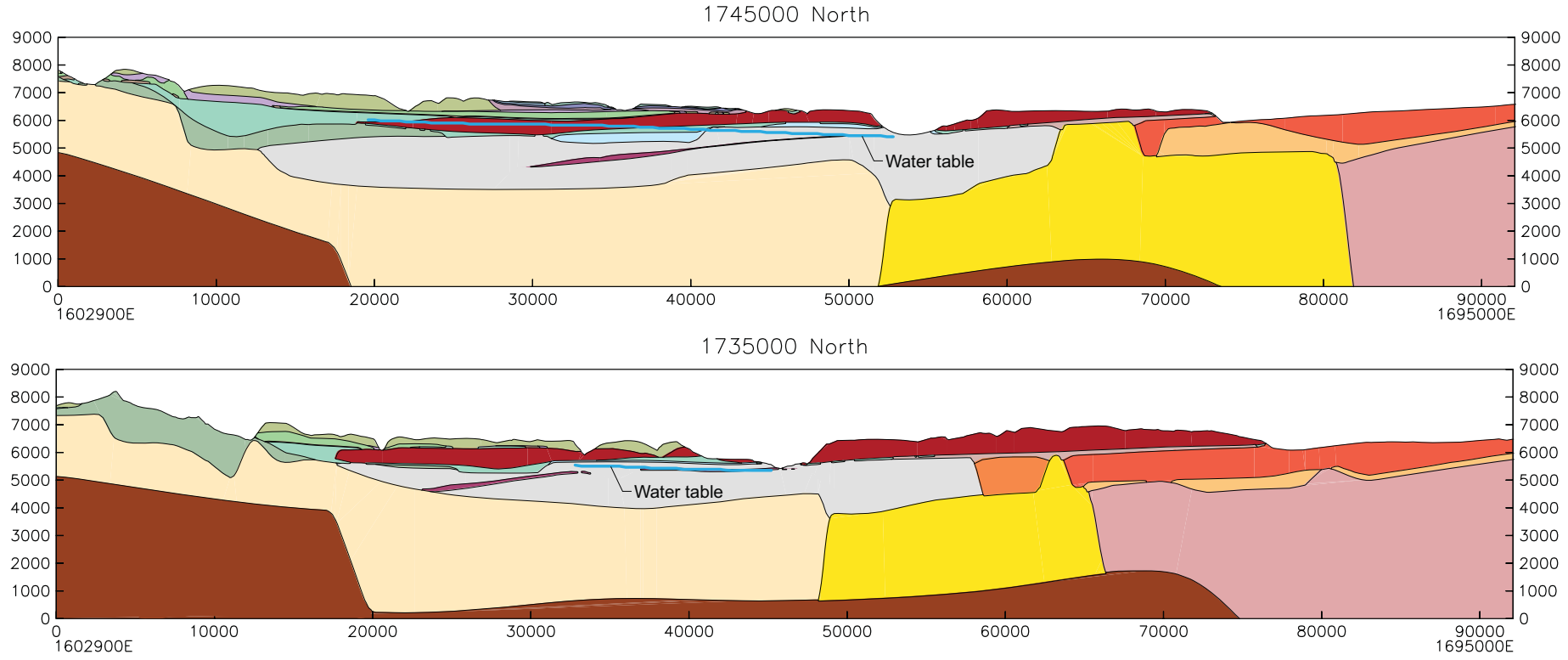
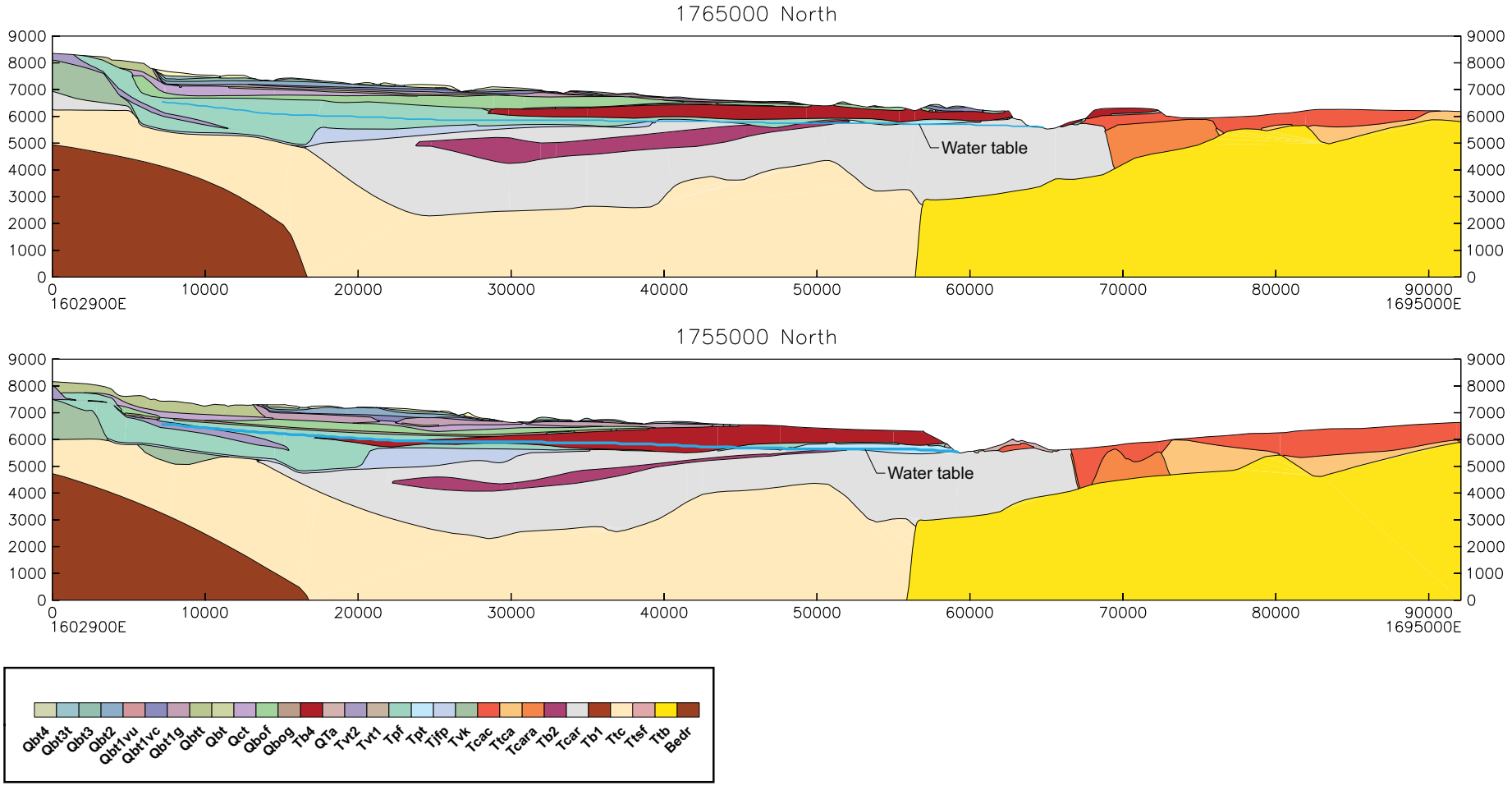
Constructed from the 2009LANL Geologic Framework Model (Cole et al. 2009, 106101)
Date: May 2009
Atlas cross sections of the 2009 GFM
Cross section name in black
Cross sections providing data for model
Data sources
GFM09 - D. Koning
GFM09 - F. Goff
Goff et al. 2002, 88776
Kempter et al. 2007
Roads
Los Alamos National Laboratory
Plate 2-84. Locations of geologic cross-section lines



Note: Vertical exaggeration = 1.75x.

Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101) Date: May 2009

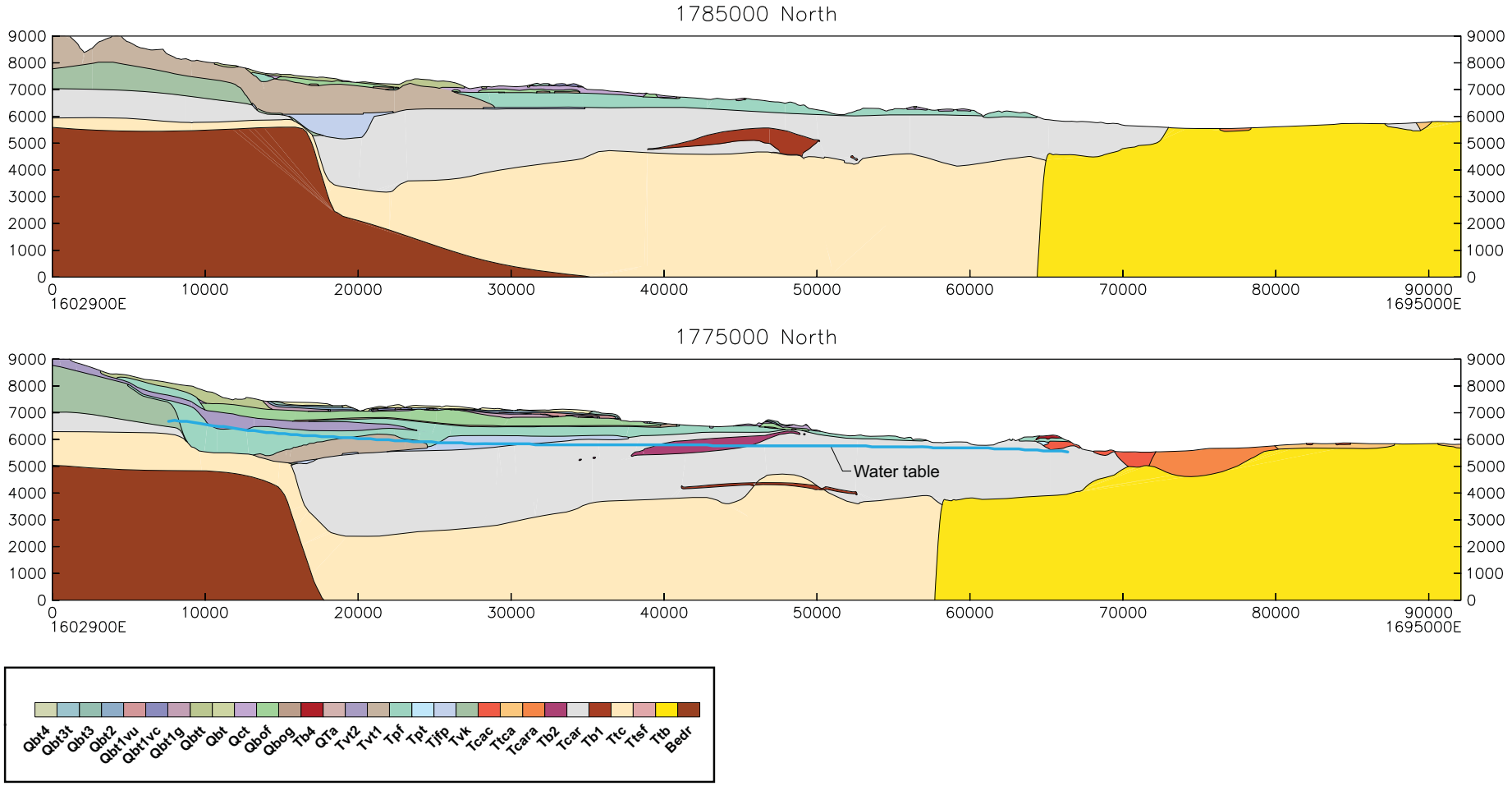
Plate 2-85. Southern east-west cross-sections (N_1735000, N_1745000)



Note: Vertical exaggeration = 1.75x.

Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101) Date: May 2009

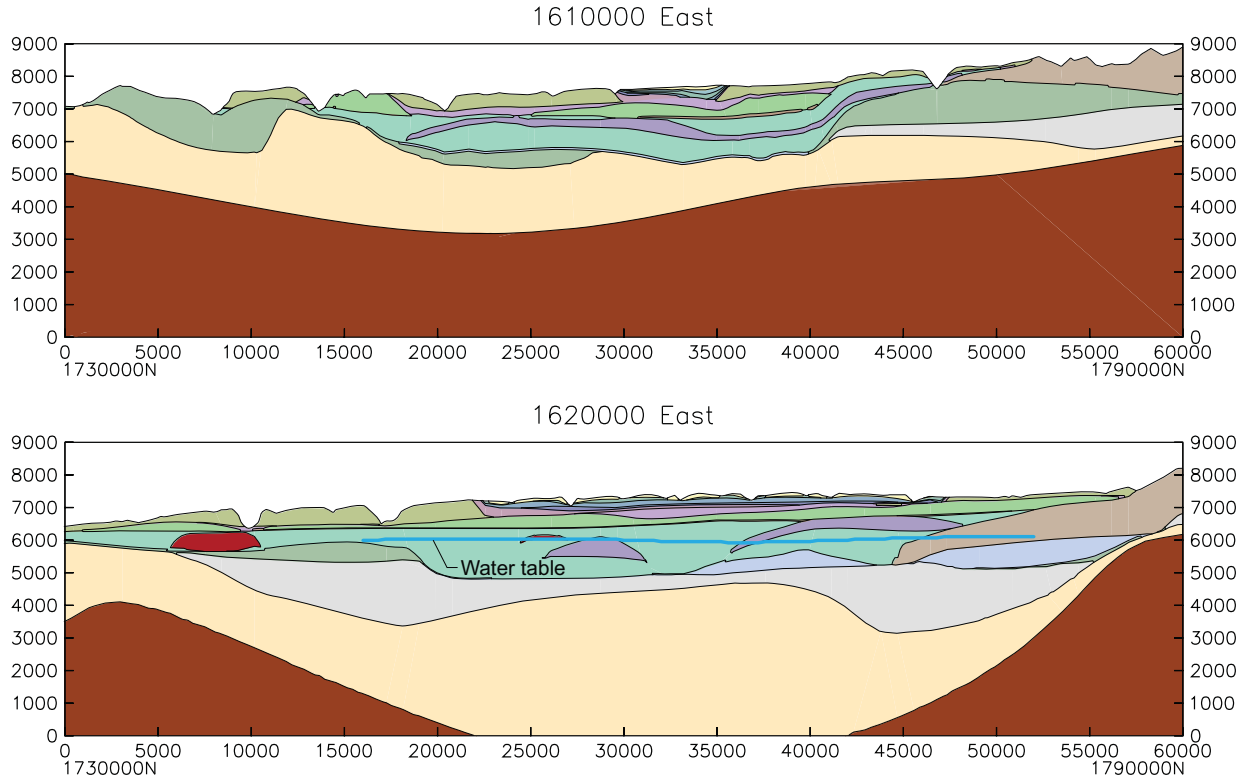
Plate 2-86. Central east-west cross-sections (N_1755000, N_1765000)

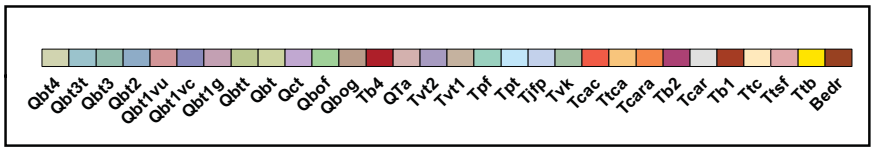


Note: Vertical exaggeration = 1.75x.

Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101) Date: May 2009

Plate 2-87. Northern east-west cross-sections (N_1775000, N_1785000)

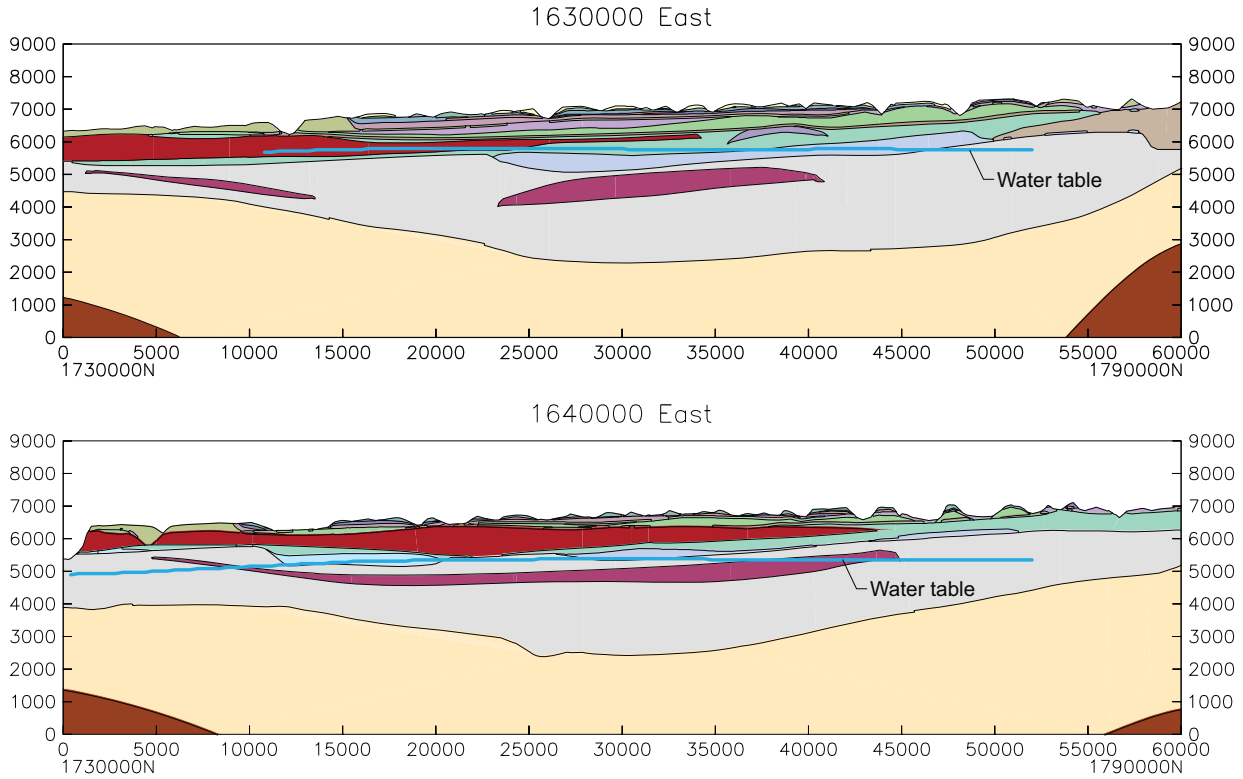


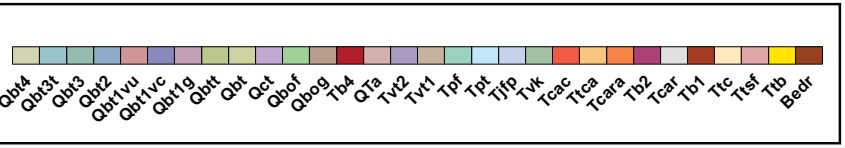


Note: Vertical exaggeration = 1.75x.

Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101) Date: May 2009

Plate 2-88. Western north-south cross-sections (E_1610000, E_1620000)

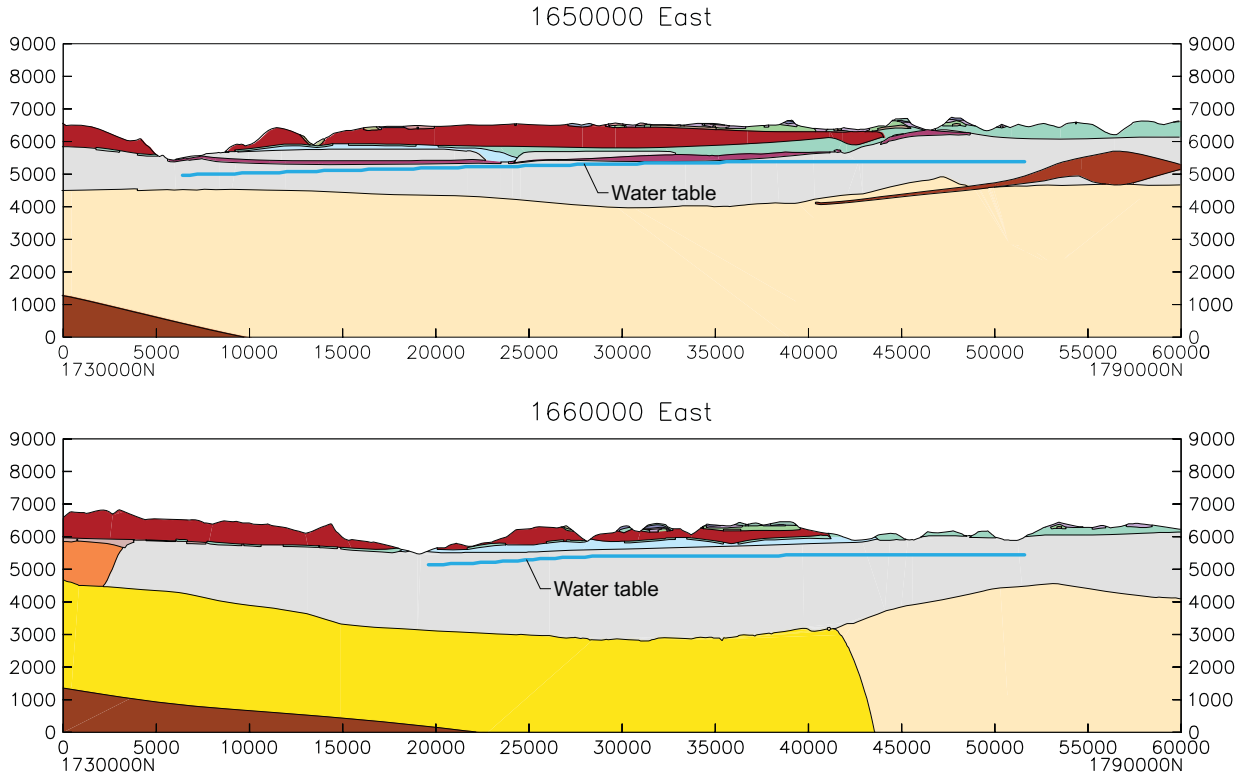


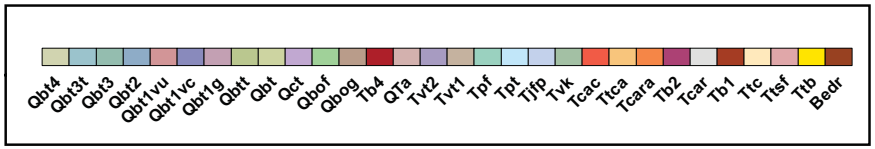


Note: Vertical exaggeration = 1.75x.

Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101) Date: May 2009

Plate 2-89. West central north-south cross-sections (E_1630000, E_1640000)

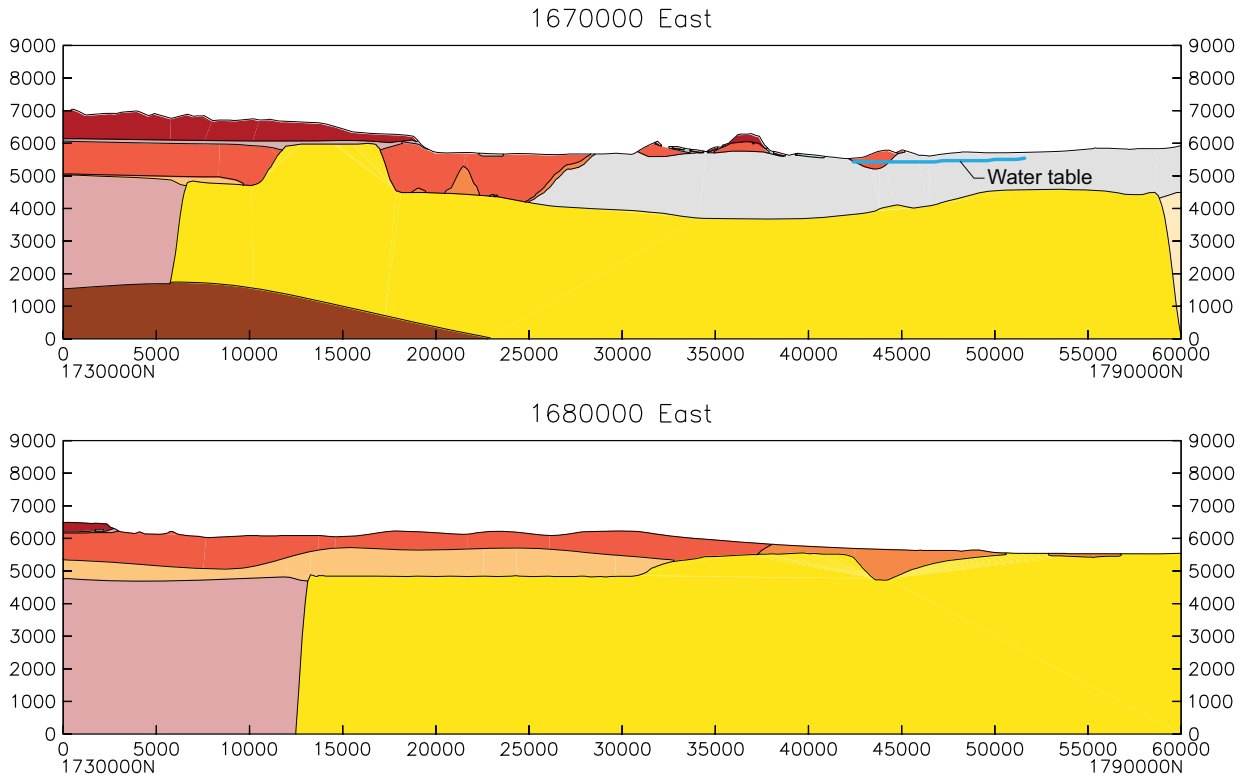




Note: Vertical exaggeration = 1.75x.

Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101) Date: May 2009

Plate 2-90. Central north-south cross-sections (E_1650000, E_1660000)

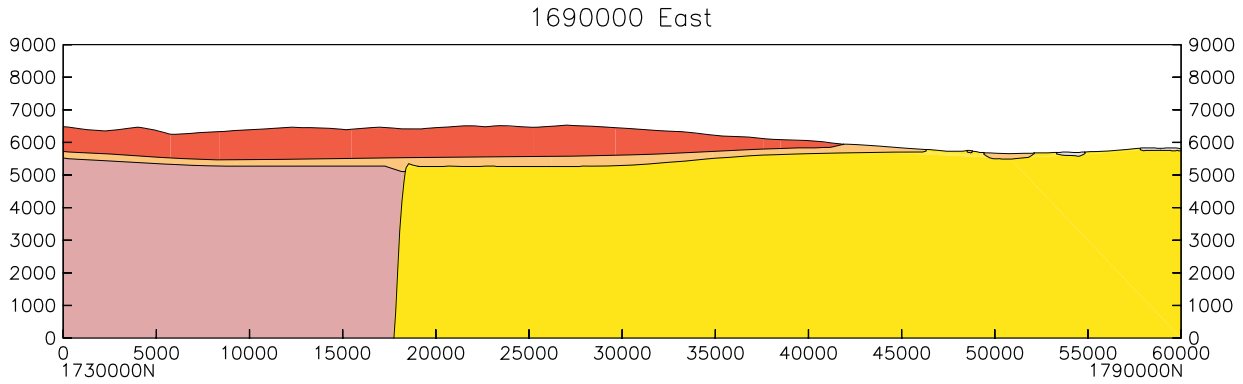


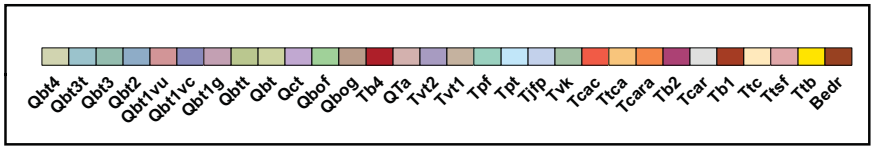


Note: Vertical exaggeration = 1.75x.

Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101) Date: May 2009

Plate 2-91. East central north-south cross-sections (E_1670000, E_1680000)

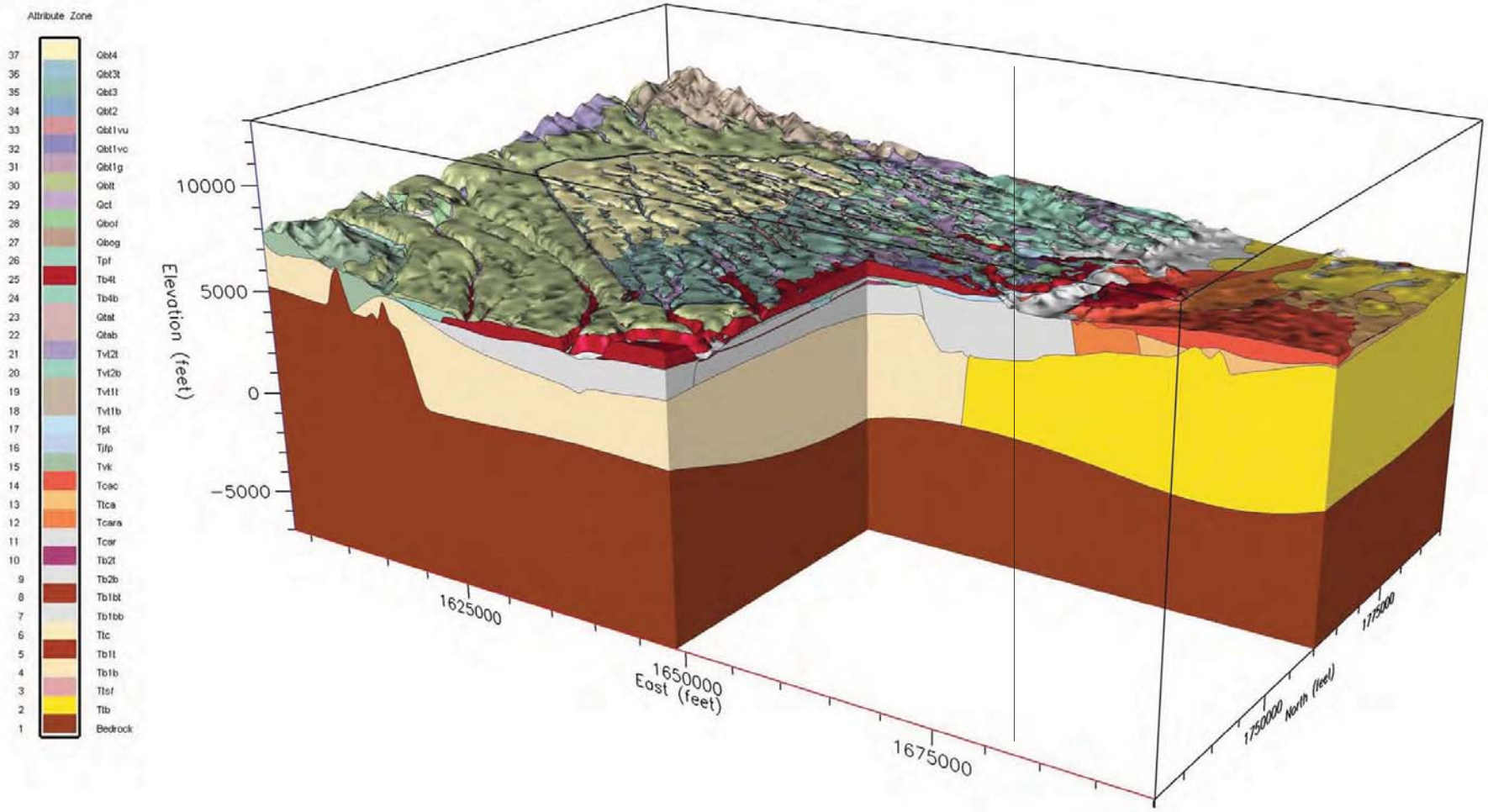




Note: Vertical exaggeration = 1.75x.

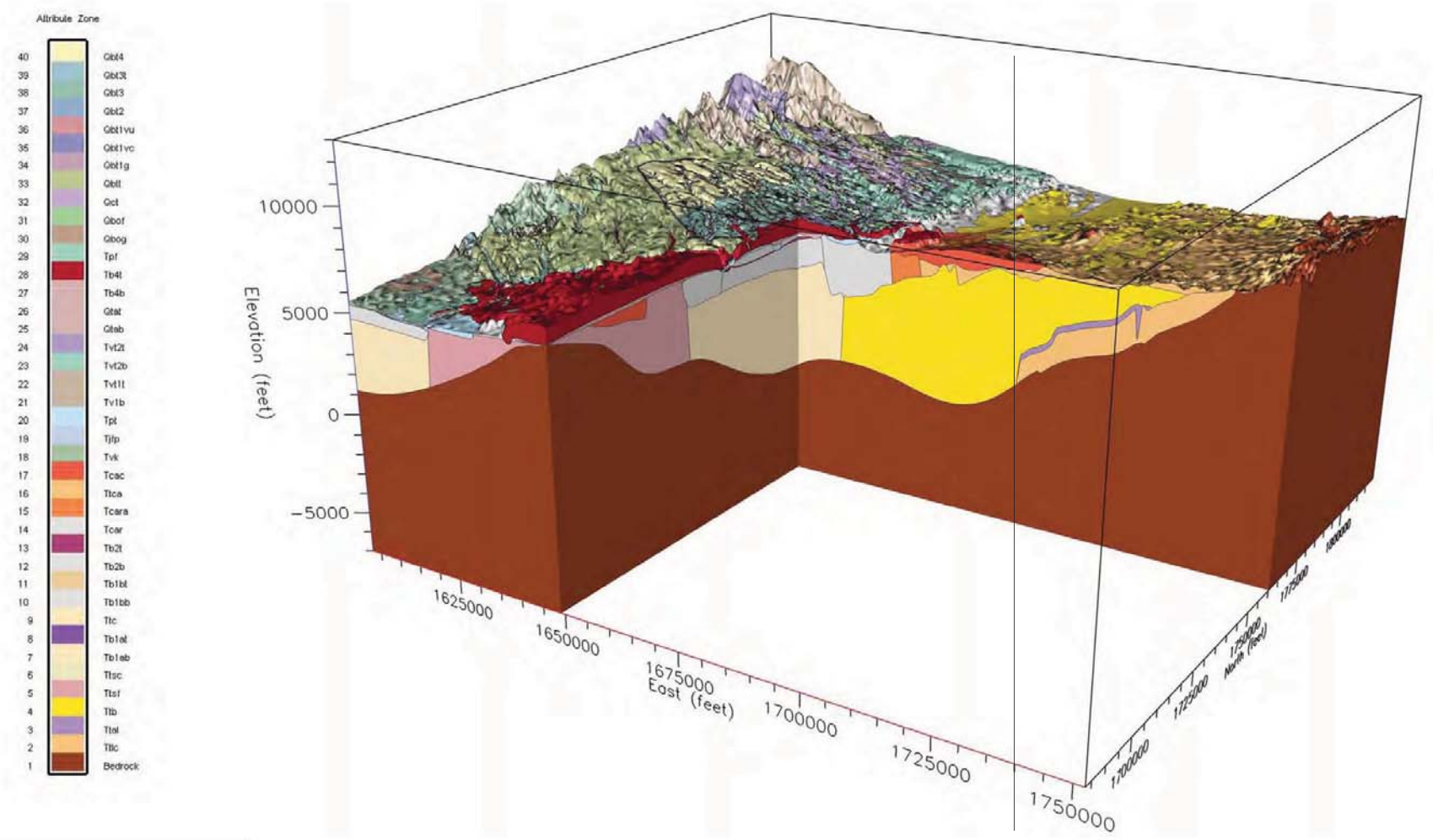
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101) Date: May 2009

Plate 2-92. Eastern north-south cross-section (E_1690000)



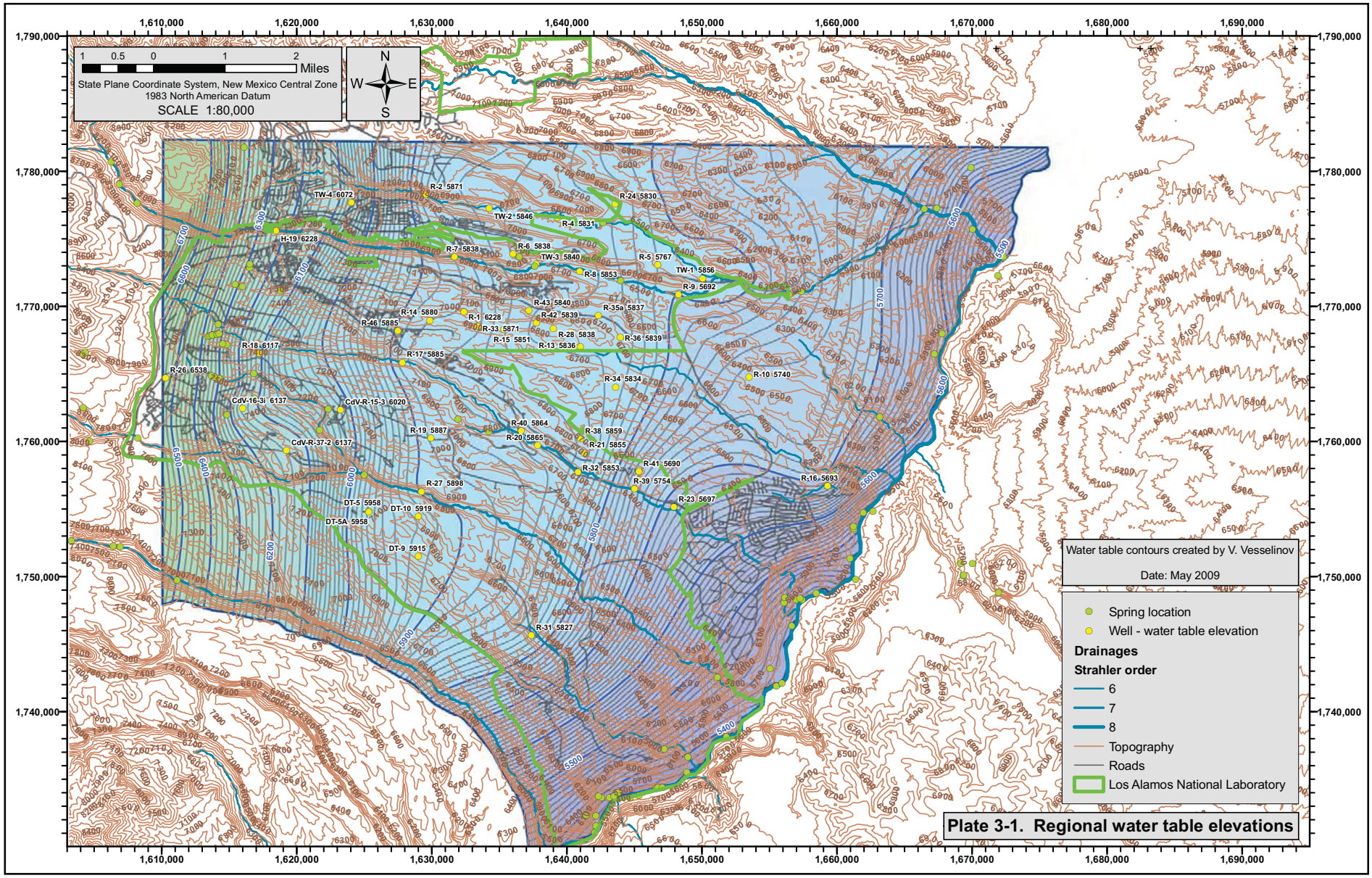
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Date: May 2009

Plate 2-93. The atlas portion of the southern Española Basin model—view from the southeast



Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Date: May 2009

Plate 2-94. The southern Española Basin model—view from the southeast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R-42 5839
R-46 5885
R-33 5871
R-28 5838
R-15 5851
R-13 5836
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R-17 5885
R-26 6538
R-34 5834
R-10 5740
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CdV-R-15-3 6020
R-40 5864
R-19 5887
R-38 5859
R-20 5865
R-21 5855
CdV-R-37-2 6137
R-32 5853
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R-27 5898
R-39 5754
R-16 5693
R-23 5697
DT-5 5958
DT-10 5919
DT-5A 5958
DT-9 5915
R-31 5827
Water table contours created by V. Vesselinov
Date: May 2009
Spring location
Well - water table elevation
Drainages
Strahler order
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Topography
Roads
Los Alamos National Laboratory
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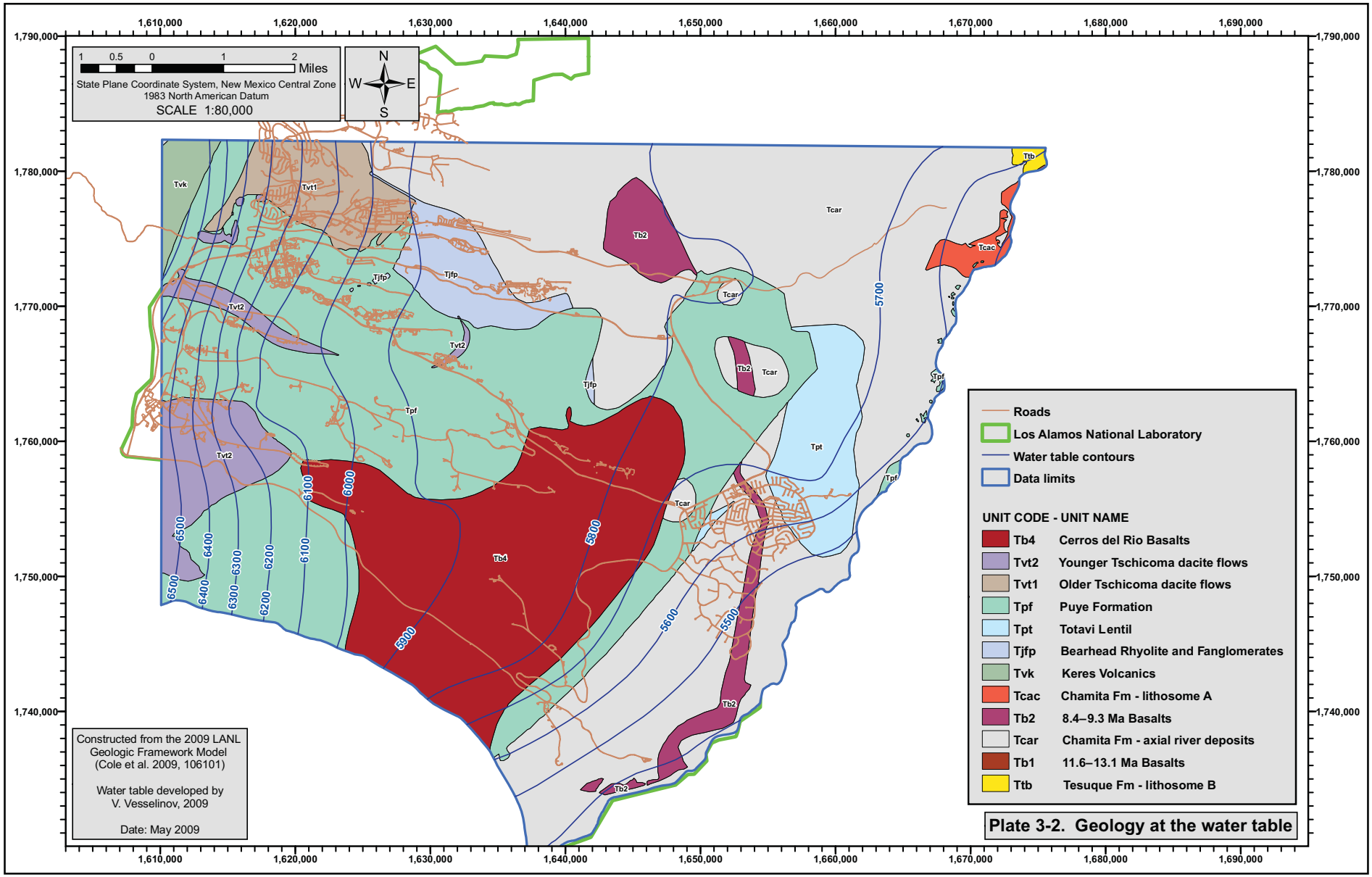
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6300
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5900
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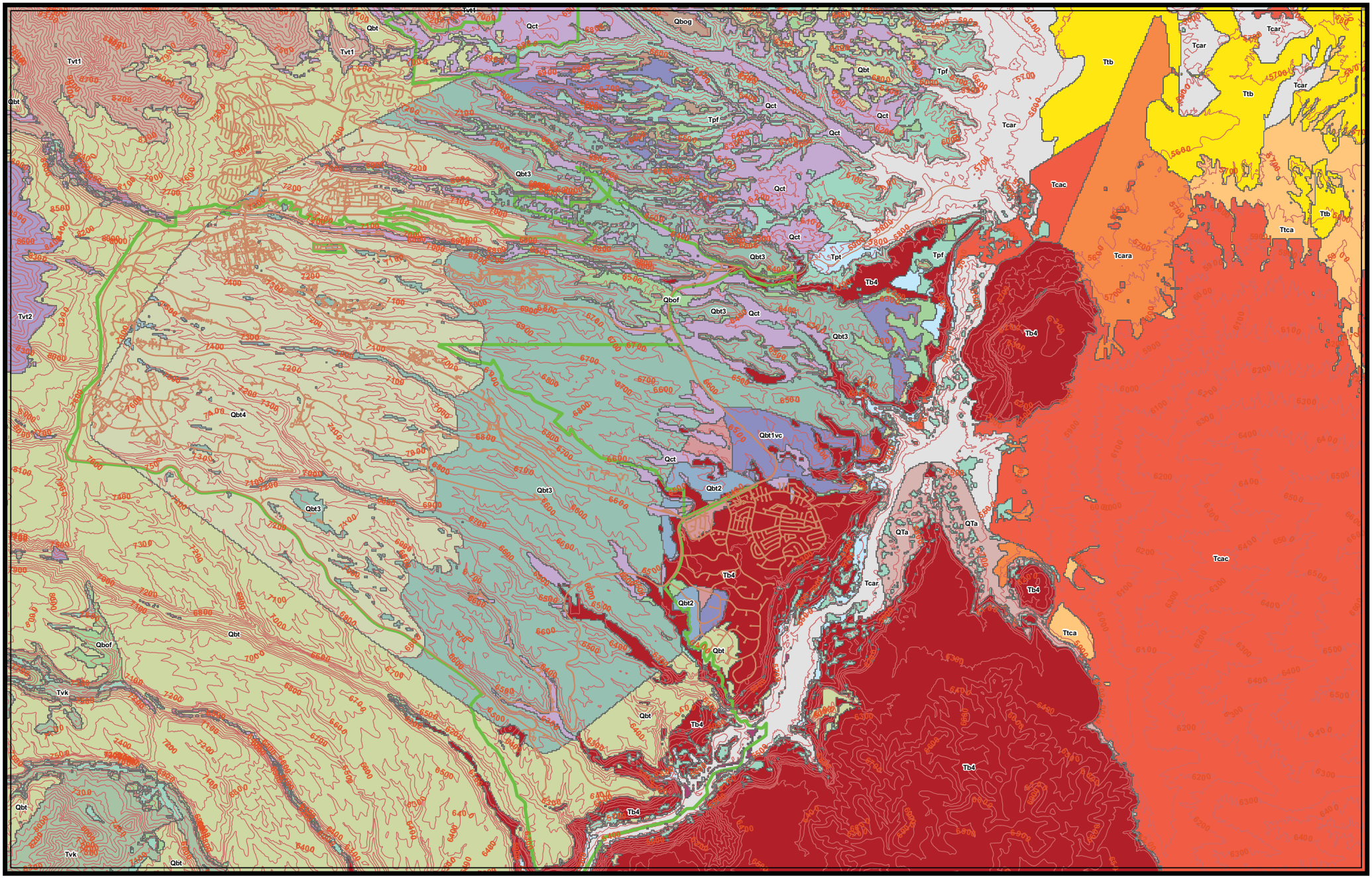
5600
5500
Roads
Los Alamos National Laboratory
Water table contours
Data limits
UNIT CODE - UNIT NAME
Tb4 Cerros del Rio Basalts
Tvt2 Younger Tschicoma dacite flows
Tvt1 Older Tschicoma dacite flows
Tpf Puye Formation
Tpt Totavi Lentil
Tjfp Bearhead Rhyolite and Fanglomerates
Tvk Keres Volcanics
Tcac Chamita Fm - lithosome A
Tb2 8.4–9.3 Ma Basalts
Tcar Chamita Fm - axial river deposits
Tb1 11.6–13.1 Ma Basalts
Ttb Tesuque Fm - lithosome B
Constructed from the 2009 LANL Geologic Framework Model (Cole et al. 2009, 106101)
Water table developed by V. Vesselinov, 2009
Date: May 2009
Plate 3-2. Geology at the water table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Qbt1vc
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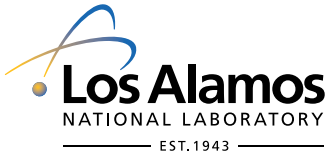
Los Alamos National Laboratory



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Edited by Hector Hinojosa, Group IRM-CAS.

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Progress Report
Issued: March 2011

Groundwater Level Status Report for 2010
Los Alamos National Laboratory

Richard J. Koch
Sarah Schmeer

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Groundwater Level Status Report for 2010
Los Alamos National Laboratory

by

Richard J. Koch and Sarah Schmeer

Abstract

The status of groundwater level monitoring at Los Alamos National Laboratory in 2010 is provided in this report. This report summarizes groundwater level data for 194 monitoring wells, including 63 regional aquifer wells (including 10 regional/intermediate wells), 34 intermediate wells, 97 alluvial wells, and 12 water supply wells. Pressure transducers were installed in 162 monitoring wells for continuous monitoring of groundwater levels. Time-series hydrographs of groundwater level data are presented along with pertinent construction and location information for each well. The report also summarizes the groundwater temperatures recorded in intermediate and regional aquifer monitoring wells and seasonal responses to snowmelt runoff observed in intermediate wells.

1.0 Introduction

This report presents and describes groundwater level data obtained by Los Alamos National Laboratory (LANL) during Fiscal Year (FY) 2010 to provide regulatory compliance and to provide other programs at LANL with groundwater level data as a resource for groundwater modeling and data assessment. The Groundwater Level Monitoring (GWLM) Project was instituted in 2005 to meet New Mexico Environment Department Compliance Order on Consent (Consent Order) requirements to collect groundwater level data.

During 2010, 63 regional aquifer monitoring wells containing 106 regional aquifer screens, 30 intermediate wells and 10 intermediate/regional monitoring wells comprising 57 intermediate screens, 97 alluvial wells, and 12 Los Alamos County (LAC) water supply wells were monitored for groundwater levels. Ten of the multiple completion regional aquifer wells monitored one or more intermediate zones; however, at least one intermediate zone was dry in seven of these wells. Six of the multiple completion regional aquifer wells also monitored intermediate groundwater levels.

Pressure transducers were installed in 61 regional aquifer wells and 30 intermediate wells; periodic manual measurements were obtained from four intermediate wells, which are typically dry and are monitored annually. Transducers were installed in 92 alluvial wells during 2010 and five alluvial wells were monitored with periodic manual measurements. Transducers have been installed in all 12 LAC water supply wells through the cooperation and efforts of the LAC Utilities Department personnel.

This report includes groundwater level data obtained during FY 2010 (October 1, 2009, through September 30, 2010) and, where available, historical data and data obtained after September 30, 2010. The groundwater level data are presented in time-series hydrographs to provide a comprehensive representation of the groundwater level characteristics, to the extent possible with available data. For the alluvial wells, the first hydrograph for each well represents the entire period of record, while the second hydrograph represents the most recent two or three years of data to provide better representation of recent and seasonal changes.

2.0 Description of Groundwater Level Data

The GWLM Project at LANL is conducted under the Quality Assurance Project Plan (QAPP) for Groundwater Level Monitoring (LANL 2006) to assure the quality of groundwater level data. The QAPP contains the work processes and the data quality objectives utilized in the GWLM Project.

Groundwater level data were collected during 2010 according to the criteria outlined in the 2010 Interim Facility-Wide Groundwater Monitoring Plan (LANL 2010). Two types of groundwater level data were collected:

- manual groundwater level measurements were obtained in monitoring wells, supply wells, and boreholes and
- pressure transducers were used to measure groundwater levels in monitoring wells and supply wells.

Manual groundwater level measurements were obtained according to Environmental Program Directorate (EPD) standard operating procedure (SOP) 5223 (formerly ENV-SOP-202), *Manual Groundwater Level Measurements.* Transducer measurements were obtained according to EPD SOP 5227 (formerly ENV-SOP-201), *Pressure Transducer Installation, Removal, and Maintenance*, and EPD SOP 5226 (formerly ENV-WQH-SOP-064), *Westbay® Pressure Transducer Installation, Removal, and Maintenance*. Groundwater level data obtained both manually and with pressure transducers were reviewed and validated according to EPD SOP 5230 (formerly ENV-WQH-SOP-062), *Groundwater Level Data Processing, Review, and Validation*.

Wells installed with pressure transducers had measurements collected at least hourly. Where possible, manual groundwater level measurements were obtained at least semi-annually to provide quality control for the transducer measurements. In the following sections, both manual measurements and transducer measurements are shown on the time-series hydrographs. Because hourly transducer measurements are too voluminous to reproduce for most hydrographs, mean daily groundwater levels are shown on most hydrographs in this report. Some monitoring wells have significant drawdown when pumped during sampling events. Because pumping of the monitoring wells for sampling usually occurs over several hours, the mean daily water level value will not usually portray the full amount of drawdown experienced during pumping of a well. For this reason, mean daily water level data are not usually appropriate for determining well characteristics such as specific capacity, etc.

Transducers that measure pressure head in wells typically have a measurement precision of ±0.1% of the full-scale measurement capability. Thus, typical measurement accuracy for a 100-psi transducer is 0.23 ft, and for a 500-psi transducer is 1.2 ft. The higher-pressure-rated transducers are required in the deeper Westbay® installations where higher water pressures are encountered. Most shallow wells and deep wells not installed with the Westbay® sampling system are equipped with 30-psi transducers, with a measurement accuracy of 0.07 ft. A few of the shallow alluvial wells are equipped with 15-psi transducers. Manual groundwater level measurements typically have an accuracy of approximately 0.1 ft per 100 ft of measurement (0.1%).

From 2000 through 2004, groundwater level data obtained during groundwater sampling of Westbay® wells was from a 1000-psi-rated transducer that had an accuracy of about ±2.3 ft. In 2005 new sampling transducers with a 500-psi rating were obtained, which have an accuracy of about 1.2 ft. The higher accuracy of the new Westbay® sampling transducers is the cause for the apparent water level shift for sampling water levels in mid 2005, as observed on many of the accompanying hydrographs for Westbay® wells. Similarly, the apparent scatter of sampling water levels on hydrographs from Westbay® wells is the result of the higher-pressure-rated and less accurate transducers that are used for sampling.

In the following sections, acronyms used to describe groundwater level data include

GW	data obtained from transducers during groundwater sampling events
Trans	measurements from transducers installed in a well
MP	Measurement Port identification in multiple completion Westbay® wells
RT	Regional aquifer top screen
RD	Regional aquifer deeper screen
I	Intermediate perched groundwater
A	Alluvial groundwater

Geologic unit codes used in the construction information tables are listed in Appendix A; Appendix B presents mean annual water level data; Appendix C summarizes transient responses to supply well pumping; Appendix D summarizes intermediate groundwater level responses to runoff; and groundwater temperature data are summarized for regional and intermediate wells in Appendix E.

Previous reports of groundwater level data at LANL were compiled for the regional aquifer test wells (TWs) by Koch et al. (2004) and for all wells in a submittal to the New Mexico Environment Department in January 2005 (LANL 2005). Groundwater levels in water supply wells at Los Alamos have been summarized in the series of water supply reports for Los Alamos, e.g., Koch and Rogers (2003). The previous reports in this series are as follows: *Groundwater Level Status Report for 2005,* issued in May 2006 (Allen and Koch 2006); *Groundwater Level Status Report for Fiscal Year 2006,* issued in March 2007 (Allen and Koch 2007); *Groundwater Level Status Report for Fiscal Year 2007,* issued in March 2008 (Allen and Koch 2008); *Groundwater Level Status Report for 2008,* issued in March 2009 (Koch and Schmeer 2009), and *Groundwater Level Status Report for 2009,* issued in March 2010 (Koch and Schmeer 2010).

3.0 Groundwater Level Data from Regional Aquifer Wells

Figure 3-1 shows the locations of the regional aquifer monitoring wells and water supply wells in the vicinity of LANL. Table 3-1 lists the regional aquifer monitoring wells that were monitored for groundwater levels in 2010. Screen intervals and port depths for each well are shown in subsequent sections.

The Appendix B table lists the mean annual water level for 2010 for each well screen located at the top of the regional aquifer. Figure 3-1 also shows the mean annual regional aquifer groundwater elevation for monitoring wells and the mean annual non-pumping water level for supply wells. Appendix C Table C-1 summarizes the transient responses observed in monitoring wells that result from supply well pumping at Los Alamos.

In the following sections reference is made to the barometric efficiency of some monitoring wells. Barometric efficiency is defined as the ratio of the water level change observed in a well divided by the concurrent atmospheric pressure change, expressed as a percentage. For a given change in atmospheric pressure, if the water in a well responds by an equal amount, the well is said to have 100% barometric efficiency; however, this type of response by the water in the well can occur only when the aquifer adjacent to the well does not experience the atmospheric pressure change. Thus, a well with a 100% barometric efficiency is installed into an aquifer that does not experience the atmospheric pressure fluctuations.

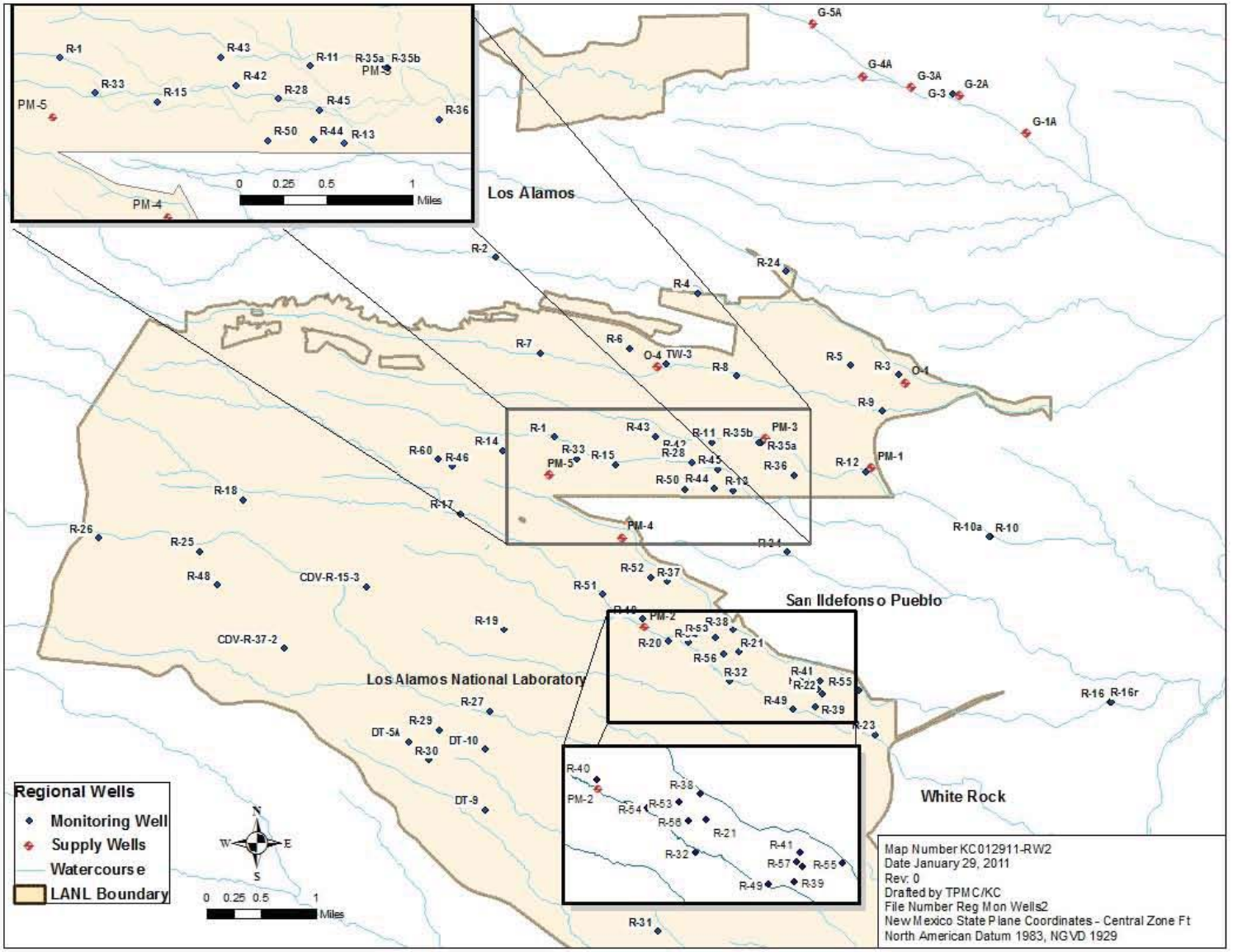


Figure 3-1. Regional aquifer monitoring wells and supply wells.

Table 3-1. Location Information for Regional Aquifer Monitoring Wells

Well Name	Date Completed	Completed Depth (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)
CdV-R-15-3	9/24/2000	1675.0	1623221.00	1762349.20	7258.90
CdV-R-37-2	8/1/2003	1587.3	1619218.96	1759327.28	7330.60
R-1	3/12/2004	1080.1	1632354.13	1769600.84	6881.21
R-2	10/28/2003	943.3	1629519.57	1778281.56	6770.38
R-3	6/21/2010	1006.8	1649037.61	1772598.75	6395.88
R-4	1/6/2004	840.0	1639287.98	1776530.28	6577.49
R-5	6/19/2001	884.0	1646707.00	1773063.00	6472.60
R-6	12/4/2004	1252.0	1636011.02	1773884.07	6995.80
R-7	2/26/2001	977.0	1631666.00	1773653.00	6779.20
R-8	4/22/2002	850.0	1641139.01	1772554.62	6544.74
R-9	10/18/1999	758.0	1648236.50	1770847.10	6382.80
R-10	10/5/2005	1079.0	1653465.92	1764766.46	6362.31
R-10a	8/18/2005	706.0	1653411.63	1764782.29	6363.74
R-11	10/8/2004	901.7	1639959.31	1769353.57	6673.72
R-13	10/6/2001	1029.4	1640991.66	1766994.17	6673.05
R-14	12/19/2002	1315.6	1629855.01	1768953.12	7062.08
R-15	9/21/1999	1030.6	1635308.60	1768272.50	6820.00
R-16	12/19/2002	1276.7	1659283.61	1756710.97	6256.87
R-16r	10/11/2005	631.4	1659289.39	1756730.68	6256.97
R-17	1/4/2006	1140.9	1627795.96	1765861.23	6921.51
R-18	12/14/2004	1405.0	1617254.37	1766545.47	7404.83
R-19	9/19/2000	1877.4	1629918.40	1760252.10	7066.30
R-20	12/19/2002	1353.3	1637835.40	1759694.51	6694.35
R-21	11/26/2002	941.4	1641284.17	1759143.06	6656.24
R-22	12/10/2000	1472.9	1645324.40	1757111.10	6650.50
R-23	10/2/2002	886.3	1647913.60	1755165.37	6527.75
R-24	9/12/2005	861.0	1643554.46	1777591.35	6547.38
R-25	9/28/2000	1934.7	1615178.42	1764060.50	7516.10
R-26	10/17/2003	1479.0	1610267.23	1764721.12	7641.69
R-27	11/7/2005	878.7	1629230.52	1756296.28	6713.72
R-28	12/17/2003	980.3	1638988.73	1768358.57	6728.61
R-29	3/12/2010	1191.8	1626779.91	1755383.32	7100.75
R-30	4/3/2010	1171.8	1626287.74	1753921.18	7073.84
R-31	12/1/2000	1077.7	1637353.80	1745648.40	6362.50
R-32	11/17/2002	1002.0	1640797.67	1757730.25	6637.63
R-33	10/13/2004	1126.0	1633401.71	1768532.65	6853.33
R-34	9/10/2004	920.7	1643595.82	1764028.77	6629.99
R-35a	6/21/2007	1086.2	1642326.53	1769310.85	6623.06
R-35b	7/11/2007	872.2	1642234.75	1769322.98	6625.21
R-36	2/12/2008	803.7	1643907.07	1767736.64	6591.37
R-37	6/6/2009	1068.8	1637828.13	1762616.71	6870.59
R-38	12/7/2008	853.4	1640998.66	1760235.07	6668.58
R-39	12/1/2008	875.6	1644995.98	1756488.99	6580.86
R-40	1/5/2009	895.0	1636628.23	1760801.14	6719.24
R-41	3/19/2009	997.1	1645217.12	1757745.55	6660.53
R-42	8/27/2008	973.5	1637709.96	1768775.73	6759.02
R-43	10/17/2008	990.4	1637236.21	1769614.70	6732.65
R-44	1/15/2009	1016.0	1640061.34	1767109.85	6714.91
R-45	1/24/2009	1016.0	1640249.62	1768017.72	6704.02
R-46	2/26/2009	1383.8	1627433.85	1768183.02	7213.33
R-48	9/26/2009	1540.0	1615977.33	1762436.24	7486.78
R-49	6/1/2009	949.3	1643900.90	1756401.85	6584.54
R-50	2/13/2010	1217.5	1638666.13	1767087.32	6904.11
R-51	2/8/2010	1046.1	1634685.79	1761983.36	6762.17
R-52	4/5/2010	1128.7	1636988.93	1762825.71	6883.04
R-53	3/29/2010	1001.9	1640109.61	1759860.57	6689.98
R-54	1/29/2010	936.0	1638803.48	1759602.87	6679.85
R-55	8/25/2010	1021.0	1647083.52	1757272.15	6533.86
R-56	7/19/2010	1078.8	1640507.31	1759044.73	6780.88
R-57	6/8/2010	1013.8	1645109.00	1757337.71	6648.04
R-60	10/18/2010	1360.9	1626734.38	1768514.75	7228.17
Test Well 3	11/20/1949	815.0	1637727.50	1773138.12	6626.90
Test Well DT-10	3/13/1960	1408.0	1628988.50	1754448.75	7019.90
Test Well DT-5A	1/25/1960	1819.5	1625310.00	1754789.37	7143.86
Test Well DT-9	2/19/1960	1501.0	1628993.62	1751492.62	6935.00

3.1 CdV-R-15-3

Location: CdV-R-15-3 is located on a mesa between upper Three-Mile Canyon and Cañon de Valle within the Cañon de Valle watershed.

Completion Type: Multiple completion, three screens in intermediate vadose zones, three screens in regional zones.

Period of Record: Westbay® installed September 17, 2000; transducers installed March 1, 2001; intermittent data to August 2, 2010, when the transducers were removed in preparation for Westbay® system removal and well testing. The transducers were removed for several months in 2009 to rebuild the cables.

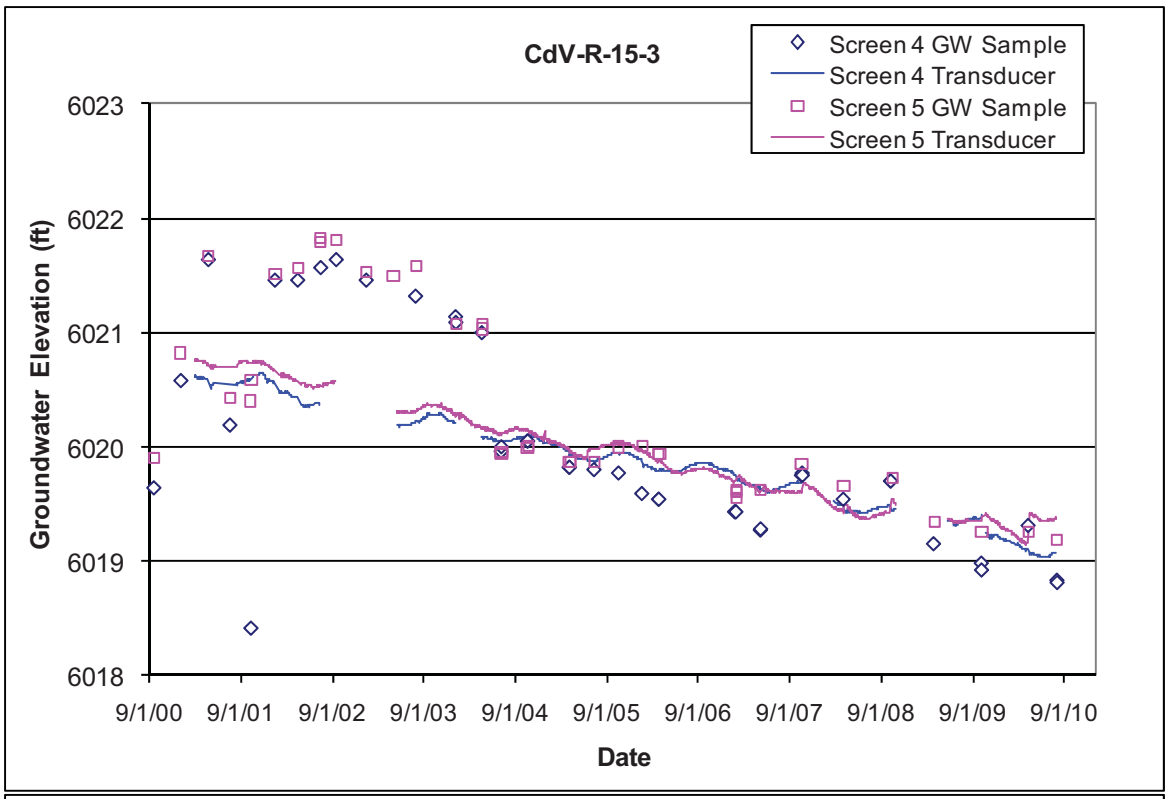
Remarks: The three intermediate screens have been dry since well installation. A transducer was never installed at screen 2. Transducers monitoring dry screens 1 and 3 were removed in January 2006. Regional screens 4 and 5 have similar heads; screen 6 head is 35 ft lower. Westbay® monitoring port MP6B has not been operational since the system was installed (Kopp et al. 2002, p. 38). Six ft of water appeared in the screen 3 sump at port MP3C October 2006; sump water still present in 2010. Screens 4 and 5 do not indicate a water level response to atmospheric pressure fluctuations; screen 6 indicates a 30% response to atmospheric pressure.

Measurement and Sampling Ports in CDV-R-15-3

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elev (ft)	Port Distance from Bottom of Screen (ft)	Comment
1	617.7	624.5	6641.2	6634.4	6.8	I	Qbo	MP1A	624.3	6634.6	0.2	Within Screen, port dry
								PP1	629.7	6629.2	-5.2	Below Screen
								MP1B	635.3	6623.6	-10.8	Below Screen, port dry
2	800.8	807.8	6458.1	6451.1	7.0	I	Tpf	MP2A	807.3	6451.6	0.5	Within Screen, port dry
								PP2	812.6	6446.3	-4.8	Below Screen
								MP2B	818.3	6440.6	-10.5	Below Screen
3	964.8	980.9	6294.1	6278.0	16.1	I	Tb4	MP3A	969.0	6289.9	11.9	Within Screen, port dry
								MP3B	979.3	6279.6	1.6	Within Screen, port dry
								PP3	984.7	6274.2	-3.8	Below Screen
								MP3C	990.3	6268.6	-9.4	Below Screen, 6' water in sump
4	1235.1	1278.9	6023.8	5980.0	43.8	RT	Tpf	**MP4A**	1254.4	6004.5	24.5	Within Screen, Regional Aquifer
								PP4A	1259.6	5999.3	19.3	Within Screen
								MP4B	1275.1	5983.8	3.8	Within Screen
								PP4B	1280.5	5978.4	-1.6	Below Screen
								MP4C	1286.1	5972.8	-7.2	Below Screen
5	1348.4	1355.3	5910.5	5903.6	6.9	RD	Tpf	**MP5A**	1350.1	5908.8	5.2	Within Screen
								PP5	1355.4	5903.5	-0.1	Below Screen
								MP5B	1361.1	5897.8	-5.8	Below Screen
6	1637.9	1644.8	5621.0	5614.1	6.9	RD	Tpf	**MP6A**	1640.1	5618.8	4.7	Within Screen
								PP6	1645.5	5613.4	-0.7	Below Screen
								MP6B	1651.1	5607.8	-6.3	Below Screen, Port inoperational

Note: CDV-R-15-3 Brass Cap Ground Elevation: 7258.9 ft; all measurements are from this elevation;

MP = Monitor Port; PP = Pump Port; Monitor Ports shown in bold are instrumented ports


CdV-R-15-3
Screen 4 GW Sample
Screen 4 Transducer
Screen 5 GW Sample
Screen 5 Transducer
Groundwater Elevation (ft)
6023
6022
6021
6020
6019
6018
9/1/00
9/1/01
9/1/02
9/1/03
9/1/04
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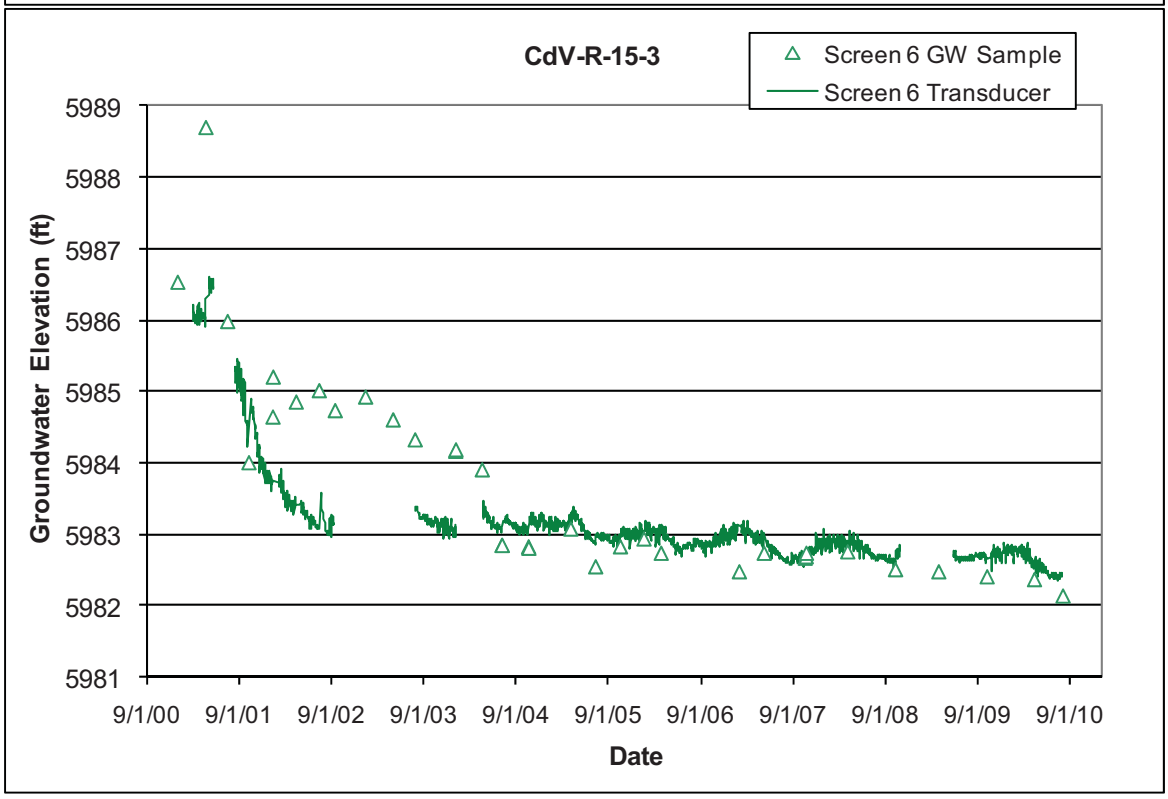
9/1/09
9/1/10
Date


CdV-R-15-3
Screen 6 GW Sample
Screen 6 Transducer
Groundwater Elevation (ft)
5989
5988
5987
5986
5985
5984
5983
5982
5981
9/1/00
9/1/01
9/1/02
9/1/03
9/1/04
9/1/05
9/1/06
9/1/07
9/1/08
9/1/09
9/1/10
Date

3.2 CdV-R-37-2

Location: CdV-R-37-2 is located on a mesa between Cañon de Valle and Water Canyon at Technical Area (TA) 37 in the Water Canyon watershed.

Completion Type: Multiple completion, one screen in an intermediate vadose zone, three screens in regional zones.

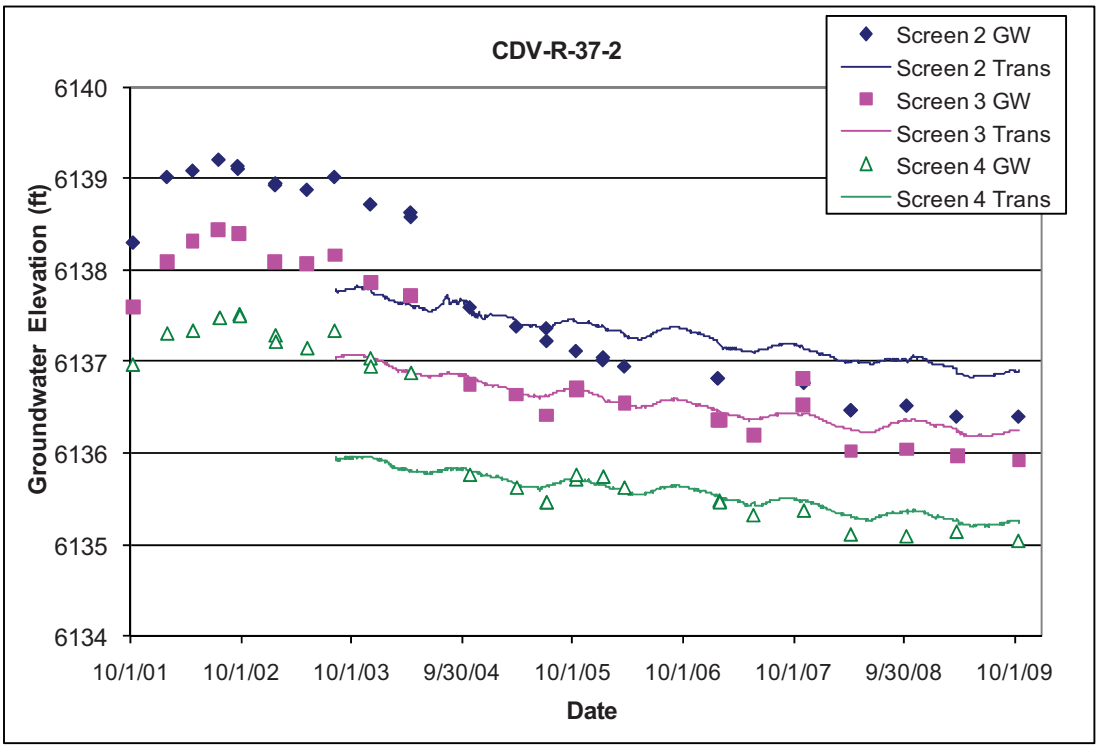
Period of Record: Westbay® installed October 8, 2001; transducers installed August 8, 2003; data to August 09, 2010, when the transducers were removed in preparation for Westbay® system removal and well testing.

Remarks: The intermediate screen has been dry since well installation; the transducer at this screen was removed in January 2006. The three regional screens have similar heads that show downward gradient of about 1 ft between each screen. The screens do not indicate a water level response to atmospheric pressure fluctuations.

Measurement and Sampling Ports in CDV-R-37-2

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elevation (ft)	Distance from Bottom of Screen (ft)	Comment
1	914.4	939.5	6416.2	6391.1	25.1	I	Tp	MP1A	934.9	6395.7	4.6	Within Screen (Dry)
								PP1	940.2	6390.4	-0.7	Below Screen
								MP1B	945.9	6384.7	-6.4	Below Screen
2	1188.7	1213.8	6141.9	6116.8	25.1	RT	Tt	**MP2A**	1200.3	6130.3	13.5	Within Screen
								PP2	1205.7	6124.9	8.1	Within Screen
								MP2B	1216.2	6114.4	-2.4	Below Screen
3	1353.7	1377.1	5976.9	5953.5	23.4	RD	Tt	**MP3A**	1359.3	5971.3	17.8	Within Screen
								PP3	1365.0	5965.6	12.1	Within Screen
								MP3B	1375.2	5955.4	1.9	Within Screen
4	1549.3	1556.0	5781.3	5774.6	6.7	RD	Tt	**MP4A**	1550.6	5780.0	5.4	Within Screen
								PP4	1556.0	5774.6	0	Base of Screen
								MP4B	1561.6	5769.0	-5.6	Below Screen

Note: CDV-R-37-2 Brass Cap Ground Elevation: 7330.6 ft; all measurements are from this elevation;
MP = Monitor Port; PP = Pump Port; Monitor Ports shown in bold are instrumented ports



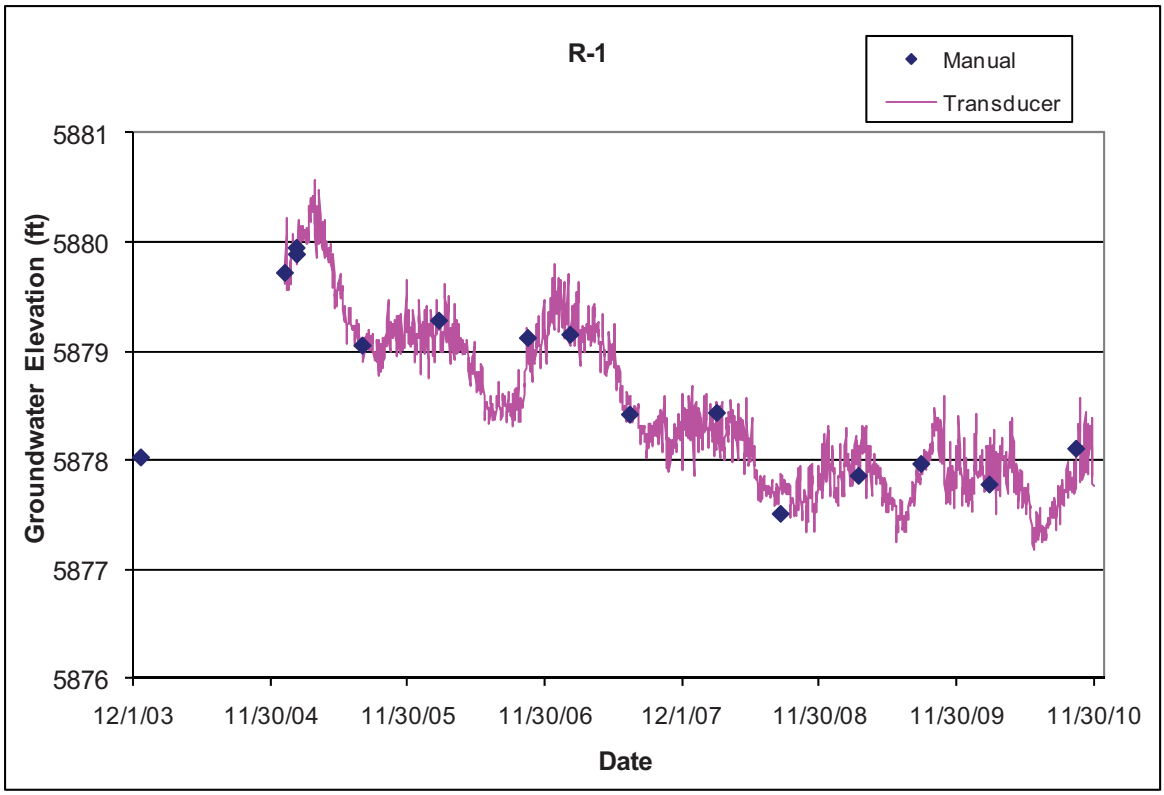
3.3 R-1

Location: R-1 is located in Mortandad Canyon about 220 ft west of former monitoring well TW-8.
Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 28 ft below the water table.
Period of Record: Well completed November 2003, transducer installed January 2005, transducer data through 2010.
Remarks: R-1 was completed to a depth of 1080.1 ft, about 80 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer has no immediate response to atmospheric pressure fluctuations. The aquifer indicates a seasonal response to supply well pumping and primarily responds to pumping at PM-5 and possibly to PM-4.

R-1 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1031.1	1057.4	5850.1	5823.8	26.3	1027.7	5853.5	1057.4	5823.8	1080.1	22.7	69.7	RT	Tp

Note: R-1 Brass Cap Ground Elevation: 6881.21 ft; all measurements are from this elevation

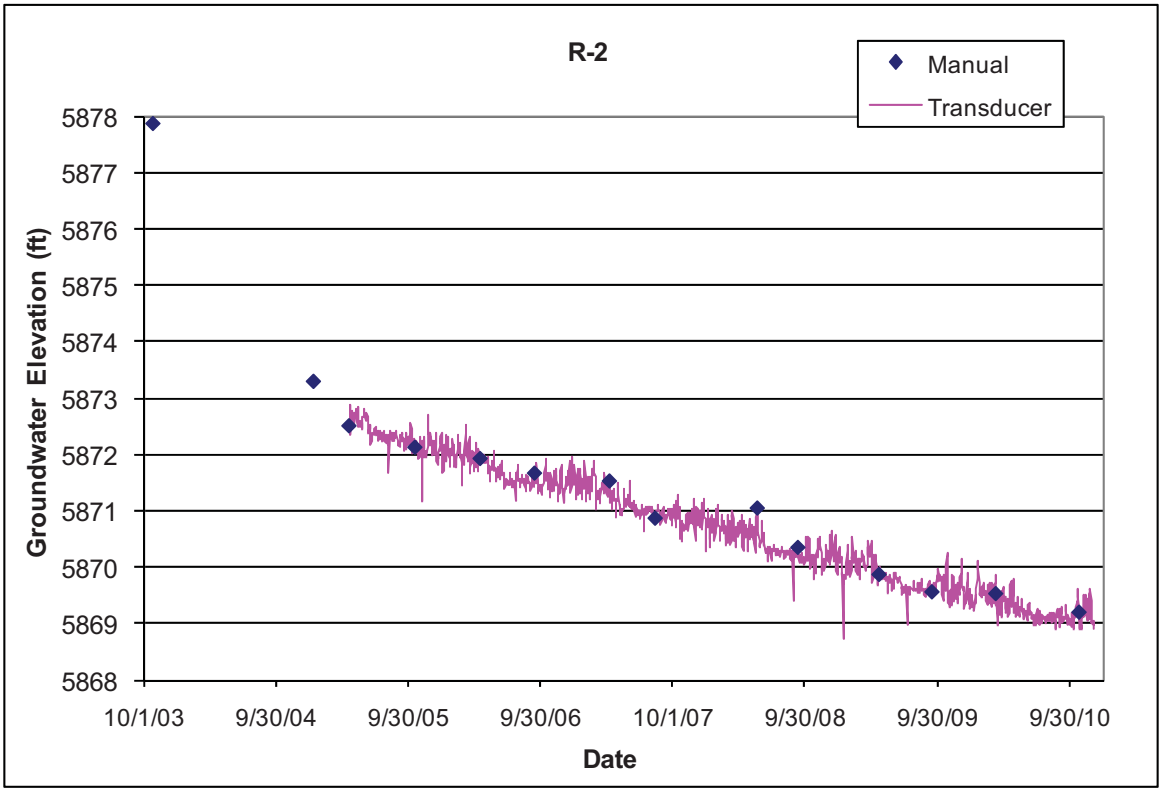


3.4 R-2

Location: R-2 is located in middle Pueblo Canyon between former monitoring wells TW-4 and TW-2.
Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 5 ft below the water table.
Period of Record: Well completed October 2003, transducer installed January 2005, transducer data through 2010.
Remarks: R-2 was completed to a depth of 943.3 ft, about 50 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer has no immediate response to atmospheric pressure fluctuations. The well shows a continuous water level decline but does not indicate a seasonal response to supply well pumping or an apparent response to pumping of any specific supply well.

R-2 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	906.4	929.6	5864.0	5840.8	23.2	917.0	5853.4	929.6	5840.8	943.3	13.7	42.1	RT	Tp
Note: R-2 Brass Cap Ground Elevation: 6770.38 ft; all measurements are from this elevation														



3.5 R-3

Location: R-3 is located in lower Pueblo Canyon about 0.5 mi east of monitor well R-5 and about 500 ft northwest of supply well O-1.

Completion Type: Single completion in the regional aquifer. The top of the screen is about 315 ft below the water table.

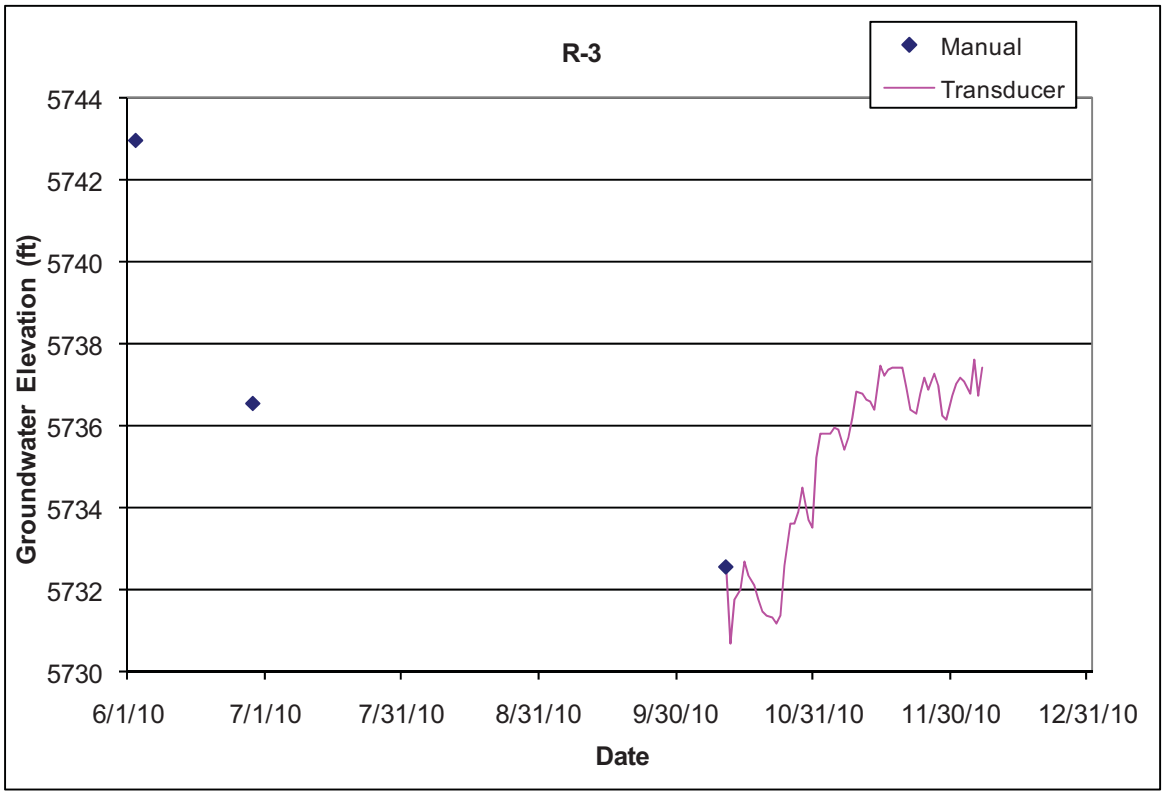
Period of Record: Well completed May 2010, transducer installed October 12, transducer data through 2010.

Remarks: R-3 was completed to a depth of 1077.7 ft, about 415 ft into the regional aquifer. The well responds to pumping at PM-1.

R-3 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Bottom Well Depth (ft)	Sump Length (ft)	Hydro Zone Code	Geo Unit Code
1	974.5	995.0	5421.4	5400.9	20.5	965.8	5430.1	995.0	5400.9	1006.8	11.8	RT	Tsf

Note: Brass Cap Ground Elevation: 6395.88 ft; all measurements are from this elevation



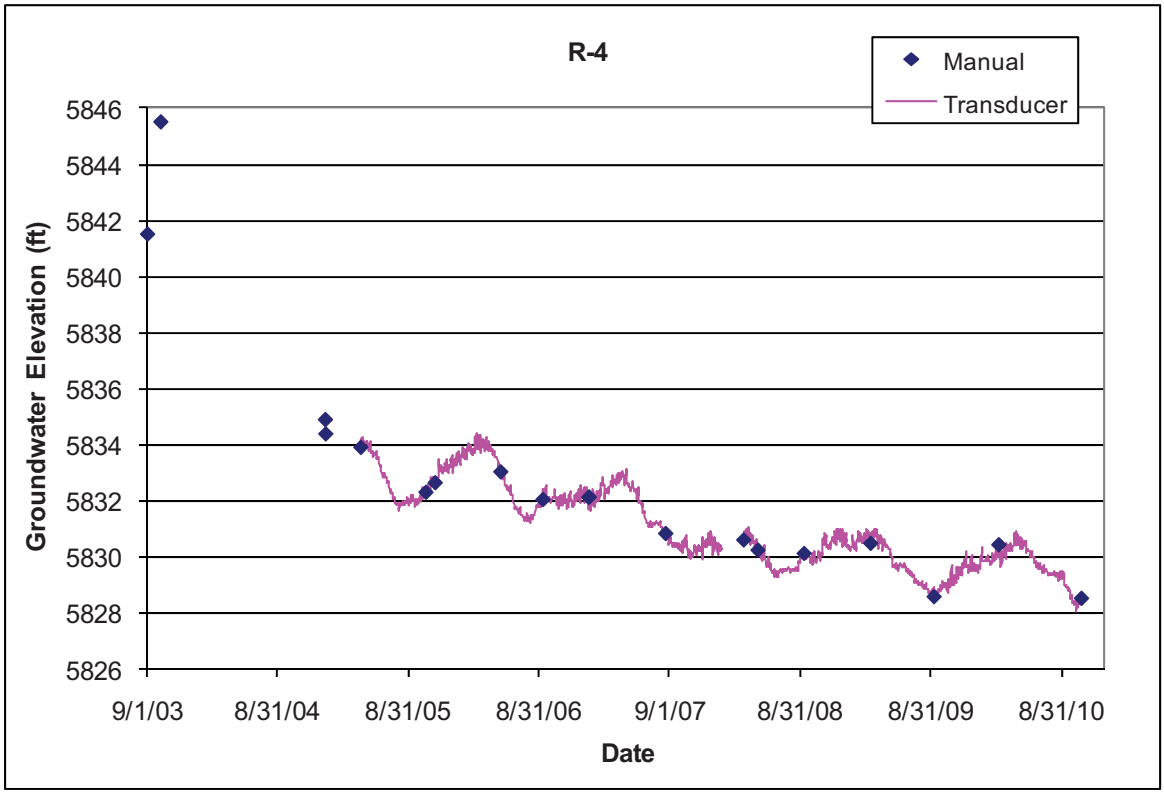
3.6 R-4

Location: R-4 is located in Pueblo Canyon near the new LAC Sewage Treatment Plant.
Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 49 ft below the piezometric water table in a confined zone.
Period of Record: Well completed September 2003, transducer installed January 2005, data through 2010. The transducer failed in January 2008 and was replaced in March 2008.
Remarks: R-4 was completed to a depth of 840 ft, about 90 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer has no immediate response to atmospheric pressure fluctuations. The aquifer indicates a seasonal response to supply well pumping and appears to respond primarily to pumping PM-3, and possibly to pumping at O-4 and the Guaje well field.

R-4 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	792.9	816	5784.6	5761.5	23.1	787.5	5790.0	816.0	5761.5	840.0	24.0	73.7	RT	Tp

Note: R-4 Brass Cap Ground Elevation: 6577.49 ft; all measurements are from this elevation



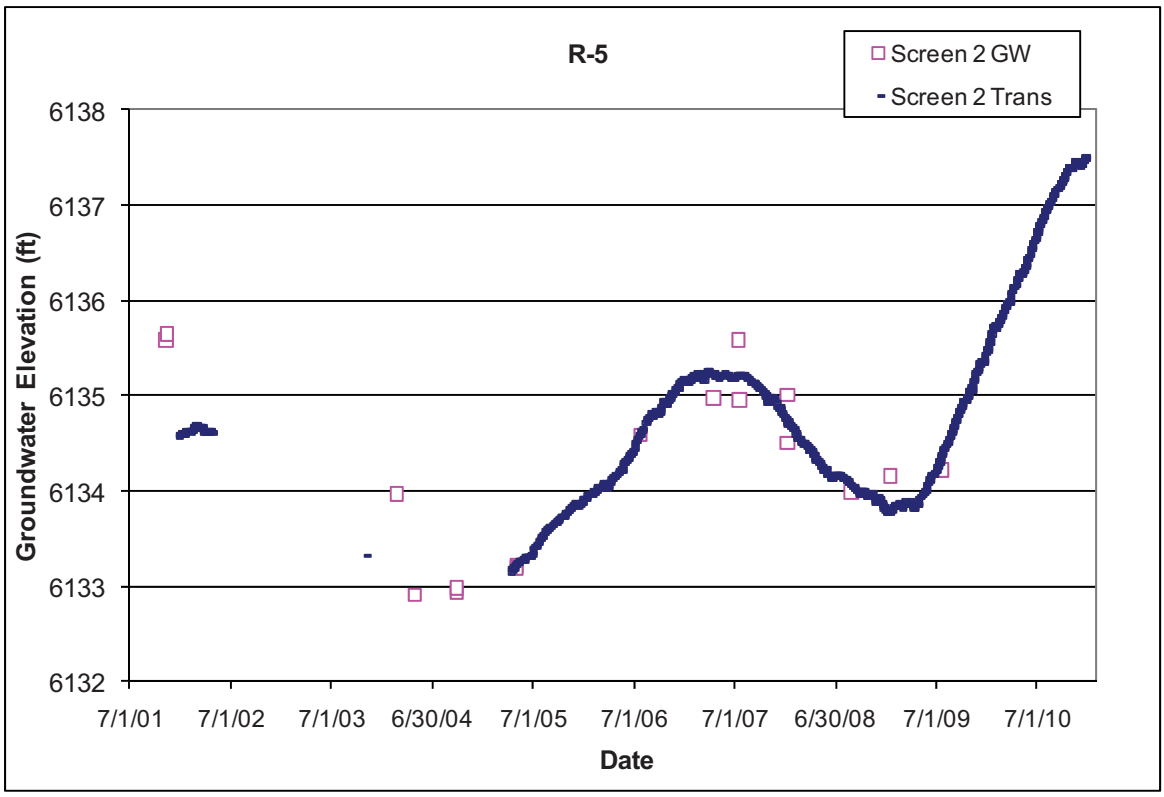
3.7 R-5

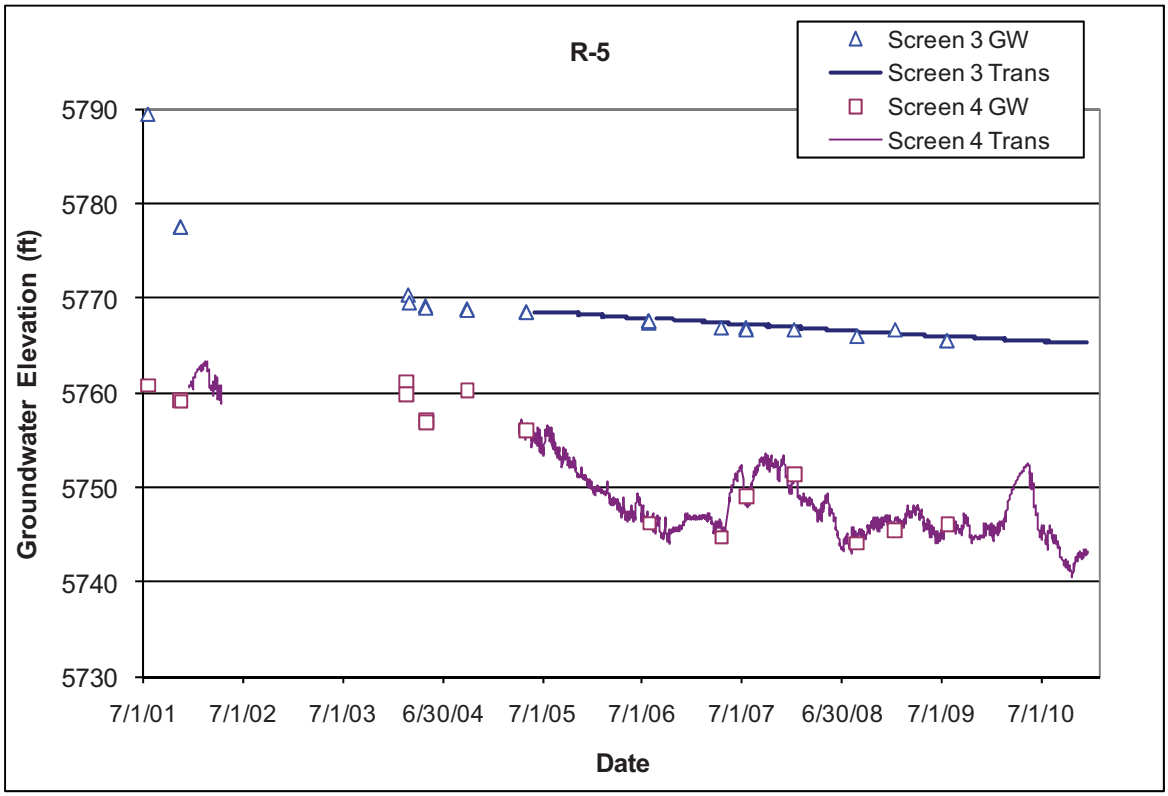
Location: R-5 is located in lower Pueblo Canyon about 0.5 mi upstream of supply well O-1.
Completion Type: Multiple completion, two screens in intermediate zones, two screens in regional zones.
Period of Record: Westbay® installed July 17, 2001, transducers installed December 17, 2001, and April 4, 2005, intermittent data through 2010.
Remarks: Screen 1 has been dry since well installation, although there is about 3 ft of water above port MP1B in the sump below screen 1. The screen 2 intermediate groundwater level is about 5 ft below the bottom of screen 1. The two regional screens have heads about 10 to 15 ft apart. The water level at the top of the regional aquifer at screen 3 declined below port MP3A in 2001; samples are collected and groundwater levels are monitored from port MP3B. The aquifer at screen 4 responds primarily to supply well pumping at PM-1, but screen 3 apparently shows little or no response. The R-5 regional aquifer screens do not indicate a response to atmospheric pressure fluctuations.

R-5 Construction and Port Data

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elevation (ft)	Distance from Bottom of Screen (ft)	Sump Volume (L)	Comment
1	326.4	331.5	6146.2	6141.1	5.1	I	Tp	**MP1A**	329.5	6143.1	2.0		Within Screen, Screen Dry
								PP1	334.9	6137.7	-3.4	9.8	Below Screen
								MP1B	350.4	6122.2	-18.9	54.7	Below Screen, 3 ft of water
2	372.8	388.8	6099.8	6083.8	16.0	I	Tp	**MP2A**	383.9	6088.7	4.9		Within Screen
								PP2	388.8	6083.8	0.0	0.0	At Bottom of Screen
								MP2B	394.4	6078.2	-5.6	16.2	Below Screen
3	676.9	720.3	5795.7	5752.3	43.4	RT	Tsf	MP3A	695.1	5777.5	25.2		Within Screen, Port Dry
								MP3B	718.6	5754.0	1.7		Within Screen, Port sampled
								PP3	724.0	5748.6	-3.7	10.7	Below Screen
4	858.7	863.7	5613.9	5608.9	5.0	RD	Tsfb	**MP4A**	860.9	5611.7	2.8		Within Screen
								PP4	866.3	5606.3	-2.6	7.5	Below Screen
								MP4B	871.9	5600.7	-8.2	23.7	Below Screen

Note: R-5 Brass Cap Ground Elevation: 6472.6 ft; all measurements are from this elevation;
MP = Monitor Port; PP = Pump Port; Monitor Ports shown in bold are instrumented ports


R-5
Screen 2 GW
Screen 2 Trans
Groundwater Elevation (ft)
6138
6137
6136
6135
6134
6133
6132
7/1/01
7/1/02
7/1/03
6/30/04
7/1/05
7/1/06
7/1/07
6/30/08
7/1/09
7/1/10
Date

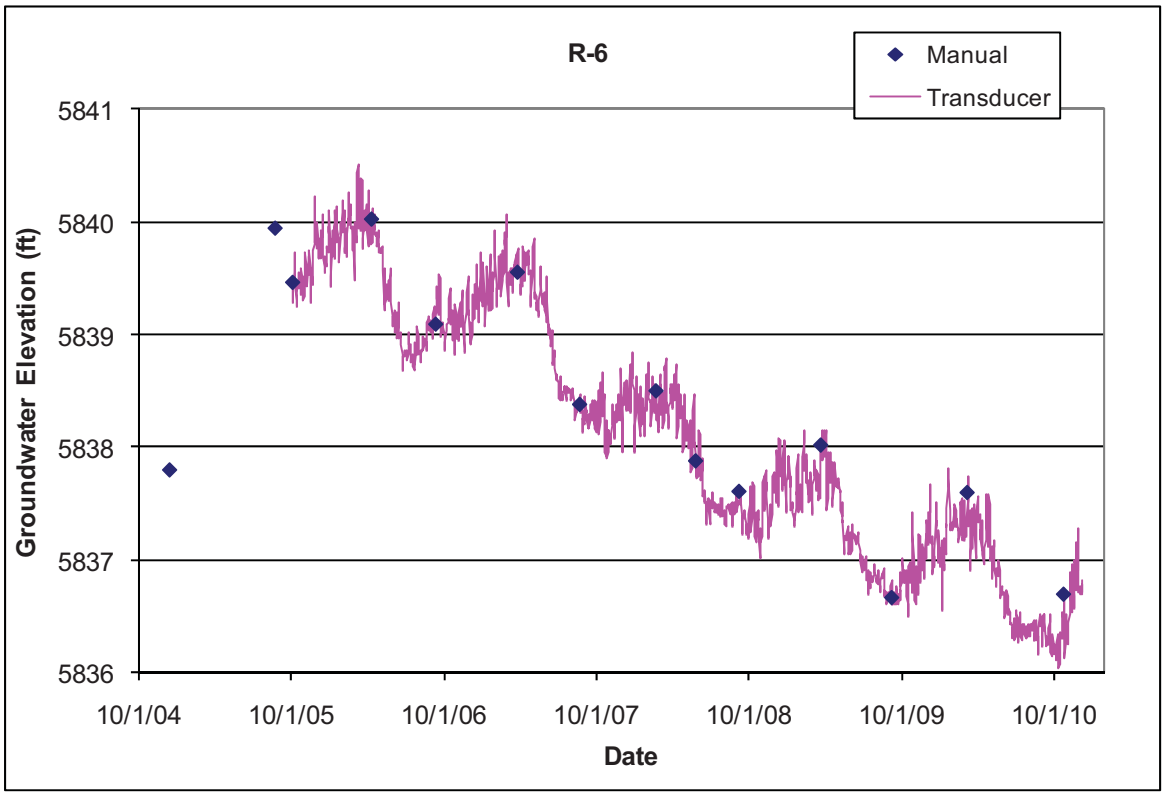

R-5
Screen 3 GW
Screen 3 Trans
Screen 4 GW
Screen 4 Trans
Groundwater Elevation (ft)
5790
5780
5770
5760
5750
5740
5730
7/1/01
7/1/02
7/1/03
6/30/04
7/1/05
7/1/06
7/1/07
6/30/08
7/1/09
7/1/10
Date

3.8 R-6

Location: R-6 is located at the east end of DP Mesa between DP Canyon and Los Alamos Canyon.
Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 44 ft below the water table.
Period of Record: Well completed November 2004, transducer installed December 2004, data through 2010.
Remarks: R-6 was completed to a depth of 1252 ft, about 100 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer has no immediate response to atmospheric pressure fluctuations.

R-6 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1205.0	1228.0	5790.8	5767.8	23.0	1197.66	5798.1	1228.0	5767.8	1252.0	24.0	73.7	RT	Tf
Note: Brass Cap Ground Elevation: 6995.80 ft; all measurements are from this elevation														



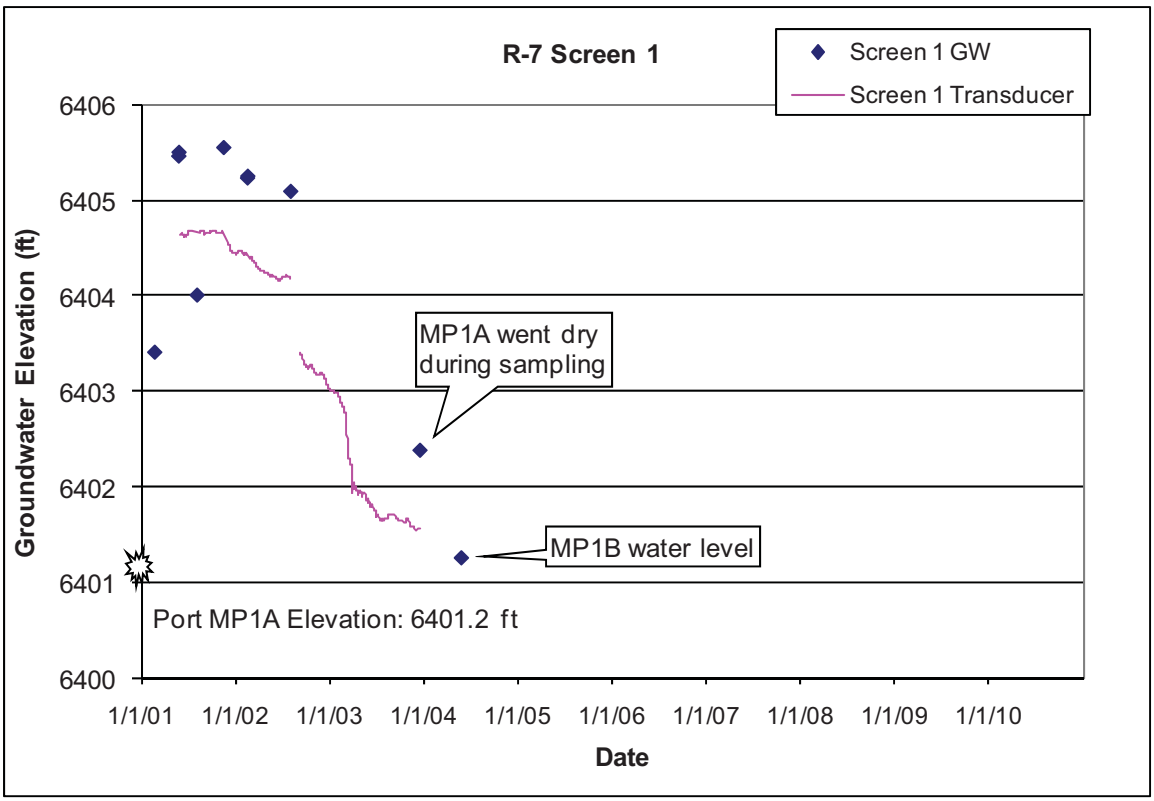
3.9 R-7

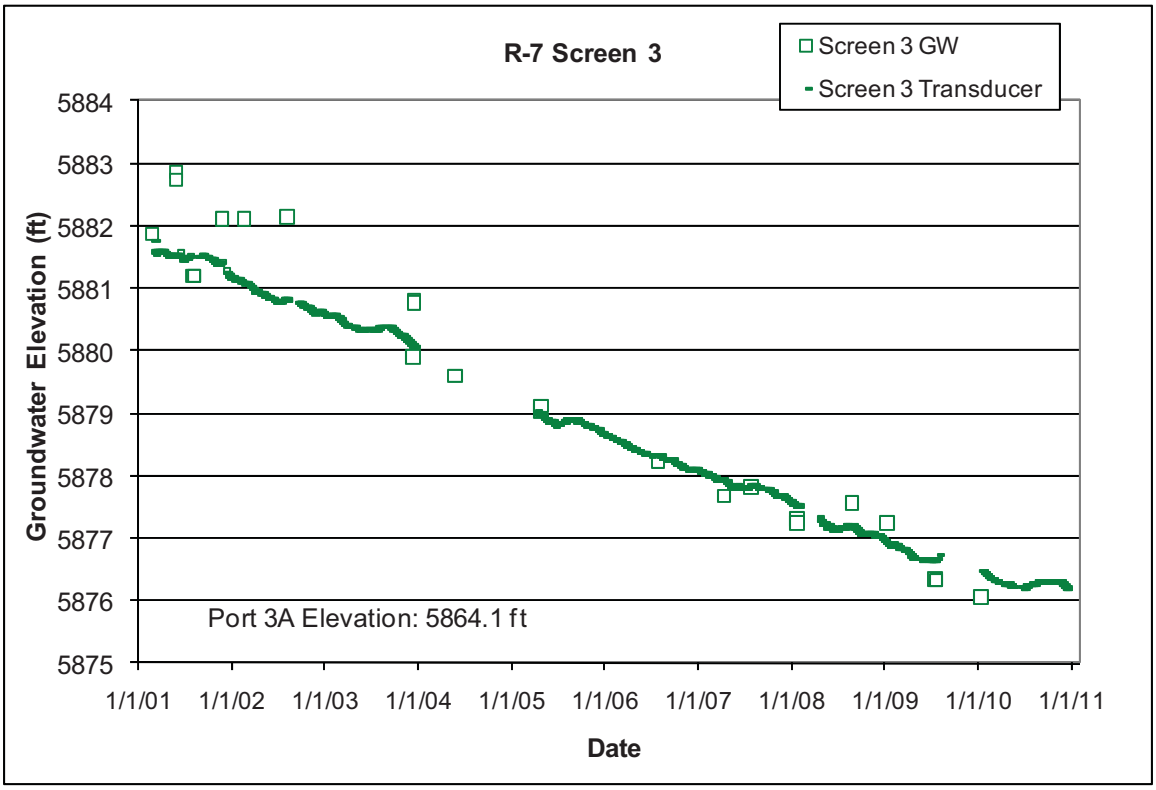
Location: R-7 is located in middle Los Alamos Canyon about 1 mi upstream of supply well O-4.
Completion Type: Multiple completion, two screens in intermediate zones, one screen at the top of the regional aquifer.
Period of Record: Westbay® installed February 25, 2001, transducers installed February 28, 2001, intermittent data to July 20, 2009. Equipment problems caused data loss from July 2009 to January 2010. Transducer data through 2010.
Remarks: Initial transducer data from MP1A are not valid because transducer apparently did not connect properly to port. Port MP1A at intermediate screen 1 went dry during sampling on December 18, 2003. Pressure data from port MP1B located in the sump have indicated 3 to 4 ft of water present above the port but about 7 ft below screen 1 since 2005. The screen 2 intermediate screen has been dry since well installation but port MP2B indicates about 1 ft of water in the sump above the port since mid 2008. The regional aquifer at R-7 screen 3 does not indicate a response to atmospheric pressure fluctuations and does not show a seasonal water level response to supply well pumping or a response to pumping any of the water supply wells, but shows a relatively constant water level decline of about 0.6 ft/yr.

R-7 Construction and Port Data

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elevation (ft)	Distance from Bottom of Screen (ft)	Comment
1	363.2	379.2	6416.0	6400.0	16.0	I	Tp	**MP1A**	378.0	6401.2	1.2	Within screen - Screen dry
								PP1	383.3	6395.9	-4.1	Below screen
								MP1B	389.0	6390.2	-9.8	Below screen
2	730.4	746.4	6048.8	6032.8	16.0	I	Tp	**MP2A**	744.8	6034.4	1.6	Within screen - Screen dry
								PP2	750.1	6029.1	-3.7	Below screen
								MP2B	755.8	6023.4	-9.4	Below screen
3	895.5	937.4	5883.7	5841.8	41.9	RT	Tp	**MP3A**	915.1	5864.1	22.3	Within screen
								MP3B	935.3	5843.9	2.1	Within screen
								PP3	940.6	5838.6	-3.2	Below screen
								MP3C	946.3	5832.9	-8.9	Below screen

Note: R-7 Brass Cap Ground Elevation: 6779.2 ft; all measurements are from this elevation;
MP = Monitor Port; PP = Pump Port; Monitor Ports shown in bold are instrumented ports


R-7 Screen 1
Screen 1 GW
Screen 1 Transducer
Groundwater Elevation (ft)
6406
6405
6404
6403
6402
6401
6400
MP1A went dry during sampling
MP1B water level
Port MP1A Elevation: 6401.2 ft
1/1/01
1/1/02
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
Date


R-7 Screen 3
Screen 3 GW
Screen 3 Transducer
Groundwater Elevation (ft)
5884
5883
5882
5881
5880
5879
5878
5877
5876
5875
Port 3A Elevation: 5864.1 ft
1/1/01
1/1/02
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
Date

3.10 R-8

Location: R-8 is located in middle Los Alamos Canyon about 0.75 mi downstream of the confluence with DP Canyon and supply well O-4.

Completion Type: Multiple completion, two screens in the regional aquifer. The top of screen 1 is about 13 ft below the water table.

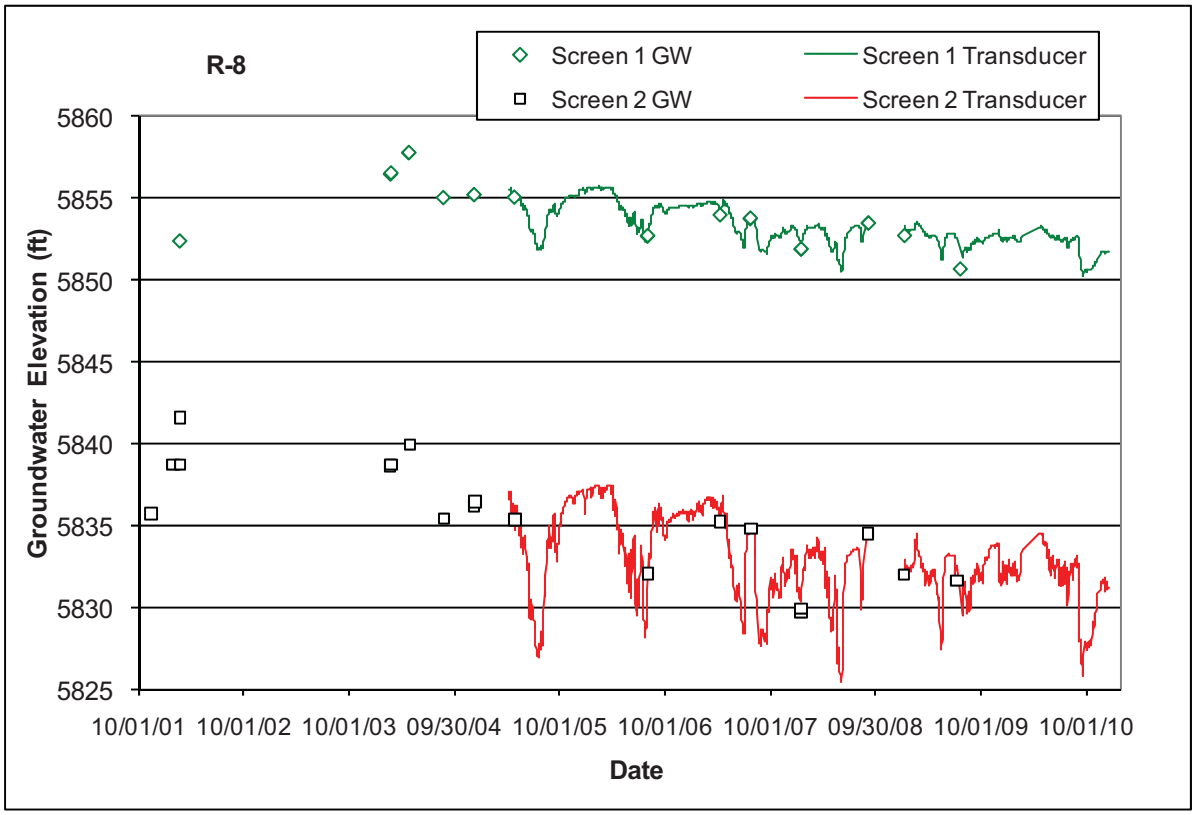
Period of Record: Westbay® installed February 23, 2002, transducers installed April 7, 2005, data through 2010.

Remarks: Screens are 66 ft apart, head in screen 2 about 20 ft lower than screen 1. The groundwater does not indicate a response to atmospheric pressure fluctuations, but the groundwater at both screens responds to pumping supply well PM-3.

R-8 Construction and Port Data

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elevation (ft)	Distance from Bottom of Screen (ft)	Comment
1	705.3	755.7	5839.4	5789.04	50.4	RT	Tp	MP1A	711.1	5833.64	44.6	Within Screen
								MP1B	721.4	5823.34	34.3	Within Screen
								MP1C	751.3	5793.44	4.4	Within Screen
								PP1	756.7	5788.04	-1.0	Below Screen
								MP1D	762.3	5782.44	-6.6	Below Screen
2	821.3	828.0	5723.4	5716.74	6.7	RD	Tp	MP2A	825.0	5719.74	3.0	Within Screen
								PP2	830.4	5714.34	-2.4	Below Screen
								MP2B	836.0	5708.7	-8.0	Below Screen

Note: R-8 Brass Cap Ground Elevation: 6544.74 ft; all measurements are from this elevation;
MP = Monitor Port; PP = Pump Port; Monitor Ports shown in bold are instrumented ports



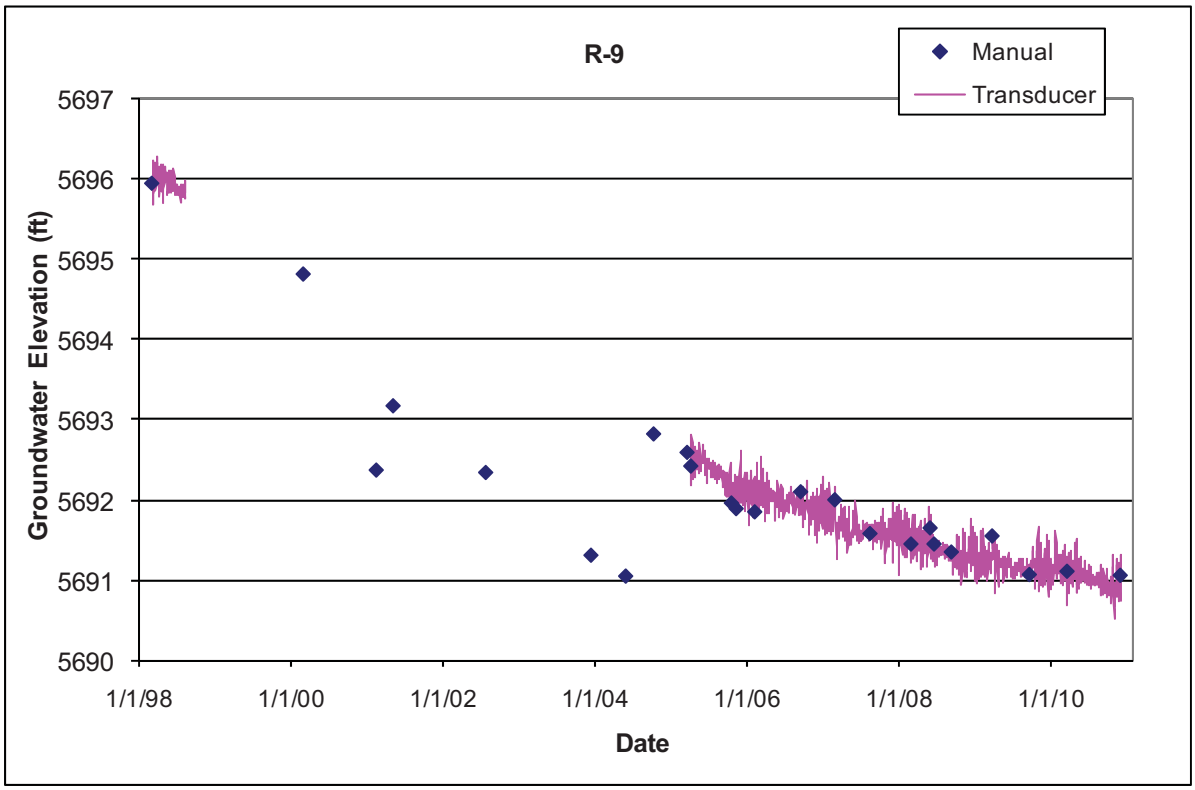
3.11 R-9

Location: R-9 is located in Los Alamos Canyon near the eastern LANL boundary.
Completion Type: Single completion at the top of the regional aquifer. The screen straddles the water table.
Period of Record: March 2, 1998, to August 12, 1998, in temporary well. Final well completed October 1999. Transducer installed April 5, 2005, data through 2010.
Remarks: R-9 was completed to a depth of 758 ft, about 70 ft into the regional aquifer. The well is 100% barometrically efficient; the groundwater has no immediate response to atmospheric pressure fluctuations. However, the aquifer indicates a delayed 65% response to atmospheric pressure.

R-9 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	683.0	748.5	5699.8	5634.3	65.5	741.4	5641.4	748.5	5634.3	758	9.5	29.7	RT	Tsfb

Note: R-9 Brass Cap Ground Elevation: 6382.8; all depths are from this elevation



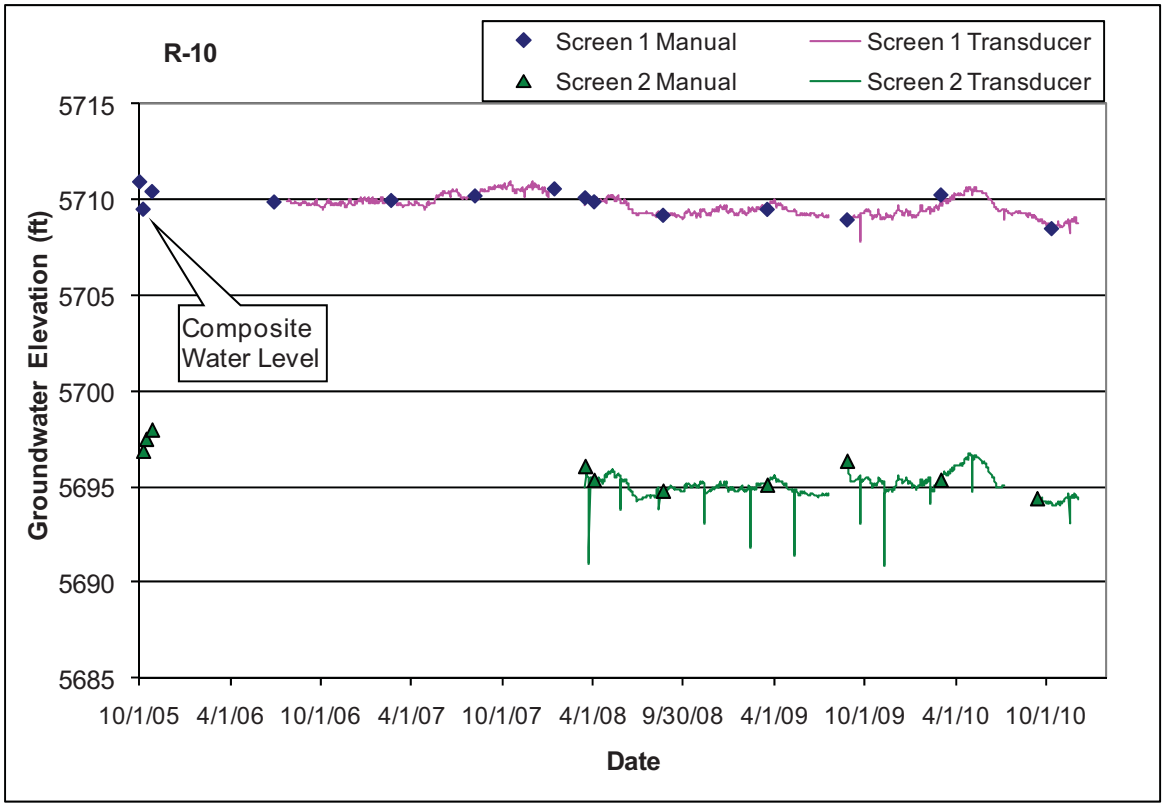
3.12 R-10

Location: R-10 is located in lower Sandia Canyon on San Ildefonso land east of the LANL boundary.
Completion Type: Dual completion in two deeper zones within the regional aquifer. Baski packer and dual valve sampling system with single submersible pump installed in May 2006.
Period of Record: Well completed October 2005, transducers installed July 26, 2006, data through 2010. The transducers were removed during repair of the Baski system in 2008 and 2009.
Remarks: R-10 screen 1 is 174 ft deeper than the screen at R-10a; due to relatively low hydraulic conductivity of the formation between these screens, the head at R-10 screen 1 is 30 ft lower than at R-10a. The screen 2 water level gage tube was inoperable until repaired in February 2008; water level data for R-10 screen 2 in 2006 and 2007 are not available. The groundwater at R-10 screens exhibit a barometric efficiency of about 45%. The regional aquifer at both screens responds to pumping at supply well PM-1.

R-10 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Packer/ Sump (ft)	Top of Packer/ Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	874.0	897.0	5488.3	5465.3	23.0	884.3	5478.0	905.2	5457.2	905.2	8.2	25.5	RD	Tsf
2	1042.0	1065.0	5320.3	5297.3	23.0	1053.1	5309.2	1065.0	5297.3	1081.6	16.6	5.8	RD	Tsf

Note: R-10 Brass Cap Ground Elevation: 6362.31 ft; all measurements are from this elevation



3.13 R-10a

Location: R-10a is located in lower Sandia Canyon on San Ildefonso land east of the LANL boundary about 55 ft west of R-10.

Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 66 ft below the water table.

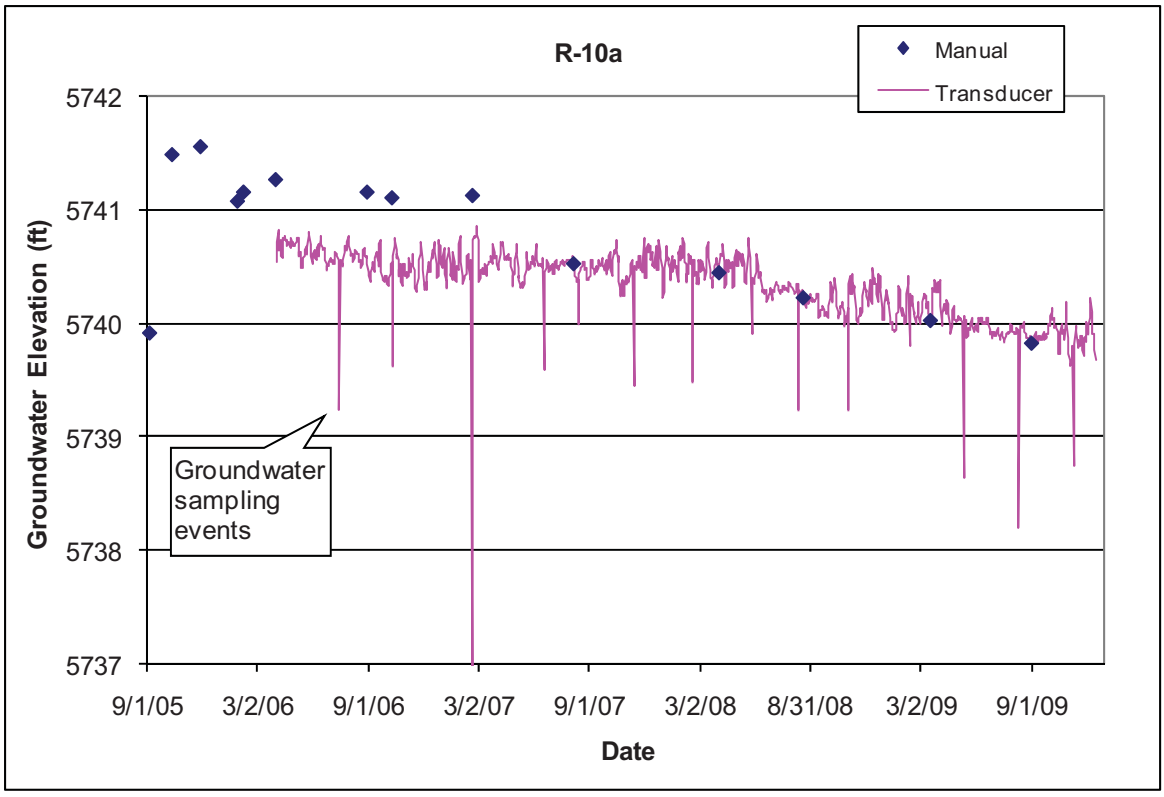
Period of Record: Well completed August 2005, transducer installed April 3, 2006, data through 2010.

Remarks: The R-10a water level is about 30 ft higher than at R-10 screen 1. The groundwater at R-10a shows an immediate 58% response to atmospheric pressure fluctuations for a well barometric efficiency of 42%. There is no apparent response to supply well pumping at R-10a.

R-10a Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	690.0	700.0	5673.7	5663.7	10.0	685.6	5678.1	700.0	5663.7	709.1	9.1	27.9	RT	Tsf

Note: Brass Cap Ground Elevation: 6363.74 ft; all measurements are from this elevation



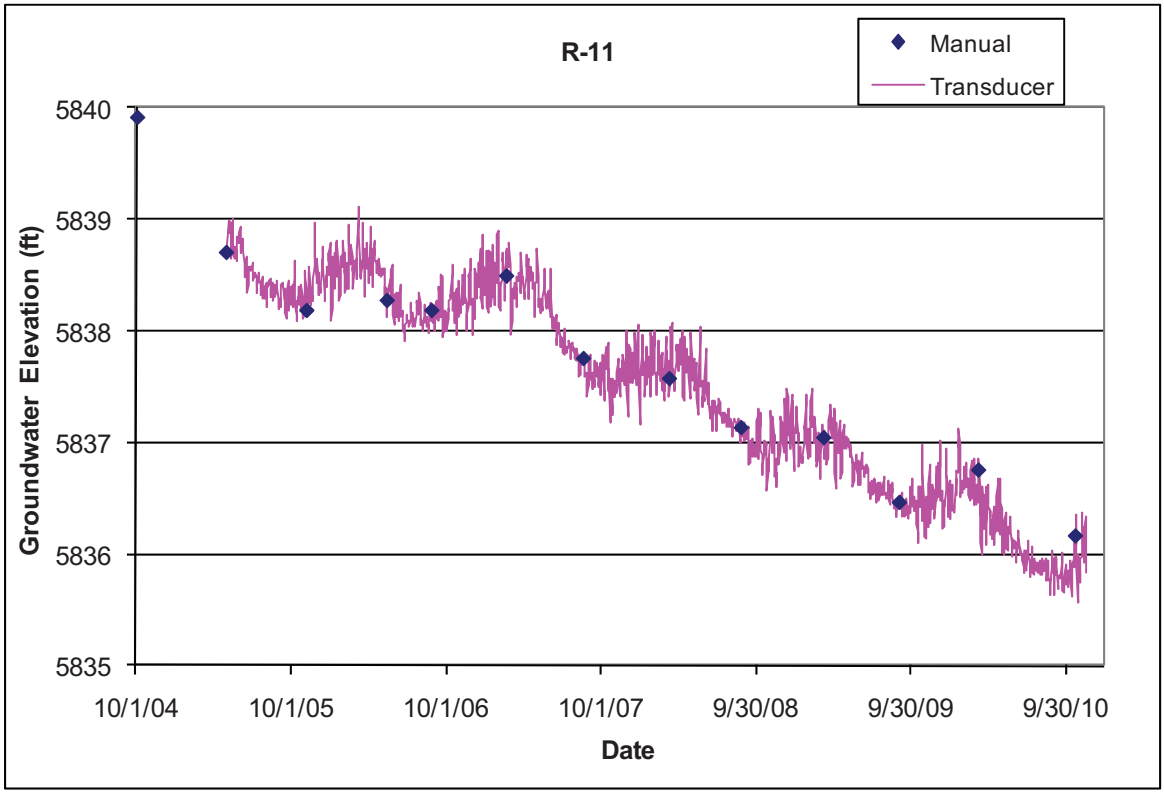
3.14 R-11

Location: R-11 is located in middle Sandia Canyon about 0.5 mi upstream of supply well PM-3.
Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 17 ft below the water table.
Period of Record: Transducer installed May 4, 2005; data through 2010.
Remarks: R-11 was completed in 2004 to a depth of 901.7 ft, about 66 ft into the regional aquifer. The well is 100% barometrically efficient; the groundwater has no immediate response to atmospheric pressure fluctuations. The aquifer at R-11 exhibits a seasonal response to supply well pumping but does not indicate a direct response to any specific supply well.

R-11 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	855.0	877.9	5818.7	5795.8	22.9	850.0	5823.7	877.9	5795.8	901.7	23.8	73.1	RT	Tp

Note: R-11 Brass Cap Ground Elevation: 6673.72 ft; all measurements are from this elevation



3.15 R-12 (Regional)

Monitoring well R-12 was recompleted as a dual screen intermediate monitoring well in December 2007. Refer to Section 4 for recent R-12 intermediate groundwater level status.

Location: R-12 is located in lower Sandia Canyon near State Route (SR) 4 and supply well PM-1.

Completion Type: Multiple completion, two screens in intermediate zones, one screen at the top of the regional aquifer until September 2006. Well recompleted as two intermediate screens on December 13, 2007, when regional screen 3 was plugged and abandoned.

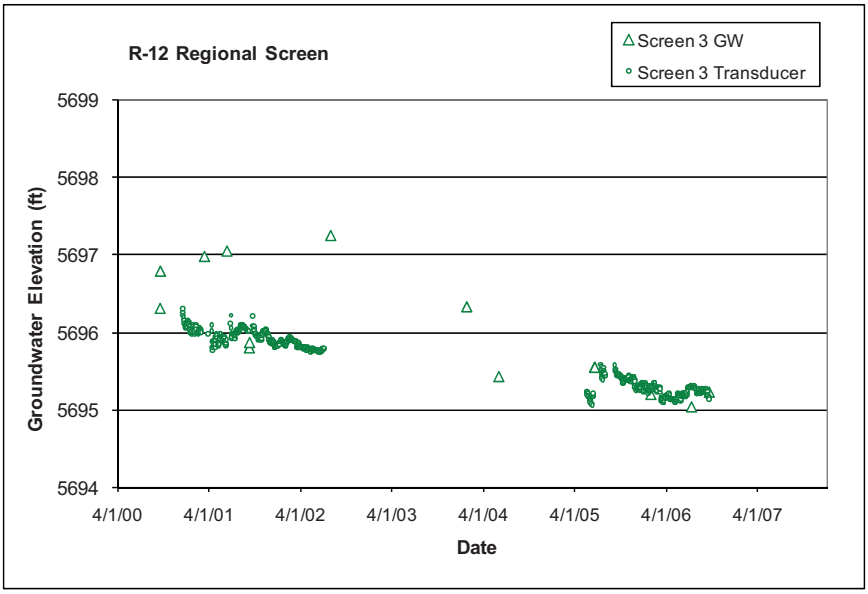
Period of Record: Westbay® installed March 21, 2000, transducers installed December 14, 2000, intermittent data to September 21, 2006, when transducers were removed for removal of the Westbay® system for well rehabilitation. No regional aquifer water level data after 2006. Transducers were reinstalled at intermediate screens 1 and 2 on December 13, 2007; data through 2010.

Remarks: In December 2007, screen 3 was abandoned and a Baski packer with dual pump sampling system was installed at the two intermediate screens. The regional aquifer at screen 3 did not exhibit a seasonal response to supply well pumping, or a response to pumping of any specific supply well, including nearby supply well PM-1. There is no immediate response to atmospheric pressure fluctuations at any screen.

R-12 Former Westbay Port Data

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elev (ft)	Distance from Bottom of Screen (ft)	Sump Volume (L)	Comment
1	459.0	467.5	6040.6	6032.1	8.5	I	Tb4	MP1A	468.1	6031.5	-0.6	1.1	Below screen
								PP1	473.5	6026.1	-6.0	11.3	Below screen
								MP1B	479.1	6020.5	-11.6	21.9	Below screen
2	504.5	508.0	5995.1	5991.6	3.5	I	Tb4	MP2A	507.0	5992.6	1.0		Within screen
								PP2	512.4	5987.2	-4.4	8.3	Below screen
								MP2B	518.0	5981.6	-10.0	18.9	Below screen
3	801.0	839.0	5698.6	5660.6	38	RT	Tsfb	MP3A	810.8	5688.8	28.2		Within screen
								PP3A	816.2	5683.4	22.8		Within screen
								MP3B	821.8	5677.8	17.2		Within screen
								PP3B	827.2	5672.4	11.8		Within screen
								MP3C	832.9	5666.7	6.1		Within screen

Brass Cap Elevation: 6499.6 ft; all measurements are from this elevation;
MP = measurement port; PP = pumping port

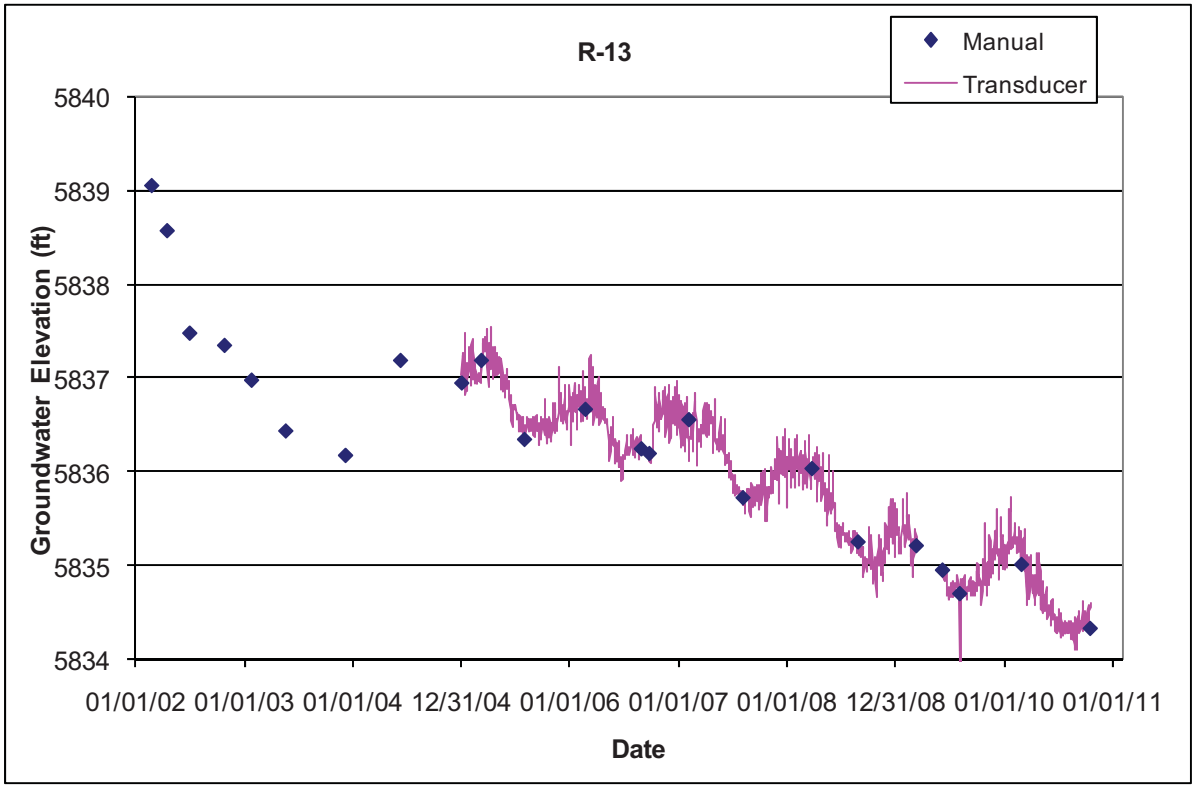


3.16 R-13

Location: R-13 is located in lower Mortandad Canyon near the LANL boundary.
Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 120 ft below the water table.
Period of Record: Well completed October 2001, transducer installed January 3, 2005, data through 2010. The transducer failed and was replaced in June 2009.
Remarks: R-13 was completed to a depth of 1029.4 ft, about 200 ft into the regional aquifer. The well is 100% barometrically efficient; the groundwater has no immediate response to atmospheric pressure fluctuations. However, the aquifer indicates a delayed 30% response to atmospheric pressure. R-13 exhibits a seasonal response to supply well pumping and responds primarily to pumping at PM-4 (McLin 2006) and possibly to PM-2 and PM-5, but apparently does not respond significantly to pumping at nearby supply well PM-3.

R-13 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Hydro Zone Code	Geo Unit Code
1	958.3	1018.7	5714.8	5654.4	60.4	933.0	5740.1	1018.7	5654.4	1029.4	10.7	RT	Tp
Note: R-13 Brass Cap Ground Elevation: 6673.05 ft; all measurements are from this elevation													



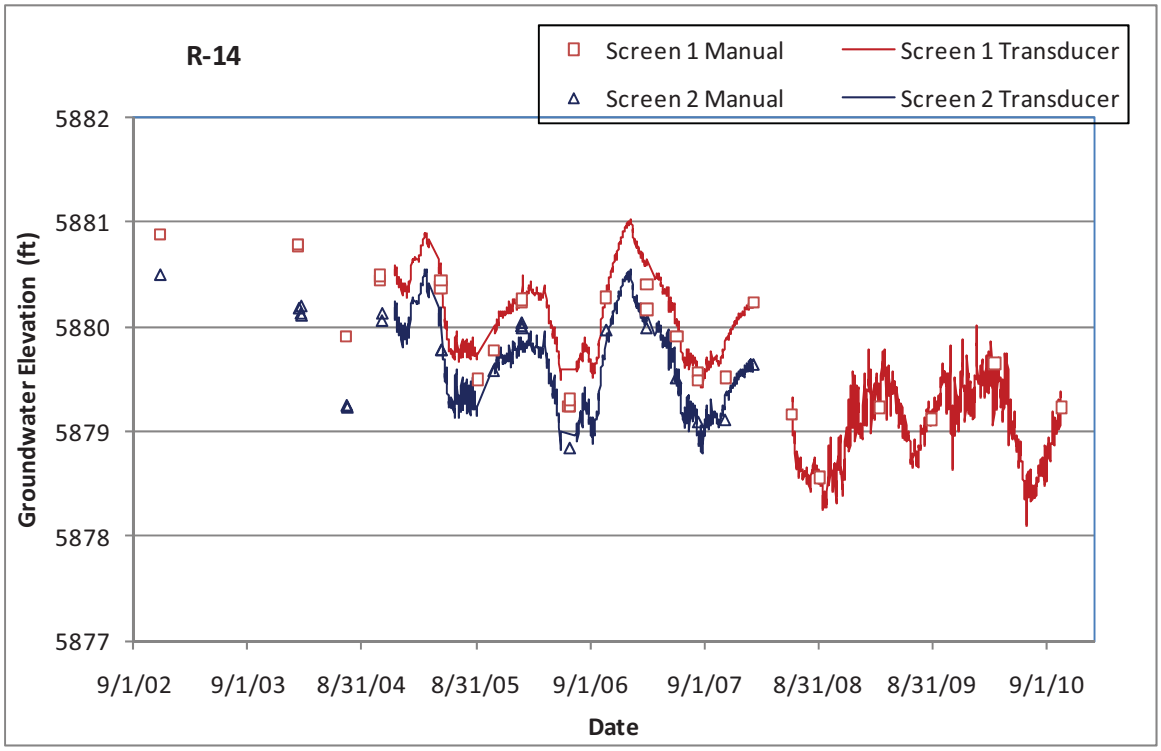
3.17 R-14

Location: R-14 is located in upper Ten Site Canyon about 0.5 mi upgradient of supply well PM-5.
Completion Type: Formerly multiple completion, two screens in the regional aquifer; recompleted in February 2008 to single screen at the top of the regional aquifer when screen 2 was plugged and abandoned. The top of screen 1 is about 20 ft below the water table.
Period of Record: Westbay® system installed November 23, 2002, transducers installed December 14, 2004, water level data from Westbay® system to February 25, 2008. Single transducer installed in recompleted single screen well June 10, 2008; data through 2010.
Remarks: Screens were formerly 53 ft apart; heads between screens were within 0.5 ft of each other. The aquifer shows no response to atmospheric pressure fluctuations. The aquifer at R-14 responds primarily to pumping supply well PM-5. After removal of the Westbay® system, an error in the Westbay® pipe tally resulted in correction of all Westbay® derived water level data downward by 3.3 ft.

R-14 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Depth (ft)	Pump Elev (ft)	Top of Packer/ Plug (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1200.6	1233.2	5861.48	5828.88	32.6	1198.0	5864.1	1244.7	11.5	36.0	RT	Tp
2	1286.5	1293.1	5775.58	5768.98	6.6	Screen 2 Plugged and Abandoned 2/08					RD	Tp

Note: R-14 brass cap elevation 7062.08 ft; all measurements from this elevation.



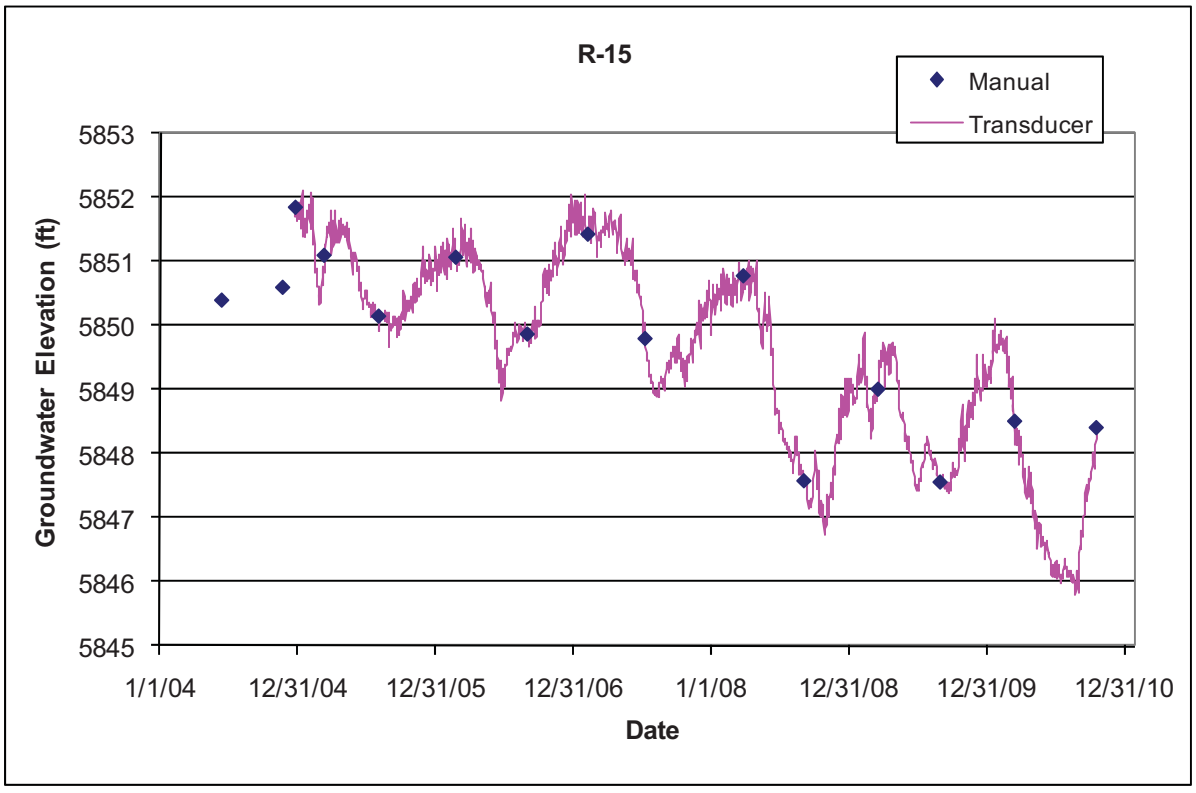
3.18 R-15

Location: R-15 is located in lower Mortandad Canyon downstream of the sediment traps.
Completion Type: Single completion at the top of the regional aquifer. The screen straddles the water table.
Period of Record: Well completed September 1999, transducer installed December 23, 2004, transducer data through 2010.
Remarks: R-15 was completed in 1999 to a depth of 1030.6 ft, about 140 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The aquifer at R-15 responds to pumping supply wells PM-4 and PM-5.

R-15 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Casing Vol (Gal.)	Hydro Zone Code	Geo Unit Code
1	958.6	1020.3	5861.4	5799.7	61.7	1015.6	5804.4	1020.3	5799.7	1030.6	10.3	60.8	RT	Tp

Note: R-15 Brass Cap Ground Elevation: 6820.0 ft; all measurements are from this elevation



3.19 R-16

Location: R-16 is located northeast of White Rock in lower Cañada del Buey near the confluence with lower Mortandad Canyon.

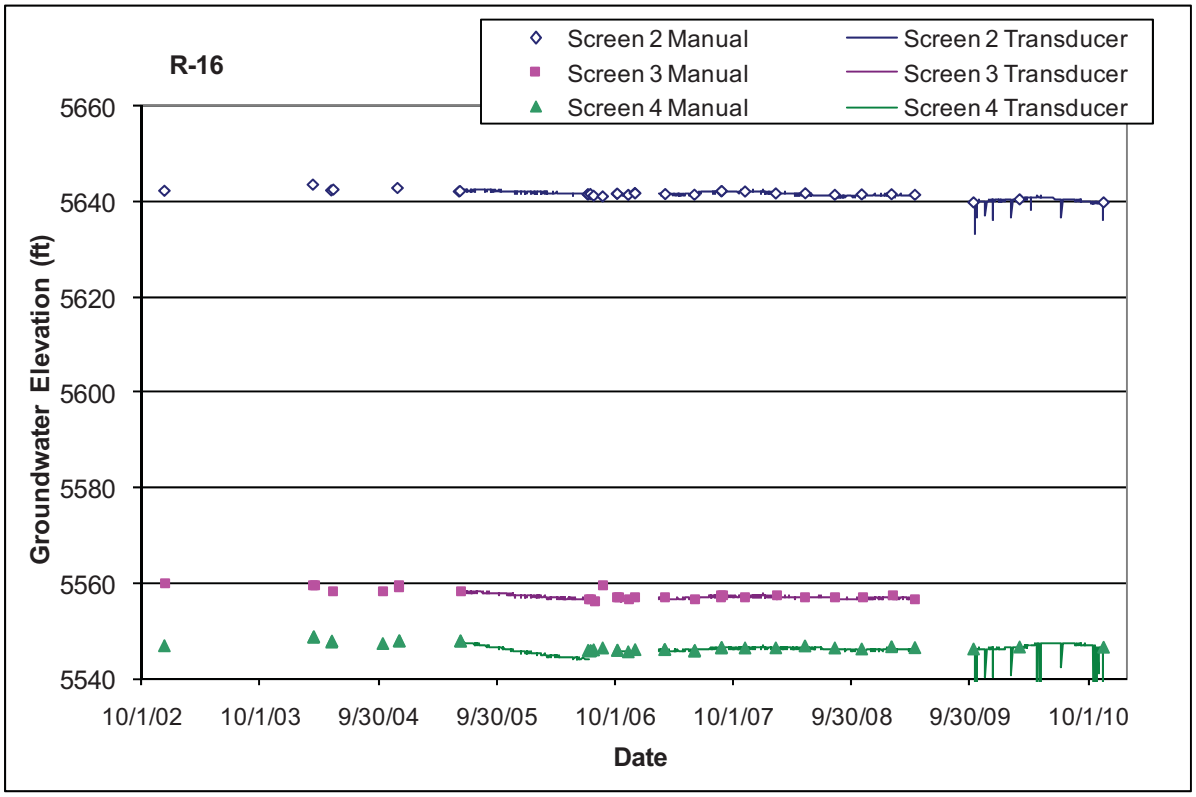
Completion Type: Multiple completion, four screens in the regional aquifer, screen 1 is blocked by casing and is not useable.

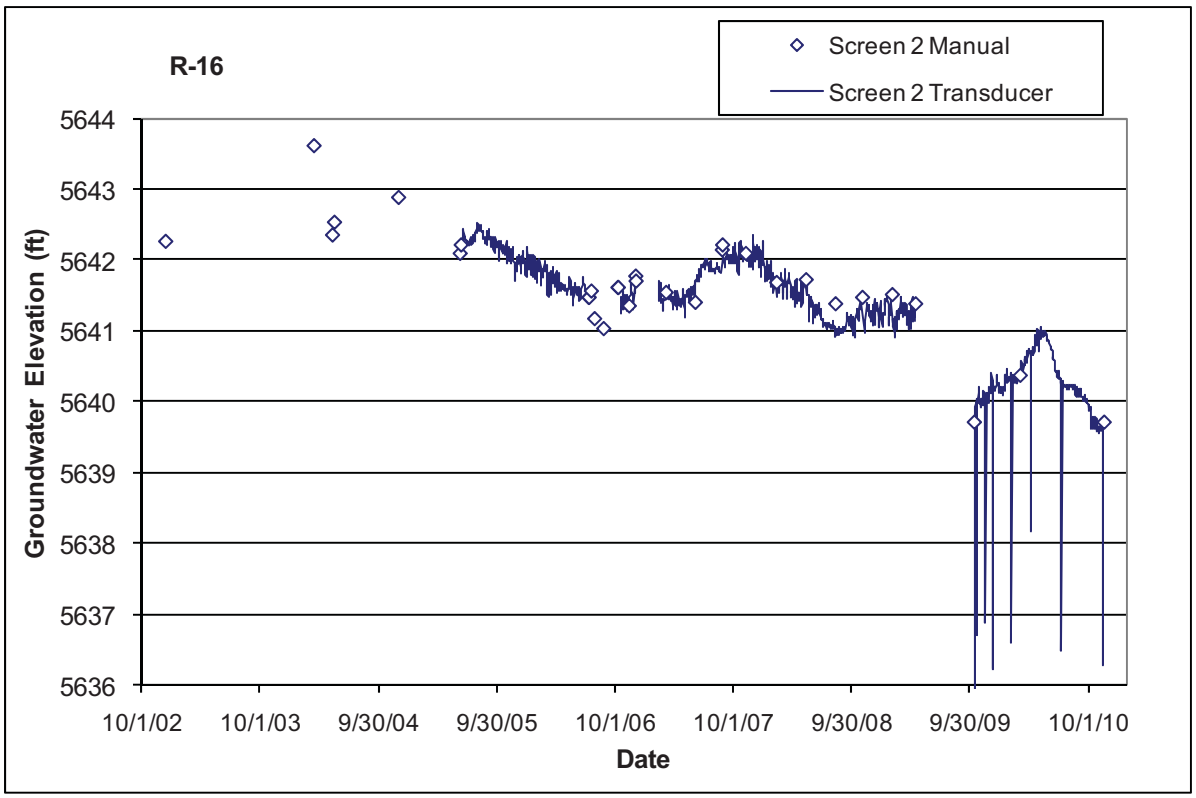
Period of Record: Westbay® installed December 14, 2002, transducers installed June 16, 2005, transducer data to July 12, 2006, when the Westbay® system was removed for additional screen development. The Westbay® system was reinstalled and transducers were reinstalled October 18, 2006. Westbay® transducer data extend to April 15, 2009, when the Westbay® system was removed for well rehabilitation and conversion. A single submersible pump with dual valve Baski sampling system was installed on October 14, 2009, to monitor screens 2 and 4; screen 3 not monitored after April 15, 2009 (LANL 2009). Groundwater level data from the dual screen sampling system are available from October 14, 2009, through 2010.

Remarks: Screens 2 and 3 are about 144 ft apart with a head difference of over 80 ft. Screens 3 and 4 are 215 ft apart and have a head difference of about 11 ft. The aquifer response to atmospheric pressure declines downward from screen 2 to screen 4, from 68% at screen 2 to 57% at screen 4.

R-16 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Packer/ Sump Bottom (ft)	Packer Bottom Depth (ft)	Bottom of Sump Elev (ft)	Sump Length (ft)	Hydro Zone Code	Geo Unit Code	Comment
1	641.0	648.6	5615.9	5608.3	7.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RT	Tp	Screen unusable
2	863.4	870.9	5393.5	5386.0	7.5	872.8	5384.1	870.9	5386.0	881.2	885.6	5375.6	10.3	RD	Tsf	Upper zone
3	1014.8	1022.4	5242.1	5234.5	7.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RD	Tsf	Screen sealed off
4	1237.0	1244.6	5019.9	5012.3	7.6	1234.6	5022.3	1244.6	5012.3	1276.7	1223.0	4980.2	32.1	RD	Tsf	Lower zone
Brass Cap Elevation: 6256.87 ft; all measurements are from this elevation																




R-16
Screen 2 Manual
Screen 2 Transducer
Groundwater Elevation (ft)
5644
5643
5642
5641
5640
5639
5638
5637
5636
10/1/02
10/1/03
9/30/04
9/30/05
10/1/06
10/1/07
9/30/08
9/30/09
10/1/10
Date


R-16
Screen 3 Manual
Screen 3 Transducer
Screen 4 Manual
Screen 4 Transducer
Groundwater Elevation (ft)
5560
5558
5556
5554
5552
5550
5548
5546
5544
5542
5540
10/1/02
10/1/03
9/30/04
9/30/05
10/1/06
10/1/07
9/30/08
9/30/09
10/1/10
Date

3.20 R-16r

Location: R-16r is located northeast of White Rock adjacent to R-16 in lower Cañada del Buey near the confluence with lower Mortandad Canyon.

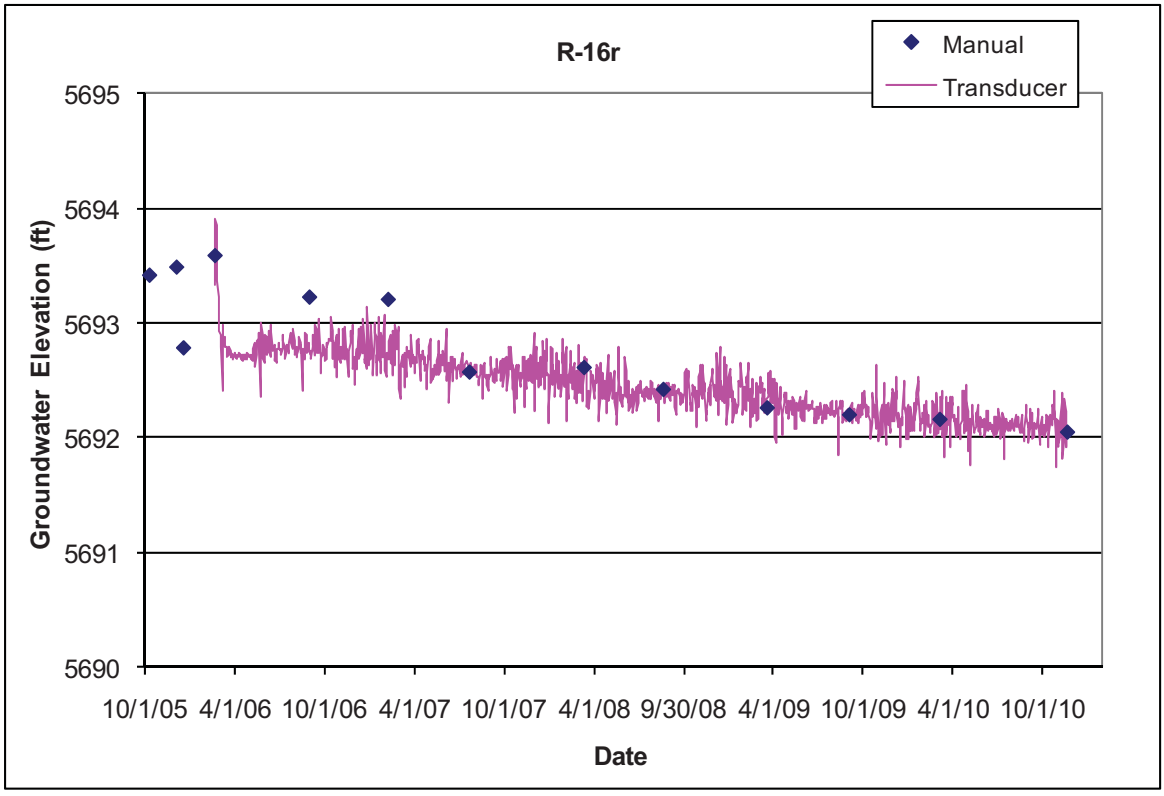
Completion Type: Single completion at the top of the regional aquifer. R-16r provides data for the top of the regional aquifer in place of R-16 screen 1, which is blocked by casing and not useable. The top of the screen is about 35 ft below the water table.

Period of Record: Well completed October 11, 2005, transducers installed February 21, 2006, data through 2010.

Remarks: R-16r water level at the top of the regional aquifer about 50 ft higher than the water level at R-16 screen 2, which is 250 ft lower than the R-16r screen. The well is 90% barometrically efficient; the aquifer indicates a 10% delayed response to atmospheric pressure.

R-16r Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (Gal.)	Hydro Zone Code	Geo Unit Code
1	600.0	617.6	5657.0	5639.4	17.6	596.6	5660.4	617.6	5639.4	631.4	13.8	11.2	RT	Tpt
Note: Brass Cap Ground Elevation: 6256.97 ft; all measurements are from this elevation														



3.21 R-17

Location: R-17 is located in middle Pajarito Canyon below the confluence with Two-Mile Canyon and about 1 mi southwest of supply well PM-5.

Completion Type: Dual completion within the regional aquifer with a Baski dual valve system and single submersible pump. The top of screen 1 is located about 20 ft below the water table. The screens are 44 ft apart.

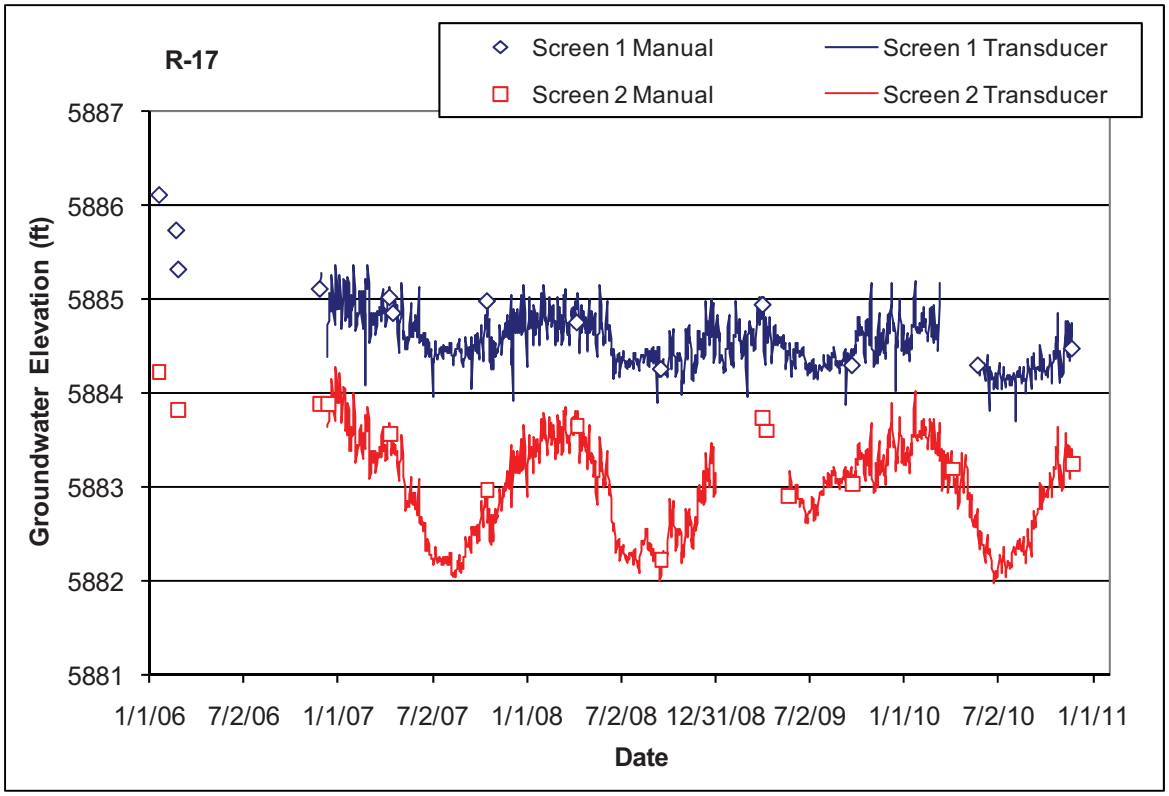
Period of Record: Completed January 4, 2006, transducers installed December 12, 2006, transducer data through 2010.

Remarks: R-17 was completed to a depth of 1140.9 ft, about 100 ft into the regional aquifer. Screen 1 is 100% barometrically efficient; the aquifer does not show a response to atmospheric pressure fluctuations. Screen 2 is 90% barometrically efficient. Both screens show a seasonal response to supply well pumping; screen 2 shows a response to pumping supply wells PM-2, PM-4, and PM-5.

R-17 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Packer/ Sump (ft)	Top of Packer/ Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1057.0	1080.0	5864.5	5841.5	23.0	1089.6	5831.9	1101.2	5820.4	1101.2	21.1	66.1	RT	Tpf
2	1124.0	1134.0	5797.5	5787.5	10.0	1128.6	5792.9	1134.0	5787.5	1140.9	6.9	21.6	RD	Tpf

Note: Brass Cap Ground Elevation: 6921.51 ft; all measurements are from this elevation



3.22 R-18

Location: R-18 is located on a mesa at TA-14 between Pajarito Canyon and Cañon de Valle, about 3000 ft northeast of R-25.

Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 70 ft bellow the water table.

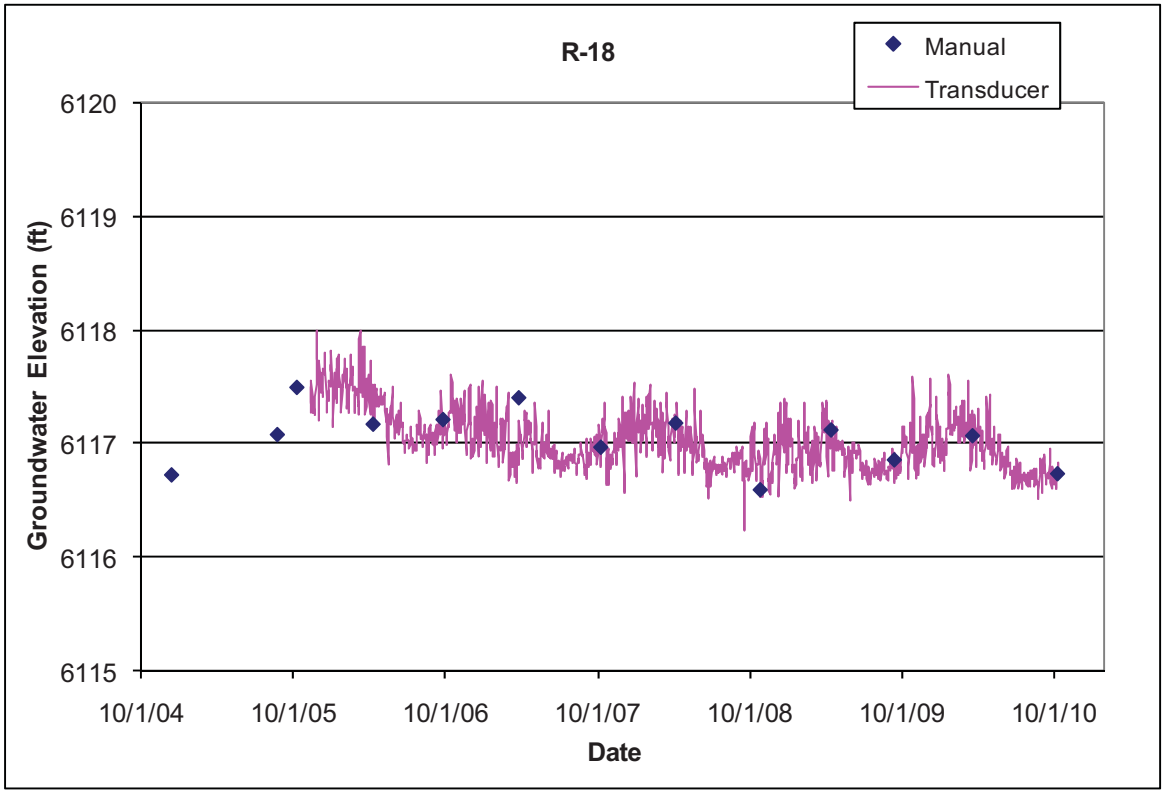
Period of Record: Completed December 12, 2004, transducer installed October 11, 2005, transducer data through 2010.

Remarks: R-18 was completed to a depth of 1405 ft, about 118 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer does not indicate a response to atmospheric pressure fluctuations. There is no apparent response to supply well pumping.

R-18 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1358.0	1381	6046.8	6023.8	23.0	1353	6051.8	1381.0	6023.8	1405	24.0	75.1	RT	Tpf

Note: Brass Cap Ground Elevation: 7404.83 ft; all measurements are from this elevation



3.23 R-19

Location: R-19 is located on a mesa south of Three-Mile Canyon about 1.2 mi west of supply well PM-2.

Completion Type: Multiple completion, two screens in intermediate zones, and five screens in the regional aquifer. Screen 3 straddles the regional water table.

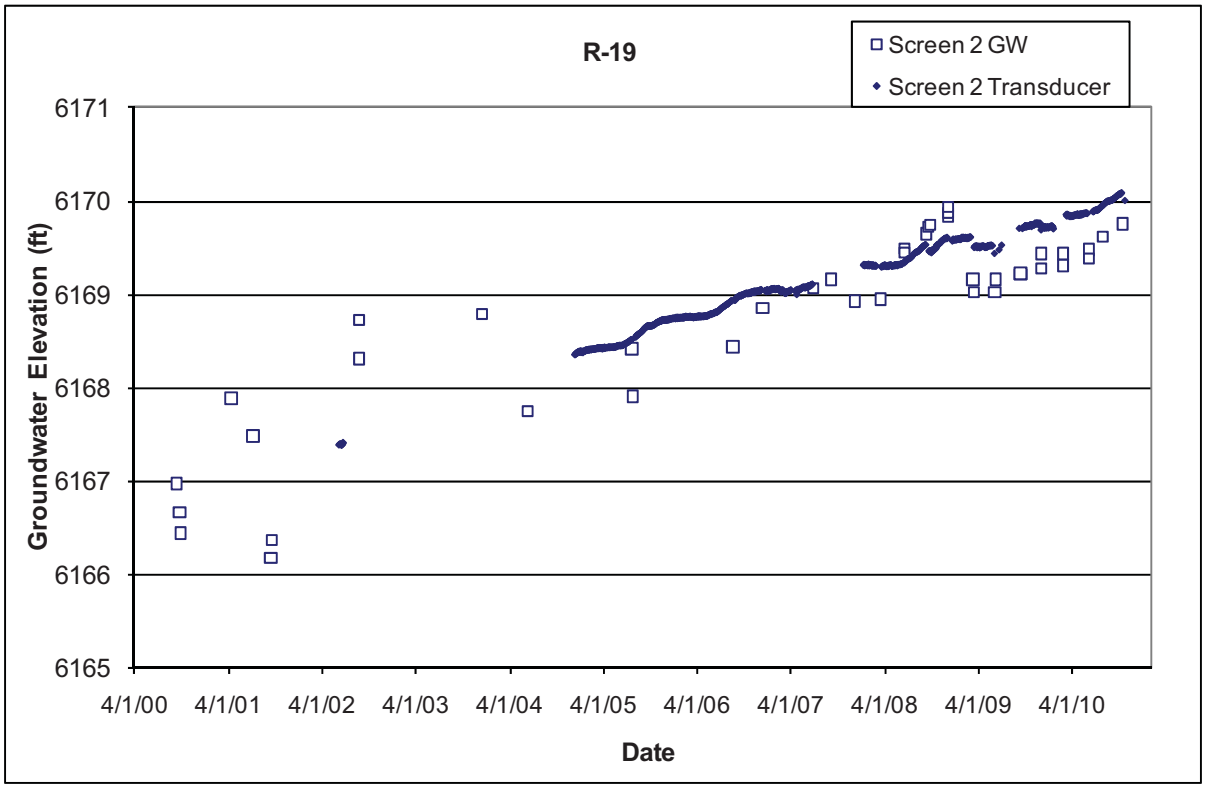
Period of Record: Westbay® installed September 11, 2000, transducers installed June 04, 2002, equipment problems occurred within two weeks. Transducers reinstalled December 10, 2004; transducer data to June 25, 2007, when the transducer string cable failed. Cable rebuilt and transducers reinstalled January 10, 2008; data are available intermittently through 2010.

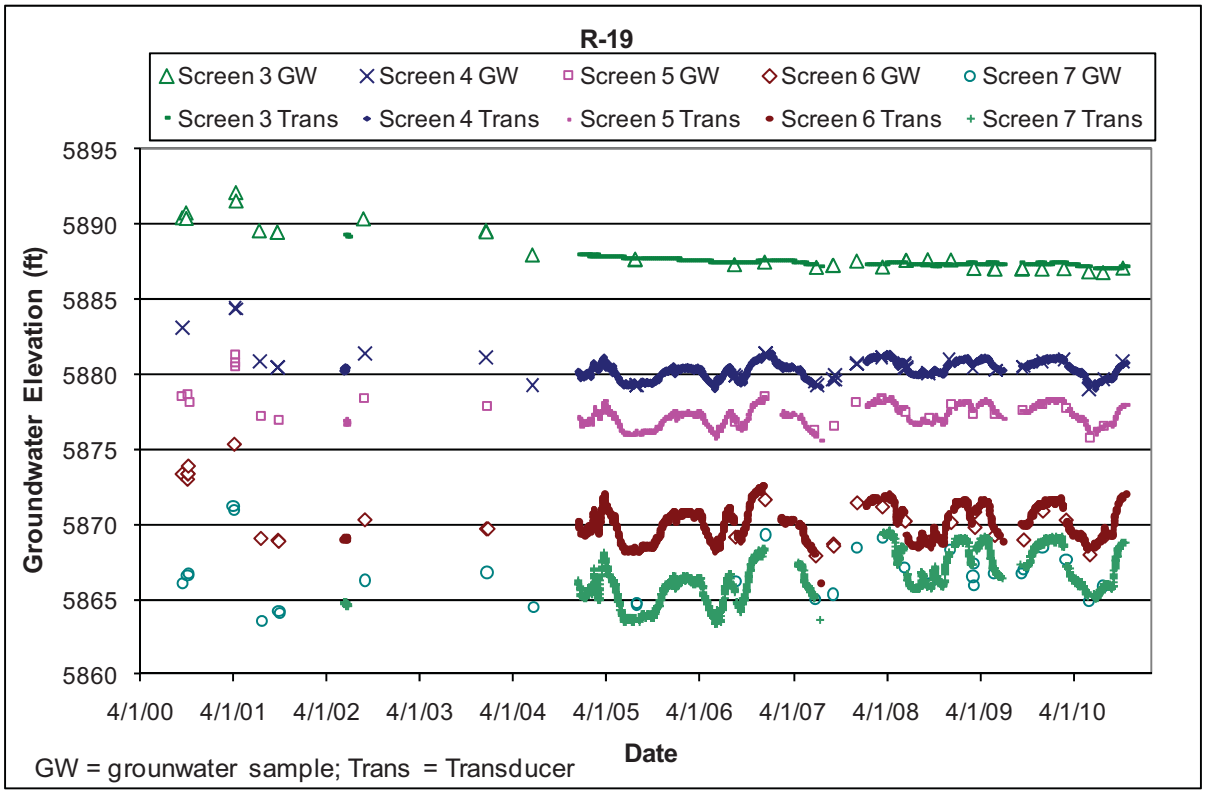
Remarks: Screen 1 has been dry since Westbay® installation. Screen 3 at the top of the regional aquifer does not show a response to atmospheric pressure fluctuations, but the deeper screens 4 through 7 indicate 40% to 50% response. The deeper screens (4 through 7) in the regional aquifer respond to supply well pumping at PM-2 and PM-4, and possibly to PM-5.

R-19 Construction Information and Port Data

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elevation (ft)	Distance from Bottom of Screen (ft)	Sump Volume (L)	Comment
1	827.2	843.6	6239.1	6222.7	16.4	I	Qbog	MP1A	844.2	6222.1	-0.6	1.3	Below Screen
								PP1	849.6	6216.7	-6	13.0	Below Screen
								MP1B	855.2	6211.1	-11.6	25.1	Below Screen
2	893.3	909.6	6173.0	6156.7	16.3	I	Tp	**MP2A**	909.3	6157.0	0.3		Within Screen
								PP2	914.7	6151.6	-5.1	11.0	Below Screen
								MP2B	920.3	6146.0	-10.7	23.1	Below Screen
3	1171.4	1215.4	5894.9	5850.9	44.0	RT	Tpf	MP3A	1190.7	5875.6	24.7		Within Screen
								PP3	1196.1	5870.2	19.3		Within Screen
								MP3B	1201.7	5864.6	13.7		Within Screen
								MP3C	1212.8	5853.5	2.6		Within Screen
4	1410.2	1417.4	5656.1	5648.9	7.2	RD	Tpf	**MP4A**	1412.9	5653.4	4.5		Within Screen
								PP4	1418.3	5648.0	-0.9	1.9	Below Screen
								MP4B	1423.9	5642.4	-6.5	14.1	Below Screen
5	1582.6	1589.8	5483.7	5476.5	7.2	RD	Tpf	**MP5A**	1586.1	5480.2	3.7		Within Screen
								PP5	1591.5	5474.8	-1.7	3.7	Below Screen
								MP5B	1597.1	5469.2	-7.3	15.8	Below Screen
6	1726.8	1733.9	5339.5	5332.4	7.1	RD	Tpf	**MP6A**	1730.1	5336.2	3.8		Within Screen
								PP6	1735.4	5330.9	-1.5	3.2	Below Screen
								MP6B	1741.1	5325.2	-7.2	15.6	Below Screen
7	1832.4	1839.5	5233.9	5226.8	7.1	RD	Tpf	**MP7A**	1834.7	5231.6	4.8		Within Screen
								PP7	1840.0	5226.3	-0.5	1.1	Below Screen
								MP7B	1845.7	5220.6	-6.2	13.4	Below Screen

Note: R-19 Brass Cap Ground Elevation: 7066.3 ft; all measurements are from this elevation;
MP = Monitor Port; PP = Pump Port; Monitor Ports shown in bold are instrumented ports


R-19
Screen 2 GW
Screen 2 Transducer
Groundwater Elevation (ft)
6171
6170
6169
6168
6167
6166
6165
4/1/00
4/1/01
4/1/02
4/1/03
4/1/04
4/1/05
4/1/06
4/1/07
4/1/08
4/1/09
4/1/10
Date


R-19
Screen 3 GW
Screen 4 GW
Screen 5 GW
Screen 6 GW
Screen 7 GW
Screen 3 Trans
Screen 4 Trans
Screen 5 Trans
Screen 6 Trans
Screen 7 Trans
Groundwater Elevation (ft)
5895
5890
5885
5880
5875
5870
5865
5860
4/1/00
4/1/01
4/1/02
4/1/03
4/1/04
4/1/05
4/1/06
4/1/07
4/1/08
4/1/09
4/1/10
Date
GW = grounwater sample; Trans = Transducer

3.24 R-20

Location: R-20 is located in lower Pajarito Canyon about 1300 ft east of supply well PM-2.

Completion Type: Multiple completion, originally three screens in the regional aquifer. Screen 3 was plugged and abandoned November 2007, leaving two screens in the regional aquifer. The top of screen 1 is about 76 ft below the regional water table. The recompleted well incorporates two packers, one below screen 1 and one above screen 2 to minimize purge volumes.

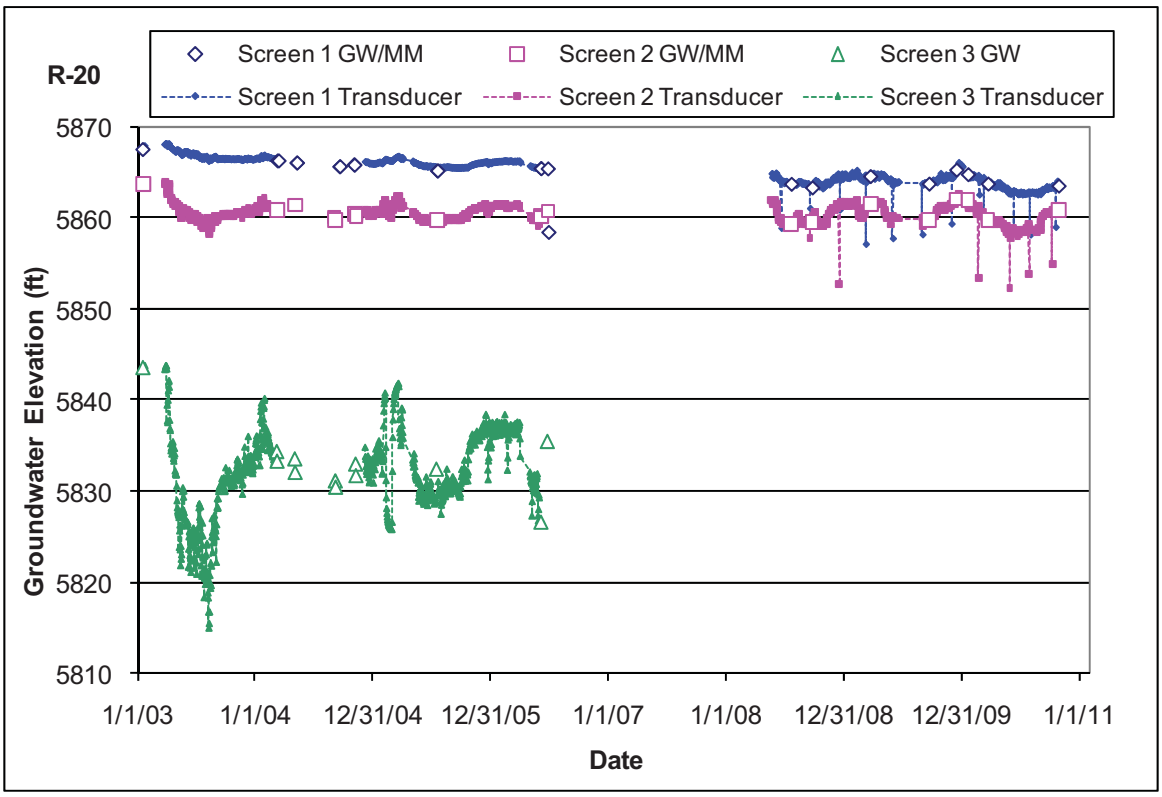
Period of Record: Westbay® installed January 18, 2003, transducers installed March 26, 2003, intermittent transducer data to June 1, 2006, when the Westbay® system was removed. No water level data in the last half of 2006 and in 2007 during well rehabilitation. Transducers installed at screens 1 and 2 in May 2008; data through 2010.

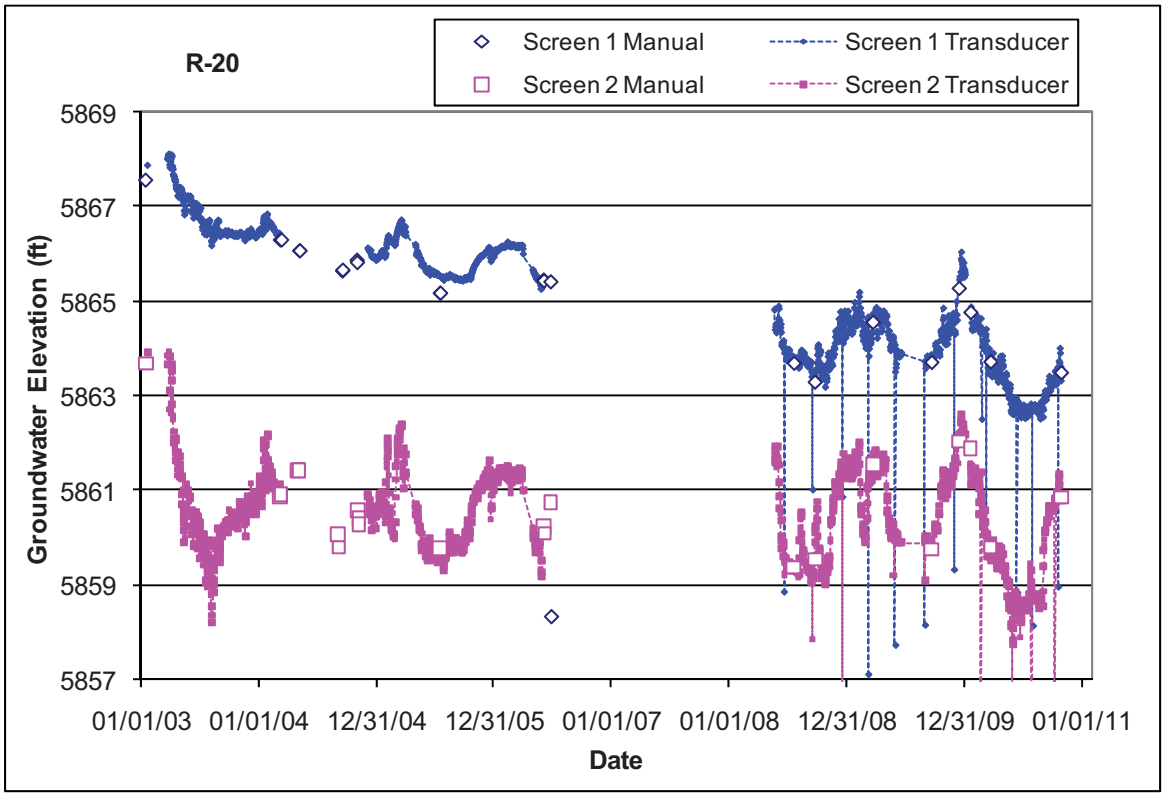
Remarks: A dual pump Baski sampling system with two packers between screens 1 and 2 installed May 2008 (LANL January 2008). Screen 1 shows no response to atmospheric pressure fluctuations. Screen 3 responded to supply well pumping at PM-2 and PM-4. The shallower screens 1 and 2 show a muted response to supply well pumping.

R-20 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top/ Bottom Packer Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (gal)	Hydro Zone Code	Geo Unit Code
1	904.6	912.2	5789.8	5782.2	7.6	908.43	5785.9	918.7	5782.2	918.7	6.5	5.3	RT	Tb4
2	1147.1	1154.7	5547.3	5539.7	7.6	1141.7	5552.6	1133.8	5539.7	1183.5	28.8	23.8	RD	Tpp
3	1328.8	1336.5	5365.6	5357.9	7.7	**Screen 3 plugged and abandoned November 2007**							RD	Tsf

Note: R-20 Brass Cap Ground Elevation: 6694.35 ft; all measurements are from this elevation


R-20
Screen 1 GW/MM
Screen 2 GW/MM
Screen 3 GW
Screen 1 Transducer
Screen 2 Transducer
Screen 3 Transducer
Groundwater Elevation (ft)
5870
5860
5850
5840
5830
5820
5810
1/1/03
1/1/04
12/31/04
12/31/05
1/1/07
1/1/08
12/31/08
12/31/09
1/1/11
Date


R-20
Screen 1 Manual
Screen 1 Transducer
Screen 2 Manual
Screen 2 Transducer
Groundwater Elevation (ft)
5869
5867
5865
5863
5861
5859
5857
01/01/03
01/01/04
12/31/04
12/31/05
01/01/07
01/01/08
12/31/08
12/31/09
01/01/11
Date

3.25 R-21

Location: R-21 is located in Cañada del Buey north of TA-54 and between Material Disposal Area (MDA) L and MDA G. R-21 is 780 ft east of R-56, 1130 ft south of R-38, and 1500 ft north of R-32.

Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 87 ft below the water table.

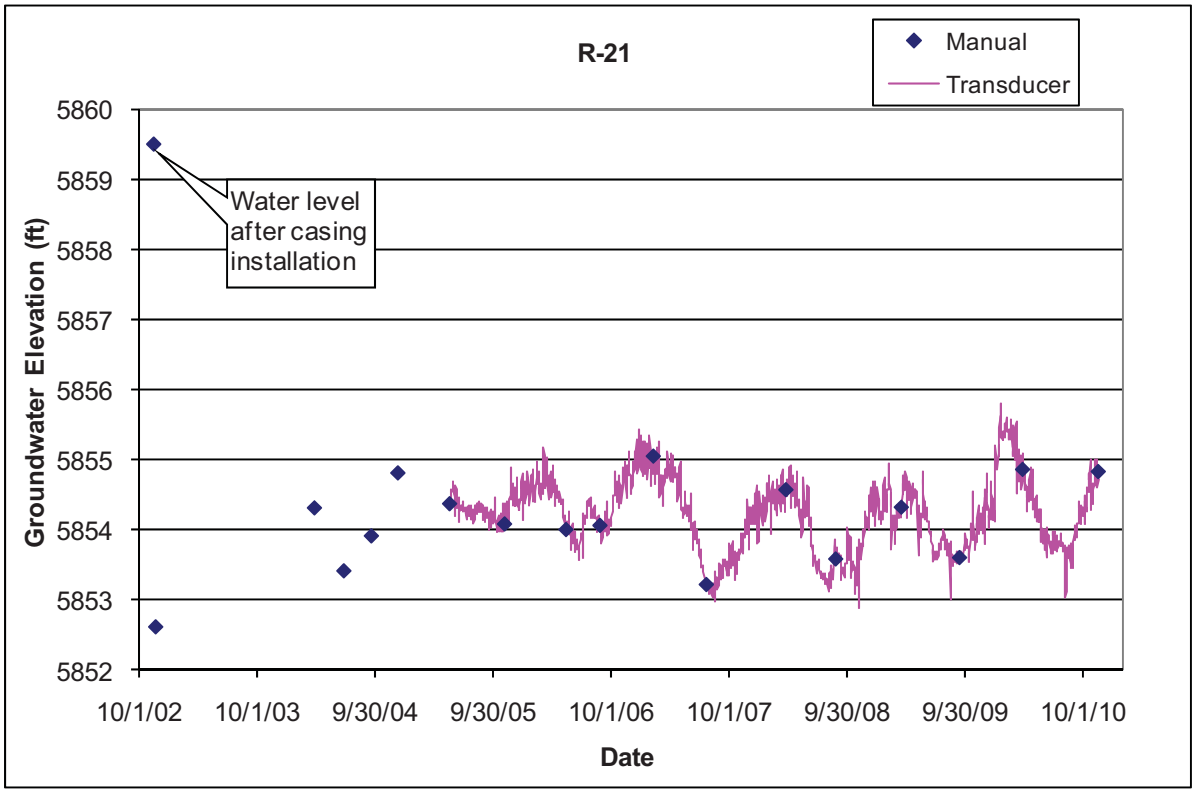
Period of Record: Well completed November 2002, transducer installed May 23, 2005, transducer data through 2010.

Remarks: R-21 installed to a depth of 941.4 ft, about 140 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The well responds to pumping of PM-2, PM-4, and possibly another well or combination of wells.

R-21 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	888.8	906.8	5767.4	5749.4	18.0	861.0	5795.2	906.8	5749.4	941.4	34.6	192.4	RT	Tpf

Note: R-21 Brass Cap Ground Elevation: 6656.24 ft; all measurements are from this elevation



3.26 R-22

Location: R-22 is located at the east end of Mesita del Buey, east of TA-54. R-22 is about 310 ft southeast of R-57, 640 ft south of R-41, and 700 ft northeast of R-39.

Completion Type: Multiple completion, five screens in the regional aquifer. Screen 1 straddles the regional water table.

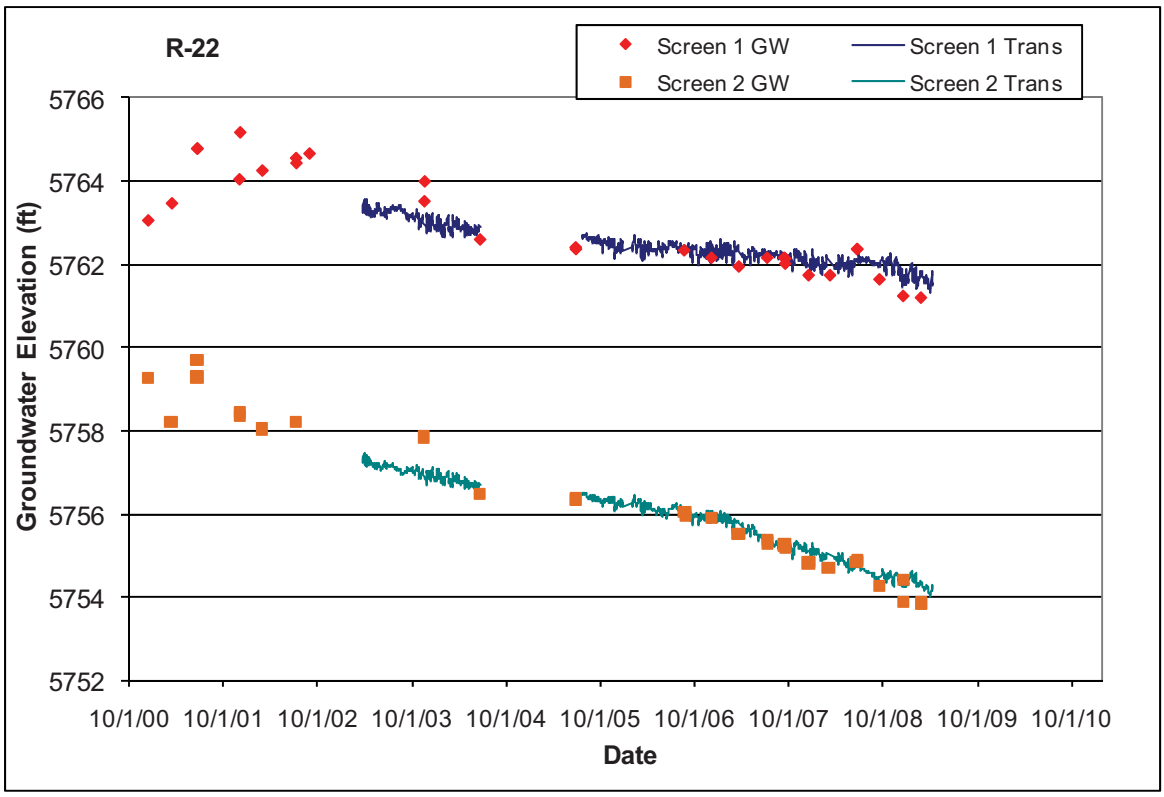
Period of Record: Westbay® installed December 11, 2000, transducers installed March 26, 2003, intermittent transducer data to April 13, 2009, when the transducers were removed in preparation for removing the Westbay® system.

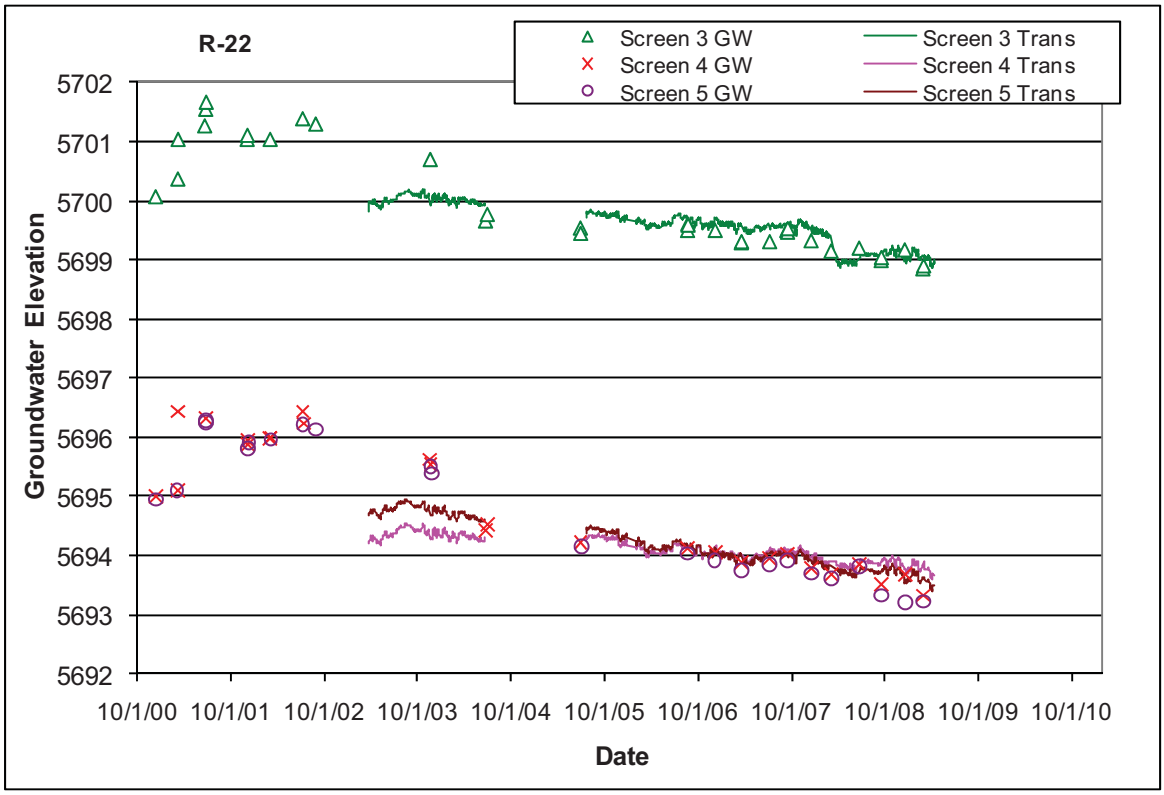
Remarks: Screens 1 and 2 have similar head values about 6 ft apart. Screens 3, 4, and 5 have similar heads within 6 ft of each other, but about 60 ft lower than screens 1 and 2. Screens 4 and 5 have nearly identical head values. The R-22 screens do not show an immediate response to atmospheric pressure fluctuations, but show a delayed response ranging from 20% to 95%. The deeper aquifer at R-22 screens 3, 4, and 5 shows an apparent small seasonal response to supply well pumping. The Westbay® system was removed on May 3, 2009, for well rehabilitation (LANL 2009).

R-22 Construction and Port Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elevation (ft)	Distance from Bottom of Screen (ft)	Sump Volume (L)	Comment
1	872.3	914.2	5778.2	5736.3	41.9	RT	Tb4	**MP1A**	907.1	5743.4	7.1		Within Screen
								PP1	912.4	5738.1	1.8		Within Screen
								MP1B	918.1	5732.4	-3.9	9.1	Below Screen
2	947.0	988.9	5703.5	5661.6	41.9	RD	Tb4	**MP2A**	962.8	5687.7	26.1		Within Screen
								PP2	967.7	5682.8	21.2		Within Screen
								MP2B	973.4	5677.1	15.5		Within Screen
3	1272.2	1278.9	5378.3	5371.6	6.7	RD	Tpf	**MP3A**	1273.5	5377.0	5.4		Within Screen
								PP3	1278.9	5371.6	0		Within Screen
								MP3B	1284.5	5366.0	-5.6	13.1	Below Screen
4	1378.2	1384.9	5272.3	5265.6	6.7	RD	Tb	**MP4A**	1378.0	5272.5	6.9		Above Screen
								PP4	1383.4	5267.1	1.5		Within Screen
								MP4B	1389.1	5261.4	-4.2	9.9	Below Screen
5	1447.3	1452.3	5203.2	5198.2	5.0	RD	Tpf	**MP5A**	1448.2	5202.3	4.1		Within Screen
								PP5	1453.6	5196.9	-1.3	3.0	Below Screen
								MP5B	1459.2	5191.3	-6.9	16.2	Below Screen

Note: R-22 Brass Cap Ground Elevation: 6650.5 ft; all measurements are from this elevation;
MP = Monitor Port; PP = Pump Port; Monitor Ports shown in bold are instrumented ports


R-22
Screen 1 GW
Screen 2 GW
Screen 1 Trans
Screen 2 Trans
Groundwater Elevation (ft)
5766
5764
5762
5760
5758
5756
5754
5752
10/1/00 10/1/01 10/1/02 10/1/03 10/1/04 10/1/05 10/1/06 10/1/07 10/1/08 10/1/09 10/1/10
Date


R-22
Screen 3 GW
Screen 4 GW
Screen 5 GW
Screen 3 Trans
Screen 4 Trans
Screen 5 Trans
Groundwater Elevation
5702
5701
5700
5699
5698
5697
5696
5695
5694
5693
5692
10/1/00 10/1/01 10/1/02 10/1/03 10/1/04 10/1/05 10/1/06 10/1/07 10/1/08 10/1/09 10/1/10
Date

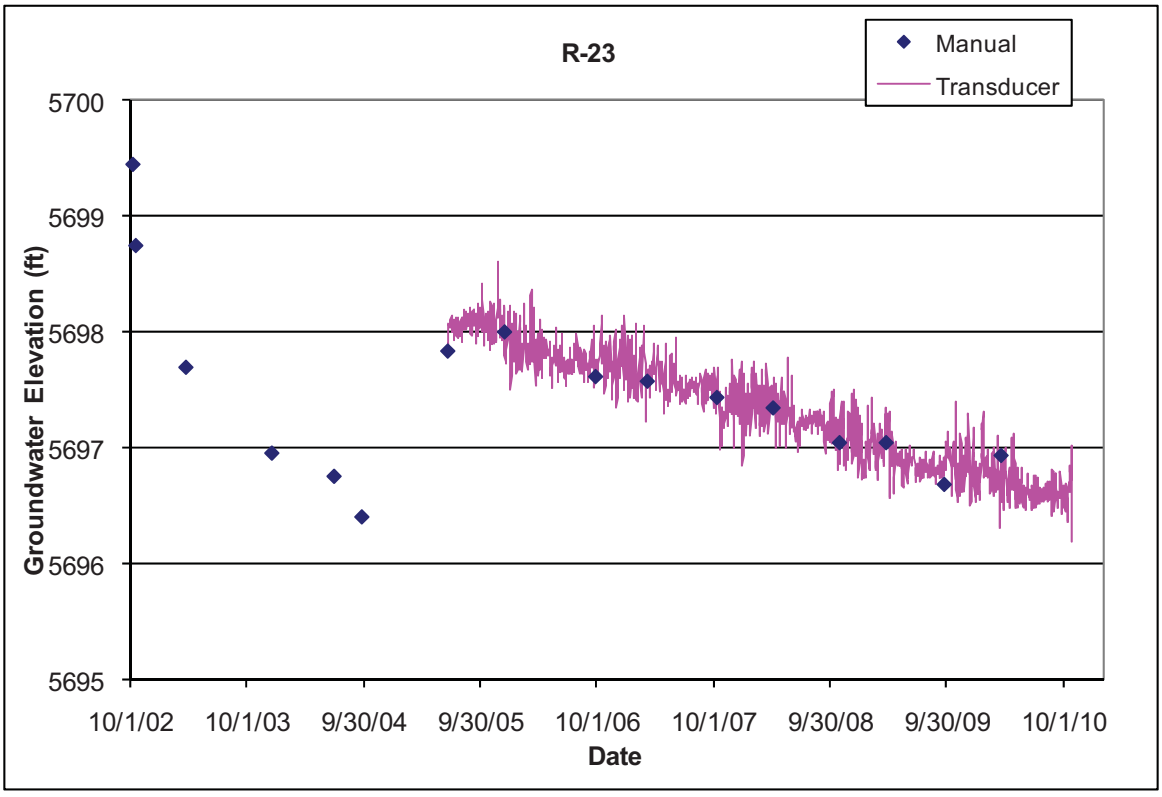
3.27 R-23

Location: R-23 is located in lower Pajarito Canyon near SR-4 and the eastern LANL boundary.
Completion Type: Single completion at the top of the regional aquifer. The screen straddles the water table.
Period of Record: Well completed October 2002, transducer installed June 20, 2005, transducer data through 2010.
Remarks: R-23 was installed to a depth of 886.3 ft, about 60 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer has no immediate response to atmospheric pressure fluctuations, however, the aquifer has a delayed response to atmospheric pressure. The aquifer at R-23 shows no apparent response to pumping the PM well field or the Buckman well field, but exhibits a steady water level decline of about 0.3 ft/yr.

R-23 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	816.0	873.2	5711.8	5654.6	57.2	870.7	5657.1	873.2	5654.6	886.3	13.1	41.0	RT	Tsf

Note: R-23 Brass Cap Ground Elevation: 6527.75 ft; all measurements are from this elevation



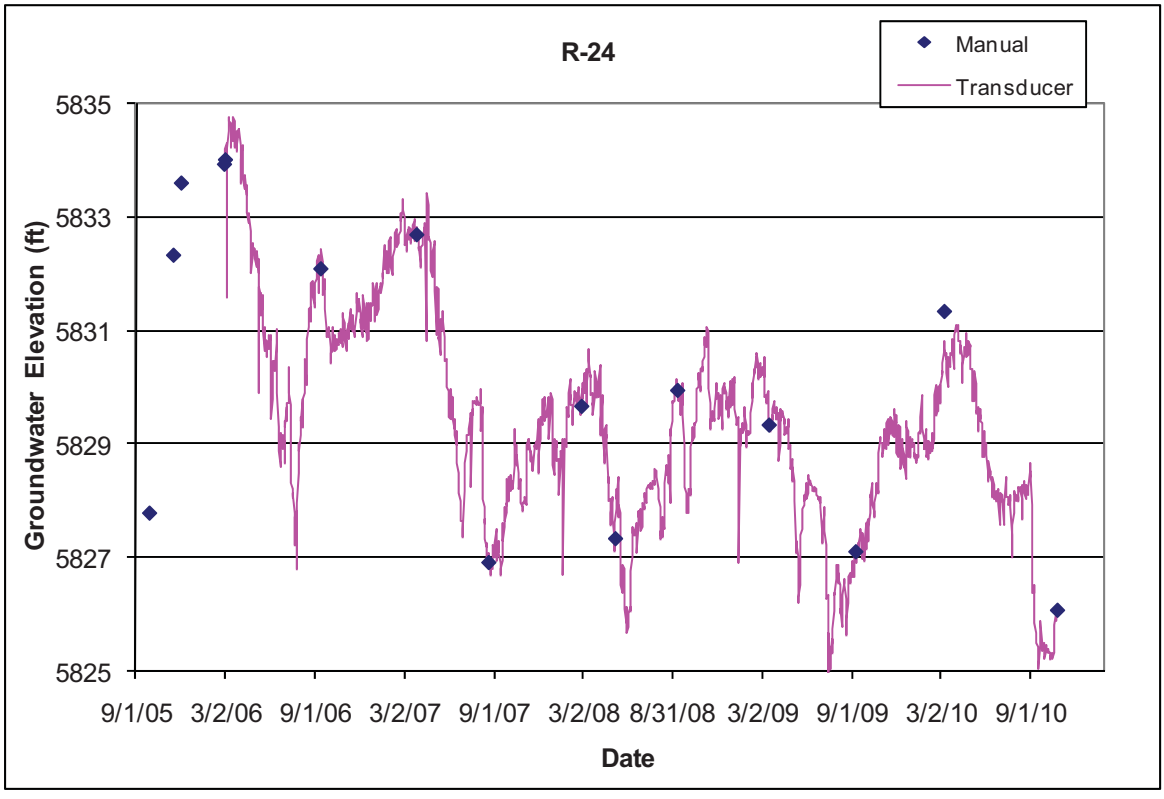
3.28 R-24

Location: R-24 is located in Bayo Canyon north of the former Bayo Sewage Treatment Plant.
Completion Type: Single completion at the top of the regional aquifer. The top of the screen is in a confined zone about 110 ft below the water table.
Period of Record: Well completed September 2005, transducer installed March 1, 2006, data through 2010.
Remarks: R-24 installed to a depth of 861 ft, about 150 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The aquifer at R-24 responds primarily to pumping at supply well PM-3 located 1.5 mi south in Sandia Canyon, but may also respond to pumping the Guaje well field and supply well O-4.

R-24 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	825.0	848.0	5722.4	5699.4	23.0	818.7	5728.7	848.0	5699.4	861	13.0	40.7	RT	Tsf

Note: R-24 Brass Cap Ground Elevation: 6547.38 ft; all measurements are from this elevation



3.29 R-25

Location: R-25 is located at TA-16 within the Cañon de Valle watershed. R-25 is about 50 ft east of R-25b, 100 ft east of R-25c, 370 ft south of CdV-16-1(i), and 425 ft southwest of CdV-16-4ip.

Completion Type: Multiple completion, four screens in intermediate zones, and five screens in the regional aquifer. Screens 3 and 9 were damaged during installation and are not reliable for water level monitoring. Screen 5 straddles the regional water table.

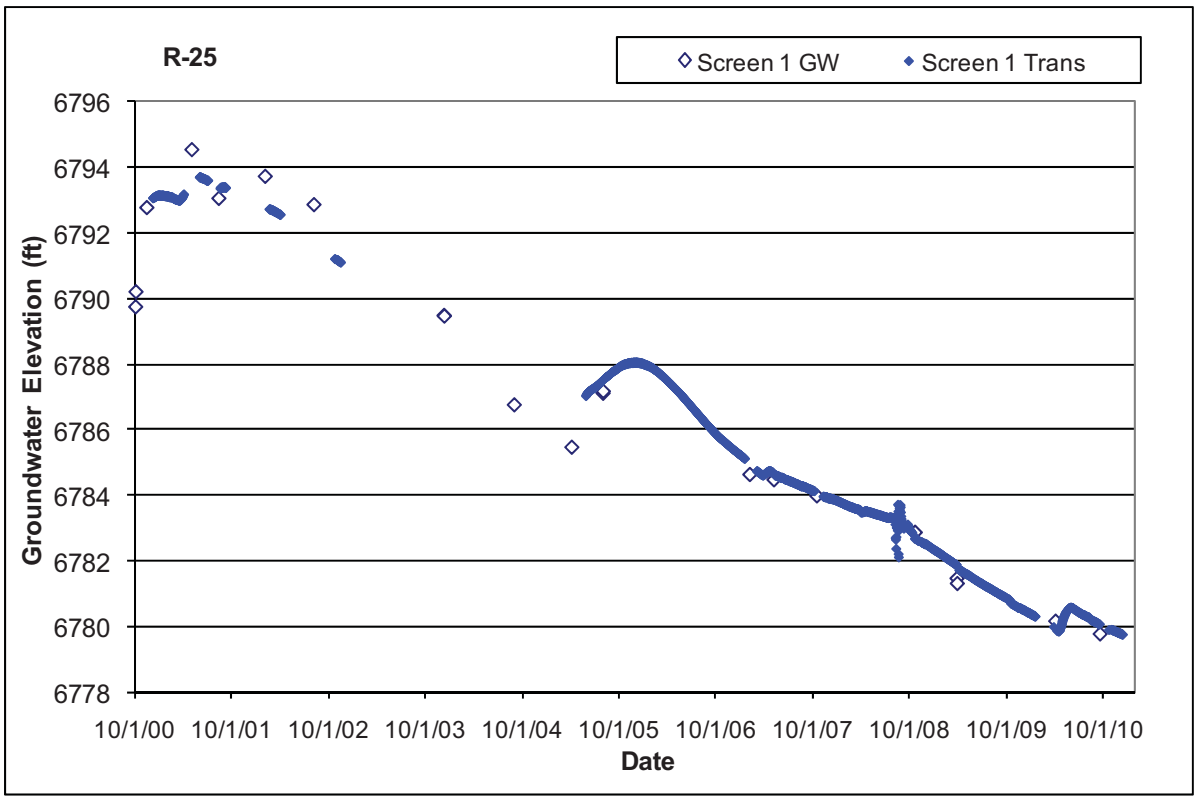
Period of Record: Westbay® installed October 3, 2000, transducers installed February 26, 2001, and between sampling events through 2002. Transducers installed again June 2, 2005; data through 2010.

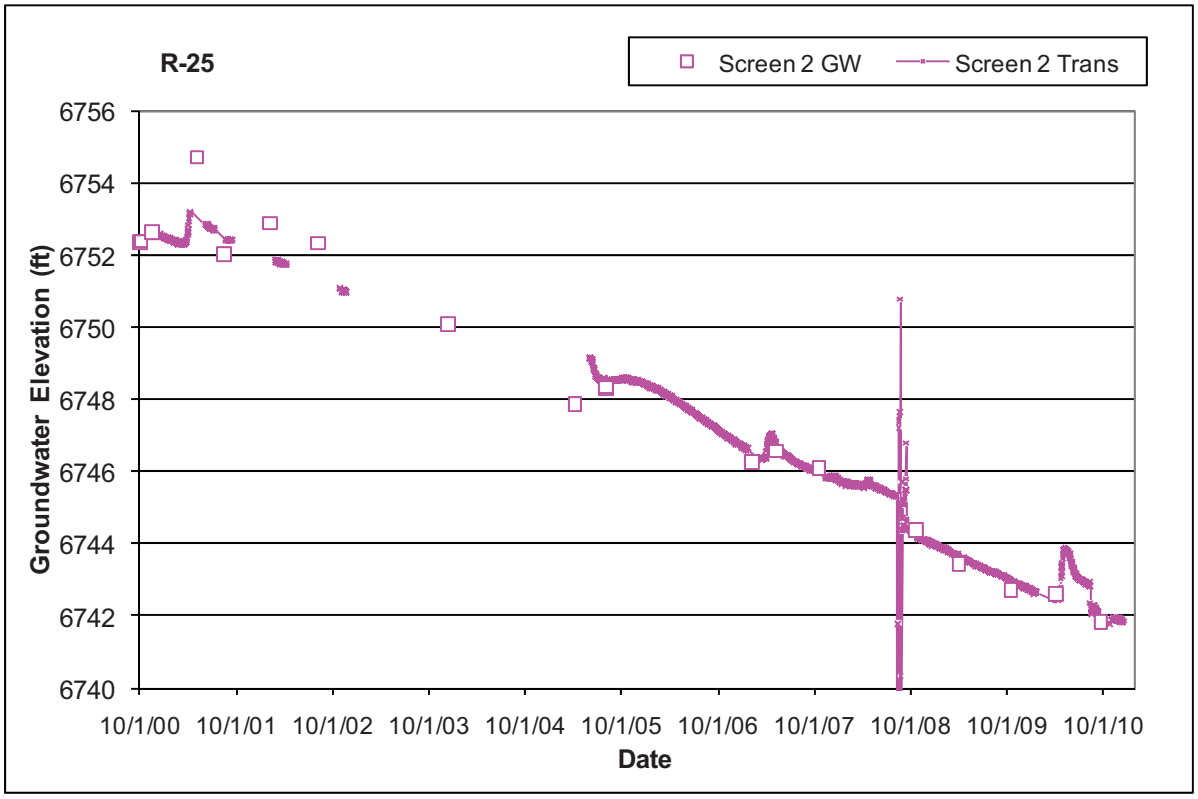
Remarks: Recurring problems with the transducer cables from 2001 to 2005 caused loss of data. The transducer cables were rebuilt in 2005. Screens 1 and 2 are in upper intermediate zones. Screen 3 has always been dry; screen 4 appears to be in a separate intermediate zone. The water level at screen 5, the top of the regional aquifer, declines significantly during low flow sampling and recovers slowly. There is no significant response to atmospheric pressure at any of the screens. Intermediate screens 1, 2, and perhaps 4 responded to snowmelt runoff in 2005, 2007, 2008, and 2010; see Appendix D for more information. The regional aquifer screens do not indicate an apparent response to supply well pumping. The intermediate groundwater at screens 1, 2, and 4 and the sump water at screen 3 responded to drilling and installation of adjacent well R-25c (replacement for R-25 screen 3) in August 2008 (LANL September 2008). Screen 2 responded during drilling of nearby well CDV-16-4ip.

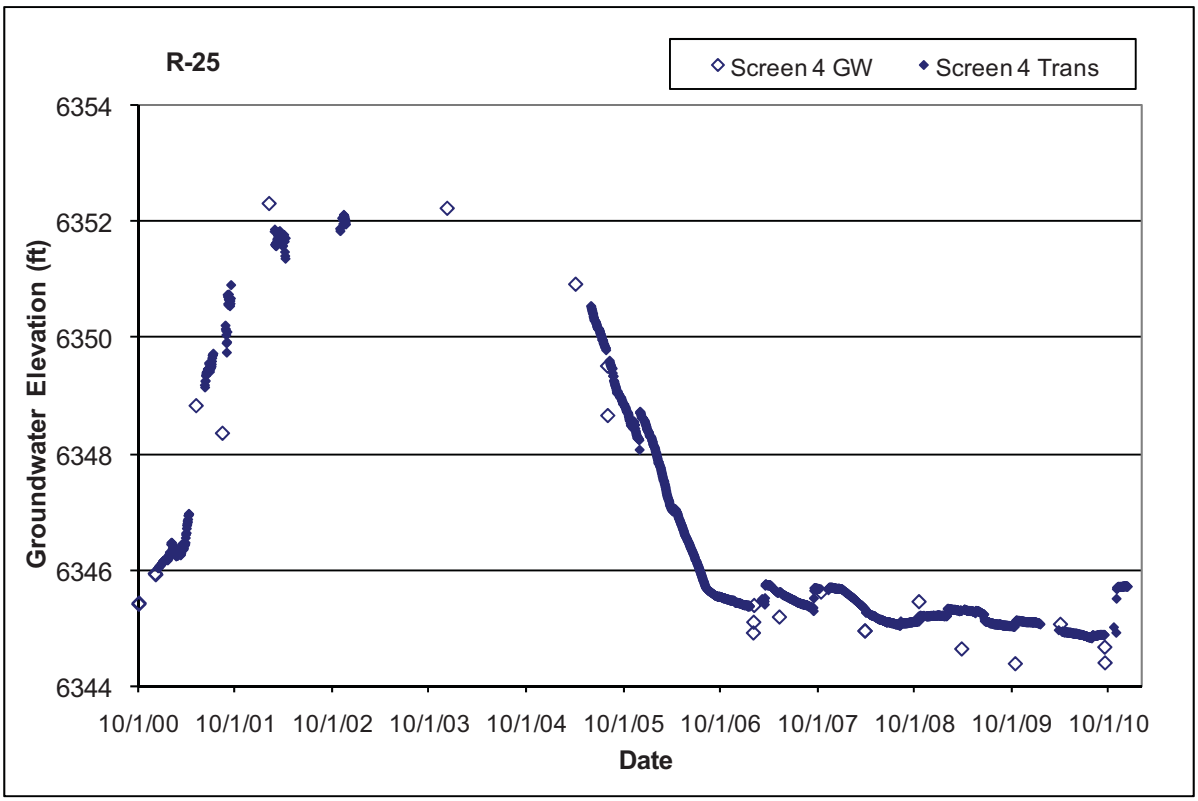
R-25 Construction and Port Information

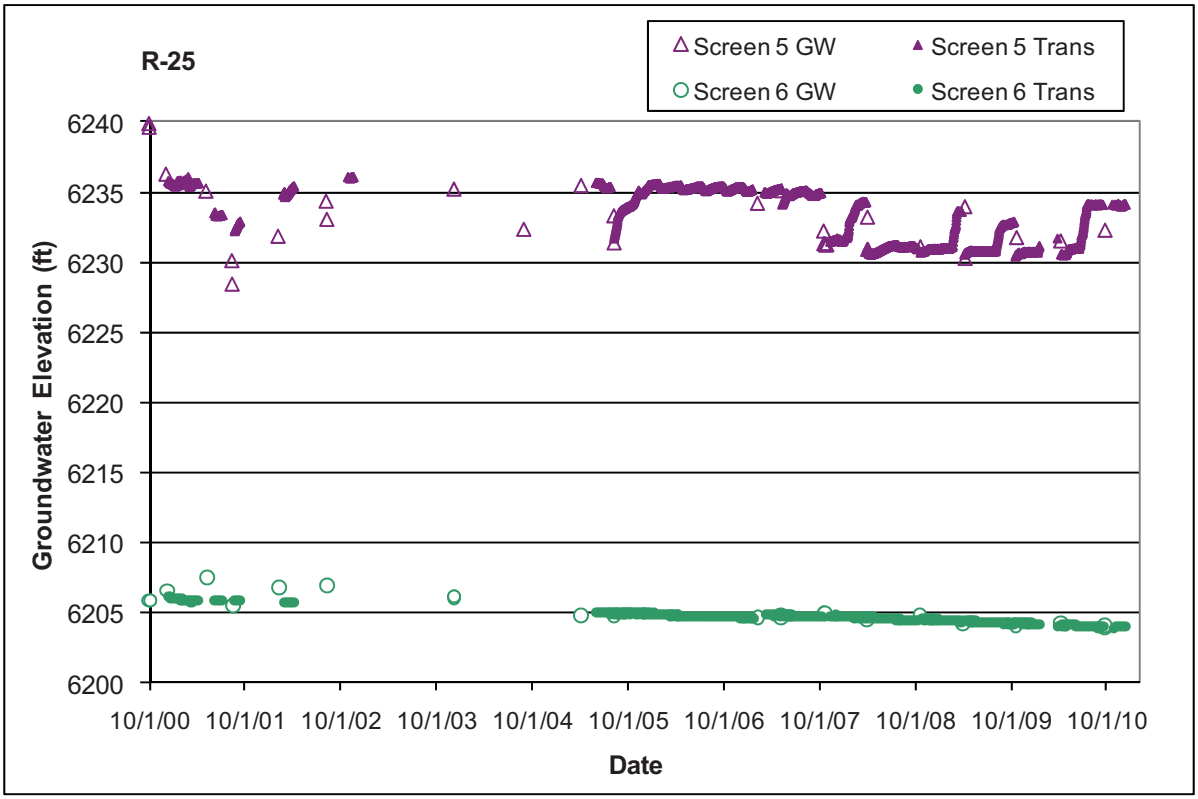
Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elev (ft)	Distance from Bottom of Screen (ft)	Sump Vol above Port (L)	Sump Vol Total (L)	Comment
1	737.6	758.4	6778.5	6757.7	20.8	I	Qbo	**MP1A**	754.8	6761.3	3.6			Within Screen
								PP1	760.1	6756.0	-1.7	4.9		Below Screen
								MP1B	765.8	6750.3	-7.4	21.4	31.9	Below Screen
2	882.6	893.4	6633.5	6622.7	10.8	I	Tpf	**MP2A**	891.8	6624.3	1.6			Within Screen
								PP2	897.2	6618.9	-3.8	11.0		Below Screen
								MP2B	902.8	6613.3	-9.4	27.2	37.9	Below Screen
3	1054.6	1064.6	6461.5	6451.5	10.0	I	Tpf	**MP3A**	1063.4	6452.7	1.2			Within Screen, screen damaged
								PP3	1068.8	6447.3	-4.2	12.2		Below Screen
								MP3B	1084.2	6431.9	-19.6	56.8	72.4	Below Screen, sump water
4	1184.6	1194.6	6331.5	6321.5	10.0	I	Tpf	**MP4A**	1192.4	6323.7	2.2			Within Screen
								PP4	1197.8	6318.3	-3.2	9.3		Below Screen
								MP4B	1203.4	6312.7	-8.8	25.5	36.5	Below Screen
5	1294.7	1304.7	6221.4	6211.4	10.0	RT	Tpf	**MP5A**	1303.4	6212.7	1.3			Within Screen
								PP5	1308.8	6207.3	-4.1	11.9		Below Screen
								MP5B	1314.4	6201.7	-9.7	28.1	39.1	Below Screen
6	1404.7	1414.7	6111.4	6101.4	10.0	RD	Tpf	**MP6A**	1406.3	6109.8	8.4			Within Screen
								PP6	1411.7	6104.4	3			Within Screen
								MP6B	1417.3	6098.8	-2.6	7.5	18.5	Below Screen
7	1604.7	1614.7	5911.4	5901.4	10.0	RD	Tpf	**MP7A**	1606.0	5910.1	8.7			Within Screen
								PP7	1611.4	5904.7	3.3			Within Screen
								MP7B	1617.1	5899.0	-2.4	7.0	17.7	Below Screen
8	1794.7	1804.7	5721.4	5711.4	10.0	RD	Tpf	**MP8A**	1796.0	5720.1	8.7			Within Screen
								PP8	1801.4	5714.7	3.3			Within Screen
								MP8B	1807.0	5709.1	-2.3	6.7	17.4	Below Screen
9	1894.7	1904.7	5621.4	5611.4	10.0	RD	Tpf	**MP9**	1825.1	5691.0	79.6			Screen 9 blocked by sediment

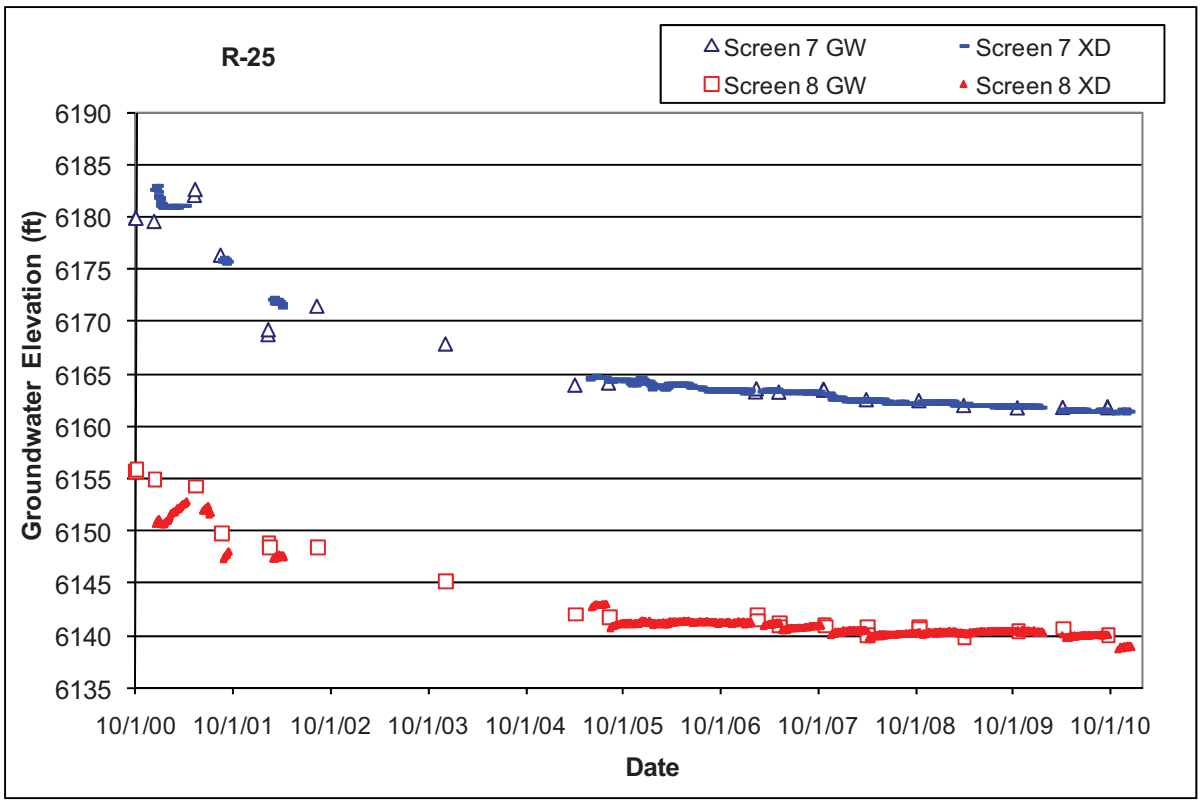
Note: R-25 Brass Cap Ground Elevation: 7516.1 ft; all measurements are from this elevation;
MP = Monitor Port; PP = Pump Port; Monitor Ports shown in bold are instrumented ports


R-25
Screen 1 GW
Screen 1 Trans
Groundwater Elevation (ft)
6796
6794
6792
6790
6788
6786
6784
6782
6780
6778
10/1/00
10/1/01
10/1/02
10/1/03
10/1/04
10/1/05
10/1/06
10/1/07
10/1/08
10/1/09
10/1/10
Date


R-25
Screen 2 GW
Screen 2 Trans
Groundwater Elevation (ft)
6756
6754
6752
6750
6748
6746
6744
6742
6740
10/1/00
10/1/01
10/1/02
10/1/03
10/1/04
10/1/05
10/1/06
10/1/07
10/1/08
10/1/09
10/1/10
Date


R-25
Screen 4 GW
Screen 4 Trans
6354
6352
6350
6348
6346
6344
Groundwater Elevation (ft)
10/1/00
10/1/01
10/1/02
10/1/03
10/1/04
10/1/05
10/1/06
10/1/07
10/1/08
10/1/09
10/1/10
Date


R-25
Screen 5 GW
Screen 5 Trans
Screen 6 GW
Screen 6 Trans
6240
6235
6230
6225
6220
6215
6210
6205
6200
Groundwater Elevation (ft)
10/1/00
10/1/01
10/1/02
10/1/03
10/1/04
10/1/05
10/1/06
10/1/07
10/1/08
10/1/09
10/1/10
Date


R-25
Screen 7 GW
Screen 7 XD
Screen 8 GW
Screen 8 XD
Groundwater Elevation (ft)
6190
6185
6180
6175
6170
6165
6160
6155
6150
6145
6140
6135
10/1/00
10/1/01
10/1/02
10/1/03
10/1/04
10/1/05
10/1/06
10/1/07
10/1/08
10/1/09
10/1/10
Date

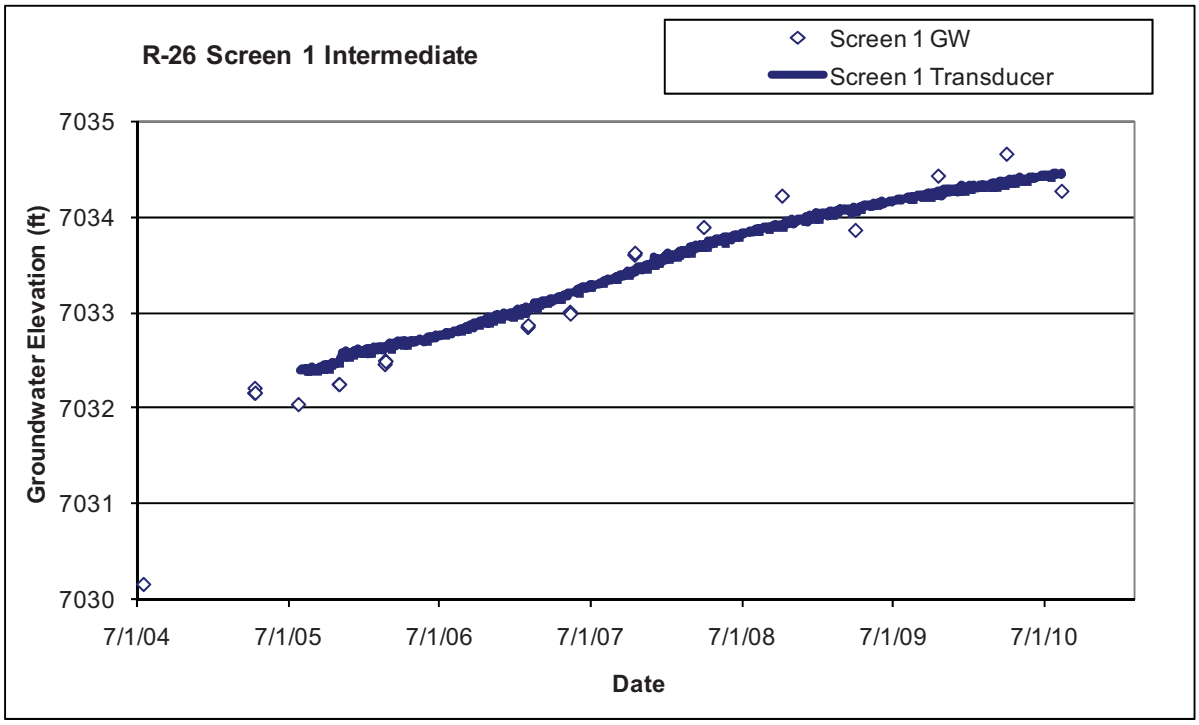
3.30 R-26

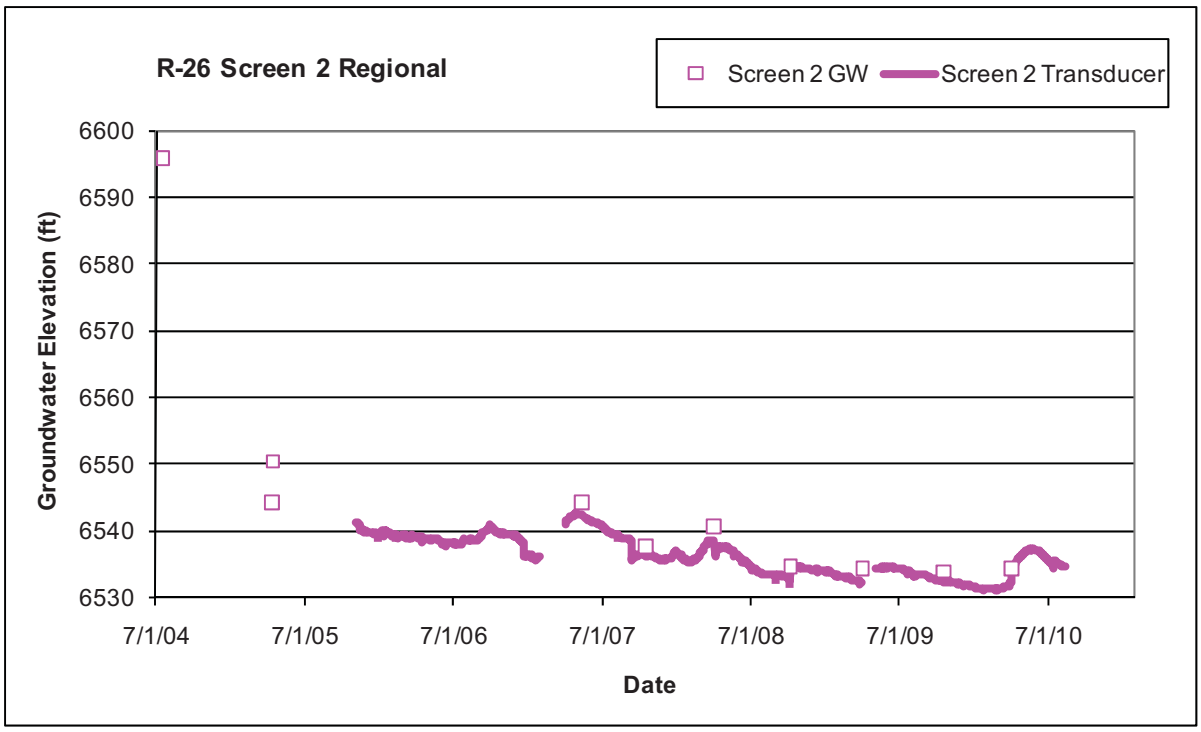
Location: R-26 is located at the western LANL boundary near Cañon de Valle.
Completion Type: Multiple completion, screen 1 is in an intermediate zone, and screen 2 is within the regional aquifer. The top of screen 2 is about 319 ft below the regional water table.
Period of Record: Westbay® installed July 18, 2004, transducers installed July 29, 2005, transducer data to August 13, 2010, when the transducers were removed in preparation for removal of the Westbay® system. When the Westbay® removal was delayed, the transducers were reinstalled December 16, 2010.
Remarks: Screen 2 is in a tight zone and/or improperly completed zone. Sampling attempts at MP2A caused plugging of the port and sampler with bentonite; the transducers were installed in the B ports on November 3, 2005; water level data from screen 2 at port MP2B appear valid with some questions as to validity pending additional data and review. There is no apparent response to supply well pumping at R-26.

R-26 Construction and Port Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elevation (ft)	Distance from Bottom of Screen (ft)	Sump Volume (L)	Comment
1	651.8	669.9	6989.9	6971.8	18.1	I	Qct	**MP1A**	659.3	6982.4	10.6		Within Screen
								PP1	664.7	6977.0	5.2		Within Screen
								MP1B	670.3	6971.4	-0.4	0.8	Below Screen
2	1421.8	1445.0	6219.9	6196.7	23.2	RT	Tp	**MP2A**	1427.0	6214.7	18.0		Within Screen
								PP2	1432.4	6209.3	12.6		Within Screen
								MP2B	1438	6203.7	7.0		Within Screen

Note: R-26 Brass Cap Ground Elevation: 7641.69 ft; all measurements are from this elevation;
MP = Monitor Port; PP = Pump Port; Monitor Ports shown in bold are instrumented ports




R-26 Screen 2 Regional
Screen 2 GW
Screen 2 Transducer
Groundwater Elevation (ft)
6600
6590
6580
6570
6560
6550
6540
6530
7/1/04
7/1/05
7/1/06
7/1/07
7/1/08
7/1/09
7/1/10
Date

3.31 R-27

Location: R-27 is located in middle Water Canyon about 0.35 mi north of DT-10 and about 0.75 mi south of R-19.

Completion Type: Single completion at the top of the regional aquifer in Puye fanglomerates. The top of the screen is about 36 ft below the water table.

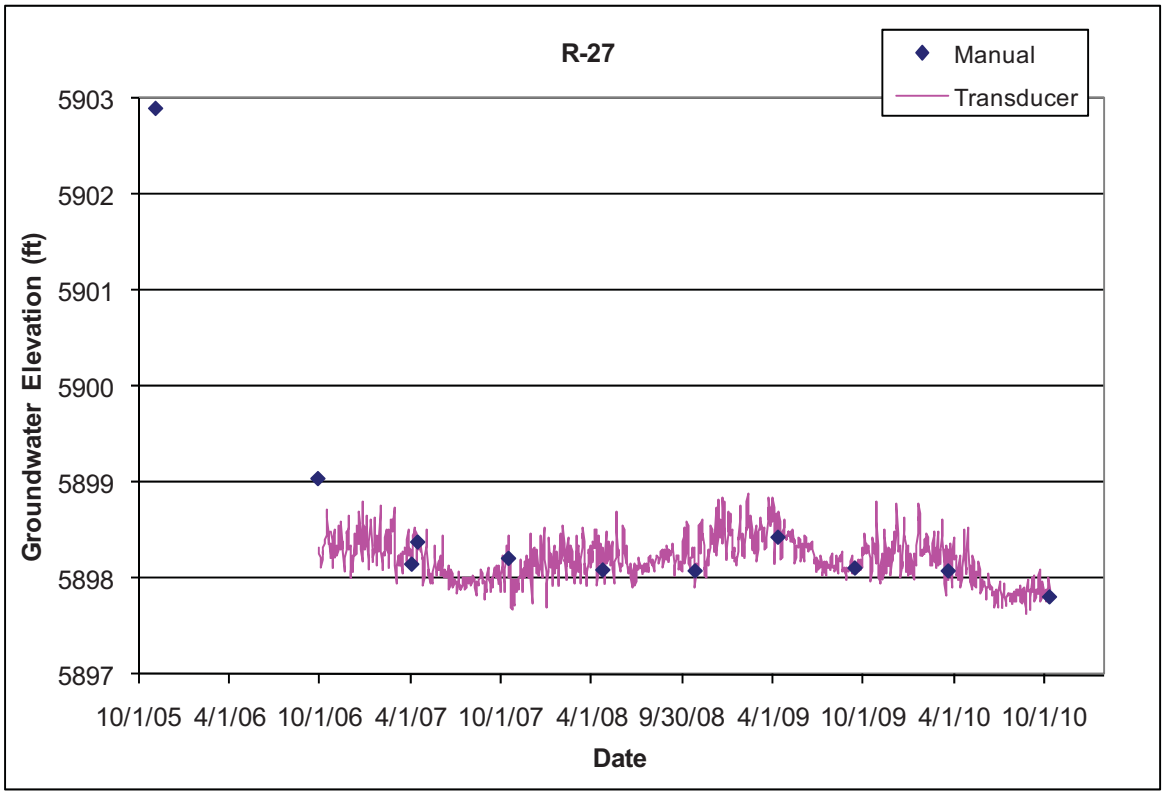
Period of Record: Well completed November 2005, transducer installed September 29, 2006, transducer data through 2010.

Remarks: R-27 is installed to a depth of 878.7 ft, about 60 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer does not show a response to atmospheric pressure fluctuations. The aquifer at R-27 may show a small seasonal response to supply well pumping at PM-2, but the general water level trend does not correlate with supply well pumping.

R-27 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	852.0	875.0	5861.7	5838.7	23.0	847	5866.7	875.0	5838.7	878.7	3.7	11.6	RT	Tpf

Note: Brass Cap Ground Elevation: 6713.72 ft; all measurements are from this elevation



3.32 R-28

Location: R-28 is located in middle/lower Mortandad Canyon between and about 1300 ft from both R-42 and R-45 and about 1300 ft north of R-50.

Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 43 ft below the water table.

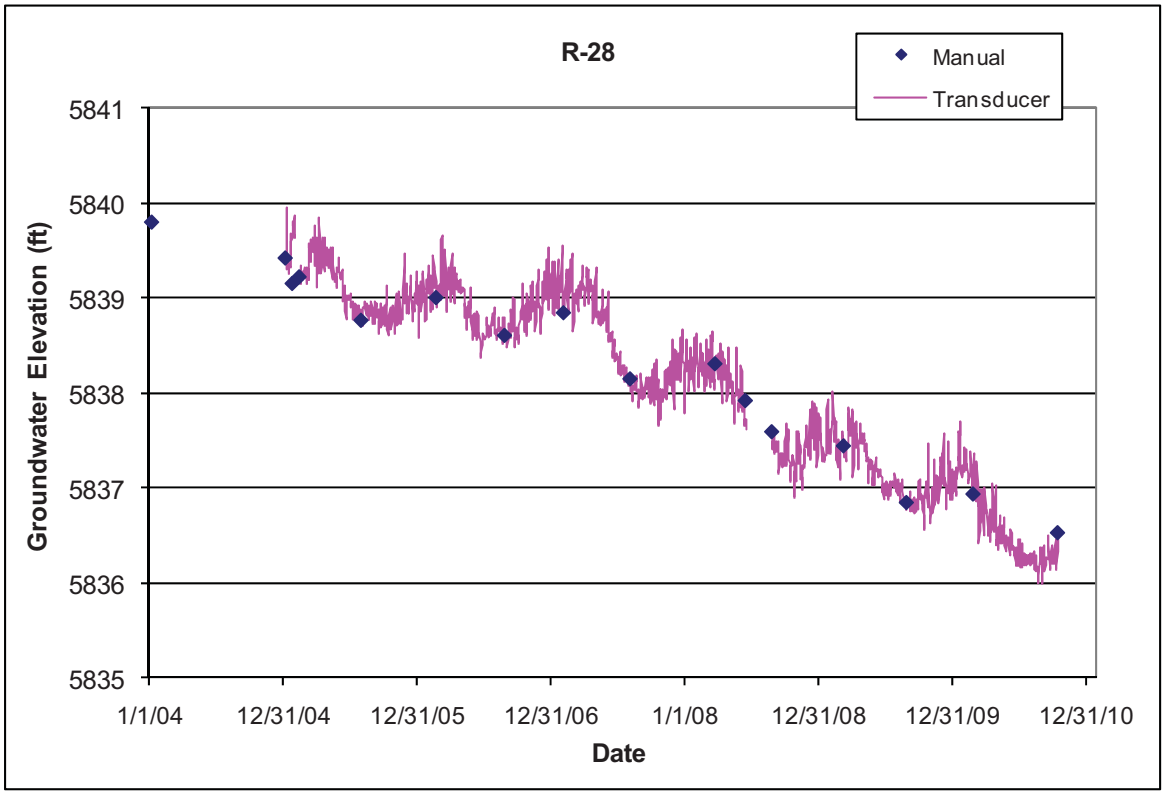
Period of Record: Well completed December 2003, transducer installed January 7, 2005, data through 2010.

Remarks: R-28 installed to a depth of 980.3 ft, about 100 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. R-28 exhibits a seasonal response to supply well pumping and responds primarily to pumping at PM-4 and PM-2 and possibly to PM-5, but apparently does not respond significantly to pumping at nearby supply well PM-3.

R-28 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	934.3	958.1	5794.3	5770.5	23.8	929.6	5799.0	958.1	5770.5	980.3	22.2	68.2	RT	Tpf

Note: R-28 Brass Cap Ground Elevation: 6728.61 ft; all measurements are from this elevation



3.33 R-29

Location: R-29 is located at TA-49 east of MDA AB and about 0.3 mi northeast of Test Well DT-5A and 0.3 mi north of R-30.

Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 17 ft below the water table.

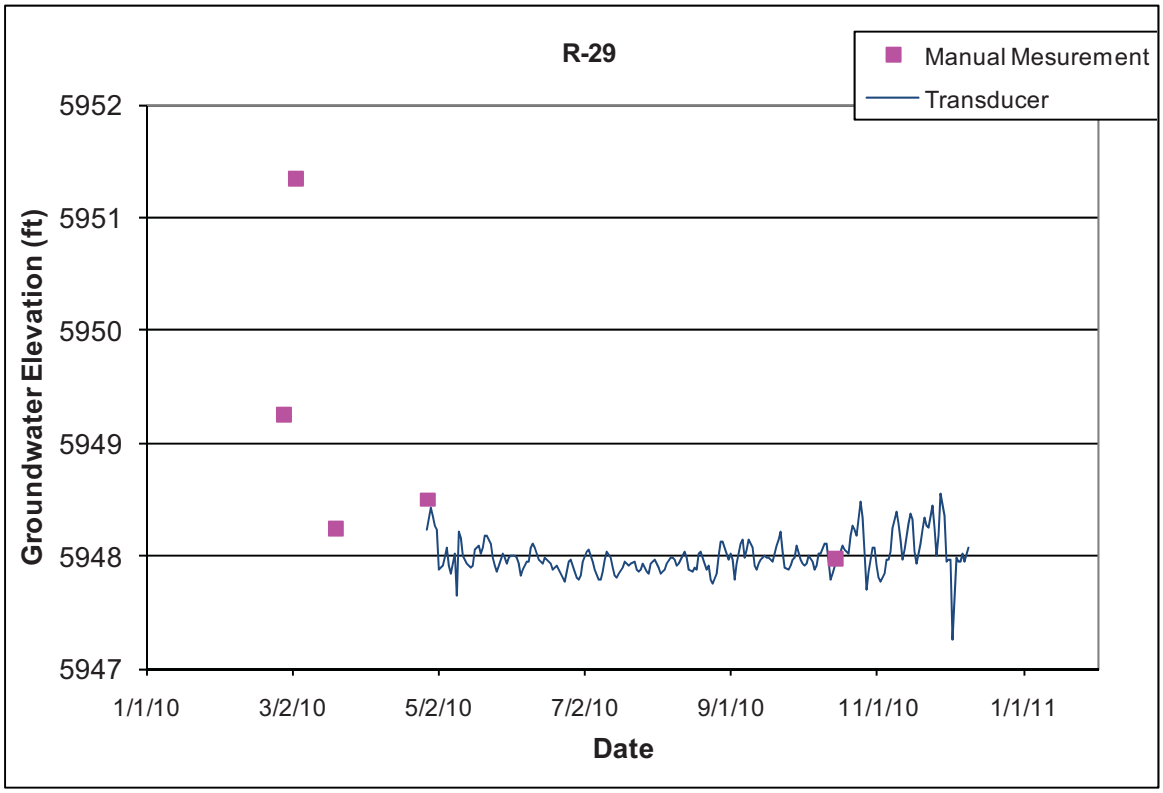
Period of Record: Well completed March 12, 2010, transducer installed April 28, 2010, data through 2010.

Remarks: R-29 installed to a depth of 1191.8 ft, about 39 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The tested specific capacity of R-29 was 0.62 gpm/ft.

R-29 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Sump Bottom (ft)	Bottom of Well Elev (ft)	Sump Length (ft)	Sump Vol (gal)	Hydro Zone Code	Geo Unit Code
1	1170.0	1180.0	5930.8	5920.8	10.0	1187.4	5913.4	1191.8	5909.0	11.8	12.0	RT	Tpf

Note: Brass Cap Ground Elevation: 7100.75 ft; all measurements are from this elevation



3.34 R-30

Location: R-30 is located at TA-49 east of MDA AB and about 0.25 mi southeast of Test Well DT-5A and 0.3 mi south of R-29.

Completion Type: Single completion at the top of the regional aquifer. The top of the screen is about 14 ft below the water table.

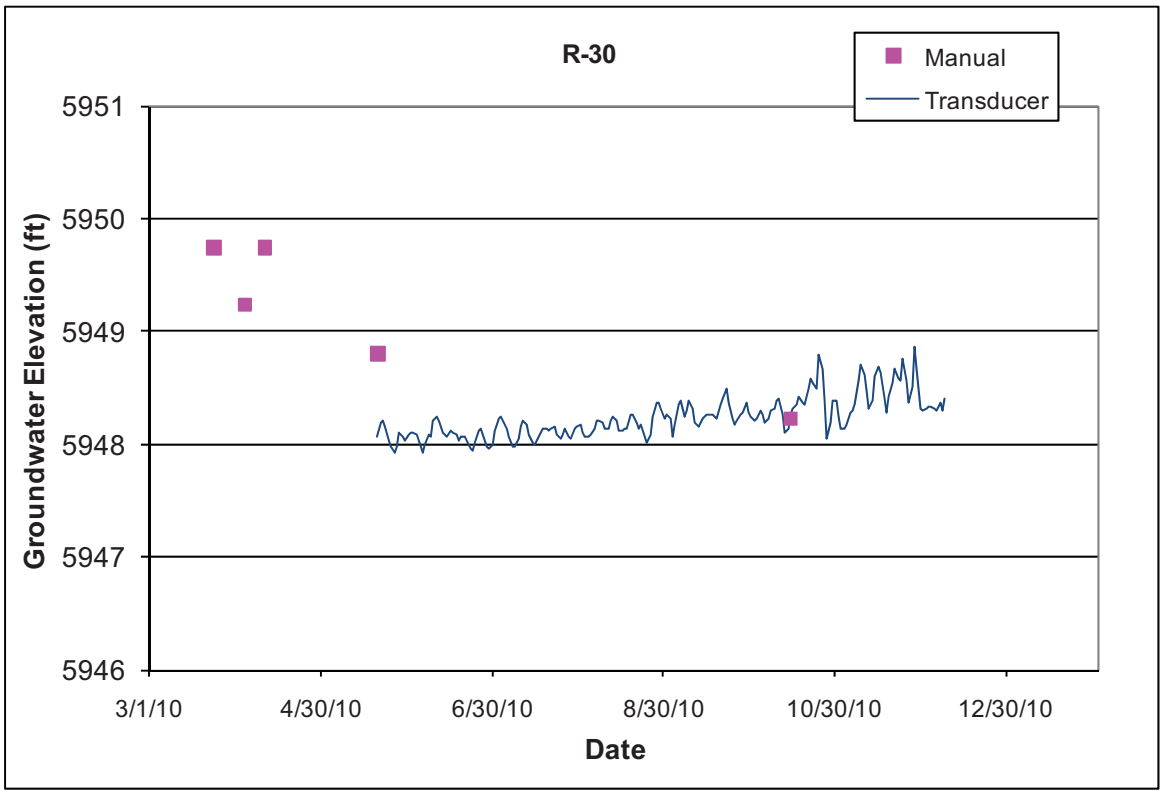
Period of Record: Well completed April 03, 2010, transducer installed May 21, 2010, data through 2010.

Remarks: R-30 installed to a depth of 1171.8 ft, about 46 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The tested specific capacity of R-30 was 2.04 gpm/ft.

R-30 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Sump Bottom Depth (ft)	Bottom of Well Elev (ft)	Sump Length (ft)	Sump Vol (gal)	Hydro Zone Code	Geo Unit Code
1	1140.0	1160.9	5933.8	5912.9	20.9	1168.0	5905.8	1171.8	5902.0	10.9	11.1	RT	Tpf

Note: Brass Cap Ground Elevation: 7073.84 ft; all measurements are from this elevation



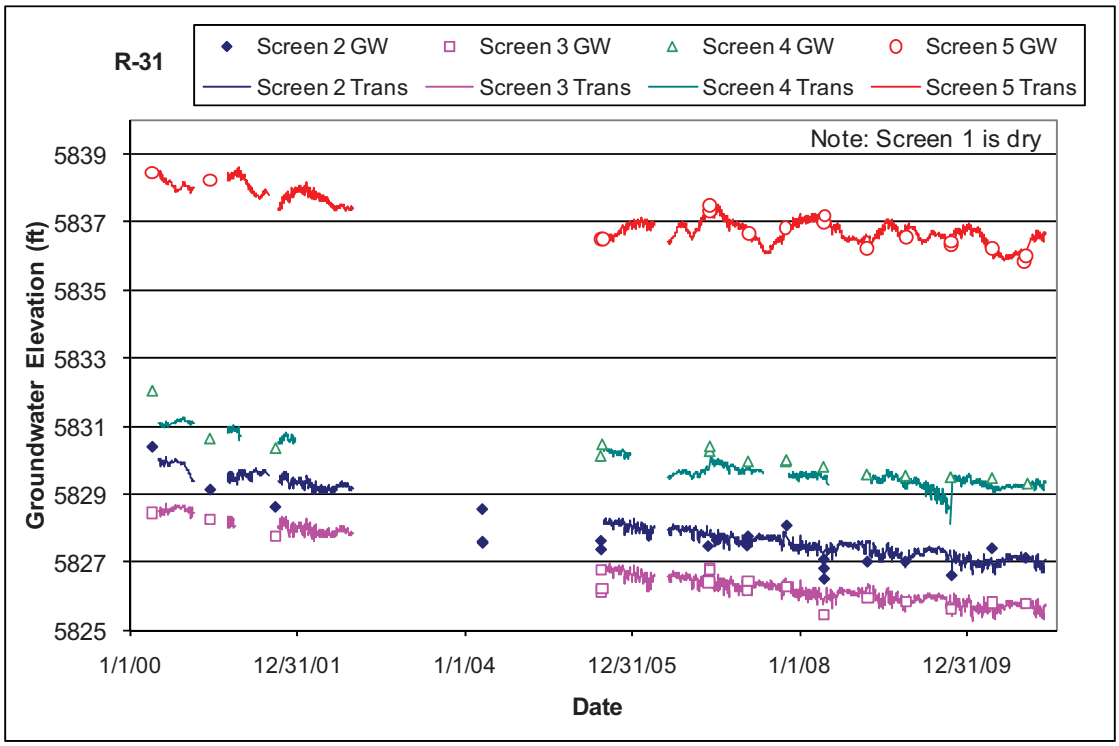
3.35 R-31

Location: R-31 is located in the southern part of LANL in the north Ancho Canyon tributary.
Completion Type: Multiple completion, one screen in an intermediate zone, and four screens in the regional aquifer. The intermediate screen 1 has been dry since Westbay® installation.
Period of Record: Westbay® installed April 7, 2000, transducers installed May 4, 2000, transducer data through 2010.
Remarks: Screen 5 has the highest head values, followed by screen 4 and screen 2; screen 3 has the lowest head values. Port MP2A was dry after Westbay® installation; port MP2B is used to collect samples and groundwater level data. Screens 2 and 3 have 80% and 100% response to atmospheric pressure fluctuations, respectively, while screens 3 and 4 have about 45% response. Screens 4 and 5 show seasonal responses to supply well pumping that coincide with the non-pumping water levels at PM-2.

R-31 Construction and Port Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elev (ft)	Distance from Bottom of Screen (ft)	Sump Volume (L)	Comment
1	439.1	454.4	5923.4	5908.1	15.3	I	Tb4	MP1A	453.8	5908.7	0.6		Screen dry
								PP1	459.2	5903.3	-4.8	13.9	Below screen
								MP1B	464.8	5897.7	-10.4	30.1	Below screen
2	515.0	545.7	5847.5	5816.8	30.7	RT	Tb4	MP2A	532.2	5830.3	13.5		Within screen, port dry
								MP2B	542.5	5820.0	3.2		Within screen
								PP2	547.9	5814.6	-2.2	6.4	Below screen
								MP2C	553.5	5809.0	-7.8	22.6	Below screen
3	666.3	676.3	5696.2	5686.2	10.0	RD	Tb4	MP3A	670.3	5692.2	6.0		Within screen
								PP3	675.6	5686.9	0.7		Within screen
								MP3B	681.3	5681.2	-5.0	14.5	Below screen
4	826.6	836.6	5535.9	5525.9	10.0	RD	Tpt	MP4A	830.9	5531.6	5.7		Within screen
								PP4	836.3	5526.2	0.3		Within screen
								MP4B	841.9	5520.6	-5.3	15.3	Below screen
5	1007.1	1017.1	5355.4	5345.4	10.0	RD	Tpt	MP5A	1011.3	5351.2	5.8		Within screen
								PP5	1016.7	5345.8	0.4		Within screen
								MP5B	1022.3	5340.2	-5.2	15.1	Below screen

Brass Cap Elevation: 6362.5 ft; all measurements are from this elevation;
MP = measurement port; PP = pumping port



3.36 R-32

Location: R-32 is located in lower Pajarito Canyon about 1 mi east of supply well PM-2 and south of TA-54 between MDA L and MDA G. R-32 is about 0.25 mi south of R-56.

Completion Type: Multiple completion, three screens in the regional aquifer until September 2007 when screens 2 and 3 were plugged and abandoned. Screen 1 is about 90 ft below the water table.

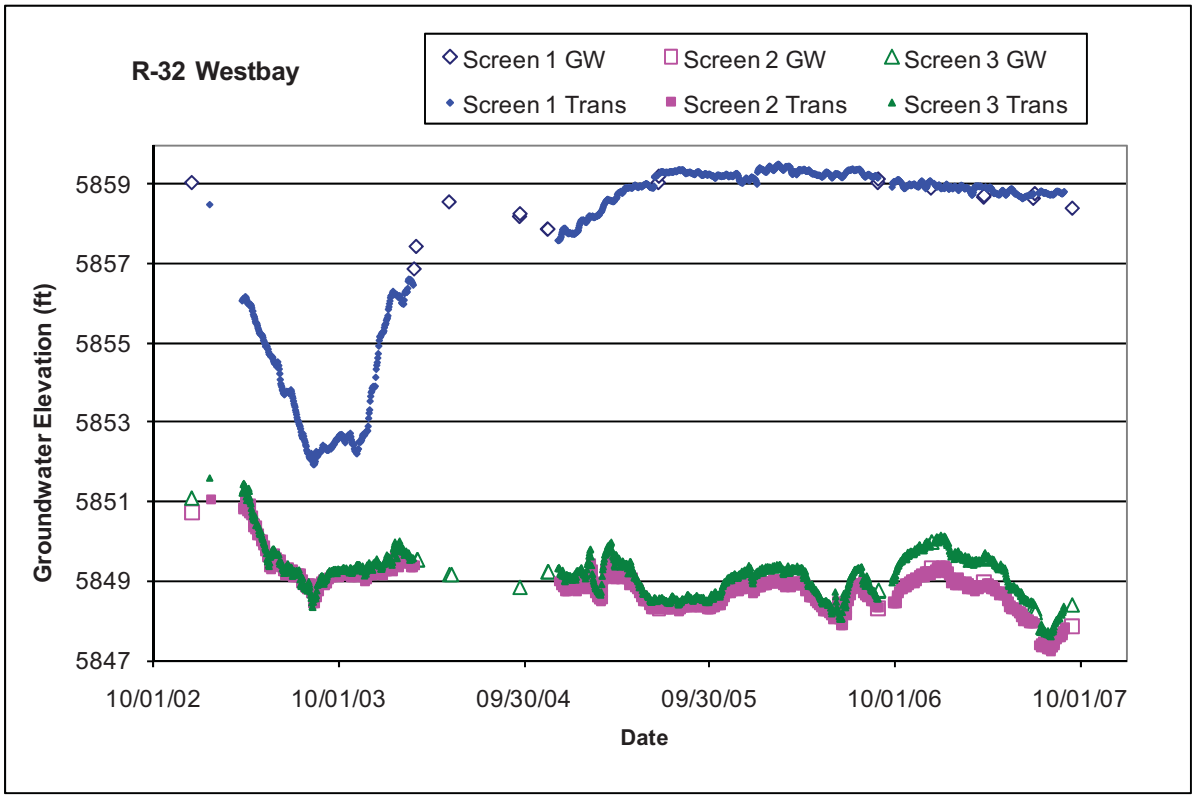
Period of Record: Westbay® installed December 14, 2002, transducers installed January 21, 2003, transducer data through August 2007. The Westbay® system was removed on September 18, 2007, and the well was rehabilitated to a single completion well at screen 1 in September 2007. A submersible pump was installed in November 2007 and a transducer was installed at screen 1 in February 2008; transducer data through 2010.

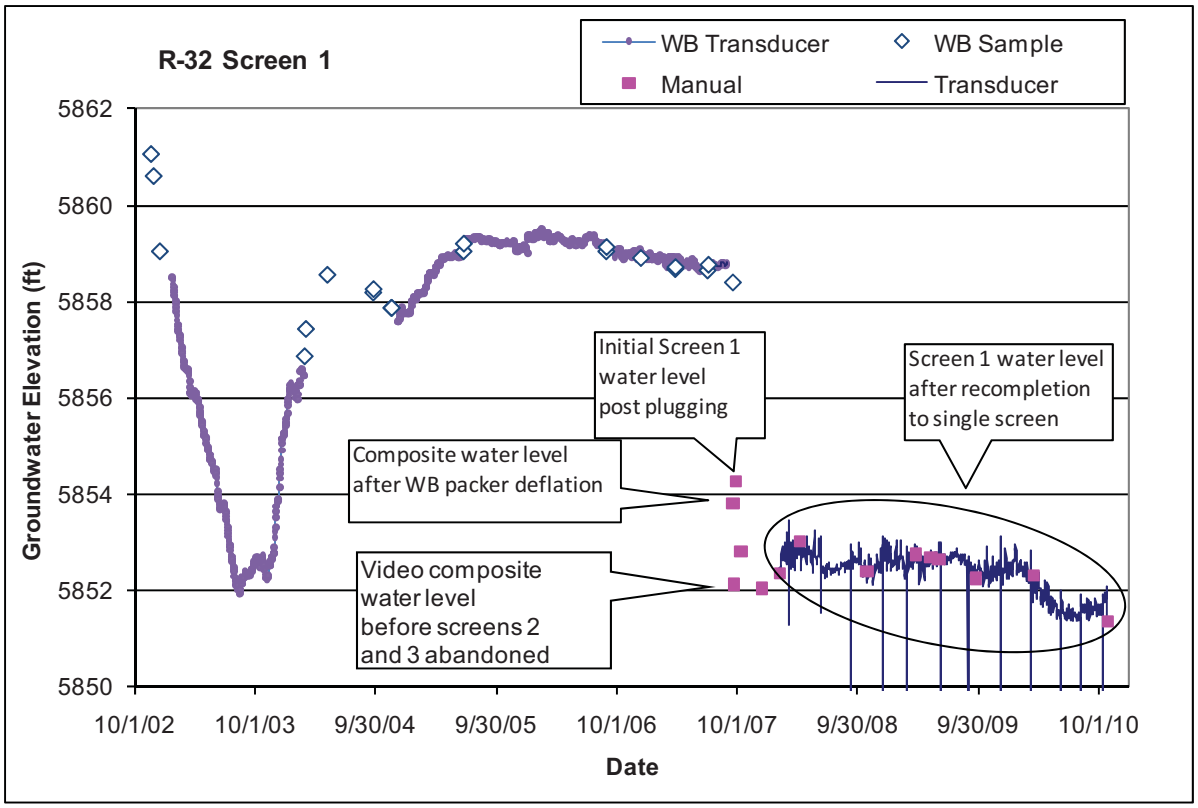
Remarks: Screens 2 and 3 had nearly identical head values and responded to pumping supply wells PM-2 and PM-4. Screen 1 apparently responded to long-term pumping of PM-4 in 2003, but vaguely to test pumping PM-2 in 2004 and PM-4 in 2005. Screens 2 and 3 responded to the PM-2 aquifer test in January 2003 (McLin 2005), to the PM-4 aquifer test in January 2005 (McLin 2006), and to PM-4 pumping in June 2006 and July 2007.

R-32 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	867.5	875.2	5770.1	5762.4	7.7	858.6	5779.0	875.2	5762.4	893.6	18.4	57.5	RT	Tb4
2	931.8	934.9	5705.8	5702.7	3.1		**Sceen plugged and abandoned Sept 2007**						RD	Tpf
3	972.9	980.6	5657.0	5657.0	7.7		**Sceen plugged and abandoned Sept 2007**						RD	Tpf

Note: R-32 Brass Cap Ground Elevation: 6637.63 ft; all measurements are from this elevation


R-32 Westbay
Screen 1 GW
Screen 2 GW
Screen 3 GW
Screen 1 Trans
Screen 2 Trans
Screen 3 Trans
Groundwater Elevation (ft)
5859
5857
5855
5853
5851
5849
5847
10/01/02
10/01/03
09/30/04
09/30/05
10/01/06
10/01/07
Date


R-32 Screen 1
WB Transducer
WB Sample
Manual
Transducer
Groundwater Elevation (ft)
5862
5860
5858
5856
5854
5852
5850
Initial Screen 1 water level post plugging
Screen 1 water level after recompletion to single screen
Composite water level after WB packer deflation
Video composite water level before screens 2 and 3 abandoned
10/1/02
10/1/03
9/30/04
9/30/05
10/1/06
10/1/07
9/30/08
9/30/09
10/1/10
Date

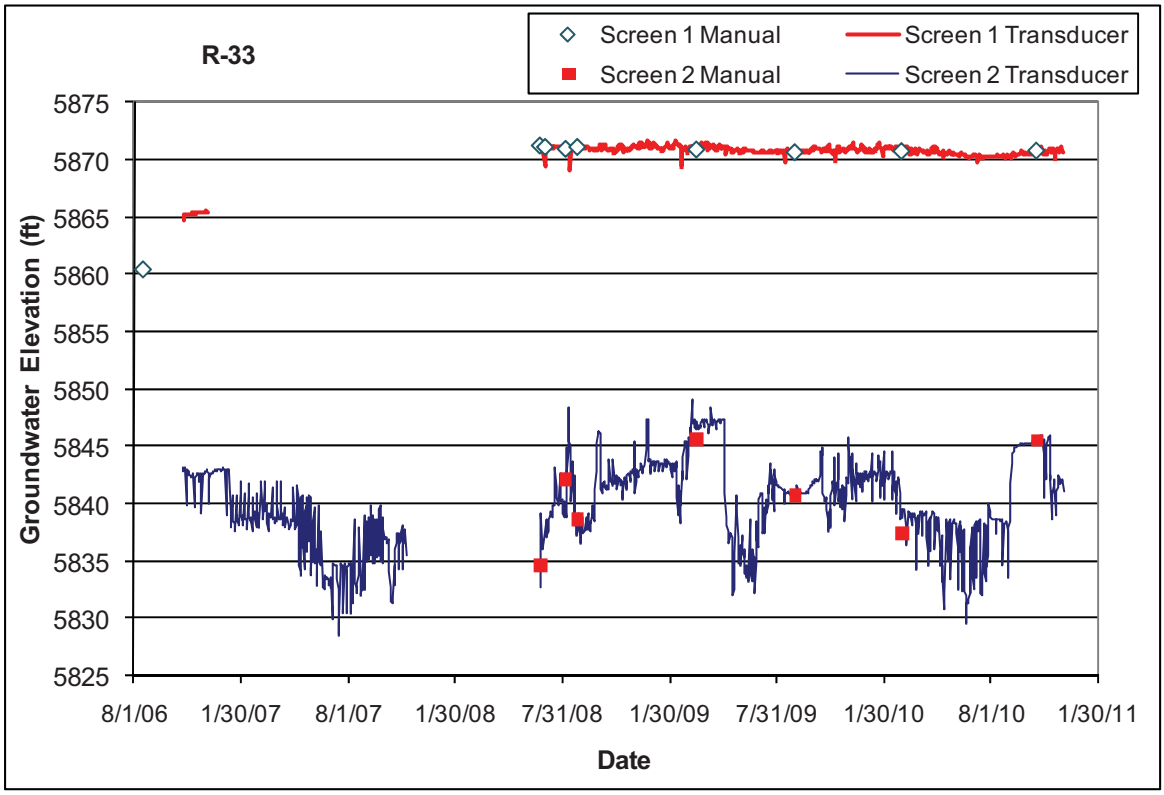
3.37 R-33

Location: R-33 is located in lower Ten Site Canyon about 1500 ft northeast of supply well PM-5.
Completion Type: Dual screen completion in the regional aquifer.
Period of Record: Well completed October 2004, transducers installed February 2005 but equipment problems hindered data collection. Transducers calibrated and the packer inflated in August 2006 and again in October 2006 with nitrogen bottle to maintain packer pressure. Water level data for screen 2 from October 24, 2006, to November 8, 2007; data for screen 1 ended December 5, 2006. New sampling system and transducers installed July 2008; water level data through 2010.
Remarks: R-33 screen 1 installed about 12 ft below the regional water table at a depth of 1018.5 ft, and screen 2 within the regional aquifer to a depth of 1126 ft, about 140 ft into the regional aquifer. Transducer equipment problems occurred from February 2005 until October 2006 when transducers and packer equipment became operational. The original transducer equipment was removed from the well on November 8, 2007, in preparation for removing the Barcad sampling system from the well. A dual valve Baski sampling system was installed July 2008 (LANL August 2008). The water level at screen 2 responds primarily to pumping of supply well PM-5 but also to pumping at PM-4.

R-33 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top/ Bottom Packer Depth (ft)	Top/ Bottom Packer Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (Gal.)	Hydro Zone Code	Geo Unit Code
1	995.5	1018.5	5857.8	5834.8	23.0	1067.0	5786.3	1074.6	5778.8	1074.6	56.1	46.3	RT	Tpp
2	1112.4	1122.3	5740.9	5731.0	9.9	1110.8	5742.6	1078.9	5774.5	1126.0	3.7	3.1	RD	Tpp

Note: R-33 Brass Cap Ground Elevation: 6853.33 ft; all measurements are from this elevation; APV = access port valve



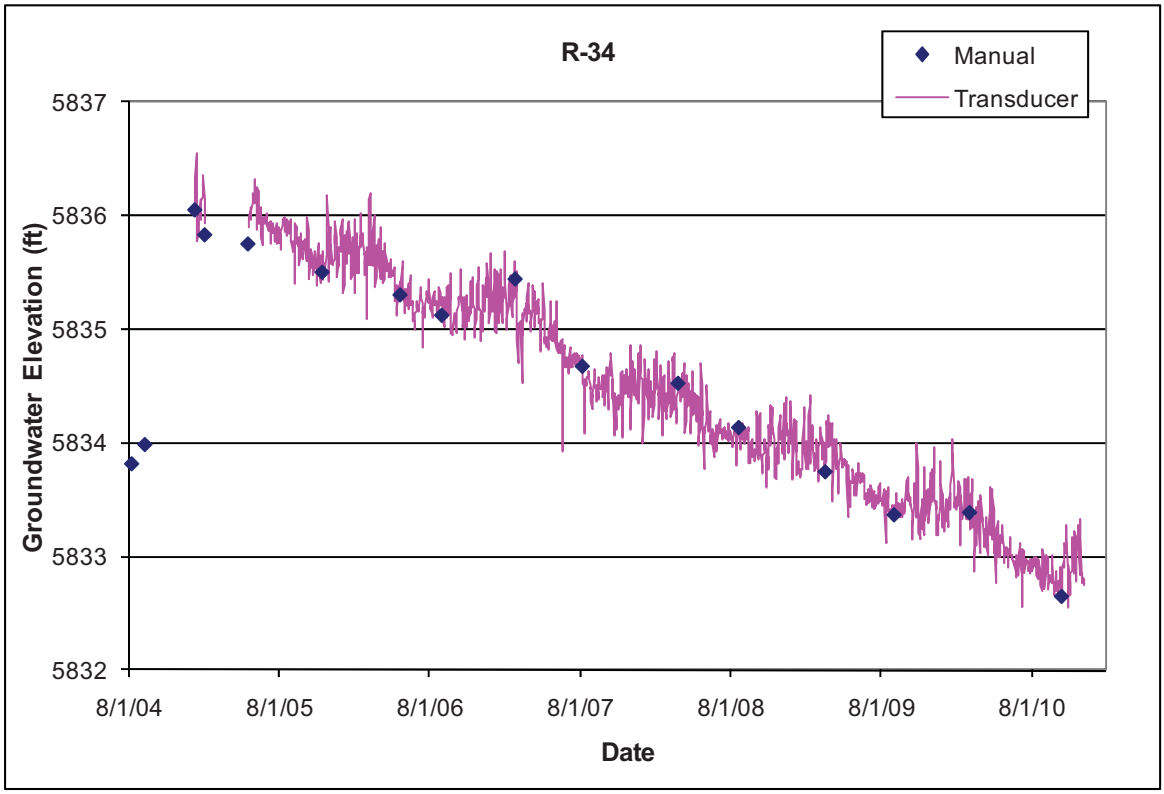
3.38 R-34

Location: R-34 is located in Cedro Canyon on San Ildefonso land east of LANL.
Completion Type: Single completion in the regional aquifer. The top of the screen is about 90 ft below the water table.
Period of Record: Well completed August 2004, transducer installed January 2005, water level data through 2010.
Remarks: R-34 installed at the top of the regional aquifer at a depth of 920.7 ft, about 110 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. R-34 exhibits a seasonal response to supply well pumping but does not indicate a response to any specific supply well. The average annual water decline has been about 0.55 ft/yr.

R-34 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	883.7	906.6	5746.3	5723.4	22.9	881.6	5748.4	906.6	5723.4	920.7	14.1	44.1	RT	Tpp

Note: R-34 Brass Cap Ground Elevation: 6629.99 ft; all measurements are from this elevation



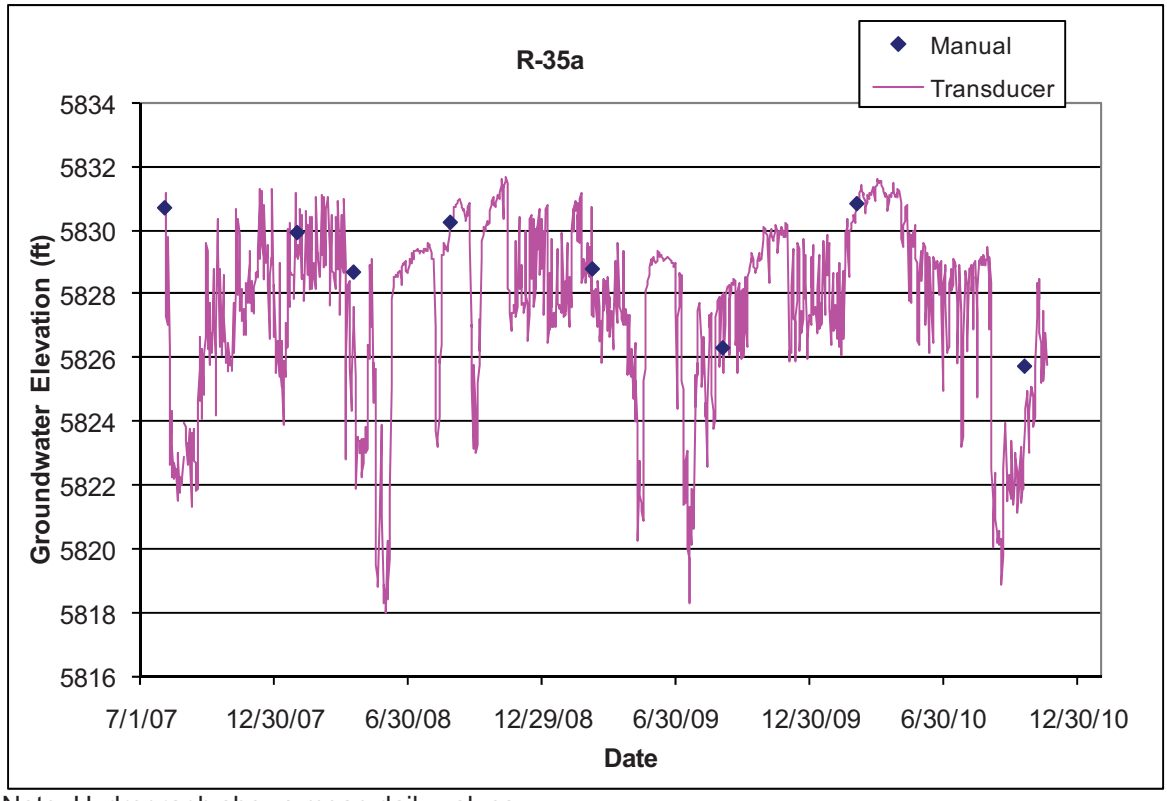
3.39 R-35a

Location: R-35a is located in Sandia Canyon about 340 ft southwest of supply well PM-3.
Completion Type: Single completion in the regional aquifer. The top of the screen is about 220 ft below the water table at the same elevation as the top of the PM-3 screen.
Period of Record: Well completed June 2007, transducer installed August 3, 2007; water level data through 2010.
Remarks: R-35a installed at a depth of 1082.2 ft, about 290 ft into the regional aquifer. R-35a responds primarily to pumping supply well PM-3, about 3 to 4 ft daily, but also shows a response to pumping supply well O-4. When the well was completed, the static water level at R-35a was about 7 ft lower than nearby monitoring well R-35b, which is screened at the top of the aquifer.

R-35a Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1013.1	1062.2	5610.0	5560.9	49.1	998.3	5624.8	1062.2	5560.9	1086.2	24.0	75.1	RD	Tsfu

Note: Brass Cap Ground Elevation: 6623.06 ft; all measurements are from this elevation



Note: Hydrograph shows mean daily values

3.40 R-35b

Location: R-35b is located in Sandia Canyon about 90 ft west of R-35a and about 400 ft southwest of supply well PM-3.

Completion Type: Single completion at the top of the regional aquifer. The top of the screen was about 37 ft below the water table when the well was installed.

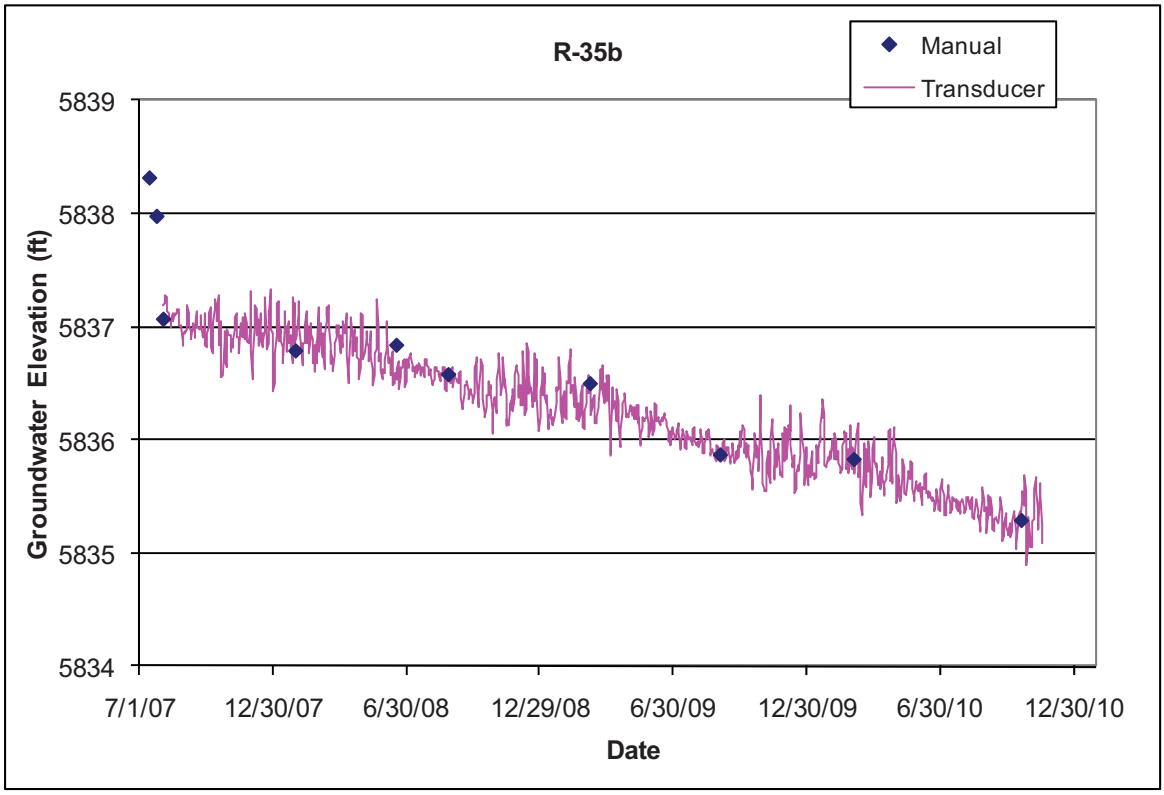
Period of Record: Well completed July 2007, transducer installed August 3, 2007; water level data through 2010.

Remarks: R-35b installed near the top of the regional aquifer at a depth of 872.2 ft, about 80 ft into the regional aquifer. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. R-35b does not indicate a response to pumping of nearby well PM-3 or to any specific supply well, but indicates a relatively continual decline of about 0.5 ft/yr in response to supply well pumping.

R-35b Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	825.4	848.5	5799.8	5776.7	23.1	832.7	5792.5	848.5	5776.7	872.2	23.7	74.1	RT	Tpf

Note: Brass Cap Ground Elevation: 6625.21 ft; all measurements are from this elevation



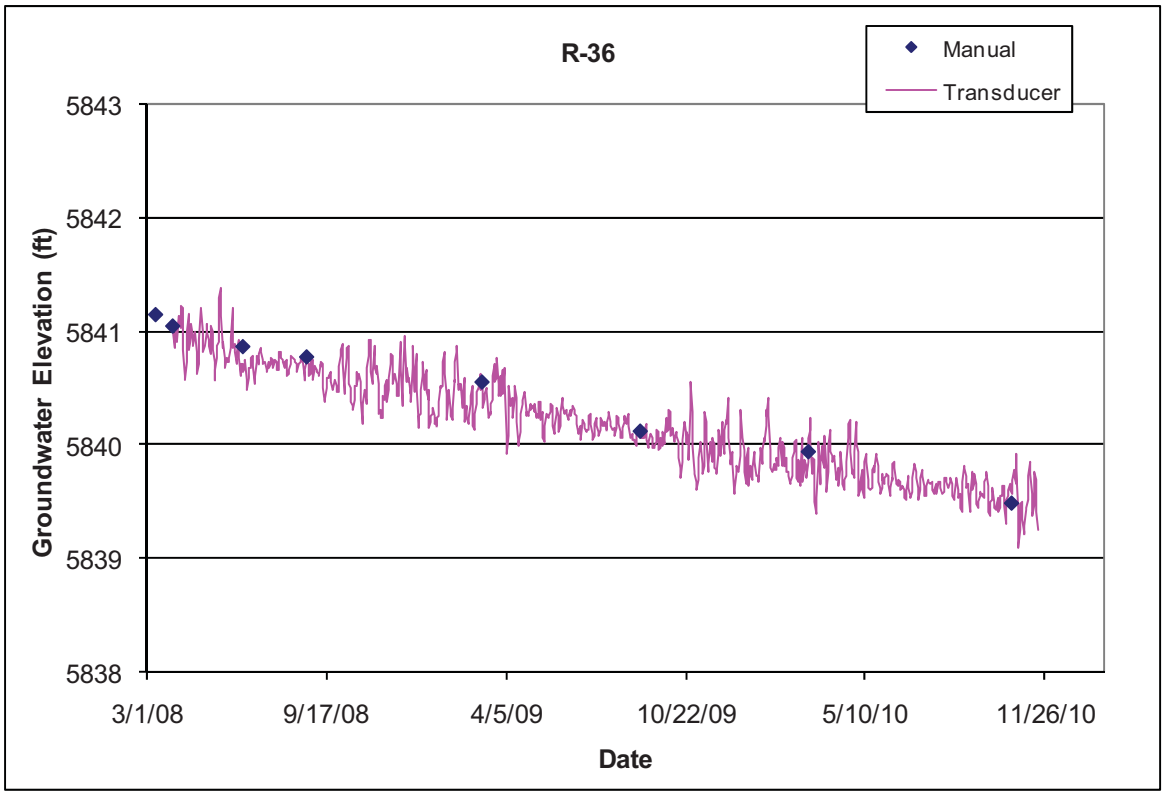
3.41 R-36

Location: R-36 is located in lower Sandia Canyon about 2200 ft southeast of supply well PM-3.
Completion Type: Single completion at the top of the regional aquifer.
Period of Record: Well completed February 2008, transducer installed March 31, 2008; water level data through 2010.
Remarks: R-36 installed near the top of the regional aquifer to a depth of 803.7 ft; top of screen is about 17 ft below the regional water table. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. Available water level data indicate that R-36 does not appear to respond to supply well pumping at nearby wells PM-1 and PM-3, but indicate a relatively continual decline of about 0.5 ft/yr in response to supply well pumping.

R-36 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	766.9	789.9	5824.5	5801.5	23.0	764.5	5826.9	789.9	5801.5	803.7	13.8	43.2	RT	Tsfu

Note: Brass Cap Ground Elevation: 6591.37 ft; all measurements are from this elevation



3.42 R-37

Location: R-37 is located at TA-54 on an unnamed mesa between Cañada del Buey and the south fork of Cañada del Buey. R-37 is about 3000 ft southeast of supply well PM-4, 2500 ft northeast of supply well PM-2, and about 1100 ft east of MDA J.

Completion Type: Dual completion in a perched intermediate zone and in the top of the regional aquifer. A Baski dual pump sampling system was installed on November 11, 2009, but due to a problem with the Bennett pump, the system was removed on December 14, 2009, and reinstalled on December 16, 2009.

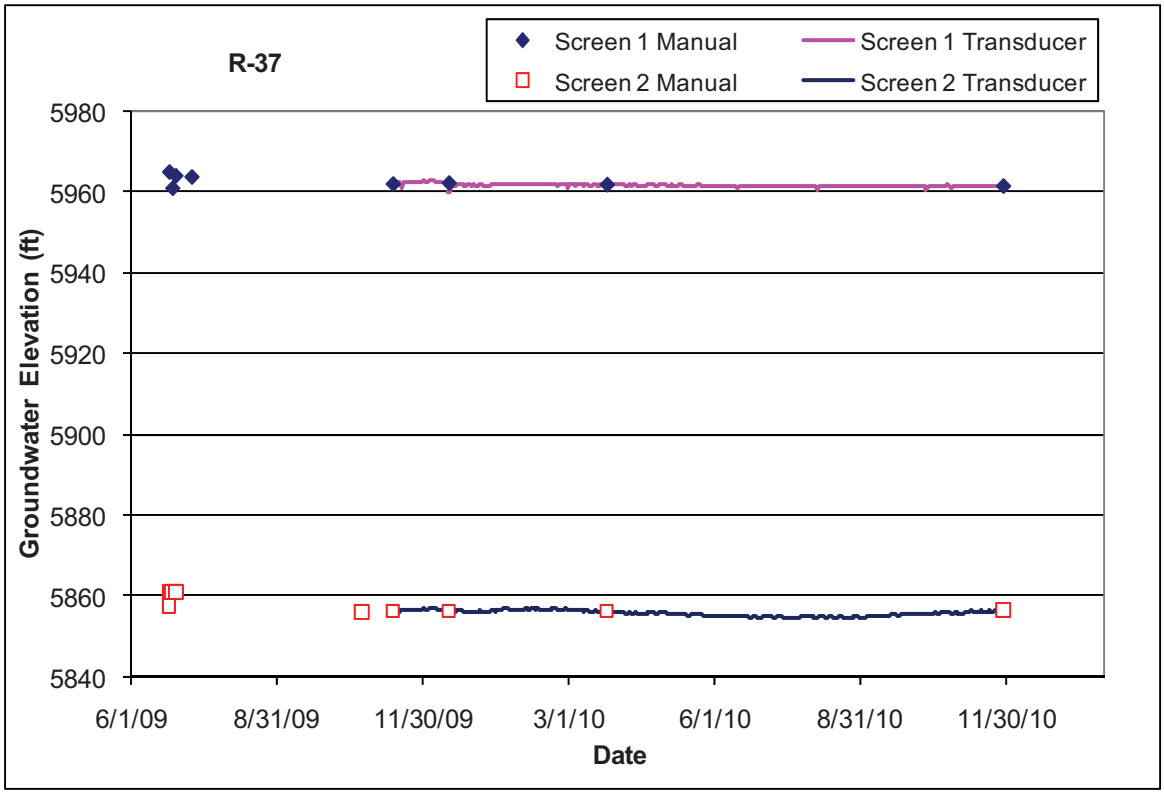
Period of Record: Well completed June 2009, transducers installed November 12, 2009, and again on December 17, 2009; water level data through 2010.

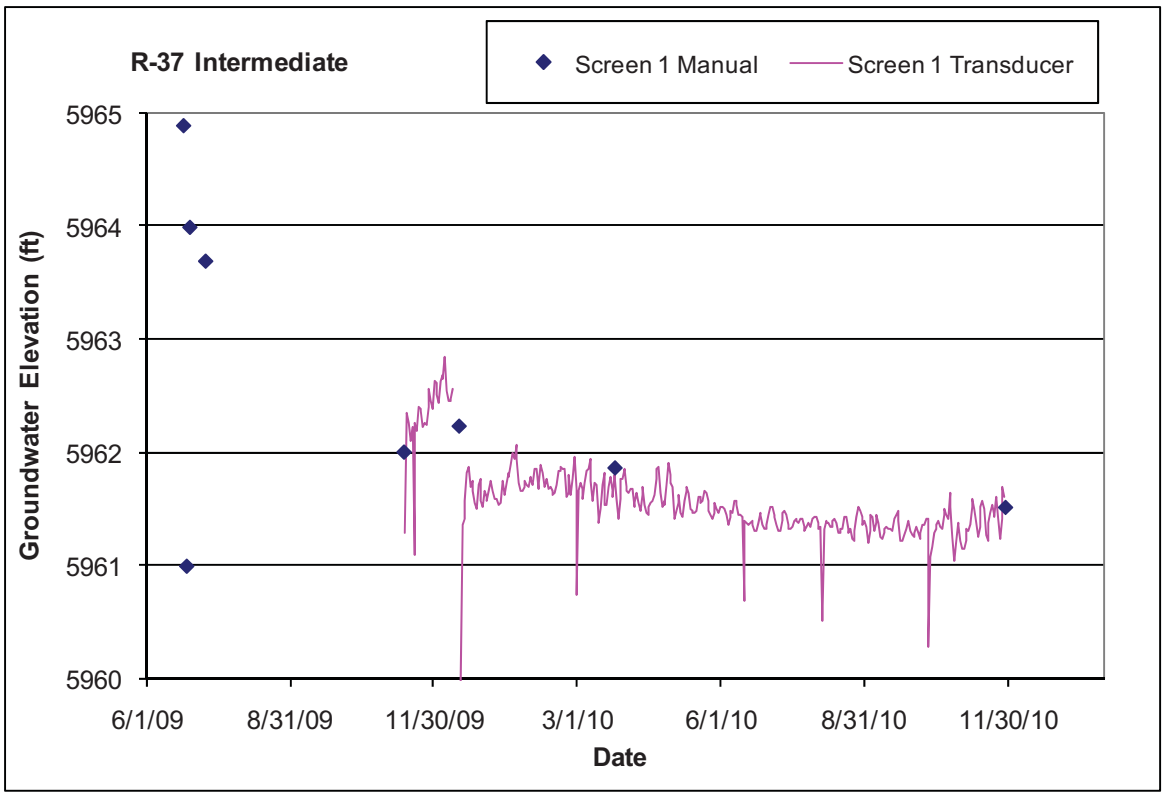
Remarks: The top of screen 2 is about 12 ft below the regional water table. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The regional aquifer at R-37 screen 2 responds to supply well pumping at nearby well PM-4.

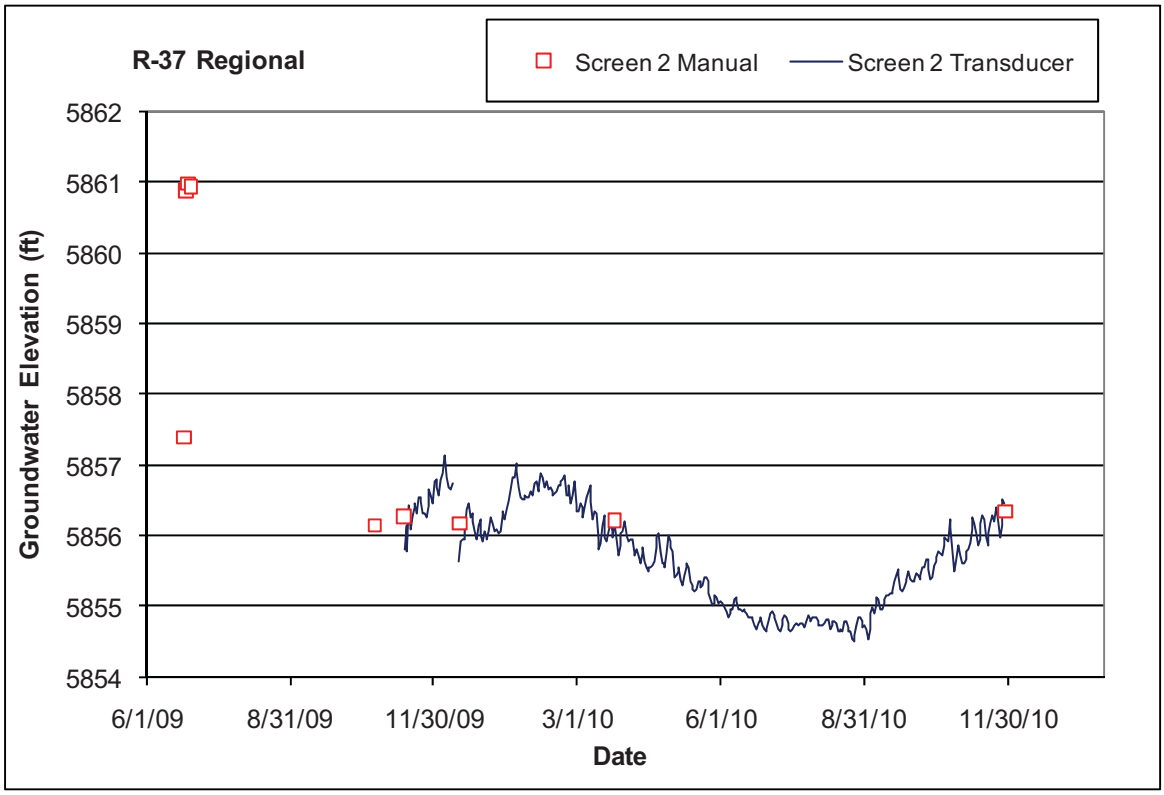
R-37 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Packer/ Sump Bottom (ft)	Depth to bottom of Packer	Sump Length (ft)	Bottom Well Elev (ft)	Hydro Zone Code	Geo Unit Code
1	929.3	950.0	5941.3	5920.6	20.7	948.9	5921.7	959.3	NA	9.3	5911.3	I	Tpf
2	1026.0	1046.6	5844.6	5824.0	20.6	1055.9	5814.7	1068.8	964.1	22.2	5801.8	RT	Tpf

Note: Brass Cap Elevation: 6870.59 ft; all measurements are from this elevation




R-37 Intermediate
Screen 1 Manual
Screen 1 Transducer
Groundwater Elevation (ft)
5965
5964
5963
5962
5961
5960
6/1/09
8/31/09
11/30/09
3/1/10
6/1/10
8/31/10
11/30/10
Date


R-37 Regional
Screen 2 Manual
Screen 2 Transducer
Groundwater Elevation (ft)
5862
5861
5860
5859
5858
5857
5856
5855
5854
6/1/09
8/31/09
11/30/09
3/1/10
6/1/10
8/31/10
11/30/10
Date

3.43 R-38

Location: R-38 is located in middle Cañada del Buey northeast of MDA L and about 960 ft northeast of R-53.

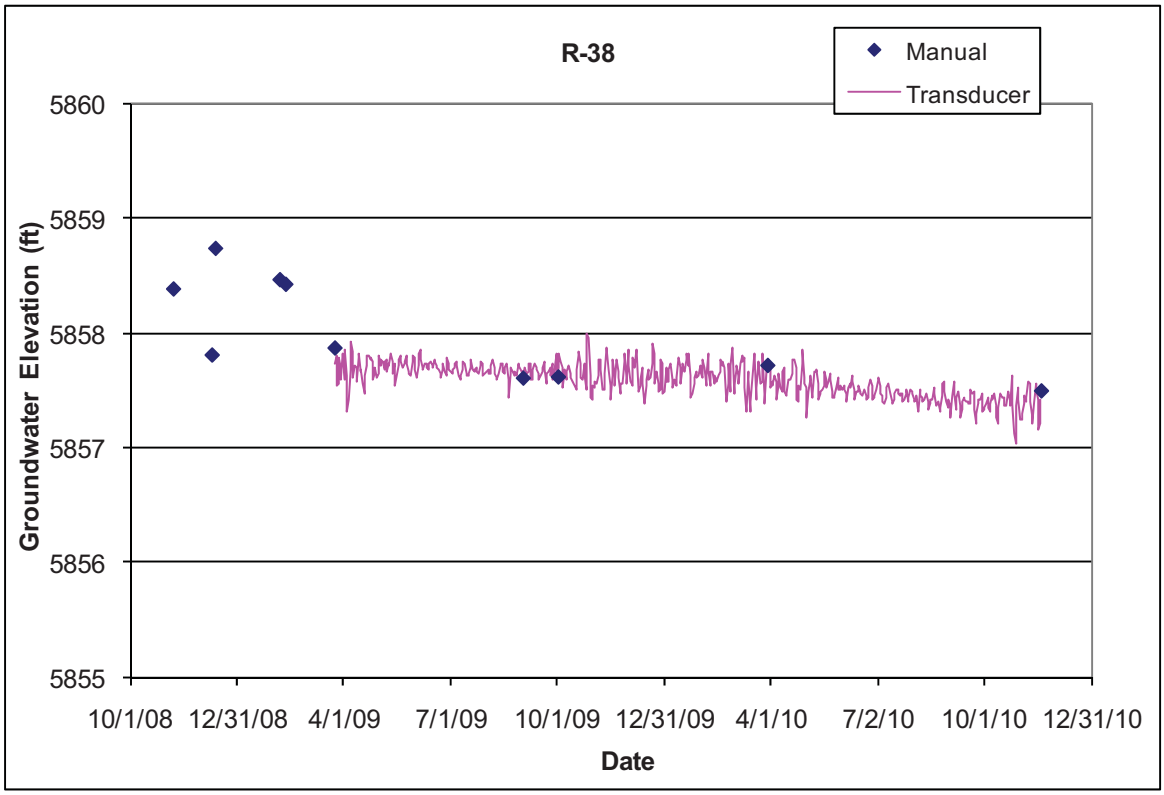
Completion Type: Single completion at the top of the regional aquifer in Cerros del Rio basalt.

Period of Record: Well completed December 2008, transducer installed March 25, 2009; data through 2010.

Remarks: R-38 installed near the top of the regional aquifer to a depth of 853 ft; top of screen is about 10 ft below the regional water table. The well is 100% barometrically efficient; however, the aquifer has a delayed response to atmospheric pressure fluctuations. Available data indicate that R-38 shows a small response to pumping at supply well PM-4.

R-38 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Bottom Well Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	821.2	831.2	5847.4	5837.4	10.0	818.5	5850.1	831.2	5837.4	853.0	21.8	84.2	RT	Tb4
Note: Brass Cap Ground Elevation: 6668.58 ft; all measurements are from this elevation														



3.44 R-39

Location: R-39 is located in lower Pajarito Canyon southeast and downgradient of TA-54 MDA G. R-38 is about 700 ft southwest of monitoring well R-22, 850 ft south of R-57, and 1100 ft east of R-49.

Completion Type: Single completion at the top of the regional aquifer in Cerros del Rio basalt.

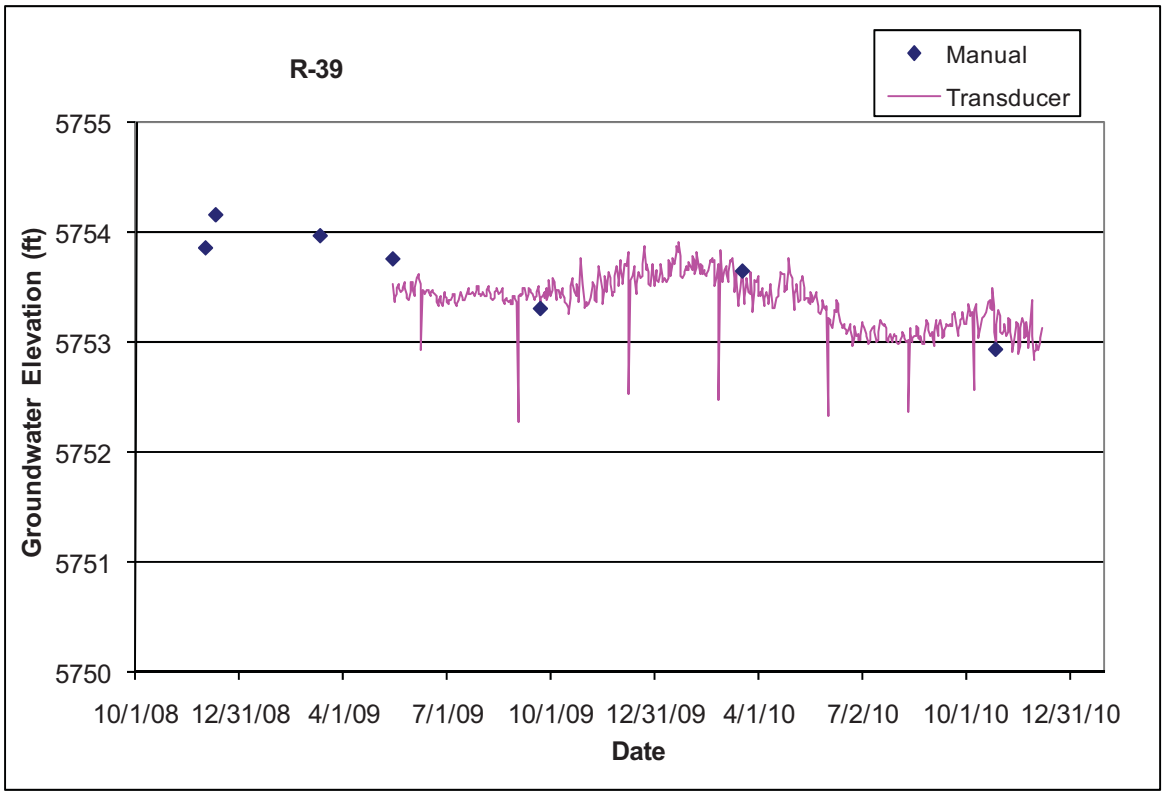
Period of Record: Well completed December 2008. Transducer installed May 15, 2009; data through 2010.

Remarks: R-39 installed near the top of the regional aquifer to a depth of 875.6 ft; top of the screen is about 30 ft below the regional water table. The well is 80% barometrically efficient; the aquifer indicates a partial response to atmospheric pressure fluctuations. The R-39 screen overlaps the lower 4 ft of R-57 screen 1 and is 36 ft above R-57 screen 2; R-39 water level is 5 ft lower than R-57 screen 1 and 3 ft higher than R-57 screen 2. The groundwater at R-39 responded during drilling R-57 and responds to pumping R-57 screen 2. The water level at R-39 is about 2 ft higher than at R-49 screen 2, which shows similar responses to R-57 screen 2 pumping.

R-39 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	859.0	869.0	5721.8	5711.8	10.0	858.8	5722.1	869.0	5711.8	875.6	6.5	25.3	RT	Tb4

Note: Brass Cap Ground Elevation: 6580.86 ft; all measurements are from this elevation



3.45 R-40

Location: R-40 is located in lower Pajarito Canyon east of TA-18, 400 ft north of supply well PM-2 and about 0.25 mi south of MDA J.

Completion Type: Three screens in two piezometers; one intermediate 3-in.-ID PVC piezometer screen (R-40i) and two 5-in.-ID stainless steel screens (R-40) with the upper screen in an intermediate zone and the lower screen at the top of the regional aquifer.

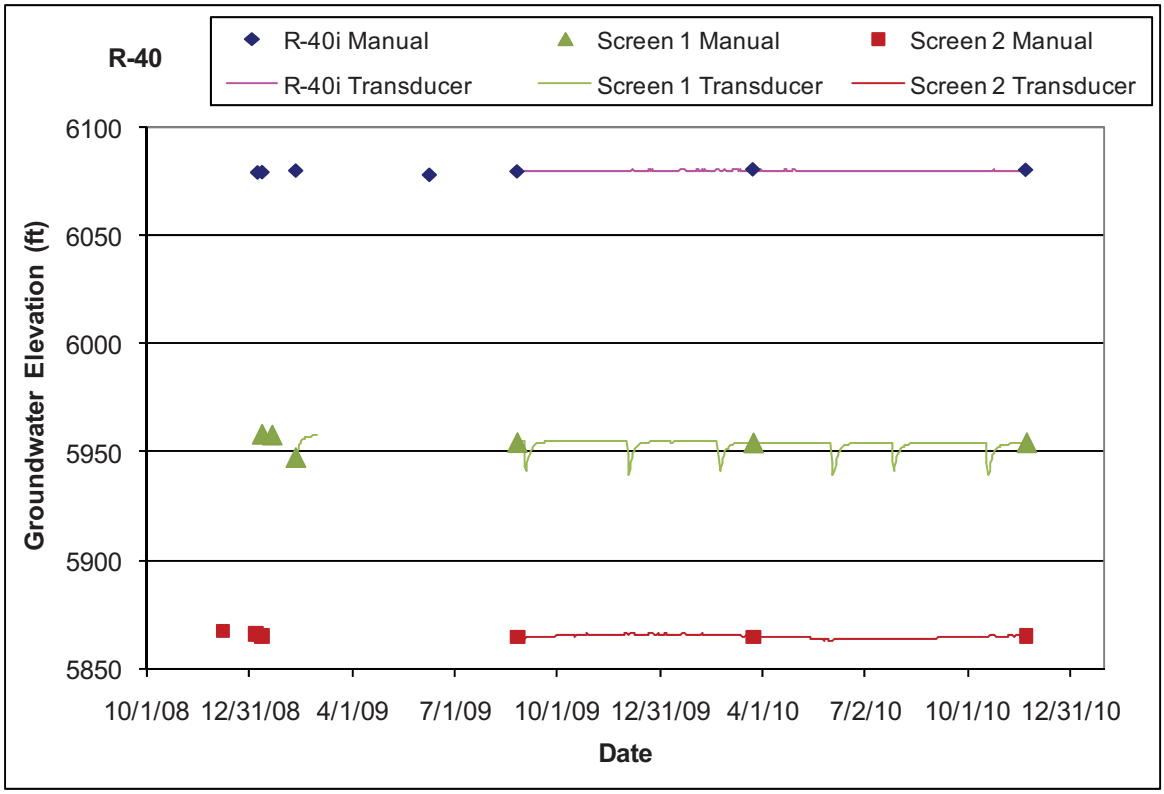
Period of Record: Well completed January 2009. Transducers installed at all three screens August 27, 2009; data through 2010. A temporary transducer was installed at the R-40 upper screen from February 11 to March 3, 2009, to monitor the slow recovery of the lower intermediate zone after attempting an aquifer test.

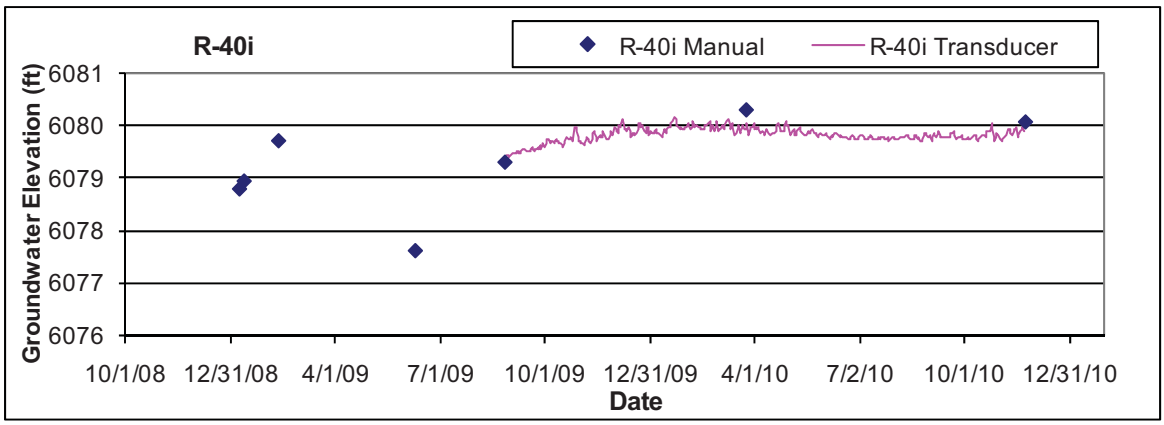
Remarks: Screen R-40i and the upper R-40 screen are completed in intermediate perched zones within the Cerros del Rio basalt. The lower R-40 screen is installed in Puye fanglomerates near the top of the regional aquifer to a depth of 895 ft; the lower R-40 screen straddles the regional water table. The regional aquifer indicates a response to pumping supply wells PM-2 and PM-4.

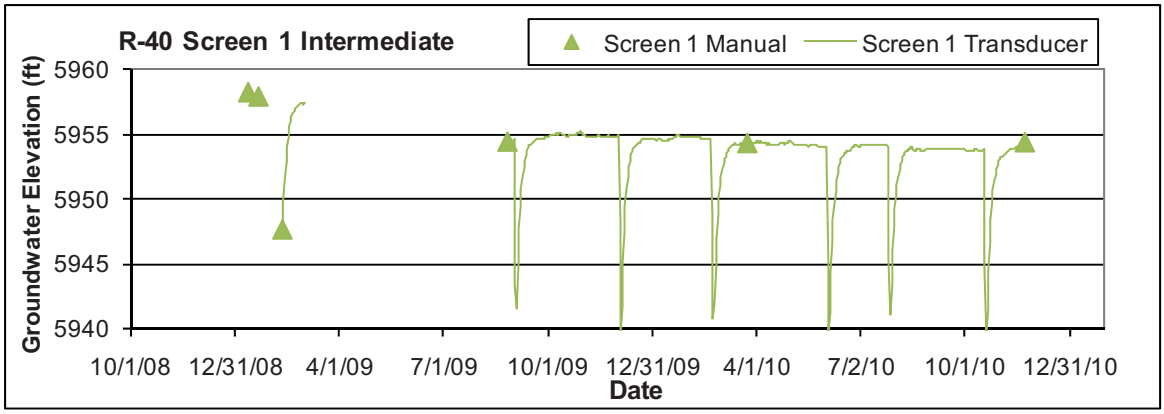
R-40 and R-40i Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Packer / Sump Bottom (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code	Comment
R-40i	649.7	669.0	6069.5	6050.2	19.3	669.0	6050.2	669.0	6050.2	674.6	5.6	7.8	I	Tb4	3" ID PVC Casing
1	751.6	785.1	5967.6	5934.1	33.5	778.0	5941.2	785.1	5934.1	794.1	9.0	34.8	I	Tb4	5" ID SS Casing
2	849.3	870.0	5869.9	5849.2	20.7	871.0	5848.2	870.0	5849.2	895.0	25.0	96.5	RT	Tpf	5" ID SS Casing

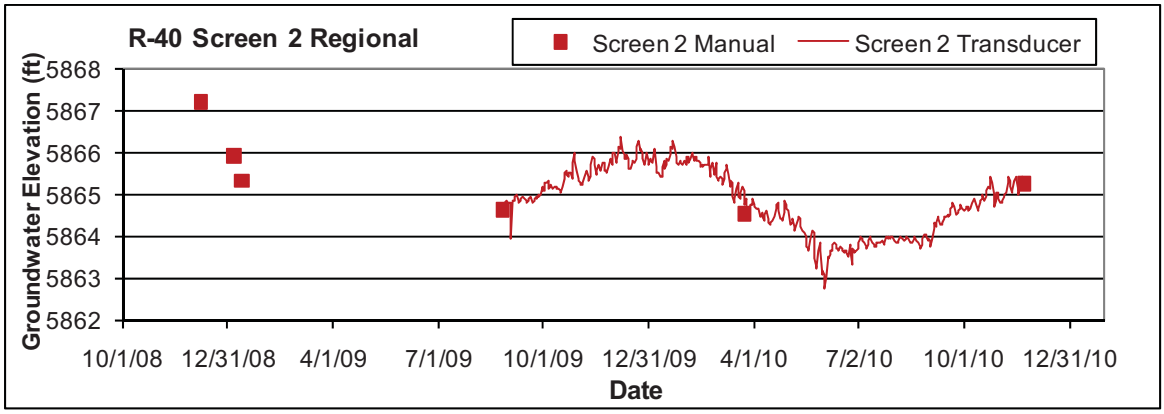
Note: Brass Cap Ground Elevation: 6719.24 ft; all measurements are from this elevation







Note scale change for R-40 Screen 1 hydrograph



3.46 R-41

Location: R-41 is located about 100 ft east of MDA G at TA-54 and about 420 ft northeast of R-57 and 650 ft north of monitoring well R-22.

Completion Type: Dual completion in a dry zone and at the top of the regional aquifer in Santa Fe Group sediments.

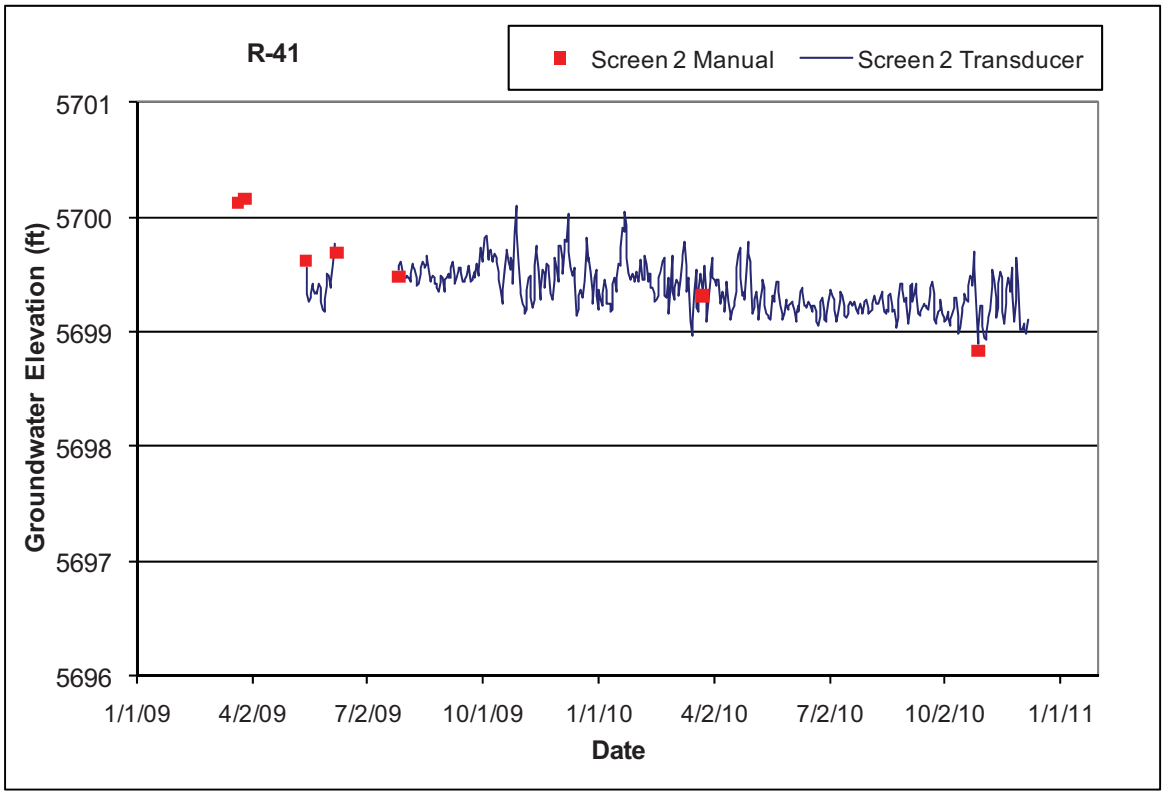
Period of Record: Well completed March 2009. Temporary transducer installed from May 15 to June 8, 2009. Dedicated transducer installed July 27, 2009; data through 2010.

Remarks: Screen 1 has been dry since installation. Screen 2 is installed near the top of the regional aquifer to a depth of 997.1 ft; the top of the screen is about 4 ft below the regional water table. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuation. The water level at R-41 is about 60 ft lower than at R-22 screen 1 and R-57 screen 1 and about 50 ft lower than at R-57 screen 2. The R-41 water level is similar to the water level at R-22 screen 3. The aquifer at R-41 showed no apparent response to pumping at nearby well R-57. Available data do not indicate a response at R-41 to supply well pumping.

R-41 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Packer/ Sump (ft)	Top of Packer/ Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Vol (gal.)	Hydro Zone Code	Geo Unit Code
1	928.0	937.7	5732.5	5722.8	9.7	NA	NA	944.8	5715.7	944.8	7.1	7.2	I	Tsf
2	965.3	975.0	5695.2	5685.5	9.7	978.5	5682.0	975.0	5685.5	997.1	22.1	22.5	RT	Tsf

Note: Brass Cap Ground Elevation: 6660.53 ft; all measurements are from this elevation



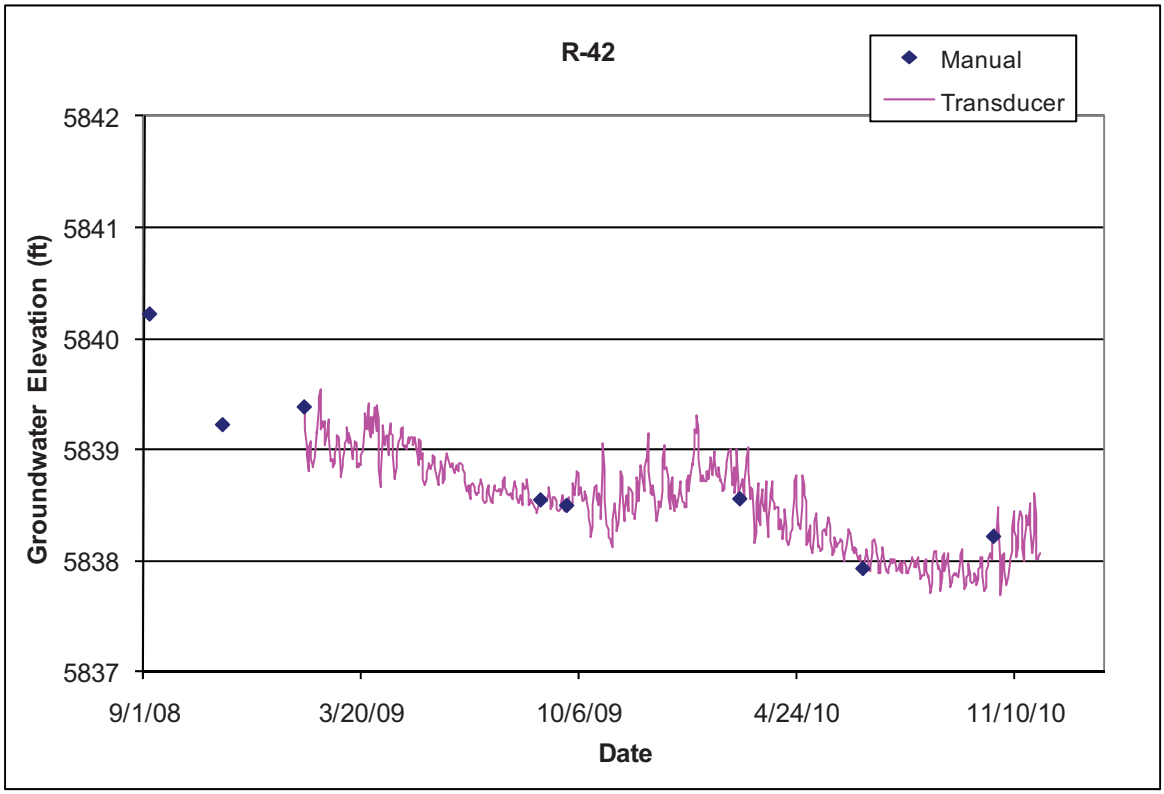
3.47 R-42

Location: R-42 is located in lower Mortandad Canyon between R-15 and R-28. R-42 is about 970 ft southeast of R-43 (located in Sandia Canyon) and 0.25 mi west of R-28.
Completion Type: Single completion within the regional aquifer in Santa Fe Group sediments.
Period of Record: Well completed August 2008. Transducer installed January 26, 2009; data through 2010.
Remarks: R-42 installed in the regional aquifer to a depth of 973.5 ft. The top of the screen is about 12 ft below the water table. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The aquifer indicates a response to pumping supply well PM-4.

R-42 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	931.8	952.9	5827.2	5806.1	21.1	930.9	5828.2	952.9	5806.1	973.5	20.6	79.5	RT	Tsfu

Note: Brass Cap Ground Elevation: 6759.02 ft; all measurements are from this elevation



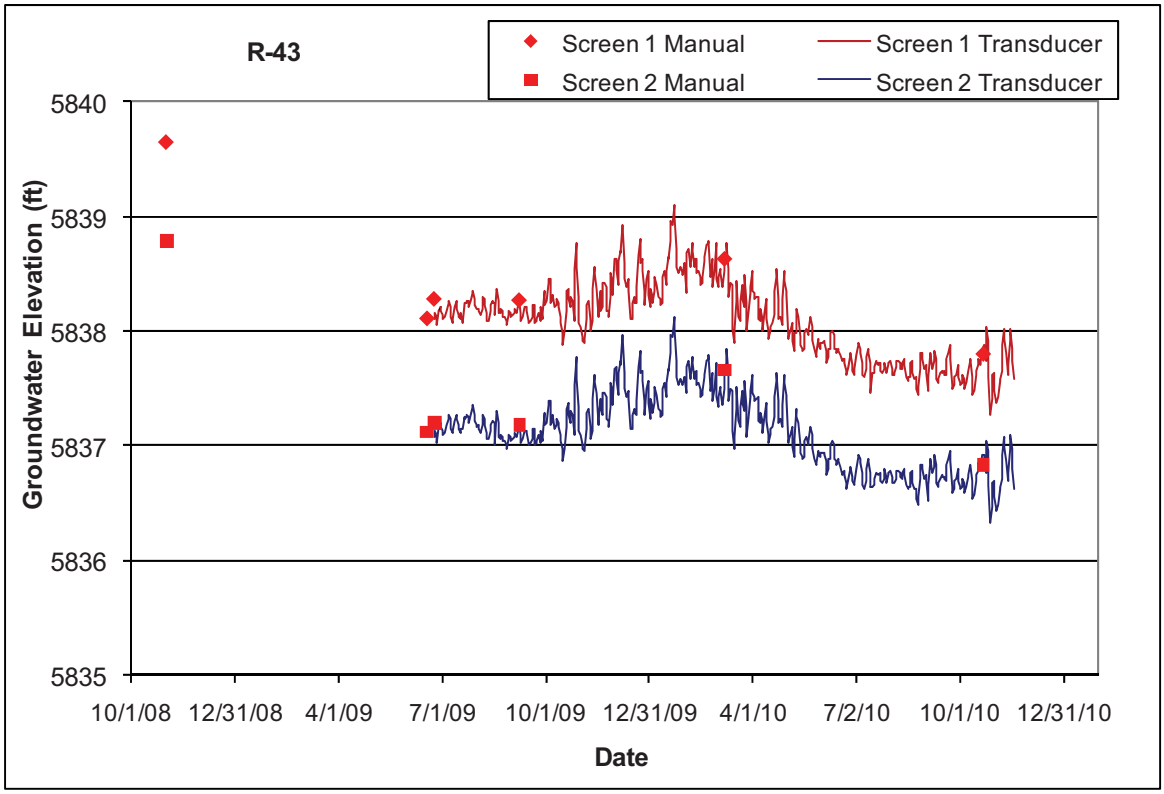
3.48 R-43

Location: R-43 is located in middle Sandia Canyon about 970 ft northwest of R-42.
Completion Type: Dual completion within the regional aquifer. The top of screen 1 is about 10 ft below the water table.
Period of Record: Well completed October 2008. Transducers installed June 25, 2009; data through 2010.
Remarks: R-43 installed in the regional aquifer to a depth of 990 ft, about 95 ft into the aquifer. A Baski packer with dual valve, single submersible pump sampling system was installed June 8, 2009. The screens are 44.5 ft apart with a head difference of about 1 ft. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The aquifer indicates a response to pumping supply well PM-4.

R-43 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top of Packer/ Sump Depth (ft)	Top of Packer/ Sump Elev (ft)	Bottom of Packer (ft)	Sump Length (ft)	Sump/ Well Bottom Elev (ft)	Hydro Zone Code	Geo Unit Code
1	903.9	924.6	5828.8	5808.1	20.7	948.4	5784.3	960.7	5772.0	NA	36.1	5772.0	RT	Tsfu
2	969.1	979.1	5763.6	5753.6	10.0	967.5	5765.2	990.4	5742.3	965.4	11.3	5742.3	RD	Tsfu

Note: Brass Cap Ground Elevation: 6732.65 ft; all measurements are from this elevation



3.49 R-44

Location: R-44 is located in lower Mortandad Canyon about 925 ft west of R-13, 940 ft south of R-45, and 0.25 mi east of R-50.

Completion Type: Dual screen completion within the regional aquifer.

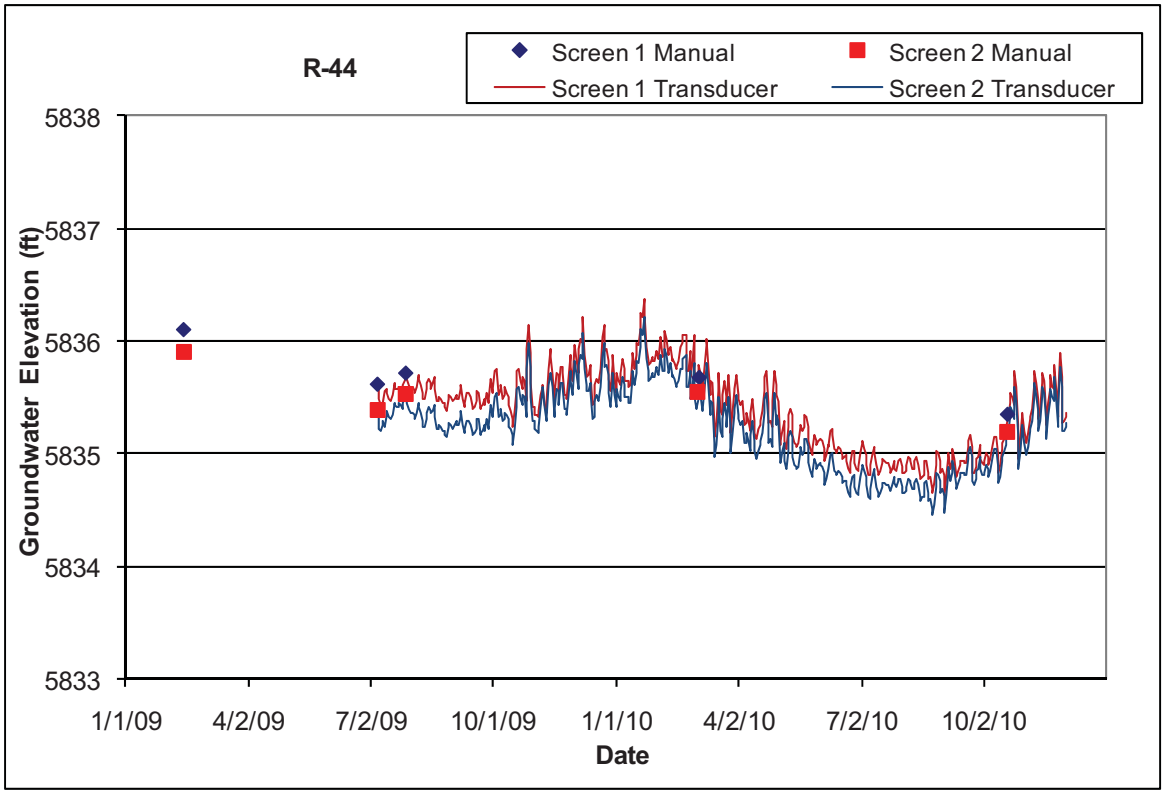
Period of Record: Well completed January 2009; transducers installed July 8, 2009; data through 2010.

Remarks: R-44 installed in the regional aquifer to a depth of 1016 ft, about 110 ft into the aquifer. The screens are 80 ft apart. Both screens exhibit a response to pumping supply well PM-4; however, screen 2 shows more response than screen 1. During pumping PM-4, the head difference between screens was about 0.25 ft; however, with PM-4 shut down, the head difference declines. The well is 100% barometrically efficient; however, the aquifer shows a delayed response to atmospheric pressure fluctuations.

R-44 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Top/Bottom of Packer (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	895.0	905.0	5819.9	5809.9	10.0	921.9	5793.0	905.0	5809.9	936.3	936.3	31.3	120.9	RT	Tpf
2	985.3	995.2	5729.6	5719.7	9.9	983.2	5731.7	995.2	5719.7	941.1	1016.0	20.8	80.3	RD	Tpf

Note: Brass Cap Ground Elevation: 6714.91 ft; all measurements are from this elevation



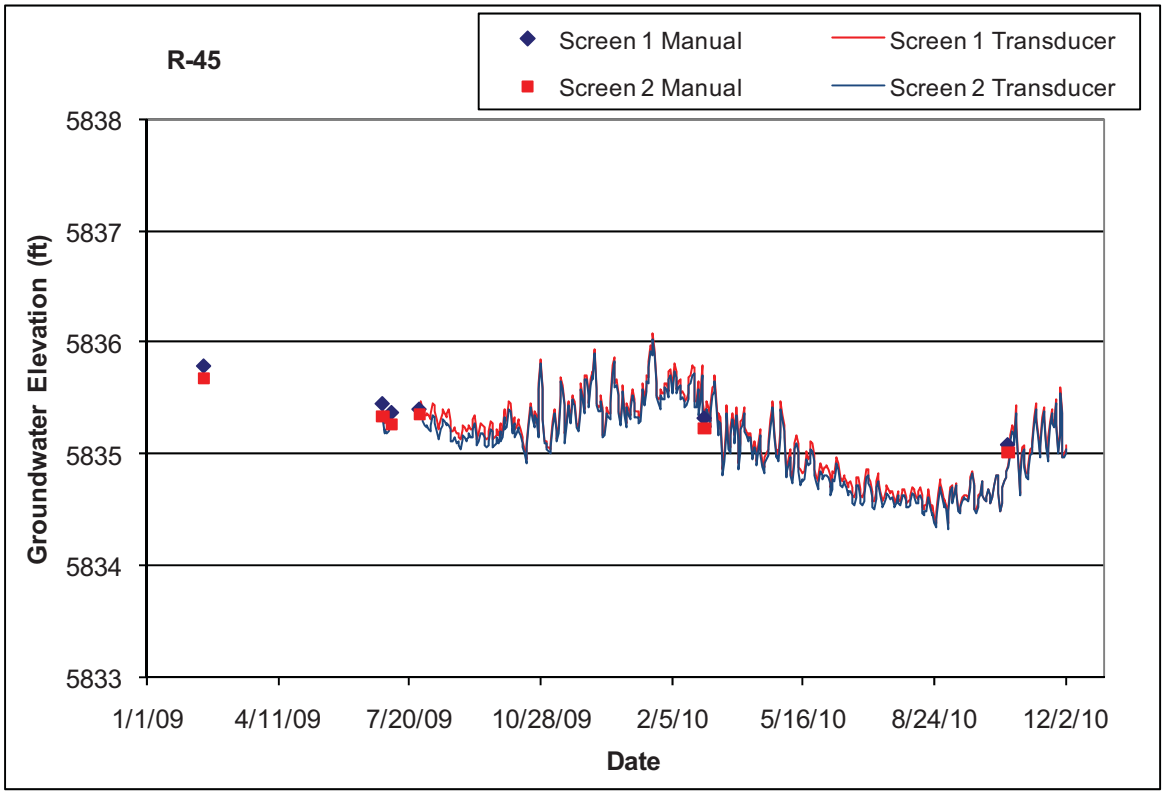
3.50 R-45

Location: R-45 is located in lower Mortandad Canyon about 925 ft north of R-44 and 1285 ft east of R-28.
Completion Type: Dual screen completion within the regional aquifer.
Period of Record: Well completed January 2009. Temporary transducers installed from June 30 to July 7, 2009. Dedicated transducers installed July 28, 2009; data through 2010.
Remarks: R-45 installed in the regional aquifer to a depth of 1016 ft, about 147 ft into the aquifer. The screens are 85 ft apart. Both screens exhibit a response to pumping supply well PM-4; however, screen 2 shows more response than screen 1. During pumping PM-4 in 2009, the head difference between screens was about 0.10 ft; however with PM-4 shut down, the head difference declines to 0.05 ft or less. The well is 100% barometrically efficient; however, the aquifer shows a delayed response to atmospheric pressure fluctuations.

R-45 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Top/ Bottom of Packer (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	880.0	890.0	5824.0	5814.0	10.0	905.5	5798.5	890.0	5814.0	921.3	921.26	31.26	120.7	RT	Tpf
2	974.9	994.9	5729.1	5709.1	20.0	973.2	5730.8	994.9	5709.1	926.0	1016.0	21.1	81.5	RD	Tsfu

Note: Brass Cap Ground Elevation: 6704.02 ft; all measurements are from this elevation



3.51 R-46

Location: R-46 is located on a mesa between Mortandad Canyon and Pajarito Canyon about 800 ft east (downgradient) of MDA C and R-60, and 4700 ft west (upgradient) of supply well PM-5.

Completion Type: Single completion at the top of the regional aquifer. The screen is located about 12 ft below the water table.

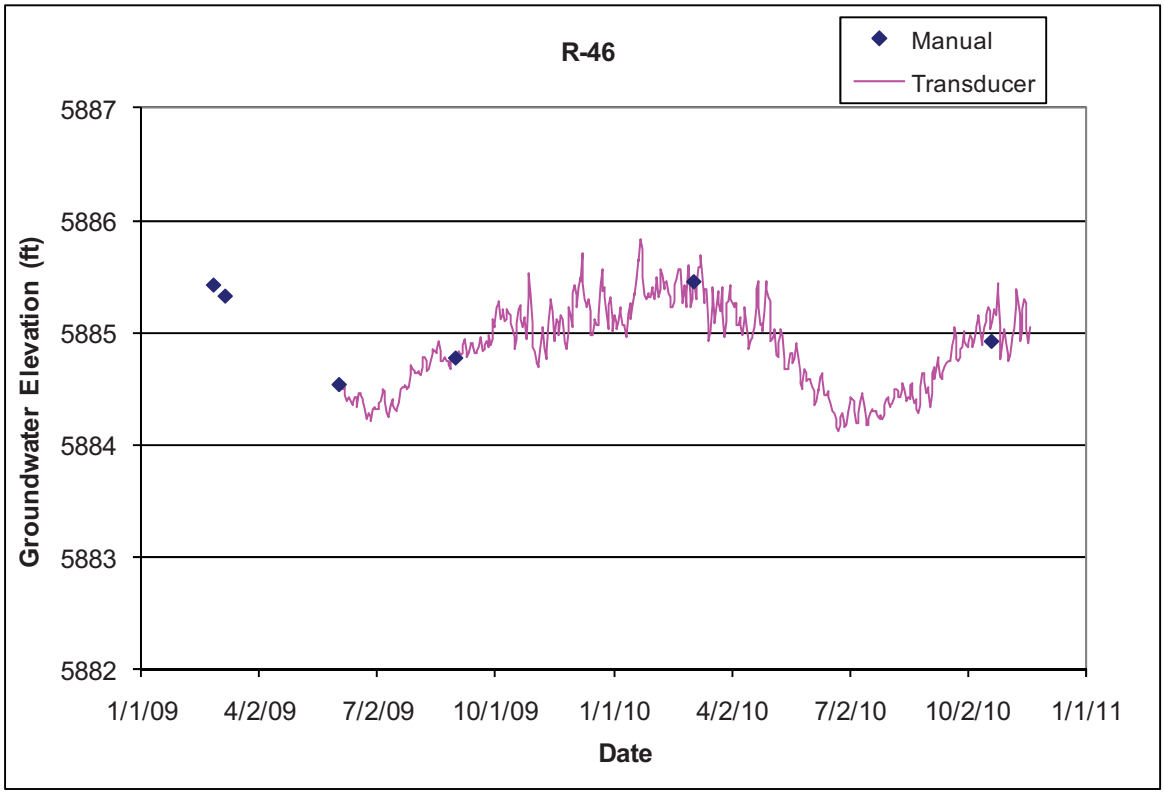
Period of Record: Well completed February 2009, transducer installed June 6, 2009, groundwater level data through 2010.

Remarks: R-46 installed in the regional aquifer to a depth of 1382.2 ft. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The groundwater responds to pumping supply wells PM-4 and PM-5.

R-46 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1340.0	1360.7	5873.3	5852.6	20.7			1360.7	5852.6	1382.2	21.5	83.0	RT	Tpf

Note: Brass Cap Ground Elevation: 7213.33 ft; all measurements are from this elevation



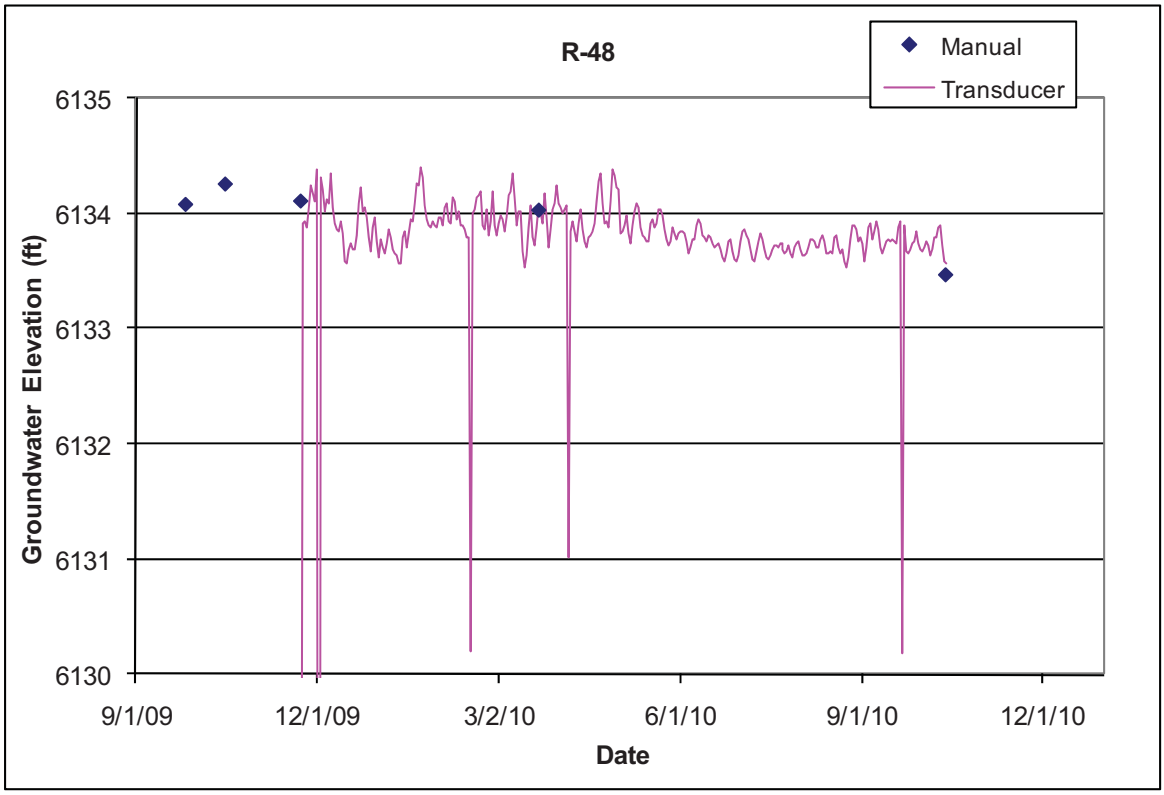
3.52 R-48

Location: R-48 is located at the east side of TA-16 about 1800 ft south of R-25. R-48 was formerly borehole CdV-16-3i, which was deepened and completed in the regional aquifer.
Completion Type: Single completion at the top of the regional aquifer. The screen is located about 147 ft below the water table in Tschicoma dacite.
Period of Record: Well completed September 2009, aquifer test conducted October 2009, transducer installed November 23, 2009, groundwater level data through 2010.
Remarks: R-48 installed in the regional aquifer to a depth of 1540 ft. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations.

R-48 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Hydro Zone Code	Geo Unit Code
1	1500.0	1520.6	5986.8	5966.2	20.6			1520.6	5966.2	1540	19.4	RT	Tt

Note: Brass Cap Ground Elevation: 7486.78 ft; all measurements are from this elevation



3.53 R-49

Location: R-49 is located in lower Pajarito Canyon south of TA-54 and MDA G and about 1100 ft west of R-39. R-49 is 1550 ft southwest of R-57.

Completion Type: Dual completion, two screens in the regional aquifer. The screens are 50 ft apart. The upper screen is located in basalt about 35 ft below the water table and the lower screen is in Puye Totavi lentil sediments.

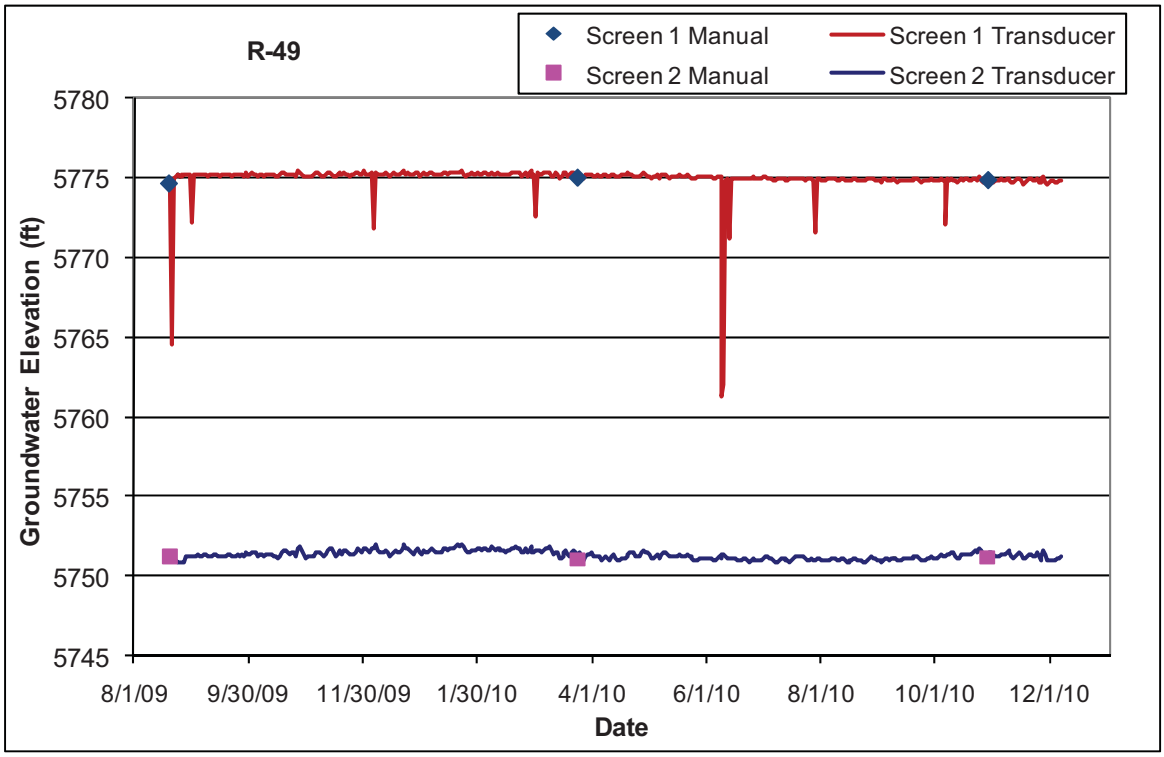
Period of Record: Well completed June 2009, transducers installed August 20, 2009, groundwater level data through 2010.

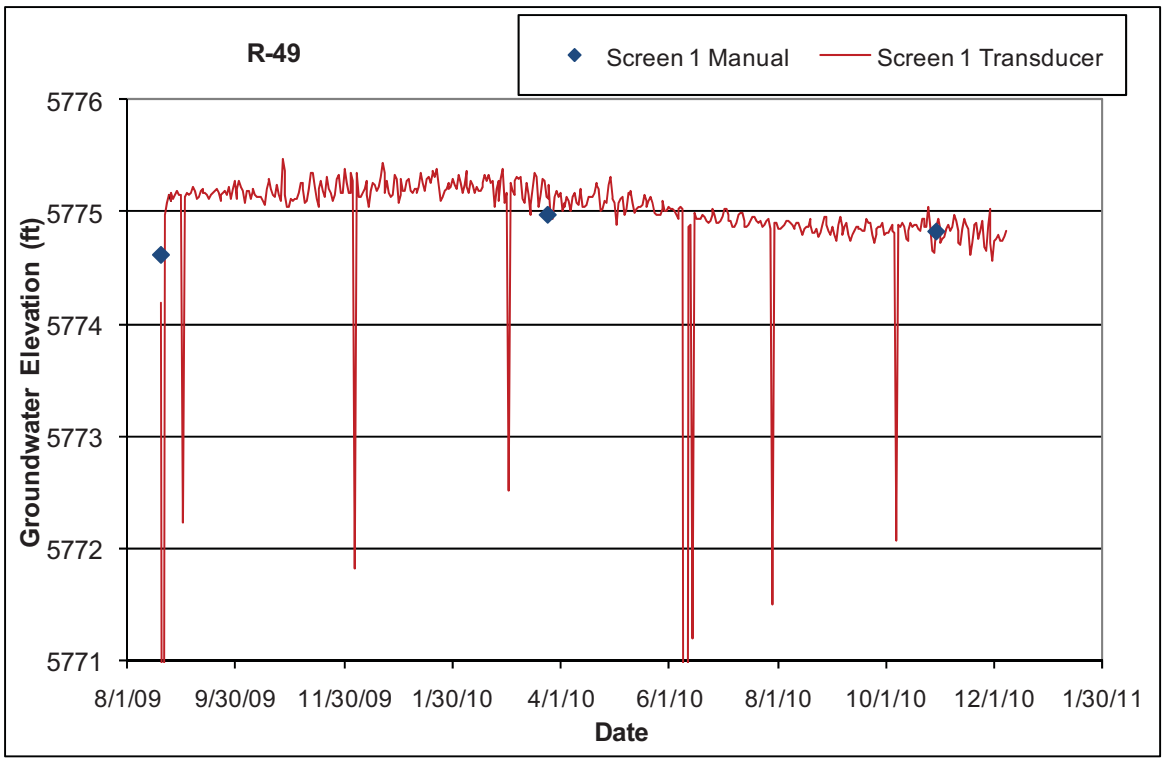
Remarks: R-49 installed in the regional aquifer to a depth of 949.3 ft. A Baski dual valve sampling system was installed in August 2009. The well is 100% barometrically efficient; the aquifer does not immediately respond to atmospheric pressure fluctuations; however, the groundwater shows a delayed response to atmospheric pressure fluctuations. The groundwater at R-49 screen 2 responds to pumping supply wells PM-4 and PM-5 and responded to drilling activities at R-57 and pumping at R-57 screen 2.

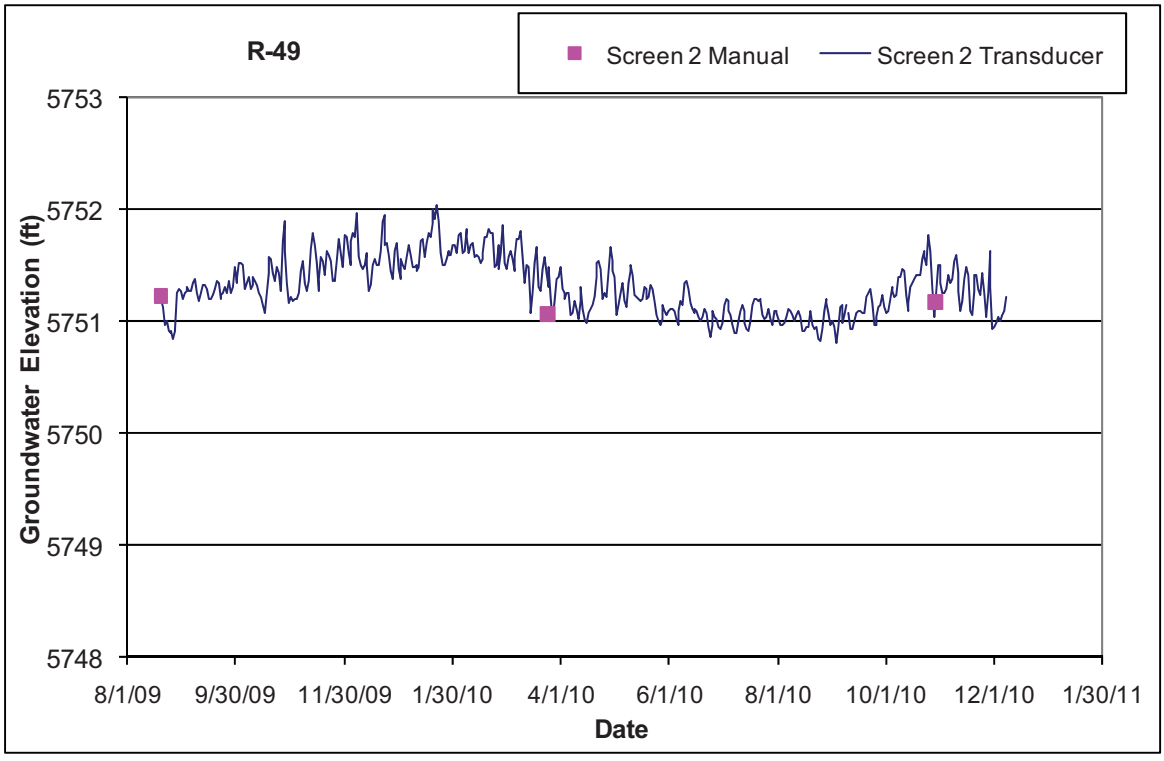
R-49 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	Pump Intake Elev (ft)	Top of Packer/ Sump Depth (ft)	Top of Packer/ Sump Elev (ft)	Bottom of Packer Depth (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	845.0	855.0	5739.5	5729.5	10.0	874.3	5710.3	887.6	5697.0	N/A	887.6	32.6	125.8	RT	Tb4
2	905.6	926.4	5678.9	5658.1	20.8	904.4	5680.1	926.4	5658.1	892.3	949.3	22.9	88.4	RD	Tpt

Note: Brass Cap Ground Elevation: 6584.54 ft; all measurements are from this elevation




R-49
Screen 1 Manual
Screen 1 Transducer
Groundwater Elevation (ft)
5776
5775
5774
5773
5772
5771
8/1/09
9/30/09
11/30/09
1/30/10
4/1/10
6/1/10
8/1/10
10/1/10
12/1/10
1/30/11
Date


R-49
Screen 2 Manual
Screen 2 Transducer
Groundwater Elevation (ft)
5753
5752
5751
5750
5749
5748
8/1/09
9/30/09
11/30/09
1/30/10
4/1/10
6/1/10
8/1/10
10/1/10
12/1/10
1/30/11
Date

3.54 R-50

Location: R-50 is located on a mesa south of Mortandad Canyon near the boundary with San Ildefonso Pueblo. R-50 is about 0.25 mi west of R-44 and 0.25 mi south of R-28.

Completion Type: Dual completion, two screens in the regional aquifer. The screens are 98 ft apart. The upper screen is located in Puye fanglomerates about 10 ft below the water table.

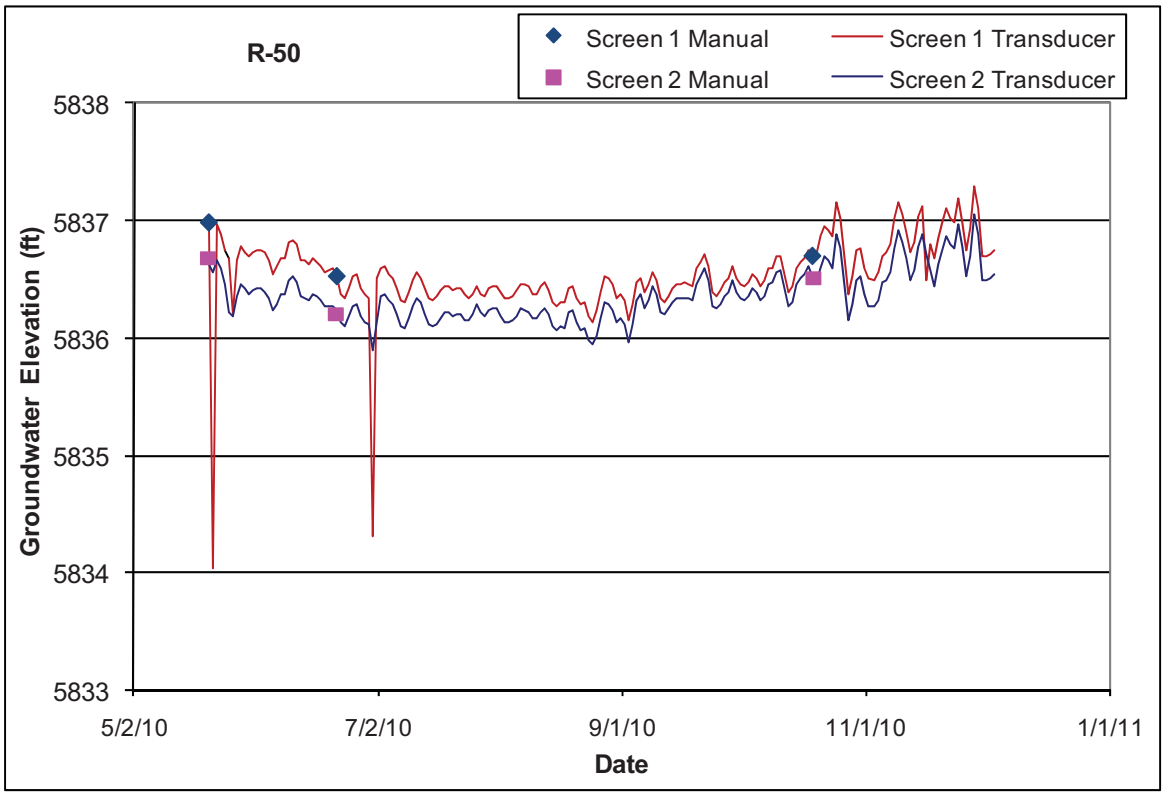
Period of Record: Well completed February 2010, transducers installed May 21, 2010, groundwater level data through 2010.

Remarks: R-50 installed in the regional aquifer to a depth of 1217.5 ft. A dual valve Baski sampling system was installed in May 2010. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The groundwater at R-50 responds to pumping supply well PM-4. The groundwater at the lower screen contains significant volumes of gas, which requires pumping screen 2 at a reduced rate during purging and sampling.

R-50 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top/ Bottom Packer Depth (ft)	Top/ Bottom of Packer Elev (ft)	LIC Top/ Bottom Depth (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (gal.)	Hydro Zone Code	Geo Unit Code
1	1077.0	1087.0	5827.1	5817.1	10.0	1104.8	5799.3	1118.1	5786.0	1106.5	1118.1	31.1	31.8	RT	Tpf
2	1185.0	1205.6	5719.1	5698.5	20.6	1183.6	5720.5	1122.9	5781.2	1111.1	1217.5	11.9	12.1	RD	Tsfu

Note: Brass Cap Ground Elevation: 6904.11 ft; all measurements are from this elevation



3.55 R-51

Location: R-51 is located in middle Pajarito Canyon west of TA-18. R-51 is about 0.55 mi south of supply well PM-4, 0.48 mi northwest of supply well PM-02, and 0.43 mi northwest and upstream of R-40.

Completion Type: Dual completion, two screens in the regional aquifer. The screens are 105.7 ft apart. Both screens are located in Puye fanglomerates; the upper screen is about 25 ft below the water table.

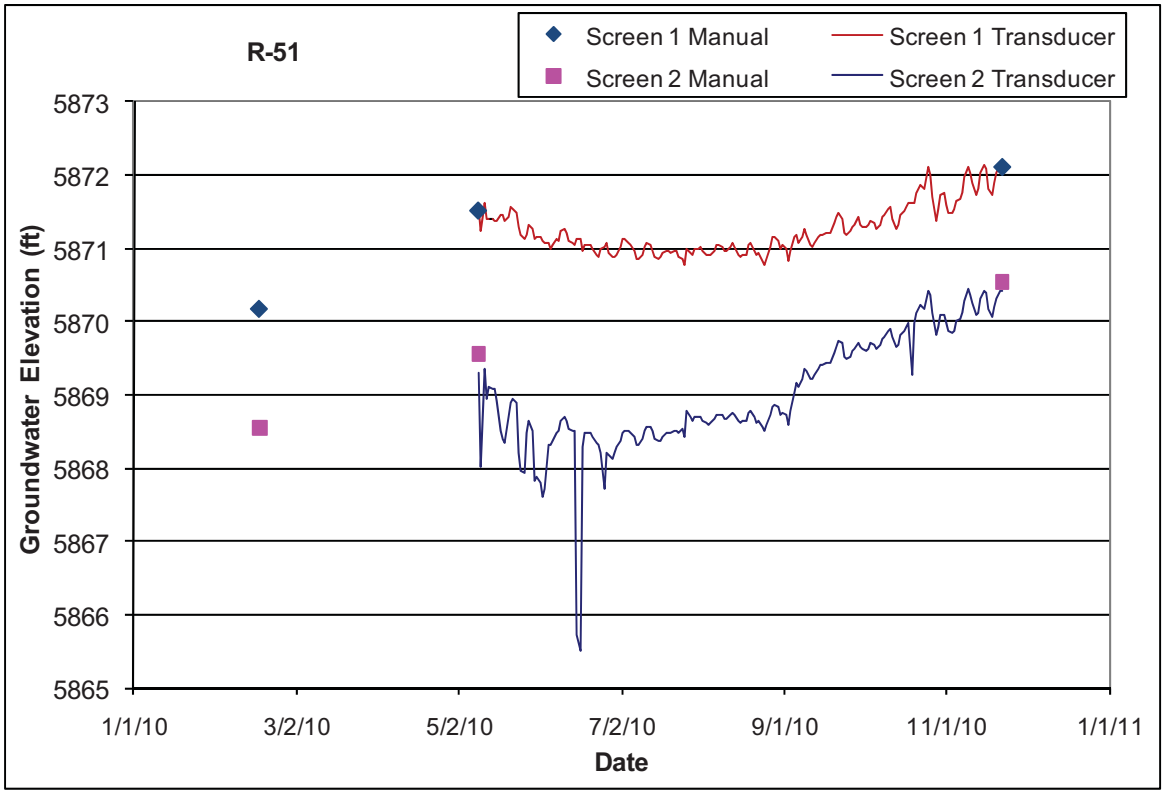
Period of Record: Well completed February 2010, transducers installed May 10, 2010, groundwater level data through 2010.

Remarks: R-51 installed in the regional aquifer to a depth of 1046.1 ft. A dual valve Baski sampling system was installed in May 2010. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The groundwater responds to pumping supply wells PM-2 and PM-4.

R-51 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top/ Bottom Packer Depth (ft)	Top/ Bottom of Packer Elev (ft)	Depth to LIC Top/ Bottom (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Vol (gal.)	Hydro Zone Code	Geo Unit Code
1	915.0	925.2	5847.2	5836.9	10.3	940.2	5822.0	952.1	5810.1	940.9	952.1	26.8	27.3	RT	Tpf
2	1031.0	1041.0	5731.2	5721.2	10.0	1030.0	5732.2	956.8	5805.4	945.5	1046.1	5.0	5.2	RD	Tpf

Note: Brass Cap Ground Elevation: 6762.17 ft; all measurements are from this elevation



3.56 R-52

Location: R-52 is located at TA-54 on an unnamed mesa between Cañada del Buey and the south fork of Cañada del Buey. The well is about 500 ft northeast of MDA J, 850 ft northwest of R-37 and 0.45 mi southeast of supply well PM-4.

Completion Type: Dual completion, two screens in the regional aquifer. The screens are 51.3 ft apart. A dual valve Baski system was installed July 17, 2010.

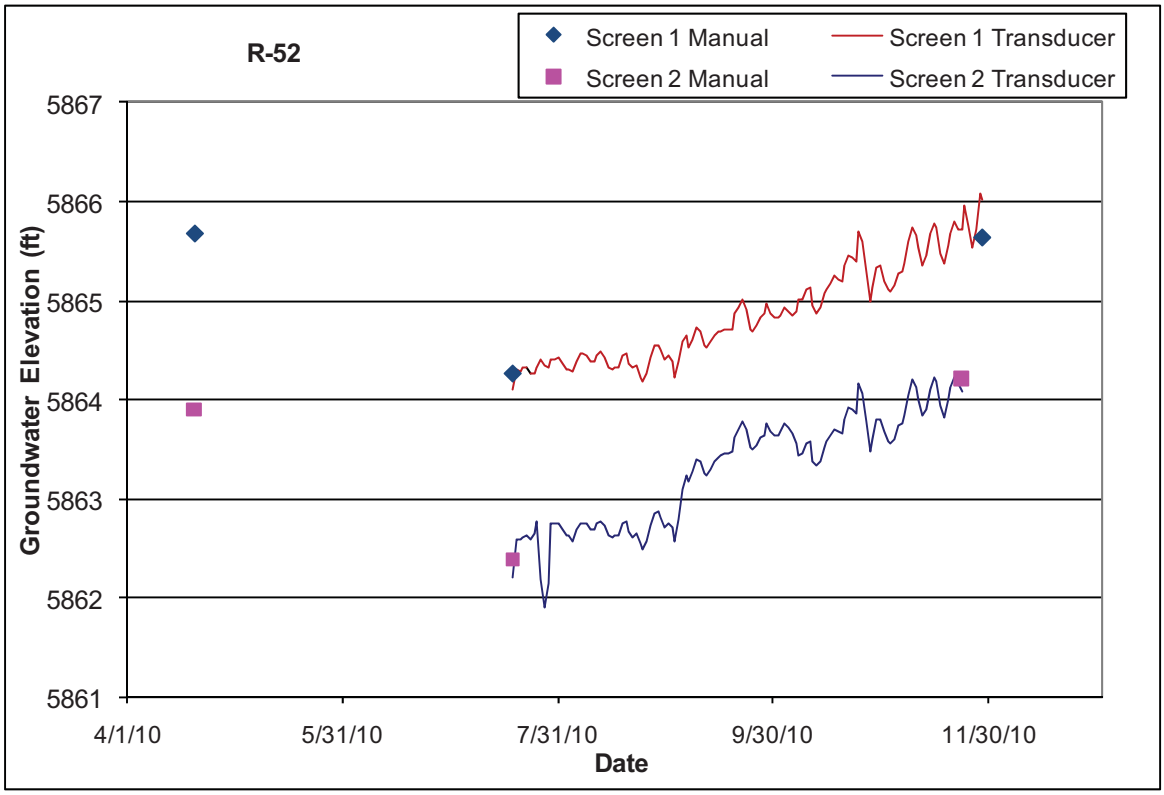
Period of Record: Well completed April 2010, transducers installed July 19, 2010, groundwater level data through 2010.

Remarks: R-51 installed in the regional aquifer to a depth of 1128.7 ft. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. The groundwater responds to pumping nearby supply well PM-4.

R-52 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top / Bottom of Packer Depth (ft)	Top / Bottom of Packer Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Vol (gal.)	Hydro Zone Code	Geo Unit Code
1	1035.2	1055.7	5847.8	5827.3	20.5	1071.4	5811.7	1081.7	5801.3	1081.7	26.0	26.5	RT	Tpf
2	1107.0	1117.0	5776.0	5766.0	10.0	1105.6	5777.4	1086.5	5796.6	1128.7	11.7	11.9	RD	Tpf

Note: Brass Cap Ground Elevation: 6883.04 ft; all measurements are from this elevation



3.57 R-53

Location: R-53 is located in the south fork of Cañada del Buey about 400 ft northeast of MDA L at TA-54. R-53 is about 950 ft west of R-38, 1370 ft northwest of R-21, and 1330 ft east of R-54.

Completion Type: Dual completion, two screens in the regional aquifer. The screens are 100.5 ft apart. A dual valve Baski system was installed July 07, 2010.

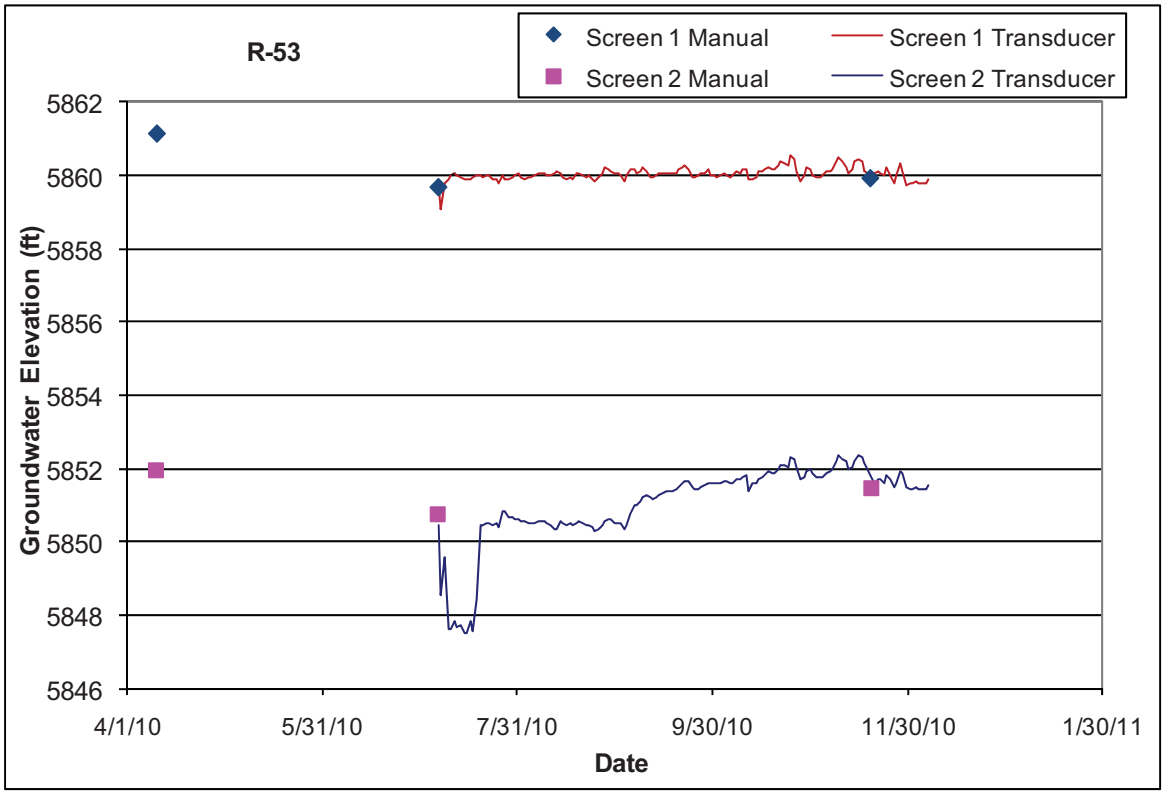
Period of Record: Well completed March 2010, transducers installed July 07, 2010, groundwater level data through 2010.

Remarks: R-53 installed in the regional aquifer to a depth of 1001.9 ft. The upper screen is located in Puye fanglomerates about 20 ft below the Cerros del Rio basalt and 19 ft below the water table; the lower screen is also in Puye fanglomerates but there does not appear to be hydraulic communication between screens. Preliminary data indicate that screen 1 is about 80% barometrically efficient and screen 2 is about 50% barometrically efficient. The groundwater at screen 2 responds to supply pumping at PM-4.

R-53 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top/ Bottom of Packer Depth (ft)	Top of Packer/ Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Vol (gal.)	Hydro Zone Code	Geo Unit Code
1	849.2	859.2	5840.8	5830.8	10.0	892.6	5797.4	905.5	5784.5	905.5	46.3	47.2	RT	Tpf
2	959.7	980.2	5730.3	5709.8	20.5	958.4	5731.6	910.2	5779.8	1001.9	21.7	22.1	RD	Tpf

Note: Brass Cap Ground Elevation: 6689.98 ft; all measurements are from this elevation



3.58 R-54

Location: R-54 is located in lower Pajarito Canyon about 985 ft east of R-20 and 2250 east of PM-2. R-54 is about 0.5 mi northwest of R-32 and 0.25 mi west of R-53.

Completion Type: Dual completion, two screens in the regional aquifer. The screens are 75 ft apart. Screen 1 is located in the Cerros del Rio basalt and screen 2 is located in Puye fanglomerates; the upper screen is about 13 ft below the water table.

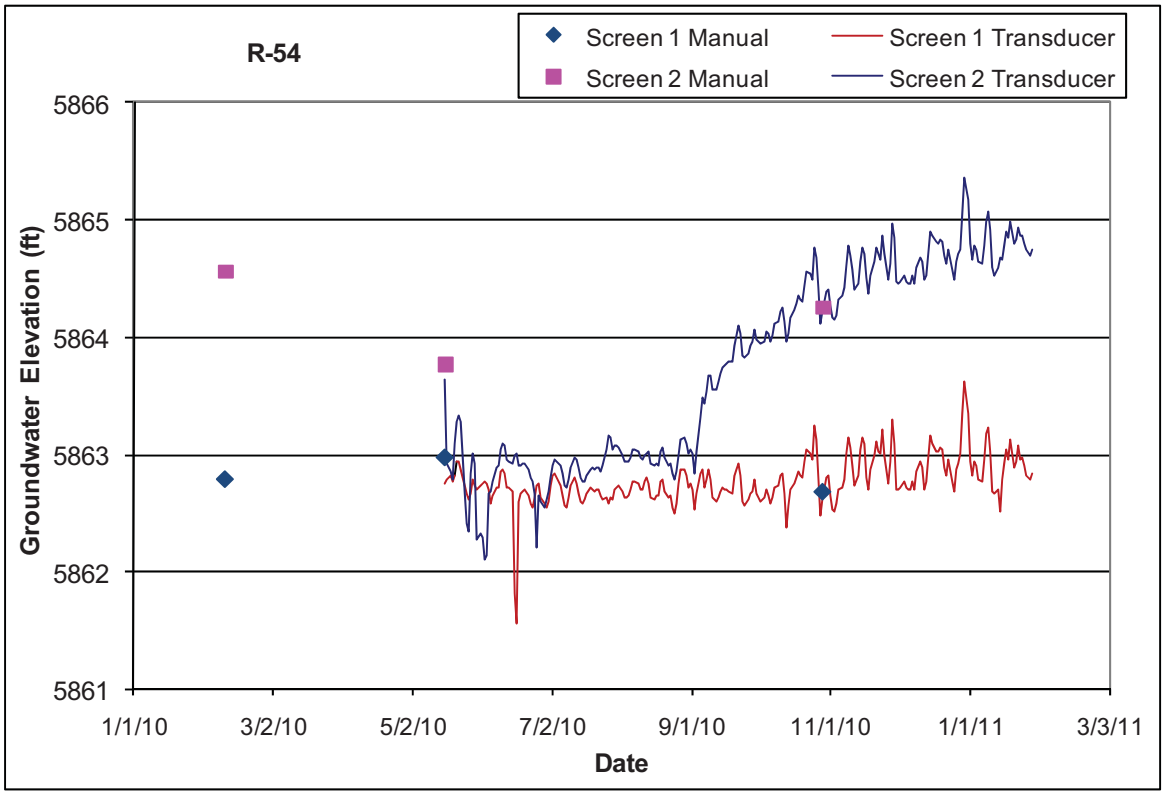
Period of Record: Well completed January 2010, transducers installed May 2010, groundwater level data through 2010.

Remarks: R-54 installed in the regional aquifer to a depth of 936 ft. A dual valve Baski sampling system was installed in May 2010. The well is 100% barometrically efficient; the aquifer does not respond to atmospheric pressure fluctuations. Note that screen 2 has a higher head than screen 1 except when supply well PM-2 is pumping. Screen 2 responds to pumping at PM-2 and PM-4.

R-54 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top/ Bottom of Packer Depth (ft)	Top of Packer/ Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (gal.)	Hydro Zone Code	Geo Unit Code
1	830.0	840.0	5849.9	5839.9	10.0	857.9	5822.0	871.3	5808.6	871.3	31.3	31.9	RT	Tb4
2	915.0	925.0	5764.9	5754.9	10.0	913.2	5766.7	876.0	5803.9	936.0	11.0	11.2	RD	Tpf

Note: Brass Cap Ground Elevation: 6679.85 ft; all measurements are from this elevation



3.59 R-55

Location: R-55 is located in lower Cañada del Buey about 0.4 mi east of MDA G at TA-54. R-55 is about 1975 ft east of R-47 and 1760 ft east-northeast of R-22.

Completion Type: Dual completion, two screens in the regional aquifer. The screens are 114 ft apart. Screen 1 is located in Puye fanglomerates and screen 2 is located in the Chamita Formation; the upper screen is about 25 ft below the water table.

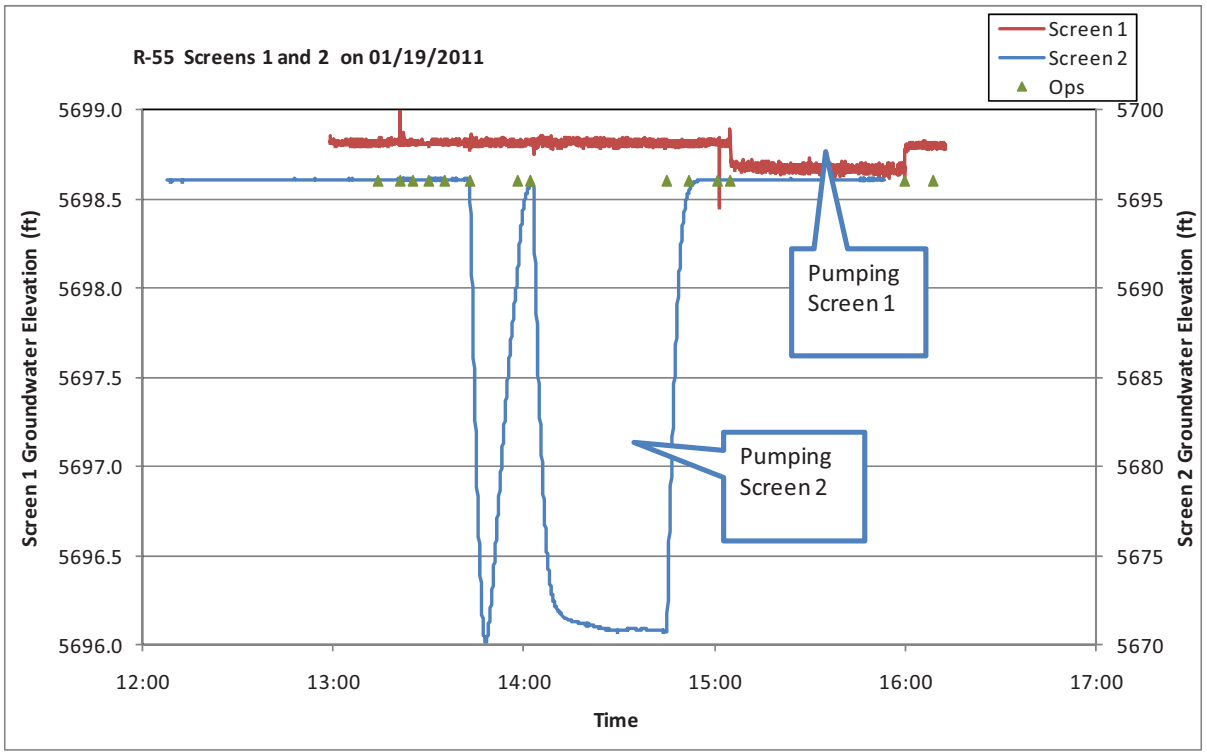
Period of Record: Well completed August 25, 2010, transducers installed January 19, 2011; groundwater level data through January 2011.

Remarks: R-55 installed in the regional aquifer to a depth of 1021 ft. A dual valve Baski sampling system was installed January 18, 2011. The head difference between screens is about 2.8 ft.

R-55 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top / Bottom of Packer Depth (ft)	Top / Bottom of Packer Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (gal.)	Hydro Zone Code	Geo Unit Code
1	860.0	880.6	5673.9	5653.3	20.6	934.9	5599.0	945.3	5588.6	945.3	64.7	66.0	RT	Tpf
2	994.4	1015.4	5539.5	5518.5	21.0	992.2	5541.7	950.0	5583.8	1021.0	5.6	5.7	RD	Tch

Note: Brass Cap Ground Elevation: 6533.86 ft; all measurements are from this elevation



Note very short time scale.

3.60 R-56

Location: R-56 is located on Mesita del Buey at TA-54 between MDA L and MDA G. R-56 is about 550 ft southeast of MDA L and about 0.25 mi northwest of MDA G. R-56 is about 780 ft west of R-21 and 900 ft southeast of R-53.

Completion Type: Dual completion, two screens in the regional aquifer. The screens are 81 ft apart. Both screens are located in dacitic gravels within the Puye fanglomerates; the upper screen is about 25 ft below the water table.

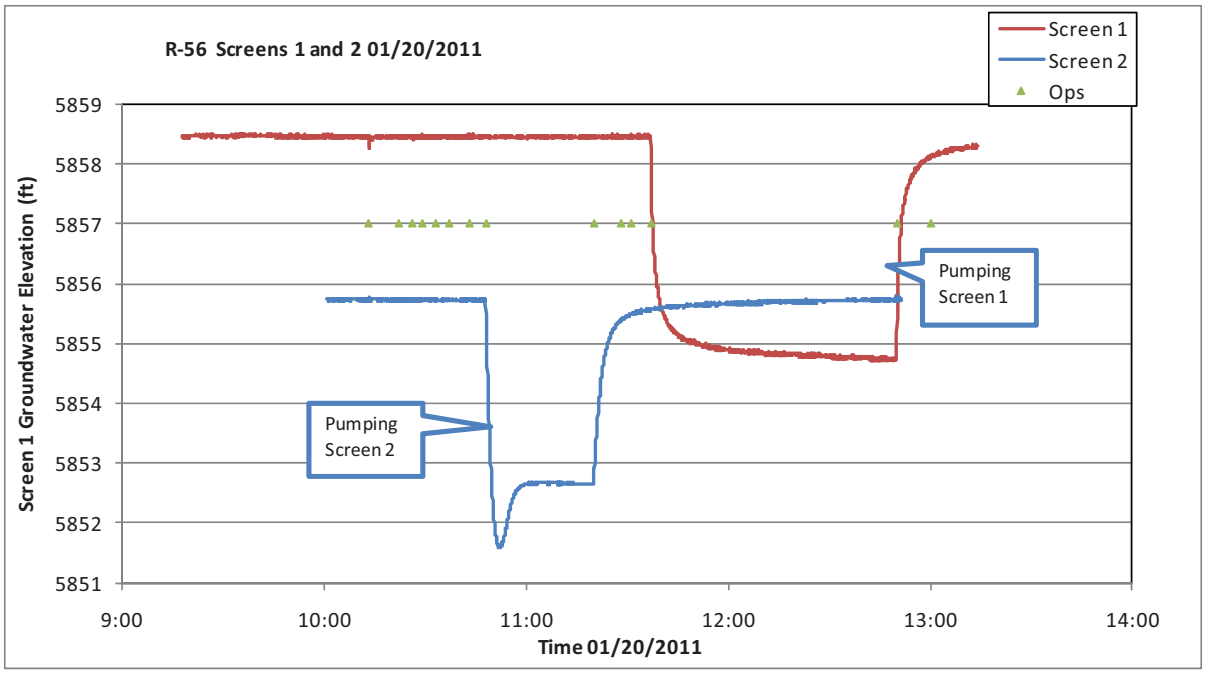
Period of Record: Well completed July 19, 2010, transducers installed January 20, 2011; groundwater level data through January 2011.

Remarks: R-56 installed in the regional aquifer to a depth of 1078 ft. A dual valve Baski sampling system was installed January 15, 2011. The head difference between screens in August 2010 was about 4 ft and, in January 2011, was about 2.7 ft.

R-56 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top / Bottom of Packer Depth (ft)	Top / Bottom of Packer Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (gal.)	Hydro Zone Code	Geo Unit Code
1	945.0	965.6	5835.9	5815.3	20.6	988.3	5792.6	1006.7	5774.2	1006.7	41.1	41.9	RT	Tpf
2	1046.6	1067.1	5734.3	5713.8	20.5	1045.6	5735.3	1011.4	5769.5	1078.8	11.7	11.9	RD	Tpf

Note: Brass Cap Ground Elevation: 6780.88 ft; all measurements are from this elevation



Note very short time scale.

3.61 R-57

Location: R-57 is located east of TA-54 MDA G about 420 ft south of R-41 and 300 ft northwest of R-22. R-57 is about 850 ft north of R-39 and 1550 ft northeast of R-49.

Completion Type: Dual completion, two screens in the regional aquifer. The screens are 41 ft apart. Screen 1 is located in the Cerros del Rio basalt and screen 2 is located in Puye Totavi lentil sediments; the upper screen is about 20 ft below the water table.

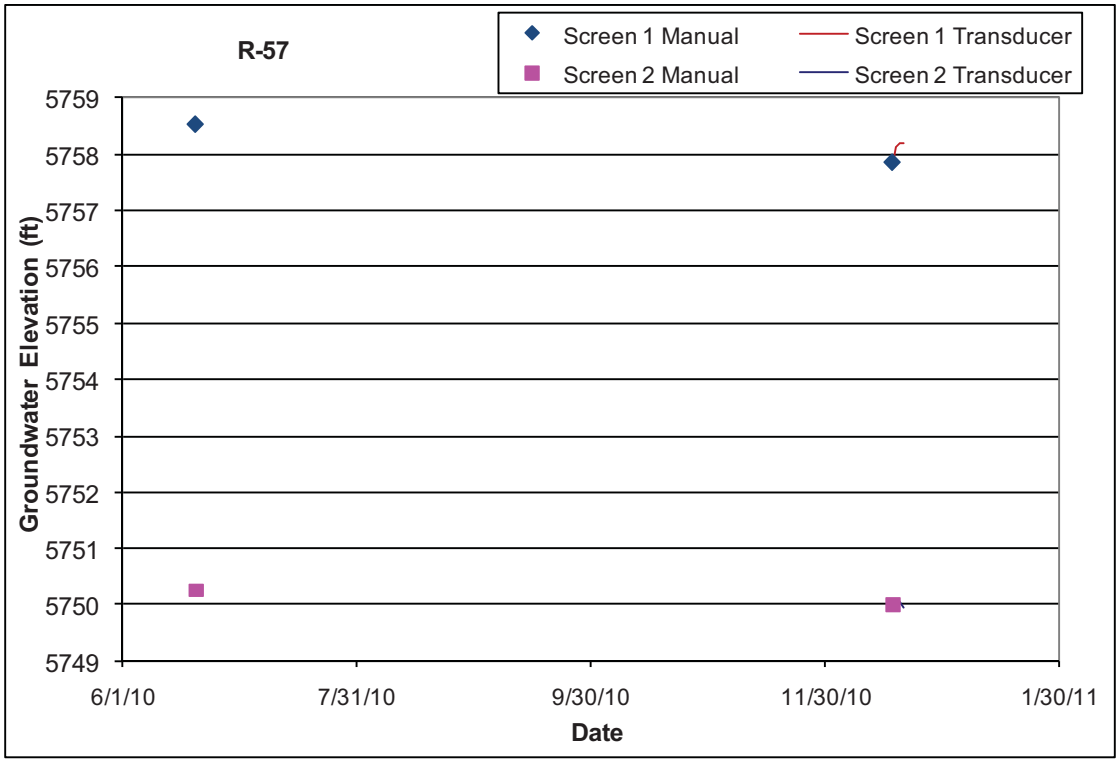
Period of Record: Well completed June 2010, transducers installed December 18, 2010, groundwater level data through 2010.

Remarks: R-57 installed in the regional aquifer to a depth of 1013.8 ft; the head separation between screens is about 8 ft. A dual valve Baski sampling system was installed December 16, 2010. R-57 screen 1 is at the approximate same elevation as nearby well R-41 screen 1, which is dry. The top of R-57 screen 2 is about 10 ft below the bottom of R-41 screen 2; however, the water level at R-41 screen 2 is about 50 ft lower than the R-57 screen 2 water level. The R-57 screen 1 water level is similar to that at R-22 screen 1; R-57 screen 2 water level is similar to that at R-22 screen 2 and about 50 ft higher than the groundwater at R-22 screen 3. R-49 screen 1 and R-57 screen 1 are at similar elevations but the water level at R-49 screen 1 is about 12 ft higher than R-57 screen 1. The lower screens at R-57 and R-49 are at equivalent elevations, and the groundwater levels are similar.

R-57 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Top/ Bottom of Packer Depth (ft)	Top of Packer/ Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (gal.)	Hydro Zone Code	Geo Unit Code
1	910.0	930.5	5738.0	5717.5	20.5	947.7	5700.4	959.0	5689.0	959.0	28.5	29.1	RT	Tb4
2	971.5	992.1	5676.5	5655.9	20.6	969.9	5678.2	963.8	5684.3	1013.8	21.7	22.1	RD	Tpt

Note: Brass Cap Ground Elevation: 6648.04 ft; all measurements are from this elevation



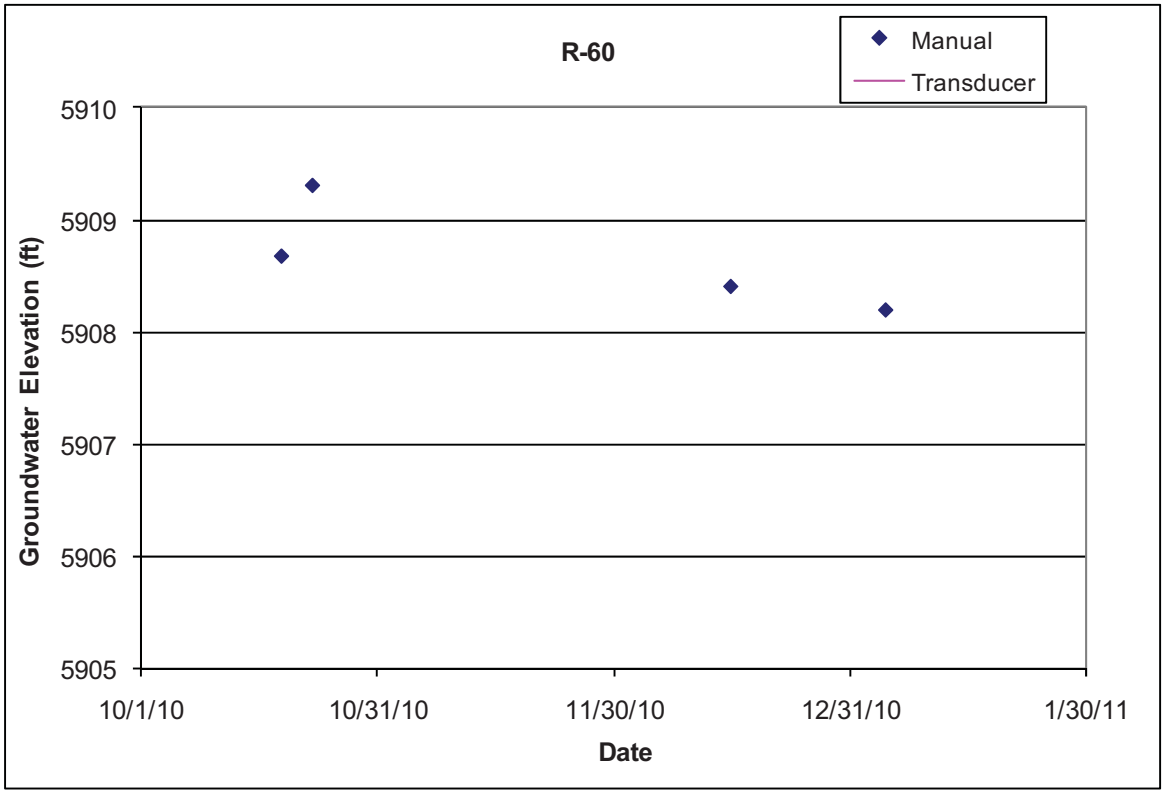
3.62 R-60

Location: R-60 is located on a mesa between Mortandad Canyon and Pajarito Canyon about 100 ft east of MDA C and about 770 ft northwest of R-46.
Completion Type: Single completion at the top of the regional aquifer. The screen is located in the Puye fanglomerates about 10 ft below the water table.
Period of Record: Well completed October 18, 2010, transducer installed January 5, 2011, groundwater level data through January 2011.
Remarks: R-60 installed in the regional aquifer to a depth of 1360.9 ft.

R-60 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	1330.0	1350.9	5898.2	5877.3	20.9	1345.8	5882.4	1350.9	5877.3	1360.9	10.0	38.6	RT	Tpf

Note: Brass Cap Ground Elevation: 7228.17 ft; all measurements are from this elevation



3.63 R-63

Location: R-63 is located at TA-16 near the Burning Grounds. R-63 is located adjacent to and on the same pad as CDV-16-2(i)r; R-63 is about 1000 ft east of intermediate well CDV-16-4ip and about 1500 ft east of R-25.

Completion Type: Single completion at the top of the regional aquifer. The screen is located in Puye fanglomerates.

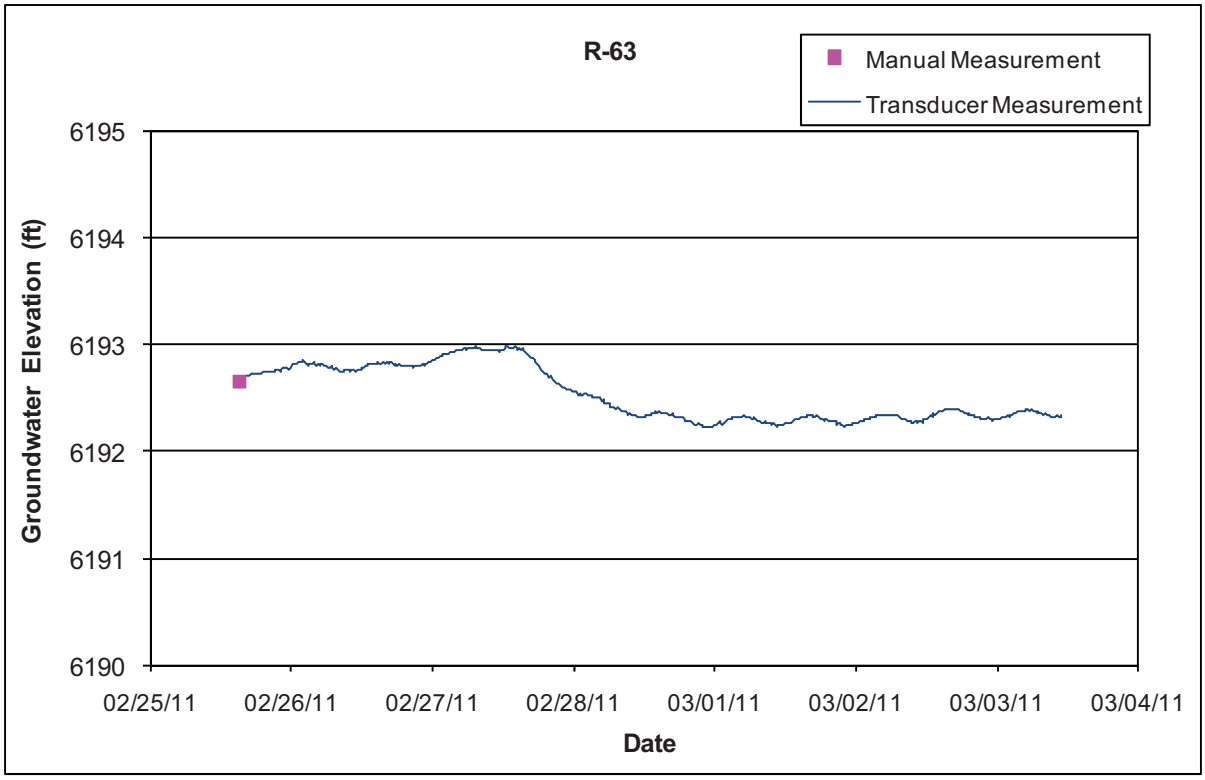
Period of Record: Well completed January 2011, pending transducer installation.

Remarks: R-63 installed in the regional aquifer to a depth of 1367 ft. Construction data pending.

R-63 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	1325.0	1345.3			20.3			1345.3		1367.0	21.7	21.7	RT	Tpf

Note: Brass Cap Ground Elevation: not yet surveyed; all measurements are from ground surface



3.64 Test Well 1

Location: TW-1 was located in lower Pueblo Canyon downstream of supply well O-1. TW-1 was plugged and abandoned in March 2010.

Completion Type: Single completion within the regional aquifer. The top of the screen was about 120 ft below the water table in 2006.

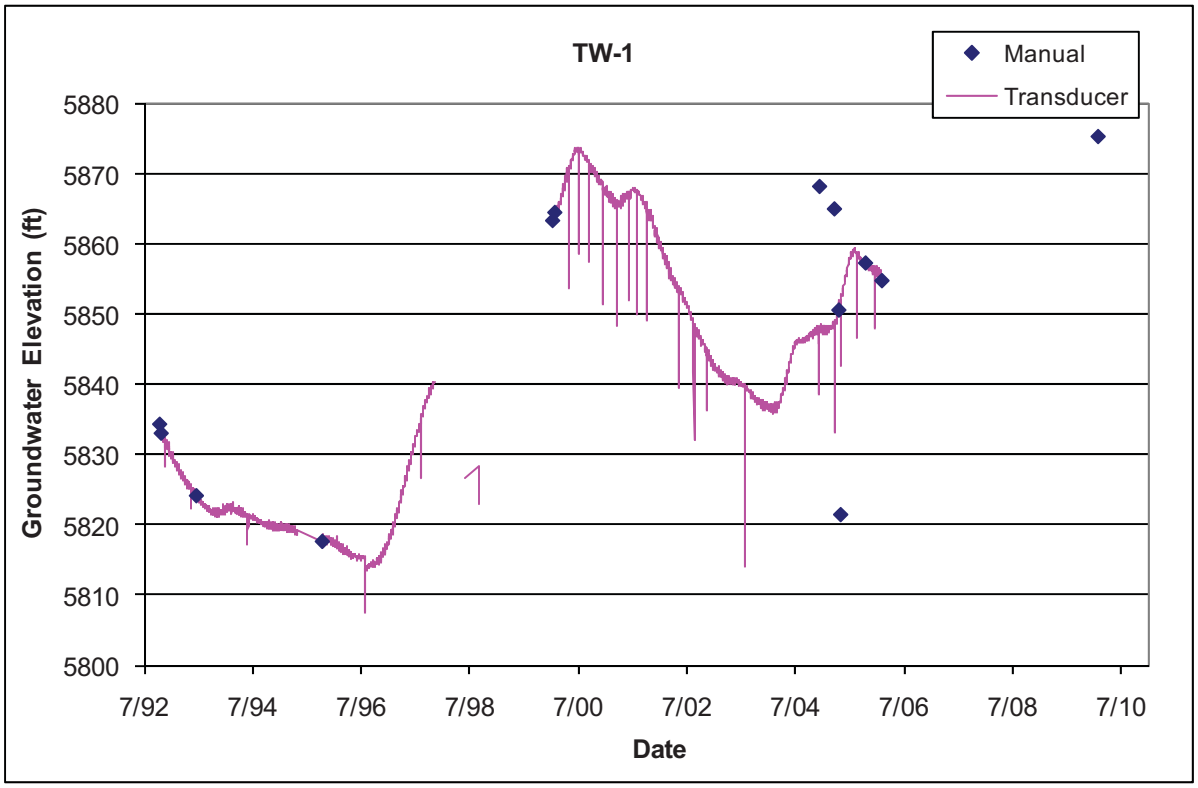
Period of Record: Well completed January 1950, transducer installed January 23, 1992, intermittent water level data to February 6, 2006, when the transducer was removed in preparation for well plugging and abandonment.

Remarks: TW-1 installed in the regional aquifer at a depth of 642 ft, about 100 ft into the regional aquifer. Water level in TW-1 was recharged locally by surface water from Pueblo Canyon (Koch and Rogers 2003) and did not correlate with the water level of surrounding regional aquifer wells. Test Well 1 was plugged and abandoned March 23, 2010 (LANL April 2010).

TW-1 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	632.0	642	5737.2	5727.2	10.0			642.0	5727.2	642	0.0	0.0	RT	Tpt

Note: TW-1 Ground Elevation: 6369.19 ft; all measurements are from this elevation



3.65 Test Well 2

Location: TW-2 was located in middle Pueblo Canyon. TW-2 was plugged and abandoned in February 2010.

Completion Type: Single completion at the top of the regional aquifer.

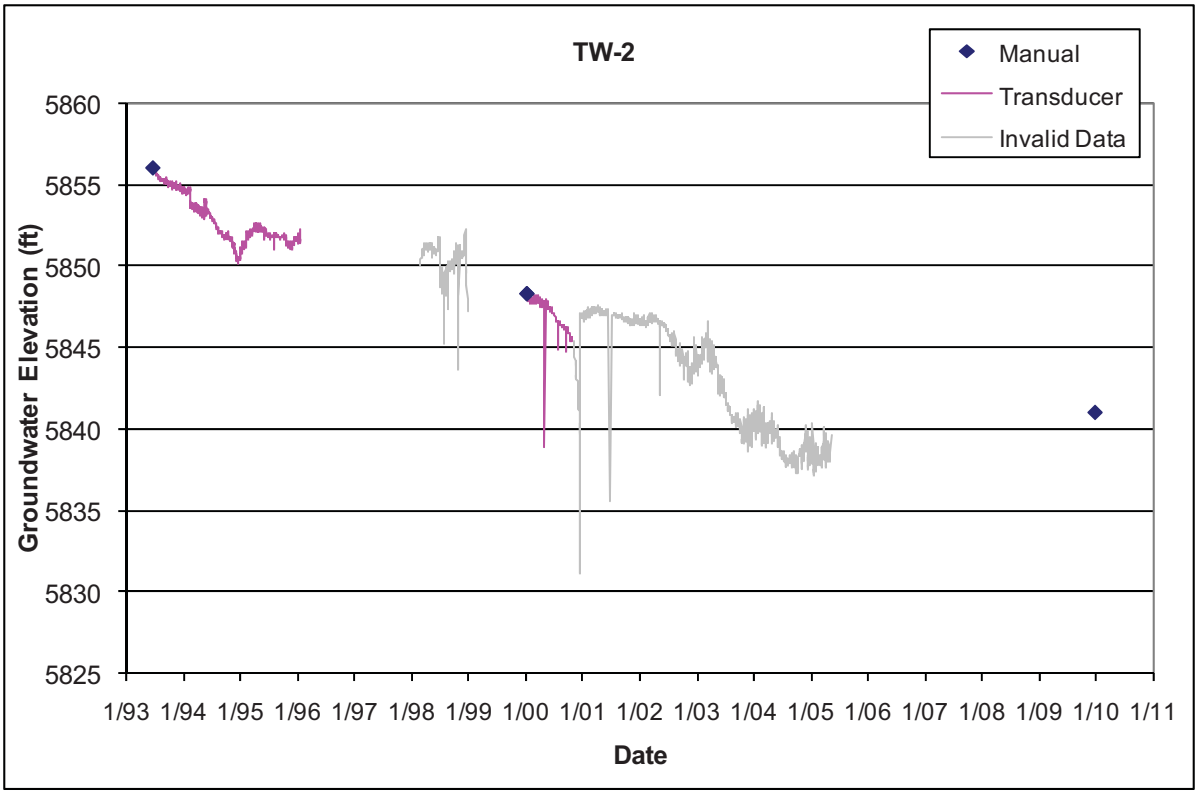
Period of Record: Well originally drilled in 1949, recompleted in 1990. Transducer installed June 1993; data to January 1996. Transducer reinstalled January 2000; transducer data to March 2005.

Remarks: TW-2 was completed at the top of the regional aquifer at a depth of 834 ft, about 35 ft into the regional aquifer. The transducer failed in November 2000, transducer data since then are questionable. A manual measurement attempt in March 2005 resulted in the measurement tape stuck in the well. Thus, transducer water level data since November 2000 are not valid with respect to elevation, but are shown for reference and character information only. TW-2 was plugged and abandoned February 8, 2010 (LANL March 2010).

TW-2 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	768.0	824	5880.1	5824.1	56.0			824.0	5824.1	834	10.0	55.6	RT	Tpt

Note: Test Well 2 Ground Elevation: 6648.06 ft; all measurements are from this elevation



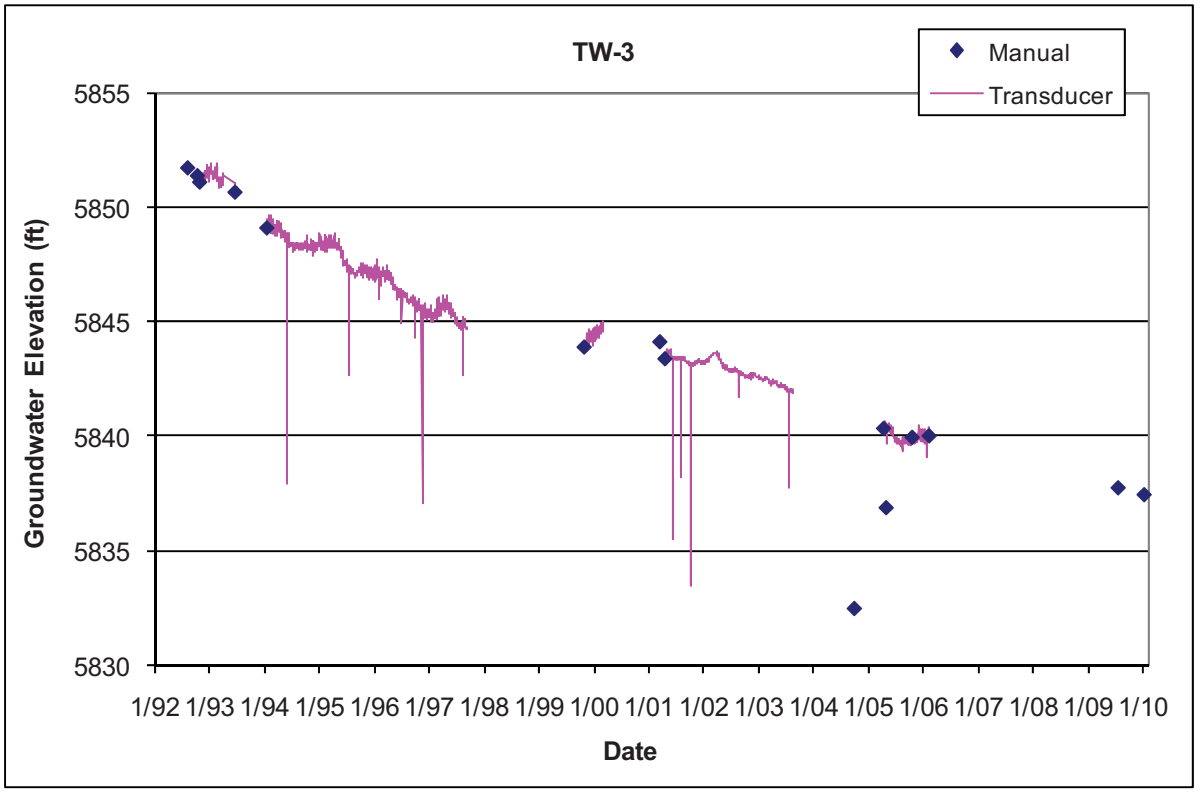
3.66 Test Well 3

Location: TW-3 is located in middle Los Alamos Canyon at the confluence with DP Canyon.
Completion Type: Single completion at the top of the regional aquifer.
Period of Record: Well drilled in 1949, transducer installed November 1992, intermittent data to February 2006. Periodic manual measurements 2009 and 2010.
Remarks: TW-3 completed at the top of the regional aquifer at a depth of 815 ft, about 30 ft into the regional aquifer. Transducer removed February 9, 2006, in preparation for well plugging and abandonment. The well was re-opened and sampled in July 2009 and January 2010.

TW-3 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	805.0	815.0	5821.9	5811.9	10.0			815.0	5811.9	815.0	0.0	0.0	RT	Tpt

Note: Ground Elevation: 6626.9 ft; all measurements are from this elevation



3.67 Test Well 4

Location: TW-4 was located in upper Pueblo Canyon east of Acid Canyon and about 1 mi west of R-2.

Completion Type: Single completion at the top of the regional aquifer.

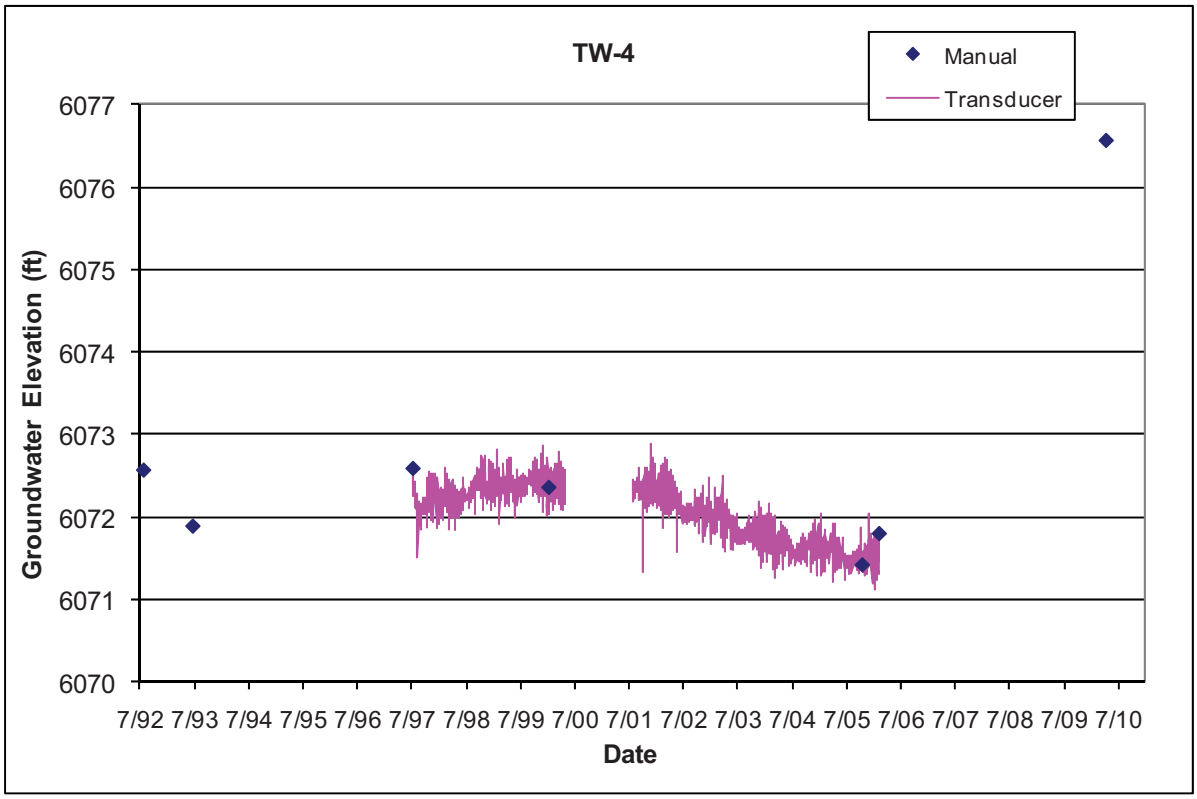
Period of Record: Well drilled in 1950, transducer installed June 1993 but problems occurred with the transducer equipment. Transducer reinstalled July 1997, intermittent data to February 8, 2006.

Remarks: Completed at the top of the regional aquifer to a depth of 1205 ft, about 30 ft into the regional aquifer. Transducer removed February 8, 2006, in preparation for well plugging and abandonment. TW-4 was plugged and abandoned May 3, 2010 (LANL July 2010). The groundwater level measurement before plugging was reported to be 6076.56 ft, but the accuracy of the measurement is questionable.

TW-4 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1195.0	1205	6049.6	6039.6	10.0			1205.0	6039.6	1205.0	0.0	0.0	RT	Tt

Note: TW-4 Ground Elevation: 7244.56 ft; all measurements are from this elevation



3.68 Test Well 8

Location: TW-8 was located in middle Mortandad Canyon about 220 ft east of R-1, which was drilled to replace TW-8.

Completion Type: Single completion at the top of the regional aquifer. The screen straddled the water table.

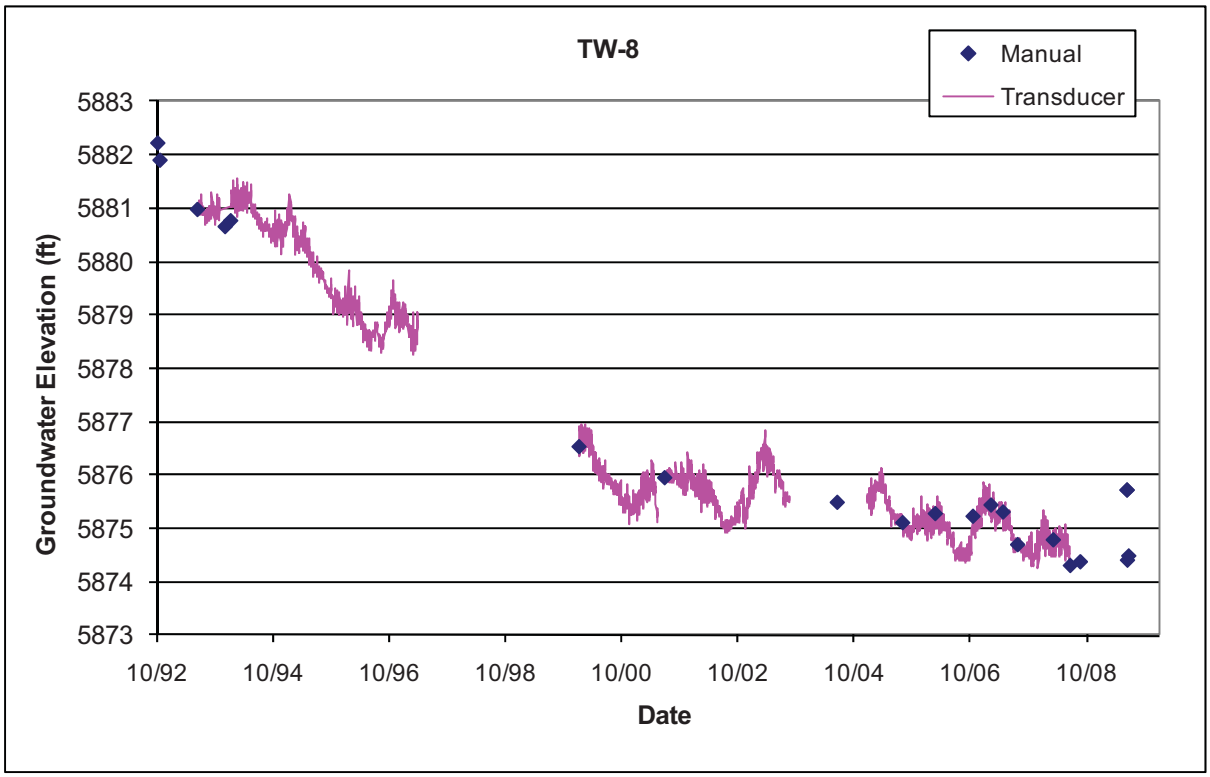
Period of Record: Well drilled in 1960, transducer installed June 1993, transducer data to March 1997. Transducer reinstalled January 2000; intermittent data to June 19, 2008, when the transducer was removed. Several manual measurements were obtained in June and July 2009 during preparations for plugging and abandonment.

Remarks: TW-8 was completed at the top of the regional aquifer at a depth of 1065 ft, about 70 ft into the regional aquifer. The well was nearly 100% barometrically efficient; the aquifer had no response to atmospheric pressure fluctuations. The aquifer indicated a seasonal response to supply well pumping and primarily responded to pumping PM-5 and possibly to pumping PM-4. The well was plugged and abandoned on August 13, 2009.

TW-8 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	953.0	1065	5920.5	5808.5	112.0			1065.0	5808.5	1065.0	0.0	0.0	RT	Tpf

Note: Ground Elevation 6873.5 ft; all measurements are from this elevation



3.69 Test Well DT-5A

Location: DT-5A is located at TA-49 near the southern boundary of LANL. DT-5A is about 1300 ft northwest of R-30 and 1600 ft west-southwest of R-29.

Completion Type: Single completion at the top of the regional aquifer. The screen straddles the water table.

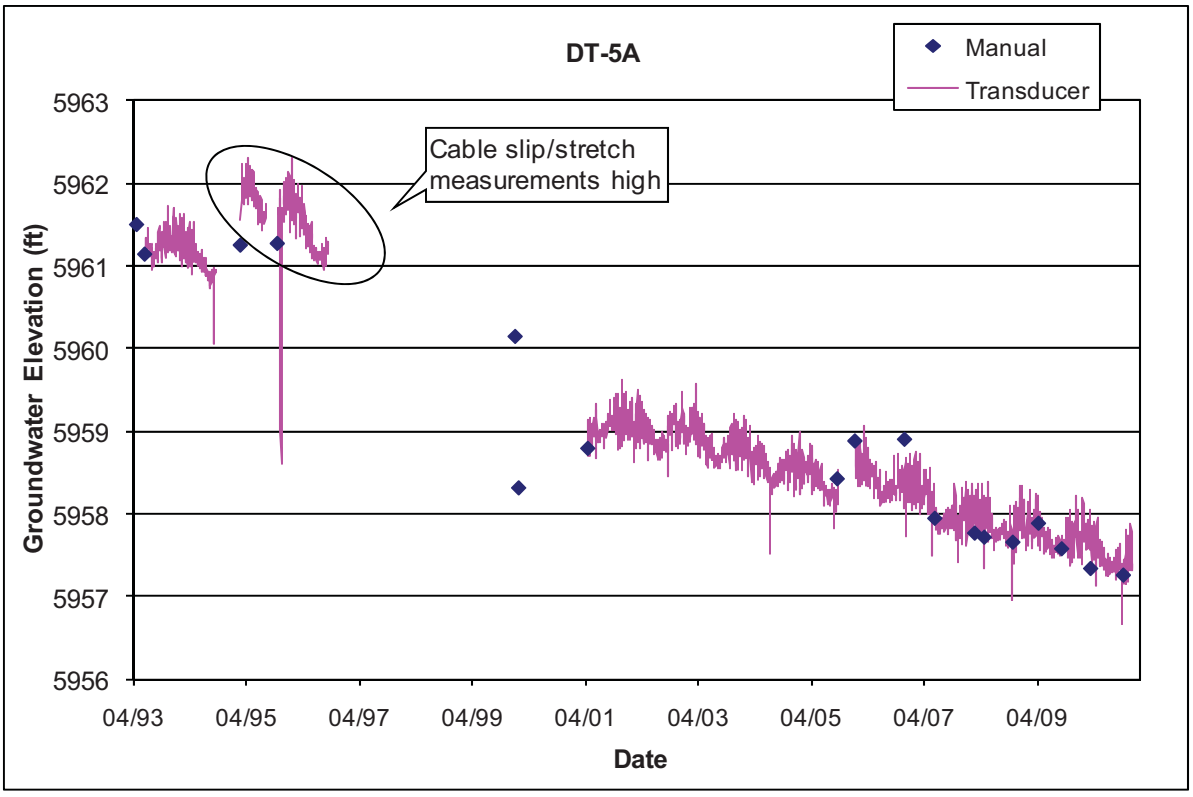
Period of Record: Well drilled in 1960, transducer installed June 1993, data to September 1996. Transducer reinstalled January 2000 but equipment problems occurred. Transducer reinstalled April 2001; data through 2010.

Remarks: DT-5A completed at the top of the regional aquifer at a depth of 1819.5 ft, about 650 ft into the regional aquifer. The long screen encompasses Tb4 basalt and Tp fanglomerates. The well is 100% barometrically efficient; the aquifer does not respond immediately to atmospheric pressure fluctuations but shows a delayed response. The long-term water level shows a decline of about 0.2 ft/yr, likely in response to supply well pumping.

Test Well DT-5A Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1171.5	1788.5	5972.4	5355.4	617.0			1788.5	5355.4	1819.5	31.0	306.4	RT	Tb4

Note: Brass Cap Elevation 7143.86 ft; all measurements are from this elevation

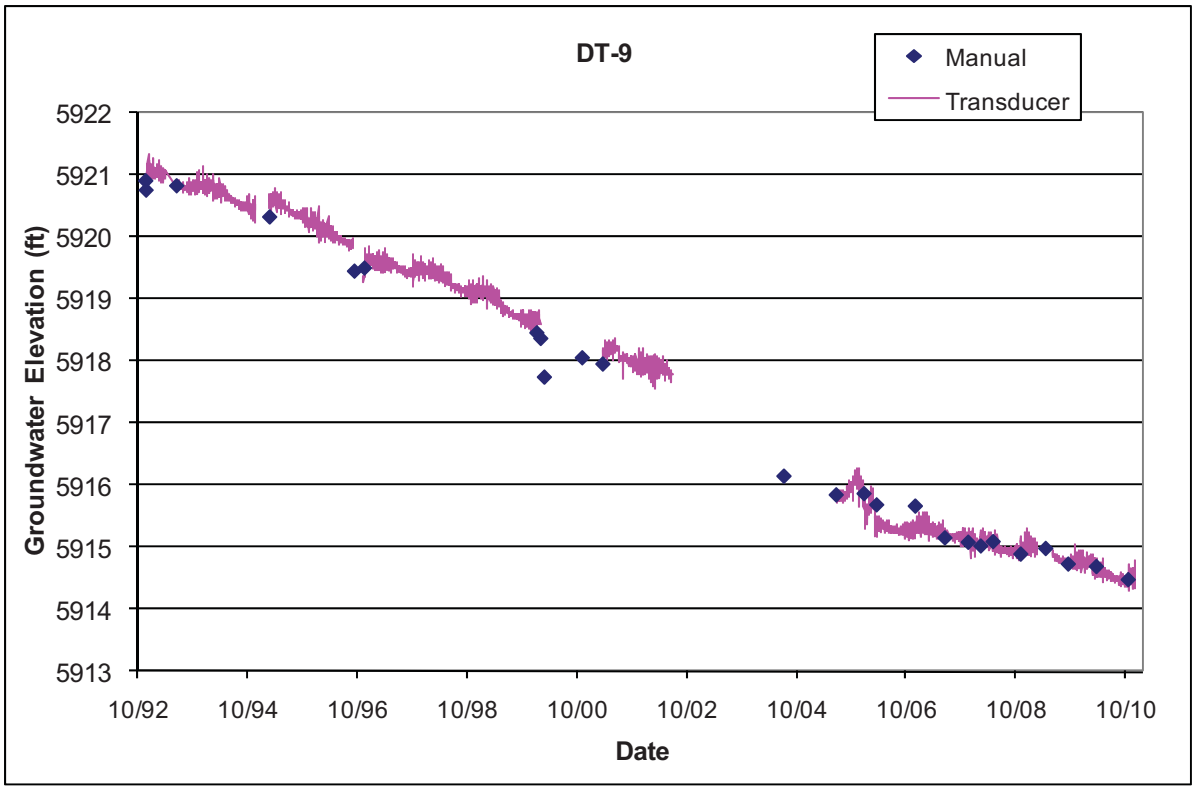


3.70 Test Well DT-9

Location: DT-9 is located at TA-49 near the southern LANL boundary.
Completion Type: Single completion at the top of the regional aquifer. The screen straddles the water table.
Period of Record: Well drilled in 1960, transducer installed November 1992, intermittent data to July 2002. Transducer reinstalled June 2005, data through 2010.
Remarks: DT-9 completed at the top of the regional aquifer at a depth of 1501 ft, about 500 ft into the regional aquifer. The long screen encompasses Tb4 basalt and Tp fanglomerates. The well is 100% barometrically efficient; the aquifer does not respond immediately to atmospheric pressure fluctuations but shows a delayed response. The aquifer shows a long-term decline of about 0.32 ft/yr, likely associated with supply well pumping.

Test Well DT-9 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	819.0	1500.0	6116.0	5435.0	681.0			1500.0	5435.0	1500.0	0.0	0.0	RT	Tb4
Note: Brass Cap Elevation 6935.0 ft; all measurements are from this elevation														



3.71 Test Well DT-10

Location: DT-10 is located at TA-49 near the southern LANL boundary. DT-10 is about 1850 ft south of R-27, 2400 ft southeast of R-29, and 2900 ft north of DT-9.

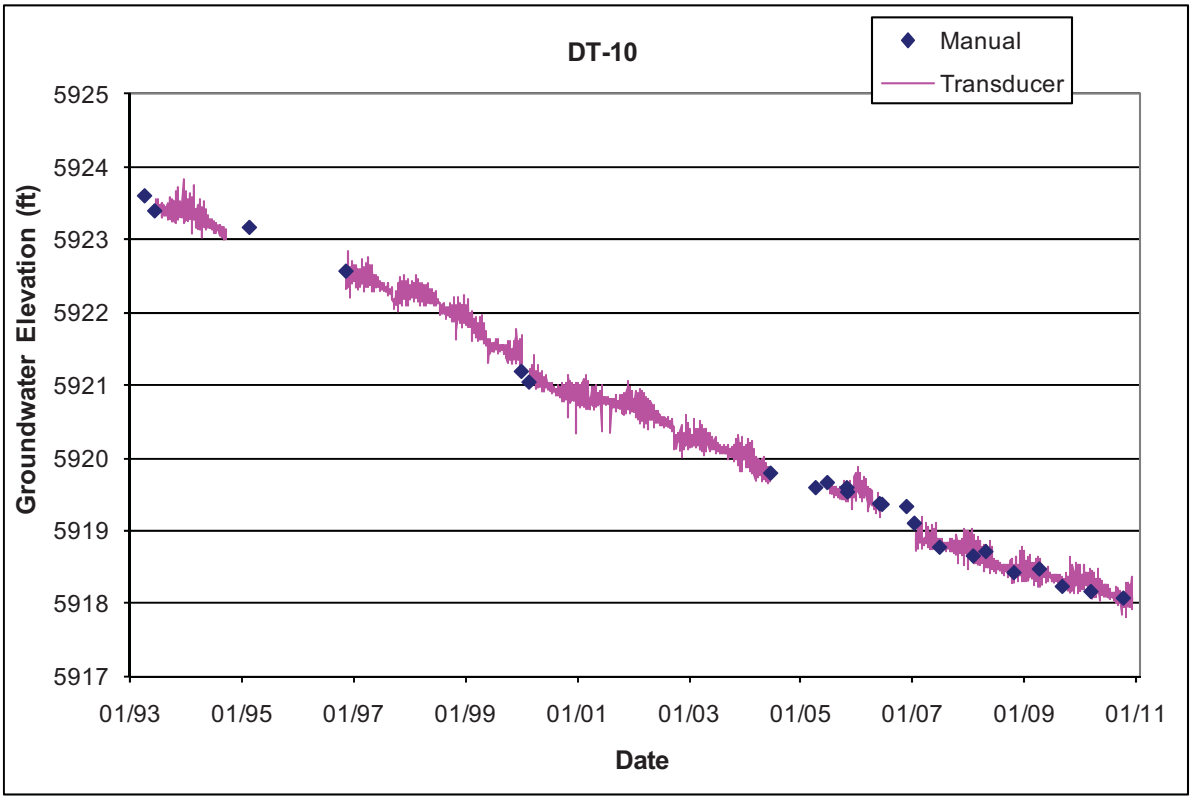
Completion Type: Single completion at the top of the regional aquifer. The screen straddles the water table.

Period of Record: Well drilled in 1960, transducer installed June 1993 and again in November 1996 and June 2005. Transducer equipment failed June 2006, new transducer installed January 2007; data through 2010.

Remarks: DT-10 completed at the top of the regional aquifer at a depth of 1408 ft, about 300 ft into the regional aquifer. The long screen encompasses Tb4 basalt and Tp fanglomerates. The well is about 70% barometrically efficient; the aquifer shows a 30% response to atmospheric pressure fluctuations. The aquifer exhibits a long-term water level decline of about 0.30 ft/yr, likely associated with supply well pumping.

Test Well DT-10 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1078.4	1408.0	5941.5	5611.9	329.6			1408.0	5611.9	1408.0	0.0	0.0	RT	Tb4
Note: Ground Elevation: 7019.90 ft; all depths are from this elevation														



4.0 Groundwater Level Data from Intermediate Wells

Table 4-1 lists the monitoring wells that specifically monitor intermediate groundwater at LANL; the table includes the well name, completed depth, surveyed location coordinates, and the date of completion. Note that R-12 was converted from a three-screen regional/intermediate to a two-screen intermediate monitoring well in December 2007. Table 4-2 lists the well construction information for the intermediate wells and for regional aquifer wells that have intermediate screens. The table includes information for the depth to the top and bottom of screens, screen casing size, geologic formation where the screen is completed, and whether the well/screen contains intermediate groundwater. The hydrographs for intermediate zones in the multiple completion regional aquifer wells are shown in the previous section.

Figure 4-1 shows the locations of the intermediate wells and regional wells that monitor intermediate groundwater. (Note that multiple completion regional wells that do not contain intermediate groundwater, such as CdV-R-15-3, CdV-R-37-2, and R-31, are not shown in Figure 4-1 because the intermediate screens in these wells are dry.) Appendix Table B-2 lists the average annual water levels for each intermediate screen.

Table 4-1. General Information for Intermediate Wells at LANL

Well Name	Date Completed	Completed Depth (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)
03-B-13	6/10/2005	32.0	1616691.69	1773317.07	7458.26
16-26644	8/17/2007	150.0	1612087.16	1763729.94	7591.43
90LP-SE-16-02669	6/10/2005	163.4	1612152.57	1763749.00	7583.26
BCO-1	11/23/1994	68.0	1640648.74	1778914.70	6641.97
CdV-16-1(i)	11/9/2003	657.8	1615078.20	1764415.20	7382.17
CdV-16-2(i)r	7/30/2005	863.2	1616673.24	1764219.40	7456.67
CDV-16-4ip	8/23/2010	1146.0	1615587.07	1764195.74	7463.91
CDV-37-1(i)	12/2/2009	657.8	1624592.30	1757798.61	6826.49
LADP-3	12/17/1993	326.0	1632989.00	1773469.10	6756.70
LAOI(a)-1.1	10/28/1994	309.8	1629427.38	1773924.51	6835.20
LAOI-3.2	5/1/2005	165.0	1637642.10	1773066.93	6622.60
LAOI-3.2a	1/20/2006	194.1	1637619.97	1773100.91	6624.43
LAOI-7	9/21/2005	264.9	1644788.53	1771584.11	6458.35
MCOI-1	1/9/2005	825.6	1628044.51	1769957.39	7106.20
MCOI-4	11/6/2004	525.7	1634128.53	1768542.01	6837.20
MCOI-5	10/25/2004	699.0	1635247.94	1768300.46	6819.70
MCOI-6	1/13/2005	713.2	1635345.65	1768428.06	6811.10
MCOI-8	1/7/2005	675.0	1633329.74	1769214.40	6859.20
MSC-16-02665	10/23/1997	124.0	1614427.59	1762530.55	7516.92
PCI-2	4/10/2009	533.3	1627648.27	1765872.63	6920.95
POI-4	5/1/1996	176.5	1649432.46	1772587.08	6372.29
R-3i	8/16/2005	220.3	1649196.5	1772599.2	6390.15
R-6i	12/20/2004	615.0	1635992.34	1773889.89	6996.90
R-9i	3/10/2000	309.9	1648202.70	1770837.80	6383.20
R-12	01/11/00	886.0	1647424.20	1767913.40	6499.60
R-23i	11/10/2005	550.7	1647898.02	1755148.04	6527.88
R-25b	10/13/2008	782.3	1615125.60	1764074.70	7517.00
R-25c	9/17/2008	1080.6	1615073.72	1764083.07	7517.59
R-26 PZ-1	10/1/2003	250.0	1610201.92	1764660.49	7639.56
R-26 PZ-2	10/1/2003	185.0	1610201.96	1764660.61	7639.56
R-27i	10/17/2009	630.2	1629129.03	1756302.42	6717.97
R-47i	11/15/2009	865.5	1619250.01	1763907.91	7358.41
R-55i			1647014.67	1757360.90	6534.91
R-6i	12/20/2004	615	1635992.3	1773889.9	6996.90
R-9i	3/10/2000	309.9	1648208.8	1770834.7	6383.20
SCI-1	10/7/2006	377.9	1636822.9	1770298.2	6738.27
SCI-2	8/31/2008	570.0	1637155.34	1769651.16	6735.70
TA-53i	3/10/2009	620.8	1635850.97	1771320.08	6987.17
TW-2Ar	3/4/2010	113.9	1634129.90	1777349.11	6651.67

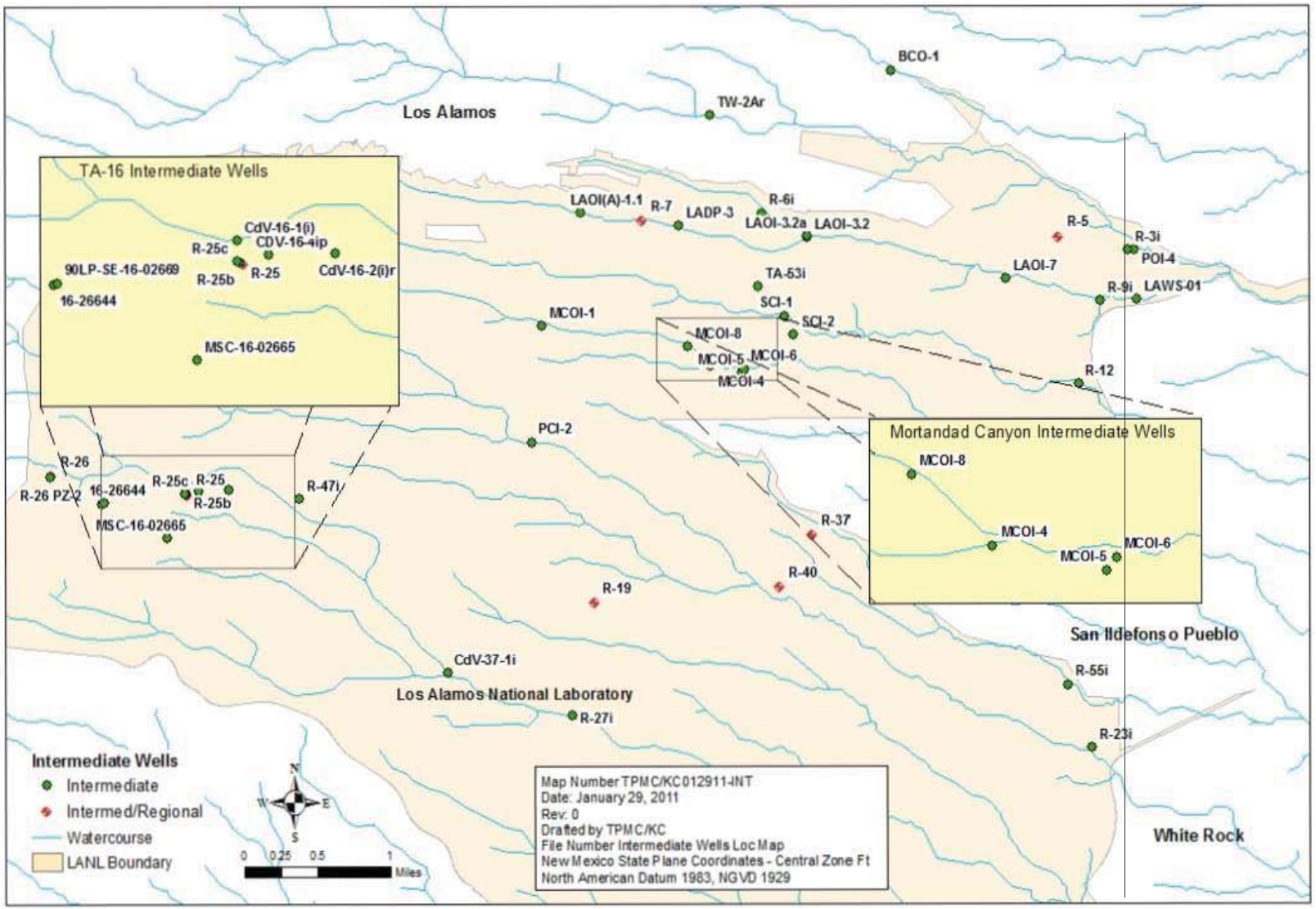


Figure 4-1. Intermediate monitoring wells.

Table 4-2. Well Completion Information for Intermediate Wells and Screens

Well Name	Screen Common Name	Screen Material	Top of Screen (ft)	Bottom of Screen (ft)	Screen Inside Diameter (in.)	Geologic Unit	Comment
03-B-13	03-B-13 Screen #1	PVC	21.5	31.5	2.00	Qbt3	
16-26644	16-26644 Screen #1	PVC	130.0	145.0	2.00	Qbt3	
90LP-SE-16-02669	16-02669 Screen #1	PVC	131.5	162.5	2.00	Qbt3	Dry
BCO-1	BCO-1 Screen #1	PVC	57.0	67.0	4.00	Tpf	Dry
CdV-16-1(i)	CdV-16-1(i) Screen #1	SS304	624.0	634.0	4.50	Qbo	
CdV-16-1(i) CH	CdV-16-1(i) PZ #1	PVC	50.0	80.0	1.50	Qbt3	Dry
CdV-16-2(i)r	CdV-16-2(i)r Screen #1	SS304	850.0	859.7	4.46	Tpf	
CDV-16-4ip	CDV-16-4ip Screen #1	SS304	815.6	879.2	5.00	Tpf	
CDV-16-4ip	CDV-16-4ip Screen #2	SS304	1110	1141.1	5.00	Tpf	
CDV-37-1(i)	CDV-37-1(i) Screen #1	SS304	632.0	652.5	5.00	Tpf	
CdV-R-15-3	CdV-R-15-3 Screen 1	SS312	617.7	624.5	4.50	Qbo	Dry
CdV-R-15-3	CdV-R-15-3 Screen 2	SS312	800.8	807.8	4.50	Tp	Dry
CdV-R-15-3	CdV-R-15-3 Screen 3	SS312	964.8	980.9	4.50	Tb	Dry
CdV-R-37-2	CdV-R37-2 Screen #1	SS304	914.4	939.5	4.50	Tp	Dry
LADP-3	LADP-3 Screen #1	PVC	316.0	325.0	3.00	Qbog	
LAOI(A)-1.1	LAOI(A)-1.1 Screen #1	PVC	295.2	305.0	3.00	Qbog	
LAOI-3.2	LAOI-3 Screen #1	PVC	153.3	162.8	4.46	Tb	
LAOI-3.2a	LAOI-3a Screen #1	SS304	181.4	191.0	3.10	Tpf	
LAOI-7	LAOI-7 Screen #1	SS304	240.0	259.6	3.00	Tb4	
MCOBT-4.4	MCOBT4.4 Screen #1	SS304	485.4	524.0	4.50	Tpf	P&A 2009
MCOI-1	MCOI-1 Screen #1	SS	815.0	825.5	1.10	Tpf	
MCOI-4	MCOI-4 Screen #1	PVC	498.9	522.0	4.50	Tpf	
MCOI-5	MCOI-5 Screen #1	PVC	689.0	699.0	4.50	Tb	
MCOI-6	MCOI-6 Screen #1	PVC	686.0	708.3	4.50	Tb	
MCOI-8	MCOI-6 Screen #1	PVC	665.0	675.0	4.46	Tb	
MSC-16-02665	16-02665 Screen #1	PVC	93.5	123.5	2.00	Qbt3	Usually dry
PCI-2	PCI-2 Screen #1	SS304	512.0	522.0	5.00	Tpf	near R-17
POI-4	POI-4 Screen #1	PVC	159.0	174.0	4.00	Tb4	
R-3i	R-3i Screen #1	PVC	215.2	220.0	2.00	Tb4	
R-12	R-12 Screen #1	SS304	459.0	467.5	4.50	Tb	
R-12	R-12 Screen #2	SS304	504.5	508.0	4.50	Tp	
R-19	R-19 Screen #1	SS304	827.2	843.6	4.50	Qbog	Dry
R-19	R-19 Screen #2	SS304	893.3	909.6	4.50	Tp	
R-23i	R-23i Screen #1	SS304	400.3	420.0	2.10	Tb4	
R-23i	R-23i Screen #2	SS304	470.2	480.1	4.50	Tb4	
R-23i	R-23i Screen #3	SS304	524.0	547.0	4.50	Tb4	
R-25	R-25 Screen #1	SS304	737.6	758.4	5.17	Qbo	
R-25	R-25 Screen #2	SS304	882.6	893.4	5.17	Tp	
R-25	R-25 Screen #3 damaged	SS304	1054.6	1064.6	5.17	Tp	Dry, sump water
R-25	R-25 Screen #4	SS304	1184.6	1194.6	5.17	Tp	
R-25b	R-25b Screen #1	SS304	750.0	770.8	5.00	Qbo	
R-25c	R-25c Screen #1	SS304	1039.6	1060.0	5.00	Tpf	Dry, sump water
R-26	R-26 Screen #1 (Upper)	SS304	643.0	662.0	4.50	Qct	
R-26 PZ-1	R-26 Piezometer Screen #1	PVC	230.0	250.0	1.00	Qbt3	Dry
R-26 PZ-2	R-26 Piezometer Screen #2	PVC	150.0	180.0	1.00	Qbt3	

Note: SS = stainless steel, PVC = polyvinyl chloride, Qbo = Otowi Member of the Bandelier Tuff, Tp = Puye Formation, Qbog = Guaje Pumice member of the Bandelier Tuff, Tpf = fluvial facies of the Puye Formation, Tb = undifferentiated basalt, Tb4 = Cerros del Rio Basaltic Rocks; Qbt3 = Unit 3 of the Tshirege Member of the Bandelier Tuff, Tt = Tschicoma Formation (dacite).

Table 4-2. Well Completion Information for Intermediate Wells and Screens (Continued)

Well Name	Screen Common Name	Screen Material	Top of Screen (ft)	Bottom of Screen (ft)	Screen Inside Diameter (in.)	Geologic Unit	Comment
R-27i	R-27i Screen #1	SS304	619.0	629.0	5.00	Qbt3	
R-31	R-31 Screen #1	SS304	439.1	454.4	4.50	Tb	Dry
R-37	R-37 Screen #1	SS304	929.3	950.0	5.00	Tb4	
R-40	R-40i	PVC	649.7	669.0	3.00	Tb4	
R-40	R-40 Screen #1	SS304	751.6	785.1	5.00	Tb4	
R-41	R-41 Screen #1	SS304	928.0	937.7	5.00	Tsf	Dry
R-47i	R-47i Screen #1	SS304	840.0	860.6	5.00	Tpf	
R-5	R-5 Screen #1	SS304	326.4	331.5	4.50	Tp	Dry
R-5	R-5 Screen #2	SS304	372.8	388.8	4.50	Tp	
R-55i	R-55i Screen #1	SS304	510.0	530.0	5.00	Tb4	Prelim information
R-6i	R-6i Screen #1	SS304	602.0	612.0	4.46	Tpf	
R-7	R-7 Screen #1	SS304	363.2	379.2	4.50	Tp	Dry since 2005
R-7	R-7 Screen #2	SS304	730.4	746.4	4.50	Tp	Dry
R-9i	R-9i Screen #1	SS304	189.1	199.5	5.00	Tb	
R-9i	R-9i Screen #2	SS304	269.6	280.3	5.00	Tb	
SCI-1	SCI-1 Screen #1	PVC	358.4	377.9	3.80	Tpf	
SCI-2	SCI-2 Screen #1	PVC	548.0	568.0	2.00	Tb4	near R-43
TA-53i	TA-53i Screen #1	SS304	600.0	610.0	5.00	Tpf	
Test Well 1A	TW-1A Screen #1	CS	215.0	225.0	6.00	Tb	P&A 2010
Test Well 2A	TW-2A Screen #1a	CS	123.0	133.0	6.00	Tp	P&A 2010
TW-2Ar	TW-2Ar Screen #1	SS304	102.0	112.0	4.88	Tpf	

Note: SS = stainless steel, PVC = polyvinyl chloride, Qbo = Otowi Member of the Bandelier Tuff, Tp = Puye Formation, Qbog = Guaje Pumice member of the Bandelier Tuff, Tpf = fluvial facies of the Puye Formation, Tb = undifferentiated basalt, Tb4 = Cerros del Rio Basaltic Rocks; Qbt3 = Unit 3 of the Tshirege Member of the Bandelier Tuff, Tt = Tschicoma Formation (dacite); P&A = plugged and abandoned.

The following sections include additional port and construction information for single and multiple completion intermediate wells at LANL. Time-series groundwater level data are shown for each well.

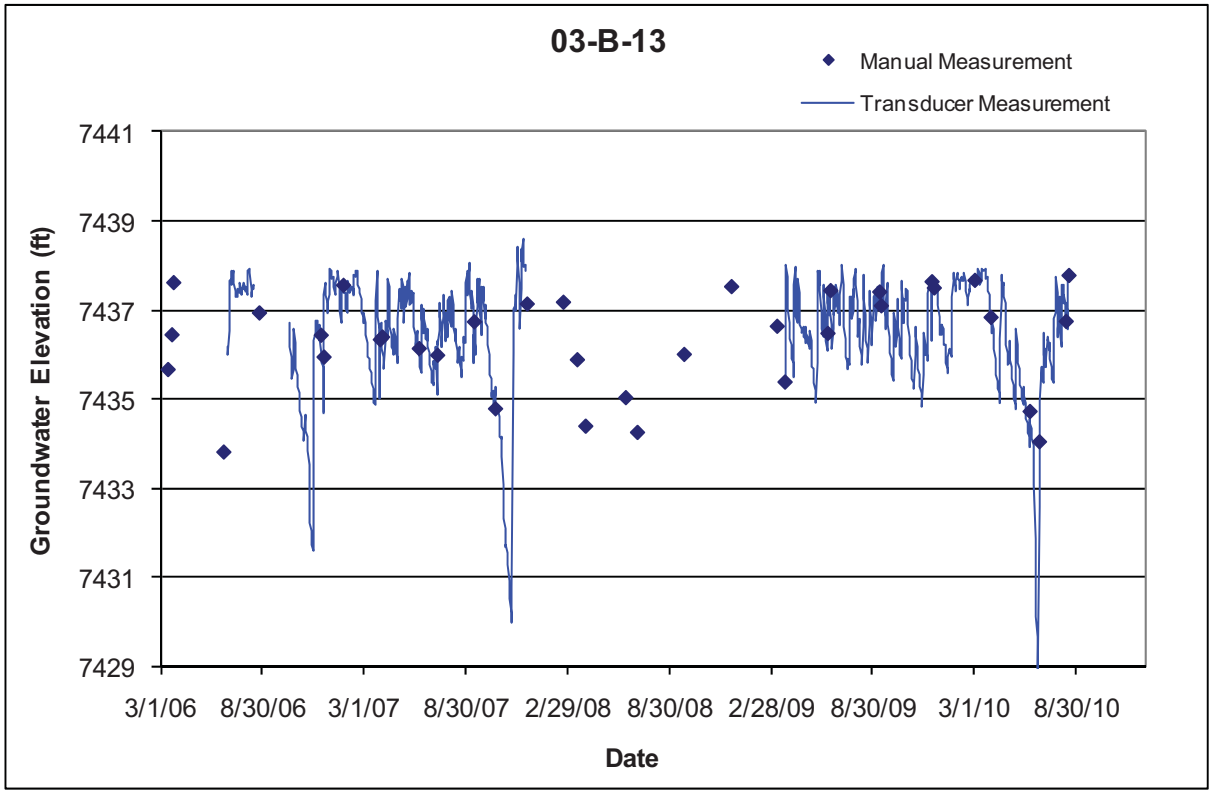
4.1 03-B-13

Location: 03-B-13 is located at TA-3 behind building SM-30.
Completion Type: Single completion in an intermediate perched zone in Unit 3 of the Bandelier Tuff. The wellhead is completed below ground surface with a waterproof well cap flush with an asphalt roadway.
Period of Record: Well completed June 2005, transducer installed June 2006, periodic measurements through 2010. Transducer equipment problems occurred in 2008.
Remarks: The surface completion was reworked in 2007. Surface water enters the well protective cover at times and may enter the well.

03-B-13 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	21.50	31.5	7436.8	7426.8	10.0	None	None	31.5	7426.8	32.0	0.5	0.3	I	Qbt3

Note: Ground elevation is 7458.26 ft; all depths from this elevation

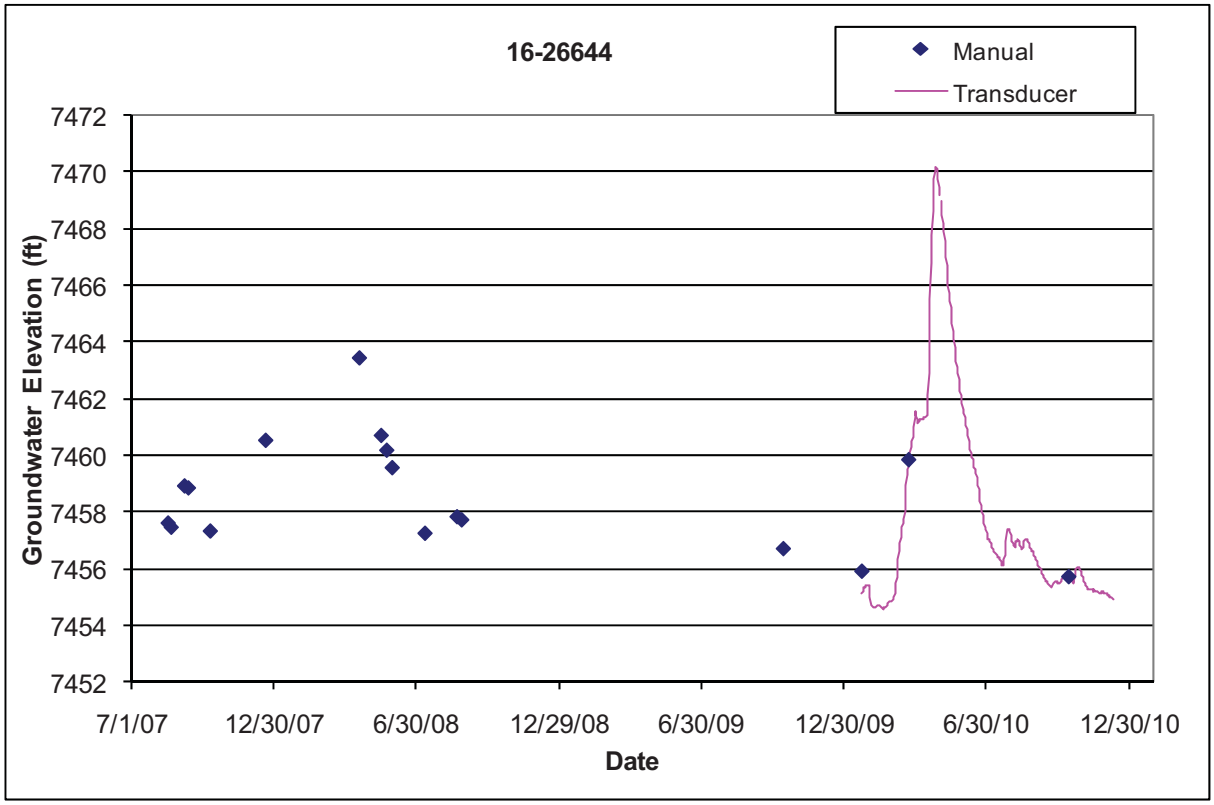


4.2 16-26644

Location: 16-26644 is located at TA-16 southeast and downgradient of the 90LP Pond and about 70 ft west of well 90LP-SE-16-02669.
Completion Type: Single completion in an intermediate zone in Unit 3 of the Bandelier Tuff.
Period of Record: Well drilled in August 2007, periodic manual measurements through 2009. A dedicated Bennett pump and transducer were installed in January 2010; data through 2010.
Remarks: The well has contained water when checked since completion of drilling, but several nearby boreholes and wells to a similar depth are dry. The groundwater appears to respond to precipitation and nearby runoff events.

16-26644 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	130.0	145.0	7461.4	7446.4	15.0	144.4	7447.0	145.0	7446.4	150.0	5.0	3.1	I	Qbt3
Note: Ground Elevation: 7591.43 ft; all measurements are from this elevation														



4.3 90LP-SE-16-02669

Location: 90LP-SE-16-02669 is located at TA-16 downgradient of the 90LP Pond. 90LP-SE-16-02669 is about 70 ft east-northeast of 16-26644
Completion Type: Single completion in an intermediate zone in Unit 3 of the Bandelier Tuff.
Period of Record: Well drilled in March 1998, periodic measurements through 2010.
Remarks: The borehole contained water at the completion of drilling, but since completion of the well, water has not been present in the well; the well was last checked April 29, 2010.

90LP-SE-16-02669 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	131.5	163.0	7451.8	7420.3	31.5	None	None	163.0	7420.3	163.4	0.4	0.2	I	Qbt3

Note: Ground Elevation: 7583.26 ft; all measurements are from this elevation

4.4 CdV-16-1(i)

Location: CdV-16-1(i) is located at TA-16 downgradient of the TA-6-260 outfall and about 360 ft north of intermediate well R-25b and R-25 and about 550 ft northwest of CDV-16-4ip.

Completion Type: Single completion in an intermediate zone. The screen is located at similar depth as R-25 screen 1 and R-25b.

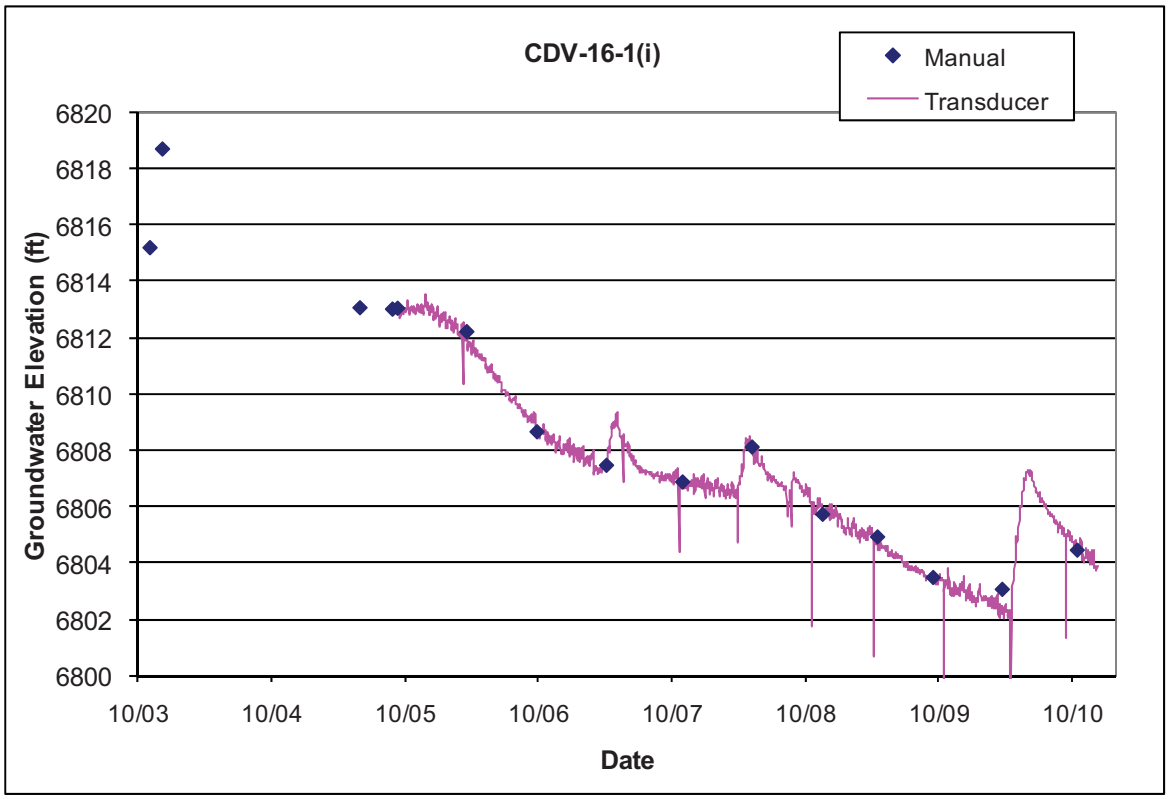
Period of Record: Well drilled in November 2003. Transducer installed September 2005; data through 2010.

Remarks: Well completed in an intermediate zone in the Otowi Member of the Tshirege Formation; the water level is about 50 ft above the top of the screen. The screen is at a similar elevation as R-25b and R-25 screen 1; the bottom of the screen is about 105 ft higher than the top of the screen at CDV-16-4ip. The well is 100% barometrically efficient; the groundwater does not respond to atmospheric pressure fluctuations. The intermediate groundwater rose in response to snowmelt runoff in the spring of 2007, 2008, and 2010 and responded to drilling activities at R-25b and R-35c in 2008.

CDV-16-1(i) Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	624.0	634	6758.2	6748.2	10.0	618.8	6763.4	634.0	6748.2	657.8	23.8	73.1	I	Qbo

Note: Ground Elevation: 7382.17 ft; all measurements are from this elevation



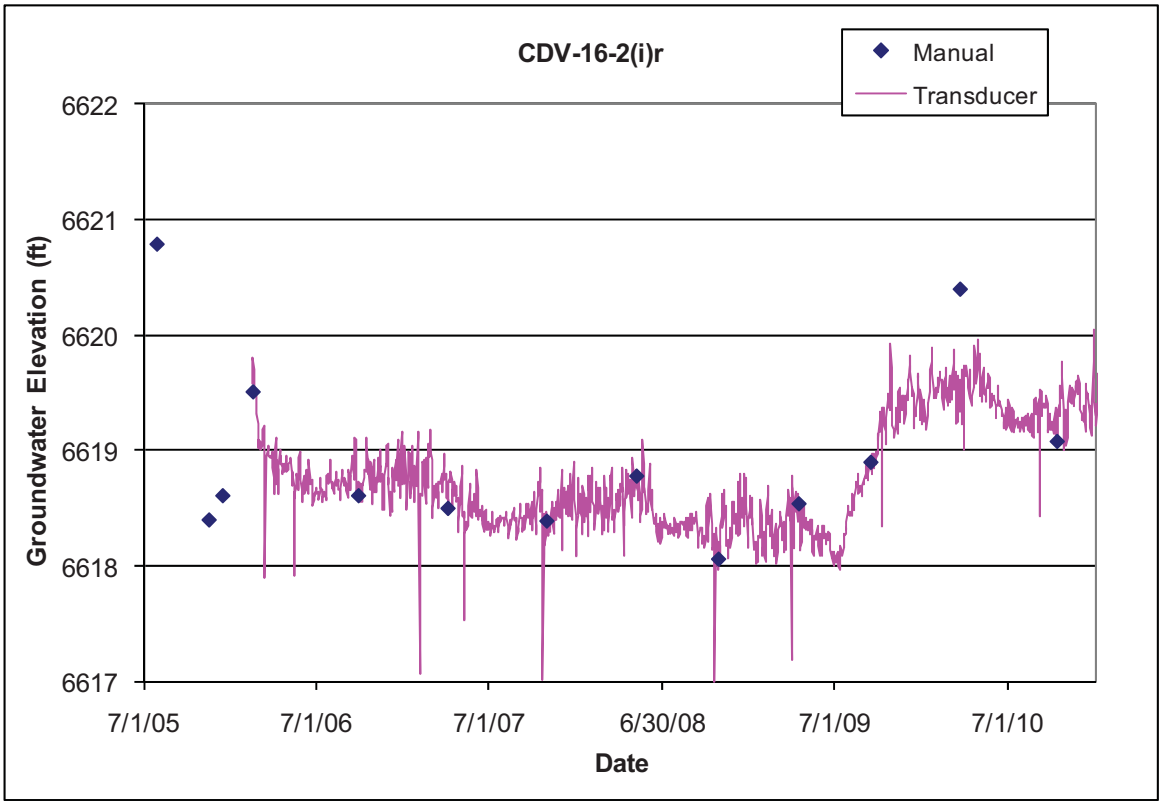
4.5 CdV-16-2(i)r

Location: CdV-16-2(i)r is located at TA-16 downgradient of the TA-6-260 outfall and about 1450 ft east of R-25.
Completion Type: Single completion in intermediate zone in the Puye Formation.
Period of Record: Well completed July 2005, periodic manual measurements in 2005. A transducer was installed February 16, 2006; data through 2010.
Remarks: Well replaces CdV-16-2(i). The water level is about 20 ft above bottom of screen. The well is about 90% barometrically efficient. The groundwater did not indicate a response to snowmelt runoff in 2007 but may have shown a small response to snowmelt runoff in the spring of 2008 and 2010. Nearby dry well CdV-16-2(i) was plugged and abandoned in July 2009 (LANL August 2009b). The groundwater level at CdV-16-2(i)r began to recover on July 9, 2009, when pressure grouting activities commenced during plugging of the nearby well; the water level recovered about 1.3 ft after CdV-16-2(i) was plugged.

CDV-16-2(i)r Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Unit Code	Geo Unit Code
1	850.0	859.7	6606.7	6597.0	9.7	855.12	6601.6	859.7	6597.0	863.2	3.5	10.8	I	Tpf

Note: Ground Elevation: 7456.67 ft; all measurements are from this elevation

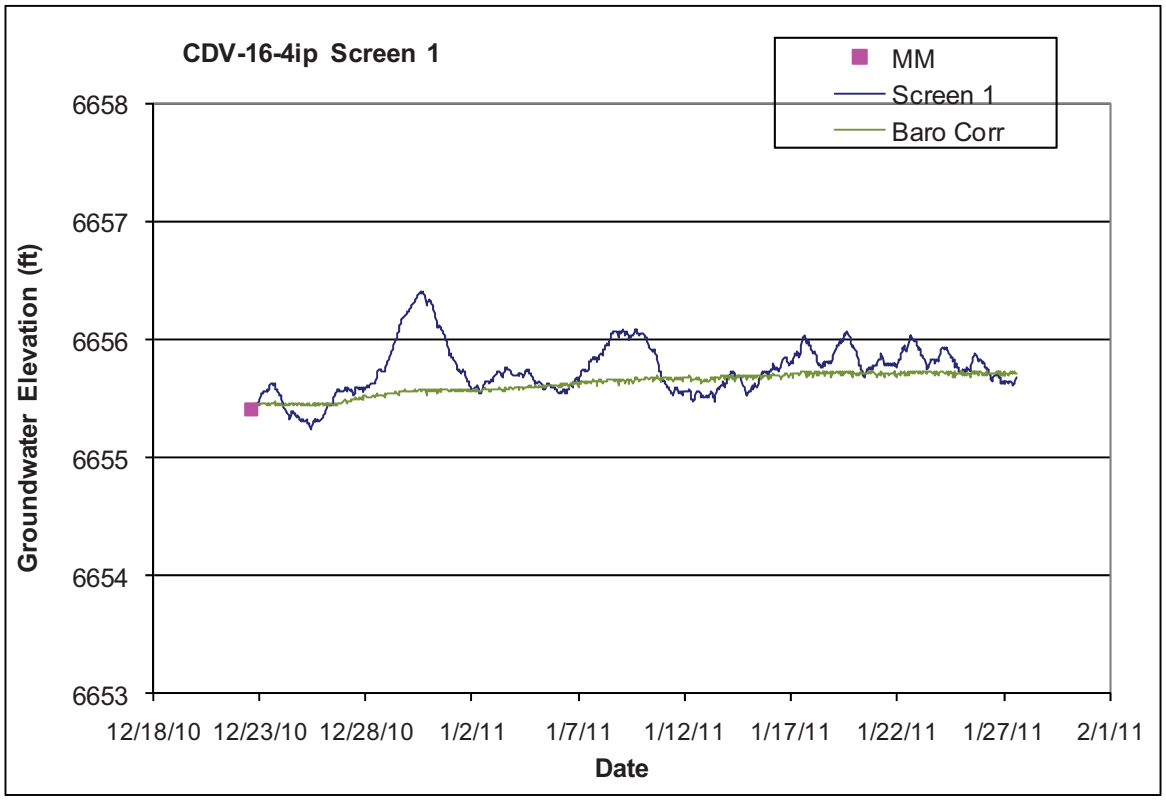


4.6 CDV-16-4ip

Location: CdV-16-2(i)r is located at TA-16 downgradient of the TA-66-260 outfall and about 430 ft east of R-25 and 750 ft southeast of CdV-16-1(i).
Completion Type: Dual completion in two intermediate zones in the Puye Formation.
Period of Record: Well completed August 2010. Temporary transducer installed at screen 1 above a temporary packer December 22, 2010, to monitor drilling activities at R-63. Installation of permanent transducers is pending.
Remarks: The upper screen is at a similar elevation as R-25 screen 2 and is 105 ft lower than the screen at CdV-16-1(i). The lower screen is at a similar elevation as R-25 screen 4. The water level at screen 1 is about 11 ft above the top of the screen. Screen 1 is 100% barometrically efficient; the groundwater does not respond to atmospheric pressure changes. Groundwater level data from screen 2 are pending.

CDV-16-4ip Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	APV Intake Depth (ft)	APV Intake Elev (ft)	Packer Top/ Bottom Depth (ft)	Packer Top/ Bottom Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (gal.)	Hydro Zone Code	Geo Unit Code
1	815.6	879.2	6648.3	6584.7	63.6		7463.9						I	Tpf
2	1110	1141.1	6353.9	6322.8	31.1		7463.9			1146.0	4.9	5.0	I	Tpf
Note: Brass Cap Ground Elevation: 7463.91 ft; all measurements are from this elevation														



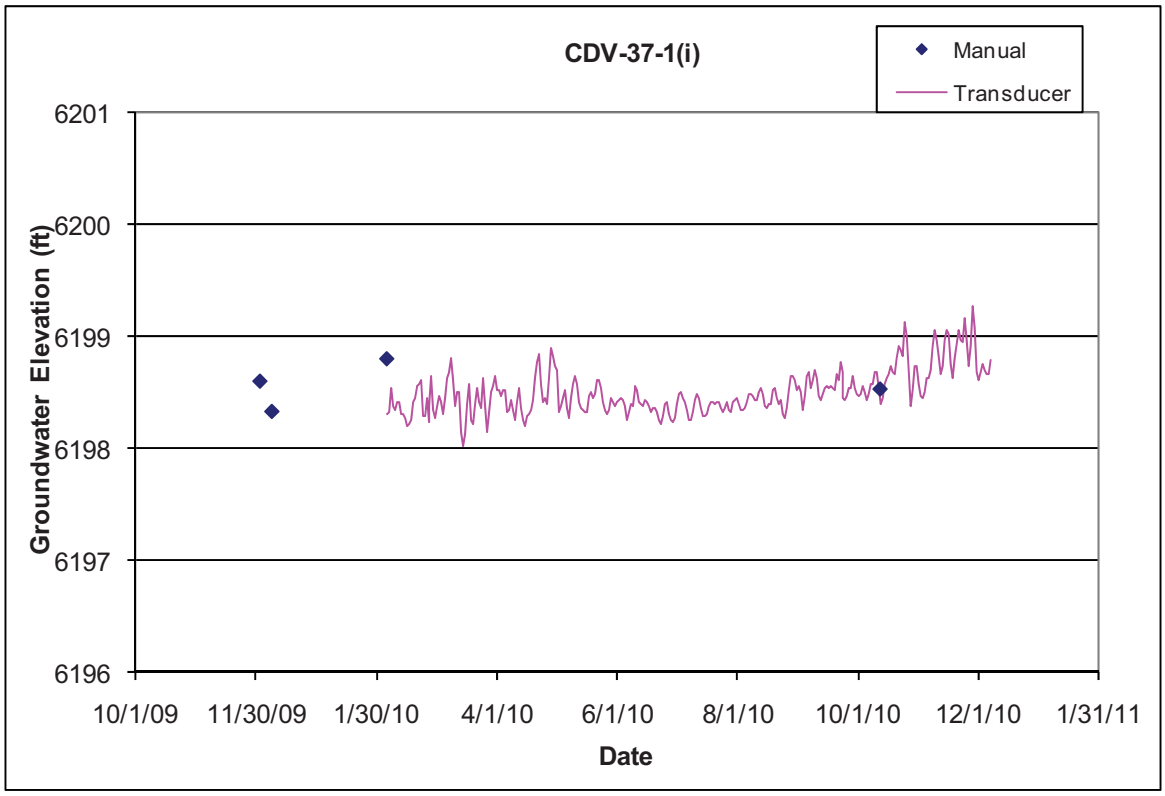
4.7 CDV-37-1(i)

Location: CDV-37-1(i) is located in Water Canyon near the confluence with Cañon de Valle and about 0.9 mi west and upstream of R-27i.
Completion Type: Single completion in an intermediate zone in the Puye Formation fanglomerates.
Period of Record: Well completed December 2009. Transducer installed February 5, 2010; data through 2010.
Remarks: A dedicated Bennett submersible pump was installed in January 2010.The screen is located about 4 ft below the level of the perched intermediate groundwater. The well is 100% barometrically efficient; the groundwater does not respond to atmospheric pressure fluctuations.

CDV-37-1(i) Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Bottom of Well Elev (ft)	Hydro Zone Code	Geo Unit Code
1	632.0	652.5	6194.5	6174.0	20.5	647.3	6179.2	652.5	6174.0	657.8	5.3	6168.7	I	Tpf

Note: Brass Cap Elevation: 6826.49 ft; all measurements are from this elevation



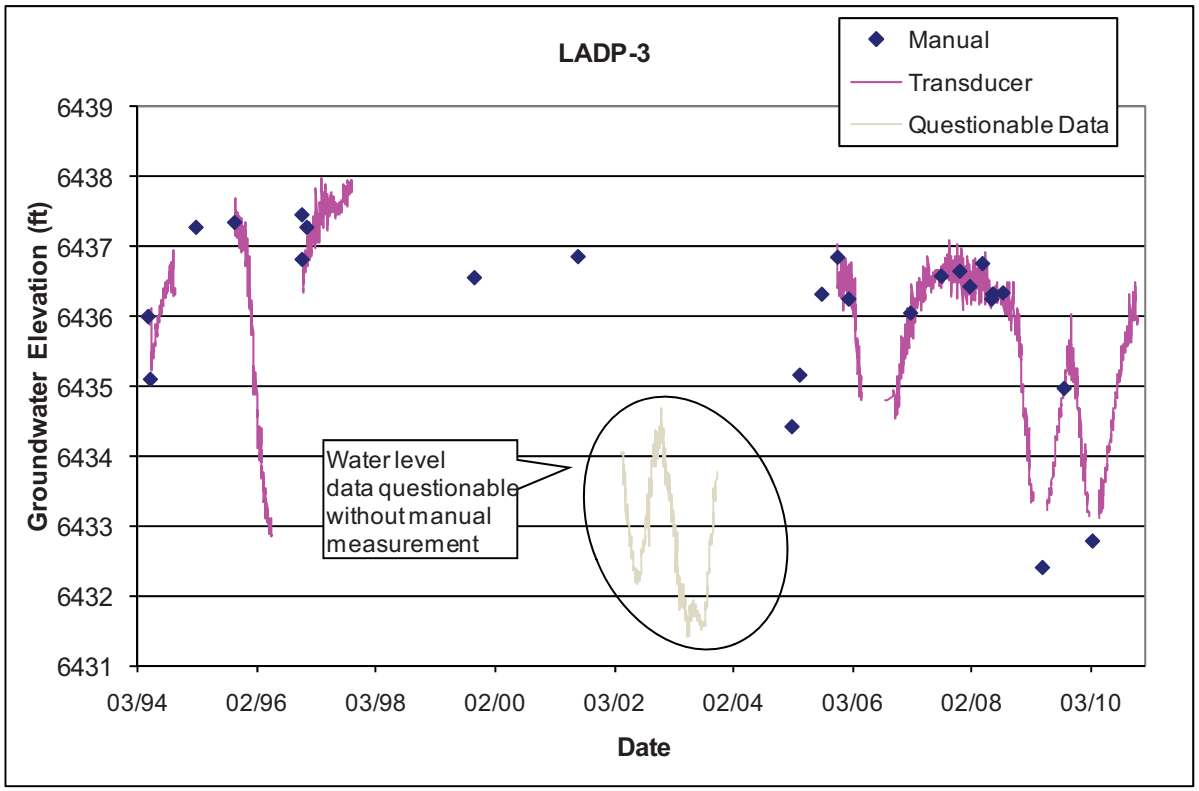
4.8 LADP-3

Location: LADP-3 is located in middle Los Alamos Canyon downgradient of TA-21 and about 0.9 mi upstream of the confluence with DP Canyon.
Completion Type: Single completion in an intermediate zone in the Guaje Pumice bed.
Period of Record: Well drilled in 1993. Transducer first installed May 1994, reinstalled in May 2005, intermittent transducer data through 2010.
Remarks: No manual measurement available for April 2002 transducer installation, data from April 2002 to November 2003 questionable. The water level declined below the transducer from April 2006 to November 2006 and again from March 2009 to June 2009. The well is 100% barometrically efficient; the groundwater does not respond to atmospheric pressure fluctuations. The groundwater did not indicate a response to snowmelt runoff in 2007, 2008, and 2010. A dedicated Bennett pump was installed in July 2008.

LADP-3 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	316.0	326	6440.7	6430.7	10.0	325.0	6431.7	326.0	6430.7	326	0.0	0.0	I	Qbog

Note: LADP-3 Ground Elevation: 6756.7 ft; all measurements are from this elevation



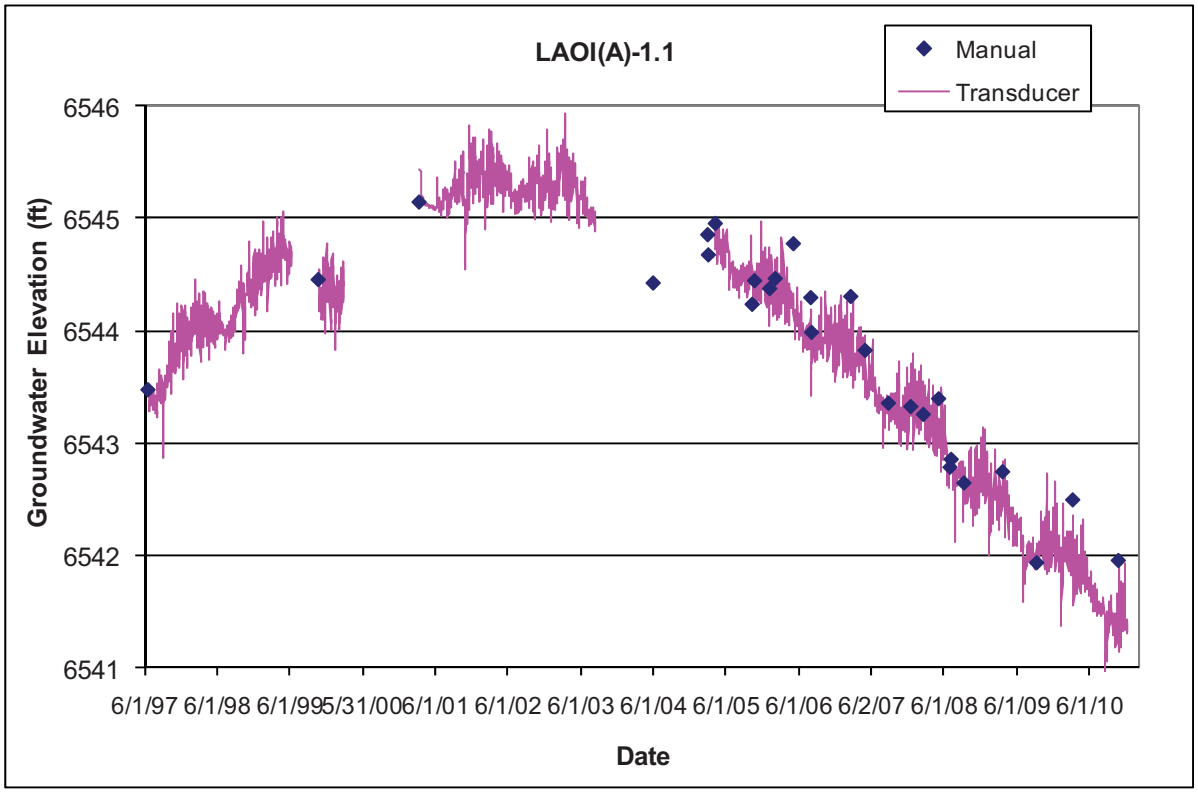
4.9 LAOI(a)-1.1

Location: LAOI(a)-1.1 is located in middle Los Alamos Canyon downstream of TA-2 and TA-41.
Completion Type: Single completion in an intermediate zone in the Guaje Pumice bed.
Period of Record: Well drilled in 1994. Transducer initially installed June 1997, reinstalled in April 2005; transducer data through 2010.
Remarks: The well is 100% barometrically efficient; the groundwater does not respond to atmospheric pressure fluctuations. The groundwater did not indicate a response to snowmelt runoff in 2007, 2008, and 2010. A dedicated Bennett pump was installed July 2008.

LAOI(A)-1.1 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	295.2	305	6540.0	6530.2	9.8	308.0	6527.2	305.0	6530.2	309.8	4.8	6.7	I	Qbog

Note: LAOI(A)-1.1 Ground Elevation: 6835.2 ft; all measurements are from this elevation



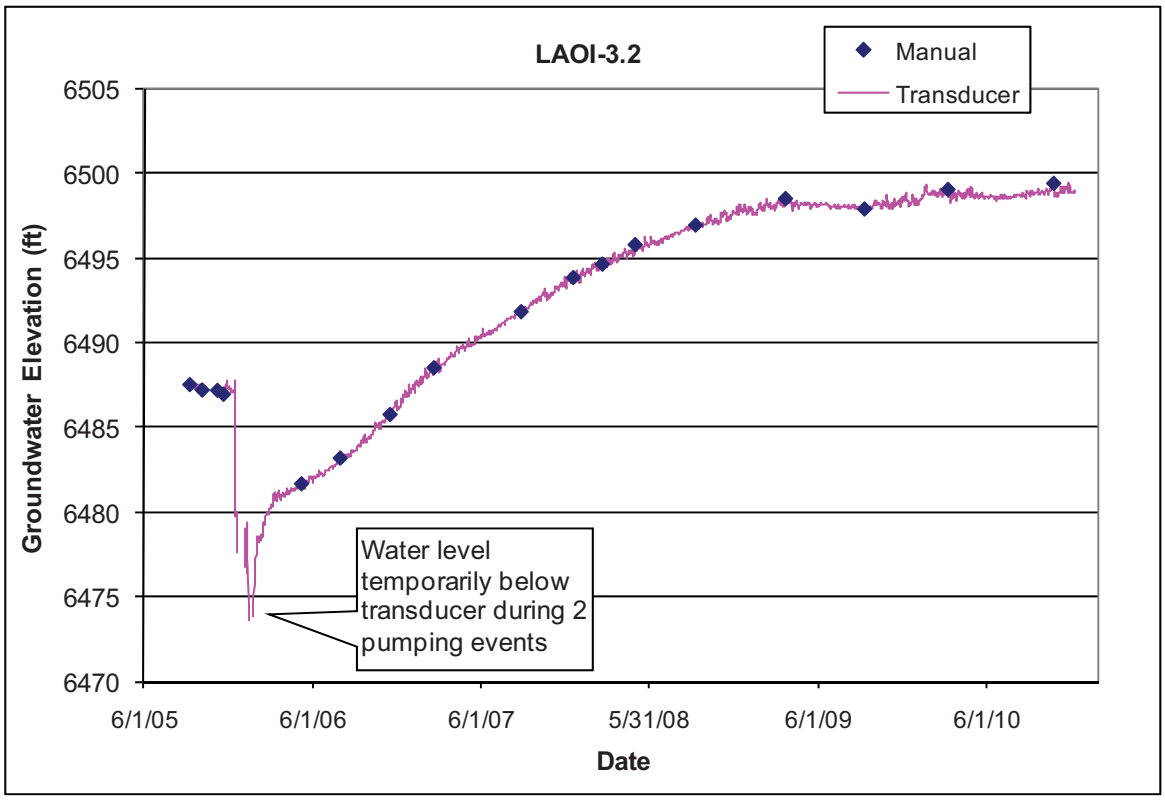
4.10 LAOI-3.2

Location: LAOI-3.2 is located in middle Los Alamos Canyon at the confluence with DP Canyon.
Completion Type: Single completion in an intermediate zone in the Guaje Pumice bed.
Period of Record: Well completed in March 2005. Transducer installed September 2005; transducer data through 2010.
Remarks: The transducer was removed in October 2005 for pump installation. The transducer was reinstalled in November 2005. The water level declined below the level of the transducer for a time during pumping of the well in December 2005. The well is 100% barometrically efficient; the groundwater does not respond to atmospheric pressure fluctuations. The groundwater did not indicate a response to snowmelt runoff in 2007, 2008, and 2010.

LAOI-3.2 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	153.3	162.8	6469.3	6459.8	9.5	159.3	6463.3	162.8	6459.8	165	2.2	1.5	I	Qbog

Note: Ground Elevation: 6622.6 ft; all measurements are from this elevation



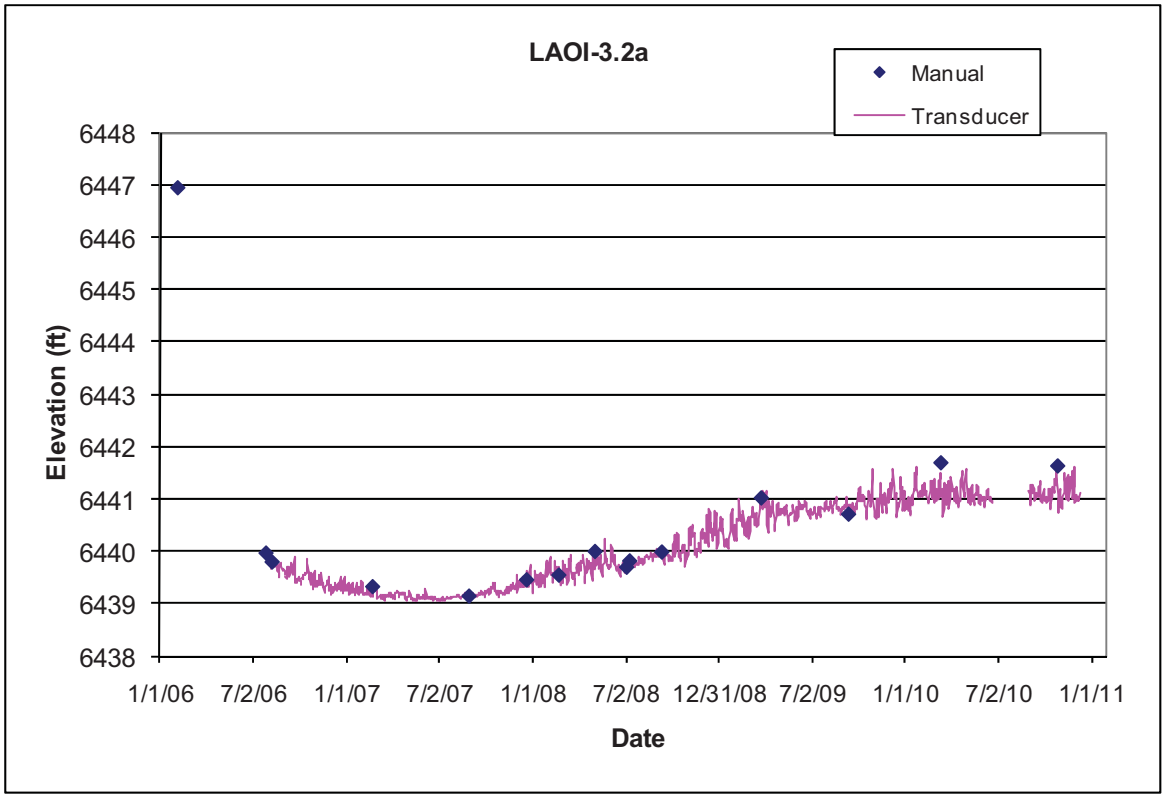
4.11 LAOI-3.2a

Location: LAOI-3.2a is located in middle Los Alamos Canyon near the confluence with DP Canyon and about 50 ft northwest of LAOI-3.2.
Completion Type: Single completion in an intermediate zone in Puye fanglomerate.
Period of Record: Well completed in January 2006. Transducer installed August 2006; transducer data through 2010.
Remarks: The water level is about 6 ft above the bottom of the screen. The well is 100% barometrically efficient, the groundwater does not respond to atmospheric pressure fluctuations. The groundwater did not indicate a response to snowmelt runoff in 2007, 2008, and 2010.

LAOI-3.2a Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	181.4	191	6443.0	6433.4	9.6	189	6435.4	191.0	6433.4	191.4	0.4	0.6	I	Tpf

Note: Ground Elevation: 6624.43 ft; all measurements are from this elevation



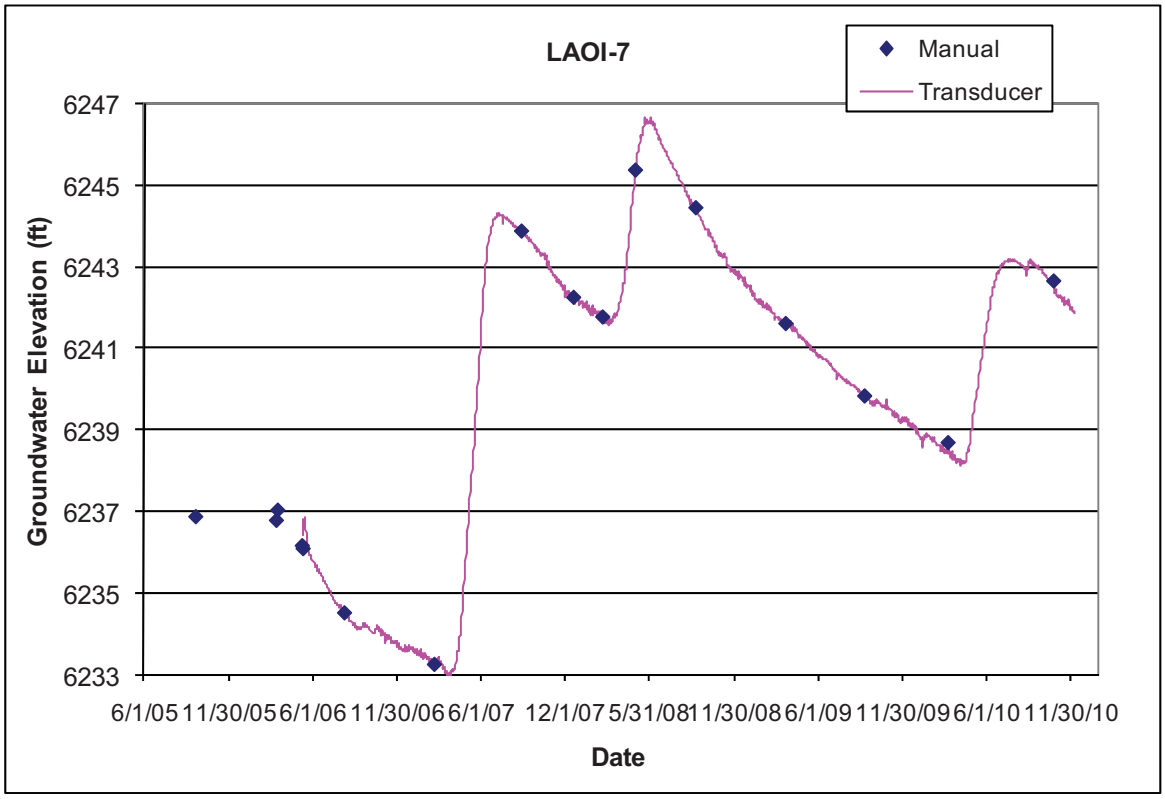
4.12 LAOI-7

Location: LAOI-7 is located in middle Los Alamos Canyon about 0.75 mi upstream of R-9i.
Completion Type: Single completion in an intermediate zone in Cerros del Rio basalt.
Period of Record: Well completed in September 2005, transducer installed May 2006, data through 2010.
Remarks: The well has an estimated 18% barometric efficiency (Kleinfelder 2006a); the groundwater shows a delayed, partial response to atmospheric pressure fluctuations. The groundwater rose about 11 ft in response to snowmelt runoff in 2007, about 5 ft in 2008, and about 5 ft in 2010.

LAOI-7 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	240.0	259.6	6218.4	6198.8	19.6	240.0	6218.4	259.6	6198.8	264.9	5.3	7.4	I	Tb4

Note: Brass Cap Elevation: 6458.35 ft; all measurements are from this elevation



4.13 MCOBT-4.4

Location: MCOBT-4.4 was located in lower Mortandad Canyon near the confluence with Ten Site Canyon.

Completion Type: Single completion at the base of the Puye Formation fanglomerate member and the top of Cerros del Rio basalt.

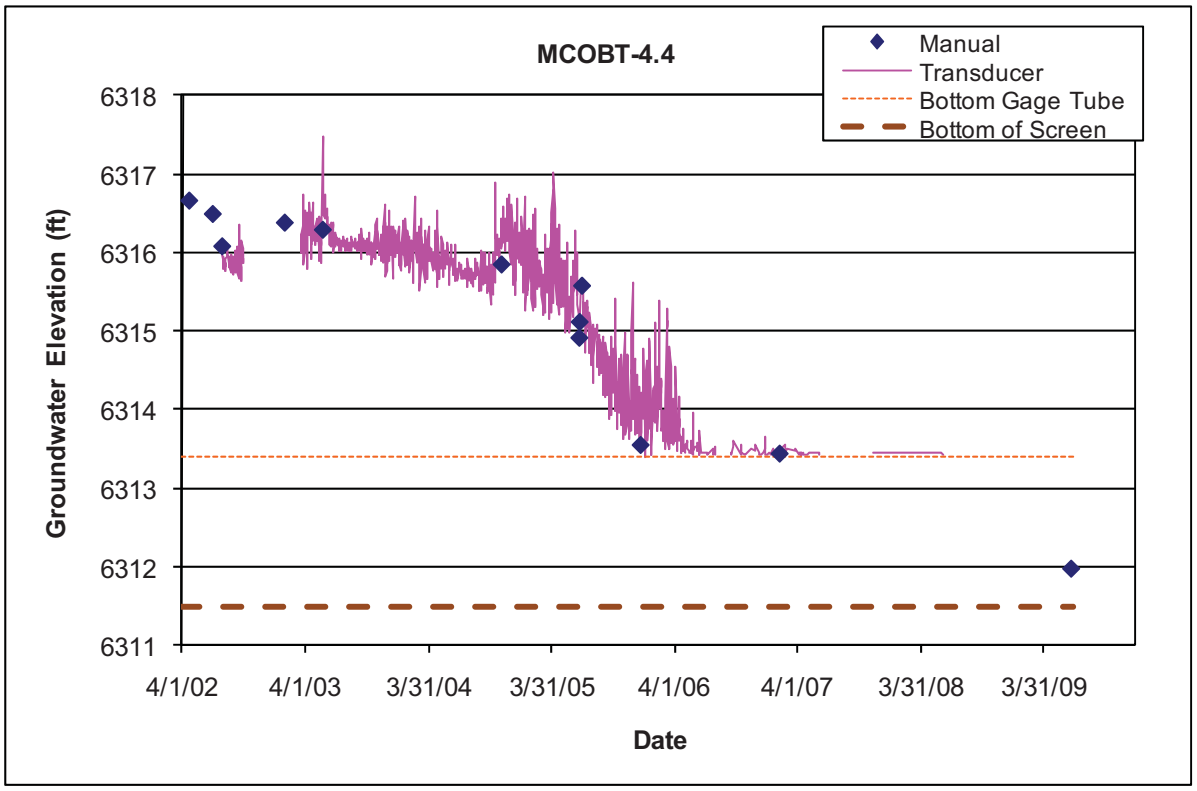
Period of Record: Well completed in June 2001, transducer installed July 2002, data to June 19, 2008, when the transducer was removed and monitoring ceased due to lack of measureable water.

Remarks: MCOI-4 was located about 70 ft west of MCOBT-4.4; the water level at MCOBT-4.4 declined after the installation of MCOI-4. The bottom of the transducer gage tube was located above the pump and about 1.2 ft above the bottom of the screen. The water level declined below the gage tube for portions of 2006 and most of 2007 and 2008. The water level remained near the bottom of the screen after 2006. MCOBT-4.4 was plugged and abandoned in July 2009 (LANL September 2009b).

MCOBT-4.4 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	485.4	524.0	6350.8	6312.2	38.6	524	6312.2	524.0	6312.2	545.0	21.0	64.5	I	Tpf

Note: Brass Cap Elevation: 6836.18 ft; all measurements are from this elevation. Well plugged and abandoned 7/29/09



4.14 MCOI-1

Location: MCOI-1 is located adjacent to upper Mortandad Canyon below the confluence with Effluent Canyon.

Completion Type: Single completion in the Puye Formation.

Period of Record: Well completed in January 2005. Periodic manual checks for water through 2007. Monitoring of well ceased in 2007.

Remarks: MCOI-1 was dry when completed and has not contained water during periodic checks. Soundings for water throughout 2006 and 2007 have been dry with a total depth of about 814 ft below ground surface, encountering sand at total depth. This total depth is above the screen; thus it appears that the well screen in the 1-in.-diameter PVC may have parted from the tubing or has been somehow damaged, potentially rendering the well inoperative.

MCOI-1 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	815.0	825.5	6291.2	6280.8	10.5	None	None	825.5	6280.8	825.58	0.1	0.0	I	Tp

Note: Ground Elevation: 7106.20 ft; all measurements are from this elevation

4.15 MCOI-4

Location: MCOI-4 is located in lower Mortandad Canyon near the confluence with Ten Site Canyon and was about 70 ft upstream of MCOBT-4.4.

Completion Type: Single completion at the base of the Puye Formation fanglomerate member and the top of Cerros del Rio basalt.

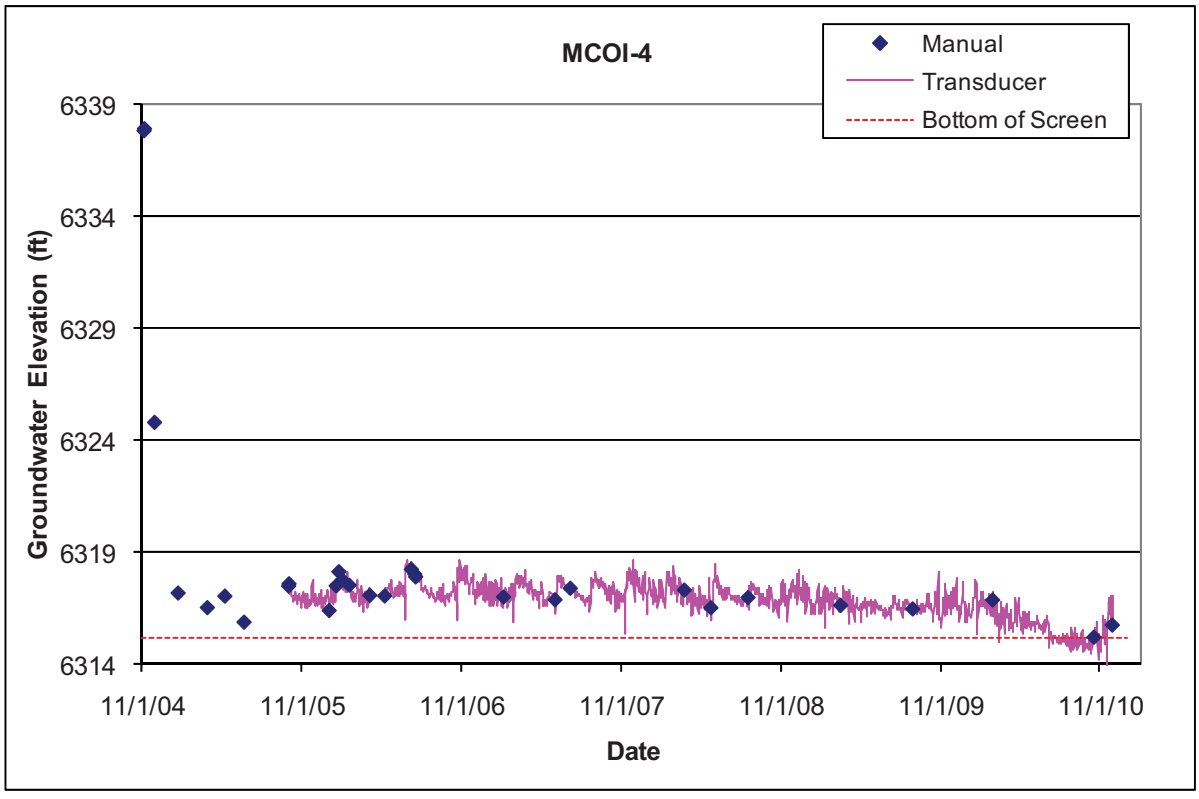
Period of Record: Well completed in November 2004, transducer installed October 2005, data through 2010.

Remarks: From 2006 to 2009, the water level in MCOI-4 was 2 to 3 ft higher than in adjacent well MCOBT-4.4 and relatively constant about 1 ft above the bottom of the screen. During plugging operations at MCOBT-4.4 from July 15 to 17, 2009, the water level at MCOI-4 rose about 1 ft and then declined over the next two weeks. The water level in the sump fluctuates indicating that the sump is not competent.

MCOI-4 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	499.0	522.0	6338.2	6315.2	23.0	524.0	6313.2	522.0	6315.2	525.7	3.7	11.6	I	Tpf

Note: Ground Elevation: 6837.20 ft; all measurements are from this elevation



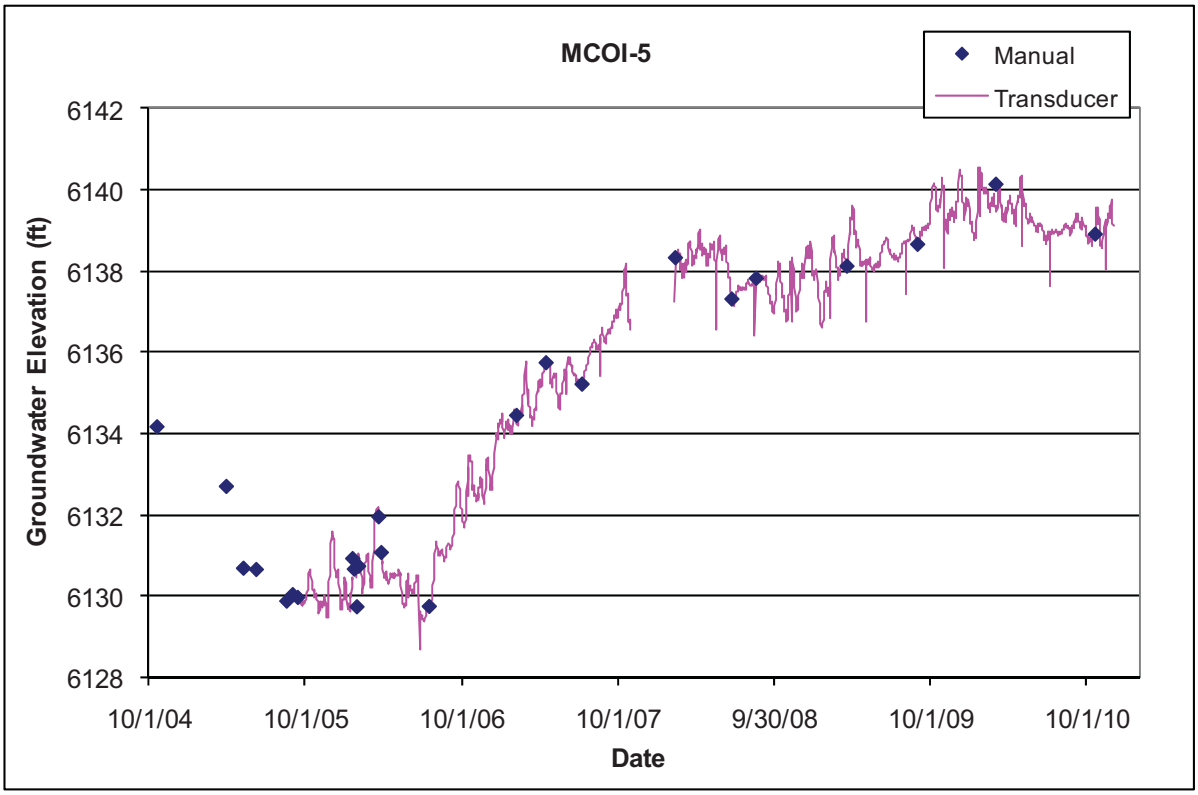
4.16 MCOI-5

Location: MCOI-5 is located in lower Mortandad Canyon about 70 ft northwest of regional aquifer well R-15.
Completion Type: Single completion in Cerros del Rio basalt.
Period of Record: Well completed in October 2004, transducer installed August 2005, data through 2010.
Remarks: The transducer was removed for bailing sampling in 2005. A dedicated submersible pump was installed March 2006. The intermediate groundwater has a delayed response to atmospheric pressure fluctuations.

MCOI-5 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	689.0	699.0	6130.7	6120.7	10.0	696.0	6123.7	699.0	6120.7	702.7	3.7	11.6	I	Tb4

Note: Brass cap elevation: 6819.70 ft; all measurements are from this elevation



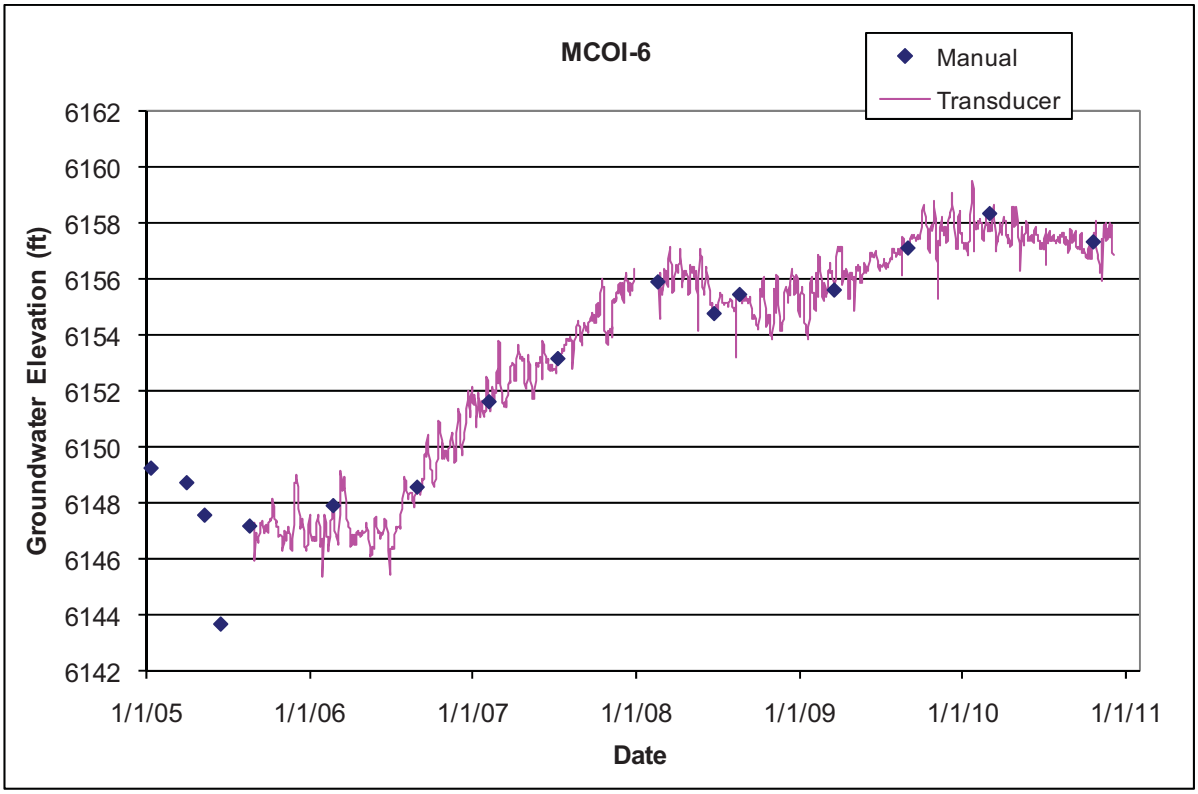
4.17 MCOI-6

Location: MCOI-6 is located in lower Mortandad Canyon about 160 ft northeast of MCOI-5.
Completion Type: Single completion in Cerros del Rio basalt.
Period of Record: Well completed in January 2005, transducer installed August 2005, data through 2010.
Remarks: The groundwater level is about 20 ft above the top of the screen and 17 to 18 ft higher than at MCOI-5. The intermediate groundwater has a delayed response to atmospheric pressure fluctuations.

MCOI-6 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	686.0	708.3	6125.1	6102.8	22.3	689.0	6122.1	708.3	6102.8	713.2	4.9	15.3	I	Tb4

Note: Brass cap elevation: 6811.10 ft; all measurements are from this elevation



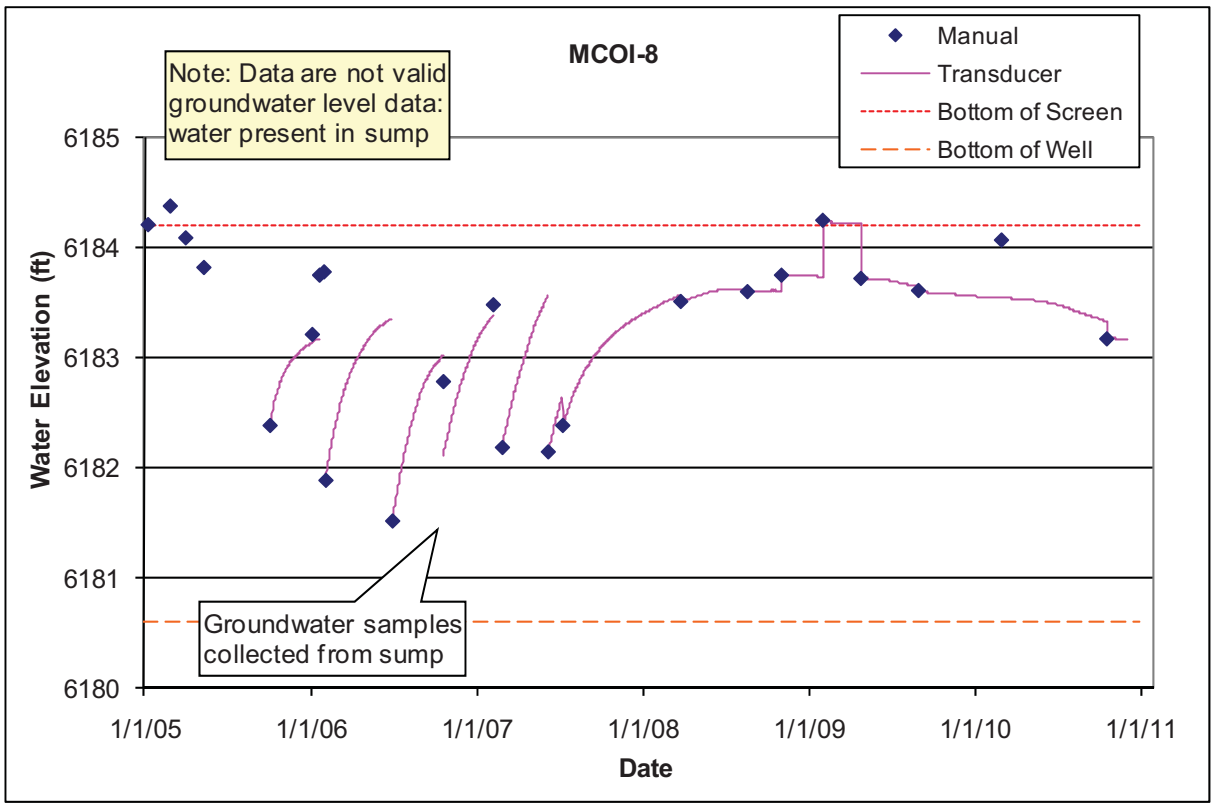
4.18 MCOI-8

Location: MCOI-8 is located in lower Mortandad Canyon above the confluence with Ten Site Canyon.
Completion Type: Single completion in Cerros del Rio basalt.
Period of Record: Well completed in January 2005, transducer installed August 2005, data through 2010.
Remarks: Since well completion, water has been measured in the sump of the well; thus data are not valid groundwater level data.

MCOI-8 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	665.0	675.0	6194.2	6184.2	10.0	None	None	675.0	6184.2	678.6	3.6	11.4	I	Tb4

Note: Ground Elevation: 6859.20 ft; all measurements are from this elevation



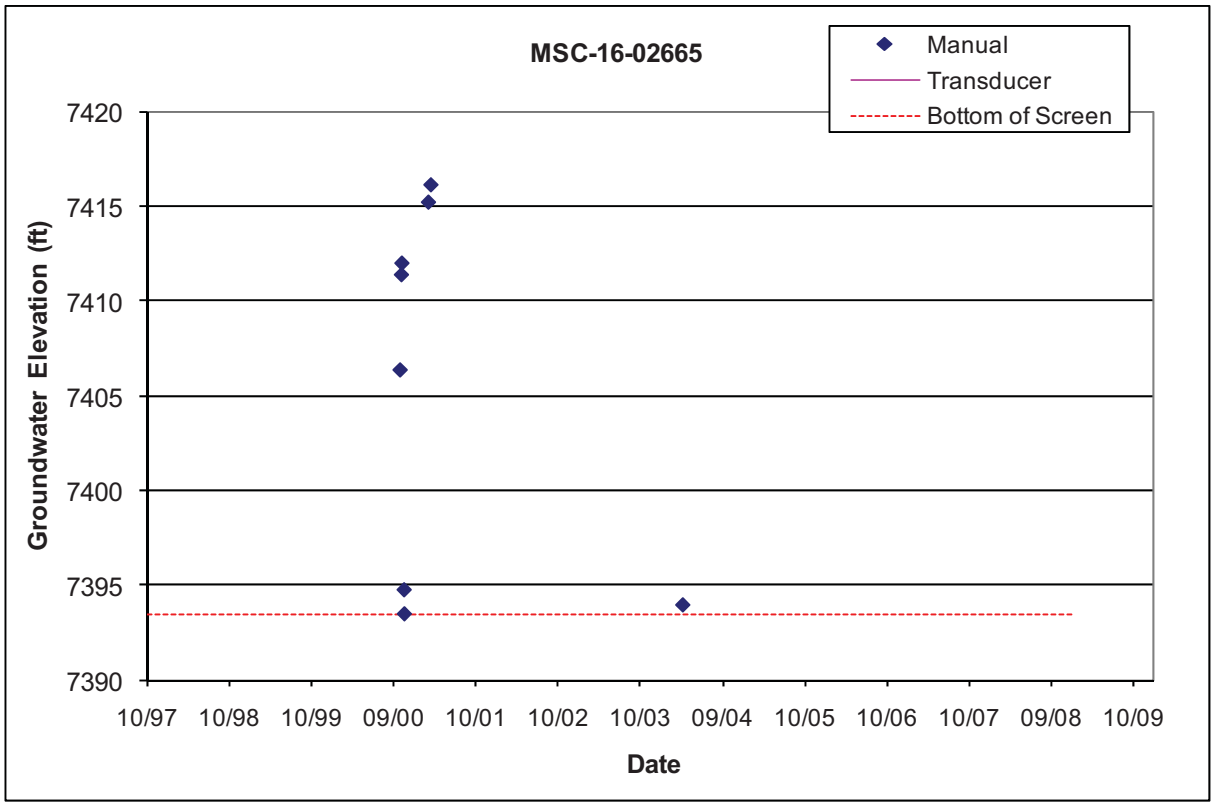
4.19 MSC-16-02665

Location: MSC-16-02665 is located at TA-16 at the head of Martin Spring Canyon (S-Site Canyon) about 1500 ft west of R-48 and about 700 ft northwest of Martin Spring.
Completion Type: Single completion in Unit 3 of the Bandelier tuff.
Period of Record: Well completed October 1997, no transducer has been installed, periodic manual measurements through April 2010.
Remarks: MSC-16-02665 has usually been dry; water has been observed in the well after heavy precipitation periods and snowmelt runoff (LANL 2003, p. 4-58). The well was dry when checked in the spring of 2005, 2006, 2007, 2008, 2009, and 2010.

MSC-16-02665 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	93.5	123.5	7423.4	7393.4	30.0	None	None	123.5	7393.4	124.0	0.5	0.3	I	Qbt3

Note: Ground Elevation: 7516.92 ft; all measurements are from this elevation



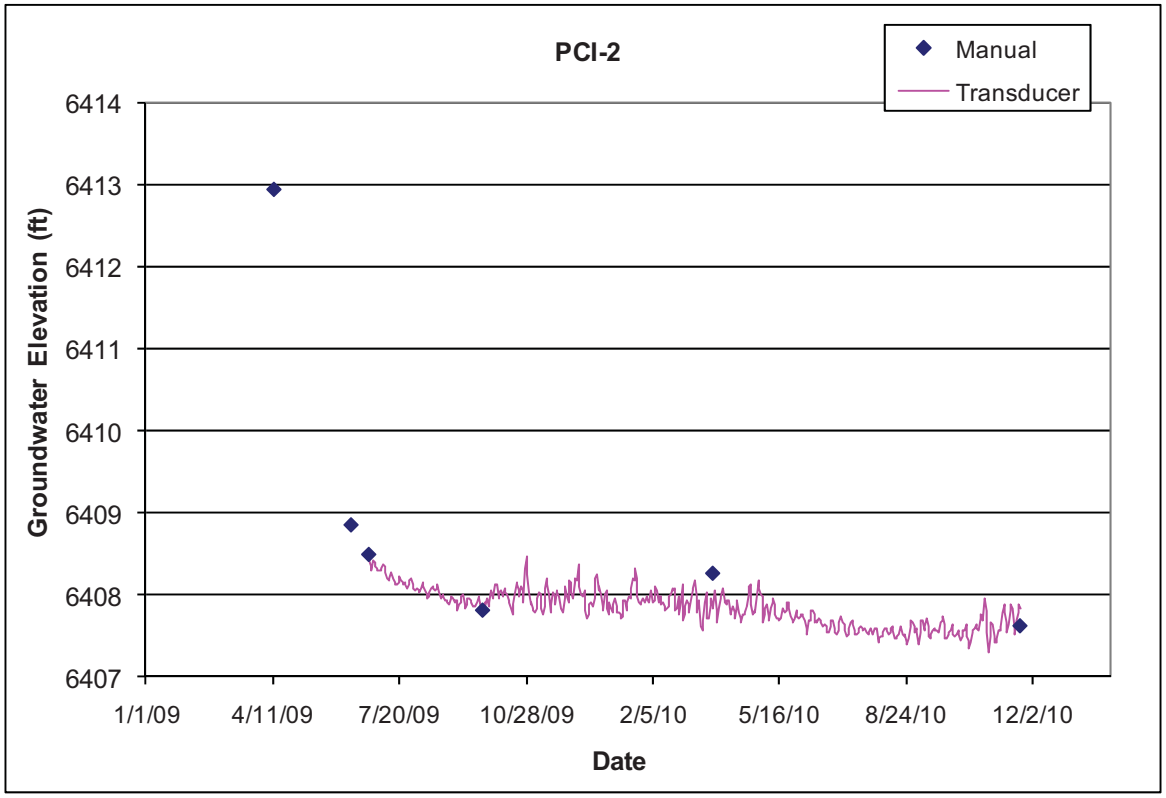
4.20 PCI-2

Location: PCI-2 is located in middle Pajarito Canyon about 150 ft west and upstream of R-17.
Completion Type: Single completion in the Puye fanglomerates and about 35 ft above Tschicoma dacite (LANL September 2009c).
Period of Record: Well completed April 2009, transducer installed June 25, 2009; data through 2010.
Remarks: The well is 100% barometrically efficient; however, the aquifer exhibits a delayed response to atmospheric pressure fluctuations.

PCI-2 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (Gal.)	Hydro Zone Code	Geo Unit Code
1	512.0	522.0	6409.0	6399.0	10.0	529.3	6391.7	522.0	6399.0	533.3	11.3	2.9	I	Tpf

Note: Brass Cap Elevation: 6920.95 ft; all measurements are from this elevation



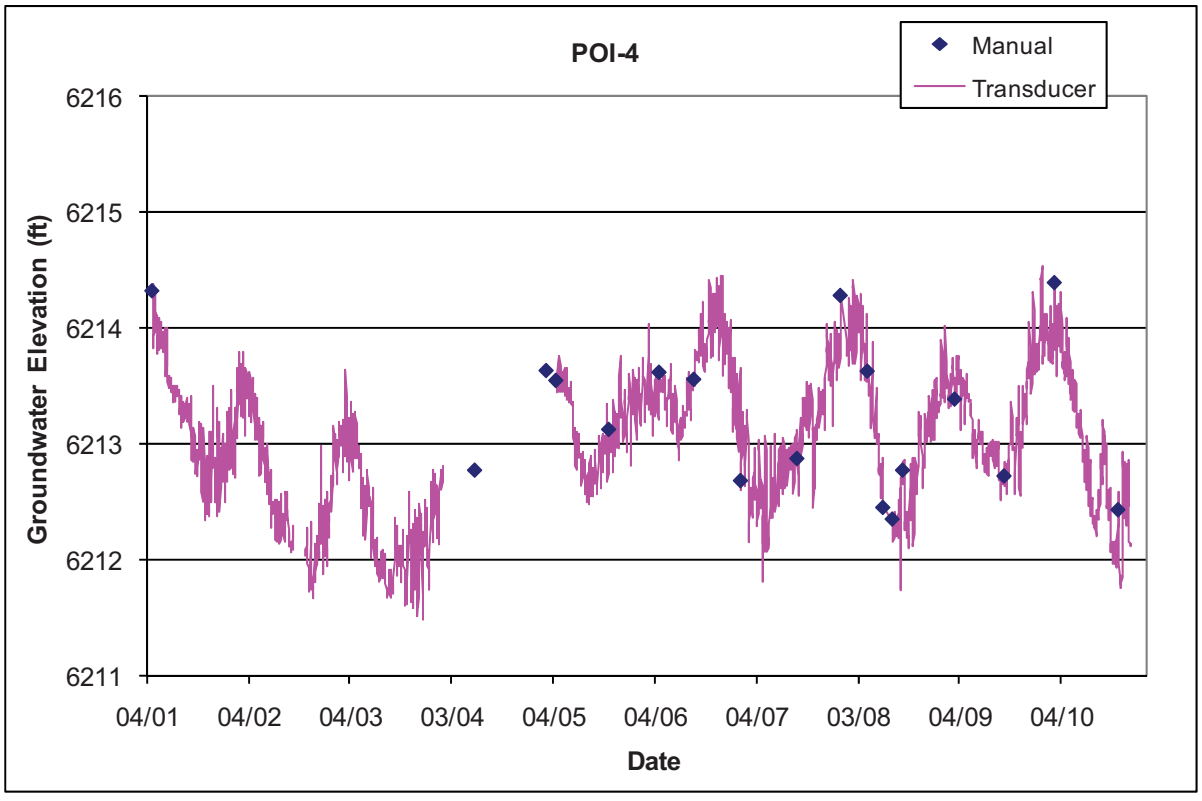
4.21 POI-4

Location: POI-4 is located in lower Pueblo Canyon about 800 ft upstream of TW-1 and about 370 ft north of supply well O-1.
Completion Type: Single completion in Cerros del Rio basalt.
Period of Record: Well completed in 1996, transducer installed April 2001 and again in April 2005; data through 2010.
Remarks: The well is 100% barometrically efficient; the groundwater displays a delayed response to atmospheric pressure fluctuations. The intermediate groundwater shows a seasonal water level fluctuation, generally lower in the summer and higher in the winter.

POI-4 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	159.0	174.0	6213.3	6198.3	15.0	173.0	6199.3	174.0	6198.3	176.5	2.5	6.2	I	Tb4

Note: Ground Elevation: 6372.29 ft; all measurements are from this elevation



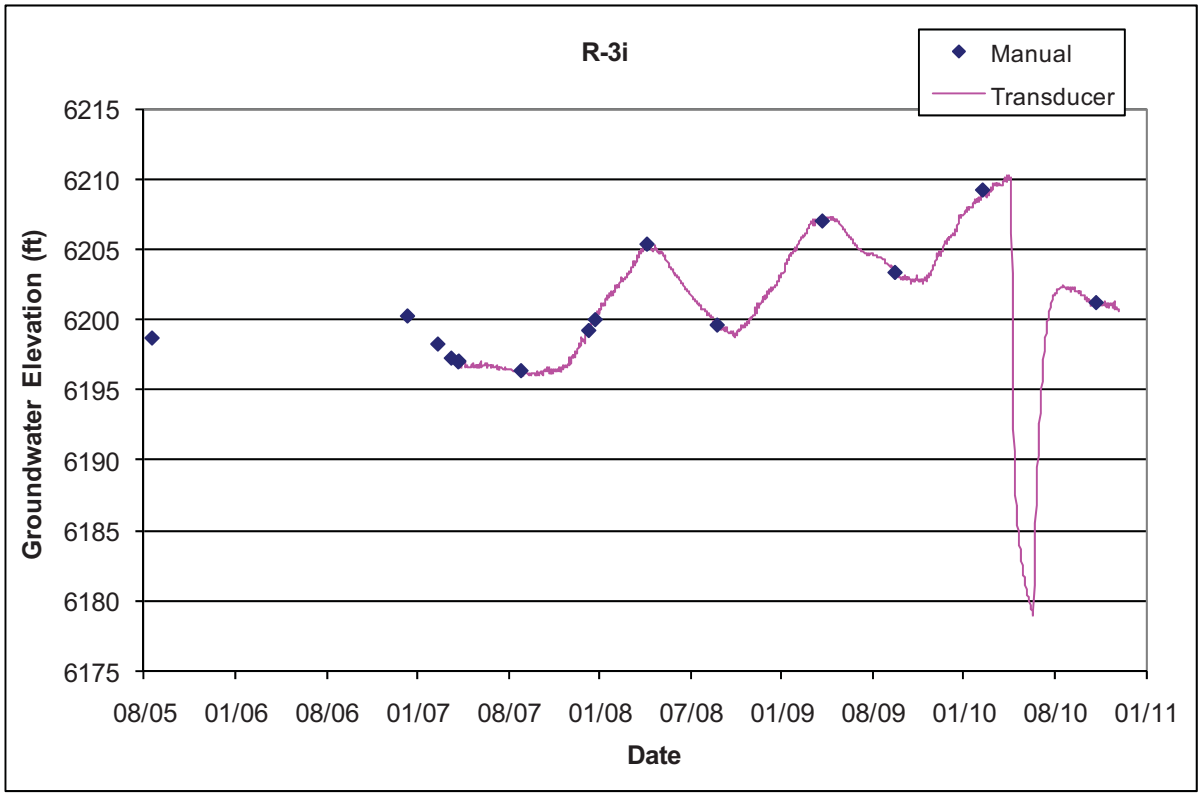
4.22 R-3i

Location: R-3i is located in lower Pueblo Canyon about 240 ft west of intermediate well POI-4 and about 425 ft northwest of supply well O-1.
Completion Type: Single completion in the Cerros del Rio basalt.
Period of Record: Well completed August 2005, transducer installed April 2007, data through 2010.
Remarks: The well is 100% barometrically efficient; the groundwater does not respond to atmospheric pressure fluctuations. The groundwater level rises during winter and falls during summer, but did not show a significant response to snowmelt runoff in 2007, 2008, or 2010. The intermediate groundwater appears to show a seasonal water level fluctuation similar to POI-4, but the water level at R-3i is 10 to 15 ft lower than at POI-4. The perched intermediate groundwater at R-3i responded to drilling activities at R-3 in the summer of 2010. When the base of the Cerros del Rio basalt was penetrated at R-3, the groundwater apparently drained into deeper units through the R-3 borehole until the casing was set and the annular seal emplaced at R-3.

R-3i Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	215.2	220	6175.0	6170.2	4.8	217.0	6173.2	220.0	6170.2	220.34	0.3	0.2	I	Tb4

Note: Ground Elevation: 6390.15 ft; all measurements are from this elevation



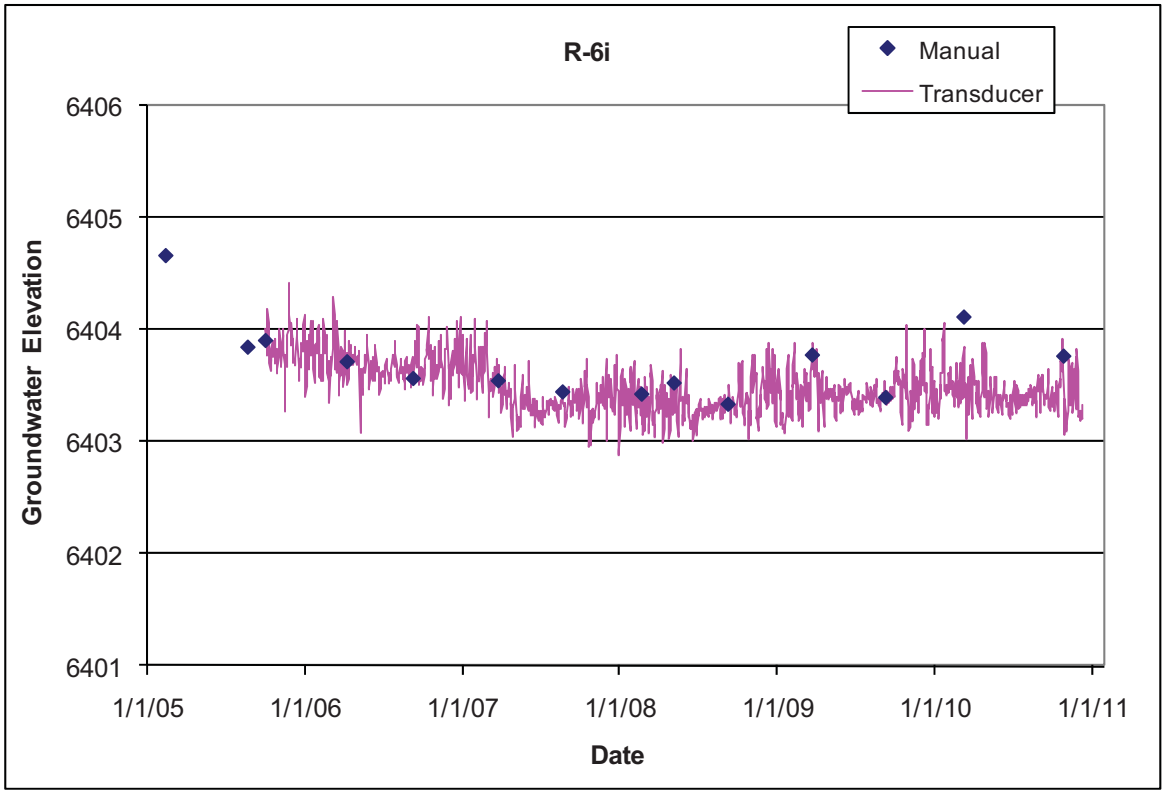
4.23 R-6i

Location: R-6i is located at the eastern extent of DP Mesa near the confluence of DP Canyon and Los Alamos Canyon and adjacent to regional aquifer monitoring well R-6.
Completion Type: Single completion in the Puye Formation fanglomerate member.
Period of Record: Well completed December 2004, transducer installed October 2005, data through 2010.
Remarks: The well is 100% barometrically efficient; the groundwater does not respond to atmospheric pressure fluctuations. The perched intermediate groundwater did not respond to snowmelt runoff in 2007, 2008, or 2010.

R-6i Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	602.0	612	6394.9	6384.9	10.0	609.0	6387.9	612.0	6384.9	615	3.0	9.2	I	Tpf

Note: Brass Cap Ground Elevation: 6996.9 ft; all depths are from this elevation



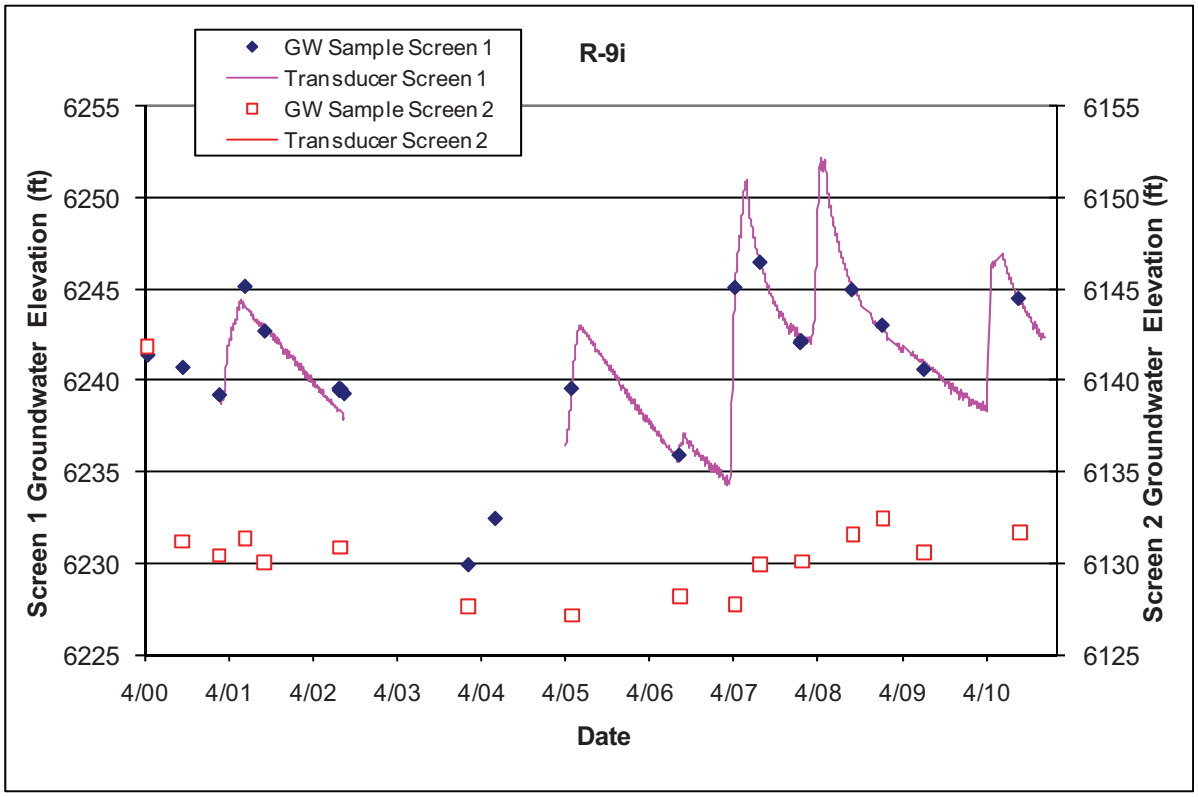
4.24 R-9i

Location: R-9i is located in Los Alamos Canyon near the eastern LANL boundary and adjacent to R-9.
Completion Type: Dual Westbay® completion; both screens in Cerros del Rio basalt.
Period of Record: Well completed March 2000, transducers installed March 2001, intermittent data through 2010.
Remarks: The screens are about 70 ft apart and the heads in the two intermediate zones are about 110 ft apart. The water level at screen 1 is about 40 ft above the top of the screen; the water level at screen 2 is about 15 ft above the top of the screen. Groundwater at screen 1 appears to be recharged from large runoff events in lower Los Alamos Canyon; the water level responded to snowmelt runoff in 2001, 2005, 2007, 2008, and 2010 and to large storm runoff events in the summer of 2006, while the water level at screen 2 shows a reduced response.

R-9i Construction and Port Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Hydro Zone Code	Geo Unit Code	Port	Port Depth (ft)	Port Elev (ft)	Distance from Bottom of Screen (ft)	Sump Vol (L)	Comment
1	189.1	199.5	6194.1	6183.7	10.4	I	Tb4	**MP1A**	198.8	6184.4	0.7		Within screen
								PP1	204.1	6179.1	-4.6	13.3	Below screen
								MP1B	209.8	6173.4	-10.3	29.8	Below screen
2	269.6	280.3	6113.6	6102.9	10.7	I	Tb4	**MP2A**	278.8	6104.4	1.5		Within screen
								PP2	284.1	6099.1	-3.8	11.0	Below screen
								MP2B	289.8	6093.4	-9.5	27.5	Below screen

Note: Brass Cap Elevation is 6383.2 ft; all measurements are from this elevation;
MP = Monitoring Port, PP = Pumping Port; Ports shown in Bold are instrumented with transducers



4.25 R-12 (Intermediate)

Location: R-12 is located in lower Sandia Canyon near SR-4 and supply well PM-1.

Completion Type: Multiple completion, originally two screens in intermediate zones, one screen at the top of the regional aquifer—until September 2006 when the well was recompleted as two intermediate screens; screen 3 was plugged and abandoned on December 13, 2007.

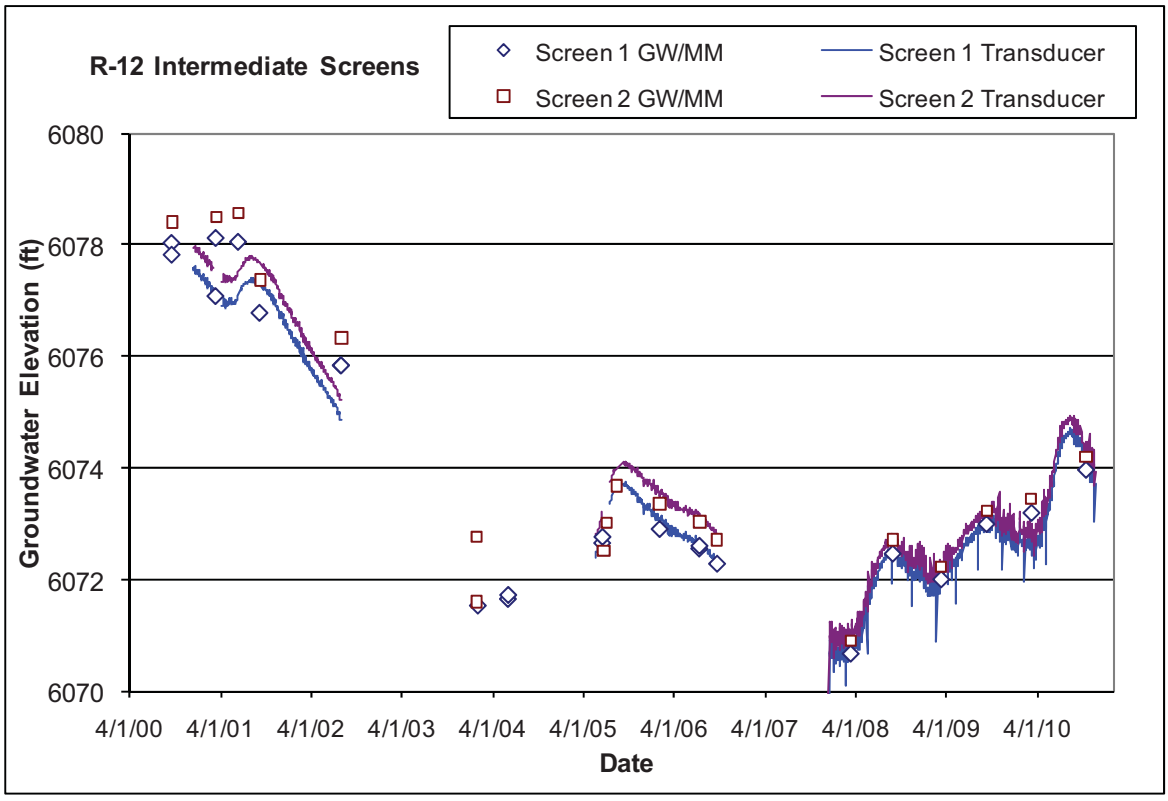
Period of Record: Westbay® system installed March 21, 2000, transducers installed December 14, 2000, intermittent data to September 21, 2006, when transducers were removed for removal of the Westbay® system for well rehabilitation and conversion. No water level data for most of 2007. Transducers were reinstalled at screens 1 and 2 on December 13, 2007; data through 2010.

Remarks: In December 2007, screen 3 was abandoned and a Baski packer with dual pump sampling system was installed at the two intermediate screens. Intermediate screens 1 and 2 have similar head values about 380 ft above the regional aquifer; intermediate screen 2 has a slightly higher head than screen 1. The intermediate screens responded to snowmelt runoff events in Los Alamos Canyon in 2001, 2005, 2008, and 2010; no data available during 2007 and no snowmelt runoff in 2009. The groundwater at screens 1 and 2 show a delayed response to atmospheric pressure fluctuations with a barometric efficiency of about 70%.

R-12 Construction Infomration

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Packer/ Sump Depth (ft)	Top of Packer/ Sump Elev (ft)	Sump Bottom Dept (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	459.0	467.5	6040.6	6032.1	8.5	465.0	6034.6	470.7	6028.9	470.7	3.2	10.0	I	Tb4
2	504.5	508.0	5995.1	5991.6	3.5	501.0	5998.6	508.0	5991.6	540.8	32.8	102.6	I	Tp
3	801.0	839.0	5698.6	5660.6	38	**Screen 3 Plugged and Abandoned December 2007**							RT	Tsfb

Brass Cap Elevation: 6499.60 ft; all measurements are from this elevation

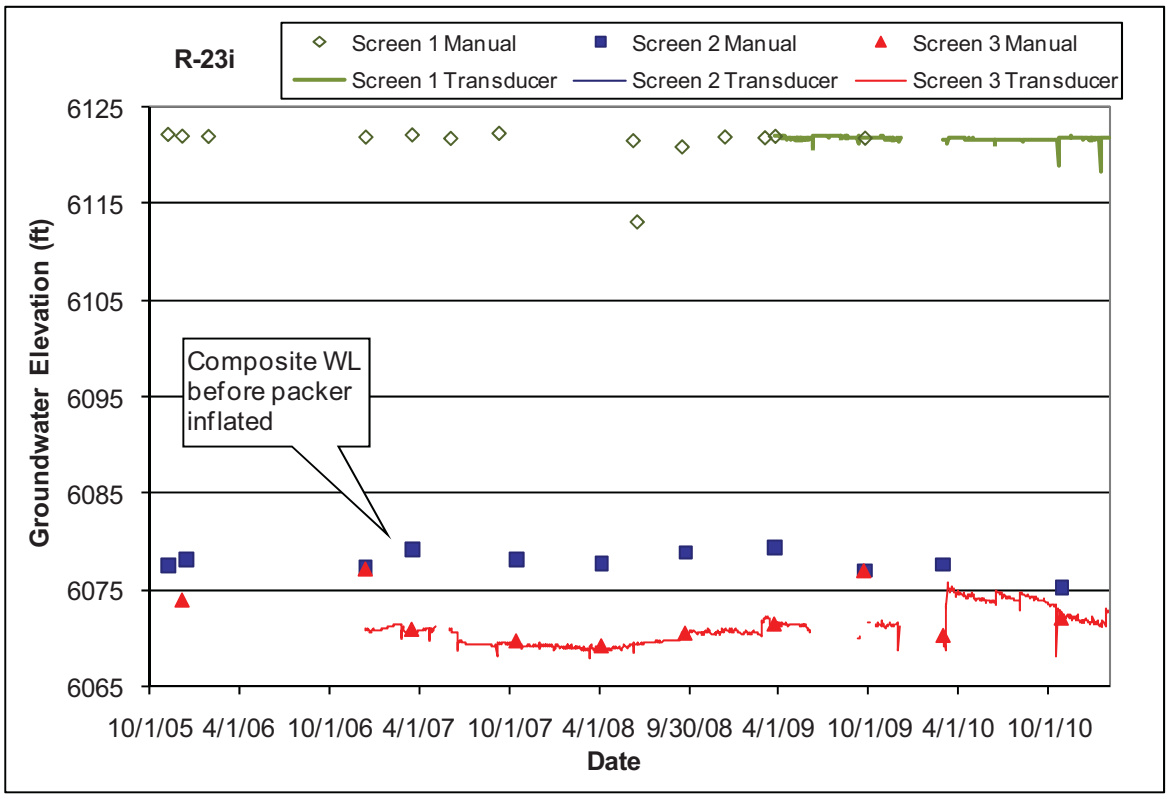


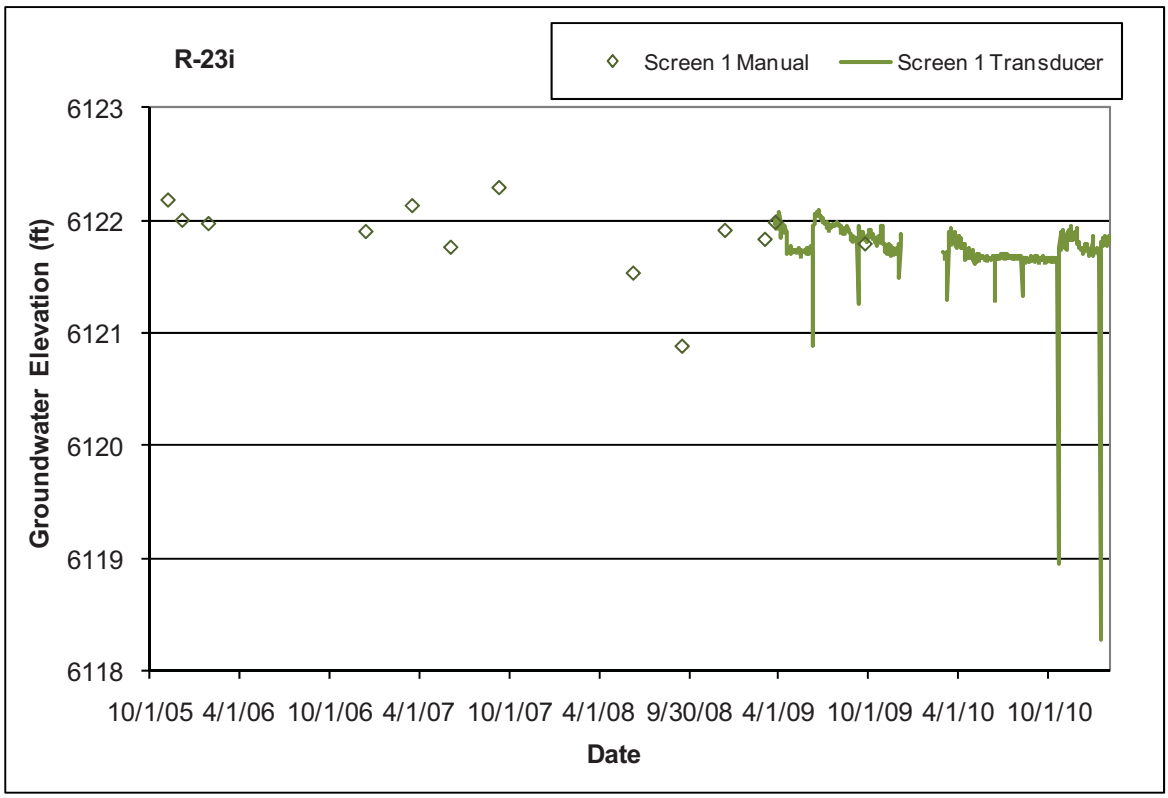
4.26 R-23i

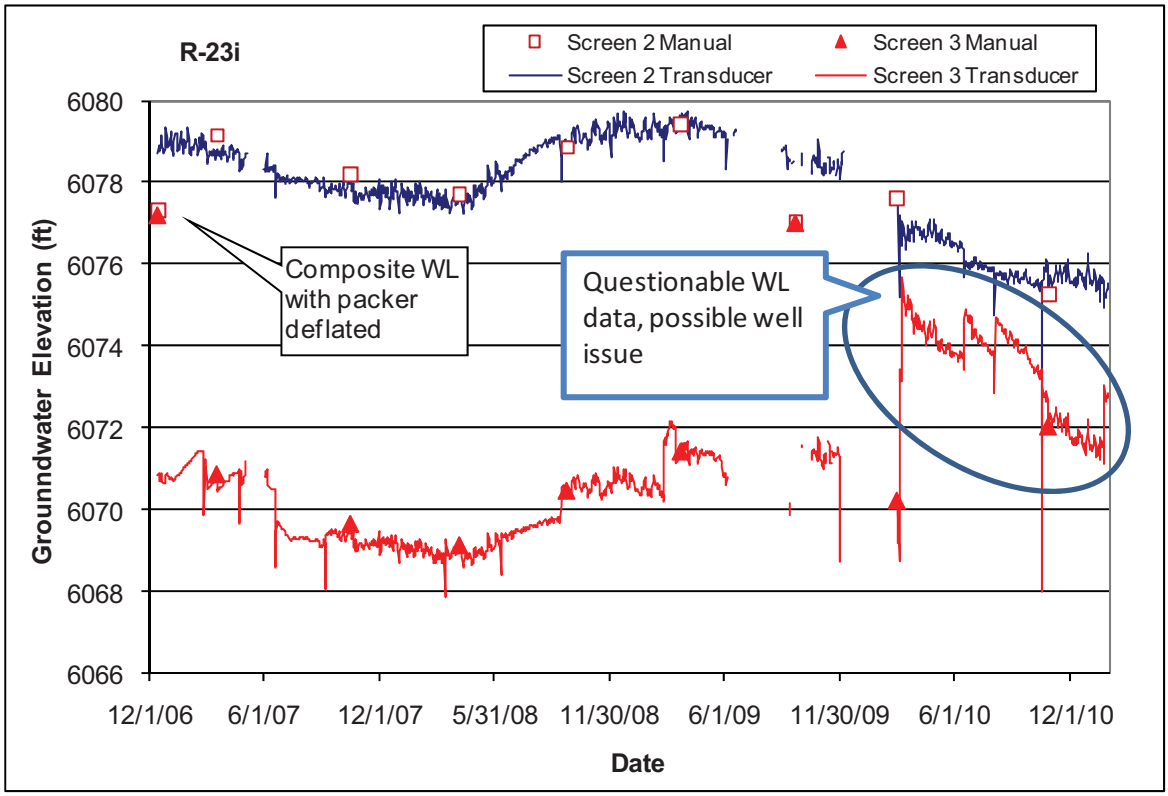
Location: R-23i is located in lower Pajarito Canyon near SR-4 and adjacent to regional well R-23.
Completion Type: Multiple completion, three screens, screen 1 is in a 2.1-in.-diameter piezometer and screens 2 and 3 are in a 4-in.-diameter well. A Baski packer and dual pump sampling system was installed at screens 2 and 3 in December 2006. All screens are in Cerros del Rio basalt.
Period of Record: Well completed November 2005; transducers installed at screens 2 and 3 in December 2006, transducer installed at screen 1 March 2009; data through 2010.
Remarks: The water levels at screens 2 and 3 are typically about 9 ft apart; the water level at screen 1 is about 44 ft higher than screen 2. The screen 3 gage tubing through the packer has shown occasional partial plugging, but water levels in the tubing appear to be representative of screen 3. Possible response to snowmelt runoff at screens 2 and 3 in the spring of 2008. Packer inflation problems in 2009 caused loss of screens 2 and 3 groundwater level data. The Baski system was removed from the well in December 2009 to repair the packer system. The repaired system was reinstalled March 2, 2010. During purging of cross flow at screen 3 in March 2010, the screen 3 water level increased with coincident water level fall at screen 2, indicating possible intermittent cross flow between screens 2 and 3, possibly through the formation.

R-23i Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Depth to Top of Packer/ Sump (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (Gal.)	Hydro Zone Code	Geo Unit Code	Comment
1	400.3	420.0	6127.6	6107.9	19.7			420.0	6107.9	425.3	5.3	4.4	I	Tb4	2.1 in. Piez
2	470.2	480.1	6057.7	6047.8	9.9	477.1	6050.8	495.3	6032.5	495.3	15.2	12.6	I	Tb4	4.5 in. well
3	524.0	547.0	6003.9	5980.9	23.0	516.7	6011.2	547.0	5980.9	550.7	3.7	3.1	I	Tb4	4.5 in. well
Note: Brass Cap Ground Elevation: 6527.88 ft; all measurements are from this elevation															




R-23i
Screen 1 Manual
Screen 1 Transducer
Groundwater Elevation (ft)
6123
6122
6121
6120
6119
6118
10/1/05 4/1/06 10/1/06 4/1/07 10/1/07 4/1/08 9/30/08 4/1/09 10/1/09 4/1/10 10/1/10
Date


R-23i
Screen 2 Manual
Screen 3 Manual
Screen 2 Transducer
Screen 3 Transducer
Grounndwater Elevation (ft)
6080
6078
6076
6074
6072
6070
6068
6066
Composite WL with packer deflated
Questionable WL data, possible well issue
12/1/06 6/1/07 12/1/07 5/31/08 11/30/08 6/1/09 11/30/09 6/1/10 12/1/10
Date

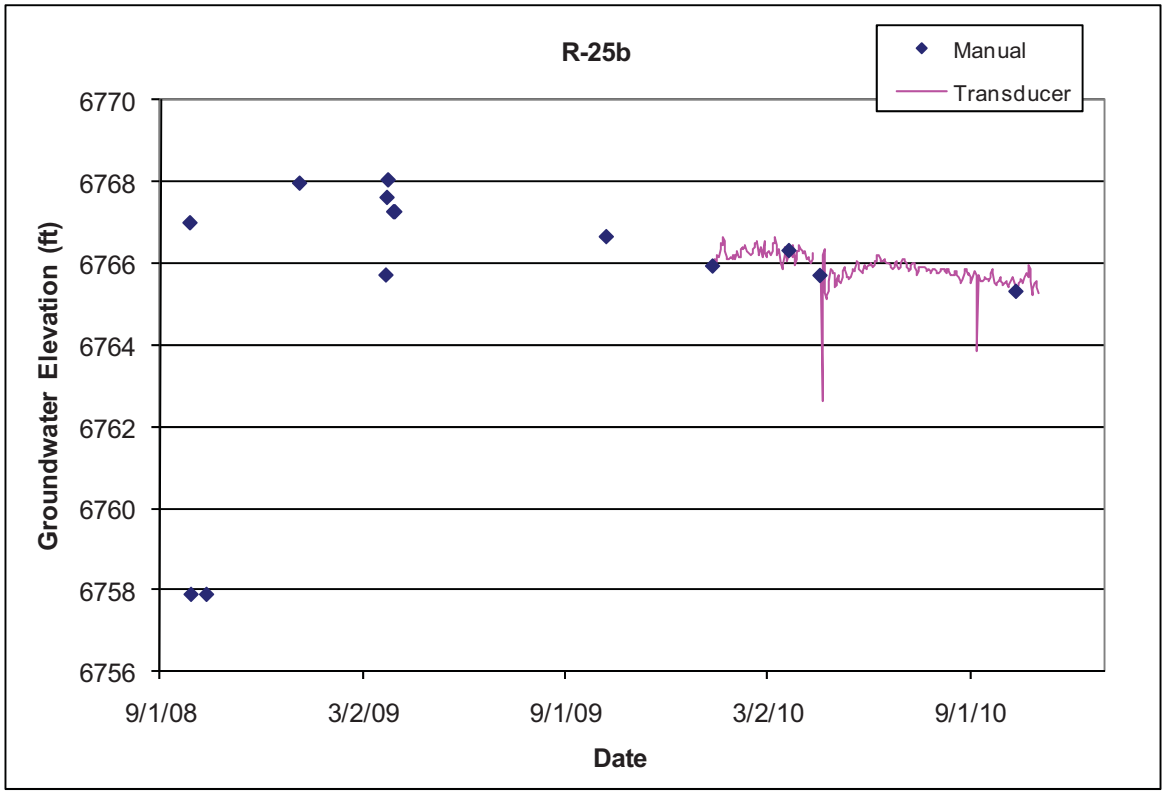
4.27 R-25b

Location: R-25b is located at TA-16 about 50 ft west of monitoring well R-25.
Completion Type: Single completion, one screen in the Otowi Member of the Bandelier Tuff at a similar elevation as R-25 screen 1.
Period of Record: Well completed October 2008. Transducer installed January 13, 2010; transducer data through 2010.
Remarks: R-25b is screened adjacent to R-25 screen 1.

R-25b Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Bottom of Well Elev (ft)	Hydro Zone Code	Geo Unit Code
1	750.0	770.8	6767.0	6746.2	20.8	770.0	6747.0	770.8	6746.2	782.3	11.5	6734.7	I	Qbo

Note: Brass Cap Ground Elevation: 7517.00 ft; all measurements are from this elevation



4.28 R-25c

Location: R-25c is located at TA-16 about 50 ft west of monitoring well R-25b and about 100 ft west of monitoring well R-25.

Completion Type: Single completion, one screen in the Puye fanglomerates at a similar elevation as R-25 screen 3.

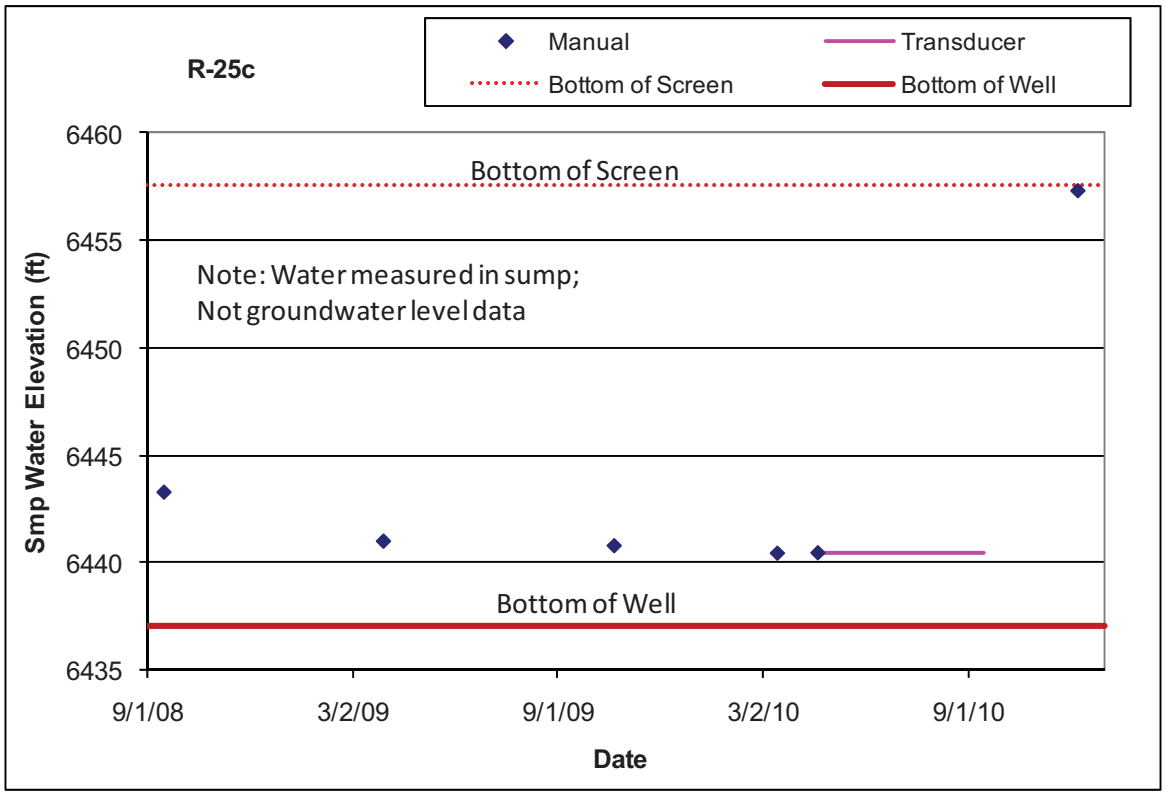
Period of Record: Well completed September 2008, transducer installed December 16, 2009. Data through 2010.

Remarks: R-25c is a replacement for R-25 screen 3. The borehole contained water during drilling, but the well was dry (some water in sump) at completion and did not retain water during attempted slug testing (LANL December 2008). A seismometer was installed at the bottom of the well in September 2010. The sump water was raised to near the bottom of the screen during the seismometer installation.

R-25c Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Bottom of Well Elev (ft)	Hydro Zone Code	Geo Unit Code
1	1039.6	1060.0	6478.0	6457.6	20.4	None	None	1080.6	20.6	6437.0	I	Tpf

Note: Brass Cap Ground Elevation: 7517.59 ft; all measurements are from this elevation



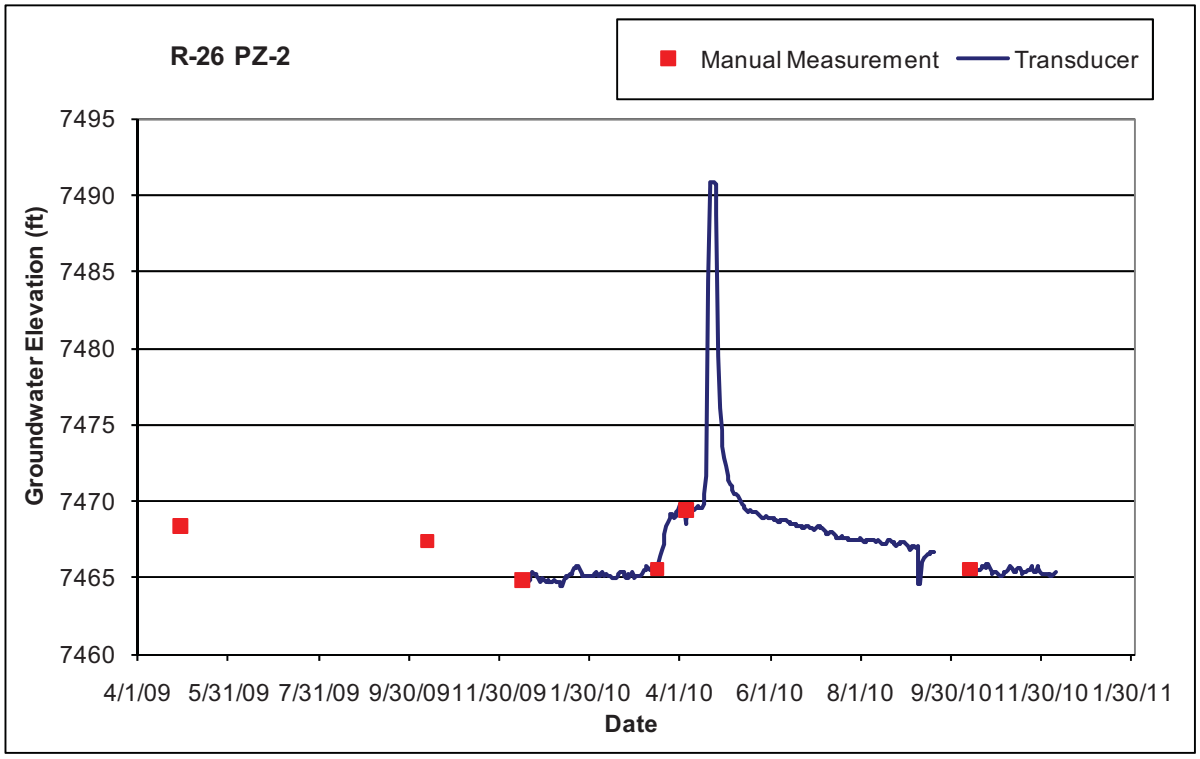
4.29 R-26 PZ-2

Location: R-26 PZ-2 is located at TA-16 about 90 ft southwest of monitoring well R-26.
Completion Type: Dual completion, R-26 PZ-1 is the deeper piezometer and R-26 PZ-2 is the shallower piezometer. Both screens are located in Unit 3 of the Tshirege Member of the Bandelier Tuff.
Period of Record: Piezometer installed October 2003, manual measurements began in April 2009, and transducer installed December 16, 2009; transducer data through 2010. The transducer malfunctioned September 2010 and was replaced October 2010.
Remarks: R-26 PZ-1 has always been dry when checked. The groundwater at R-26 PZ-2 appears to have responded to snowmelt runoff in the spring of 2010.

R-26 Piezometer Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Bottom of Sump Depth (ft)	Bottom of Sump Elev (ft)	Sump Length (ft)	Sump Vol (gal.)	1 CV Purge Vol (gal.)	Hydro Zone Code	Geo Unit Code
PZ-1	230.0	250.0	7409.6	7389.6	20.0	250.0	7389.6	0.0	0.0	0.0	I	Qbt3t
PZ-2	150.0	180.0	7489.6	7459.6	30.0	185.0	7454.6	5.0	0.8	1.5	I	Qbt3t

Note: R-26 Ground Elevation: 7639.56 ft; all measurements are from this elevation; Top of Casing Elevation: 7641.9



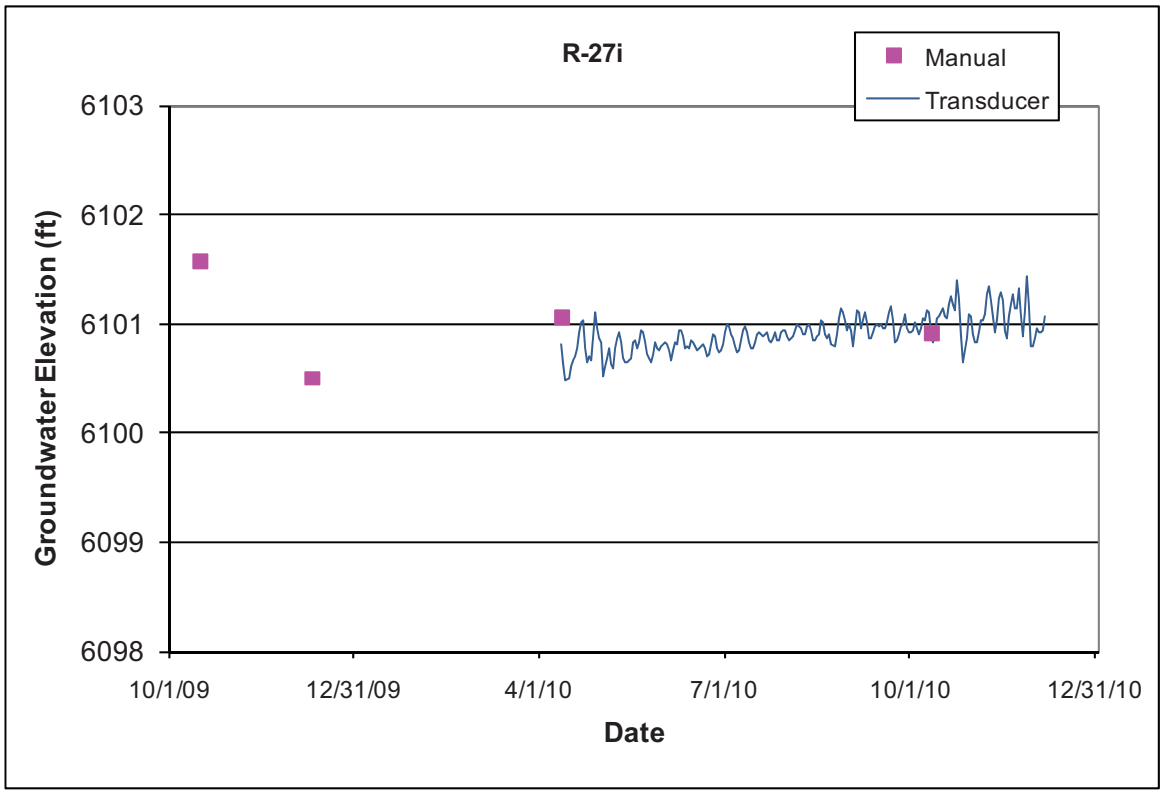
4.30 R-27i

Location: R-27i is located in Water Canyon near monitoring well R-27.
Completion Type: Single completion in an intermediate perched zone; one screen in the Puye fanglomerates.
Period of Record: Well completed October 2009. Dedicated Bennett pump and transducer installed April 13, 2010; transducer data through 2010.
Remarks: The groundwater level is about 2 ft above the top of the screen. The well is 100% barometrically efficient; the groundwater has no immediate response to atmospheric pressure fluctuations, however, the groundwater shows a delayed response to atmospheric pressure fluctuations.

R-27i Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Sump Bottom Depth (ft)	Bottom of Well Elev (ft)	Sump Length (ft)	Sump Vol (gal)	Hydro Zone Code	Geo Unit Code
1	619.0	629.0	6099.0	6089.0	10.0	627.9	6090.1	630.2	6087.8	1.2	1.2	I	Tpf

Note: Brass Cap Ground Elevation: 6717.97 ft; all measurements are from this elevation



4.31 R-47i

Location: R-47i is located at TA-14 downgradient from TA-16 and about 0.5 mi east of well CdV-16-2(i)r and about 0.8 mi northwest of well CdV-R-15-3.

Completion Type: Single completion in an intermediate perched zone; one screen in the Puye fanglomerates.

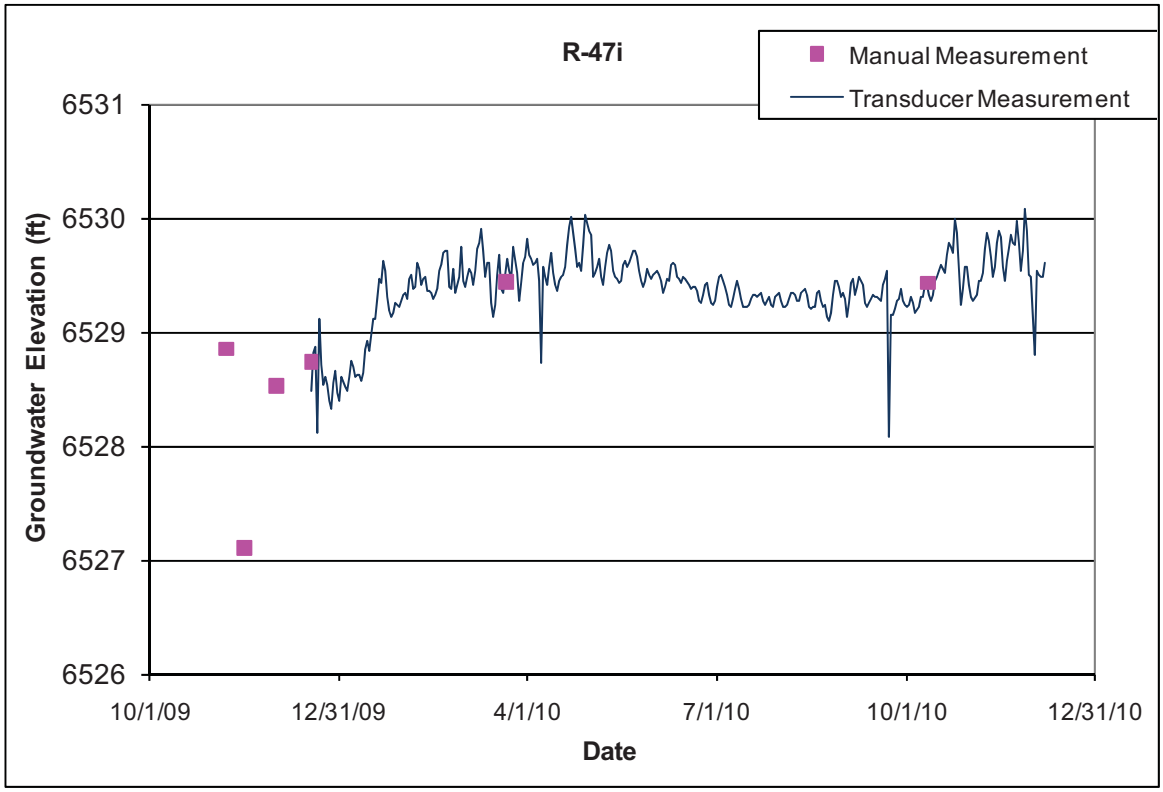
Period of Record: Well completed November 15, 2009. Dedicated submersible pump and transducer installed December 18, 2009; transducer data through 2010.

Remarks: The groundwater level is about 11 ft above the top of the screen. The well is 100% barometrically efficient; the groundwater has no immediate response to atmospheric pressure fluctuations.

R-47i Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Sump Bottom Depth (ft)	Bottom of Well Elev (ft)	Sump Length (ft)	Sump Vol (gal)	Hydro Zone Code	Geo Unit Code
1	840.0	860.6	6518.4	6497.8	20.6	860.3	6498.1	865.5	6492.9	4.9	5.0	I	Tpf

Note: Brass Cap Ground Elevation: 7358.41ft; all measurements are from this elevation



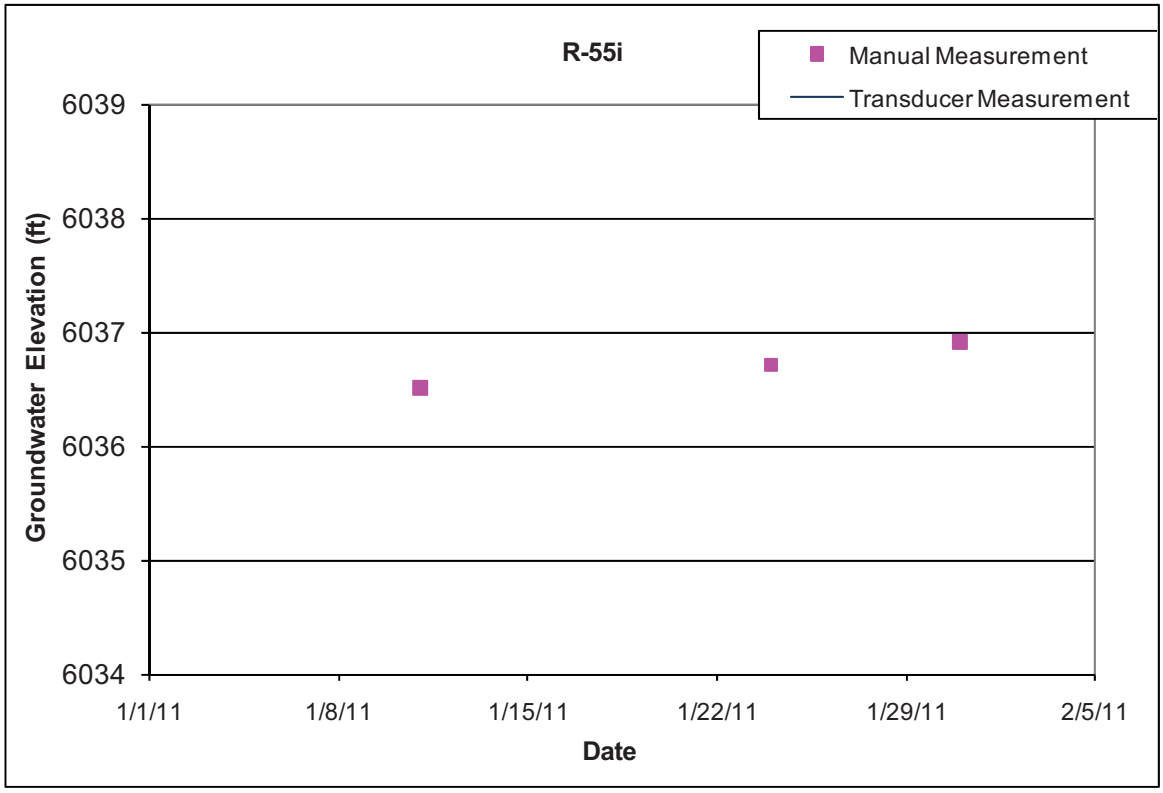
4.32 R-55i

Location: R-55i is located in lower Cañada del Buey adjacent to R-55.
Completion Type: Single completion in an intermediate perched zone; one screen in unconsolidated sediments associated with basaltic lava flows of the Cerros del Rio basalts.
Period of Record: Well completed January 2011. Transducer installation is pending.
Remarks: The groundwater level before aquifer testing on January 31, 2011, was 498.0 ft below ground surface at an elevation of 6036.91 ft.

R-55i Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Sump Bottom Depth (ft)	Bottom of Well Elev (ft)	Sump Length (ft)	Sump Vol (gal)	Hydro Zone Code	Geo Unit Code
1	510.0	531.1	6024.9	6003.8	21.1			541.4	5993.5	10.3	10.5	I	Tb4

Note: Brass Cap Ground Elevation: 6534.91 ft; all measurements are from this elevation



4.33 SCI-1

Location: SCI-1 is located in Sandia Canyon between intermediate wells LAOI-3.2 in Los Alamos Canyon to the north and MCOI-6 in Mortandad Canyon to the southwest.

Completion Type: Single completion in the Puye Formation fanglomerate member; the screen is located above the Cerros del Rio basalt.

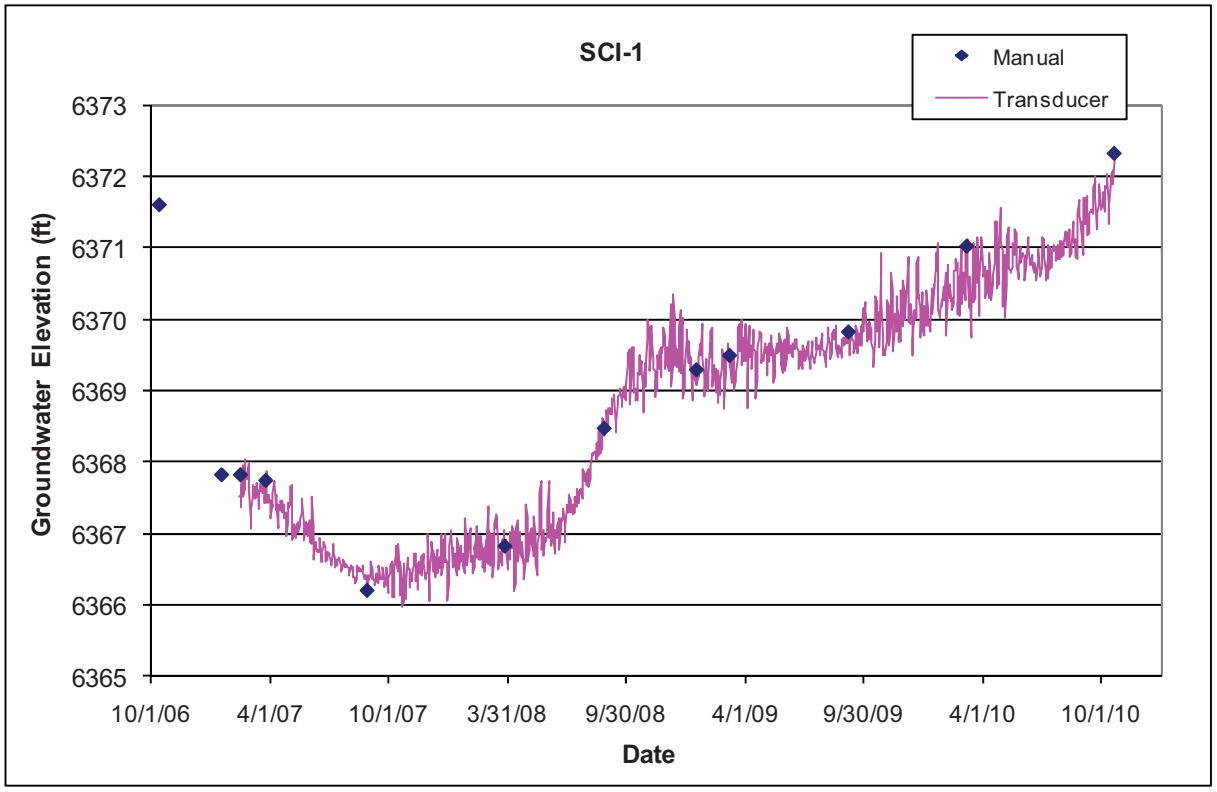
Period of Record: Well completed October 2006, transducer installed in February 2007, data through 2010.

Remarks: Originally drilled as core hole SCC-1, completed as intermediate well and named SCI-1. The well is immediately 100% barometrically efficient; however the groundwater shows a delayed response to atmospheric pressure fluctuations.

SCI-1 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	358.4	377.9	6379.9	6360.4	19.5	376.0	6362.3	377.9	6360.4	377.9	0.0	0.0	I	Tpf

Note: Brass Cap Elevation: 6738.27 ft; all measurements are from this elevation



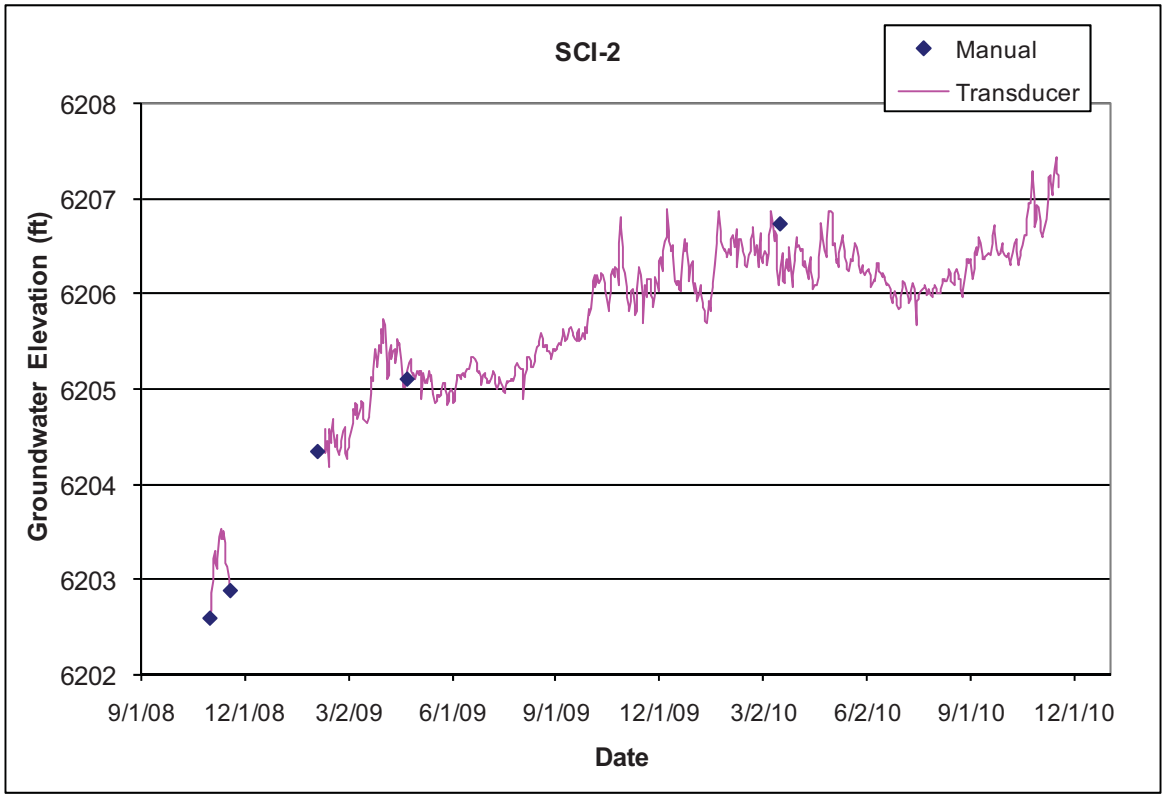
4.34 SCI-2

Location: SCI-2 is located in middle Sandia Canyon adjacent to regional monitoring well R-43.
Completion Type: Single completion in an intermediate perched zone in the Cerros del Rio basalt.
Period of Record: Well completed August 2008, temporary transducer installed November 2008 for R-42 and R-43 aquifer testing; dedicated Bennett pump and transducer installed February 10, 2009; data through 2010.
Remarks: The initial groundwater elevation at completion of the well was 6221.4 ft; subsequent measurements have been about 15 ft lower. The well is 100% barometrically efficient, the groundwater does not respond to atmospheric pressure fluctuations; however, the groundwater shows a delayed response to atmospheric pressure fluctuations.

SCI-2 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	548.0	568.0	6187.7	6167.7	20.0	548.7	6187.0	568.0	6167.7	570	2.0	0.2	I	Tb4

Note: Brass Cap Elevation: 6735.70 ft; all measurements are from this elevation



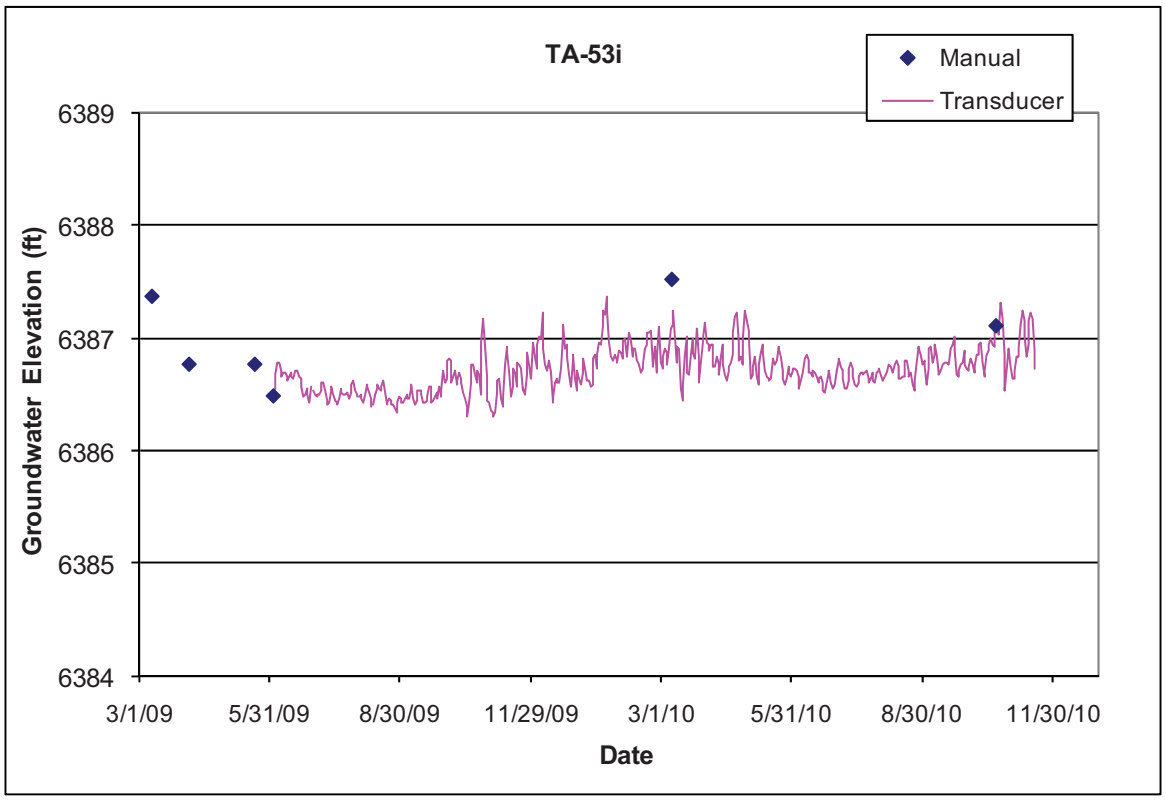
4.35 TA-53i

Location: TA-53i is located on Mesita de Los Alamos at TA-53 about 1400 ft northwest of SCI-1.
Completion Type: Single completion in a perched intermediate zone in the Puye fanglomerates just above the Cerros del Rio basalt.
Period of Record: Well completed March 2009, transducer installed June 2009; data through 2010.
Remarks: The well is 100% barometrically efficient, the groundwater has no immediate response to atmospheric pressure fluctuations; however, the aquifer shows a delayed response to atmospheric pressure fluctuations.

TA-53i Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	600.0	610	6387.2	6377.2	10.0	610.8	6376.4	610.0	6377.2	620.8	10.8	41.7	I	Tpf

Note: Brass Cap Elevation: 6987.17 ft; all measurements are from this elevation



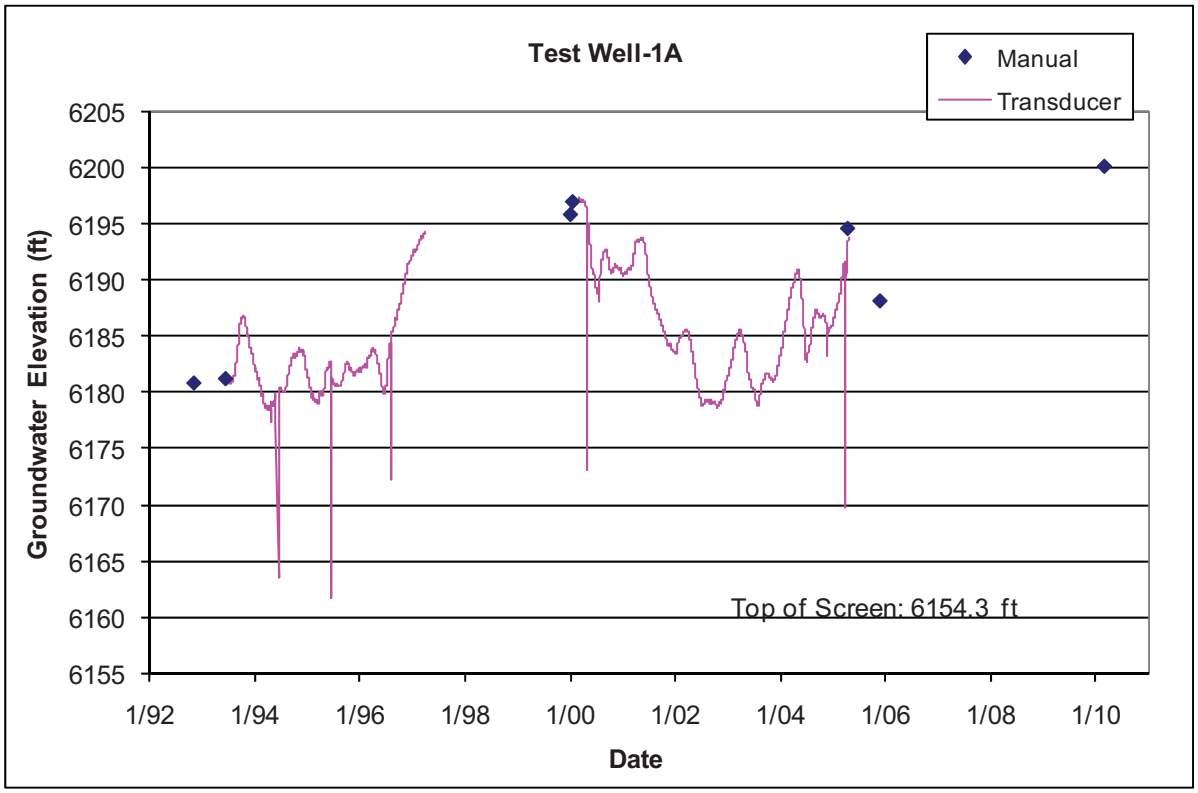
4.36 Test Well 1A

Location: TW-1A is located in lower Pueblo Canyon adjacent to TW-1.
Completion Type: Single completion in Cerros del Rio basalt.
Period of Record: Well completed in 1950, transducer installed June 1993, intermittent data to April 2005 when problems were encountered with equipment and the transducer was removed from the well.
Remarks: The wellhead equipment was removed from the well in February 2006 in preparation for plugging and abandonment of the well. The well was plugged and abandoned March 15, 2010 (LANL April 2010).

TW-1A Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	215.0	225	6154.3	6144.3	10.0	None	None	225.0	6144.3	225	0.0	0.0	I	Tb4

Note: TW-1A Ground Elevation: 6369.28 ft; all measurements are from this elevation



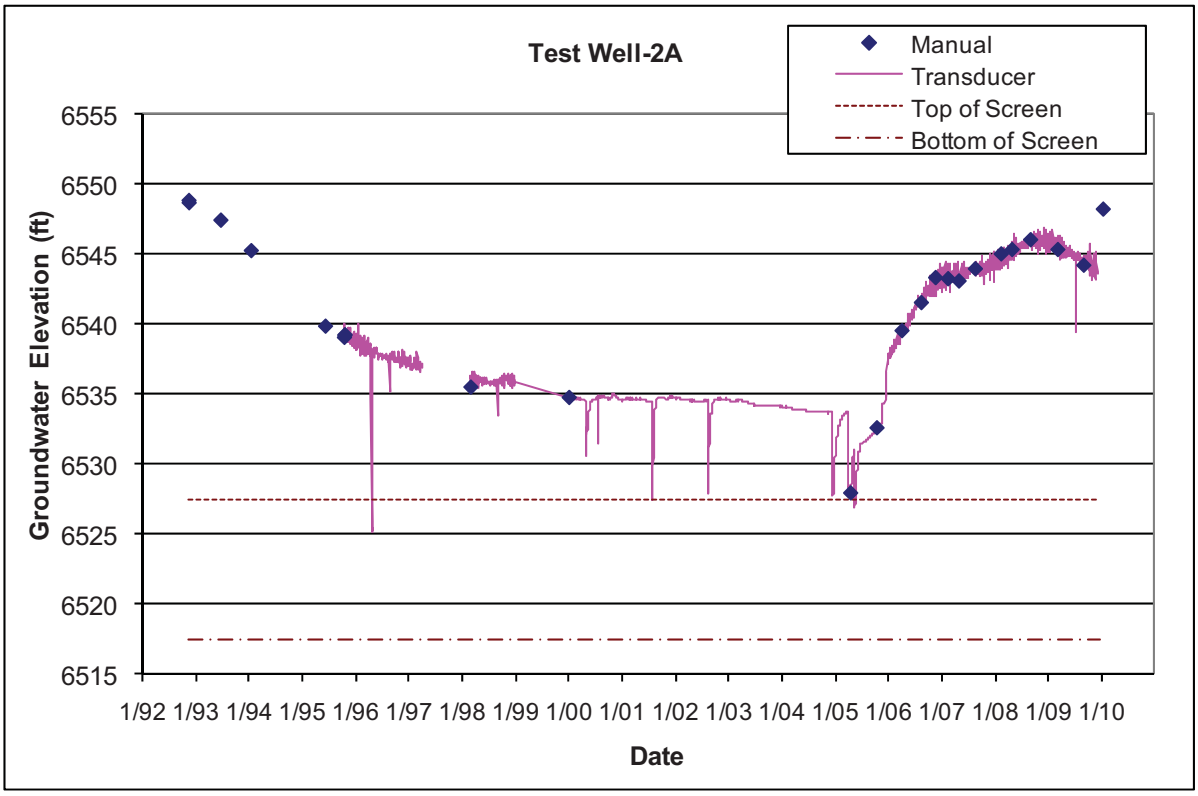
4.37 Test Well 2A

Location: TW-2A is located in middle Pueblo Canyon adjacent to TW-2.
Completion Type: Single completion in the Puye Formation.
Period of Record: Well completed in 1950, transducer installed January 1994 but equipment problems preclude data until 1995; intermittent data through 2009.
Remarks: Recent pumping of TW-2A when the water level is below 6535 ft has shown slow recovery of the intermediate groundwater. The well was plugged and abandoned February 8, 2010 (LANL March 2010).

TW-2A Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	123.0	133.0	6527.4	6517.4	10.0	130.0	6520.4	133.0	6517.4	133.0	0.0	0.0	I	Tp

Note: TW-2A Ground Elevation: 6650.4 ft; all measurements are from this elevation



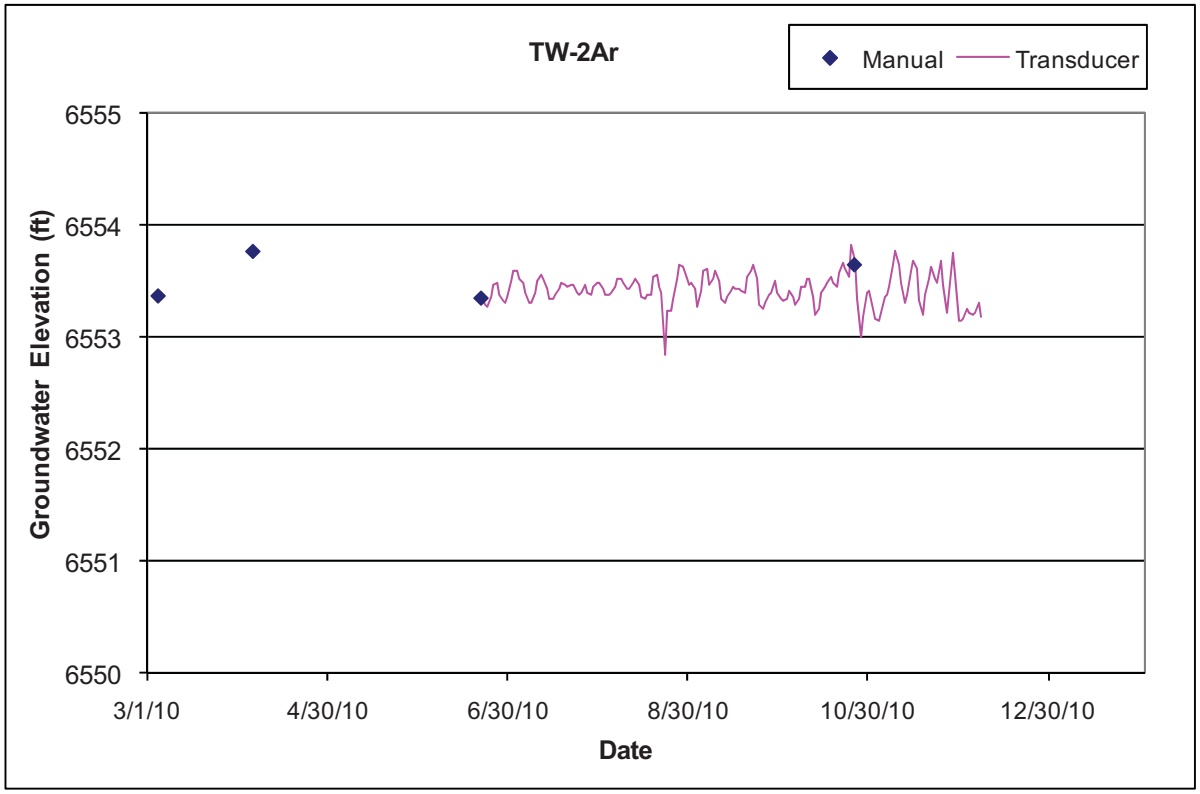
4.38 TW-2Ar

Location: TW-2Ar is located in middle Pueblo Canyon adjacent to former wells TW-2 and TW-2A.
Completion Type: Single completion in the Puye Formation.
Period of Record: Well completed March 4, 2010, transducer installed June 22, 2010; transducer data through 2010.
Remarks: TW-2Ar is a replacement well for former well TW-2A. The perched intermediate groundwater level is about 3 ft above the top of the screen. The well is 100% barometrically efficient, the groundwater does not indicate an immediate response to atmospheric pressure fluctuations; however, the groundwater shows a delayed response to atmospheric pressure fluctuations.

TW-2Ar Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Hydro Zone Code	Geo Unit Code
1	102.0	112.0	6549.7	6539.7	10.0	110.2	6541.5	112.0	6539.7	113.9	1.9	I	Tpf

Note: TW-2Ar Brass cap elevation: 6651.67 ft; all measurements are from this elevation



5.0 Groundwater Level Data from Alluvial Wells

Table 5-1 lists the alluvial wells that were monitored for groundwater levels in 2010. The table provides the well name, date of completion, well depth, surveyed location coordinates, ground surface elevation, and the screen top and bottom depths for each well. Figure 5-1 shows the locations of the wells. In the following alluvial groundwater sections, the first hydrograph for each well represents the entire period of record, while the second hydrograph represents groundwater level data for recent years. Alluvial groundwater levels respond to snowmelt runoff, storm runoff, and, in some canyons, effluent discharges. Some alluvial wells have been historically dry and do not show a seasonal response to precipitation and runoff.

Table 5-1. Information and Location Data for Alluvial Aquifer Wells at LANL

Well Name	Date Completed	Completed Depth (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Screen Top Depth (ft)	Screen Bottom Depth (ft)
18-BG-1	08/01/94	35.0	1634152.90	1762575.36	6776.45	10.0	35.0
18-MW-11	08/11/94	47.0	1636001.69	1761139.83	6740.13	27.0	47.0
18-MW-18	07/31/95	23.0	1639925.00	1758247.20	6654.70	12.5	23.0
18-MW-8	08/04/94	37.9	1634714.26	1760658.14	6747.79	8.0	38.0
18-MW-9	07/21/94	21.0	1635949.81	1760893.56	6732.91	6.0	21.0
3MAO-2	06/04/08	30.0	1633782.48	1760716.45	6759.44	14.7	24.7
APCO-1	08/15/90	19.7	1649209.62	1773020.12	6367.53	4.7	14.7
CDBO-1	04/17/85	13.0	1637968.59	1760943.96	6757.60	5.1	13.1
CDBO-2	04/18/85	18.0	1638119.02	1761103.11	6748.20	5.9	17.9
CDBO-3	04/18/85	12.0	1640677.11	1759611.02	6670.20	4.4	12.4
CDBO-4	04/18/85	12.0	1645474.90	1758546.90	6564.50	4.1	12.1
CDBO-5	06/01/92	17.0	1633583.37	1765818.37	6879.01	7.0	17.0
CDBO-6	06/01/92	49.0	1636209.25	1764759.75	6817.20	34.0	44.0
CDBO-7	06/01/92	44.0	1637400.00	1763301.00	6771.81	29.0	39.0
CDBO-8	06/01/92	23.0	1639294.00	1762366.00	6722.47	3.0	13.0
CDBO-9	06/01/92	34.0	1642119.12	1759702.87	6633.00	19.0	29.0
CDV-16-02655	09/27/97	7.6	1611299.09	1764153.13	7583.70	2.3	7.3
CDV-16-02656	11/05/97	8.2	1613634.46	1764932.79	7443.18	3.0	8.0
CDV-16-02657	10/10/97	5.7	1613813.19	1764850.10	7433.25	0.4	5.4
CDV-16-02658	09/16/97	7.2	1615071.38	1764469.56	7375.60	1.9	6.9
CDV-16-02659	09/08/97	7.0	1616712.08	1765035.06	7300.50	1.7	6.7
CDV-16-611921	02/02/10	12.3	1615097.97	1764439.62	7378.85	6.3	11.3
CDV-16-611923	02/02/10	8.7	1615123.85	1764472.96	7373.83	3.2	8.2
CDV-16-611929	02/02/10	13.3	1615128.56	1764419.45	7378.38	7.0	12.0
CDV-16-611930	02/02/10	13.0	1615131.25	1764435.40	7377.54	7.0	12.0
CDV-16-611931	02/02/10	12.0	1615139.60	1764460.06	7374.18	5.0	10.0
CDV-16-611938	02/02/10	8.5	1615492.23	1764529.67	7356.25	3.0	8.0
FCO-1	08/22/89	12.4	1642414.82	1751181.06	6510.13	2.4	12.4
FLC-16-25278	10/10/05	3.2	1618820.88	1762605.72	7272.20	1.6	3.2
FLC-16-25279	10/10/05	4.3	1617679.48	1762856.43	7309.30	2.7	4.3
FLC-16-25280	10/10/05	4.2	1616646.29	1763365.10	7352.90	2.6	4.2
LAO-0.3	05/17/94	11.3	1624799.00	1774511.60	6968.13	5.9	10.9
LAO-0.6	05/06/94	13.4	1626748.10	1774332.90	6910.74	8.0	13.0
LAO-1	02/01/96	28.0	1629395.00	1773956.37	6836.24	8.0	28.0
LAO-1.6G	03/20/96	30.8	1636083.42	1772557.63	6658.01	10.5	25.5

Well Name	Date Completed	Completed Depth (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Screen Top Depth (ft)	Screen Bottom Depth (ft)
LAO-1.8	04/15/69	18.0	1635446.25	1772661.37	6680.00	8.0	18.0
LAO-2	02/01/96	32.0	1637607.75	1773095.87	6623.00	7.0	32.0
LAO-3A	09/14/89	14.7	1637980.87	1773099.75	6609.10	4.7	14.7
LAO-4.5C	11/01/89	23.3	1643547.37	1772076.50	6486.50	13.3	23.3
LAO-5	02/15/66	25.0	1646202.25	1771424.12	6427.10	5.0	25.0
LAO-6a	08/01/89	14.2	1646221.62	1771344.00	6424.70	4.2	14.2
LAO-B	04/28/94	27.2	1615148.80	1775170.40	7323.59	11.8	26.8
LAUZ-1		10.6	1633435.13	1774809.81	7032.42	5.4	10.4
LLAO-1b	07/16/97	24.2	1659738.70	1772381.65	5850.34	11.3	21.3
LLAO-4	09/30/96	18.1	1671820.23	1774468.01	5515.46	5.2	15.2
MCA-1	01/24/05	5.9	1626586.50	1770410.77	7070.60	2.4	5.4
MCA-5	02/01/05	6.0	1627354.17	1770233.59	7053.80	1.8	5.8
MCA-8	09/29/04	86.3	1641325.48	1767372.92	6668.80	66.0	81.0
MCO-0.6	02/25/99	3.1	1623987.80	1771179.50	7188.28	1.1	3.1
MCO-2	11/01/60	9.0	1625919.25	1770135.12	7136.60	2.0	9.0
MCO-3	03/01/67	12.0	1627362.50	1770236.75	7052.60	2.0	12.0
MCO-4B	08/01/90	33.9	1632036.37	1769697.00	6886.75	8.9	28.9
MCO-5	10/01/60	46.0	1632466.12	1769538.00	6875.66	21.0	46.0
MCO-6	03/01/74	47.0	1633635.37	1769012.75	6849.48	27.0	47.0
MCO-7	10/01/60	69.0	1634517.87	1768509.87	6827.31	39.0	69.0
MCO-7.5	04/01/74	60.0	1635454.87	1768440.50	6808.88	35.0	60.0
MCWB-5	12/06/94	33.0	1632578.31	1769484.60	6876.22	17.0	27.0
MCWB-5.5B	12/22/94	37.5	1633420.54	1769125.78	6856.89	22.5	32.5
MCWB-6.2A	12/07/94	45.5	1633754.49	1768968.15	6848.29	30.5	40.5
MCWB-6.5E	12/21/94	50.0	1633833.36	1768583.81	6843.80	35.0	45.0
MCWB-7.4B	12/13/94	70.0	1635287.73	1768407.84	6813.07	45.0	65.0
MCWB-7.7B	12/20/94	70.0	1635921.84	1768517.26	6798.97	55.0	65.0
MCWB-7A	12/09/94	52.0	1634356.62	1768551.02	6831.17	37.0	47.0
MSC-16-06293	01/27/00	7.3	1615809.67	1761331.78	7370.79	2.0	7.0
MSC-16-06294	01/26/00	7.6	1617848.17	1761298.78	7288.44	2.5	7.3
MSC-16-06295	01/31/00	6.9	1618630.67	1761004.78	7257.03	1.5	6.5
MT-2	11/01/88	64.0	1636019.79	1768544.59	6796.20	44.0	64.0
MT-3	11/01/88	74.0	1635980.95	1768657.83	6796.65	44.0	64.0
MT-4	11/01/88	74.0	1636558.75	1768634.37	6783.59	54.0	64.0
PAO-1	10/30/98	13.7	1624165.85	1778988.72	6954.97	5.9	10.9
PAO-2	11/02/98	13.9	1625040.90	1778710.00	6930.98	6.1	11.1
PAO-4	07/24/97	9.8	1646090.28	1775098.35	6437.37	2.0	7.0
PCAO-5	05/03/08	30.0	1627159.64	1765953.14	6943.29	14.7	24.7
PCAO-6	06/05/08	20.0	1627610.36	1765888.72	6921.40	8.0	15.0
PCAO-7a	05/30/08	25.0	1636938.56	1760549.16	6711.97	9.7	19.7
PCAO-7b1	05/21/08	60.0	1636831.47	1760490.10	6713.62	44.0	54.0
PCAO-7b2	05/27/08	25.0	1636846.45	1760481.06	6713.39	10.0	20.0
PCAO-7c	05/16/08	25.0	1636706.72	1760335.39	6714.57	9.7	19.7
PCAO-8	06/02/08	25.0	1643865.52	1756372.09	6584.45	9.7	19.7
PCAO-9	06/12/08	21.0	1645540.81	1755980.24	6558.60	6.0	16.0

Well Name	Date Completed	Completed Depth (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Screen Top Depth (ft)	Screen Bottom Depth (ft)
PCO-2	06/30/85	9.5	1641700.37	1757442.75	6618.30	1.5	9.5
PCO-3	06/30/85	17.7	1646088.62	1755489.37	6546.30	5.7	17.7
SCA-1	08/25/06	2.1	1622482.45	1773264.59	7211.22	1.3	1.9
SCA-1-DP	02/18/09	2.7	1622482.45	1773264.59	7211.20	2.2	2.7
SCA-2	08/24/06	15.6	1636114.63	1770283.36	6749.08	10.3	15.0
SCA-3	09/09/06	32.6	1637200.62	1769918.81	6723.22	27.6	32.0
SCA-4	09/10/06	42.0	1638260.55	1769567.21	6703.58	37.0	41.5
SCA-5	09/11/06	64.9	1639878.16	1769726.40	6669.02	55.0	64.4
SCP-1abc	09/12/06	41.8	1638254.68	1769567.80	6703.65	39.4	39.9
SCP-1abc	09/12/06	41.8	1638254.68	1769567.80	6703.65	41.2	41.7
SCP-1abc	09/12/06	41.8	1638254.68	1769567.80	6703.65	37.8	38.3
SCP-2a	09/13/06	45.1	1637209.65	1769911.26	6722.95	44.5	45.0
SCP-2b	09/12/06	50.1	1637205.05	1769914.53	6723.11	49.5	50.0
TMO-1	06/09/08	6.5	1626830.56	1766161.13	6945.20	3.5	6.5
TSCA-6	11/09/04	21.3	1632954.60	1768471.44	6863.20	16.2	20.9
WCO-1r	12/22/09	16.4	1632736.78	1755106.26	6617.12	6.0	16.0
WCO-2	10/26/89	23.5	1636870.37	1753228.37	6524.57	13.5	23.5
WCO-3r	12/22/09	10.1	1640114.87	1750476.65	6437.17	4.7	9.7

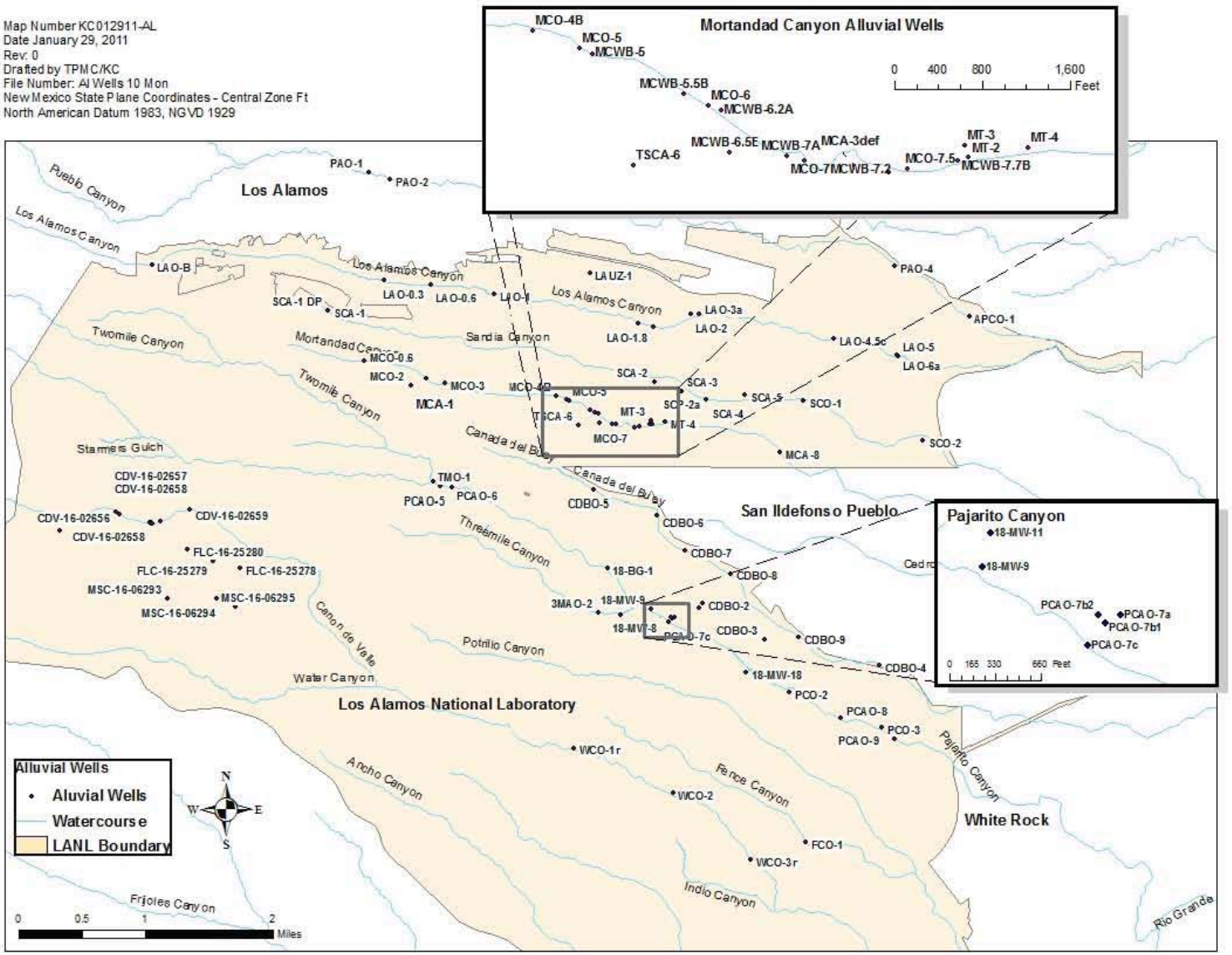


Figure 5-1. Alluvial wells monitored for groundwater levels in 2010.

5.1 Previously Monitored Alluvial Wells:

The following wells have not been monitored since at least December 2008. For information on these wells, refer to the "Groundwater Level Status Report for 2009."

Previously Monitored Wells	
Well	**Date Monitoring Ceased**
18-BG-4	12/1/2008
18-MW-7	12/18/2006
18-MW-17	9/30/2007
MCA-2	11/28/2007
MCA-3abcdef	11/28/2007
MCA-4	11/29/2007
MCA-9	11/29/2007
MT-1	11/27/2007
PCO-1	5/7/2008
TSWB-6	2/7/2008

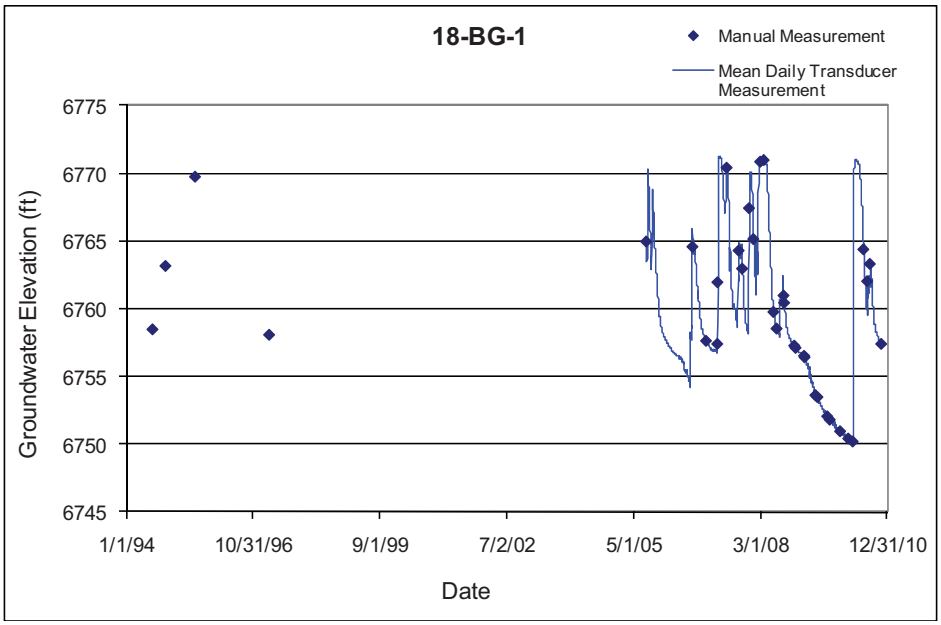
5.2 18-BG-1

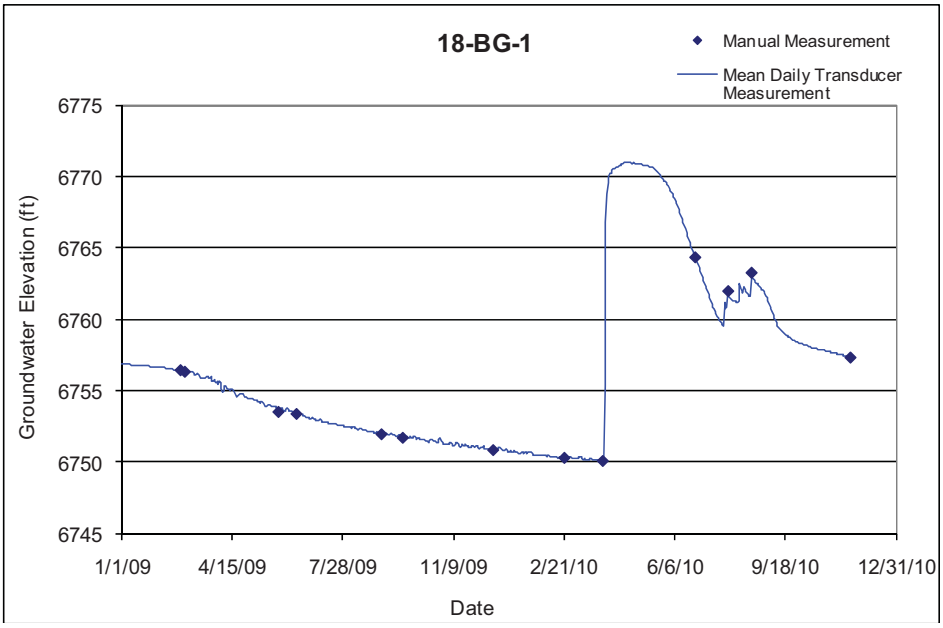
Location: Lower Pajarito Canyon, about 0.4 mi west of the TA-18 facilities.
Period of Record: August 1, 1994, through November 18, 2010.
Remarks: None.

18-BG-1 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	10.0	35.0	6766.5	6741.5	25.0			35.0	6741.5	35	0.0	0.0	Alluvial groundwater

Note: Ground Elevation: 6776.45 ft; all depths are from this elevation



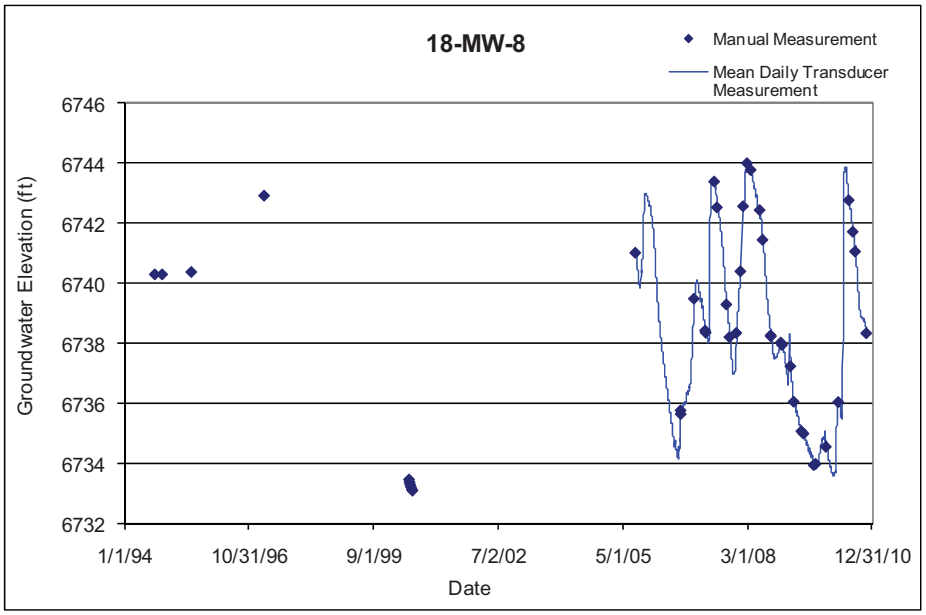


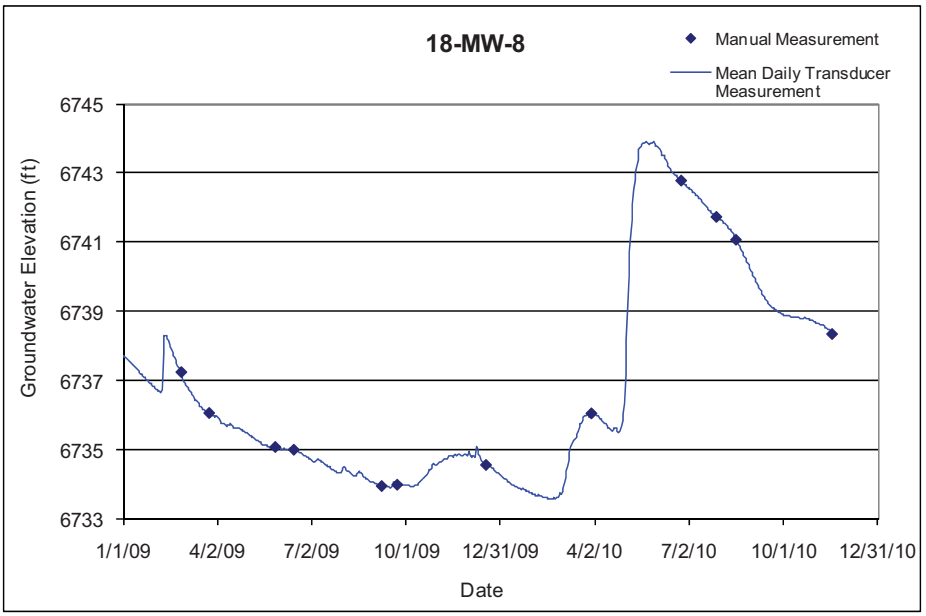
5.3 18-MW-8

Location: In Three-Mile Canyon above the confluence with Pajarito Canyon, about 0.1 mi west of the TA-18 facilities.
Period of Record: September 15, 1994, through November 18, 2010.
Remarks: None.

18-MW-8 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	8.0	38.0	6739.8	6709.8	30.0			38.0	6709.8	38.0	0.0	0.0	Alluvial groundwater

Note: Ground Elevation: 6747.79 ft; all depths are from this elevation





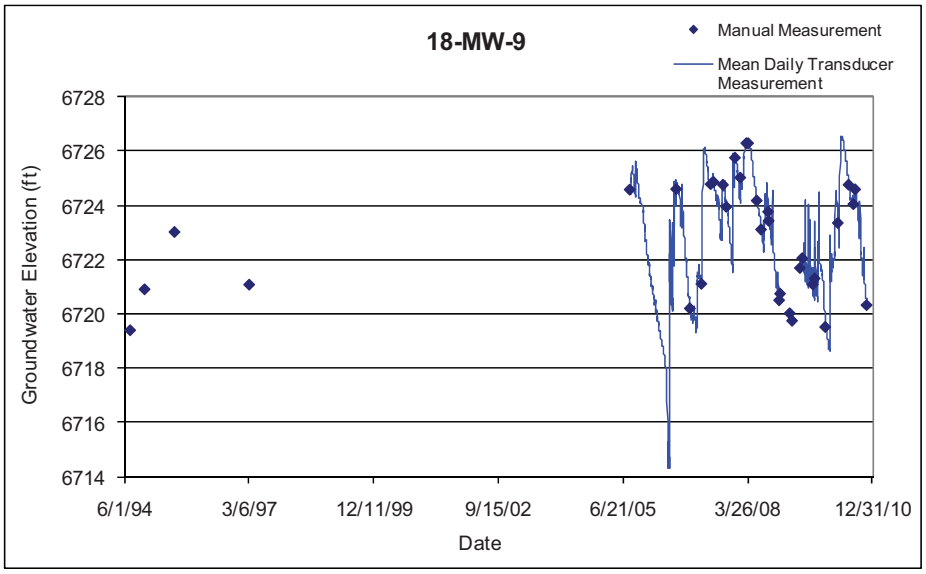
5.4 18-MW-9

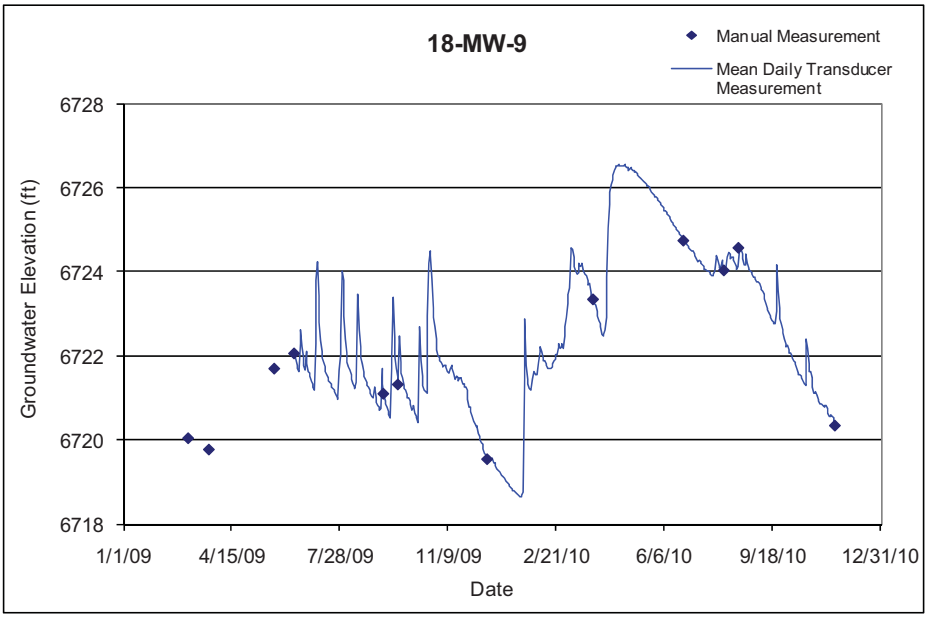
Location: Pajarito Canyon, directly south of the main guard gate to TA-18.
Period of Record: July 21, 1994, through November 18, 2010.
Remarks: Data gap from December 2008 through April 2010 resulted from a succession of malfunctioning transducers.

18-MW-9 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	6.0	21.0	6726.9	6711.9	15.0			21.0	6711.9	21	0.0	0.0	Alluvial groundwater

Note: Ground Elevation: 6732.91 ft; all depths are from this elevation





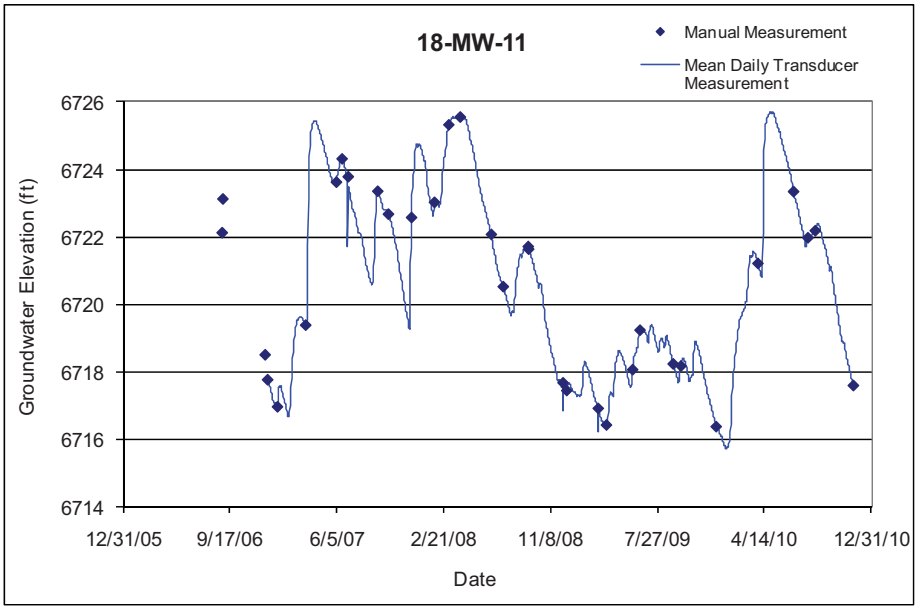
5.5 18-MW-11

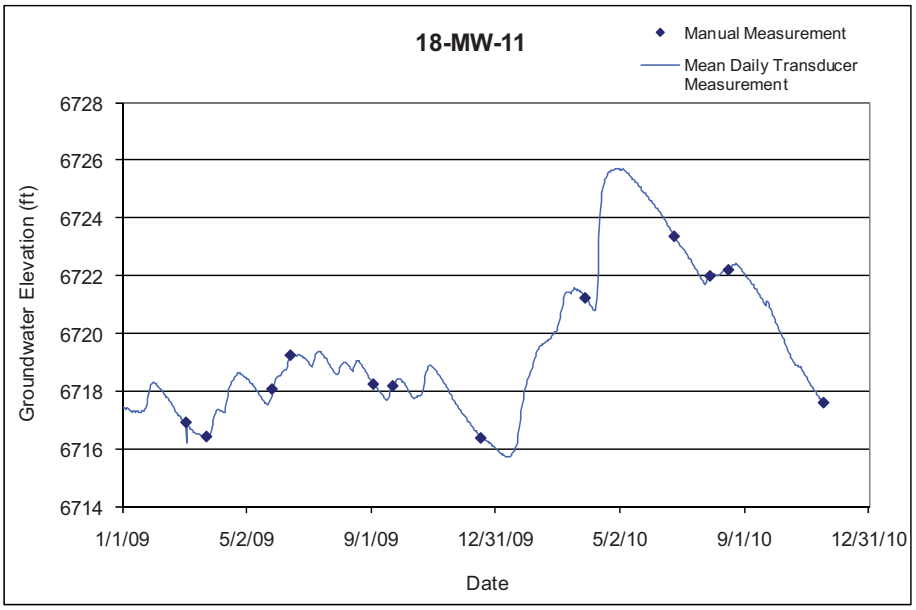
Location: Pajarito Canyon, approximately 200 ft north of 18-MW-9 in the TA-18 parking lot.
Period of Record: August 29, 2006, through November 18, 2010.
Remarks: None.

18-MW-11 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	27.0	47.0	6713.1	6693.1	20.0			47.0	6693.1	0	0.0	0.0	Alluvial Groundwater

Note: Ground Elevation: 6740.13 ft; all measurements are from this elevation





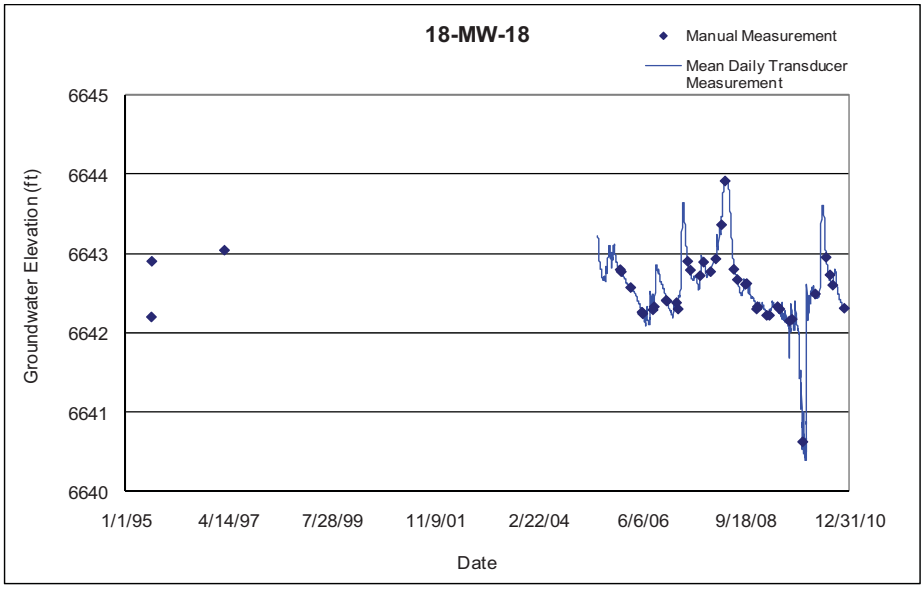
5.6 18-MW-18

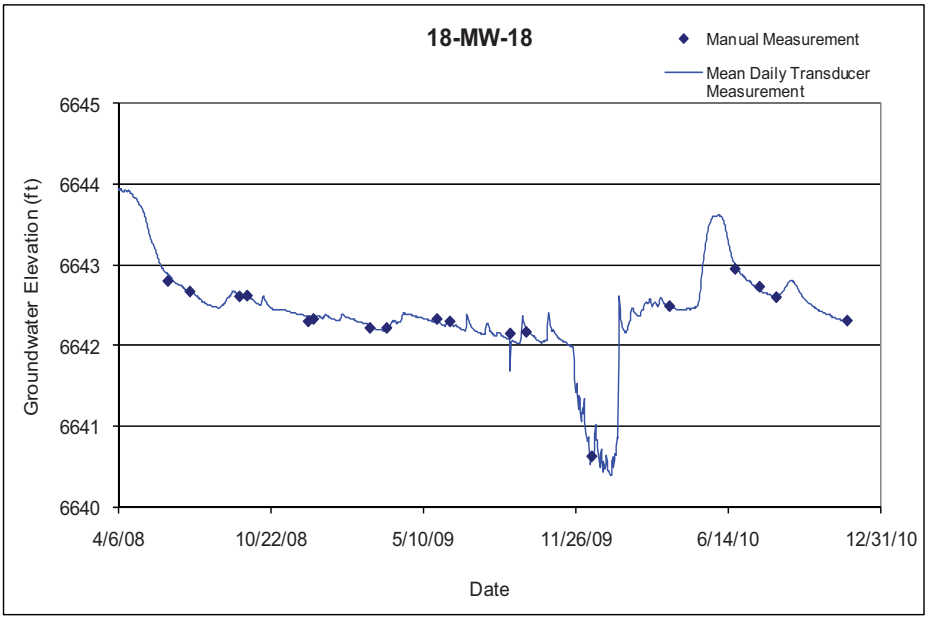
Location: Alluvial well 18-MW-18 is located in Pajarito Canyon, 1000 ft east of 18-MW-17.
Period of Record: July 31, 1995, through November 18, 2010.
Remarks: None.

18-MW-18 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	12.5	23	6642.2	6631.7	10.5			23	6631.7	23	0	0	Alluvial groundwater

Note: Ground Elevation: 6654.7 ft; all depths are from this elevation



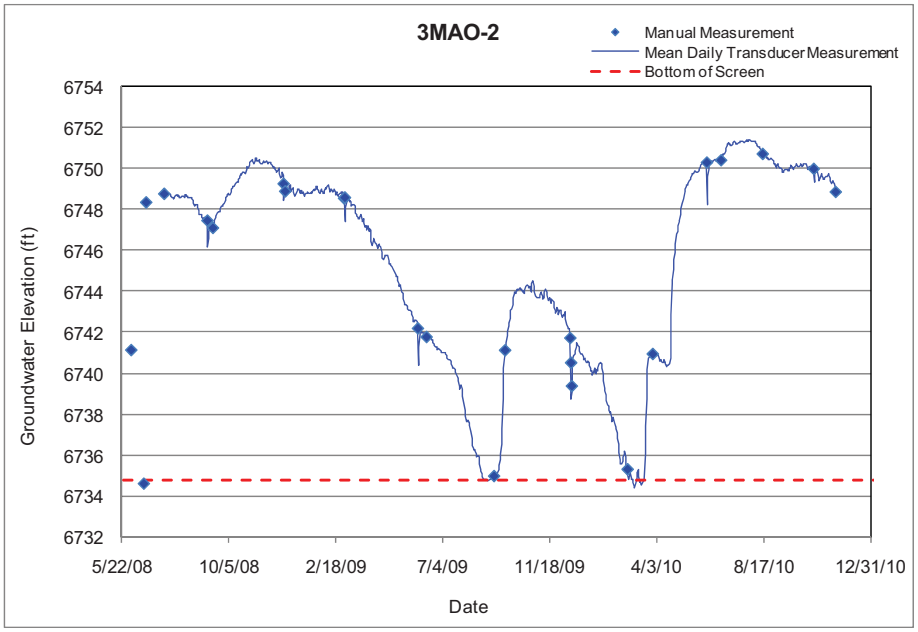


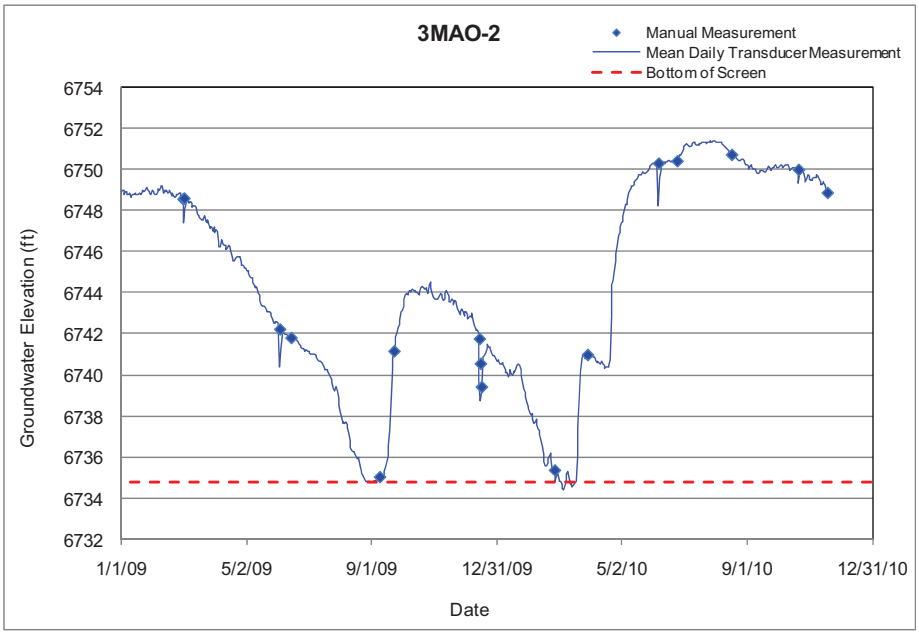
5.7 3MAO-2

Location: In lower Three-Mile Canyon in TA-18, just above the confluence with Pajarito Canyon, on the south bank of the stream; located roughly half way between 18-BG-4 and 18-MW-18.
Period of Record: June 4, 2008, through November 18, 2010.
Remarks: None.

3MAO-2 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	14.7	24.7	6744.7	6734.7	10.0			24.7	6734.7	30.0	5.3	13.1	Alluvial groundwater

Note: Ground elevation is 6759.44 ft; all depths from this elevation





5.8 39-UM-3

Location: Ancho Canyon, TA-39, approximately 2100 ft north of regional well R-31.
Period of Record: March 9, 2006, through July 2, 2009.
Remarks: Well has historically been dry during quarterly manual measurements. There was no transducer installed in this well. Monitoring was discontinued in August 2009.

39-UM-3 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	44.0	54.0	6350.2	6340.2	10.0			54.0	6340.2	54.0	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6394.20 ft; all depths are from this elevation

39-UM-3 Manual Water Levels	
Date	Comments
3/9/2006	Dry
6/13/2006	Dry
9/7/2006	Dry
11/30/2006	Dry
12/12/2006	Dry
3/15/2007	Dry
5/10/2007	Dry
6/6/2007	Dry
9/5/2007	Dry
11/1/2007	Dry
1/16/2008	Dry
4/7/2008	Dry
7/26/2008	Dry
10/15/2008	Dry
3/31/2009	Dry
7/2/2009	Dry

5.9 39-DM-6

Location: Ancho Canyon, TA-39, approximately 1600 ft north of regional well R-31.
Period of Record: March 9, 2006, through July 2, 2009.
Remarks: Well has historically been dry during quarterly manual measurements. There was no transducer installed in this well. Monitoring was discontinued In August 2009.

39-DM-6 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	50.0	60.0	6334.6	6324.6	10.0			60.0	6324.6	60.0	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6384.57 ft; all depths are from this elevation

39-DM-6 Manual Water Levels	
Date	Comment
3/9/2006	Dry
6/13/2006	Dry
9/7/2006	Dry
11/30/2006	Dry
12/12/2006	Dry
3/15/2007	Dry
5/10/2007	Dry
6/6/2007	Dry
9/5/2007	Dry
11/1/2007	Dry
1/16/2008	Dry
4/7/2008	Dry
7/26/2008	Dry
10/15/2008	Dry
3/31/2009	Dry
7/2/2009	Dry

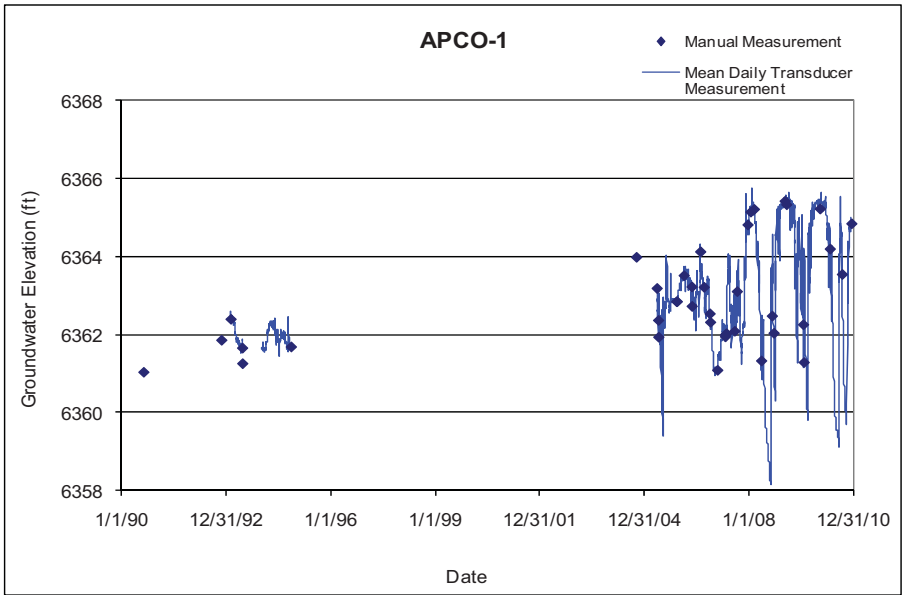
5.10 APCO-1

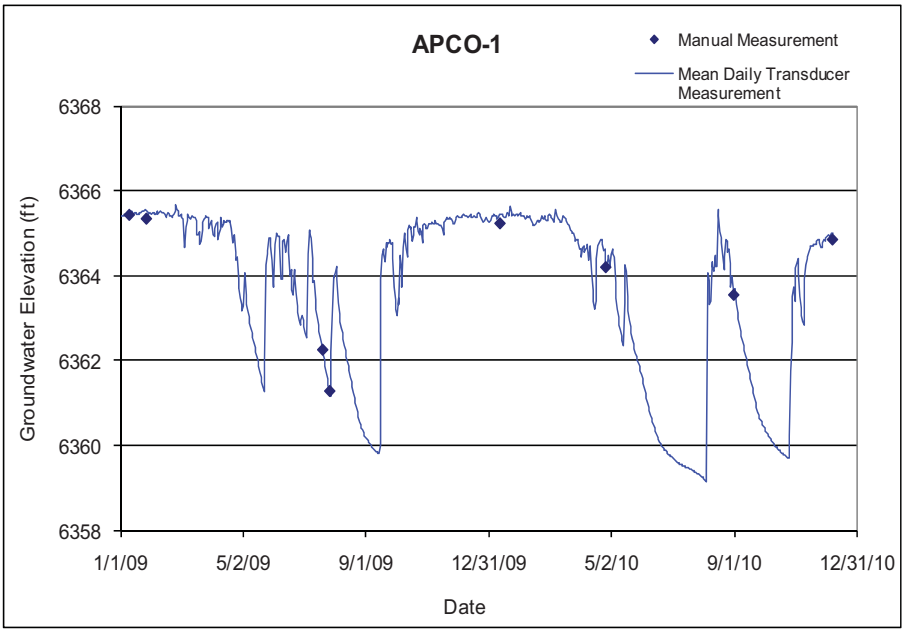
Location: In lower Pueblo Canyon, approximately 0.1 mi north of POI-4 and R-3i.
Period of Record: August 17, 1990, through December 18, 2010.
Remarks: A pressure transducer was installed in APCO-1 from February 17, 1993, through June 17, 1993; from January 11, 1994, through November 9, 1994; and from May 9, 2005, through present.

APCO-1 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	4.7	14.7	6362.83	6352.83	10.0			14.7	6352.83	19.7	5.0	3.1	Alluvial groundwater

Note: Ground Elevation: 6367.53 ft; all depths are from this elevation





5.11 CDBO-1

Location: Alluvial well CDBO-1 is located in Cañada del Buey, approximately 1320 ft north of regional well R-20.

Period of Record: March 8, 2006, through June 25, 2010.

Remarks: Well has historically been dry during quarterly measurements. There was no transducer installed in this well. Monitoring was discontinued June 25, 2010.

CDBO-1 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	5.1	13.1	6752.5	6744.5	8.0			13.1	6744.5	13.0	0.1	0.2	Alluvial groundwater

Note: Ground elevation is 6757.6 ft; all depths are from this elevation

CDBO-1 Manual Water Levels	
Date	Comments
3/8/2006	Dry
6/26/2006	Dry
9/6/2006	Dry
9/27/2006	Dry
12/8/2006	Dry
2/22/2007	Dry
3/19/2007	Dry
6/5/2007	Dry
6/11/2007	Dry
9/10/2007	Dry
1/24/2008	Dry
2/11/2008	Dry
4/1/2008	Dry
5/22/2008	Dry
7/24/2008	Dry
8/11/2008	Dry
11/3/2008	Dry
2/3/2009	Dry
4/27/2009	Dry
8/25/2009	Dry
6/25/2010	Dry

5.12 CDBO-2

Location: Alluvial well CDBO-2 is located in Cañada del Buey, approximately 260 ft northeast of CDBO-1.
Period of Record: March 8, 2006, through June 25, 2010.
Remarks: Well has historically been dry during quarterly measurements. There was no transducer installed in this well. Monitoring was discontinued June 25, 2010.

CDBO-2 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	5.9	17.9	6742.3	6730.3	12.0			17.9	6730.3	18.0	0.1	0.2	Alluvial groundwater

Note: Ground elevation is 6748.2 ft; all depths are from this elevation

CDBO-2 Manual Water Levels	
Date Time	Comments
3/8/2006	Dry
6/26/2006	Dry
9/6/2006	Dry
9/27/2006	Dry
12/8/2006	Dry
2/22/2007	Dry
3/19/2007	Dry
6/5/2007	Dry
6/11/2007	Dry
6/11/2007	Dry
9/10/2007	Dry
1/24/2008	Dry
2/11/2008	Dry
4/1/2008	Dry
5/22/2008	Dry
7/24/2008	Dry
8/11/2008	Dry
11/3/2008	Dry
2/3/2009	Dry
4/27/2009	Dry
8/25/2009	Dry
6/25/2010	Dry

5.13 CDBO-3

Location: Alluvial well CDBO-3 is located in Cañada del Buey, approximately 630 ft northwest of regional well R-21.

Period of Record: December 6, 2005, through June 25, 2010.

Remarks: Well has historically been dry during quarterly measurements. There was no transducer installed in this well. Monitoring was discontinued June 25, 2010.

CDBO-3 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	4.4	12.4	6665.8	6657.8	8.0			12.4	6657.8	12.0	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6670.2 ft; all depths are from this elevation

CDBO-3 Manual Water Levels	
Date	Comments
12/6/2005	Dry
3/8/2006	Dry
6/26/2006	Dry
9/6/2006	Dry
9/27/2006	Dry
12/8/2006	Dry
2/22/2007	Dry
3/19/2007	Dry
6/5/2007	Dry
6/11/2007	Dry
9/10/2007	Dry
1/24/2008	Dry
2/11/2008	Dry
4/1/2008	Dry
5/22/2008	Dry
7/24/2008	Dry
8/11/2008	Dry
11/3/2008	Dry
2/3/2009	Dry
4/27/2009	Dry
8/25/2009	Dry
6/25/2010	Dry

5.14 CDBO-4

Location: Alluvial well CDBO-4 is located in Cañada del Buey, approximately 1600 ft north of regional well R-22.

Period of Record: December 7, 2005, through December 2, 2010.

Remarks: Well has historically been dry during quarterly measurements. A transducer was installed in this well January 9, 2009, and has not yet recorded any water in the well.

CDBO-4 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	4.1	12.1	6560.4	6552.4	8.0			12.1	6552.4	12.0	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6564.5 ft; all depths are from this elevation

CDBO-4 Manual Water Levels	
Date	Comments
12/7/2005	Dry
3/8/2006	Dry
6/26/2006	Dry
9/6/2006	Dry
10/2/2006	Dry
12/8/2006	Dry
2/22/2007	Dry
3/19/2007	Dry
6/5/2007	Dry
6/11/2007	Dry
9/10/2007	Dry
1/24/2008	Dry
2/11/2008	Dry
4/1/2008	Dry
5/22/2008	Dry
7/24/2008	Dry
8/11/2008	Dry
11/3/2008	Dry
1/9/2009	Dry
2/3/2009	Dry
4/27/2009	Dry
7/14/2009	Dry
8/4/2009	Dry
12/14/2009	Dry
3/8/2010	Dry
6/1/2010	Dry
7/27/2010	Dry
12/2/2010	Dry

5.15 CDBO-5

Location: Alluvial well CDBO-5 is located in Cañada del Buey, approximately 0.5 mi west-northwest of CDBO-6.

Period of Record: December 7, 2005, through November 19, 2010.

Remarks: Well has historically been dry during quarterly measurements. A transducer was installed in this well January 12, 2009, and has not yet recorded any water in the well.

CDBO-5 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	7.0	17.0	6872.0	6862.0	10.0			17.0	6862.0	17.0	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6879.01 ft; all depths are from this elevation

CDBO-5 Manual Water Levels	
Date	Comments
12/7/2005	Dry
10/2/2006	Dry
12/8/2006	Dry
2/22/2007	Dry
3/19/2007	Dry
6/5/2007	Dry
9/11/2007	Dry
1/24/2008	Dry
2/11/2008	Dry
4/1/2008	Dry
5/22/2008	Dry
7/24/2008	Dry
8/11/2008	Dry
11/3/2008	Dry
1/12/2009	Dry
2/3/2009	Dry
4/27/2009	Dry
7/14/2009	Dry
8/4/2009	Dry
12/14/2009	Dry
3/8/2010	Dry
6/1/2010	Dry
7/27/2010	Dry
11/19/2010	Dry

5.16 CDBO-6

Location: In Cañada del Buey, a branch of Mortandad Canyon, approximately 420 ft east of production well PM-4.

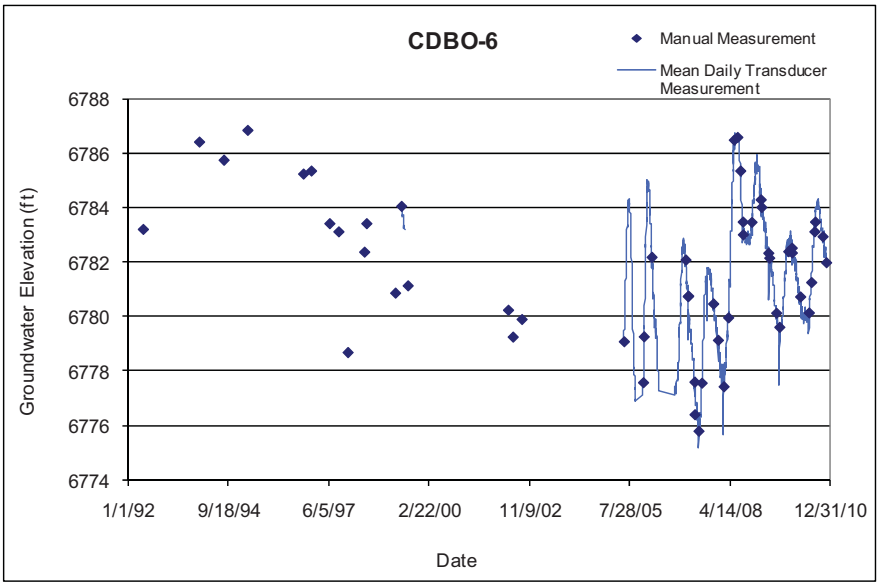
Period of Record: June 1, 1992, through November 19, 2010.

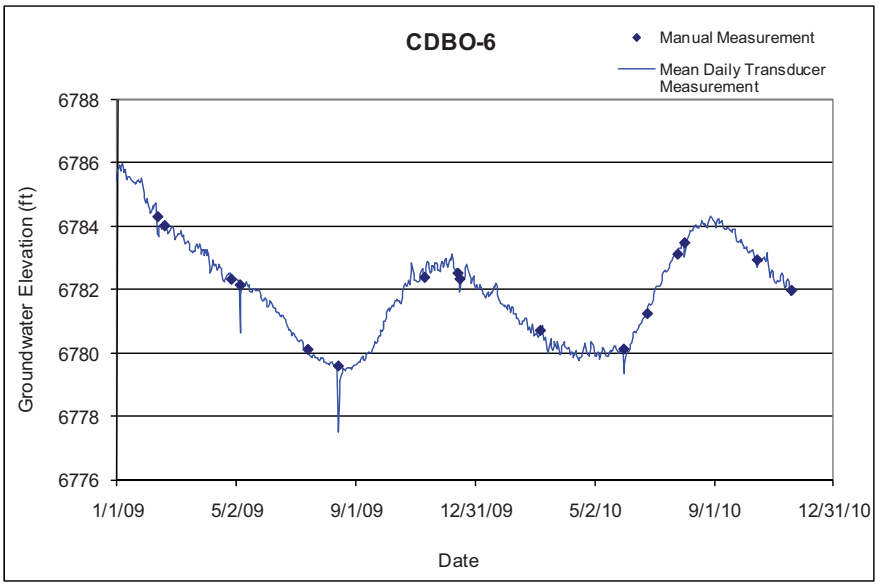
Remarks: A pressure transducer was installed above the pump until April 30, 2007, when the pump was removed from the well. Transducer data before April 30, 2007, do not represent water levels below 6776.83 ft. The dedicated pump was reinstalled November 10, 2009, and the transducer is once again located above the pump.

CDBO-6 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	34.0	44.0	6783.2	6773.2	10.0			44.0	6773.2	49.0	5.0	3.1	Alluvial groundwater

Note: Ground Elevation: 6817.2 ft; all depths are from this elevation





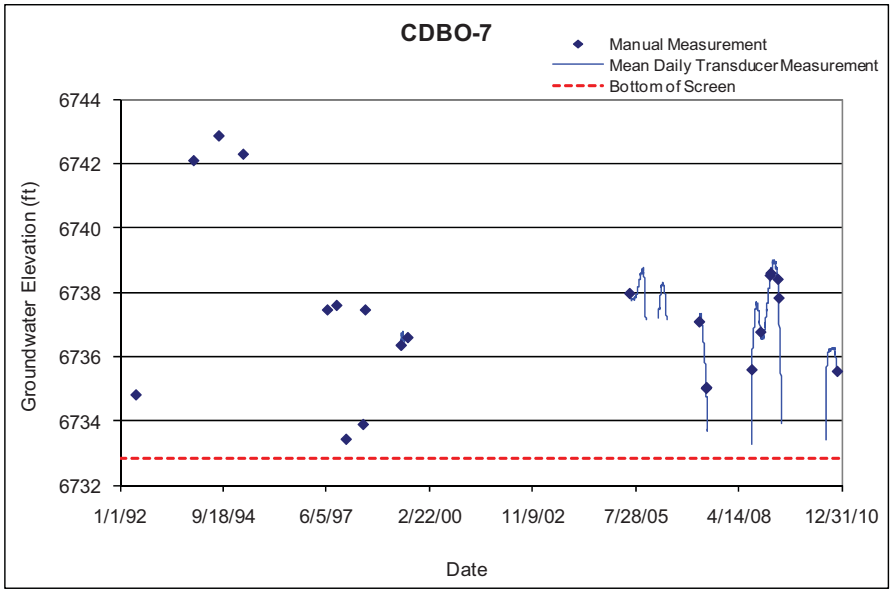
5.17 CDBO-7

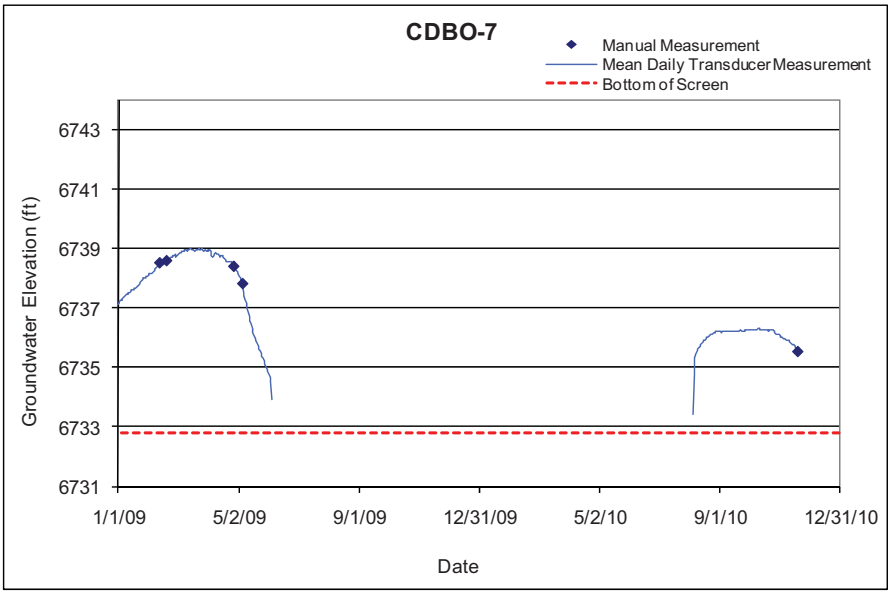
Location: In Cañada del Buey, a branch of Mortandad Canyon, approximately 0.3 mi southeast of CDBO-6.
Period of Record: June 1,1992, through December 19, 2010.
Remarks: Initially, a pressure transducer was installed above the well's bladder pump at an elevation of 6737.14 ft. The transducer was lowered in the well after removal of the pump on April 2, 2007. Data before April 2, 2007, do not represent water levels below 6737.14 ft.

CDBO-7 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	29.0	39.0	6742.8	6732.8	10.0			39.0	6732.8	44.0	5.0	3.1	Alluvial groundwater

Note: Ground Elevation: 6771.81 ft; all depths are from this elevation





5.18 CDBO-8

Location: Alluvial well CDBO-8 is located in Cañada del Buey, approximately 0.4 mi southeast of CDBO-7.

Period of Record: July 2, 2001, through December 2, 2010.

Remarks: Well has historically been dry during quarterly measurements. A transducer was installed in this well January 9, 2009, and has not yet recorded any water in the well.

CDBO-8 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	3.0	13.0	6719.5	6709.5	10.0			13.0	6709.5	23.0	10.0	6.2	Alluvial groundwater

Note: Ground elevation is 6722.47 ft; all depths are from this elevation

CDBO-8 Manual Water Levels			
Date	Comments	Date	Comments
7/2/2001	Dry	9/10/2007	Dry
8/22/2001	Dry	1/24/2008	Dry
10/18/2001	Dry	2/11/2008	Dry
4/16/2002	Dry	4/1/2008	Dry
8/27/2002	Dry	5/22/2008	Dry
11/15/2002	Dry	7/24/2008	Dry
2/19/2003	Dry	8/11/2008	Dry
12/7/2005	Dry	11/3/2008	Dry
3/8/2006	Dry	1/12/2009	Dry
6/26/2006	Dry	2/3/2009	Dry
9/7/2006	Dry	4/27/2009	Dry
10/2/2006	Dry	7/14/2009	Dry
12/8/2006	Dry	8/4/2009	Dry
2/22/2007	Dry	12/14/2009	Dry
3/19/2007	Dry	3/8/2010	Dry
6/5/2007	Dry	6/1/2010	Dry
6/8/2007	Dry	7/26/2010	Dry
		12/2/2010	Dry

5.19 CDBO-9

Location: Alluvial well CDBO-9 is located in Cañada del Buey, approximately 0.7 mi southeast of CDBO-8.

Period of Record: July 2, 2001, through December 2, 2010.

Remarks: Well has historically been dry during quarterly measurements. A transducer was installed in this well January 9, 2009, and has not yet recorded any water in the well.

CDBO-9 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	19.0	29.0	6614.0	6604.0	10.0			29.0	6604.0	34.0	5.0	3.1	Alluvial groundwater

Note: Ground elevation is 6633.0 ft; all depths are from this elevation

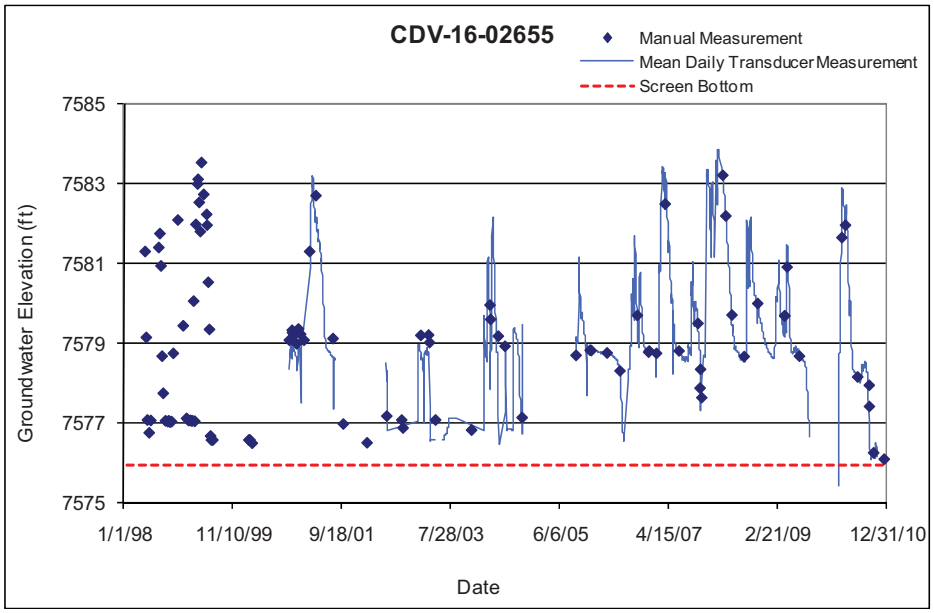
CDBO-9 Manual Water Levels				
Date	Comments		Date	Comments
7/2/2001	Dry		9/10/2007	Dry
8/22/2001	Dry		1/24/2008	Dry
10/18/2001	Dry		2/11/2008	Dry
4/16/2002	Dry		4/1/2008	Dry
8/27/2002	Dry		5/22/2008	Dry
11/15/2002	Dry		7/24/2008	Dry
2/19/2003	Dry		8/11/2008	Dry
6/3/2003	Dry		11/3/2008	Dry
12/6/2005	Dry		1/9/2009	Dry
3/8/2006	Dry		2/3/2009	Dry
6/26/2006	Dry		4/27/2009	Dry
9/6/2006	Dry		7/14/2009	Dry
10/2/2006	Dry		8/4/2009	Dry
12/8/2006	Dry		12/14/2009	Dry
2/22/2007	Dry		3/8/2010	Dry
3/19/2007	Dry		6/1/2010	Dry
6/5/2007	Dry		7/26/2010	Dry
6/8/2007	Dry		12/2/2010	Dry

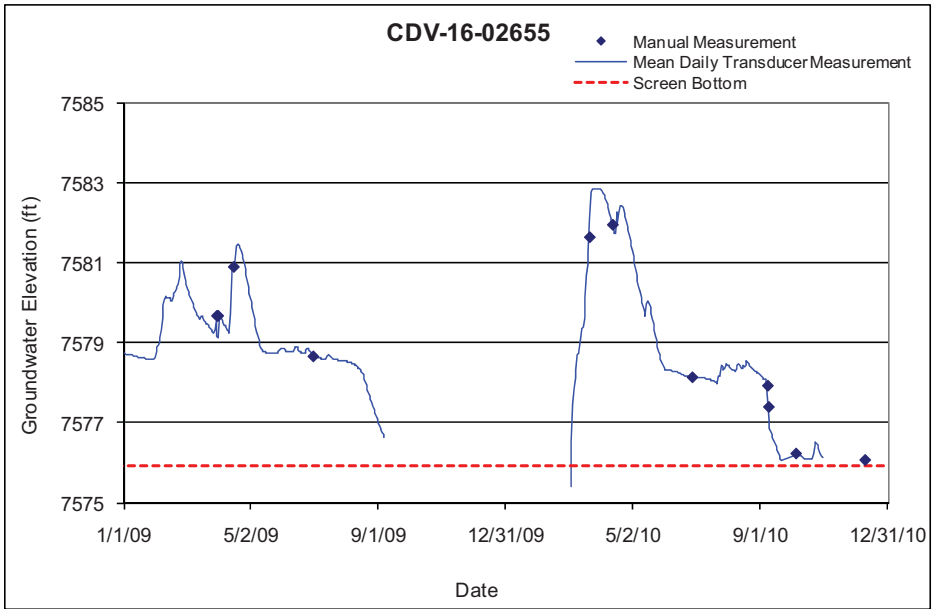
5.20 CDV-16-02655

Location: Westernmost upper Cañon de Valle in TA-16, approximately 800 ft east of Anchor Ranch Road.
Period of Record: May 15, 1998, through December 10, 2010.
Remarks: None.

CDV-16-02655 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	2.3	7.3	7580.91	7575.91	5.0			7.3	7575.91	7.6	0.3	0.7	Alluvial groundwater

Note: Aluminum cap elevation: 7583.70; Ground Elevation: 7583.21 ft; all depth measurements are from this elevation



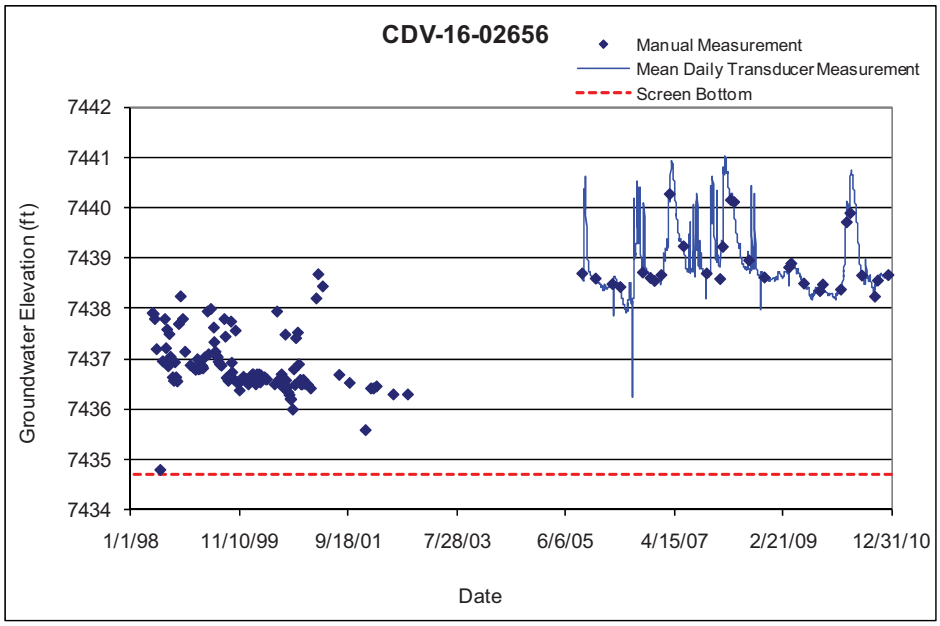


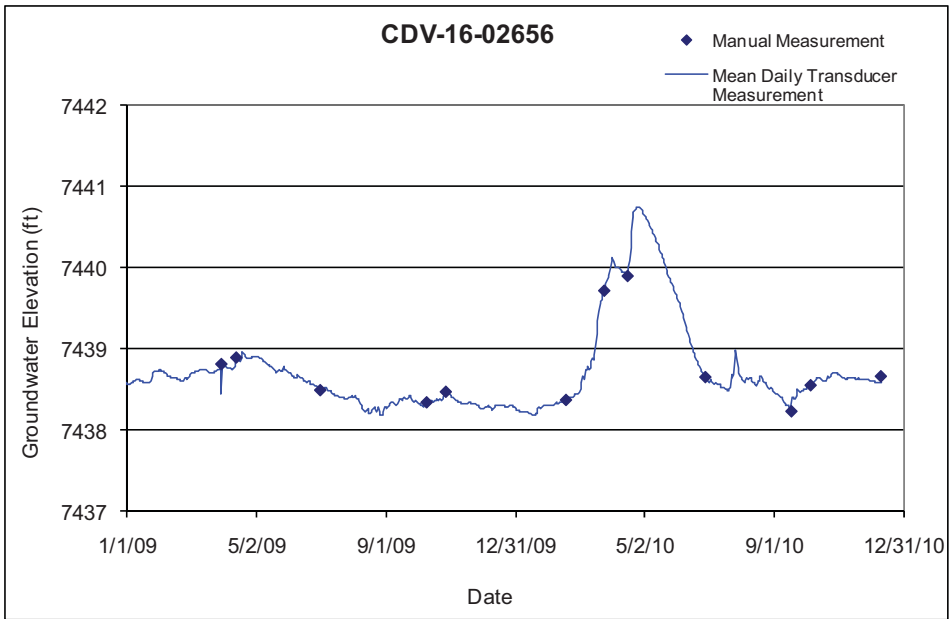
5.21 CDV-16-02656

Location: In upper Cañon de Valle at the northern boundary of TA-16.
Period of Record: May 15, 1998, through December 10, 2010.
Remarks: None.

CDV-16-02656 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	3.0	8.0	7439.69	7434.69	5.0			8.0	7434.69	8.3	0.3	0.7	Alluvial groundwater

Note: Aluminum cap Elevaton: 7443.18 ft; Ground Elevation: 7442.69 ft; all depths are from this elevation





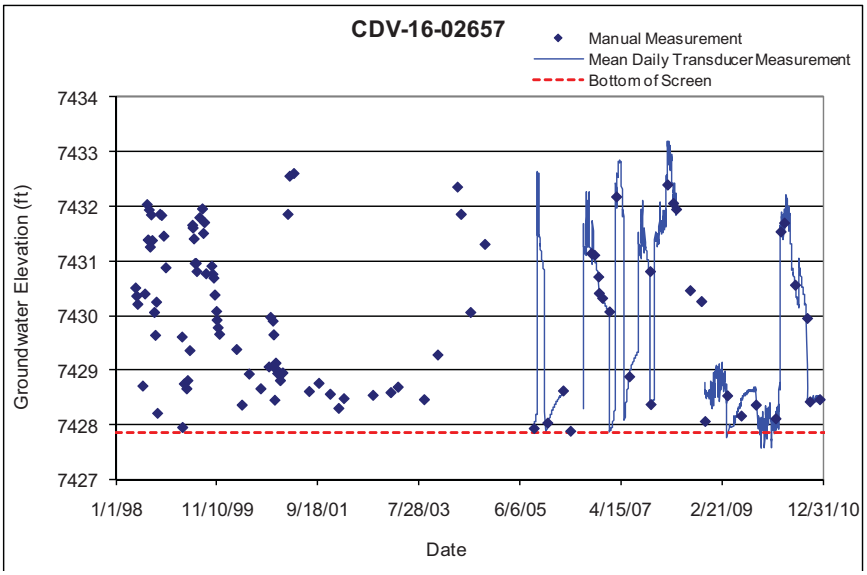
5.22 CDV-16-02657

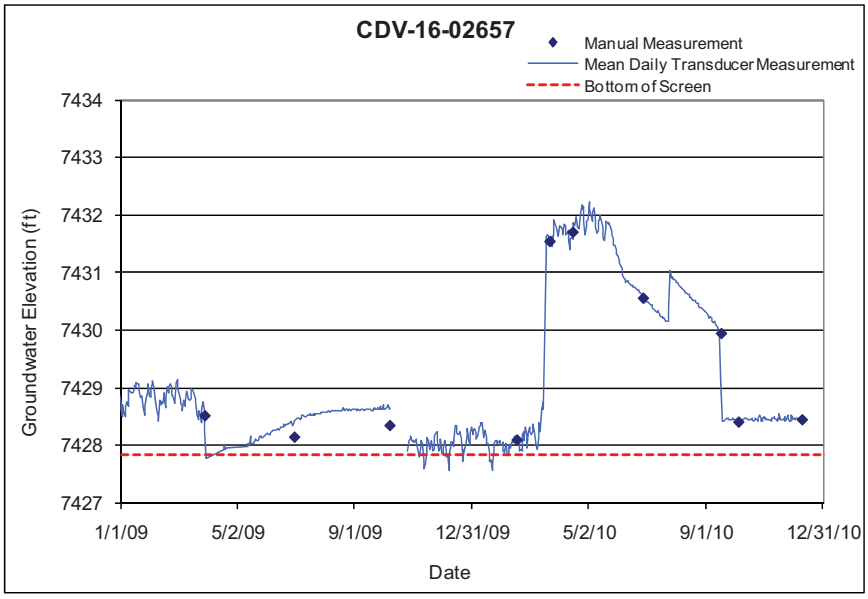
Location: Upper Cañon de Valle at northern boundary of TA-16, approximately 200 ft east-southeast of well CDV-16-02656.
Period of Record: May 15, 1998, through December 10, 2010.
Remarks: Transducer began to malfunction around April 21, 2008; replaced October 31, 2008. This well is closed by a manhole cover, and the cable often cannot vent, resulting in mean daily transducer measurements that differ from the corresponding manual measurements. The erratic values possibly come from a compromised sump.

CDV-16-02657 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	0.4	5.4	7432.85	7427.85	5.0			5.4	7427.85	5.7	0.3	0.7	Alluvial groundwater

Note: Ground Elevation: 7433.25 ft; all depths are from this elevation

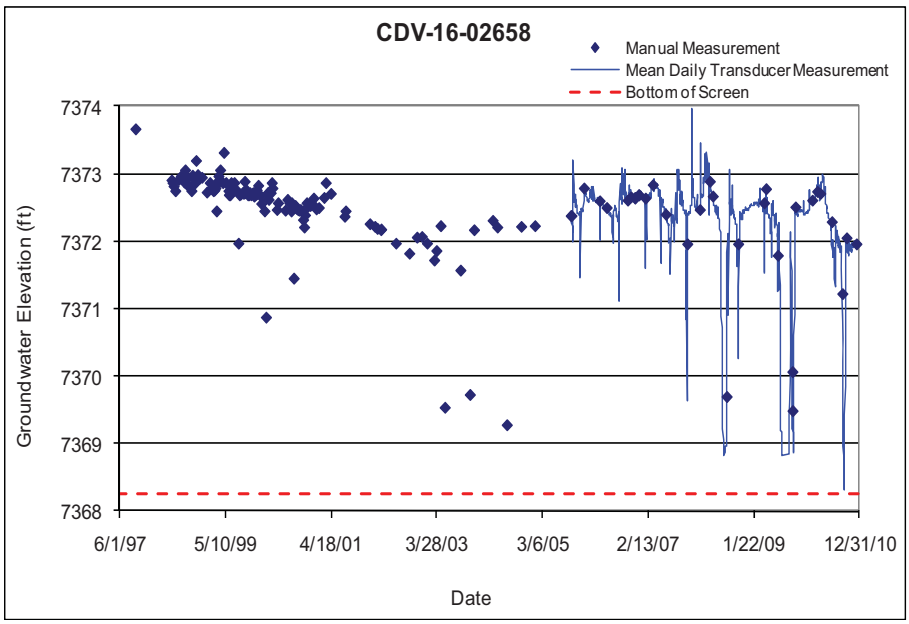


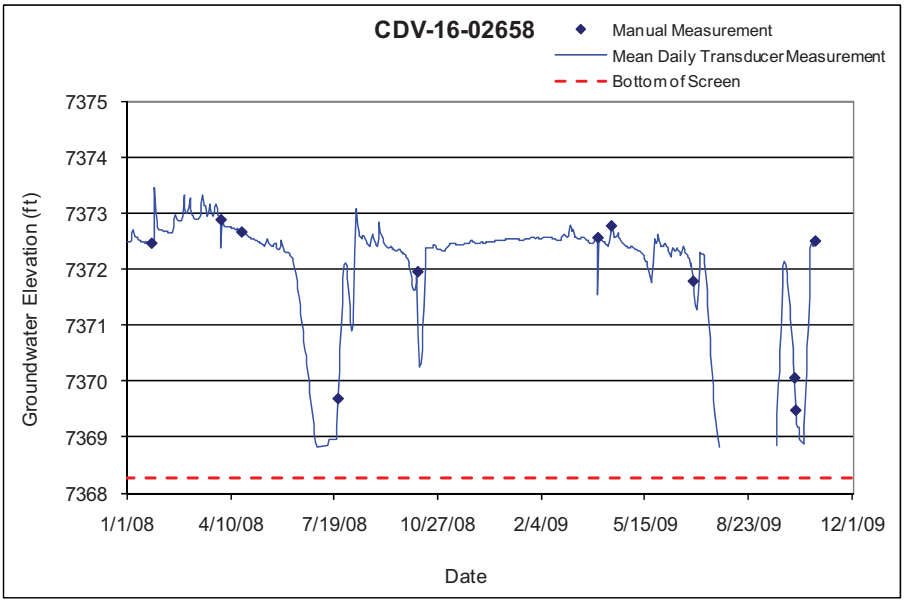


5.23 CDV-16-02658

Location: Upper Cañon de Valle at northern boundary of TA-16, approximately 200 ft east-southeast of well CDV-16-02657 and approximately 800 ft east-southeast of Burning Ground Spring.
Period of Record: September 15, 1997, through December 10, 2010.
Remarks: None.

CDV-16-02658 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	1.9	6.9	7373.26	7368.26	5.0			6.9	7368.26	7.2	0.3	0.7	Alluvial groundwater
Note: Aluminum Cap Elevation: 7375.60 ft; Ground Elevation: 7375.16 ft; all depths are from this elevation													



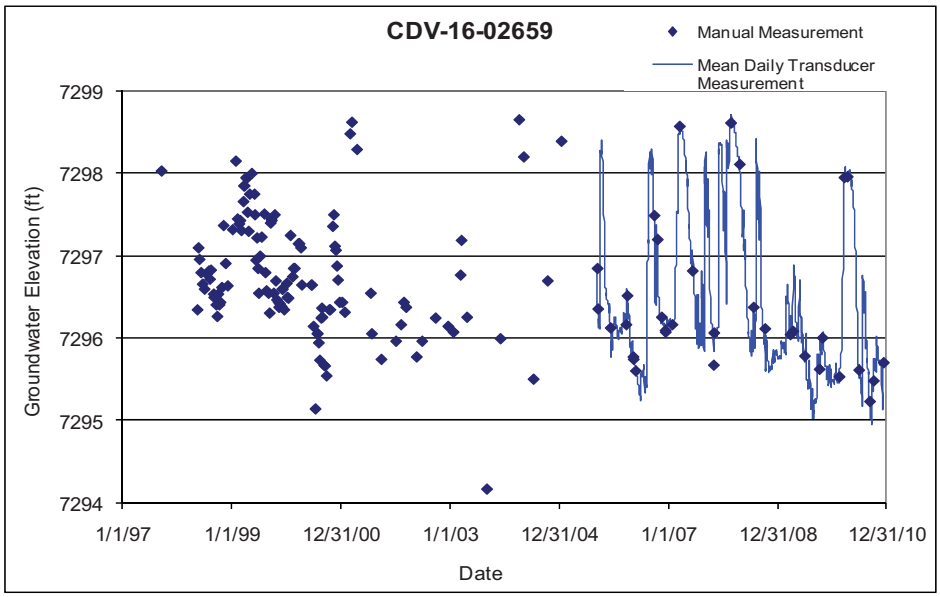


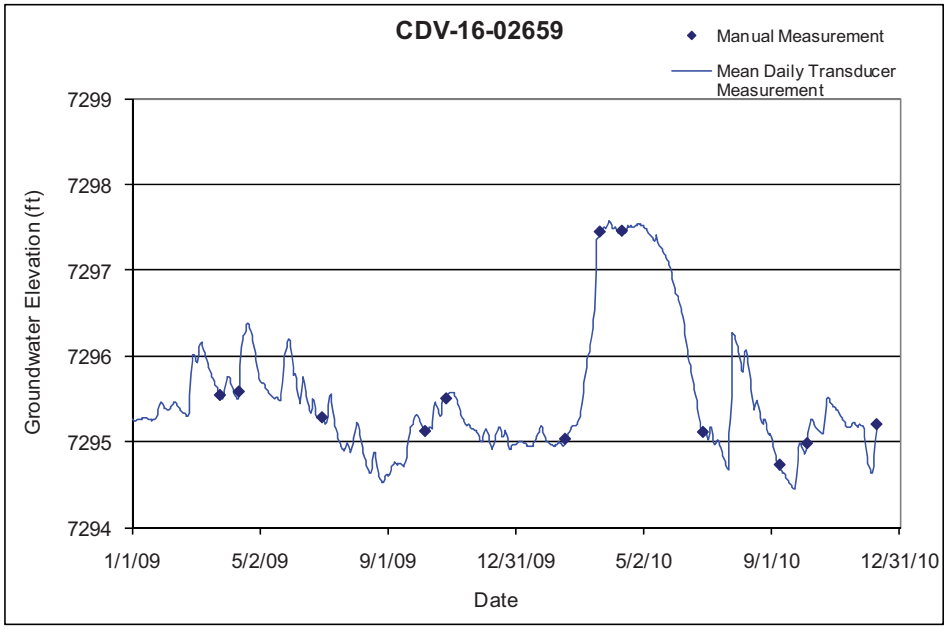
5.24 CDV-16-02659

Location: Upper Cañon de Valle at northern boundary of TA-16, approximately 1800 ft east-northeast of well CDV-16-02657.
Period of Record: September 17, 1997, through December 10, 2010.
Remarks: None.

CDV-16-02659 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	1.7	6.7	7298.32	7293.32	5.0			6.7	7293.32	7.0	0.3	0.7	Alluvial groundwater

Note: Aluminum Cap Elevation: 7300.50 ft, Ground Level: 7300.02; all depths are from this elevation



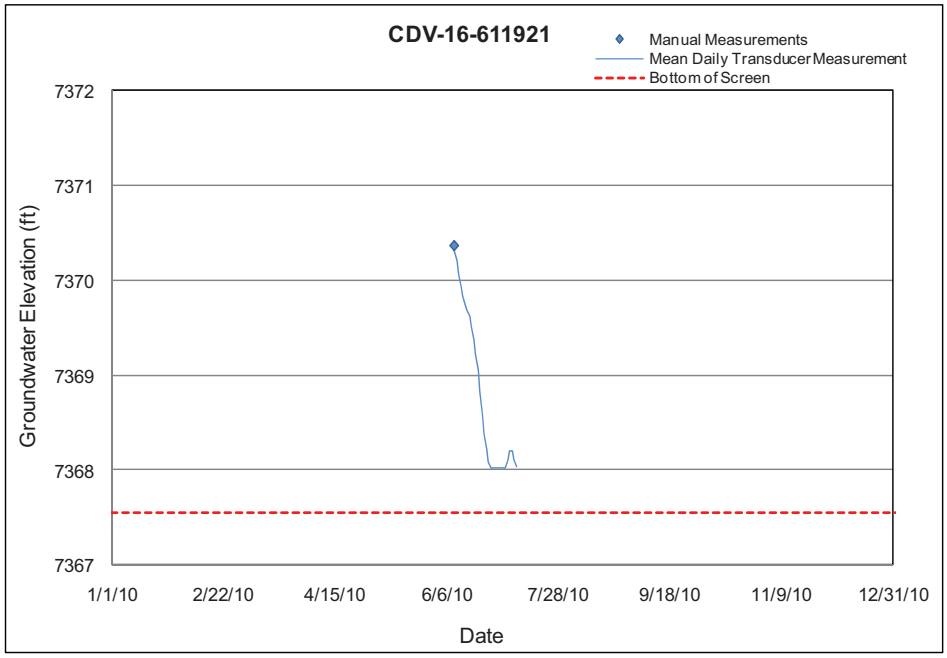


5.25 CDV-16-611921

Location: Upper Cañon de Valle at northern boundary of TA-16, upstream of the Permeable Reactive Barrier (PRB) wall on the south bank.
Period of Record: June 10, 2010, through December 8, 2010.
Remarks: No water in the well since early July 2010.

CDV-16-611921 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	6.3	11.3	7372.6	7367.6	5.0	NA	NA	11.3	7367.6	12.5	1.2	0.7	Alluvial groundwater

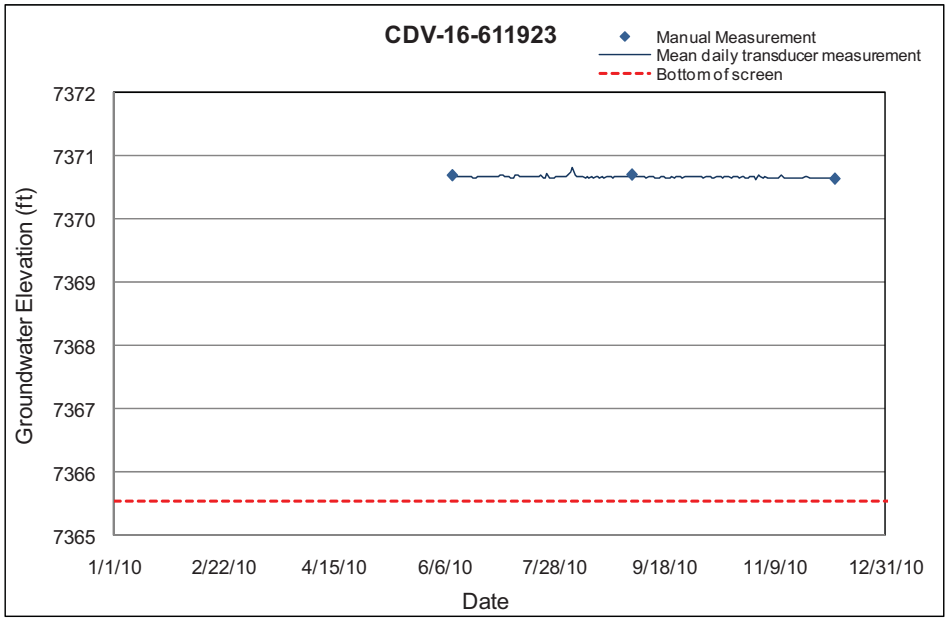
Note: Monument Marker: 7378.85 ft; all depths are from this elevation



5.26 CDV-16-611923

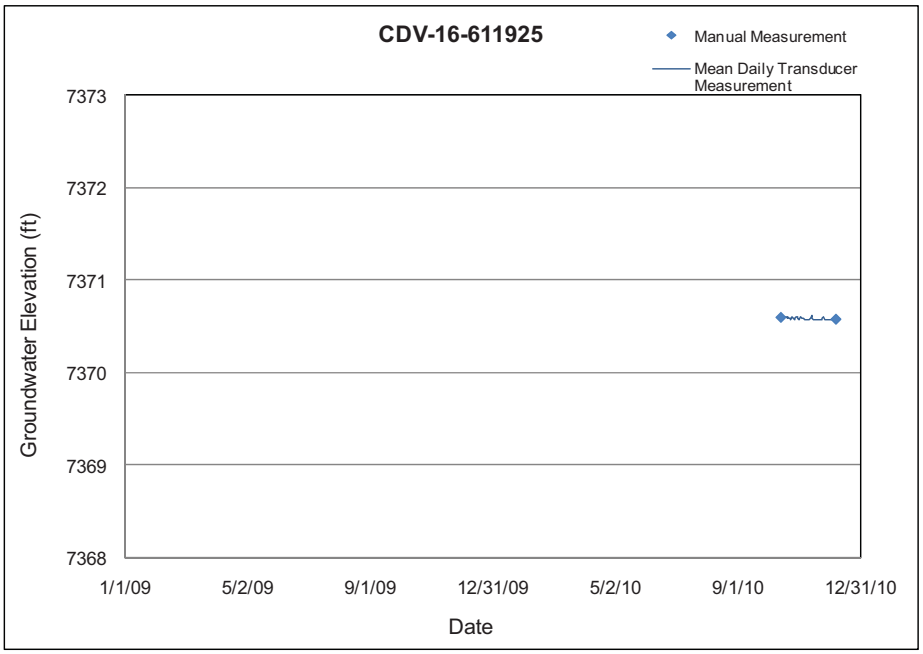
Location: Upper Cañon de Valle at northern boundary of TA-16, upstream of the PRB wall on the north bank.
Period of Record: June 10, 2010, through December 8, 2010.
Remarks:

CDV-16-611923 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Vol (L)	Comment
1	3.2	8.2	7373.6	7368.6	5.0			8.2	7368.6	8.7	0.5	0.3	Alluvial groundwater
Note: Top of Protective Housing: 7376.81 ft; Top of PVC Casing 7376.43 ft; Ground Level 7373.83 ft; all depths are from this elevation													



5.27 CDV-16-611925

Location: Upper Cañon de Valle at northern boundary of TA-16, in an access tube within the PRB wall on the south bank.
Period of Record: October 14, 2010, through December 8, 2010.
Remarks: Not a well, but an access tube into the PRB. Purpose of this transducer is to ensure that water is being effectively dammed by the PRB and that water is flowing through the conduits within the wall.

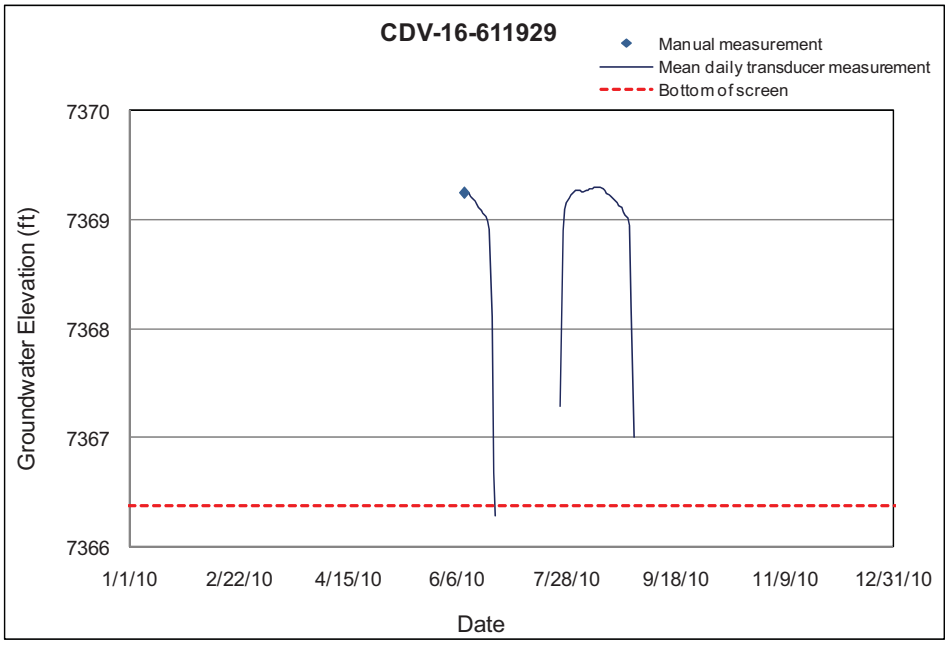


5.28 CDV-16-611929

Location: Upper Cañon de Valle at northern boundary of TA-16, downstream of the PRB wall on the south bank.
Period of Record: October 14, 2010, through December 8, 2010.
Remarks: None.

CDV-16-611929 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	7.0	12.0	7371.4	7366.4	5.0	NA	NA	12.0	7366.4	13.1	1.1	0.7	Alluvial groundwater

Note: Monument Marker: 7378.38 ft; all depths are from this elevation

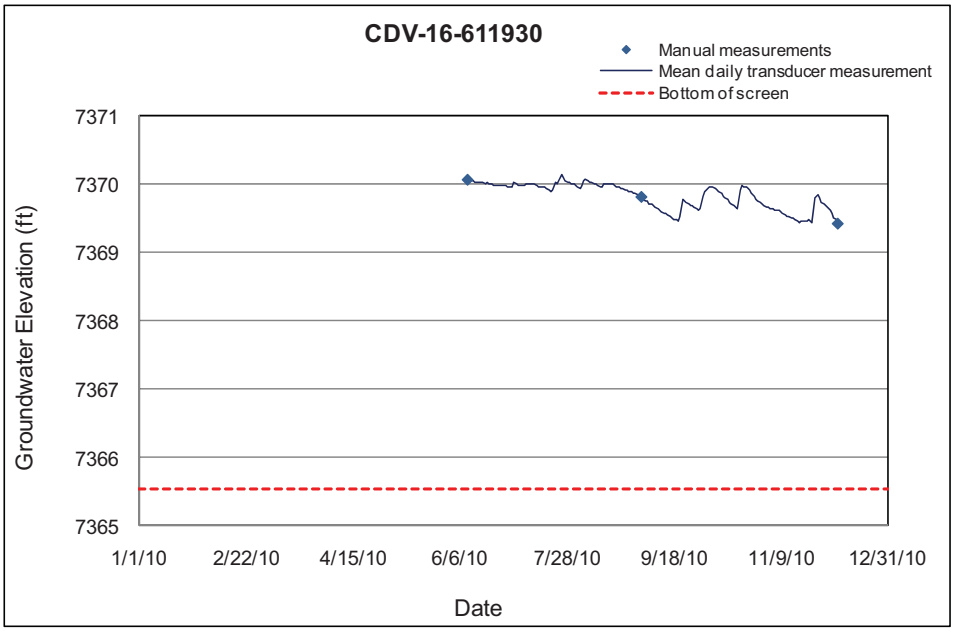


5.29 CDV-16-611930

Location: Upper Cañon de Valle at northern boundary of TA-16, downstream of the PRB wall on the south bank.
Period of Record: June 10, 2010, through December 8, 2010.
Remarks: None.

CDV-16-611930 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	7.0	12.0	7370.5	7365.5	5.0			12.0	7365.5	13.0	1.0	0.6	Alluvial groundwater

Note: Monument Marker: 7377.54 ft; all depths are from this elevation



5.30 CDV-16-611931

Location: Upper Cañon de Valle at northern boundary of TA-16, downstream of the PRB wall on the north bank.
Period of Record: June 10, 2010, through October 14, 2010.
Remarks: None.

CDV-16-611931 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	5.0	10.0	7369.2	7364.2	5.0			10.0	7364.2	12.0	2.0	1.2	Alluvial groundwater

Note: Monument Marker: 7374.18 ft; all depths are from this elevation

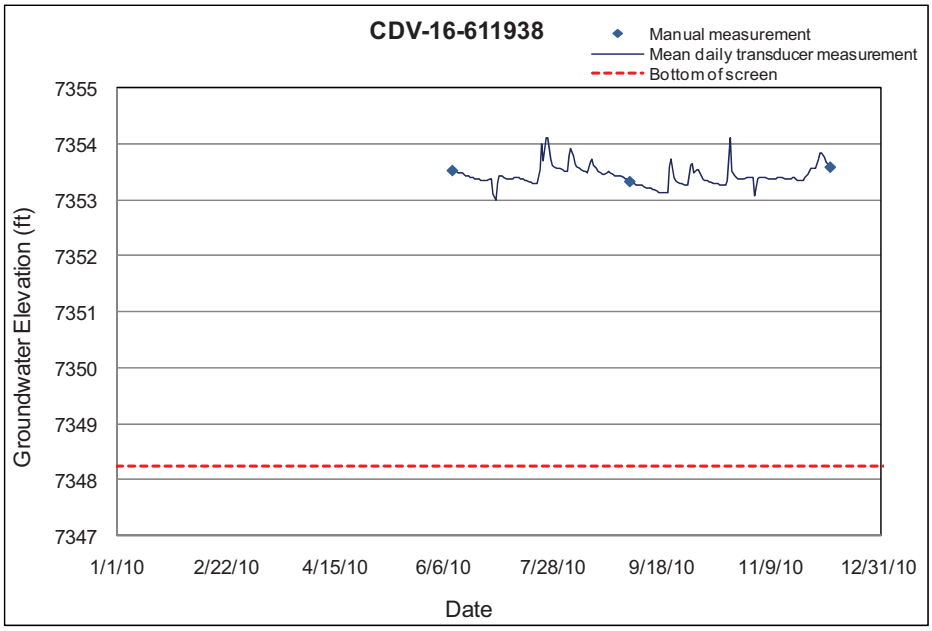
CDV-16-611931 Manual Measurements		
Date	Water Elevation (ft)	Comments
6/10/2010	7362.01	Sump
9/3/2010	7361.99	Sump
10/14/2010	7361.94	Sump

5.31 CDV-16-611938

Location: Upper Cañon de Valle at northern boundary of TA-16, approximately 350 ft downstream of the PRB wall on the south bank.
Period of Record: June 10, 2010, through December 8, 2010.
Remarks: None.

CDV-16-611938 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	3.0	8.0	7353.3	7348.3	5.0			8.0	7348.3	8.5	0.5	0.3	Alluvial groundwater

Note: Ground surface: 7356.25 ft; all depths are from this elevation



5.32 FCO-1

Location: Fence Canyon, approximately 0.1 mi northwest of SR-4.
Period of Record: June 9, 1997, through September 7, 2010.
Remarks: Well has been dry since completion. A transducer was installed January 16, 2008. Well has remained dry since installation. Monitoring was discontinued September 7, 2010.

FCO-1 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev(ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Comment
1	2.4	12.4	6507.7	6497.7	10.0			2.4	6507.7	12.4	0.0	0.0	Alluvial groundwater
Note: Ground elevation is 6510.13 ft; all depths are from this elevation													

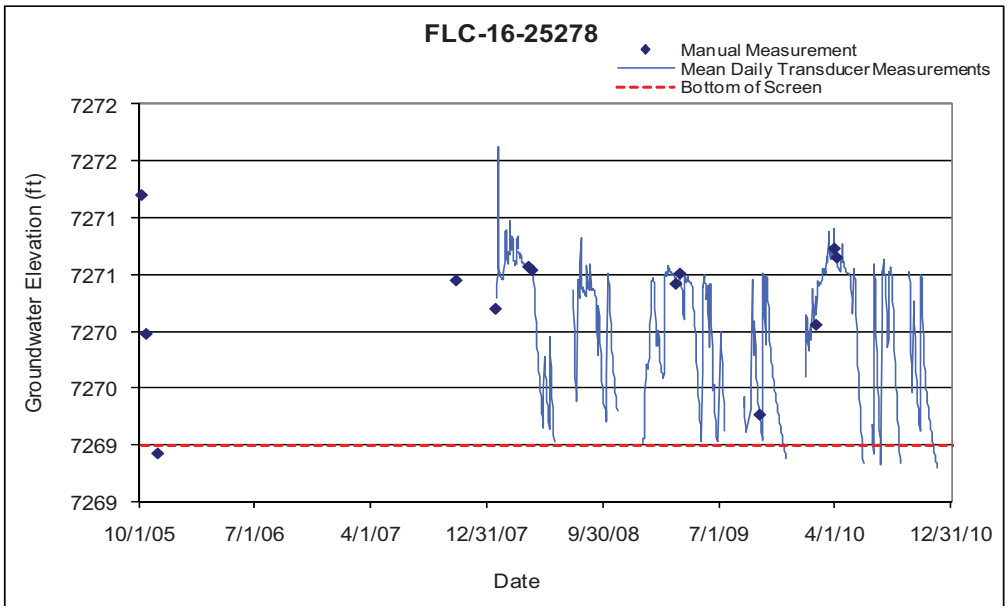
FCO-1 Manual Water Levels

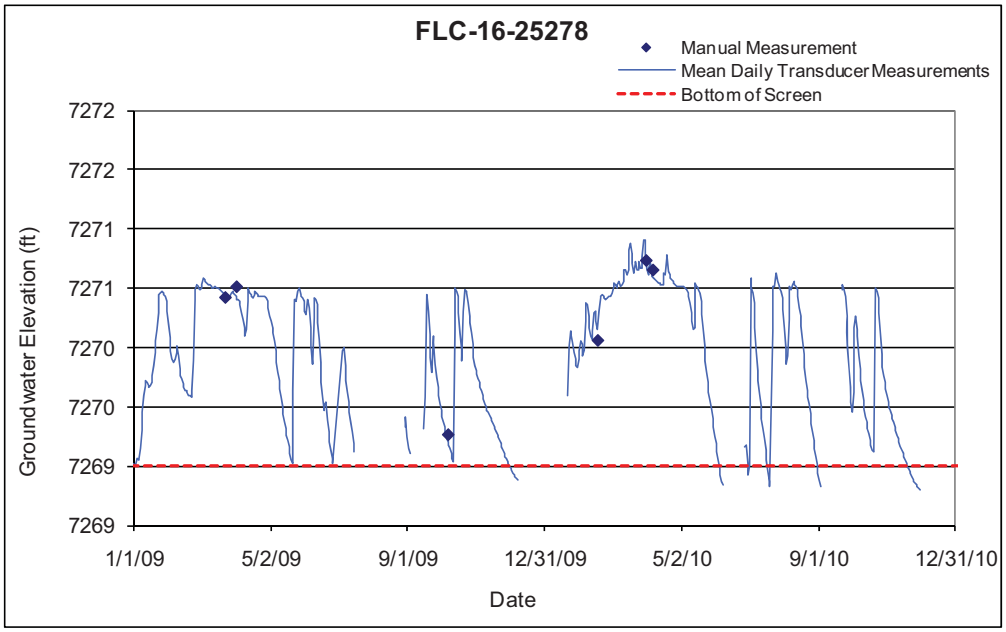
Date	Comments	Date	Comments
6/9/1997	Dry	9/14/2005	Dry
10/13/1997	Dry	6/23/2006	Dry
3/25/1998	Dry	9/8/2006	Dry
5/29/1998	Dry	12/15/2006	Dry
7/28/1998	Dry	1/24/2007	Dry
3/3/1999	Dry	3/15/2007	Dry
6/23/1999	Dry	5/24/2007	Dry
8/30/1999	Dry	6/6/2007	Dry
11/15/1999	Dry	9/5/2007	Dry
3/26/2000	Dry	10/17/2007	Dry
5/16/2000	Dry	1/16/2008	Dry
8/30/2000	Dry	4/8/2008	Dry
10/8/2000	Dry	4/25/2008	Dry
4/16/2002	Dry	7/18/2008	Dry
8/19/2002	Dry	10/7/2008	Dry
11/13/2002	Dry	4/1/2010	Dry
2/19/2003	Dry	6/29/2010	Dry
5/18/2003	Dry	9/7/2010	Dry
4/7/2004	Dry		

5.33 FLC-16-25278

Location: Fish Ladder Canyon, approximately 0.1 mi southeast of the TA-16 Burning Grounds.
Period of Record: June 9, 1997, through December 8, 2010.
Remarks: Water levels frequently drop below the screen.

FLC-16-25278 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Comment
1	1.6	3.2	7270.6	7269.0	1.6			3.2	7269	3.4	0.2	0.12	Alluvial groundwater
Note: Ground Elevation: 7272.20 ft; all measurements are from this elevation													





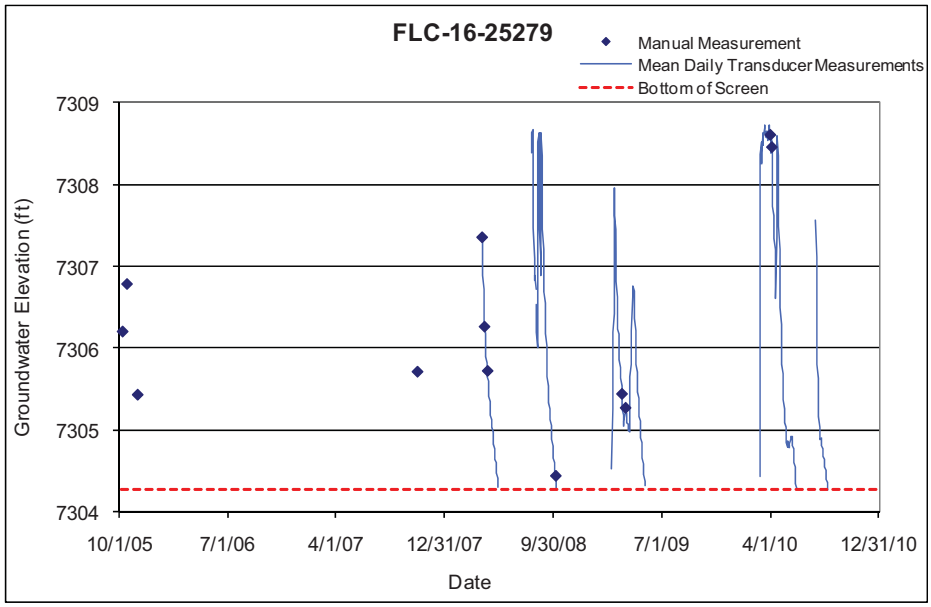
5.34 FLC-16-25279

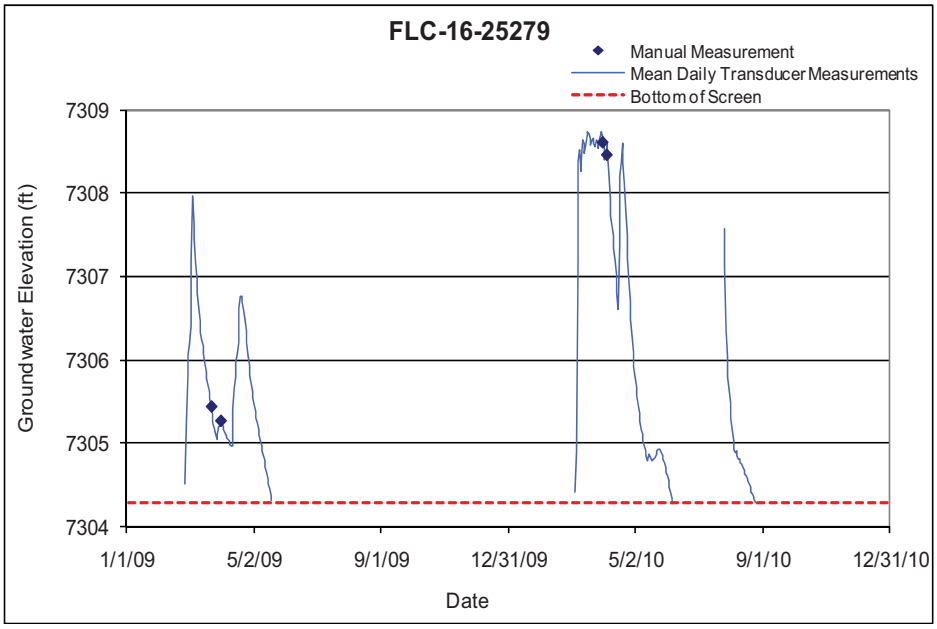
Location: Fish Ladder Canyon, approximately 0.2 mi east of FLC-16-25278.
Period of Record: June 9, 1997, through December 8, 2010.
Remarks: Water levels frequently drop below the screen. Bottom of screen is calculated to be at 7304.29 ft, rather than what was originally reported.

FLC-16-25279 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	2.7	4.3	7306.60	7305.00	1.6			4.3	7305	4.5	0.2	0.12	Alluvial groundwater

Note: Ground Elevation: 7309.30 ft; all measurements are from this elevation



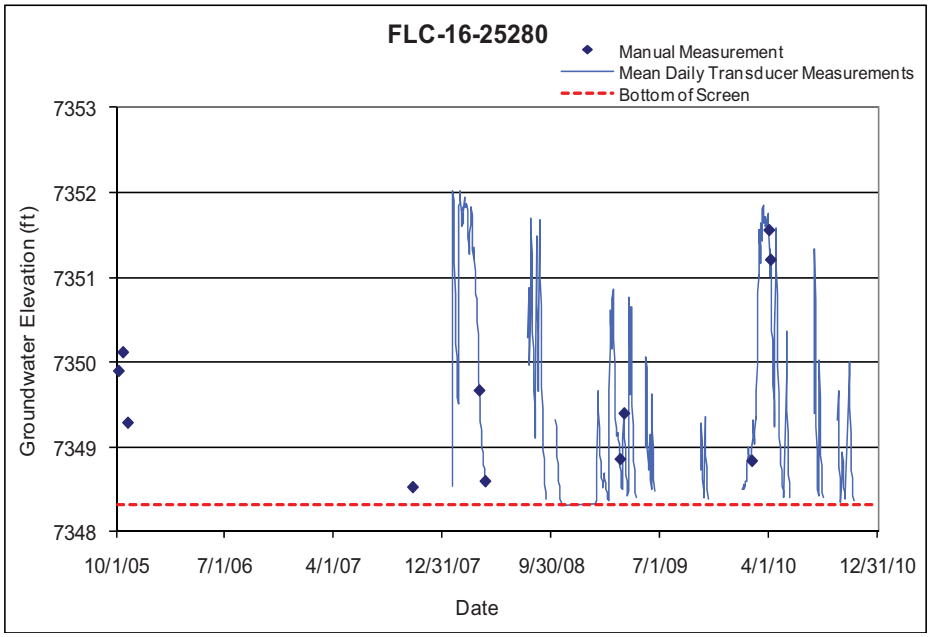


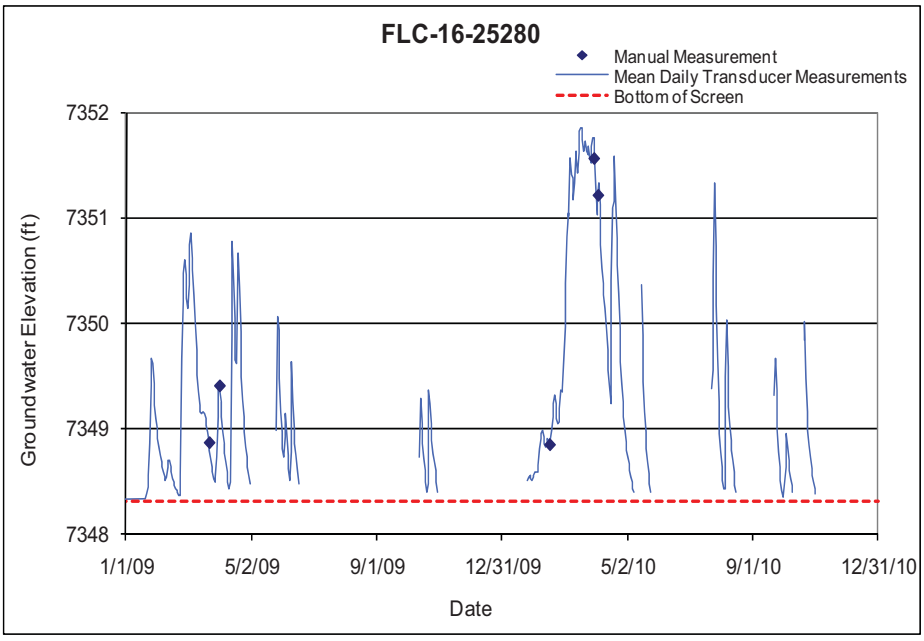
5.35 FLC-16-25280

Location: Fish Ladder Canyon, approximately 0.2 mi east of FLC-16-25279.
Period of Record: June 9, 1997, through December 8, 2010.
Remarks: Water levels frequently drop below the screen.

FLC-16-25280 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	2.6	4.2	7350.3	7348.7	1.6			4.2	7348.7	4.4	0.2	0.12	Alluvial groundwater

Note: Ground Elevation: 7352.90 ft; all measurements are from this elevation





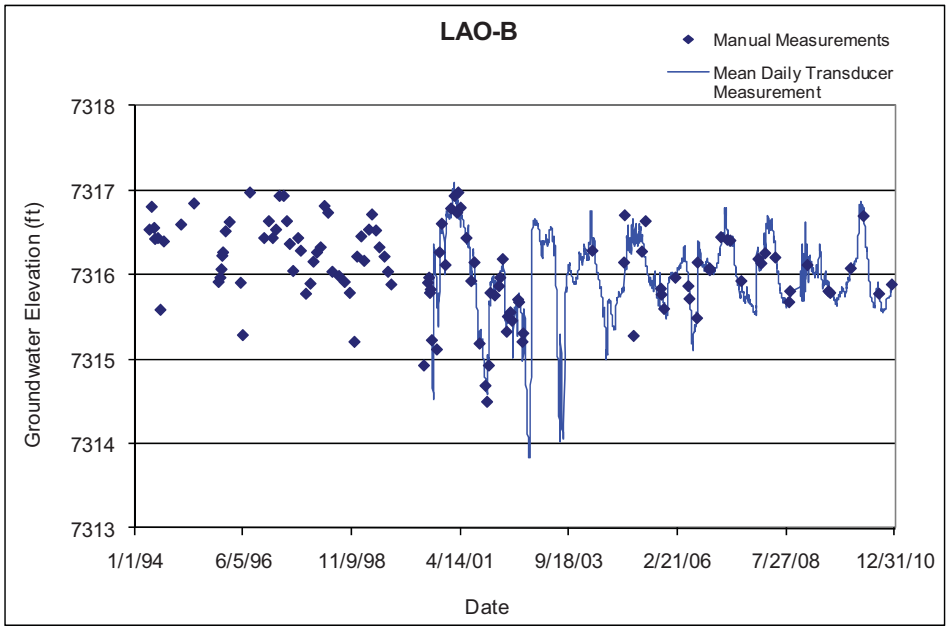
5.36 LAO-B

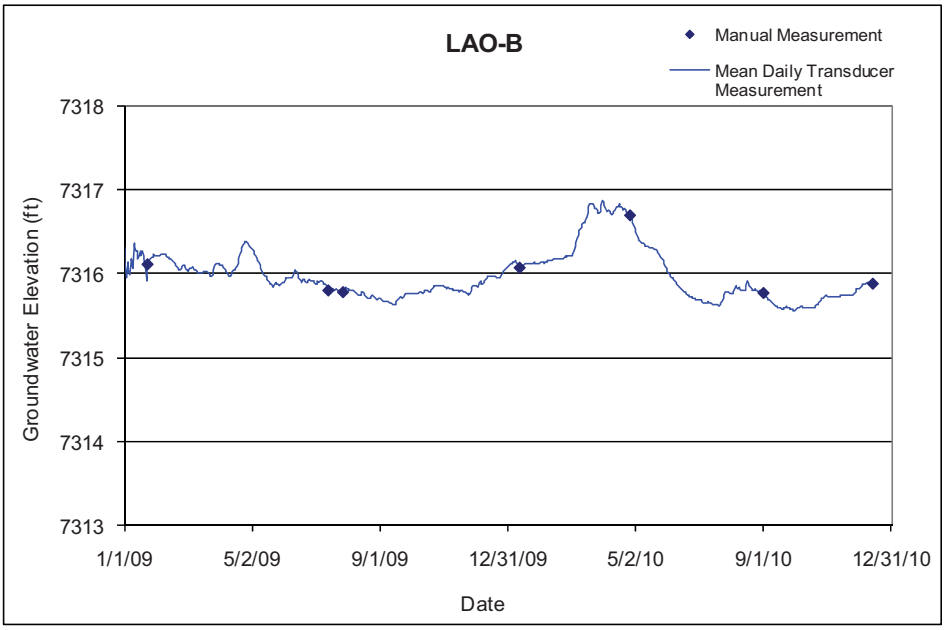
Location: Upper Los Alamos Canyon, approximately 3000 ft west of the Omega Bridge.
Period of Record: April 28, 1994, through December 14, 2010.
Remarks: None.

LAO-B Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	11.8	26.8	7311.8	7296.8	15.0			26.8	7296.8	27.2	0.4	0.9	Alluvial groundwater

Note: Ground elevation is 7323.59 ft; all depths are from this elevation





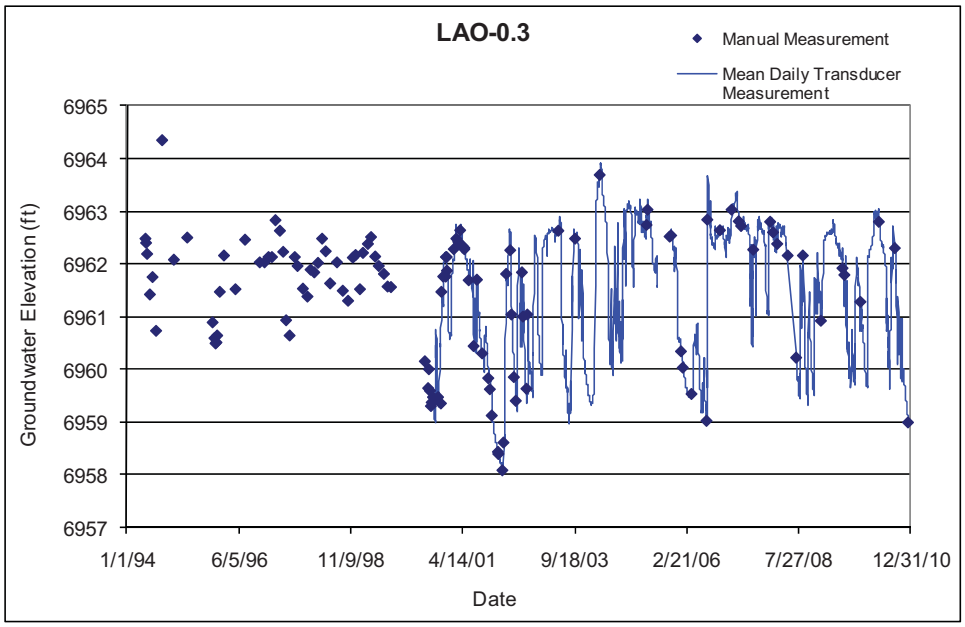
5.37 LAO-0.3

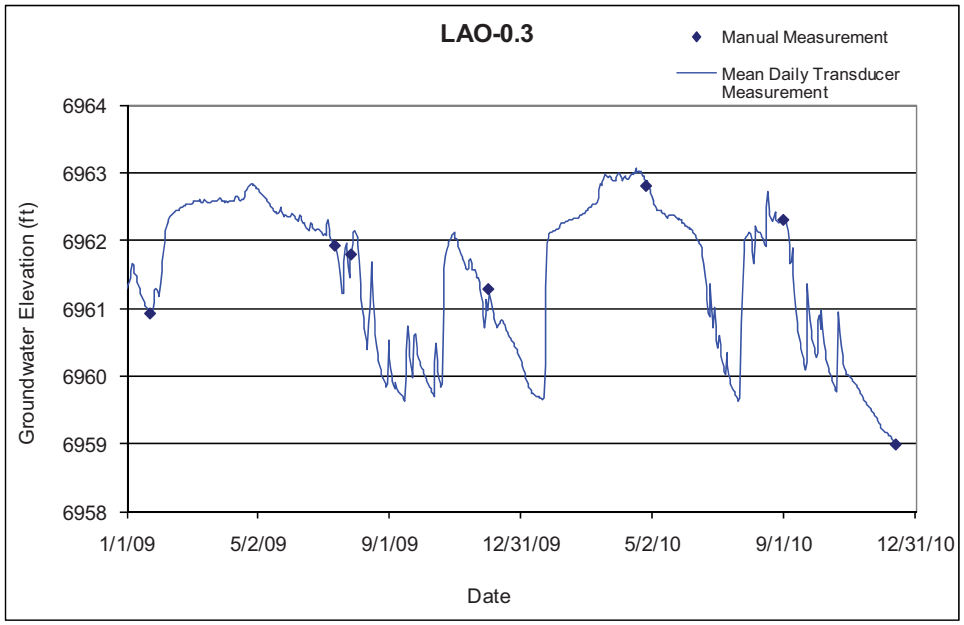
Location: Upper Los Alamos Canyon, approximately 5700 ft east of the Omega Bridge.
Period of Record: June 1, 1994, through December 14, 2010.
Remarks: Transducer readings were not valid from July 7, 2005, through October 12, 2005; the pressure sensor was in the mud at the bottom of the well.

LAO-0.3 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	5.9	10.9	6962.23	6957.23	5.0			10.9	6957.23	11.25	0.35	0.86	Alluvial groundwater

Note: LAO-0.3 Ground elevation is 6968.13 ft; all depths are from this elevation



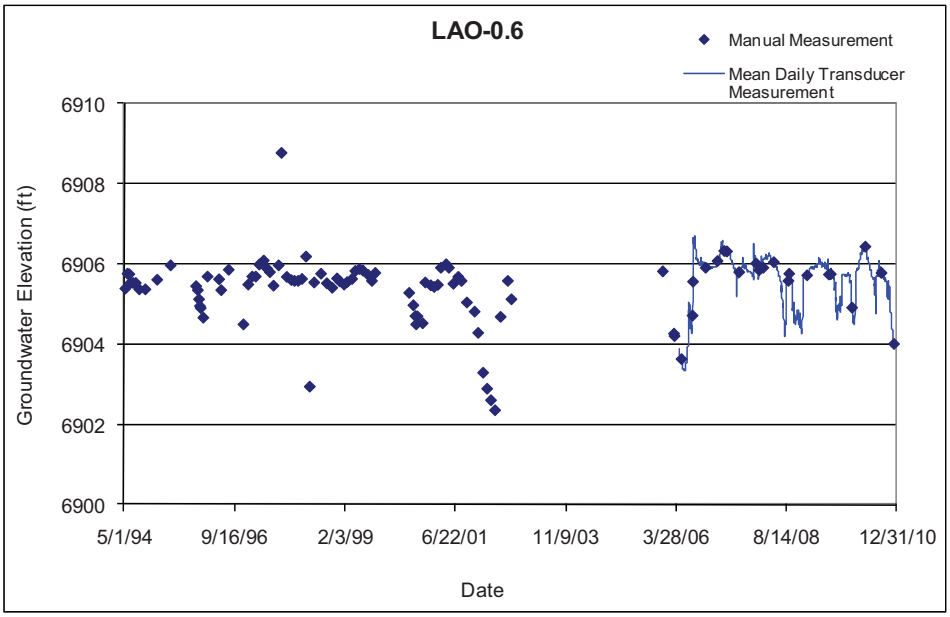


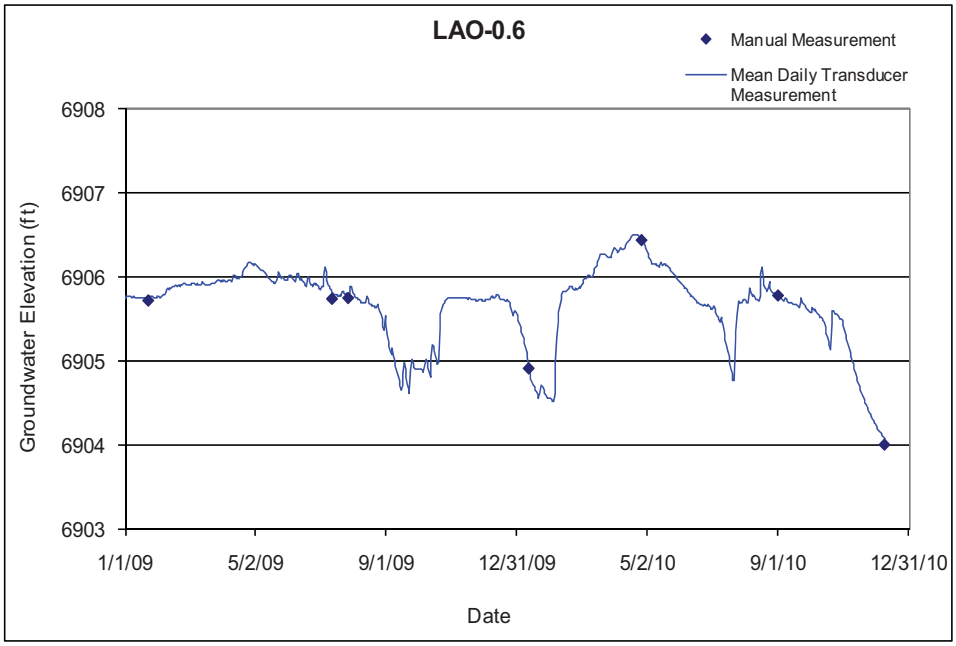
5.38 LAO-0.6

Location: Los Alamos Canyon, approximately 7500 ft east of the Omega Bridge.
Period of Record: May 6, 1994, through December 9, 2010.
Remarks: None.

LAO-0.6 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	8.0	13.0	6902.34	6897.34	5			13.0	6897.34	13.35	0.35	0.86	Alluvial Groundwater

Note: Aluminum Cap Elevation: 6910.74 ft; Ground elevation is 6910.34 ft; all depths are from this elevation



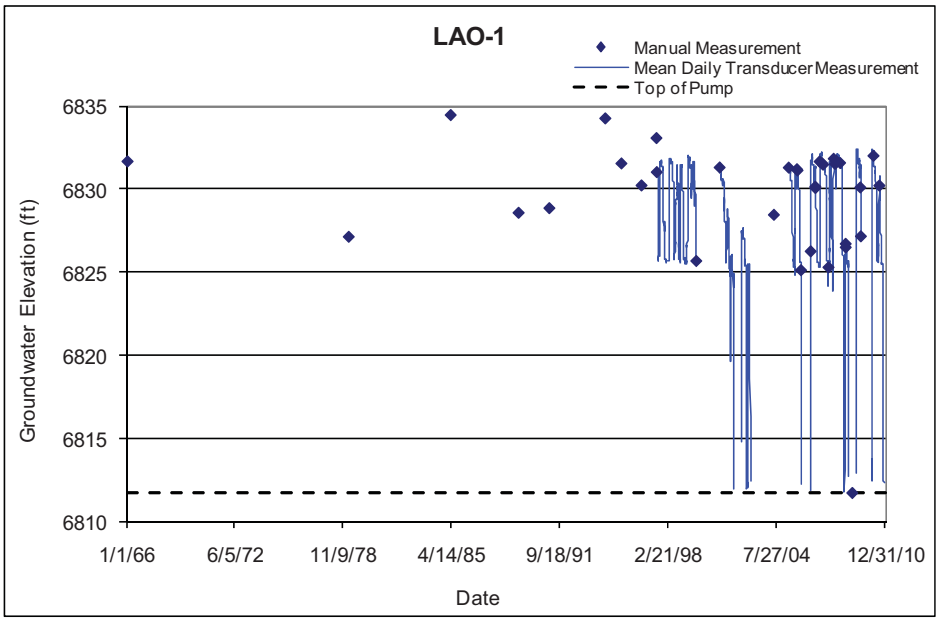


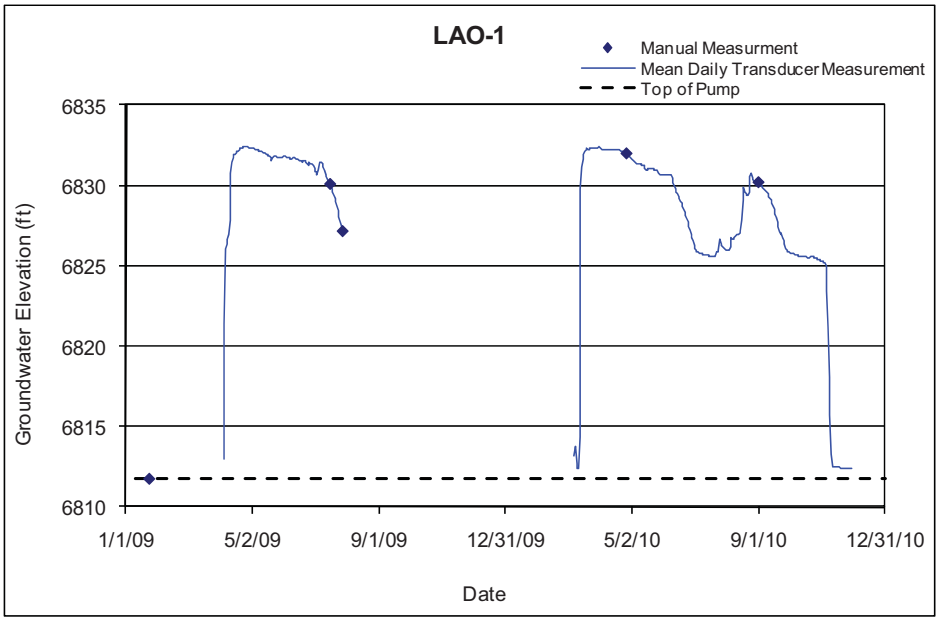
5.39 LAO-1

Location: Los Alamos Canyon, near the eastern border of TA-2.
Period of Record: February 15, 1966, through December 9, 2010.
Remarks: LAO-1 is a 2-in.-diameter well with a dedicated bladder pump. The transducer is sitting on top of the pump. Water levels were below the transducer in December 2008 and January 2009.

LAO-1 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	8	28	6828.24	6808.24	20			28	6808.24	28	0	0	Alluvial groundwater

Note: Ground elevation is 6836.24 ft; all depths are from this elevation



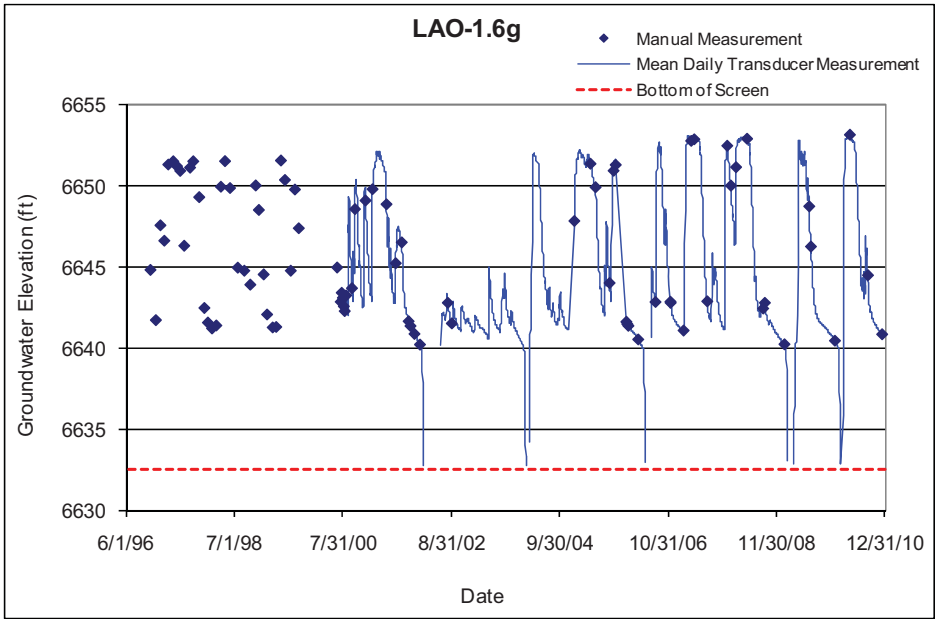


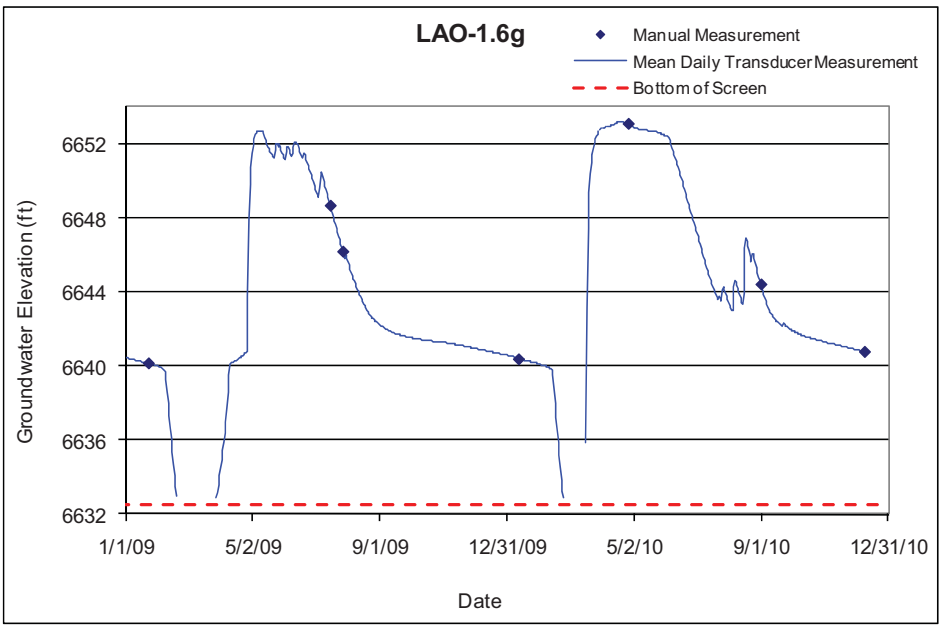
5.40 LAO-1.6g

Location: Los Alamos Canyon, approximately 400 ft west of the confluence with DP Canyon.
Period of Record: November 22, 1996, through December 9, 2010.
Remarks: None.

LAO-1.6G Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	10.5	25.5	6647.5	6632.5	15.0		6658.0	25.5	6632.5	30.82	5.4	13.2	Alluvial well

Note: Ground elevation is 6658.01 ft; all depths are from this elevation



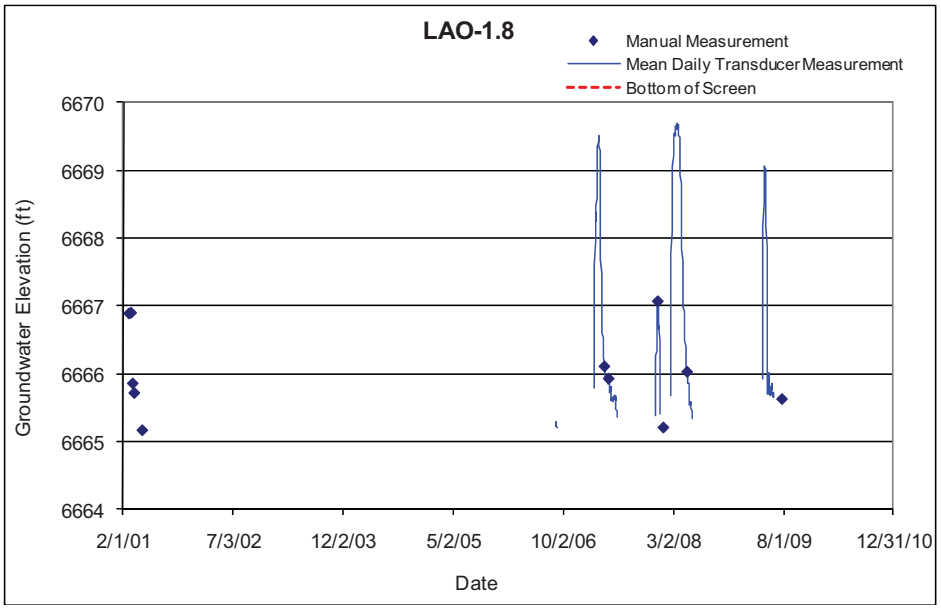


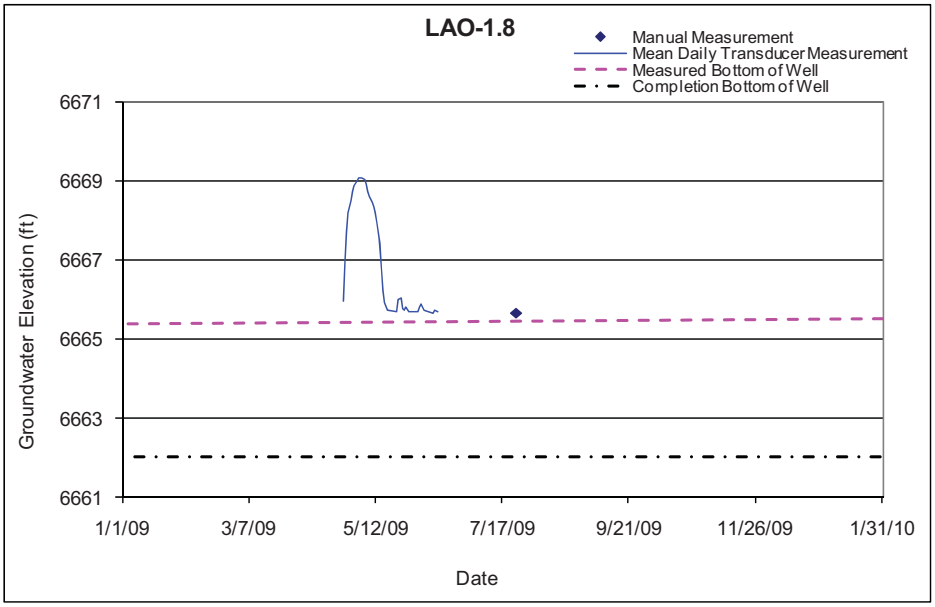
5.41 LAO-1.8

Location: Los Alamos Canyon, approximately 650 ft west of LAO-1.6g.
Period of Record: January 8, 2001, through January 7, 2010.
Remarks: This well frequently runs dry. The total depth of the well has changed over the years as it silts in, and is currently around 6665.6 ft. Monitoring in this well ceased on January 7, 2010.

LAO-1.8 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	8	18	6672.00	6662.00	10			18	6662.00	18	0	0	Alluvial Groundwater

Note: Brass Cap Elevation: 6680.00 ft; all depths are from this elevation

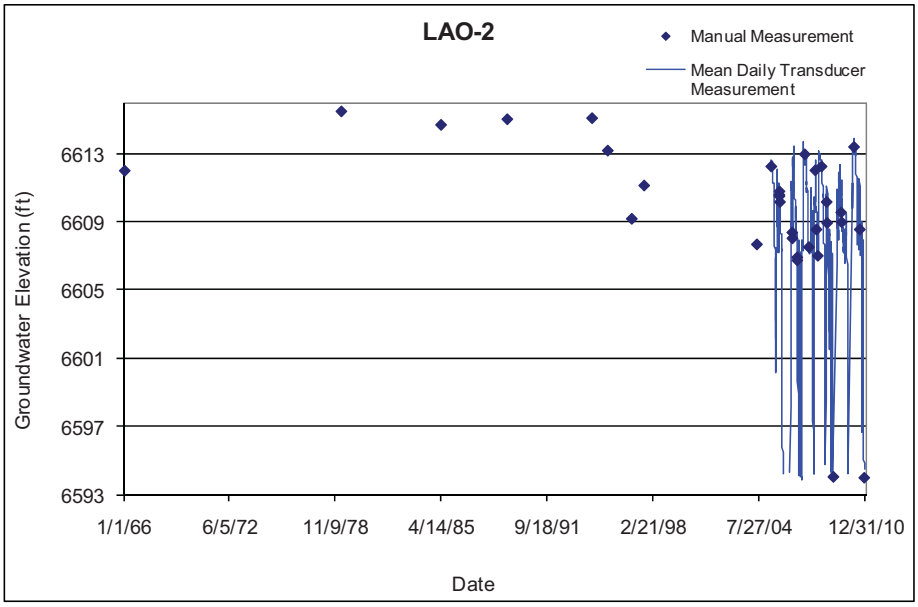


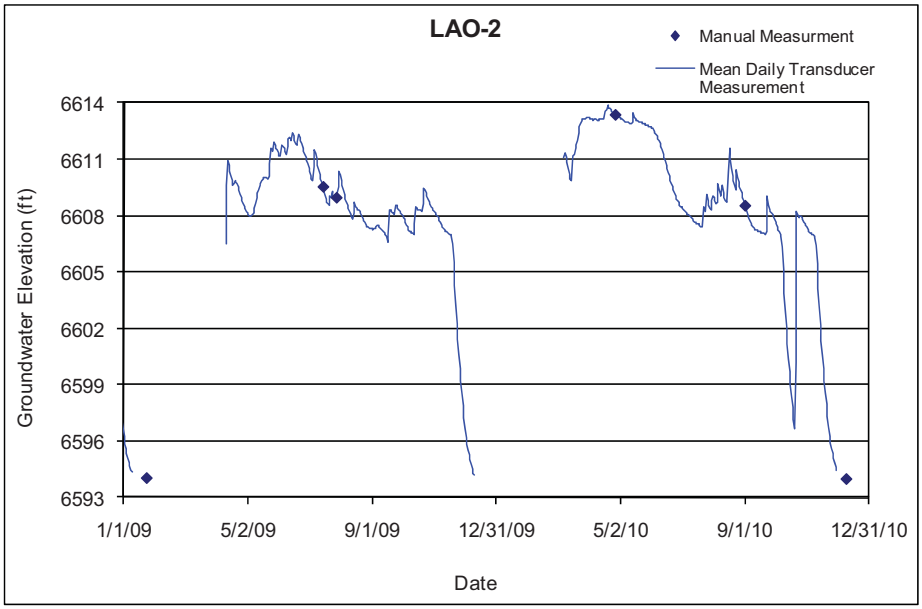


5.42 LAO-2

Location: Los Alamos Canyon, approximately 75 ft north of the confluence with DP Canyon.
Period of Record: February 1, 1966, through December 9, 2010.
Remarks: The transducer in this well is installed above the top of the pump with the transducer sensor at 6563.88 ft. Water level elevations below 6563.88 ft are not represented by transducer data.

LAO-2 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Comment
1	12	32	6611	6591	20			32	6591.0	32.0	0	0	Alluvial Groundwater
Note: Brass Cap Elevation is 6623.00 ft; all depths are from this elevation													

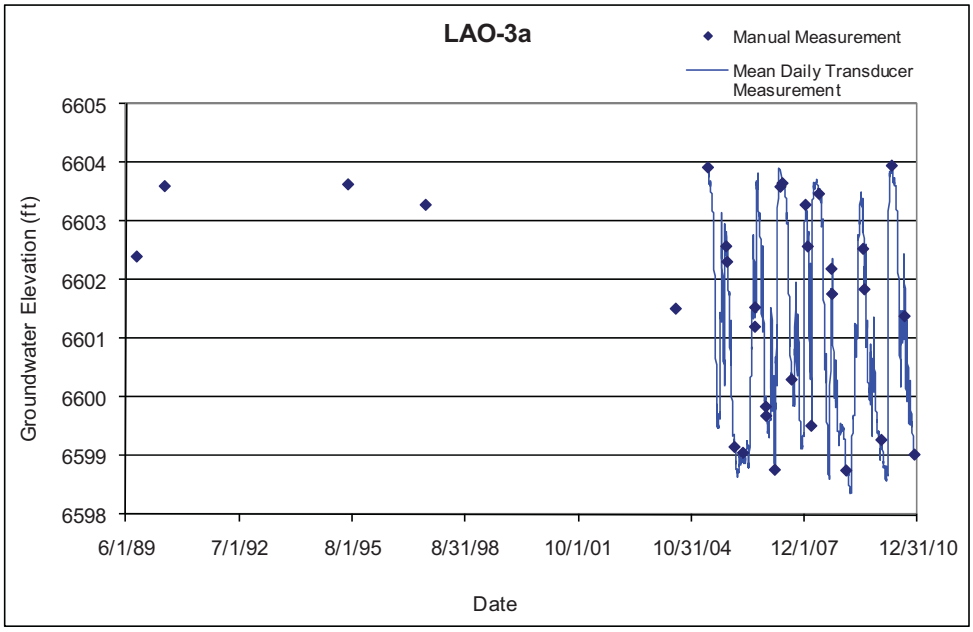


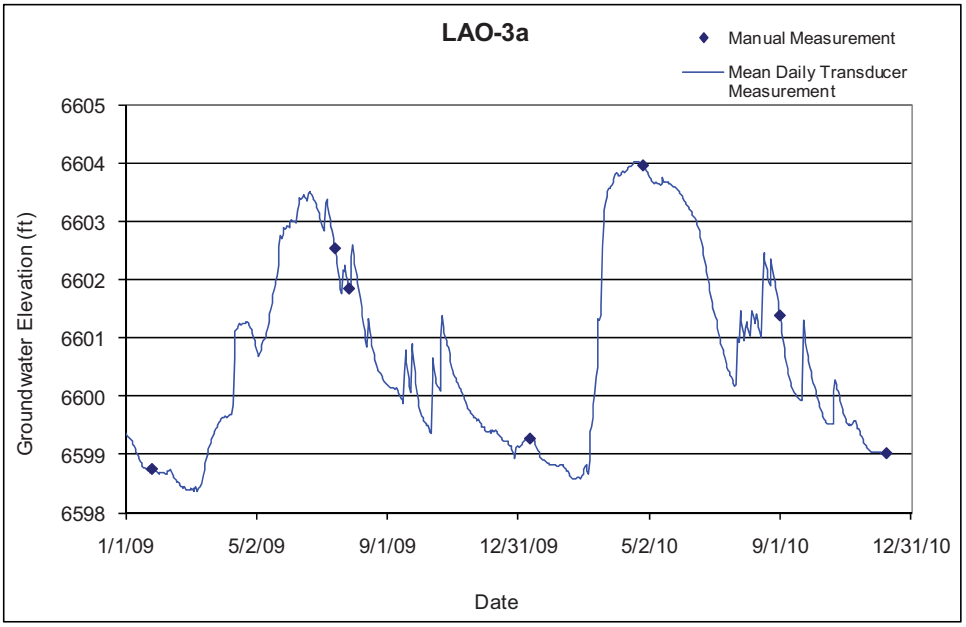


5.43 LAO-3a

Location: Los Alamos Canyon, approximately 1000 ft east of the confluence with DP Canyon.
Period of Record: September 15,1989, through December 9, 2010.
Remarks: None.

LAO-3a Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Comment
1	4.7	14.7	6604.4	6594.4	10.0			14.7	6594.4	15	0.3	0.2	Alluvial groundwater
Note: Ground elevation is 6609.10 ft; all depths are from this elevation													

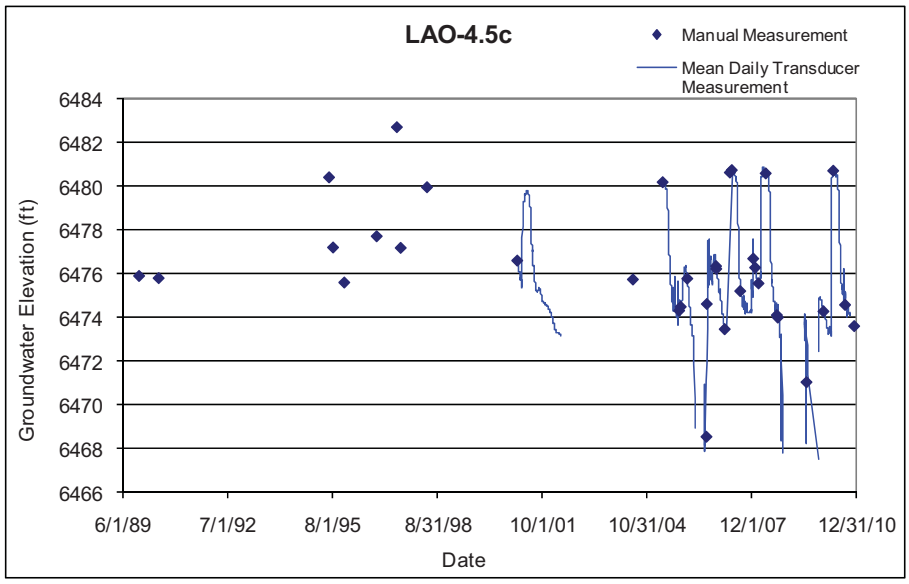


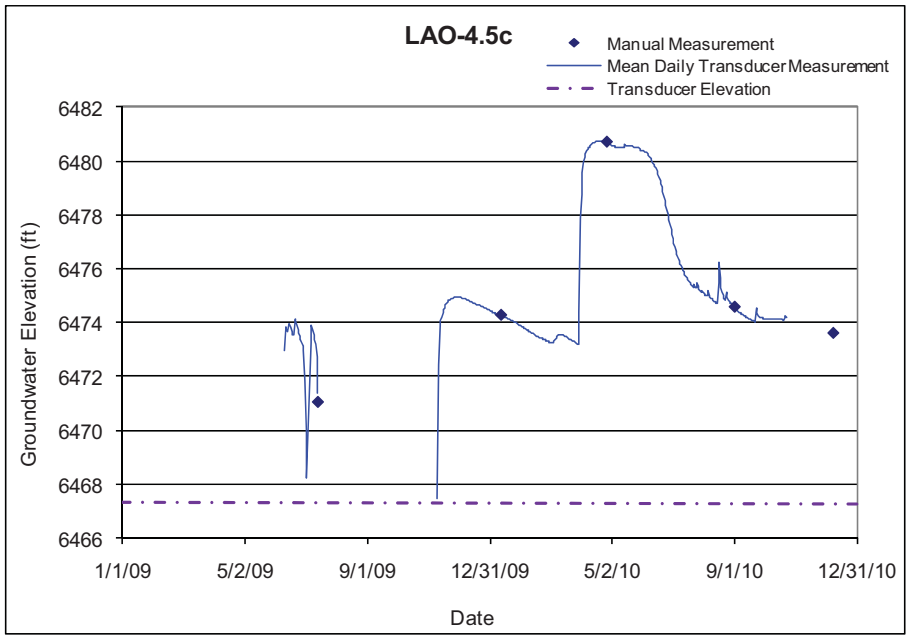


5.44 LAO-4.5c

Location: Los Alamos Canyon, approximately 1.25 mi east of the confluence with DP Canyon.
Period of Record: November 22, 1989, through December 8, 2010.
Remarks: The transducer is resting on top of the bladder pump; water levels below 6438.34 ft are not recorded by the transducer. This well also tends to run dry.

LAO-4.5c Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Comment
1	13.3	23.3	6473.2	6463.2	10.0			23.3	6463.2	23.3	0.0	0.0	Alluvial groundwater
Note: Ground elevation is 6486.50 ft; all depths are from this elevation													

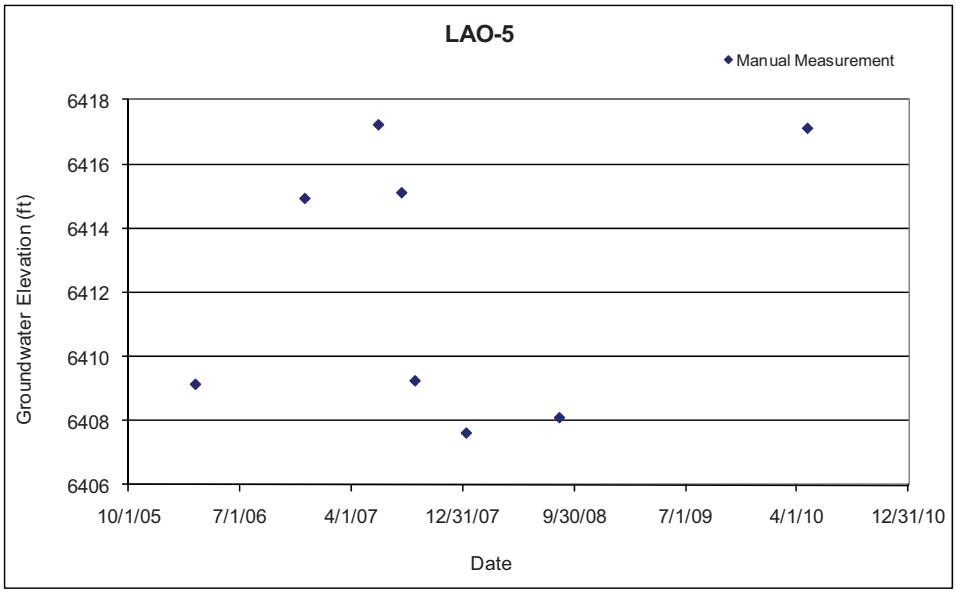




5.45 LAO-5

Location: Los Alamos Canyon, approximately 1 mi west of SR-4.
Period of Record: December 14, 2005, through December 8, 2010.
Remarks: LAO-5 was not installed with a pressure transducer and was measured manually on a quarterly schedule. Regular monitoring of the well was discontinued January 9, 2008, and manual water levels are currently only taken for sampling events.

LAO-5 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Comment
1	5.0	25.0	6422.1	6402.1	20.0			25.0	6402.1	25.0	0.0	0.0	Alluvial groundwater
Note: Ground elevation is 6427.10 ft; all depths are from this elevation													



LAO-5 Manual Water Levels	
Date	Manual Water Level (ft)
12/14/05	Dry
3/14/06	6409.12
6/13/06	Dry
8/2/06	Dry
8/3/06	Dry
9/7/06	Dry
12/8/06	6414.92
3/13/07	Dry
6/7/07	6417.22
8/3/07	6415.1
9/5/07	6409.23
1/9/08	6407.6
8/25/08	6408.08
1/6/09	Dry
7/8/09	Dry
1/7/2010	Dry
4/27/2010	6417.11
9/1/2010	6409.38
12/8/2010	Dry

5.46 LAO-6

Location: Los Alamos Canyon, approximately 1 mi west of SR-4.
Period of Record: June 26, 1995, through January 28, 2009.
Remarks: Regular monitoring of this well was discontinued January 2, 2008, and manual water levels were obtained for sampling events only. All monitoring of this well was discontinued as of July 28, 2009.

LAO-6 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	6.0	16.0	6389.3	6379.3	10.0			16.0	6379.3	16.0	0.0	0.0	Alluvial groundwater

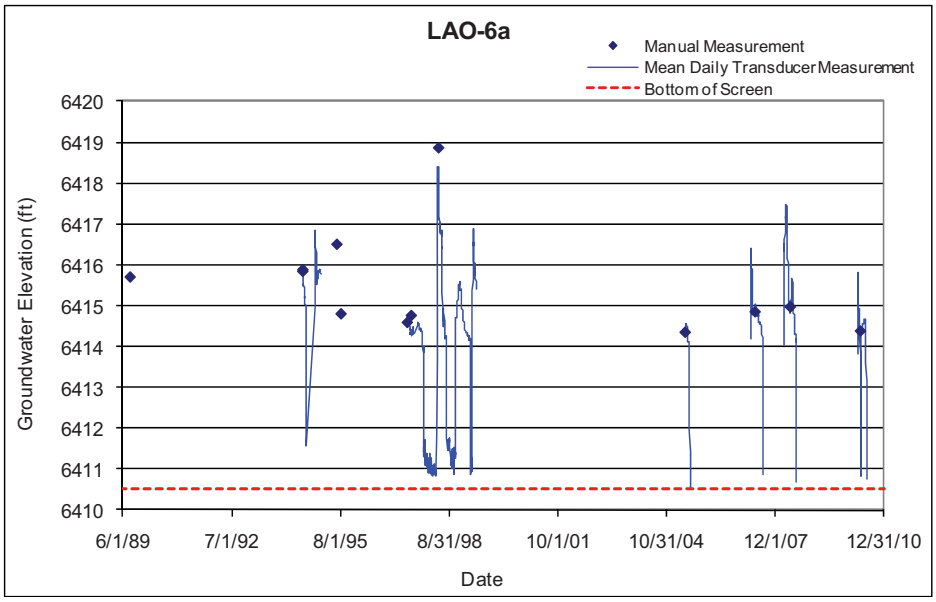
Note: Ground elevation is 6395.3 ft; all depths are from this elevation

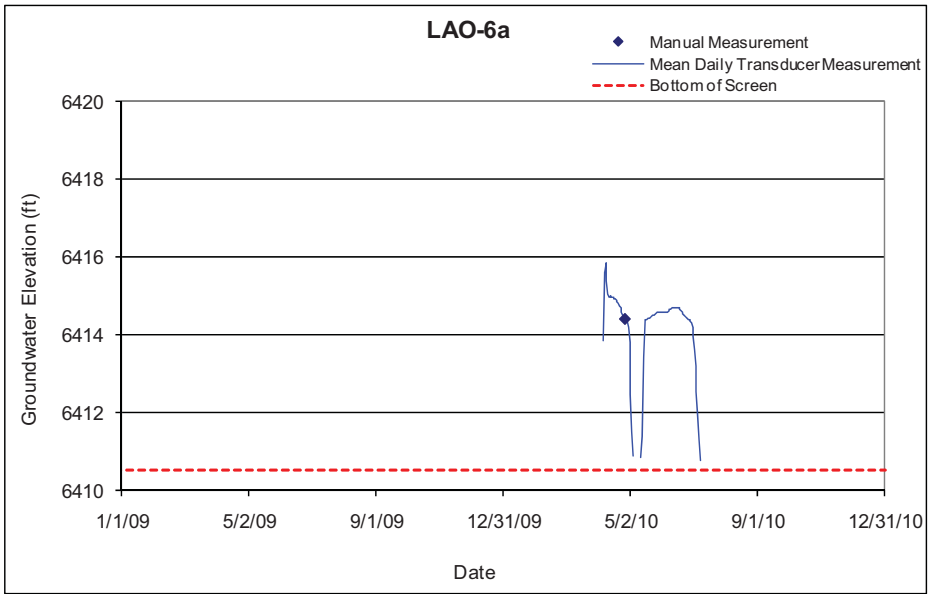
LAO-6	
Date	Manual Water Level (ft)
6/26/1995	6413.8
8/8/1995	6413.3
12/7/1995	6411.7
3/14/2006	Dry
4/19/2006	Dry
6/13/2006	Dry
7/27/2006	Dry
9/7/2006	Dry
12/8/2006	Dry
3/13/2007	Dry
6/7/2007	6411.67
9/5/2007	Dry
1/9/2008	Dry
1/7/2009	Dry
7/28/2009	Dry

5.47 LAO-6a

Location: Los Alamos Canyon, approximately 1 mi west of SR-4.
Period of Record: August 17, 1989, through December 8, 2010.
Remarks: Well is seasonally dry.

LAO-6a Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Comment
1	4.2	14.2	6420.5	6410.5	10.0			14.2	6410.5	14.2	0.0	0.0	Alluvial groundwater
Note: Ground elevation is 6424.70 ft; all depths are from this elevation													



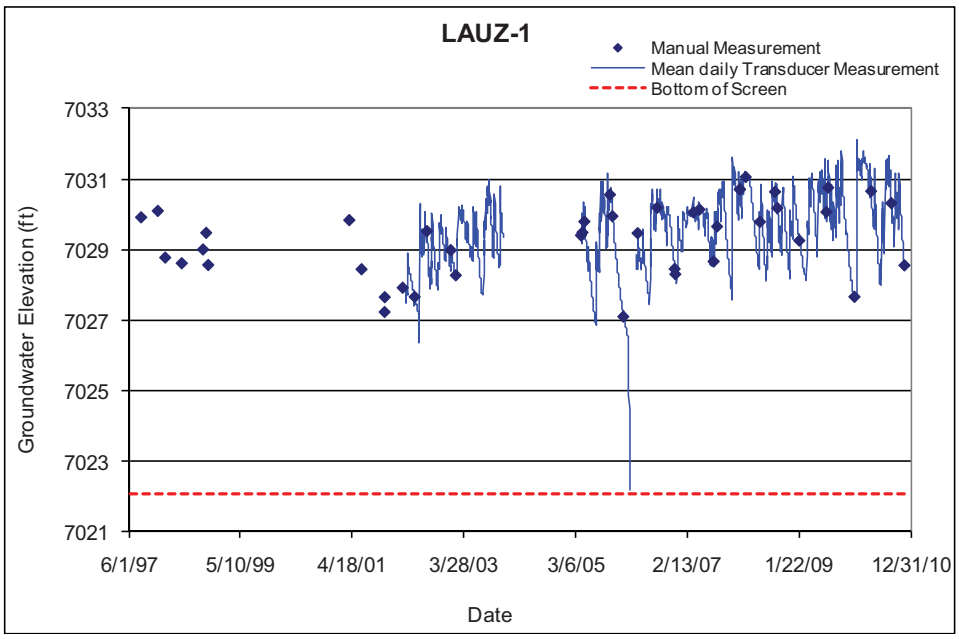


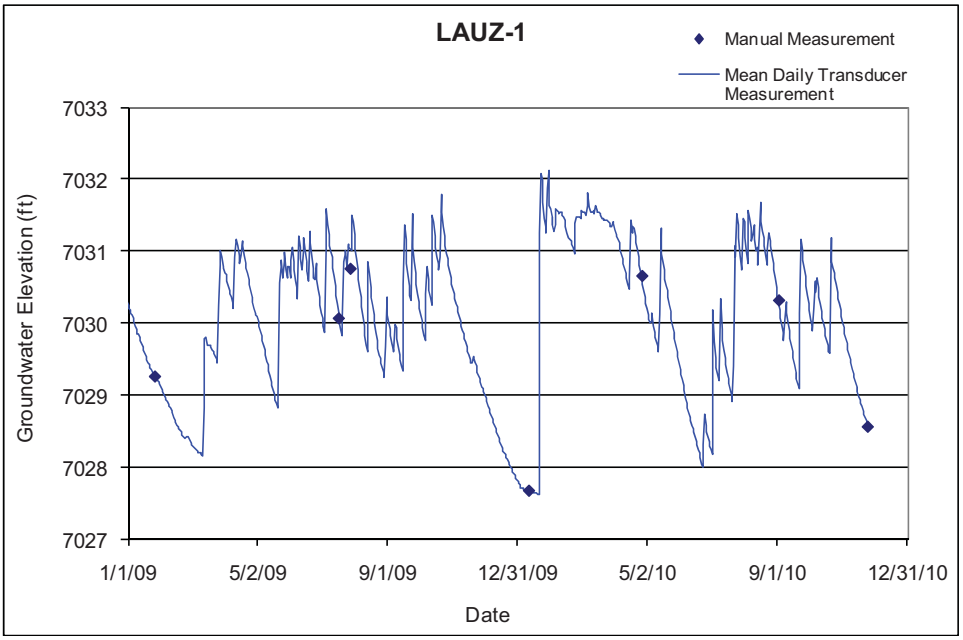
5.48 LAUZ-1

Location: DP Canyon, north of TA-21.
Period of Record: August 20, 1997, through November 24, 2010.
Remarks: None.

LAUZ-1 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	5.35	10.35	7027.07	7022.07	5.00			10.35	7022.07	10.55	0.20	0.49	Alluvial groundwater

Note: Ground elevation is 7032.42 ft; all depths are from this elevation



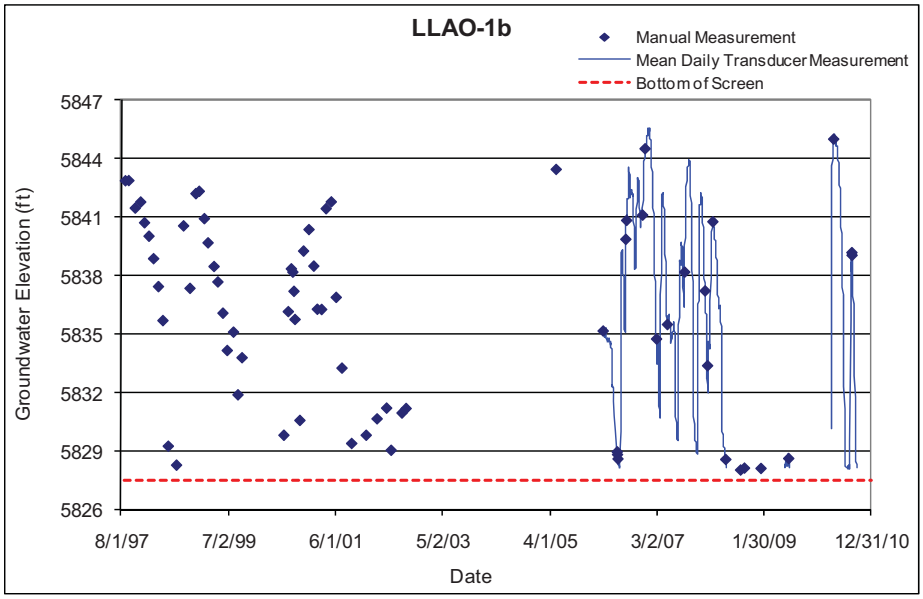


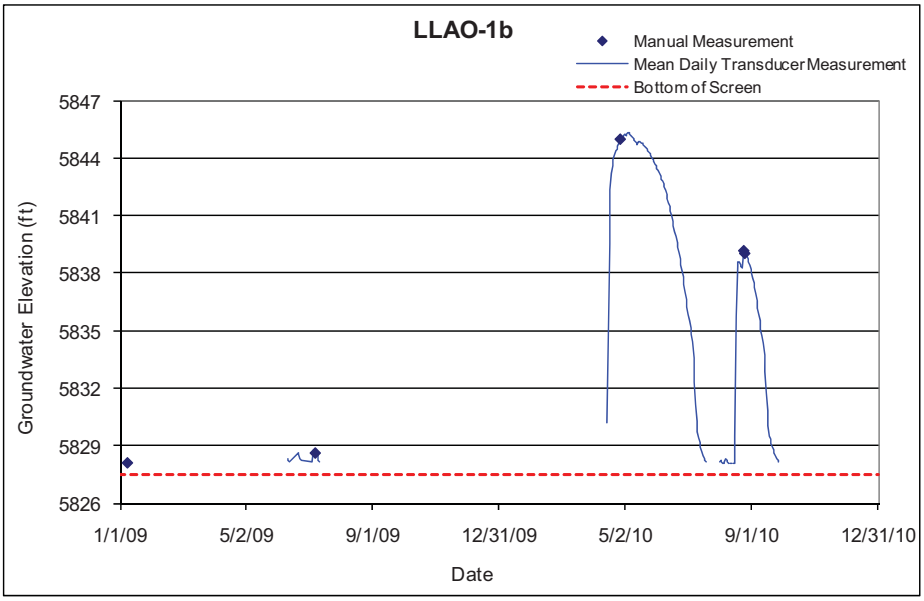
5.49 LLAO-1b

Location: Lower Los Alamos Canyon, approximately 3000 ft southwest of Totavi on San Ildefonso Pueblo land.
Period of Record: August 27, 1997, through December 7, 2010.
Remarks: Well has mostly remained dry since June 1, 2008, with the exception of a brief rise in June 2009.

LLAO-1b Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	11.32	21.32	5837.52	5827.52	10.00			21.32	5827.52	24.17	2.85	7.04	Alluvial groundwater

Note: Ground elevation is 5850.34 ft; all measurements are from this elevation



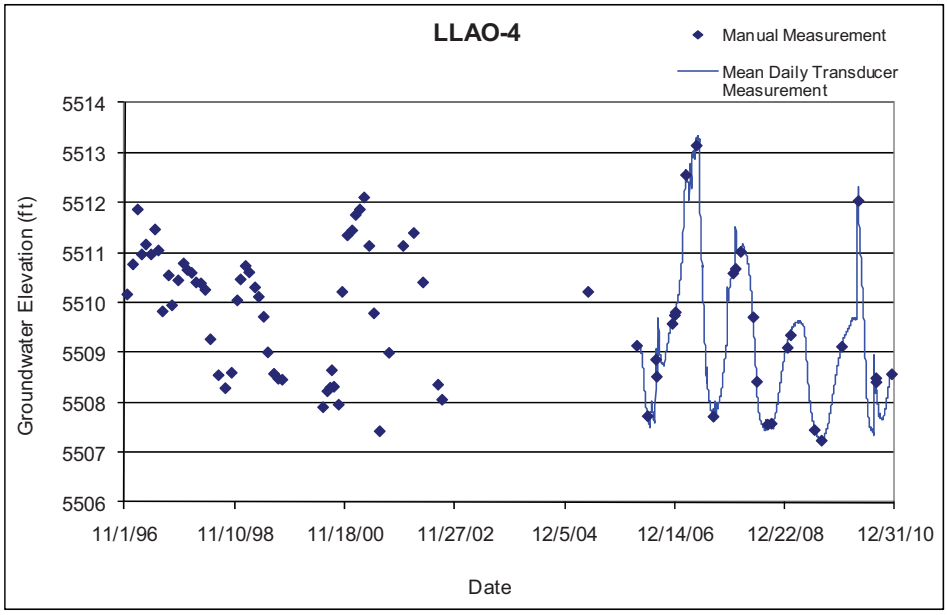


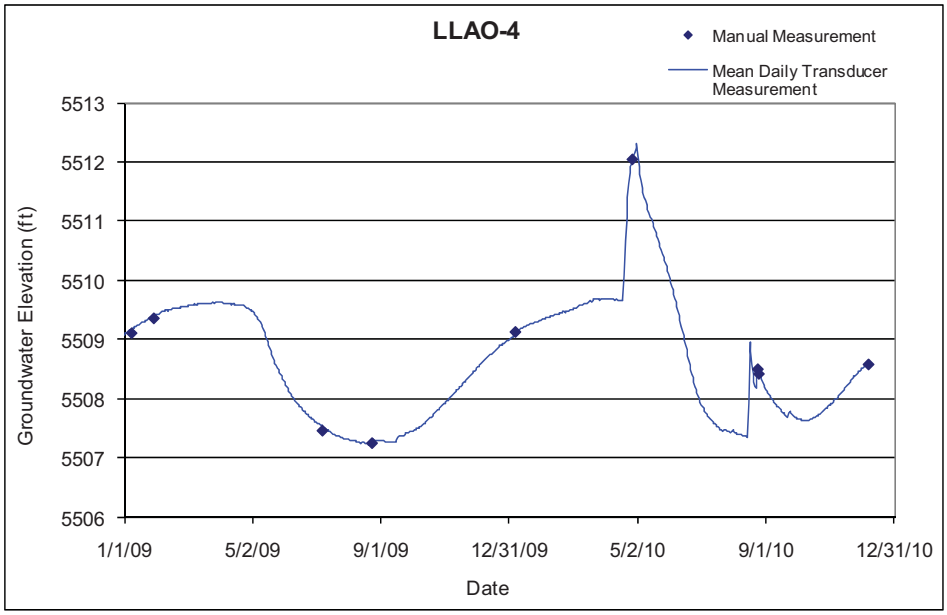
5.50 LLAO-4

Location: Lower Los Alamos Canyon, approximately 700 ft northwest of the Rio Grande at SR-502 on San Ildefonso Pueblo land.
Period of Record: November 22, 1996, through December 8, 2010.
Remarks: None.

LLAO-4 Construction Information														
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	5.24	15.24	5509.97	5499.97	10.00			15.24	5499.97	18.09	2.85	7.04	Alluvial groundwater

Note: Ground elevation is 5515.46 ft; all depths are from this elevation





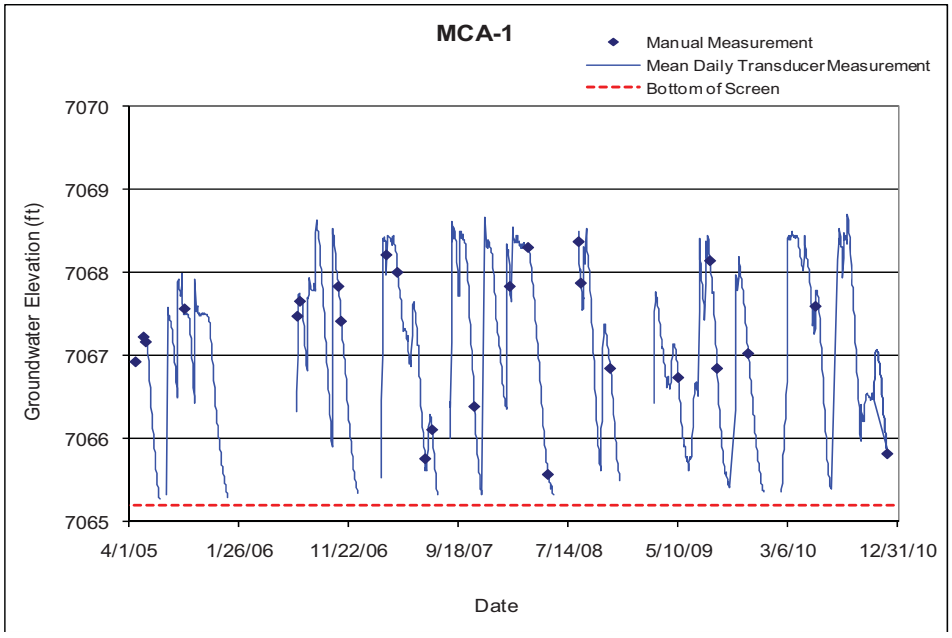
5.51 MCA-1

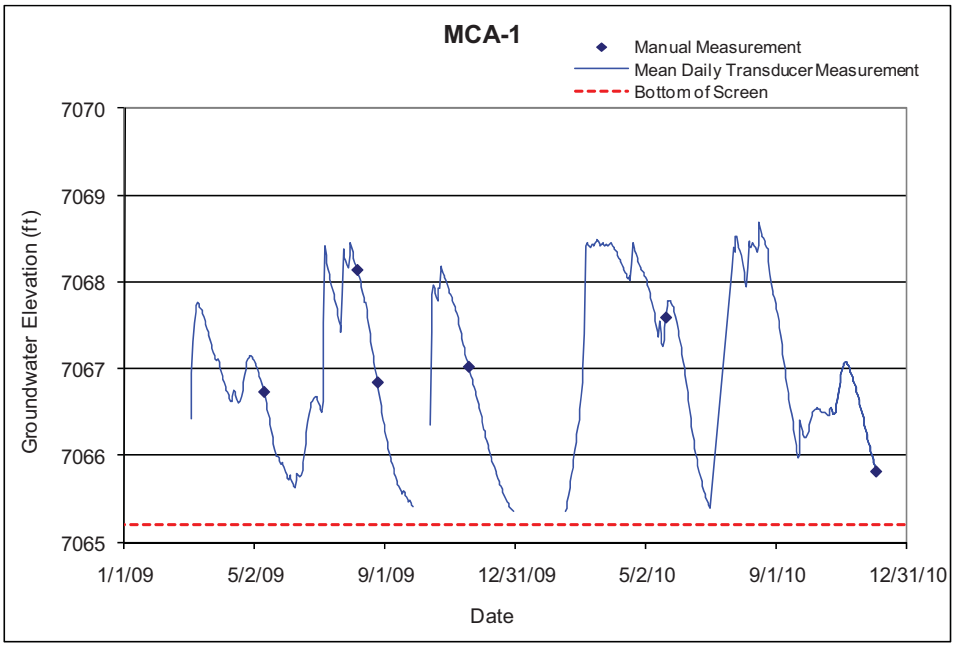
Location: Upper Mortandad Canyon, approximately 700 ft northeast of the TA-50 outfall.
Period of Record: April 20, 2005, through December 3, 2010.
Remarks: None.

MCA-1 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	2.4	5.4	7068.2	7065.2	3.0			5.4	7065.2	5.9	0.5	0.1	Alluvial groundwater

Note: Ground Elevation: 7070.6 ft; all depths are from this elevation





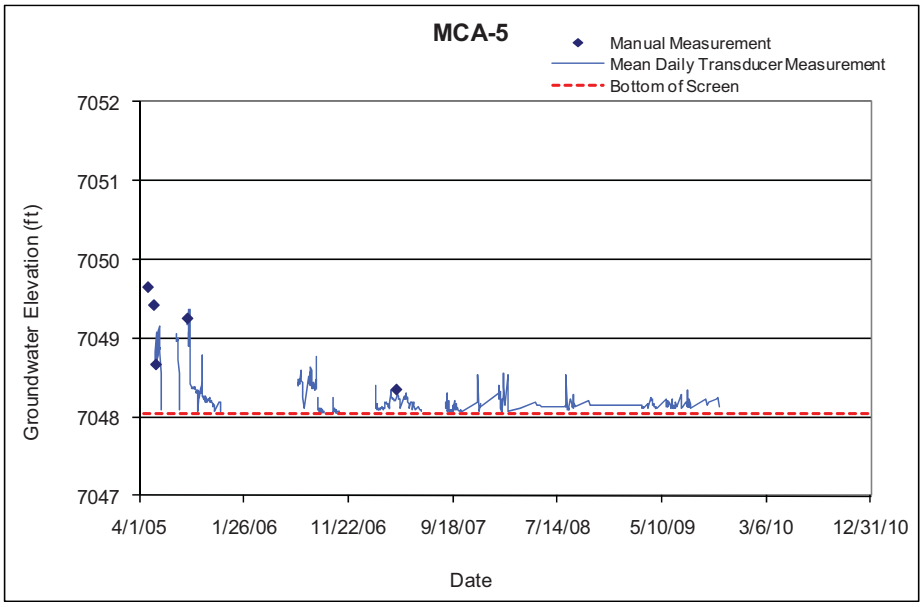
5.52 MCA-5

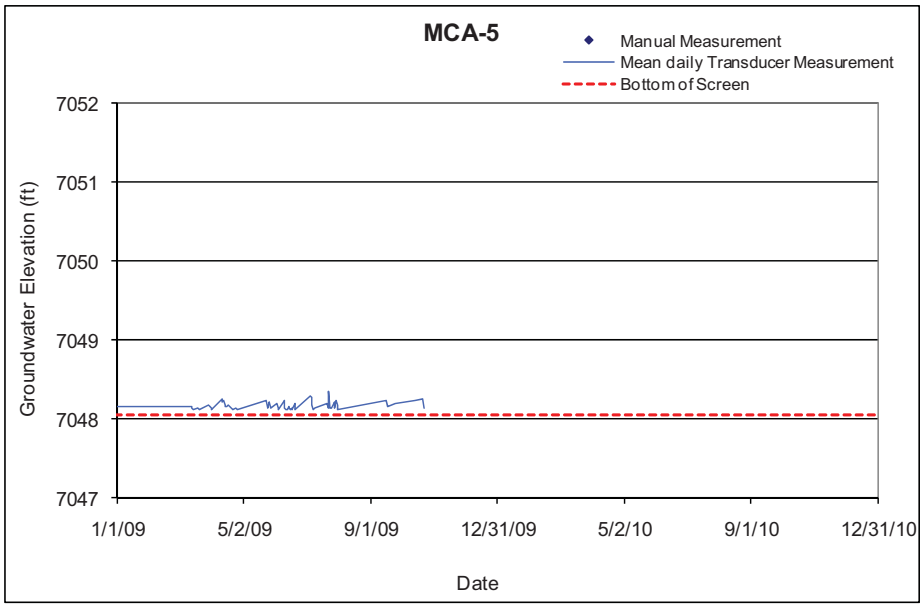
Location: Upper Mortandad Canyon, approximately 1250 ft downstream of TA-50 outfall.
Period of Record: April 25, 2005, through February 11, 2010.
Remarks: This well is intermittently dry. Monitoring was discontinued February 11, 2010, and moved exclusively to MCO-3.

MCA-5 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	1.75	5.75	7052.05	7048.05	4.0			5.75	7048.05	6.0	0.25	0.04	Alluvial groundwater

Note: Ground elevation is 7053.8 ft; all depths are from this elevation





5.53 MCA-8

Location: Lower Mortandad Canyon.
Period of Record: October 3, 2005, through February 10, 2010.
Remarks: No valid water level data exist for this well. Water has occurred only in the sump since completion on September 29, 2004. Monitoring was discontinued February 10, 2010.

MCA-8 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	66	81	6602.7	6587.7	15			81	6587.7	86.3	5.3	14.4	Alluvial groundwater

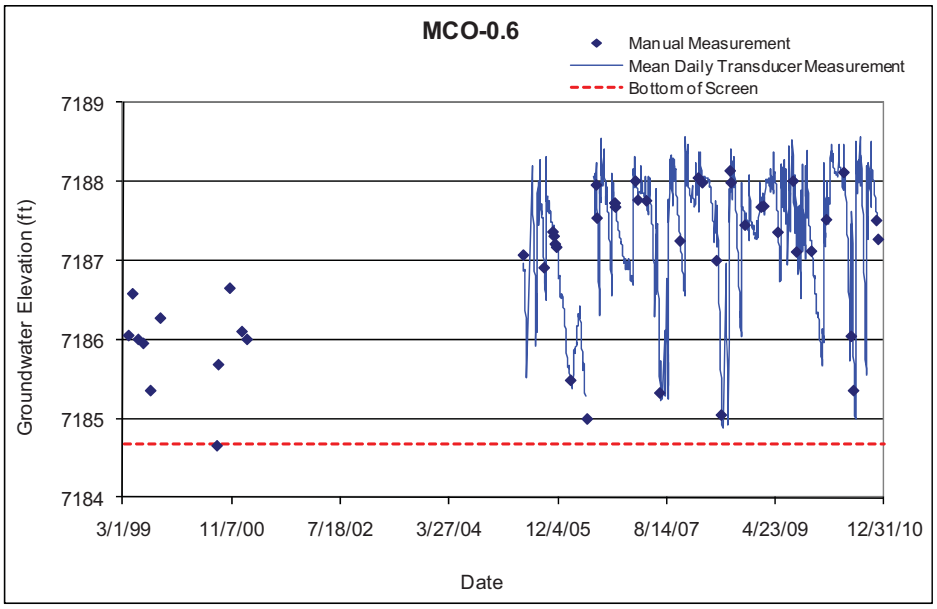
Note: Brass Cap Ground elevation is 6668.8 ft; all depths are from this elevation

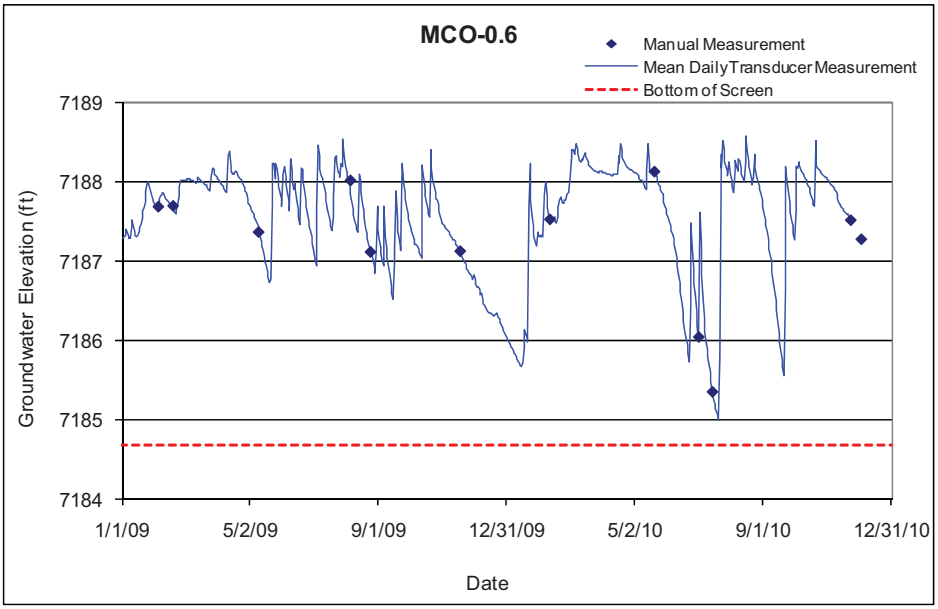
MCA-8 Manual Water Levels		
Date	Water Level (ft)	Comments
10/3/2005	6582.43	Sump water
1/4/2006	6583.52	Sump water
4/13/2006	6584.09	Sump water
7/18/2006	6584.14	Sump water
10/30/2006	6584.17	Sump water
9/5/2006	6584.16	Sump water
1/26/2007	6584.12	Sump water
4/12/2007	6584.11	Sump water
7/3/2007	6584.1	Sump water
11/29/2007	6584.11	Sump water
12/5/2007	6583.94	Sump water
3/26/2008	6583.99	Sump water
6/19/2008	6584.09	Sump water
8/11/2008	6584.1	Sump water
8/19/2008	6584.01	Sump water
8/19/2008	6584.01	Sump water
2/19/2009	6584.01	Sump water
5/19/2009	6584.13	Sump water
8/25/09	6584.11	Sump water
11/18/09	6584.11	Sump water
2/10/10	6583.96	Sump water

5.54 MCO-0.6

Location: Upper Mortandad Canyon, north of TA-48.
Period of Record: March 31, 1999, through December 3, 2010.
Remarks: None.

MCO-0.6 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	1.05	3.05	7186.68	7184.68	2.00			3.05	7184.68	3.10	0.05	0.04	Alluvial groundwater
Note: Brass Cap elevation: 7188.28 ft; Ground elevation: 7187.73 ft; all depths are from this elevation													



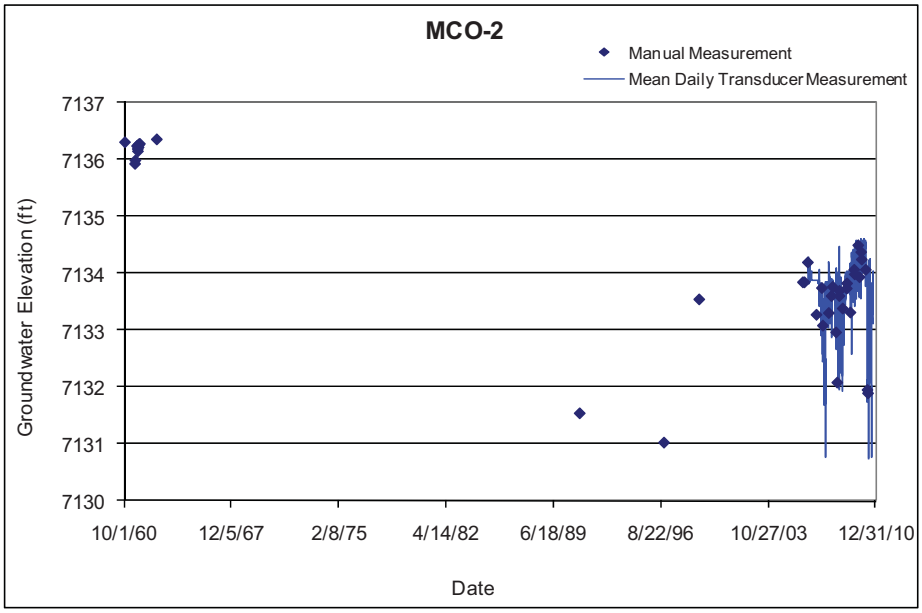


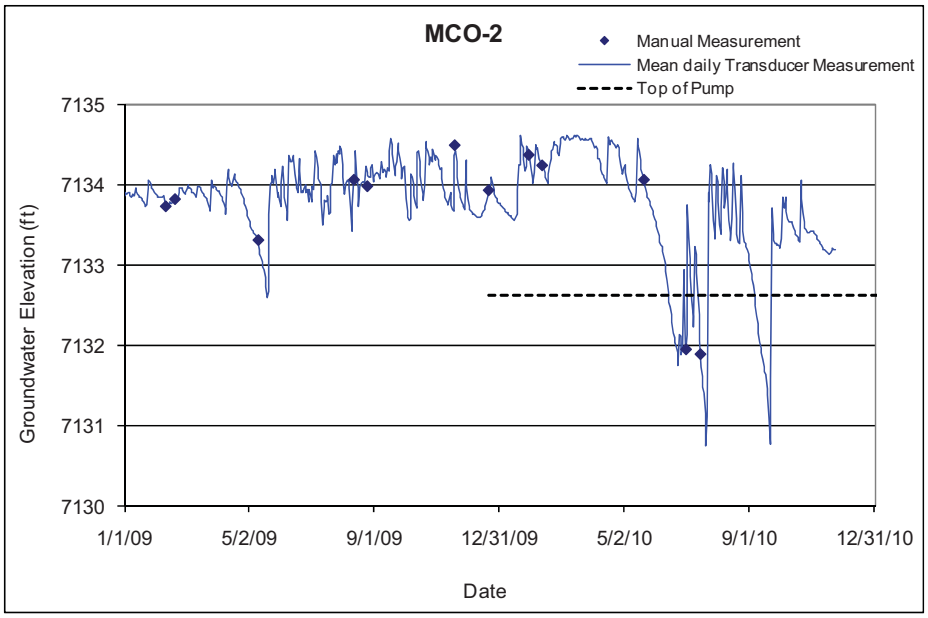
5.55 MCO-2

Location: Upper Effluent Canyon, approximately 200 ft west of TA-50 outfall.
Period of Record: November 1, 1960, through November 23, 2010.
Remarks: The transducer was sitting on top of the bladder pump in a 2-in.-diameter well at an elevation of 7133.8 ft until April 12, 2007. The pump was removed from the well on April 12, 2007, and the transducer was lowered to a more functional level.

MCO-2 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	2.0	9.0	7134.6	7127.6	7.0			9.0	7127.6	9.0	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 7136.6 ft; all depths are from this elevation



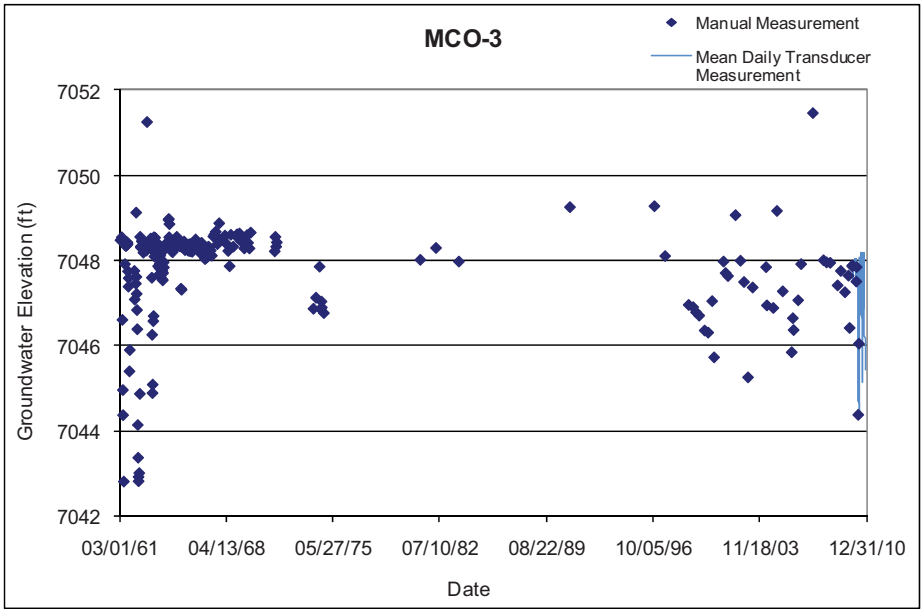


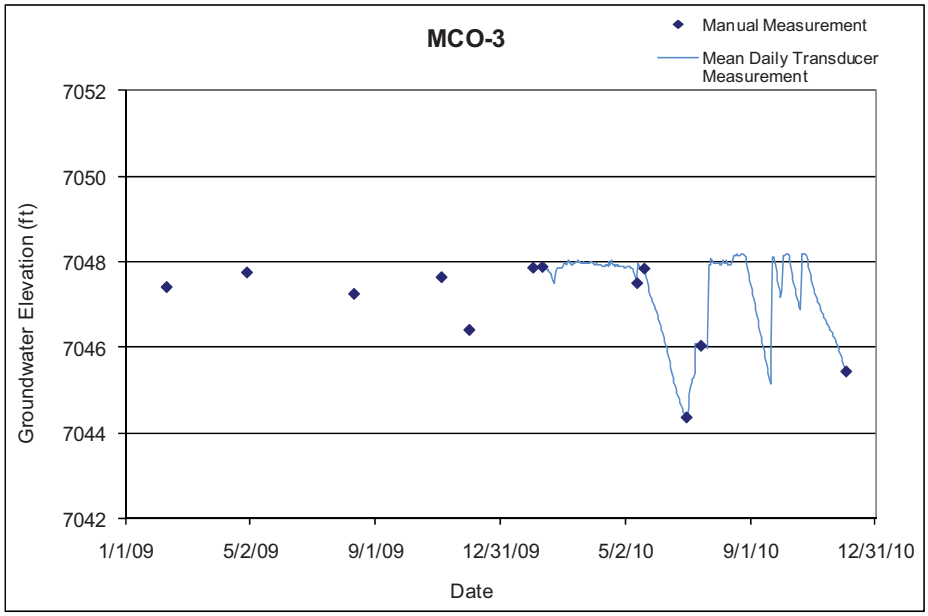
5.56 MCO-3

Location: Upper Mortandad Canyon, approximately 1250 ft downstream of TA-50 outfall and 8 ft east of MCA-5.
Period of Record: March 27, 1961, through December 3, 2010.
Remarks: There was no transducer installed in this well until February 11, 2010; continuous monitoring switched from MCA-5 to this well since MCO-3 is the well which is sampled.

MCO-3 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	2.0	12.0	7050.6	7040.6	10.0			12.0	7040.6	12.0	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 7052.6 ft; all depths are from this elevation



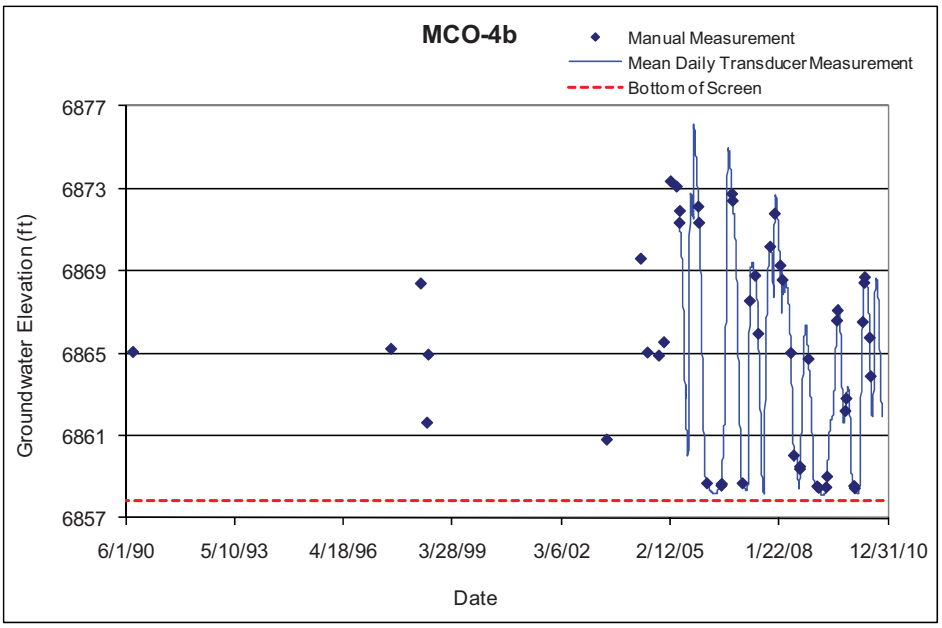


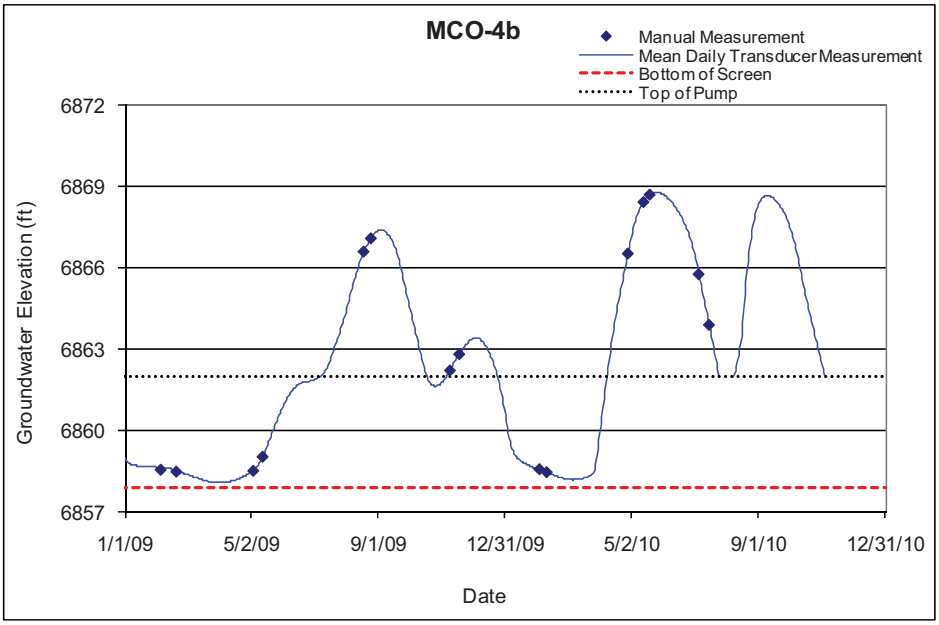
5.57 MCO-4b

Location: Middle Mortandad Canyon, approximately 3000 ft up canyon from sediment traps.
Period of Record: August 21, 1990, through December 2, 2010.
Remarks: Pump was removed for maintenance, and transducer was relocated above pump at that time.

MCO-4b Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	8.9	28.9	6877.9	6857.9	20.0			28.9	6857.9	33.9	5.0	3.1	Alluvial groundwater

Note: Ground elevation is 6886.75 ft; all depths are from this elevation





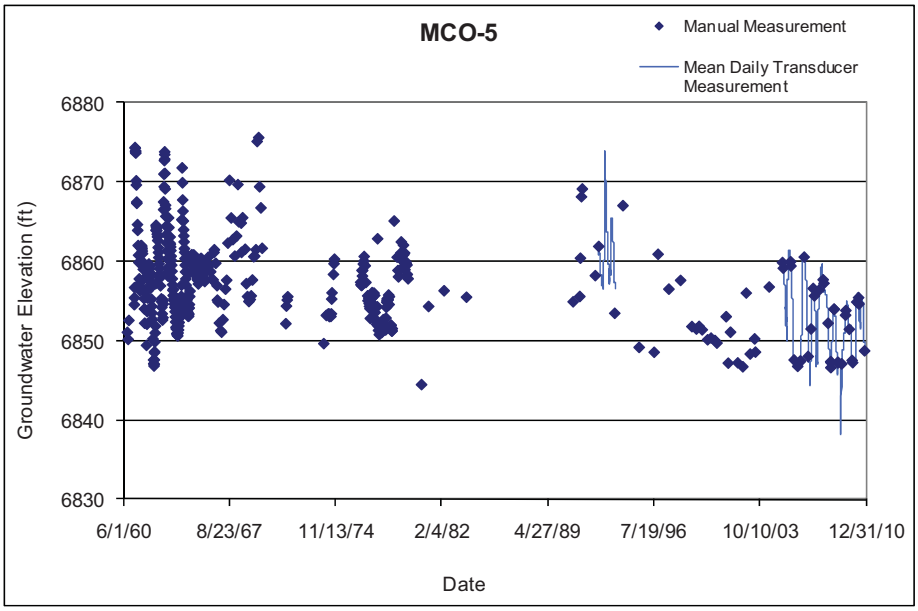
5.58 MCO-5

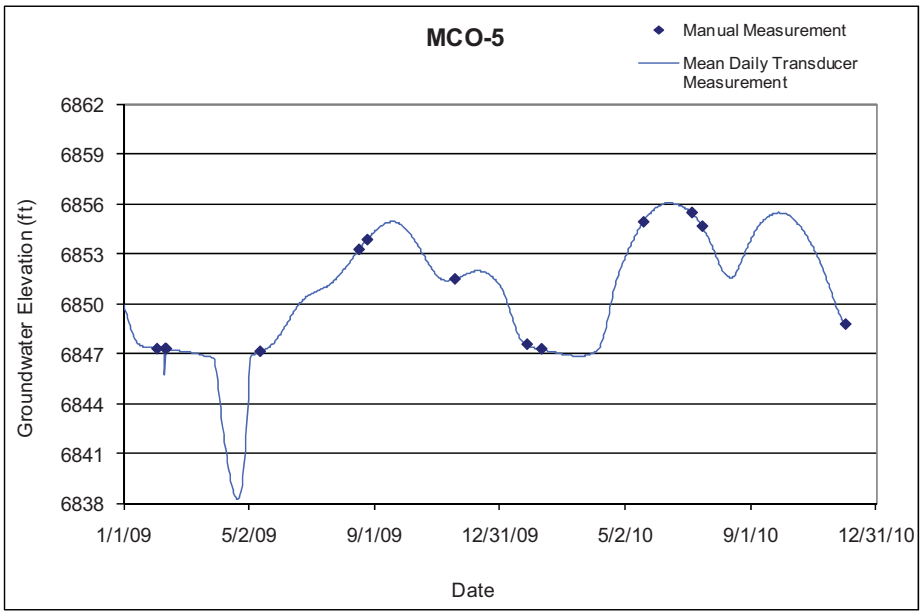
Location: Middle Mortandad Canyon, approximately 2300 ft up canyon from sediment traps.
Period of Record: October 1, 1960, through December 2, 2010.
Remarks: None.

MCO-5 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	21.0	46.0	6854.66	6829.66	25.0			46.0	6829.66	46.0	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6875.66 ft; all depths are from this elevation





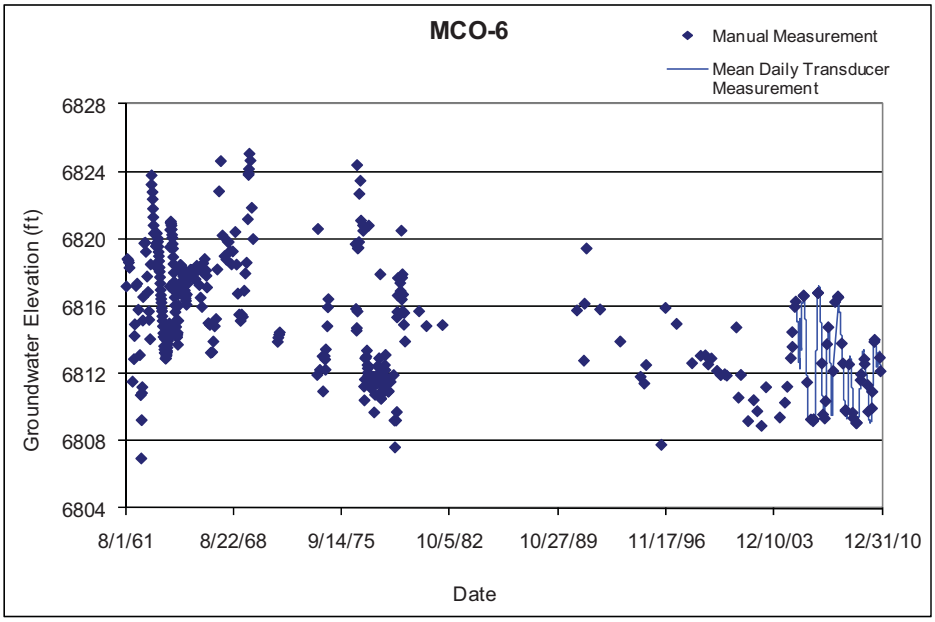
5.59 MCO-6

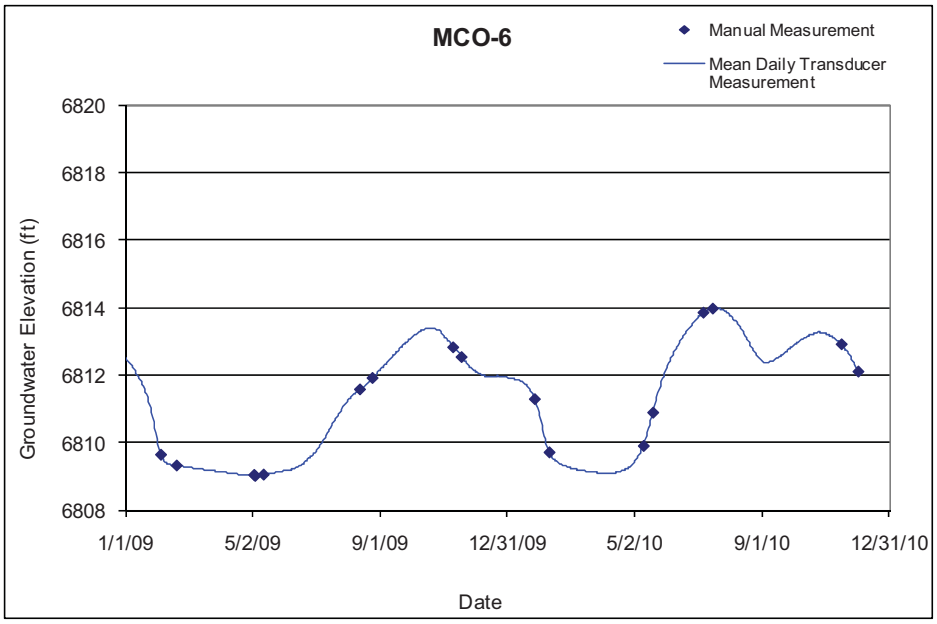
Location: Middle Mortandad Canyon, approximately 0.25 mi east of MCO-5.
Period of Record: August 25, 1961, through December 2, 2010.
Remarks: The transducer was removed from the well October 30, 2007, and replaced February 28, 2008.

MCO-6 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	27.0	47.0	6822.5	6802.5	20.0			47.0	6802.5	47.0	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6849.48 ft; all depths are from this elevation



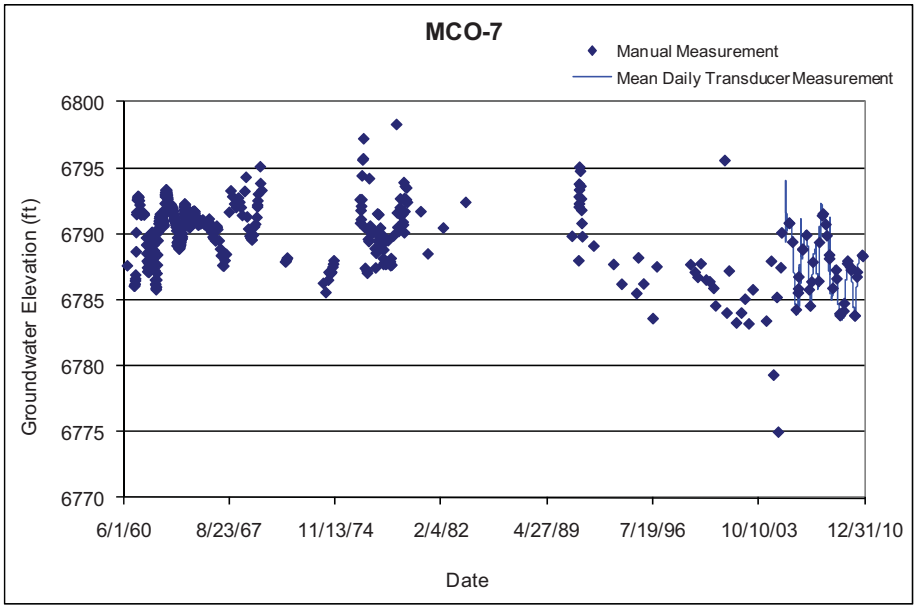


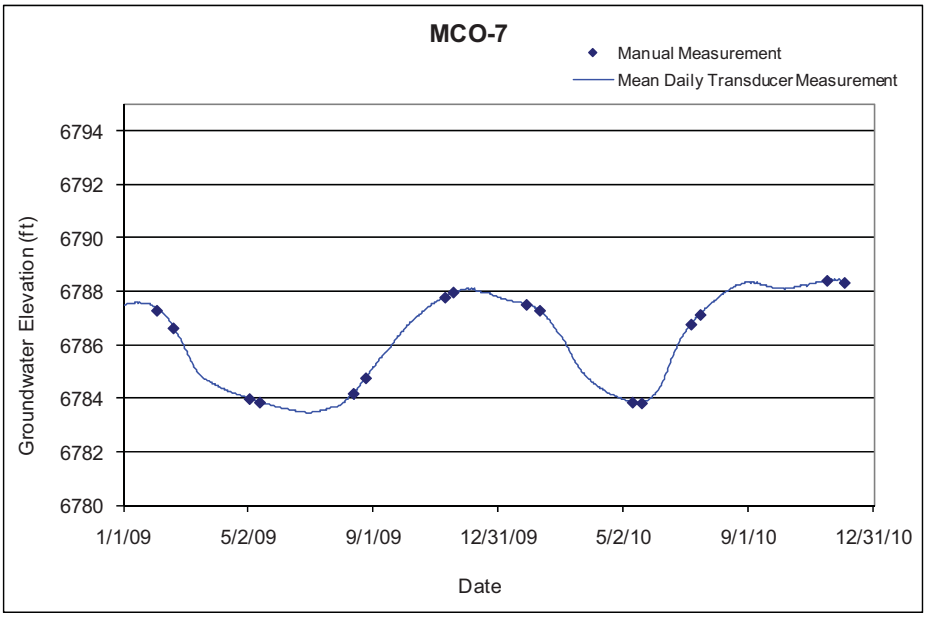
5.60 MCO-7

Location: Middle Mortandad Canyon, approximately 0.2 mi east of MCO-6.
Period of Record: October 1, 1960, through December 3, 2010.
Remarks: None.

MCO-7 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	39	69	6788.31	6758.31	30			69	6758.31	69	0	0	Alluvial groundwater

Note: Ground elevation is 6827.31 ft; all depths are from this elevation



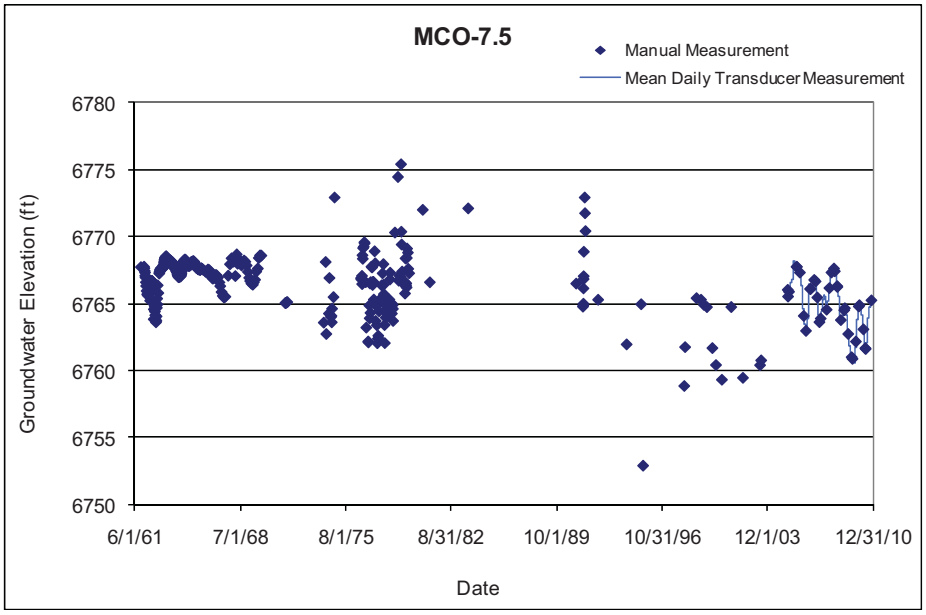


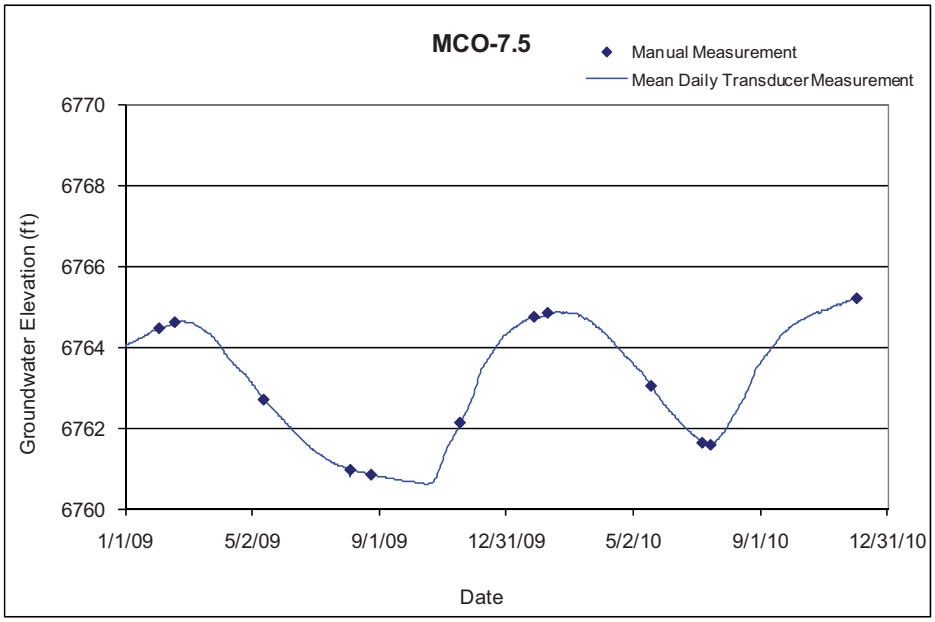
5.61 MCO-7.5

Location: Middle Mortandad Canyon, approximately 0.2 mi east of MCO-7.
Period of Record: November 1, 1961, through December 3, 2010.
Remarks: None.

MCO-7.5 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	35	60	6773.88	6748.88	25			60	6748.88	60	0	0	Alluvial groundwater

Note: Ground Elevation: 6808.881 ft; all depths are from this elevation





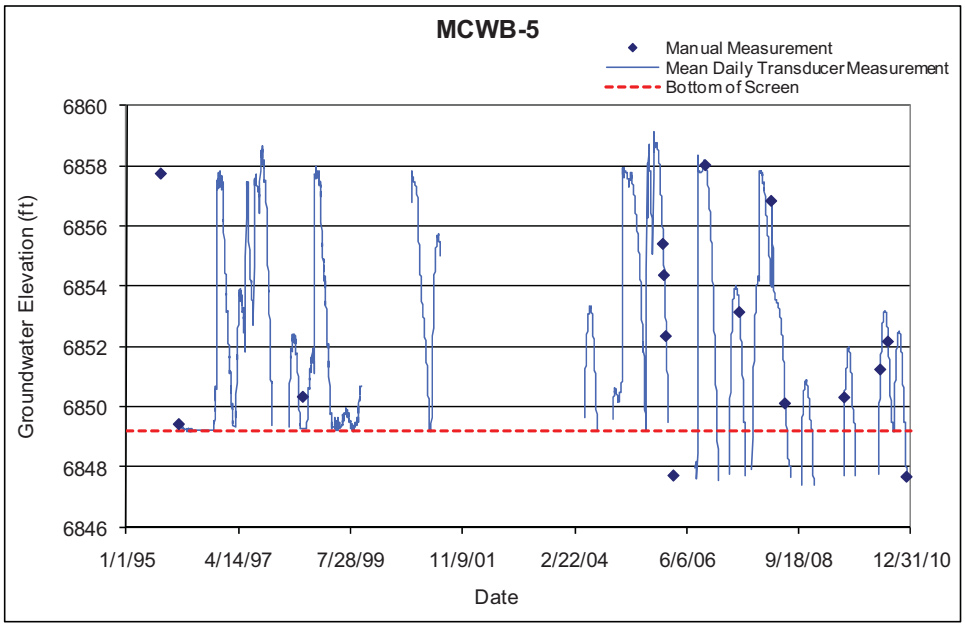
5.62 MCWB-5

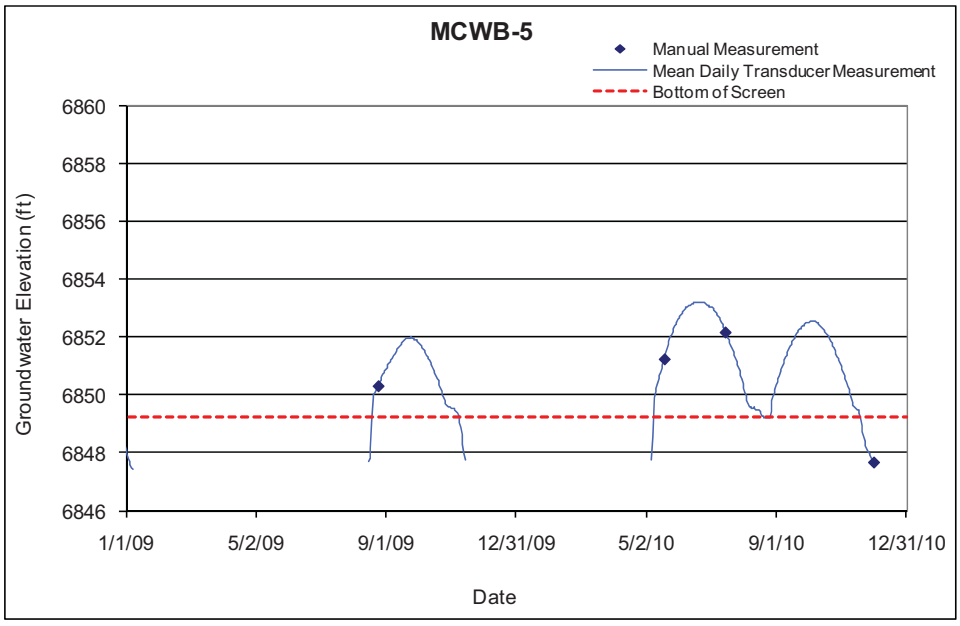
Location: Middle Mortandad Canyon, up canyon from the sediment traps.
Period of Record: January 9, 1995, through December 2, 2010.
Remarks: Water in the sump is not considered invalid as it appears to respond to groundwater level fluctuations. Transducer hangs above bottom of well; groundwater elevations below 6847 ft are not recorded by the transducer.

MCWB-5 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	17.0	27.0	6859.2	6849.2	10.0			27.0	6849.2	32.0	5.0	7.0	Alluvial groundwater

Note: Ground elevation is 6876.22 ft; all depths are from this elevation



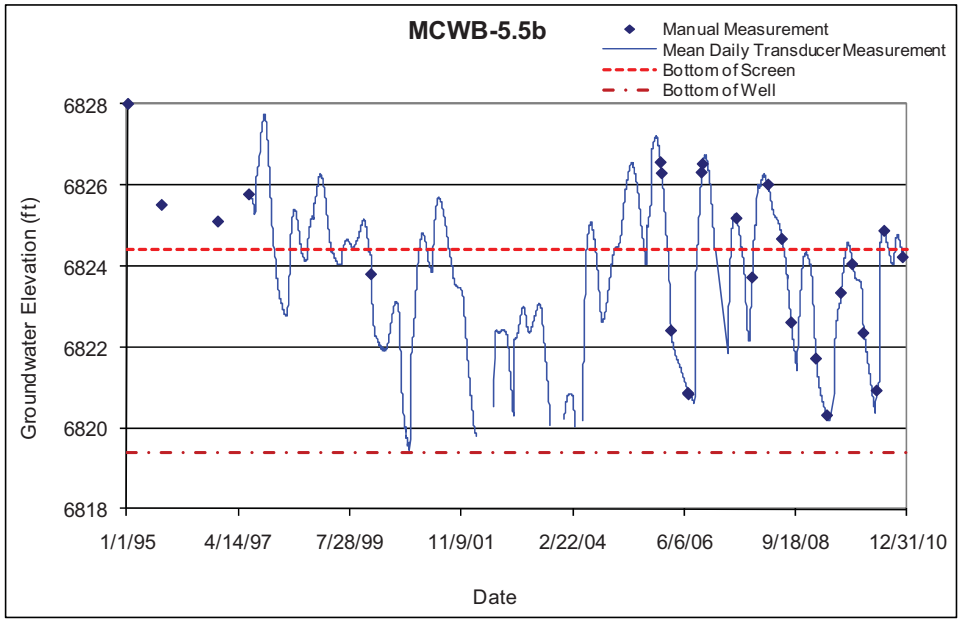


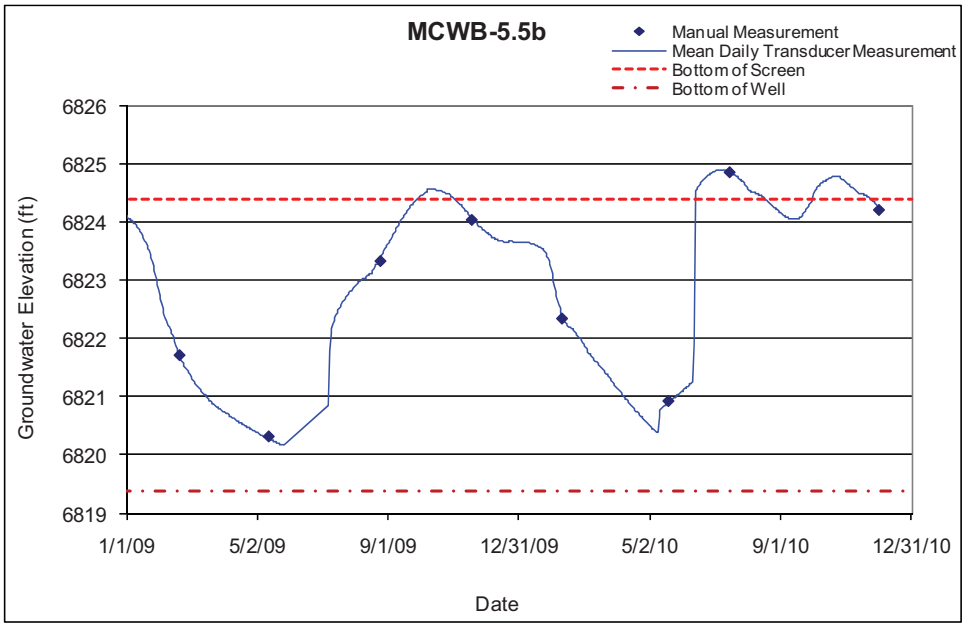
5.63 MCWB-5.5b

Location: Middle Mortandad Canyon, up canyon from sediment traps.
Period of Record: January 9, 1995, through December 2, 2010.
Remarks: Water in sump is not invalidated as it appears to represent formation water.

MCWB-5.5b Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	22.5	32.5	6834.4	6824.4	10.0			32.5	6824.4	37.5	5.0	7.0	Alluvial groundwater

Note: Ground elevation is 6856.89 ft; all depths are from this elevation





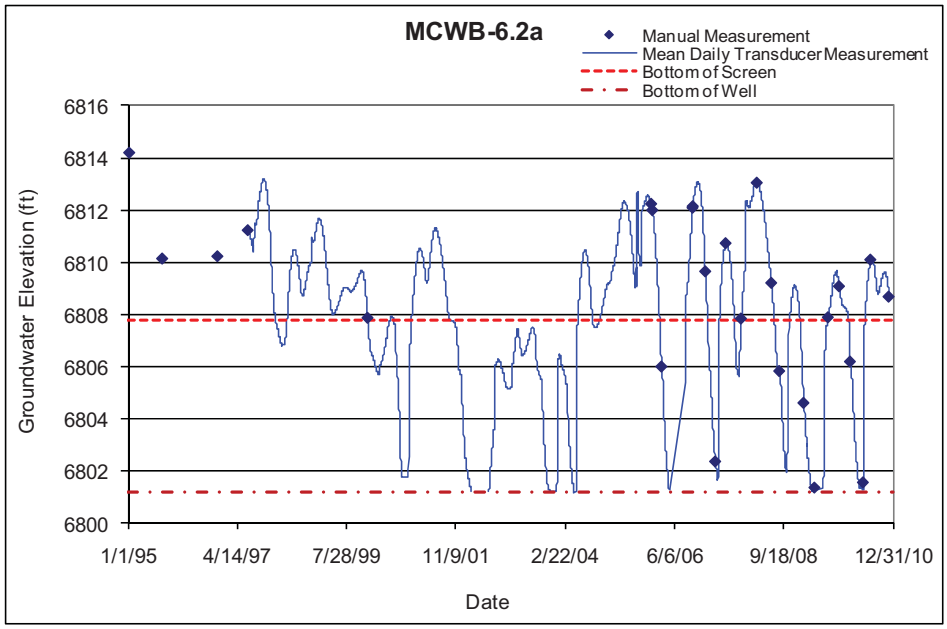
5.64 MCWB-6.2a

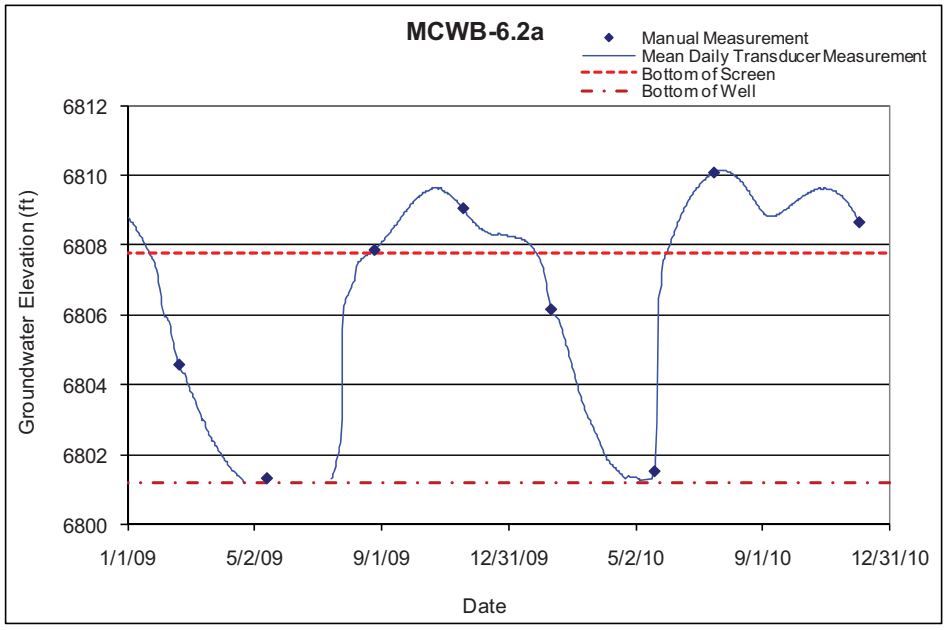
Location: Middle Mortandad Canyon, up canyon from sediment traps.
Period of Record: January 9, 1995, through December 2, 2010.
Remarks: Water in the sump is not invalidated, as it appears to respond to groundwater level fluctuations. Transducer data indicate that the bottom of the well is at 6801.2 ft.

MCWB-6.2a Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	30.5	40.5	6817.8	6807.8	10.0			40.5	6807.8	45.5	5.0	7.0	Alluvial groundwater

Note: Ground elevation is 6848.29 ft; all depths are from this elevation



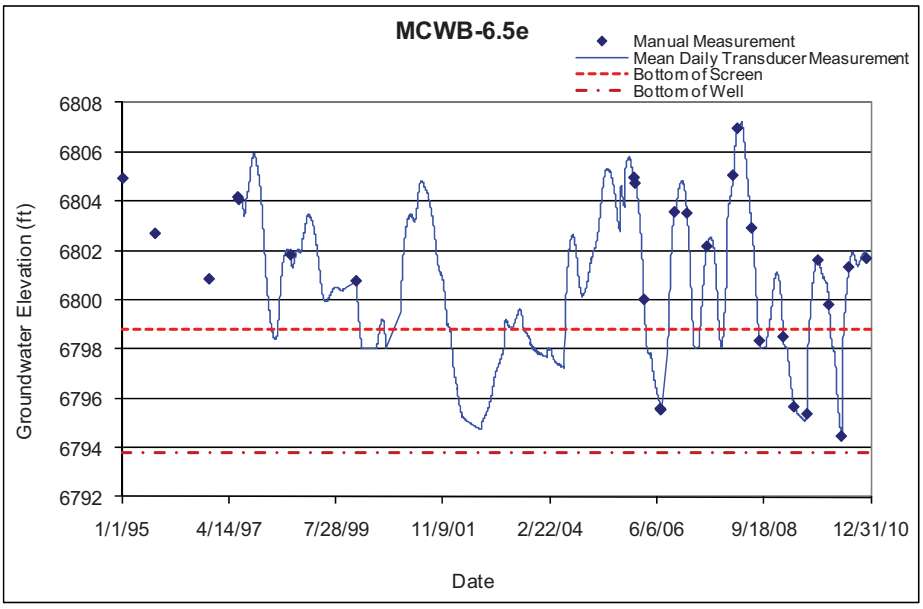


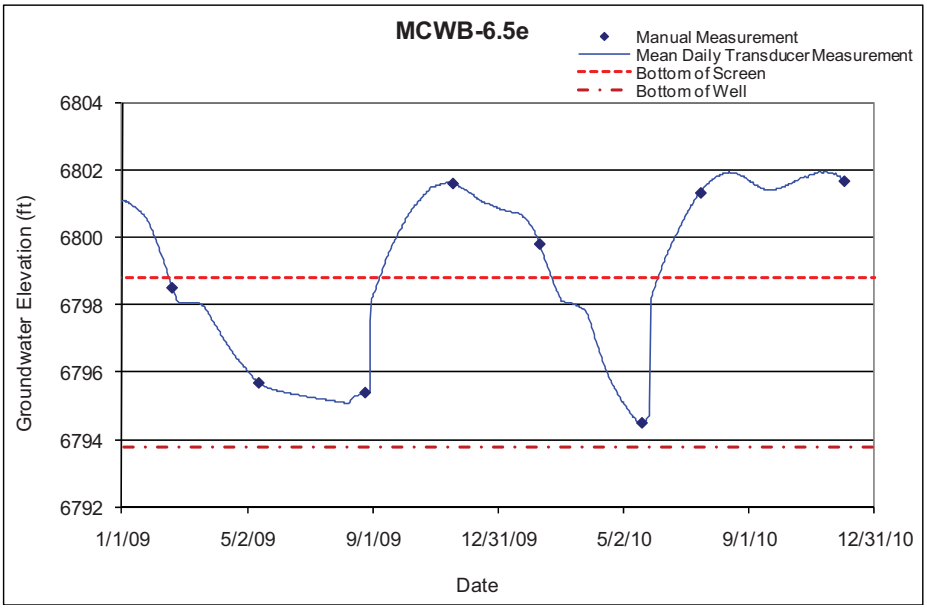
5.65 MCWB-6.5e

Location: Middle Mortandad Canyon, up canyon of the sediment traps.
Period of Record: January 9, 1995, through December 2, 2010.
Remarks: Water in sump is not invalidated, as it appears to respond to groundwater level fluctuations. Water is below transducer from March 23, 2007, to May 4, 2008, and from August 26, 2008, to October 8, 2008.

MCWB-6.5e Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	35.0	45	6808.8	6798.8	10.0			45.0	6798.8	50.0	5.0	7.0	Alluvial groundwater

Note: Ground elevation is 6843.80 ft; all depths are from this elevation



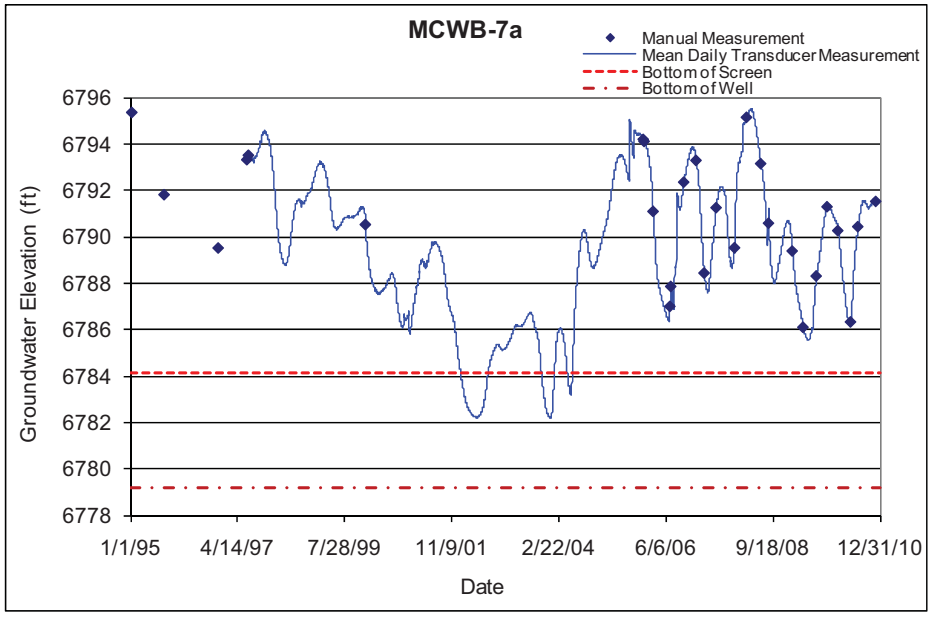


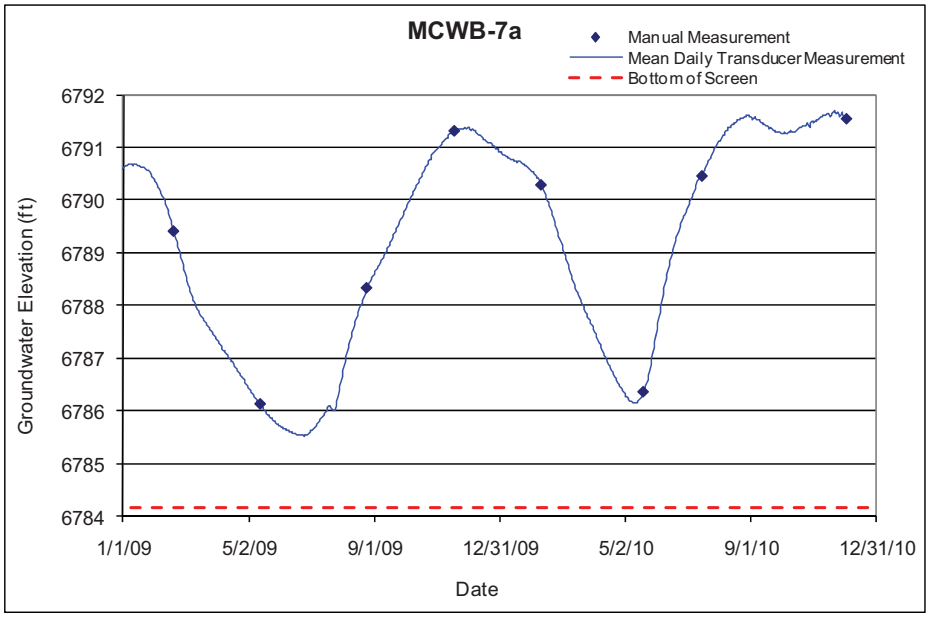
5.66 MCWB-7a

Location: Middle Mortandad Canyon, near sediment traps.
Period of Record: January 9, 1995, through December 3, 2010.
Remarks: Water in sump is not invalidated, as it appears to respond to groundwater level fluctuations.

MCWB-7a Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	37.0	47.0	6794.17	6784.17	10.0			47.0	6784.2	52.0	5.0	7.0	Alluvial groundwater

Note: Ground elevation is 6831.17 ft; all depths are from this elevation



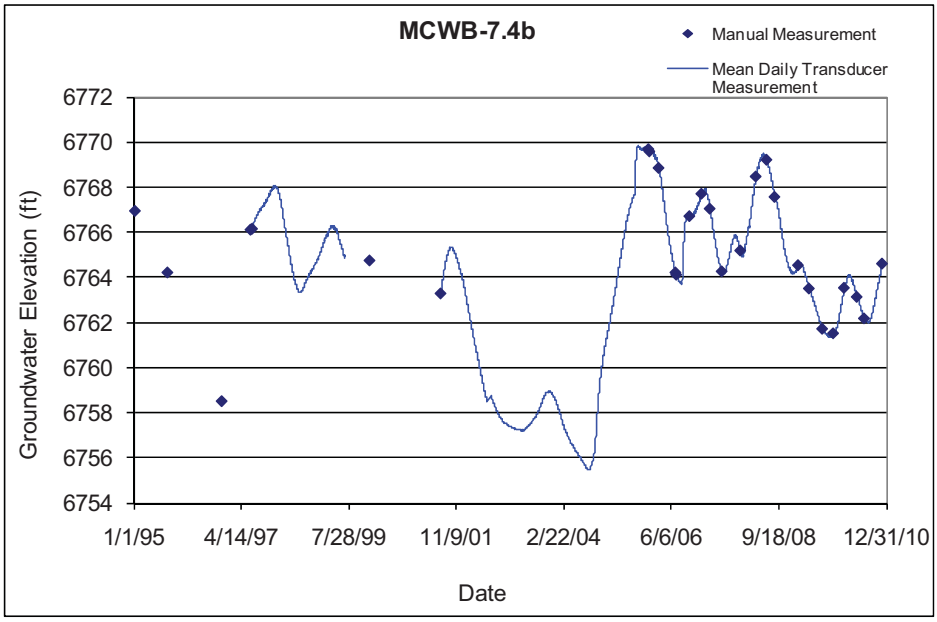


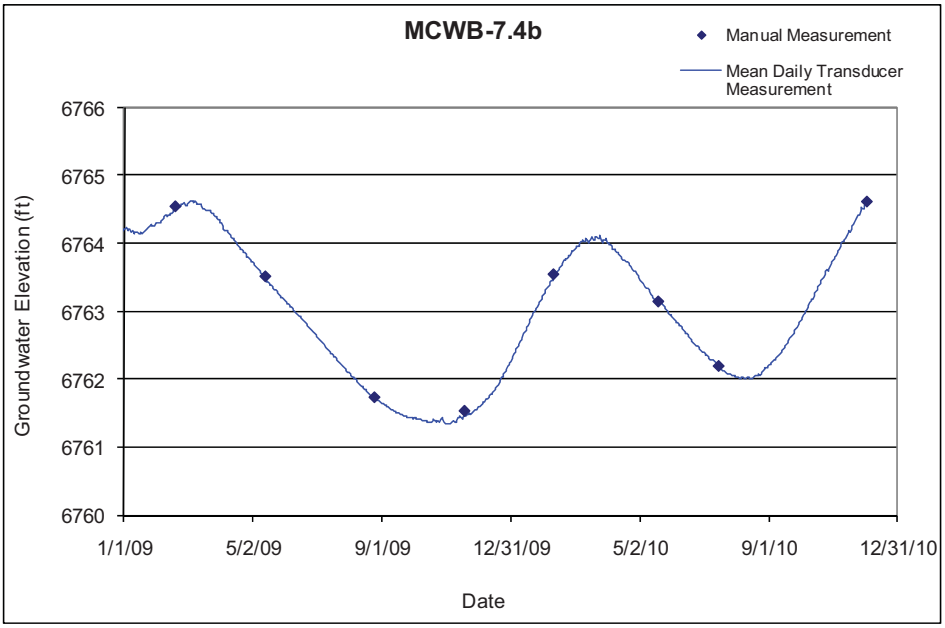
5.67 MCWB-7.4b

Location: Middle Mortandad Canyon, down canyon from sediment traps.
Period of Record: January 9, 1995, through December 3, 2010.
Remarks: None.

MCWB-7.4b Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	45.0	65.0	6768.07	6748.07	20.0			65.0	6748.1	70.0	5.0	7.0	Alluvial groundwater

Note: Ground elevation is 6813.07 ft; all depths are from this elevation



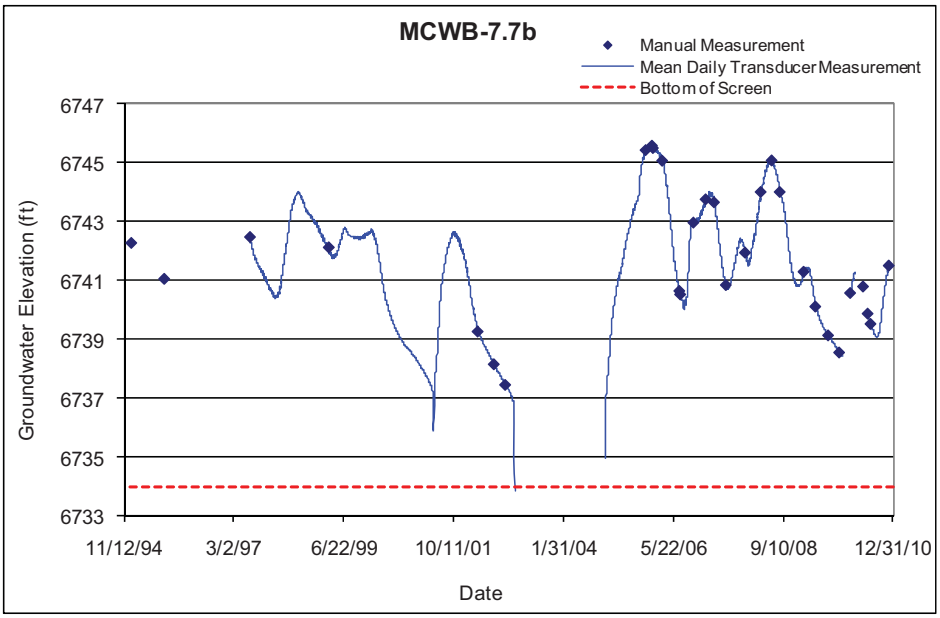


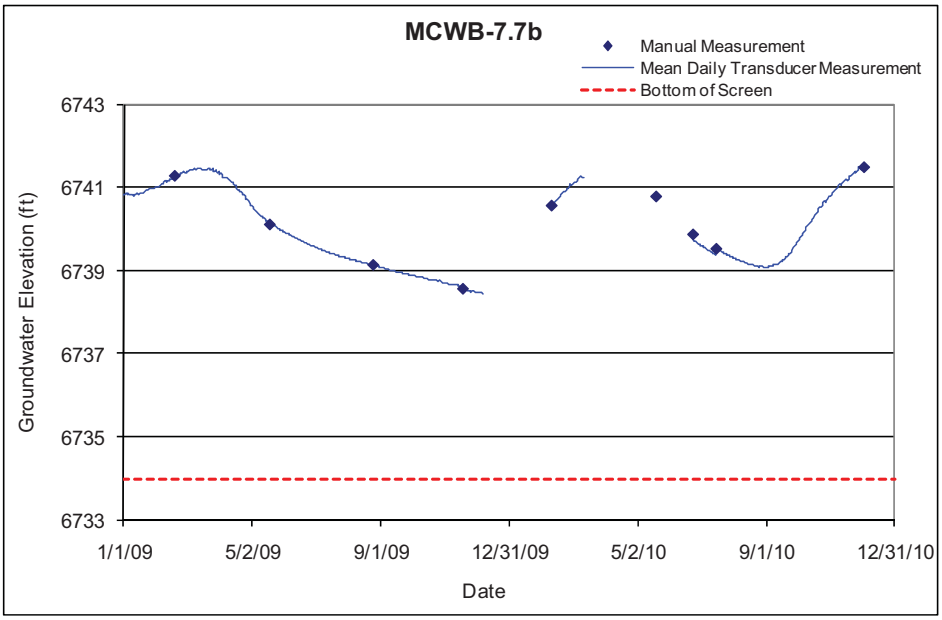
5.68 MCWB-7.7b

Location: Middle Mortandad Canyon, down canyon from sediment traps.
Period of Record: January 9, 1995, through December 3, 2010.
Remarks: None.

MCWB-7.7b Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	55.0	65	6744.0	6734.0	10.0			65.0	6734.0	70	5.0	7.0	Alluvial groundwater

Note: Ground elevation is 6798.97 ft; all depths are from this elevation





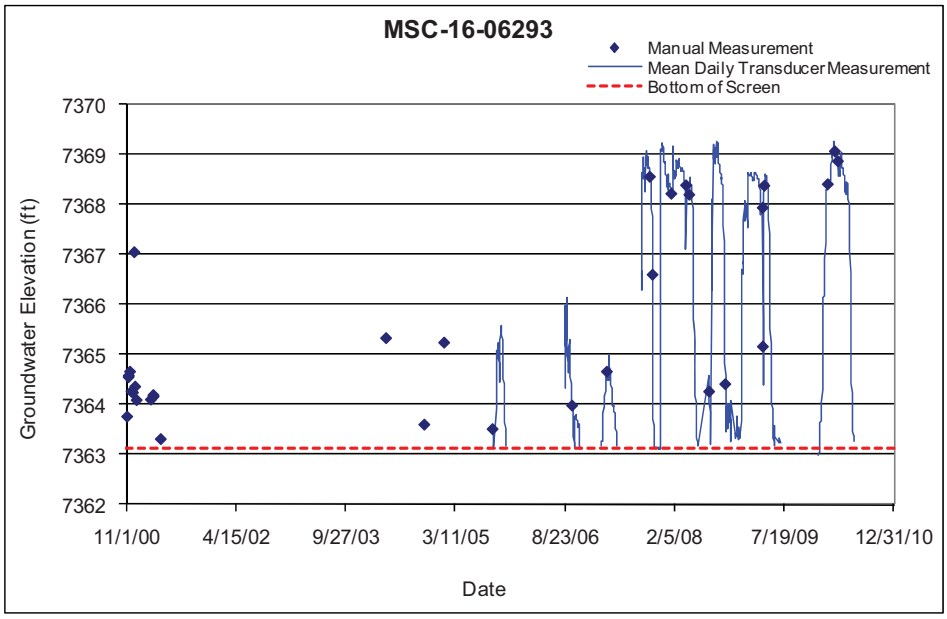
5.69 MSC-16-06293

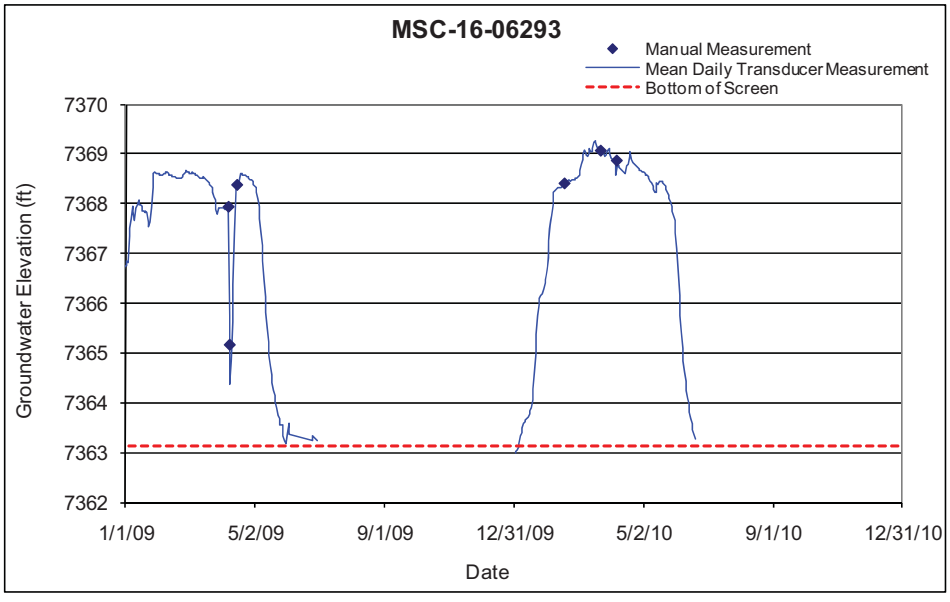
Location: Martin Spring Canyon, about 1600 ft downstream from the Martin Spring outlet.
Period of Record: November 6, 2000, through December 8, 2010.
Remarks: This well periodically runs dry.

MSC-16-06293 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	2.3	7.3	7368.14	7363.14	5.0			7.30	7363.14	7.84	0.54	1.33	Alluvial groundwater

Note: Brass Cap Elevation: 7370.79 ft; Ground elevation: 7370.44 ft; all depths are from this elevation





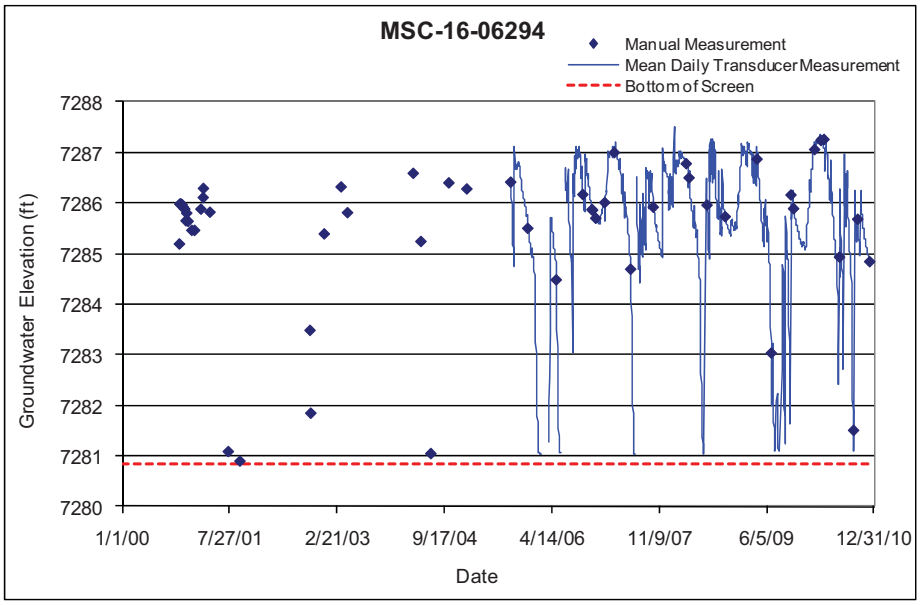
5.70 MSC-16-06294

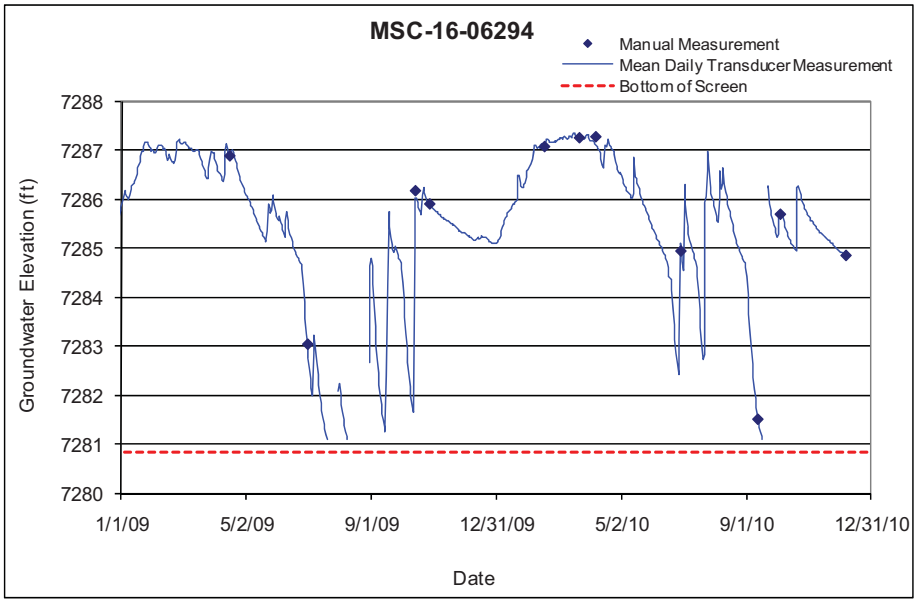
Location: Martin Spring Canyon, about 1600 ft upstream of the K-site wetlands.
Period of Record: November 6, 2000, through December 8, 2010.
Remarks: None.

MSC-16-06294 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	2.3	7.3	7285.84	7280.84	5.0			7.3	7280.84	7.65	0.35	0.86	Alluvial groundwater

Note: Brass Cap Elevation: 7288.44; Ground elevation: 7288.14 ft; all depths are from this elevation



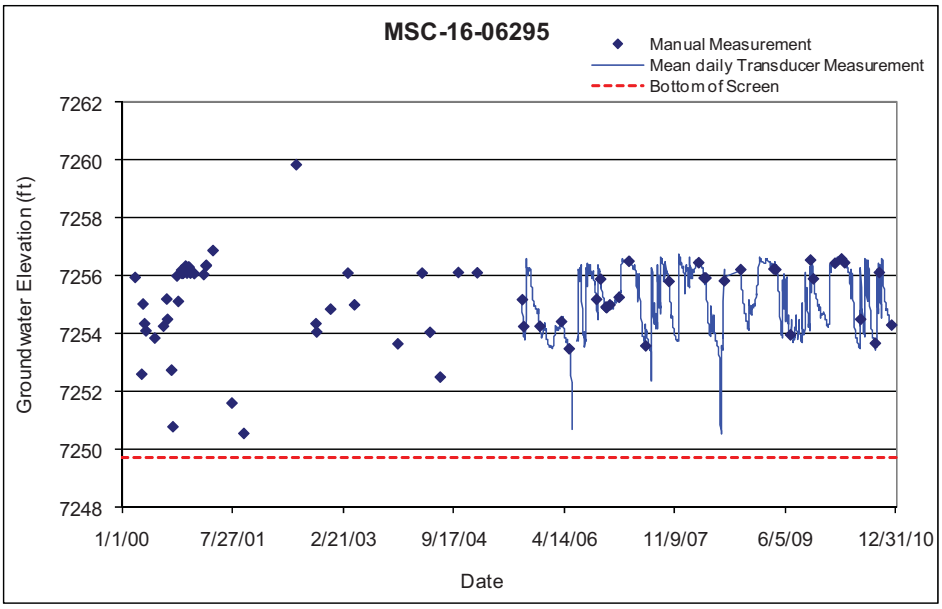


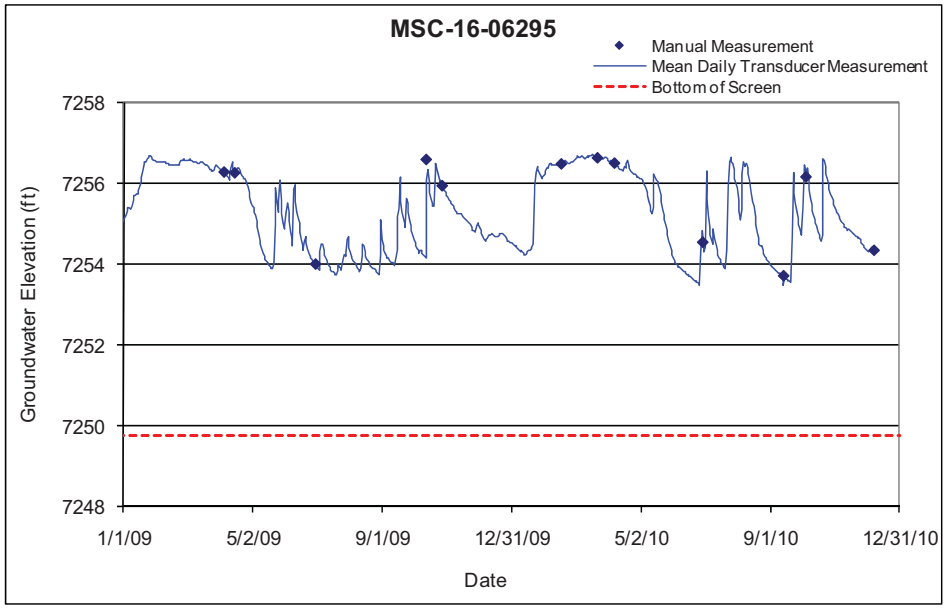
5.71 MSC-16-06295

Location: Martin Spring Canyon, just downstream of the K-site wetlands and north of the TA-11 drop tower.
Period of Record: March 10, 2000, through December 8, 2010.
Remarks: Transducer malfunctioned from July 2008 through October 2008.

MSC-16-06295 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	1.5	6.5	7254.74	7249.74	5.0			6.50	7249.74	6.85	0.35	0.86	Alluvial groundwater

Note: Brass Cap Elevation: 7257.03 ft; Ground elevation: 7256.24 ft; all depths are from this elevation





5.72 MT-2

Location: Middle Mortandad Canyon, down canyon of sediment traps, approximately 0.12 mi east of MT-1.

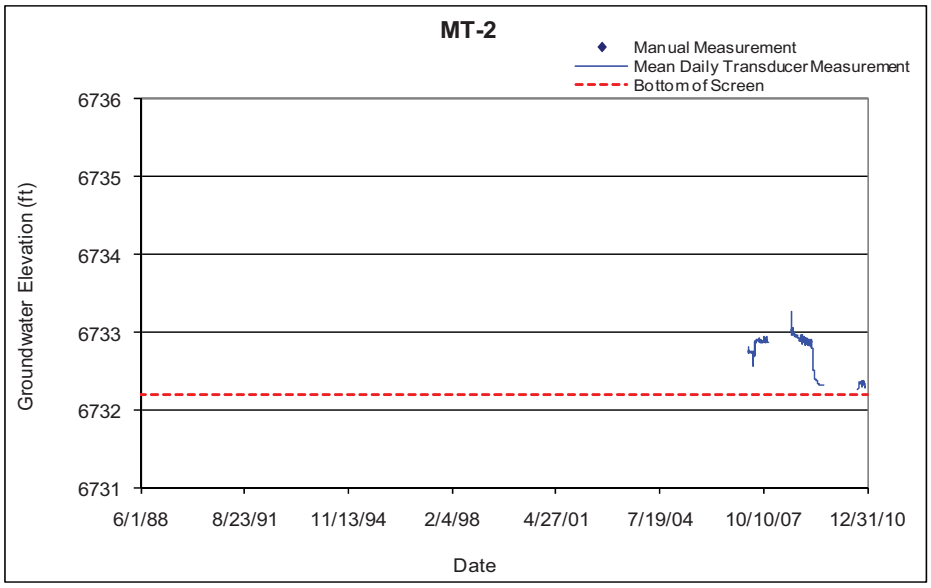
Period of Record: November 1, 1988, through December 3, 2010.

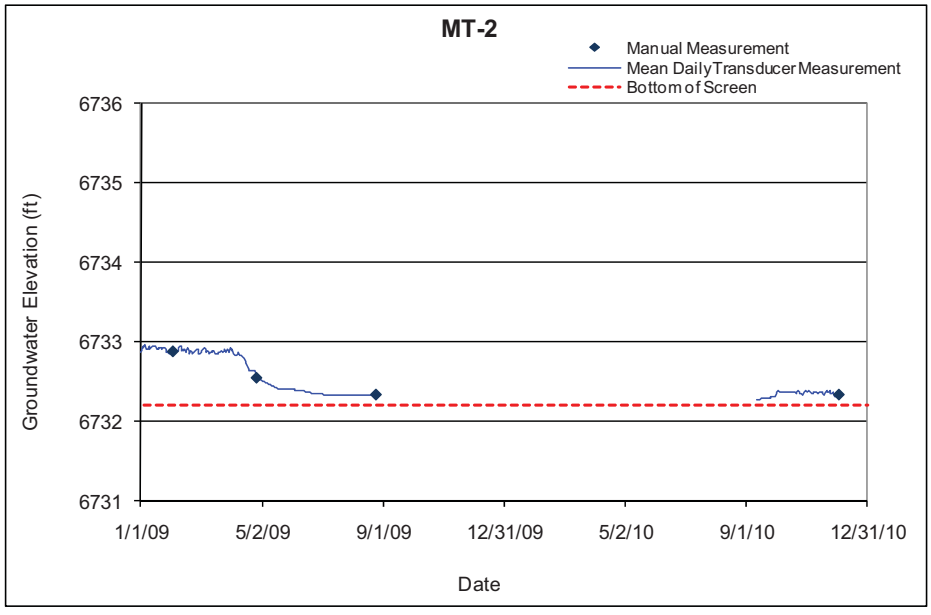
Remarks: The transducer was above the pump until April 17, 2007; transducer data before April 17, 2007, do not represent water levels below 6749.3 ft. Transducer was removed from well from November 28, 2007, through August 19, 2008.

MT-2 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	44.0	64	6752.2	6732.2	20.0			64.0	6732.2	64.3	0.3	0.2	Alluvial groundwater

Note: Ground elevation is 6796.20 ft; all depths are from this elevation



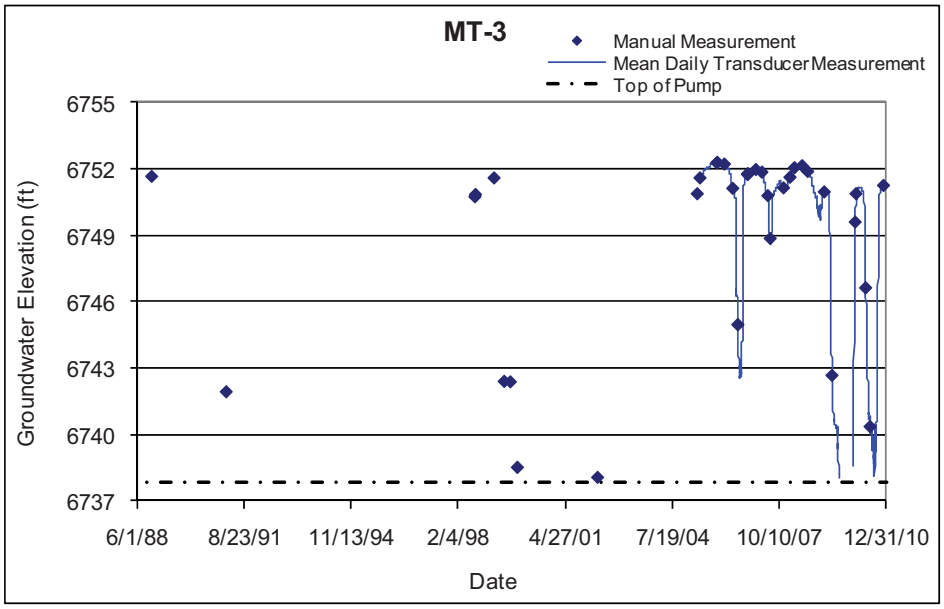


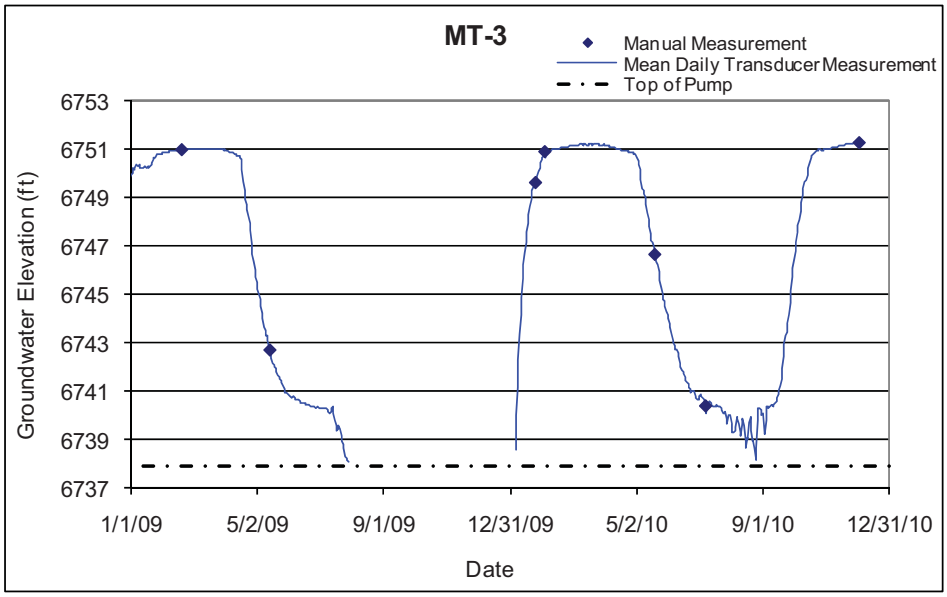
5.73 MT-3

Location: Middle Mortandad Canyon, down canyon of sediment traps, approximately 0.12 mi east of MT-1 and approximately 50 ft north of MT-2.
Period of Record: November 1, 1988, through December 3, 2010.
Remarks: None.

MT-3 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	44.0	64.0	6752.7	6732.7	20.0			64.0	6732.7	74.0	10.0	6.2	Alluvial groundwater

Note: Ground elevation is 6796.65 ft; all depths are from this elevation



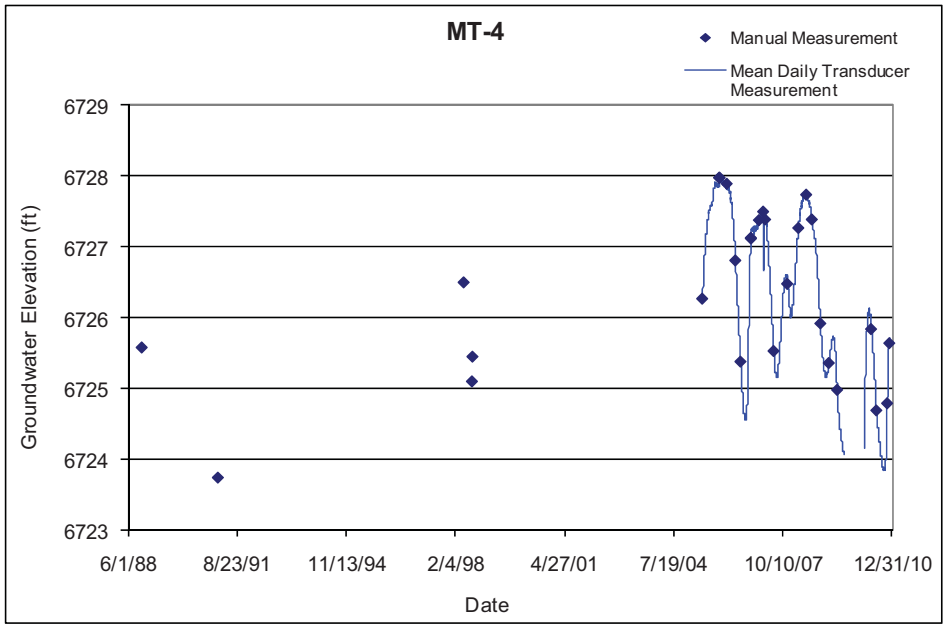


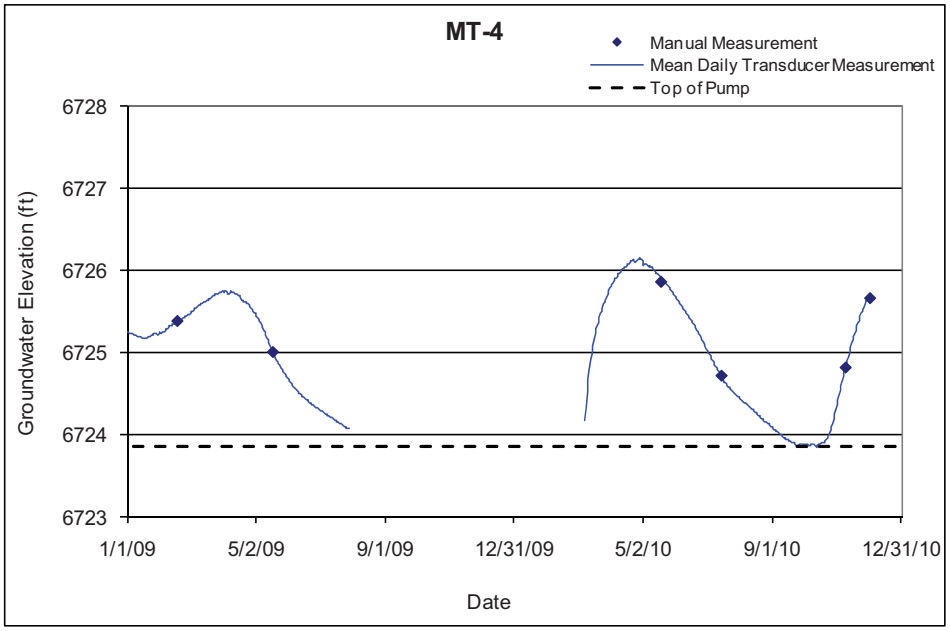
5.74 MT-4

Location: Middle Mortandad Canyon, down canyon of the sediment traps, approximately 525 ft east of MT-3.
Period of Record: November 1, 1988, through December 3, 2010.
Remarks: Pump was removed December 3, 2010 to enable transducer to record deeper water levels.

MT-4 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	54	64	6729.59	6719.59	10			64	6719.59	74	10	6	Alluvial groundwater

Note: Ground elevation is 6783.59 ft; all depths are from this elevation





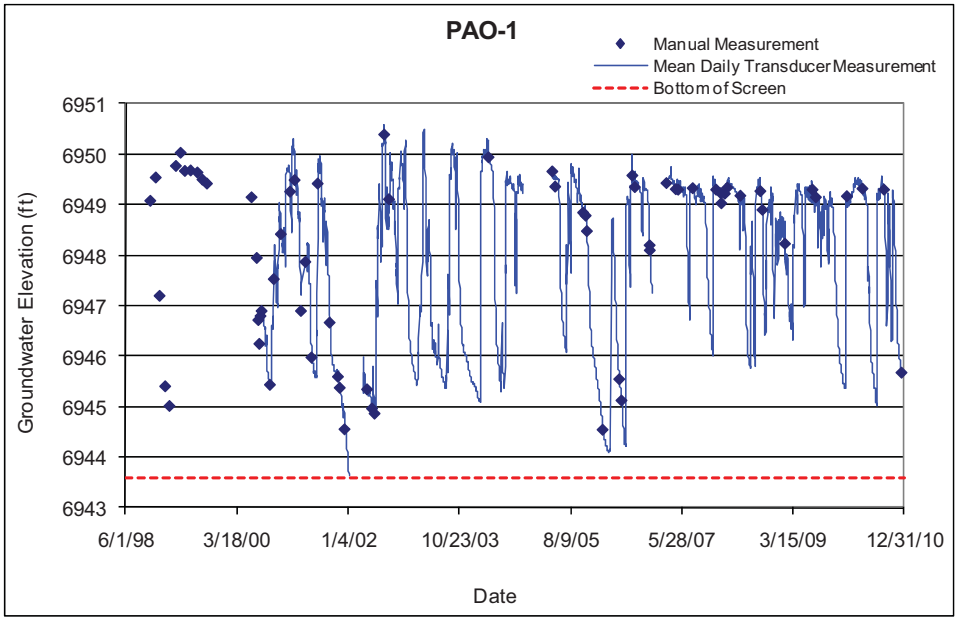
5.75 PAO-1

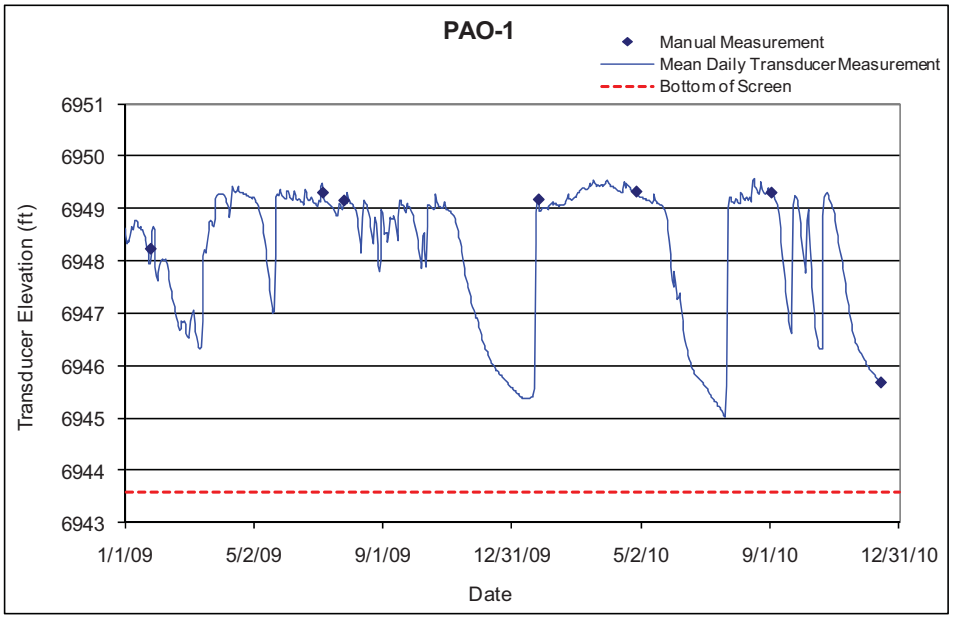
Location: Upper Pueblo Canyon, approximately 1000 ft west of the confluence with Acid Canyon.
Period of Record: October 29,1998, through December 14, 2010.
Remarks: The transducer batteries failed on December 3, 2006, and were replaced on February 27, 2007.

PAO-1 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	5.89	10.89	6948.58	6943.58	5.00			10.89	6944.08	13.74	2.85	7.04	Alluvial groundwater

Note: Brass Cap Elevation: 6954.97 ft; Ground elevation is 6954.47 ft; all depths are from this elevation



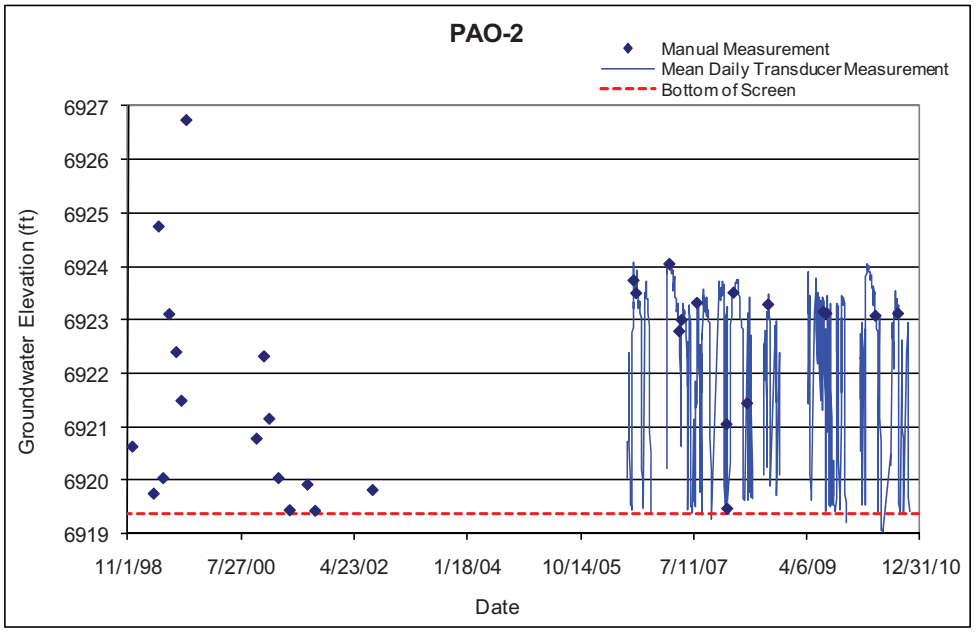


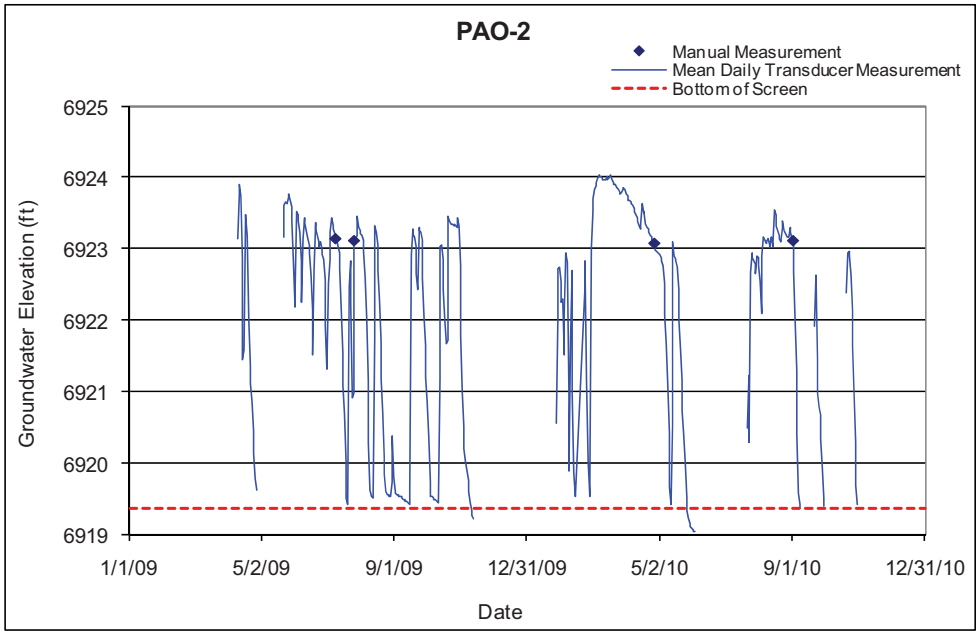
5.76 PAO-2

Location: Upper Pueblo Canyon, approximately 500 ft east of the Acid Canyon confluence.
Period of Record: November 30, 1998, through November 29, 2010.
Remarks: The water level frequently drops below the screen.

PAO-2 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	6.06	11.06	6914.37	6919.37	5.00			11.06	6919.37	13.91	2.85	7.04	Alluvial groundwater

Note: Ground elevation is 6930.98 ft; all measurements are from this elevation



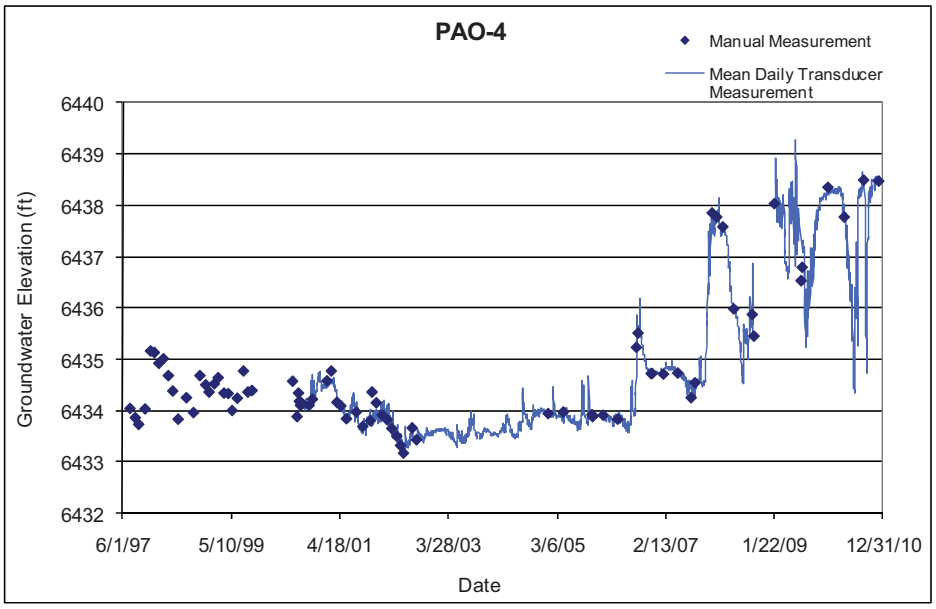


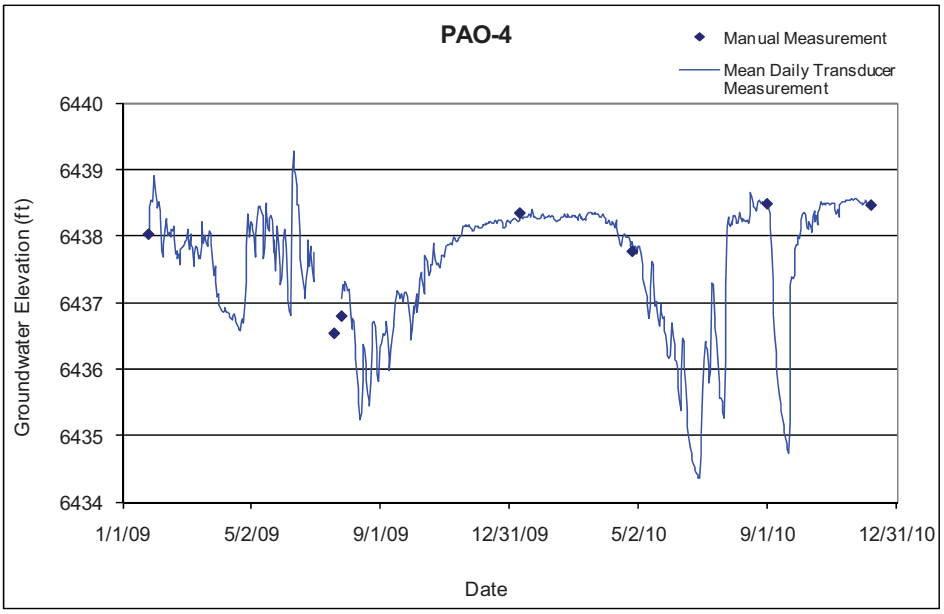
5.77 PAO-4

Location: Lower Pueblo Canyon, approximately 3100 ft southeast of the old LAC Sewage Treatment Plant location.
Period of Record: July 24, 1997, through December 8, 2010.
Remarks: Transducer failed from September 2008 through January 2009, and from June 2009 through July 2009.

PAO-4 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	1.97	6.97	6435.07	6430.07	5.00			6.97	6430.07	9.82	2.85	7.04	Alluvial groundwater

Note: Brass Cap Elevation: 6437.37 ft; Ground elevation: 6437.04 ft; all depths are from this elevation



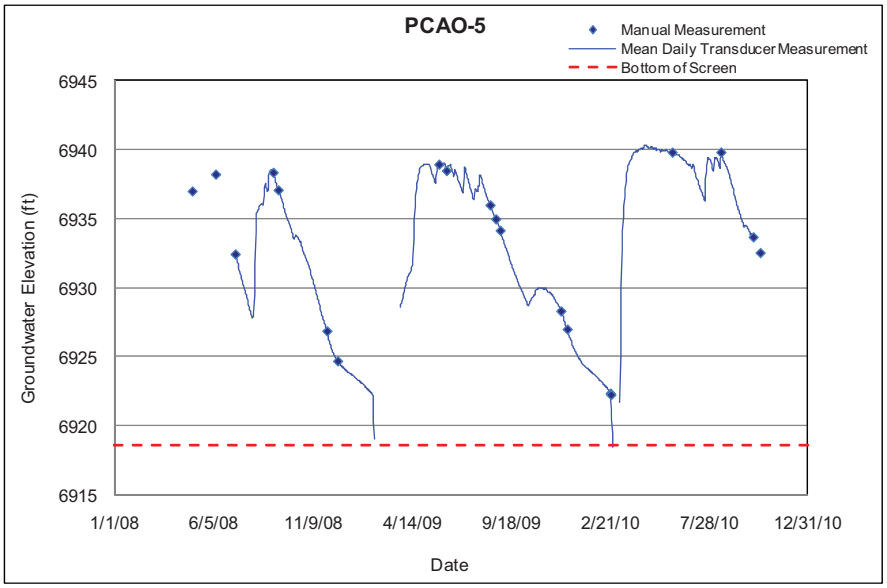


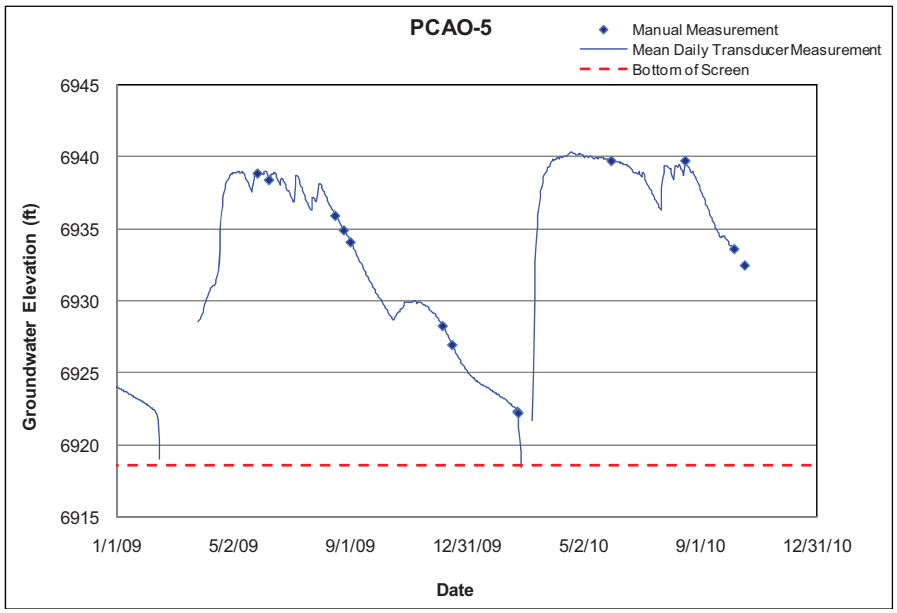
5.78 PCAO-5

Location: Middle Pajarito Canyon, adjacent to and on the north side of the stream channel, approximately 100 ft upstream of the flood retention dam.
Period of Record: May 3, 2008, through October 18, 2010.
Remarks: None.

PCAO-5 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	14.7	24.7	6928.6	6918.6	10.0			24.7	6918.6	30.0	5.3	13.1	Alluvial Groundwater

Note: Ground elevation is 6943.29 ft; all depths from this elevation





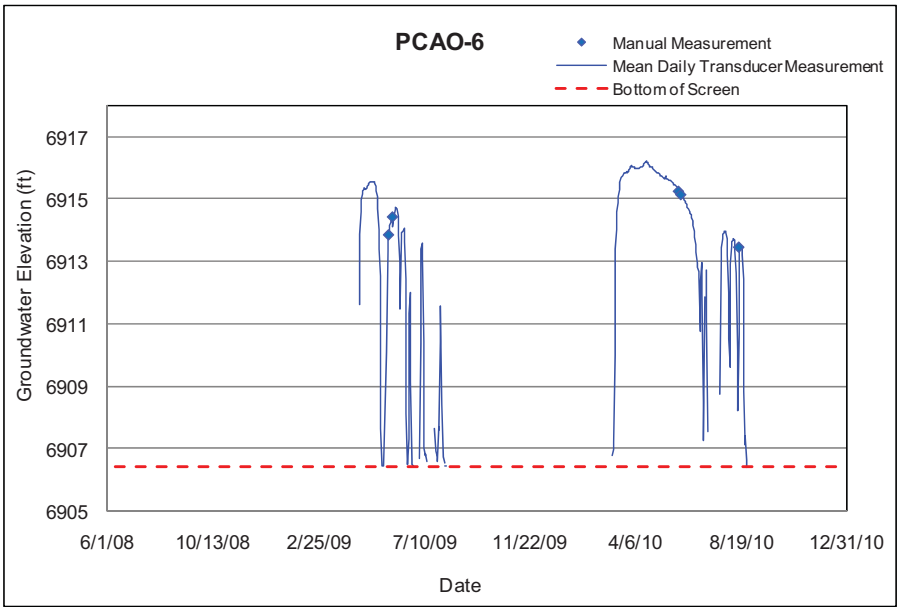
5.79 PCAO-6

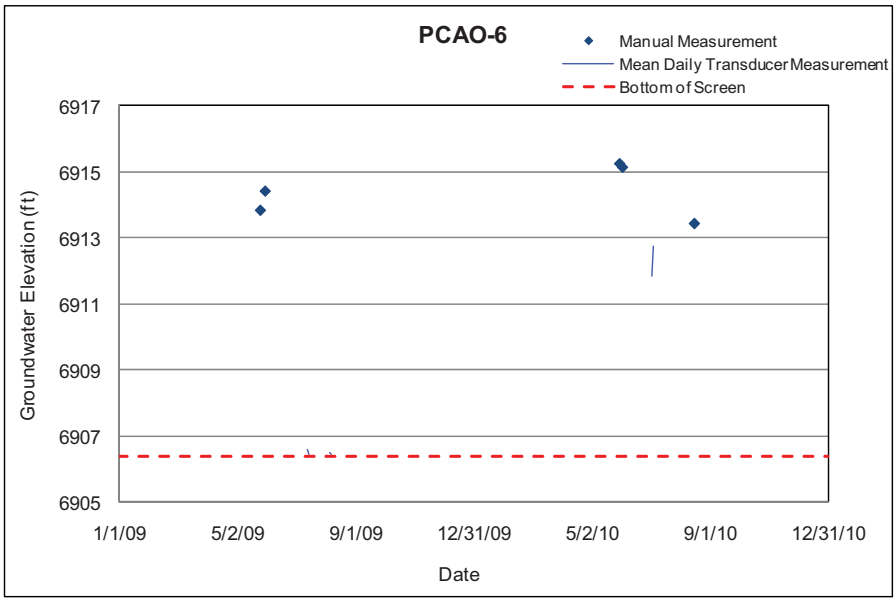
Location: Middle Pajarito Canyon, on the south side of the stream channel, approximately 300 ft downstream of the flood retention dam, and approximately 100 ft west of regional well R-17.
Period of Record: June 5, 2008, through October 7, 2010.
Remarks: Well was purged dry during drilling (less than one gallon of water). Until April 2009, water did not rise above the sump. Well remained wet during the summers of 2009 and 2010.

PCAO-6 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	8.0	15.0	6913.4	6906.4	7.0			15.0	6906.4	20.0	5.0	12.4	Alluvial Groundwater

Note: Ground elevation is 6921.40 ft; all depths from this elevation



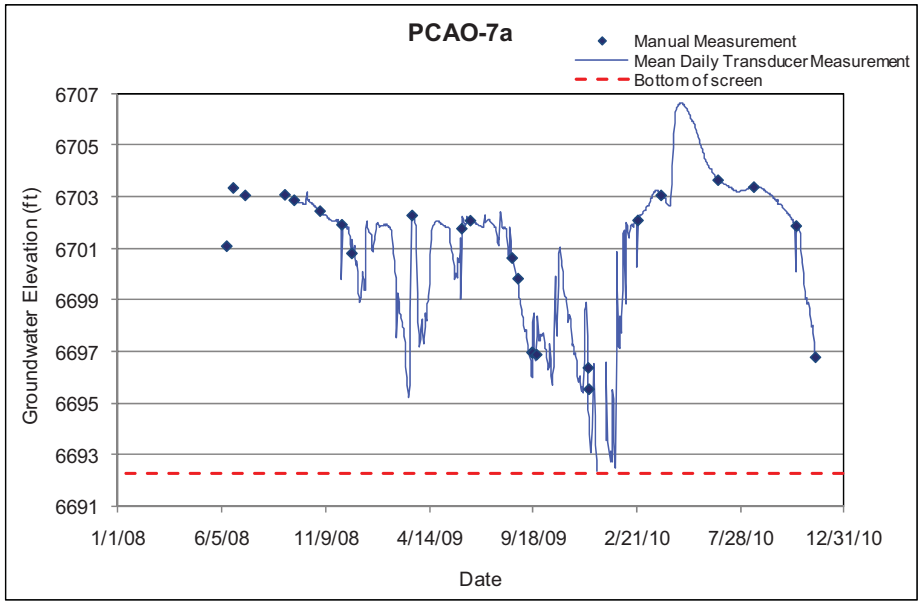


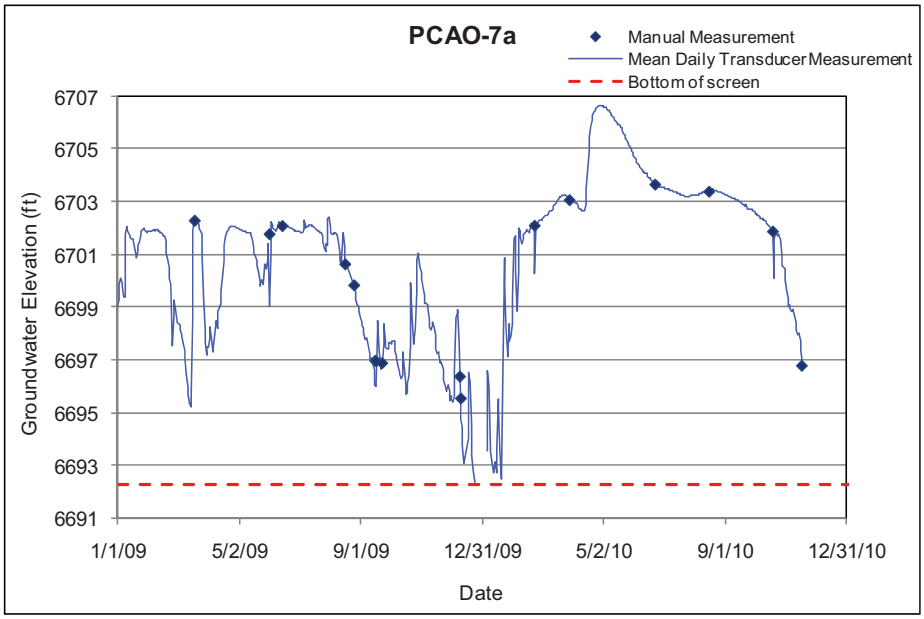
5.80 PCAO-7a

Location: In TA-18 in lower Pajarito Canyon on the north side of Pajarito Road, approximately 100 ft from the TA-18 entrance.
Period of Record: June 12, 2008, through November 18, 2010.
Remarks: None.

PCAO-7a Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	9.7	19.7	6702.3	6692.3	10.0			19.7	6692.3	24.7	5.0	12.4	Alluvial Groundwater

Note: Ground elevation is 6711.97 ft; all depths are from this elevation.





5.81 PCAO-7b1

Location: In lower Pajarito Canyon, in TA-18, on the north side of Pajarito Road directly across from the TA-18 entrance. PCAO-7b1 and PCAO-7b2 are approximately 10 ft apart.
Period of Record: May 21, 2008, through November 18, 2010.
Remarks: Well was bailed dry during drilling, and water has not risen above the sump since.

PCAO-7b(1) Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	44.0	54	6669.6	6659.6	10.0			54.0	6659.6	59.3	5.3	13.1	Alluvial groundwater

Note: Ground elevation is 6713.62 ft; all depths from this elevation

PCAO-7b1 Manual Water Levels

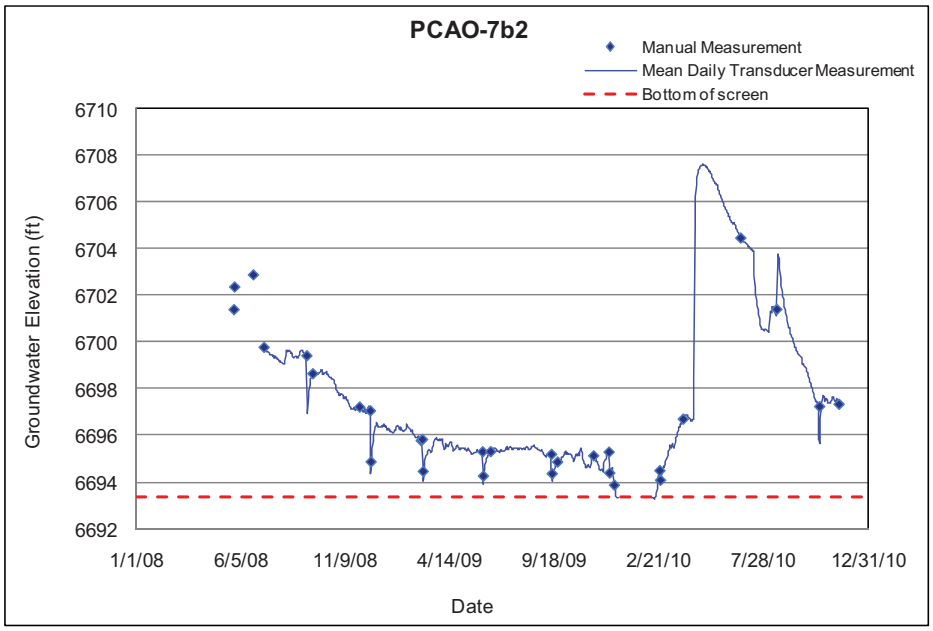
Date	Water Level (ft)	Comments
5/21/2008	6656.7	Sump water
5/28/2008	6657.34	Sump water
6/24/2008		Dry
7/11/2008	6653.82	Sump water
7/11/2008	6653.82	Sump water
9/8/2008	6653.86	Sump water
12/1/2008	6653.85	Sump water
3/3/2009	6653.85	Sump water
5/28/2009	6653.83	Sump water
9/23/2009	6653.85	Sump water
12/17/2009	6653.83	Sump water
3/30/2010		Dry
6/24/2010	6653.86	Sump water
8/17/2010	6653.86	Sump water
11/18/2010	6653.86	Sump water

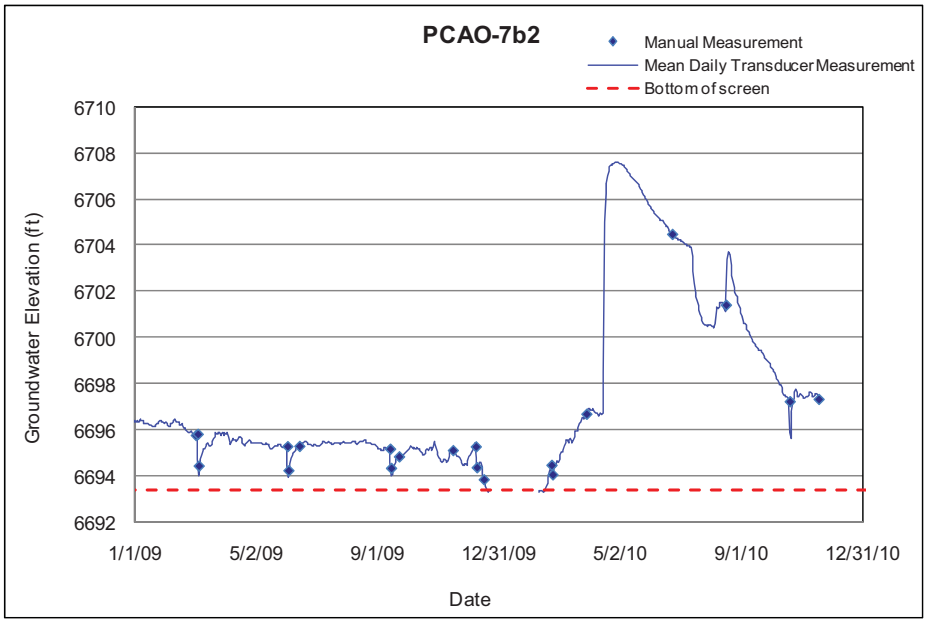
5.82 PCAO-7b2

Location: In lower Pajarito Canyon, in TA-18, on the north side of Pajarito Road directly across from the TA-18 entrance. PCAO-7b1 and PCAO-7b2 are approximately 10 ft apart.
Period of Record: May 27, 2008, through November 18, 2010.
Remarks: None.

PCAO-7b(2) Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	10.0	20	6703.4	6693.4	10.0			20.0	6693.4	25.0	5.0	12.4	Alluvial groundwater

Note: Ground elevation is 6713.39 ft; all depths are from this elevation





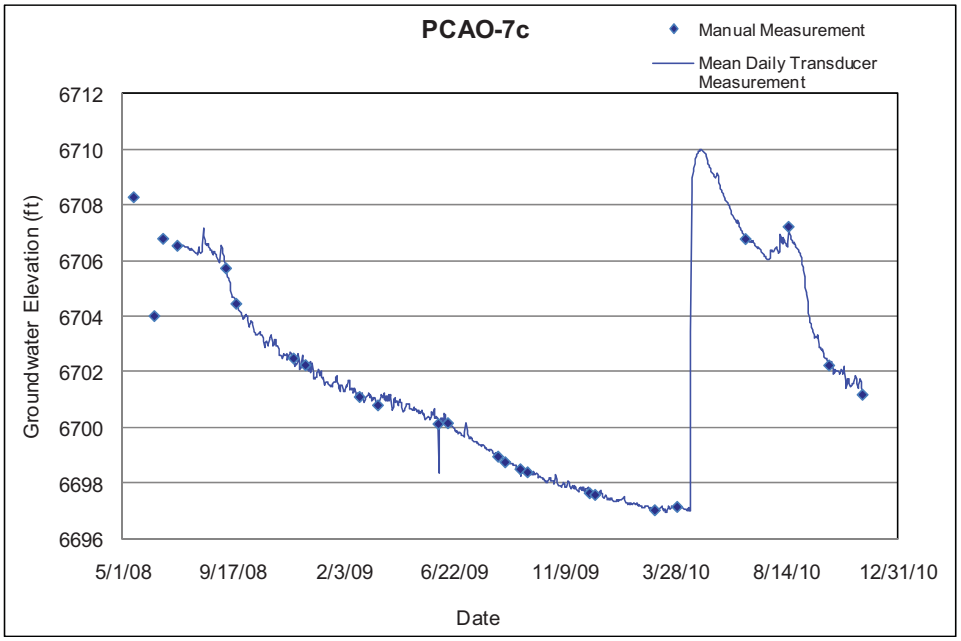
5.83 PCAO-7c

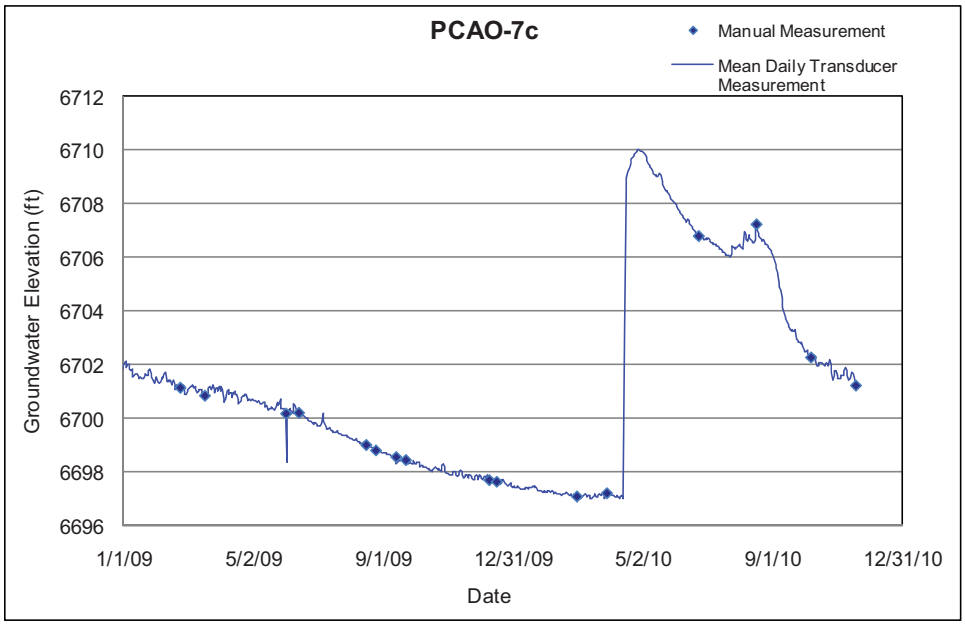
Location: Lower Pajarito Canyon, in TA-18 on the south side of Pajarito Road, approximately 50 ft from the TA-18 entrance.
Period of Record: May 16, 2008, through November 18, 2010.
Remarks: None.

PCAO-7c Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	9.7	19.7	6704.9	6694.9	10.0			19.7	6694.9	25.0	5.3	13.1	Alluvial groundwater

Note: Ground elevation is 6714.57 ft; all depths from this elevation



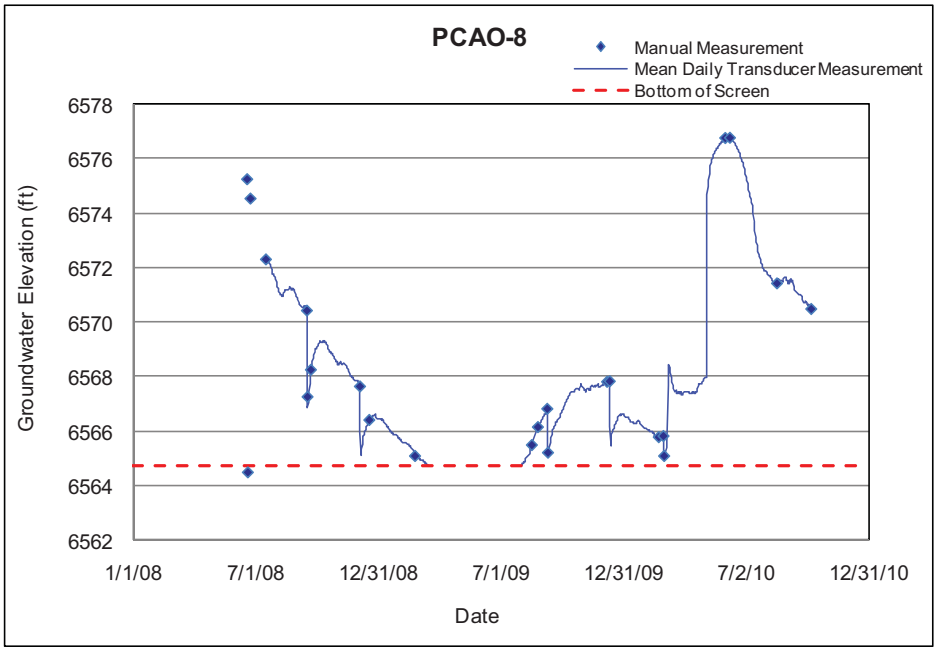


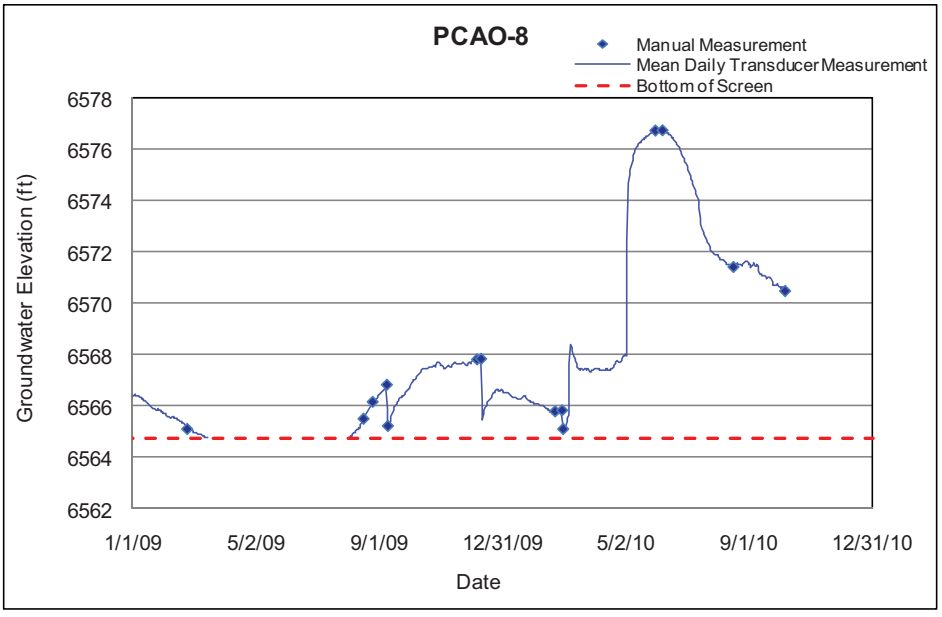
5.84 PCAO-8

Location: In lower Pajarito Canyon, on the south side of Pajarito Road in TA-36, approximately a quarter mile west of PCAO-9.
Period of Record: June 2, 2008, through October 7, 2010.
Remarks: None.

PCAO-8 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	9.7	19.7	6574.8	6564.8	10.0			19.7	6564.8	25.0	5.3	13.1	Alluvial groundwater

Note: Ground elevation is 6584.45 ft; all depths from this elevation



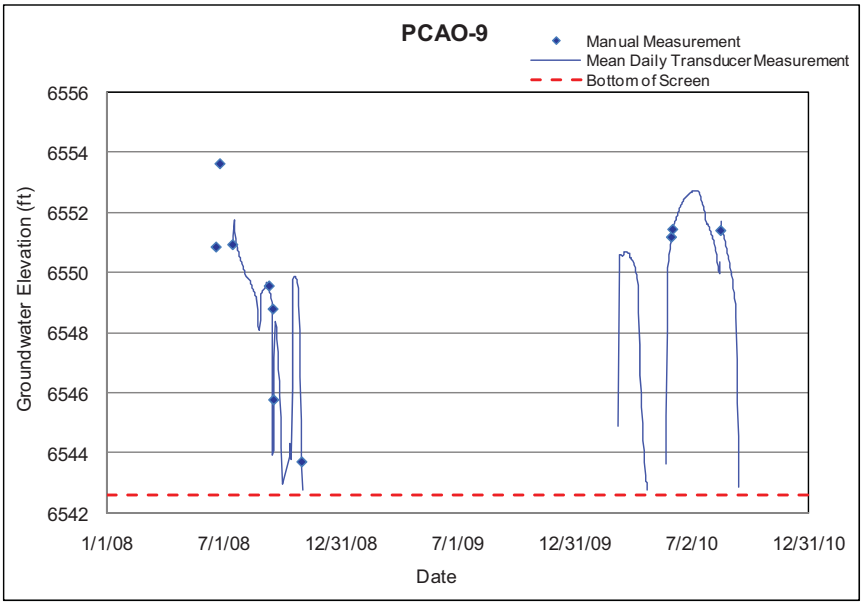


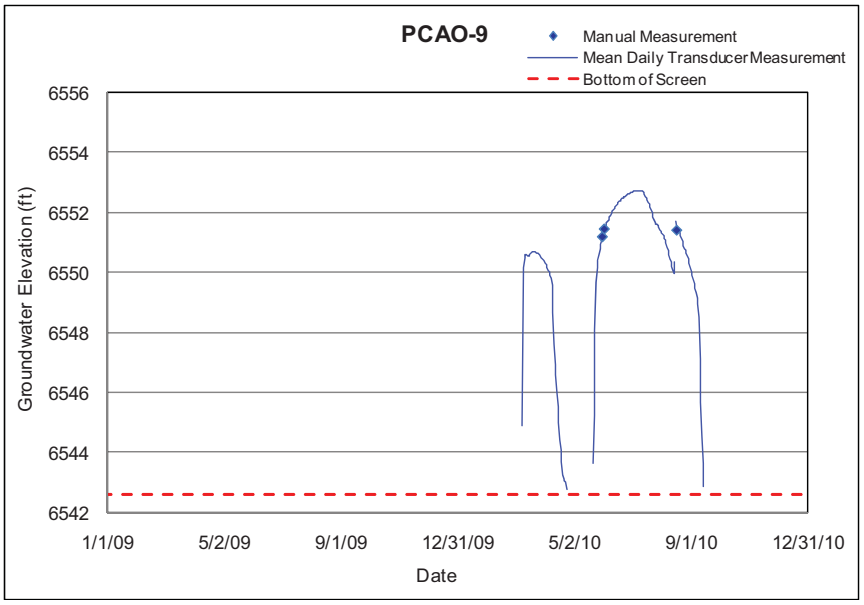
5.85 PCAO-9

Location: In lower Pajarito Canyon on the south side of Pajarito Road in TA-36, approximately a quarter mile west of the security check point, and a quarter mile east of PCAO-8.
Period of Record: June 12, 2008, through October 7, 2010.
Remarks: None.

PCAO-9 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	6.0	16.0	6552.6	6542.6	10.0			16.0	6542.6	21.0	5.0	12.4	Alluvial groundwater

Note: Ground elevation is 6558.60 ft; all depths from this elevation





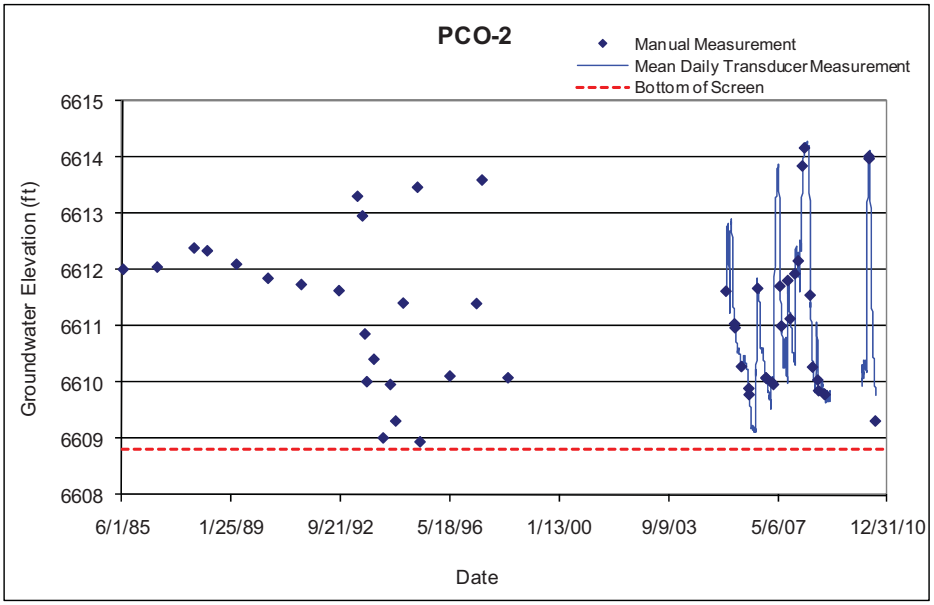
5.86 PCO-2

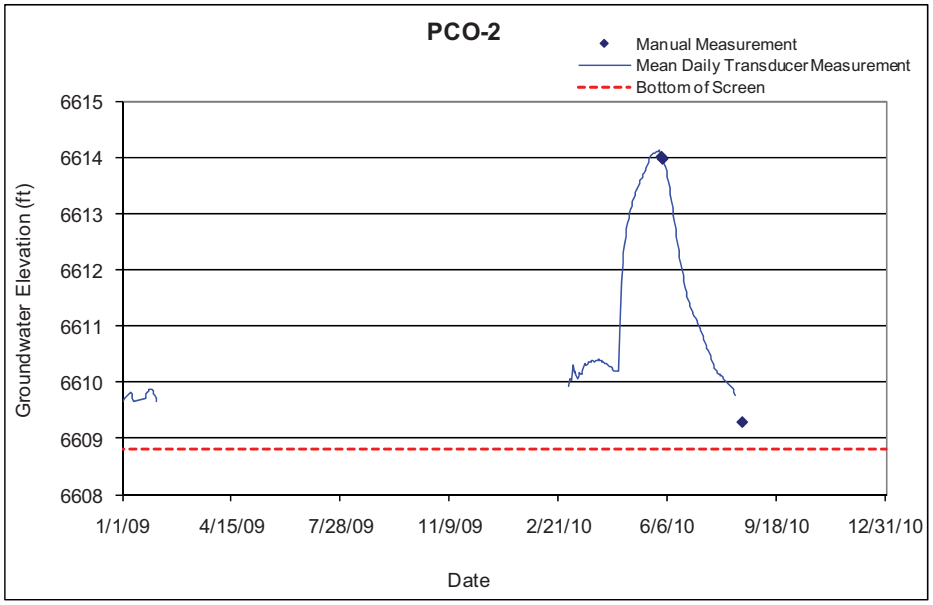
Location: In lower Pajarito Canyon on the north side of Pajarito Road, approximately 0.1 mi east of R-32.
Period of Record: June 11, 1985, through October 7, 2010.
Remarks: None.

PCO-2 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	1.5	9.5	6616.8	6608.8	8			9.5	6608.8	9.5	0	0	Alluvial groundwater

Note: Ground Elevation: 6618.3 ft; all depths are from this elevation



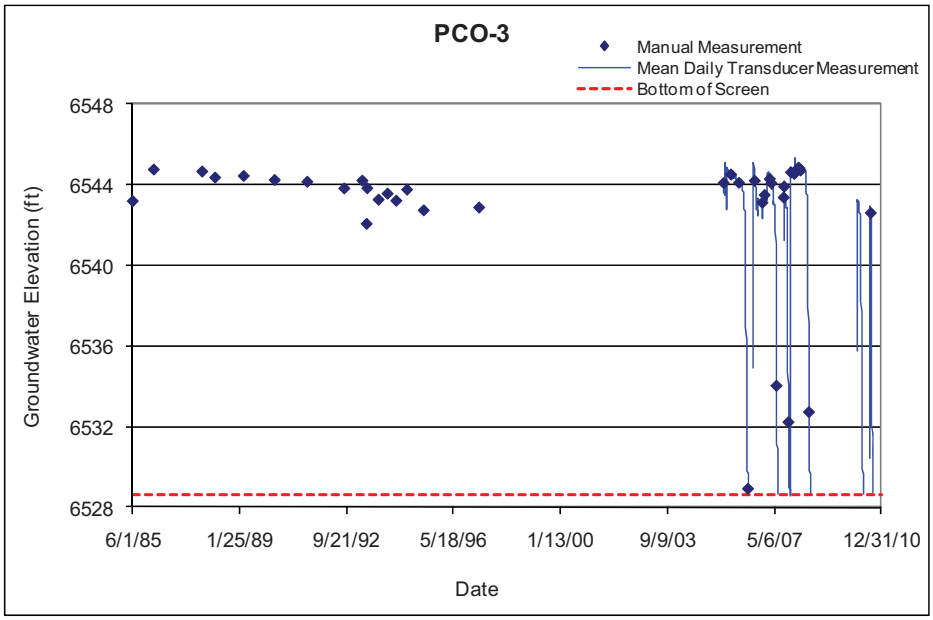


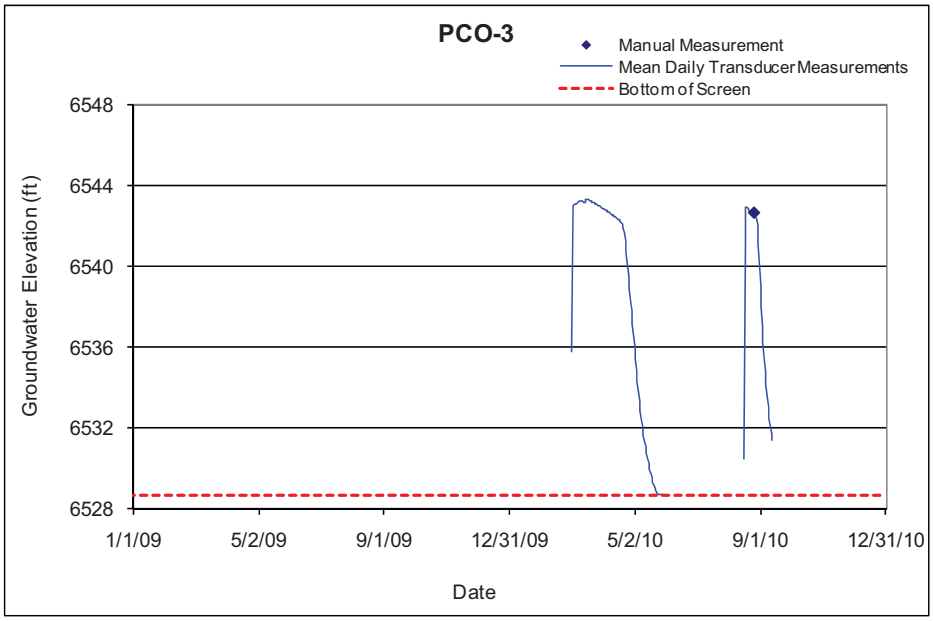
5.87 PCO-3

Location: Lower Pajarito Canyon, approximately 1 mi east of R-32, in wetlands on the south side of Pajarito Road.
Period of Record: June 11, 1985, through December 12, 2010.
Remarks: None.

PCO-3 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	5.7	17.7	6540.6	6528.6	12.0			17.7	6528.6	17.7	0.0	0.0	Alluvial groundwater

Note: Ground Elevation: 6546.30 ft; all depths are from this elevation



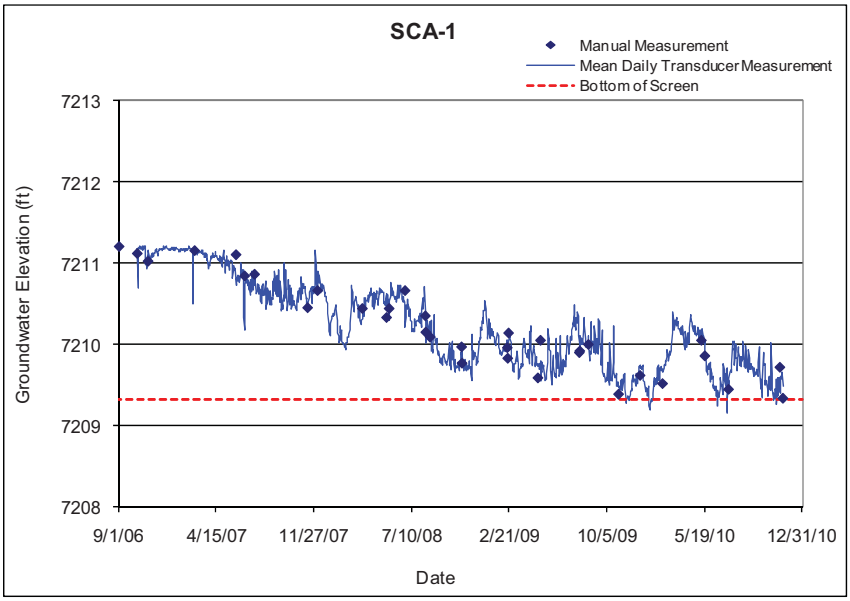


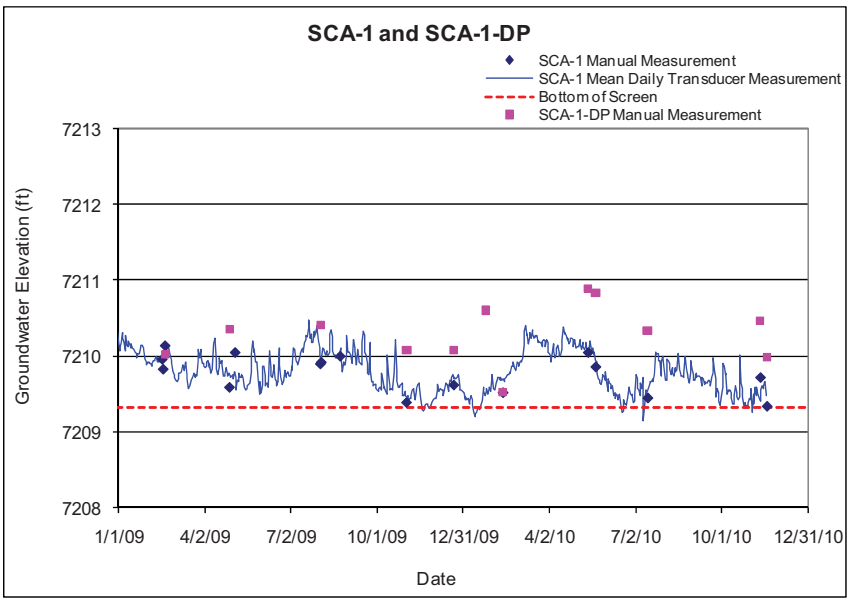
5.88 SCA-1 and SCA-1-DP

Location: In upper Sandia Canyon, in the wetlands approximately 350 ft upstream from gaging station E123. SCA-1-DP is located approximately 15 ft west of SCA-1.
Period of Record: October 13, 2006, through November 18, 2010.
Remarks: SCA-1 is a shallow alluvial well located in a wetland. Recent sampling events have moved to temporary drive point well SCA-1-DP due to silting-in of the screen in SCA-1. Continuous water levels are monitored at SCA-1, and manual measurements are taken in conjunction at SCA-1-DP. SCA-1-DP was removed and replaced in the same hole in November 2010.

SCA-1 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	1.3	1.9	7209.9	7209.3	0.6			1.9	7209.3	2.1	0.2	0.1	Alluvial groundwater

Note: Ground elevation is 7211.22 ft; all depths are from this elevation



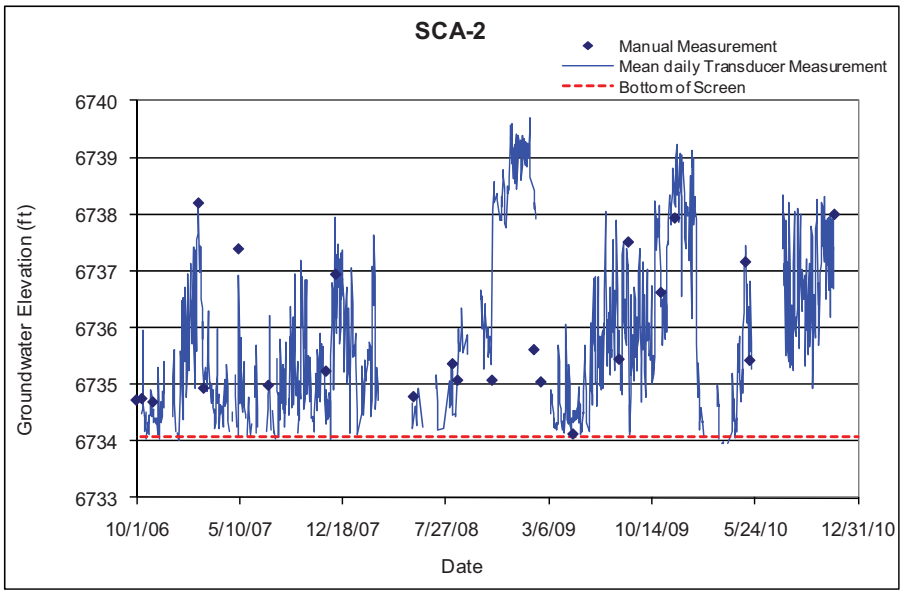


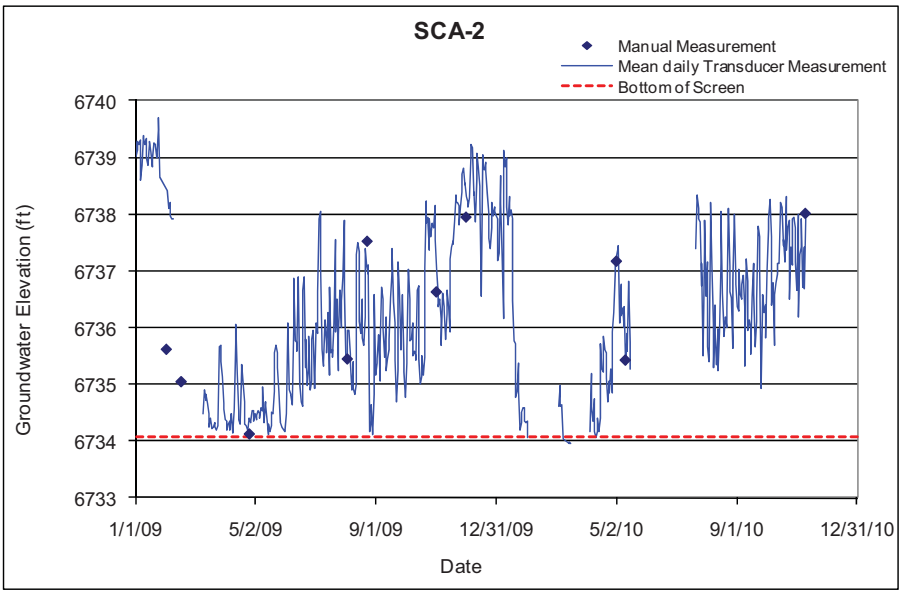
5.89 SCA-2

Location: Middle Sandia Canyon, approximately 700 ft upstream of gaging station E124.
Period of Record: October 13, 2006, through November 17, 2010.
Remarks: SCA-2 responds to the sewer treatment plant discharge in upper Sandia Canyon. Water levels frequently drop below the screen. From August 22, 2008, though March 11, 2009, the transducer was set too high in the well, not recording water levels below 6735.7 ft, and not matching manual measurements. Transducer has since been lowered to record all water level data.

SCA-2 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	10.3	15.0	6738.8	6734.1	4.7			15.0	6733.8	15.6	0.6	0.4	Alluvial groundwater

Note: Groundwater elevation is 6749.08 ft; all depths are from this elevation





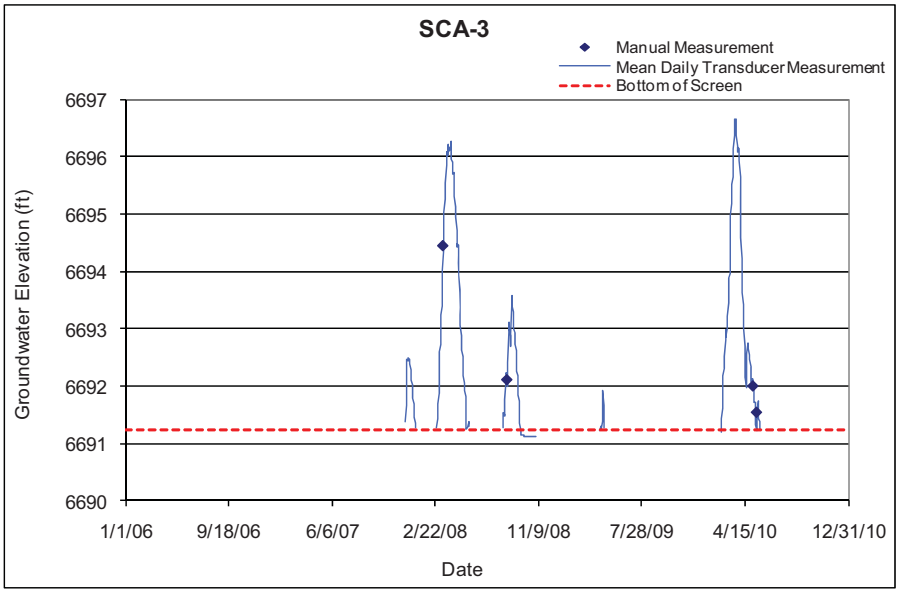
5.90 SCA-3

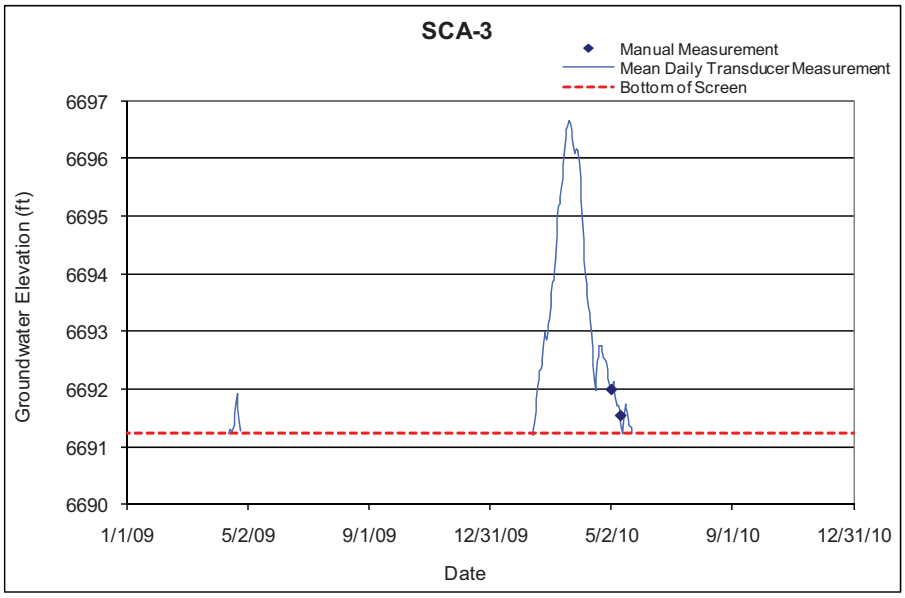
Location: Middle Sandia Canyon, approximately 700 ft downstream of gaging station E124.
Period of Record: October 13, 2006, through November 10, 2010.
Remarks: Water rose above the sump for the first time on December 10, 2007. Since then the well has periodically run dry.

SCA-3 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	27.6	32.0	6695.6	6691.2	4.4			32.0	6691.2	32.6	0.6	4.4	Alluvial groundwater

Note: Ground elevation is 6723.22 ft; all depths are from this elevation



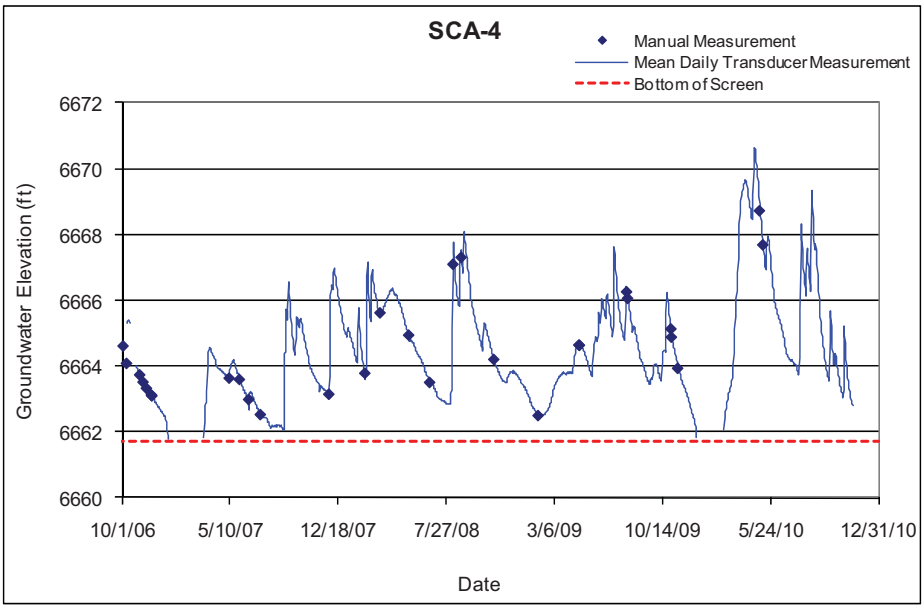


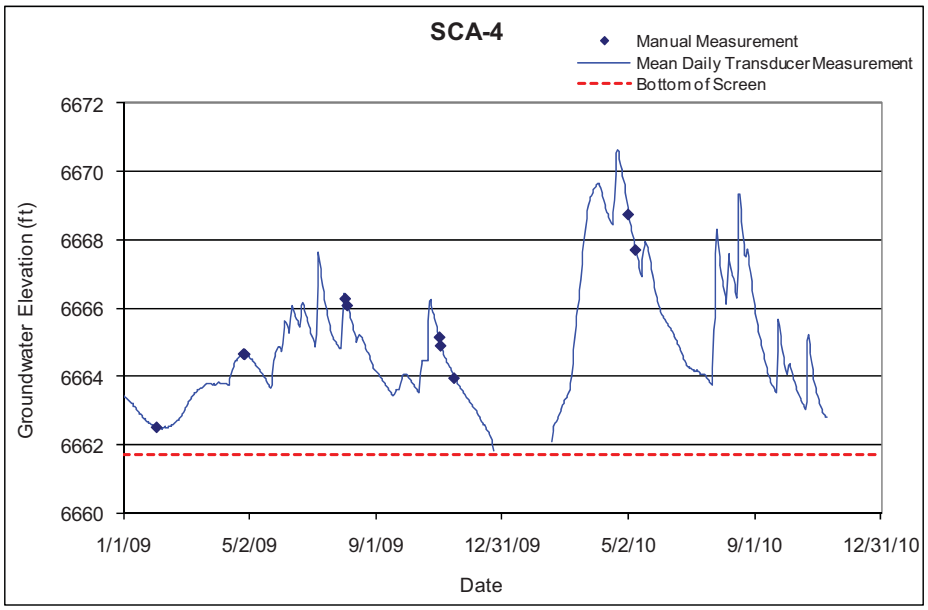
5.91 SCA-4

Location: Middle Sandia Canyon, approximately 700 ft downstream from SCA-3.
Period of Record: October 3, 2006, through November 17, 2010.
Remarks: The transducer was installed on October 3, 2006, above the top of the pump at an elevation of 6665.28 ft. The pump was removed on October 31, 2006, to allow more thorough water level monitoring.

SCA-4 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	37.0	41.5	6666.2	6661.7	4.5			41.5	6661.7	42.0	0.5	3.7	Alluvial groundwater

Note: Brass Cap Elevation: 6703.58 ft; Ground elevation: 6703.20 ft; all depths are from this elevation





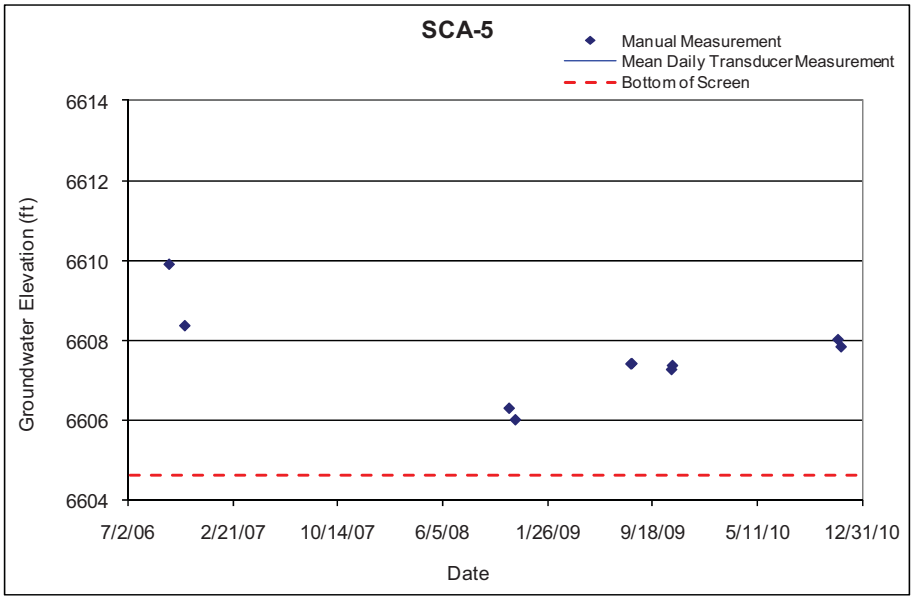
5.92 SCA-5

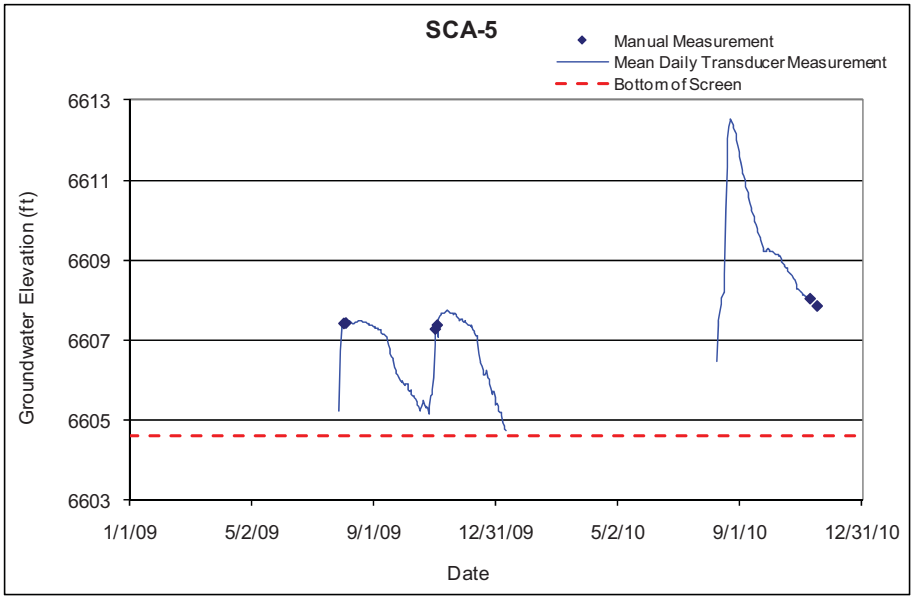
Location: Middle Sandia Canyon, approximately 650 ft upstream from the firing range at TA-72 and about 325 ft north of R-11.
Period of Record: October 3, 2006, through November 17, 2010.
Remarks: Until spring 2008, the transducer was installed above the pump in the 2-in. casing and the transducer data did not represent water levels below 6608.1 ft. Since spring 2008, the transducer has recorded all water in the well. This well has run dry frequently since installation of the pressure transducer.

SCA-5 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	55.00	64.4	6614.0	6604.6	9.4			64.4	6604.6	64.9	0.5	0.3	Alluvial groundwater

Note: Ground elevation is 6669.02 ft; all depths from this elevation





5.93 SCO-1

Location: Sandia Canyon, approximately 0.1 mi east of R-11.
Period of Record: June 7, 1997, through August 24, 2009.
Remarks: No valid data; well has been dry for every measurement event. There is no transducer installed in this well. Monitoring ceased in August 2009.

SCO-1 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	9.3	19.3	6609.4	6599.4	10.0			19.3	6599.4	19.3	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6618.67 ft; all depths are from this elevation

SCO-1 Manual Water Levels			
Date	Comments	Date	Comments
8/14/1989	Dry	10/18/2005	Dry
6/9/1997	Dry	12/8/2005	Dry
10/13/1997	Dry	3/7/2006	Dry
3/25/1998	Dry	6/13/2006	Dry
5/29/1998	Dry	8/28/2006	Dry
7/28/1998	Dry	9/7/2006	Dry
3/3/1999	Dry	10/3/2006	Dry
6/23/1999	Dry	12/8/2006	Dry
8/30/1999	Dry	2/12/2007	Dry
11/15/1999	Dry	3/13/2007	Dry
3/26/2000	Dry	6/7/2007	Dry
5/16/2000	Dry	6/12/2007	Dry
8/30/2000	Dry	9/5/2007	Dry
10/8/2000	Dry	11/12/2007	Dry
7/2/2001	Dry	1/24/2008	Dry
8/22/2001	Dry	2/12/2008	Dry
10/18/2001	Dry	4/3/2008	Dry
1/27/2002	Dry	5/12/2008	Dry
4/19/2002	Dry	7/22/2008	Dry
8/27/2002	Dry	8/11/2008	Dry
2/19/2003	Dry	11/3/2008	Dry
5/18/2003	Dry	2/2/2009	Dry
2/28/2005	Dry	4/27/2009	Dry
6/7/2005	Dry	8/24/2009	Dry
6/14/2005	Dry		

5.94 SCO-2

Location: Sandia Canyon, approximately 300 ft west of R-12.
Period of Record: June 9, 1997, through August 24, 2009.
Remarks: No valid data; well has been dry for every measurement event. There is no transducer installed in this well. Monitoring ceased in August 2009.

SCO-2 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	9.4	19.4	6491.3	6481.3	10.0			19.4	6481.3	19.4	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6500.67 ft; all depths are from this elevation

SCO-2 Manual Water Levels			
Date	Comments	Date	Comments
8/16/1989	Dry	10/18/2005	Dry
6/9/1997	Dry	12/8/2005	Dry
10/13/1997	Dry	3/7/2006	Dry
3/25/1998	Dry	6/13/2006	Dry
5/29/1998	Dry	8/28/2006	Dry
7/28/1998	Dry	9/7/2006	Dry
3/3/1999	Dry	10/3/2006	Dry
6/23/1999	Dry	12/8/2006	Dry
8/30/1999	Dry	2/12/2007	Dry
11/15/1999	Dry	3/13/2007	Dry
3/26/2000	Dry	6/7/2007	Dry
5/16/2000	Dry	6/12/2007	Dry
8/30/2000	Dry	9/5/2007	Dry
10/8/2000	Dry	11/12/2007	Dry
7/2/2001	Dry	1/24/2008	Dry
8/22/2001	Dry	2/12/2008	Dry
10/18/2001	Dry	4/3/2008	Dry
4/19/2002	Dry	5/12/2008	Dry
8/27/2002	Dry	7/22/2008	Dry
10/27/2002	Dry	8/11/2008	Dry
2/19/2003	Dry	11/3/2008	Dry
5/18/2003	Dry	2/2/2009	Dry
6/7/2005	Dry	4/27/2009	Dry
6/14/2005	Dry	8/24/2009	Dry

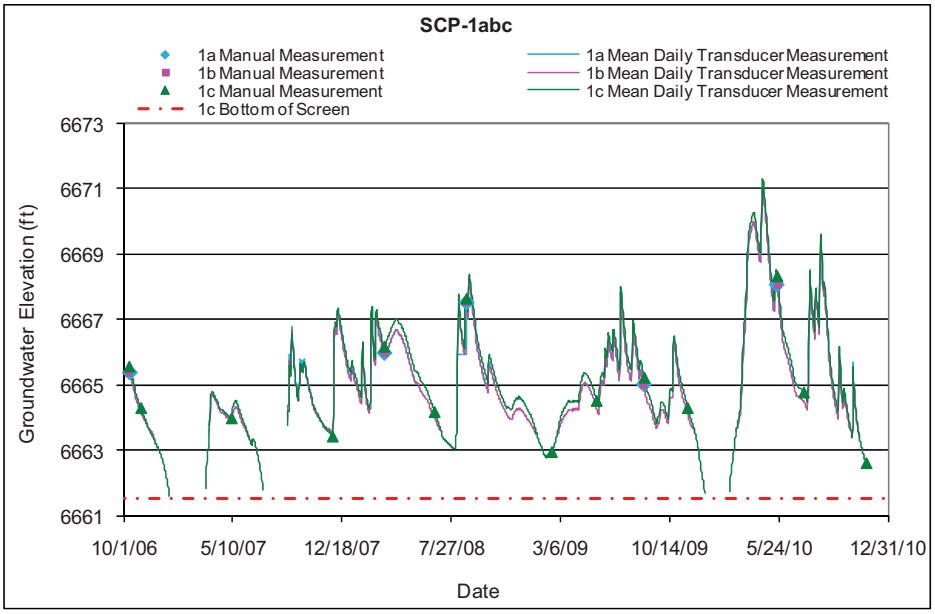
5.95 SCP-1abc

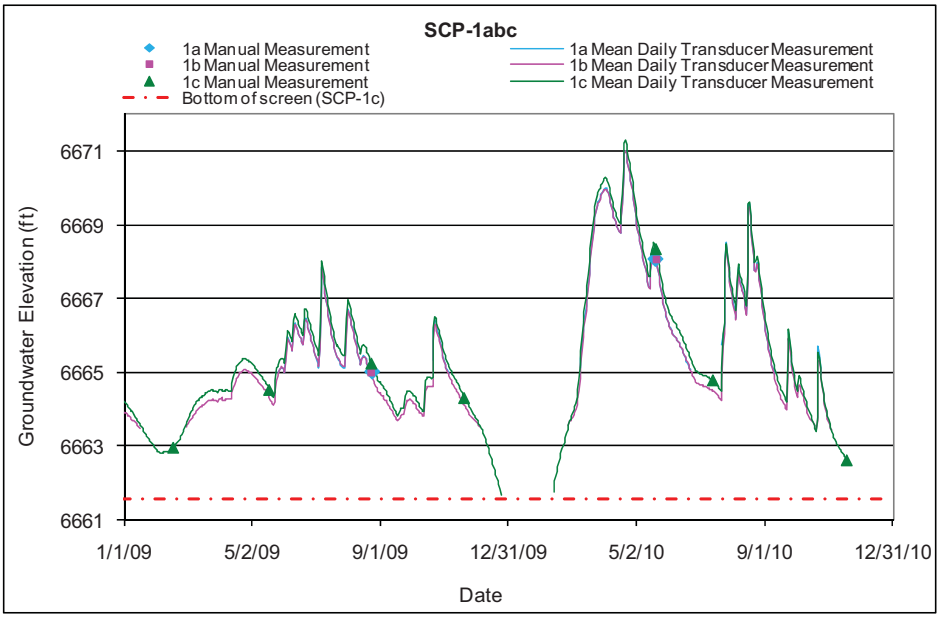
Location: Middle Sandia Canyon, approximately 5 ft west of SCA-4.
Period of Record: October 13, 2006, through November 18, 2010.
Remarks: SCP-1abc is a triple-nested piezometer.

SCP-1abc Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
a	37.80	38.3	6665.44	6664.94	0.5			38.3	6664.9	38.4	0.1	0.004	Alluvial groundwater
b	39.4	39.9	6663.84	6663.34	0.5			39.9	6663.34	40.0	0.1	0.004	Alluvial groundwater
c	41.2	41.7	6662.04	6661.54	0.5			41.7	6661.54	41.8	0.1	0.004	Alluvial groundwater

Note: Brass Cap Elevation: 6703.65 ft; Ground elevation: 6703.24 ft; all depths are from this elevation



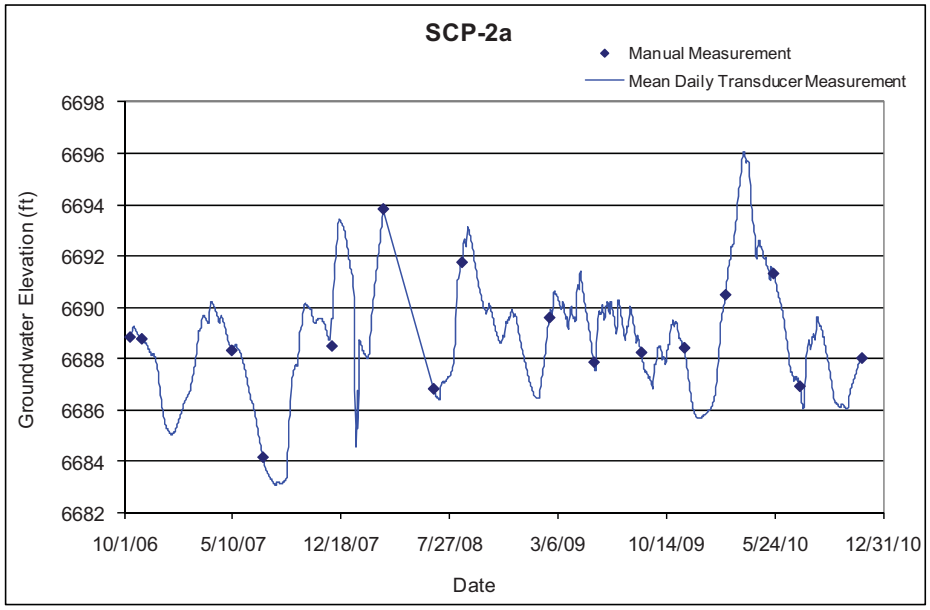


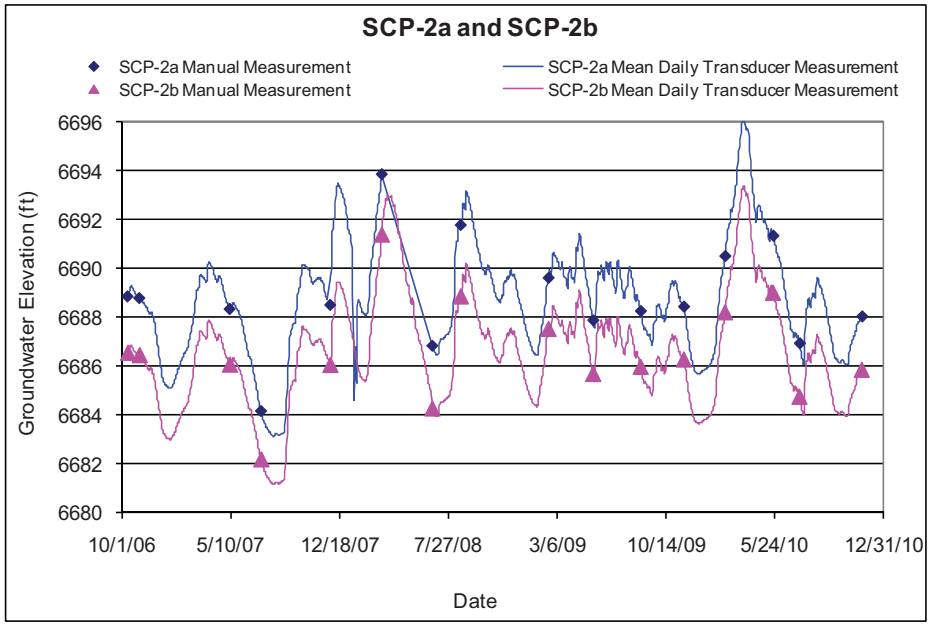
5.96 SCP-2a

Location: Middle Sandia Canyon, approximately 10 ft east of SCA-3 and 5 ft east of SCP-2b.
Period of Record: October 13, 2006, through November 18, 2010.
Remarks: None.

SCP-2a Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
2a	44.5	45.0	6678.1	6677.6	0.5			45.0	6678.0	45.1	0.1	0.02	Alluvial groundwater

Note: Brass Cap Elevation: 6722.95 ft; Ground elevation: 6722.57 ft; all depths are from this elevation



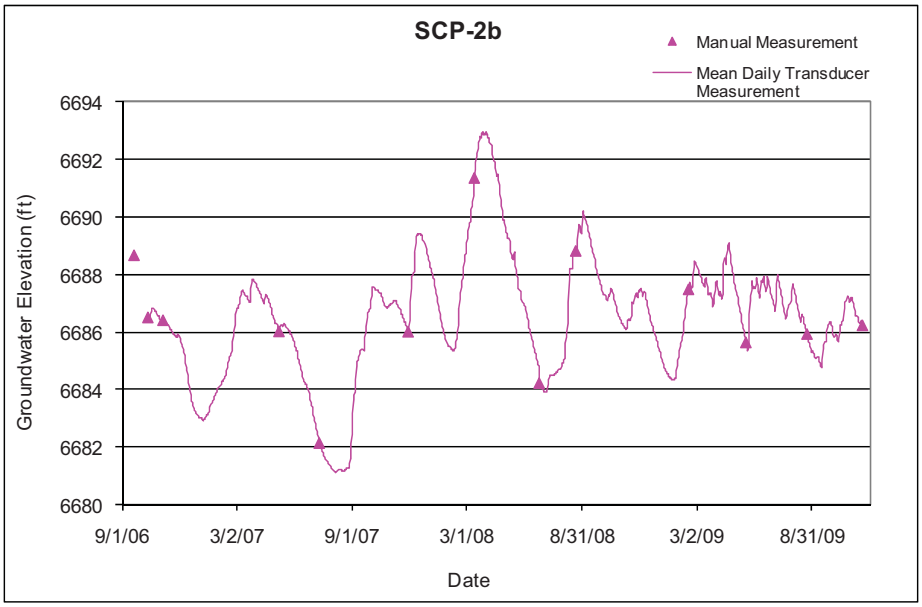


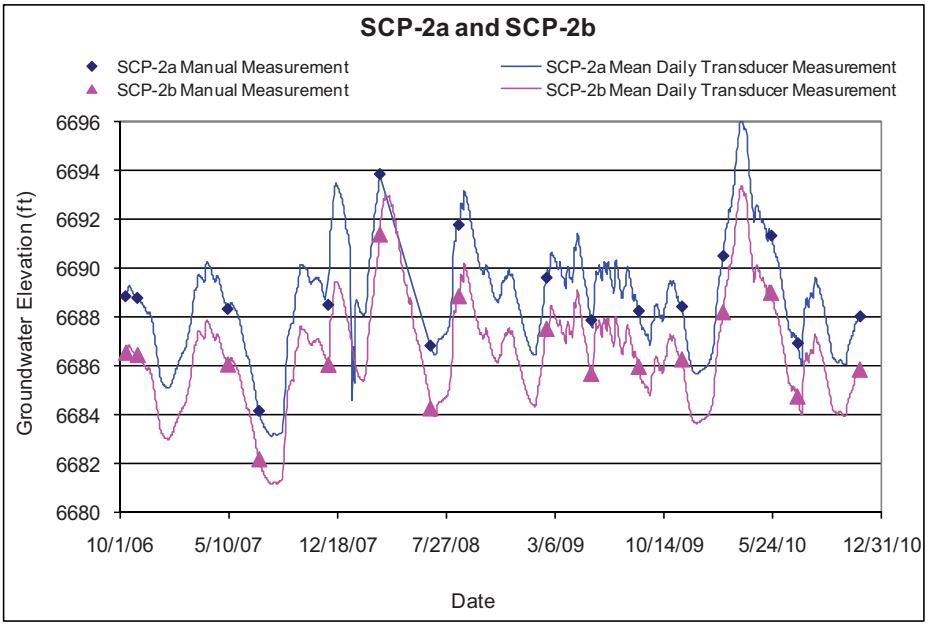
5.97 SCP-2b

Location: Middle Sandia Canyon, approximately 5 ft east of SCA-3 and 5 ft west of SCP-2a.
Period of Record: October 13, 2006, through November 18, 2010.
Remarks: None.

SCP-2b Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
2b	49.5	50.0	6673.1	6672.6	0.5			50.0	6673.1	50.1	0.1	0.02	Alluvial groundwater

Note: Brass Cap Elevation: 6723.11, Ground Elevation: 6722.57 ft; all depths are from this elevation





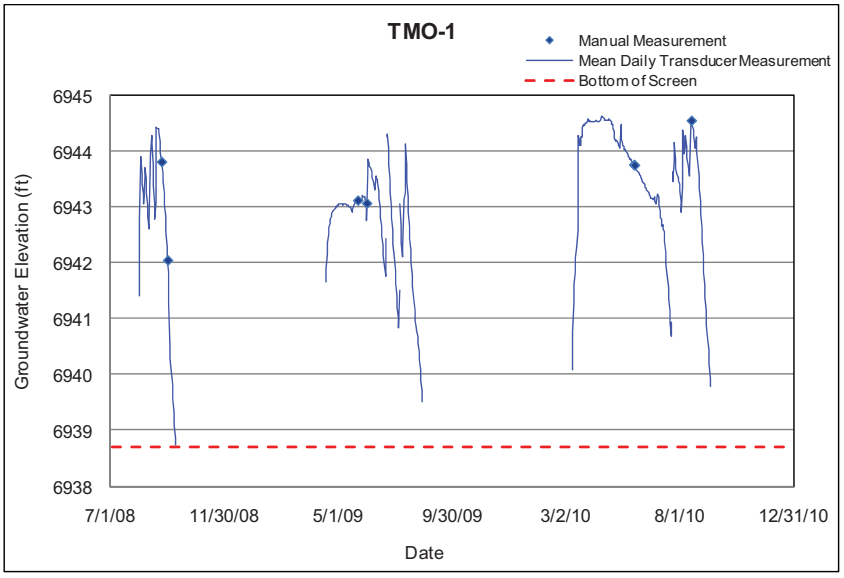
5.98 TMO-1

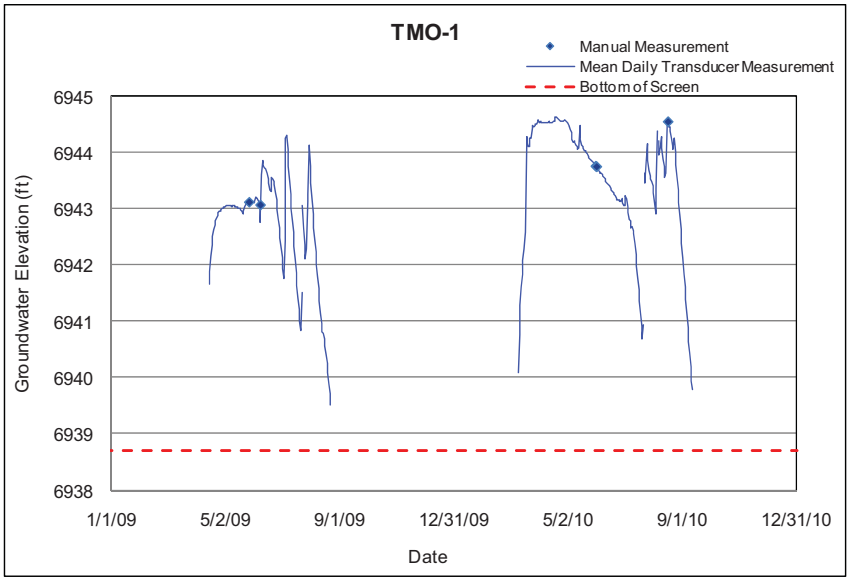
Location: In lower Two-Mile Canyon, just above the confluence with Pajarito Canyon; approximately 500 ft upstream of PCAO-5 and the flood retention dam.
Period of Record: July 17, 2008, through October 7, 2010.
Remarks: Data from July 17, 2008, through August 9, 2008, were invalidated because transducer was hanging above level of water. The transducer was lowered to the bottom of the well on December 12, 2009.

TMO-1 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elevation (ft)	Screen Bottom Elevation (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comments
1	3.5	6.5	6941.7	6938.7	3.0			6.5	6938.7	6.5	0.0	0.0	Hand-augered well

Note: Ground elevation is 6945.20 ft; all depths from this elevation



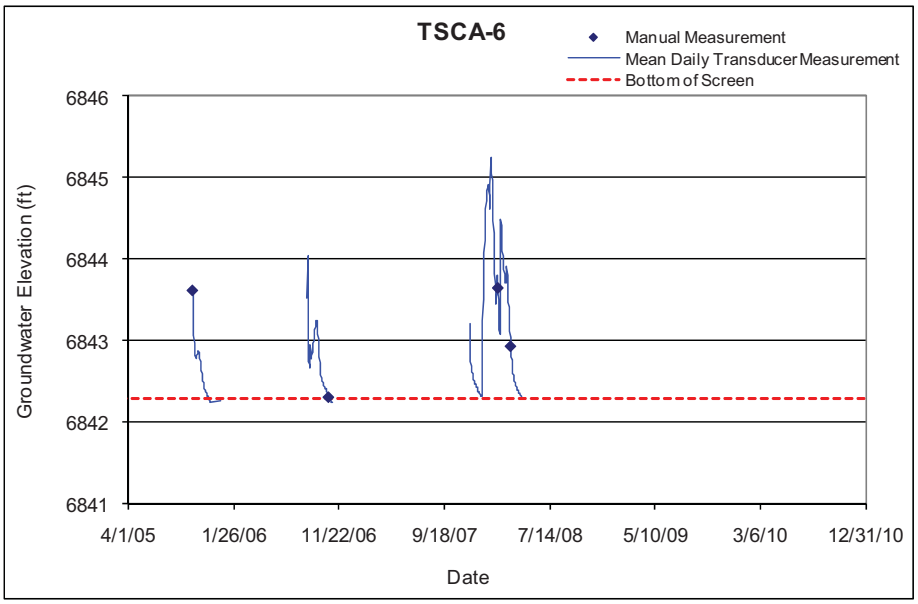


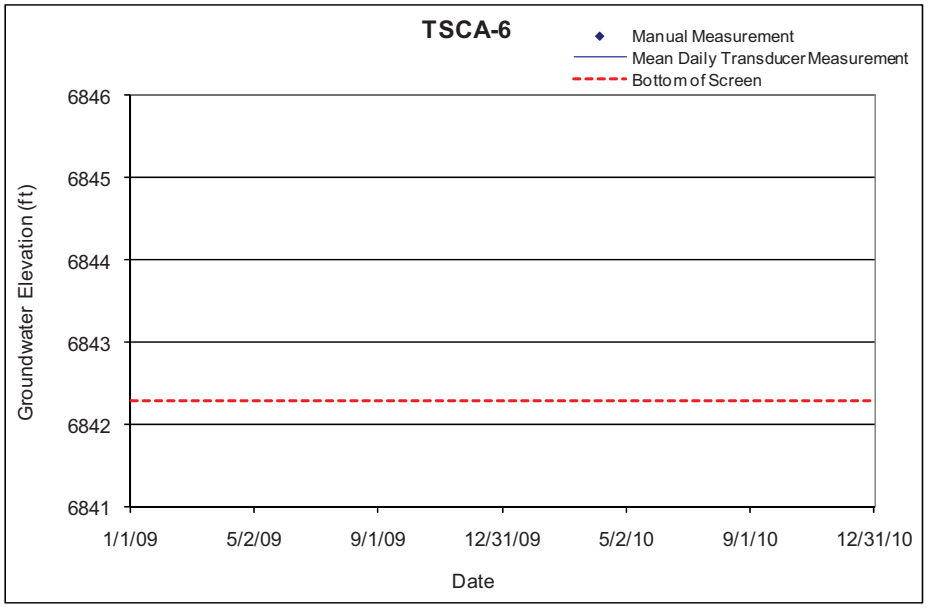
5.99 TSCA-6

Location: Ten Site Canyon, approximately 600 ft west of Mortandad Canyon confluence.
Period of Record: April 18, 2005, through December 2, 2010.
Remarks: This well tends to run dry seasonally, and has been dry since May 2008.

TSCA-6 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	16.20	20.9	6847.0	6842.3	4.7			20.9	6842.3	21.3	0.4	0.2	Alluvial groundwater

Note: Ground elevation is 6863.2 ft; all depths are from this elevation





5.100 WCO-1

Location: Water Canyon, near western border of TA-68.
Period of Record: October 31,1989, through December 20, 2009.
Remarks: This well is usually dry. There are only two records indicating water in well. This well was plugged and abandoned in December 2009. Monitoring has moved to WCO-1r.

WCO-1 Construction Information

Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	24.4	34.4	6592.0	6582.0	10.0			34.4	6582.0	34.4	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6616.41 ft; all depths are from this elevation

WCO-1 Manual Water Levels

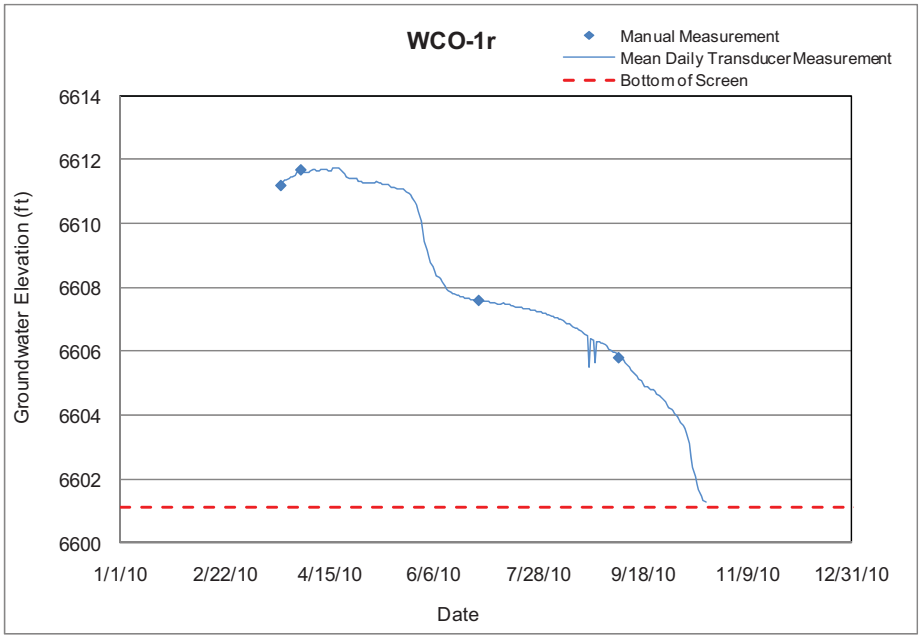
Date	Groundwater Elevation (ft)	Date	Groundwater Elevation (ft)
10/31/1989	Dry	6/19/2003	Dry
11/1/1989	Dry	9/14/2005	Dry
8/24/1990	Dry	12/22/2005	Dry
6/23/1997	6582.75	3/13/2006	Dry
10/13/1997	Dry	6/23/2006	Dry
3/25/1998	Dry	9/13/2006	Dry
5/29/1998	6582.75	12/15/2006	Dry
7/28/1998	Dry	1/24/2007	Dry
3/3/1999	Dry	3/15/2007	Dry
6/23/1999	Dry	5/24/2007	Dry
8/30/1999	Dry	6/6/2007	Dry
11/15/1999	Dry	9/5/2007	Dry
3/26/2000	Dry	10/17/2007	Dry
5/16/2000	Dry	1/16/2008	Dry
8/30/2000	Dry	4/8/2008	Dry
10/8/2000	Dry	4/25/2008	Dry
7/2/2001	Dry	7/18/2008	Dry
8/22/2001	Dry	10/7/2008	Dry
10/18/2001	Dry	2/6/2009	Dry
4/19/2002	Dry	3/23/2009	Dry
8/19/2002	Dry	7/2/2009	Dry
11/13/2002	Dry	10/7/2009	Dry
2/18/2003	Dry	12/20/2009	Dry

5.101 WCO-1r

Location: Water Canyon, near western border of TA-68, approximately 30 ft northwest of WCO-1.
Period of Record: March 22, 2010, through December 7, 2010.
Remarks: New well drilled to replace WCO-1.

WCO-1r Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	6.0	16.00	6611.1	6601.1	10.0			16.0	6601.1	16.4	0.4		Alluvial groundwater

Note: Ground elevation is 6617.12 ft; all measurements are from this elevation

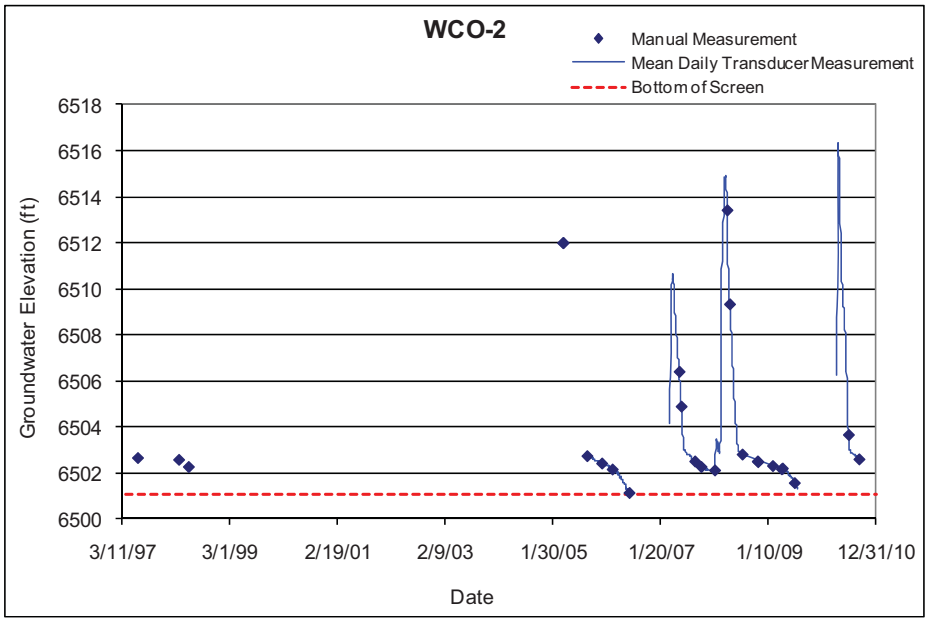


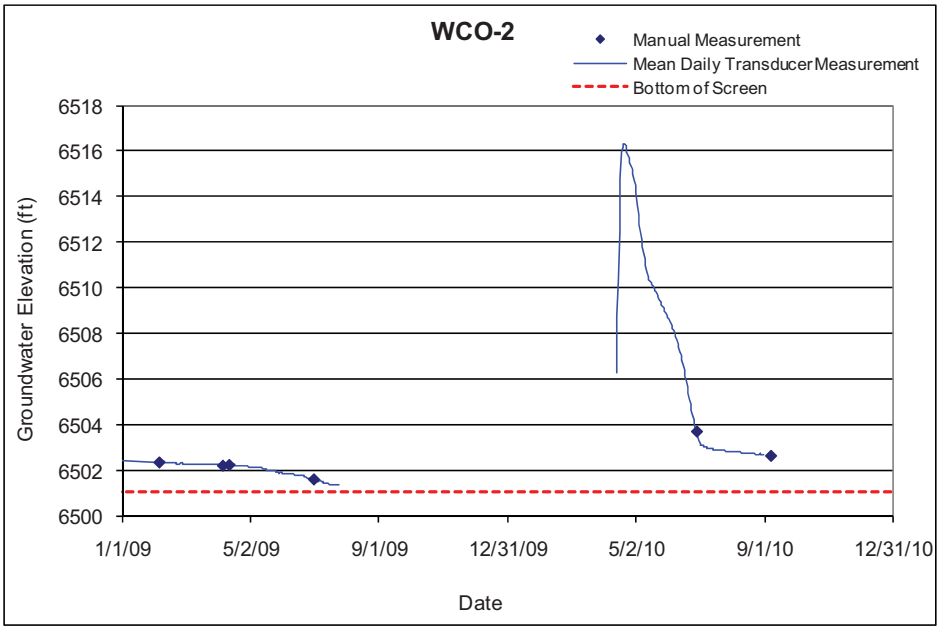
5.102 WCO-2

Location: Water Canyon, about 0.9 mi west of gate 9 on SR-4.
Period of Record: October 26, 1989, through December 10, 2010.
Remarks: The transducer malfunctioned on August 23, 2008, and was fixed February 6, 2009. The replacement transducer and/or cable malfunctioned in September 2010 and was replaced December 10, 2010, with a newer transducer and cable.

WCO-2 Construction Information														
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	13.5	23.5	6511.1	6501.1	10.0			23.5	6501.1	23.5	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6524.57 ft; all measurements are from this elevation





5.103 WCO-3

Location: Water Canyon, approximately 0.1 mi west of gate 9 on SR-4.
Period of Record: October 25, 1989, through December 20, 2009.
Remarks: Well is typically dry. A transducer was installed January 16, 2008, and never recorded any water in the well. This well was plugged and abandoned in December 2009. Monitoring has moved to WCO-3r.

WCO-3 Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Depth to Top of Sump (ft)	Top of Sump Elevation (ft)	Depth to Sump Bottom (ft)	Sump Length (ft)	Sump Volume (L)	Comment
1	7.4	12.4	6429.0	6424.0	5.0			12.4	6424.0	12.4	0.0	0.0	Alluvial groundwater

Note: Ground elevation is 6436.43 ft; all depths are from this elevation

WCO-3 Manual Water Levels			
Date	Water level (ft)	Date	Water level (ft)
10/25/1989	Dry	6/19/2003	Dry
8/24/1990	Dry	9/14/2004	Dry
6/23/1997	6424.6	12/22/2005	Dry
3/25/1998	Dry	3/13/2006	Dry
5/29/1998	Dry	6/23/2006	Dry
7/28/1998	Dry	9/13/2006	Dry
3/3/1999	Dry	12/15/2006	Dry
6/23/1999	Dry	1/24/2007	Dry
8/30/1999	Dry	3/15/2007	Dry
11/15/1999	Dry	5/24/2007	Dry
3/26/2000	Dry	6/6/2007	Dry
5/16/2000	Dry	9/5/2007	Dry
8/30/2000	Dry	10/17/2007	Dry
10/8/2000	Dry	1/16/2008	Dry
7/2/2001	Dry	4/8/2008	Dry
8/22/2001	Dry	7/18/2008	Dry
10/18/2001	Dry	10/7/2008	Dry
4/19/2002	Dry	2/6/2009	Dry
8/19/2002	Dry	3/23/2009	Dry
11/13/2002	Dry	7/2/2009	Dry
2/18/2003	Dry	10/7/2009	Dry
		12/20/2009	Dry

5.104 WCO-3r

Location: Water Canyon, approximately 0.1 mi west of gate 9 on SR-4 and 150 ft south of WCO-1.
Period of Record: March 22, 2010, through December 7, 2010.
Remarks: New well installed to replace WCO-3. Water level has thus far not risen above the sump.

WCO-3r Construction Information													
Zone	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elevation (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Comment
1	4.7	9.7	6432.5	6427.5	5.0			9.7	6427.5	10.1	0.4	0.2	Alluvial groundwater
Note: Ground elevation is 6437.17 ft; all measurements are from this elevation													

WCO-3r Manual Measurements		
Date	Groundwater Elevation (ft)	Comments
3/22/2010	6427.17	Water in Sump
4/1/2010	6427.28	Water in Sump
6/29/2010	6427.25	Water in Sump
10/12/2010	6427.30	Water in Sump
12/7/2010	6427.34	Water in Sump

6.0 Groundwater Level Data from Water Supply Wells

Table 6-1 lists the LAC water supply wells; all supply wells were monitored for groundwater levels in 2010 after transducers were installed at G-1A and O-4. The table provides the well name, date of completion, well depth, surveyed location coordinates, ground surface elevation, and the screen top and bottom depths for each well. See Figure 3-1 for the locations of the wells.

The LANL GWLM Project integrated the water supply wells in the monitoring project beginning in 2007 with the cooperation of LAC Utility personnel. Recently obtained groundwater level data for the supply wells are provided in the following sections. Historical groundwater level data for the supply wells were summarized by Koch and Rogers (2003) and other preceding Water Supply Reports for Los Alamos.

Table 6-1. General Information for Los Alamos County Water Supply Wells

Well Name	Date Completed	Completed Depth (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Screen Top Depth (ft)	Screen Bottom Depth (ft)
G-1A	12/15/1954	1519	1655240.9	1784353.3	6014	272	1513
G-2A	3/21/1998	2000	1651973.8	1786166.3	6138	565	1980
G-3	8/25/1999	1800	1651676.4	1786218.3	6139	441	1100
G-3A	5/9/1998	2000	1649661.5	1786585.3	6212	590	1980
G-4A	4/1/1998	2000	1647318.2	1787112.9	6299	655	1980
G-5A	5/20/1998	2000	1644877.2	1789636.0	6414	765	1980
O-1	8/1/1990	2497	1649396.3	1772232.1	6396	1017	2477
O-4	3/1/1990	2617	1637337.4	1772995.1	6627	1115	2596
PM-1	2/1/1965	2499	1647734.3	1768112.1	6520	945	2479
PM-2	7/15/1965	2300	1636697.5	1760406.4	6715	1004	2280
PM-3	11/1/1966	2552	1642590.0	1769530.0	6610	956	2532
PM-4	8/15/1981	2874	1635623.0	1764740.0	6920	1260	2854
PM-5	9/1/1982	3092	1632110.0	1767790.0	7095	1440	3072

All LAC water supply wells are powered by electric motors except for PM-4, which has a natural-gas-powered motor. The electric-powered wells are typically operated at night and on weekends when electricity rates are lower. Thus these wells usually cycle on and off daily, in contrast to PM-4, which usually runs continuously when in use, which is usually just during the summer months when water demand is highest. Thus, due to the operational characteristics of the electric-powered wells, the data displayed in the following sections for these wells are the maximum daily water level, or the “non-pumping” water level, and the minimum daily or “pumping” water level. The difference between the non-pumping and the pumping water level is the drawdown for each well. The data shown for the wells that aren’t operated cyclically, which are PM-4 and O-1 (which hasn’t been used in recent years), are mean daily water levels.

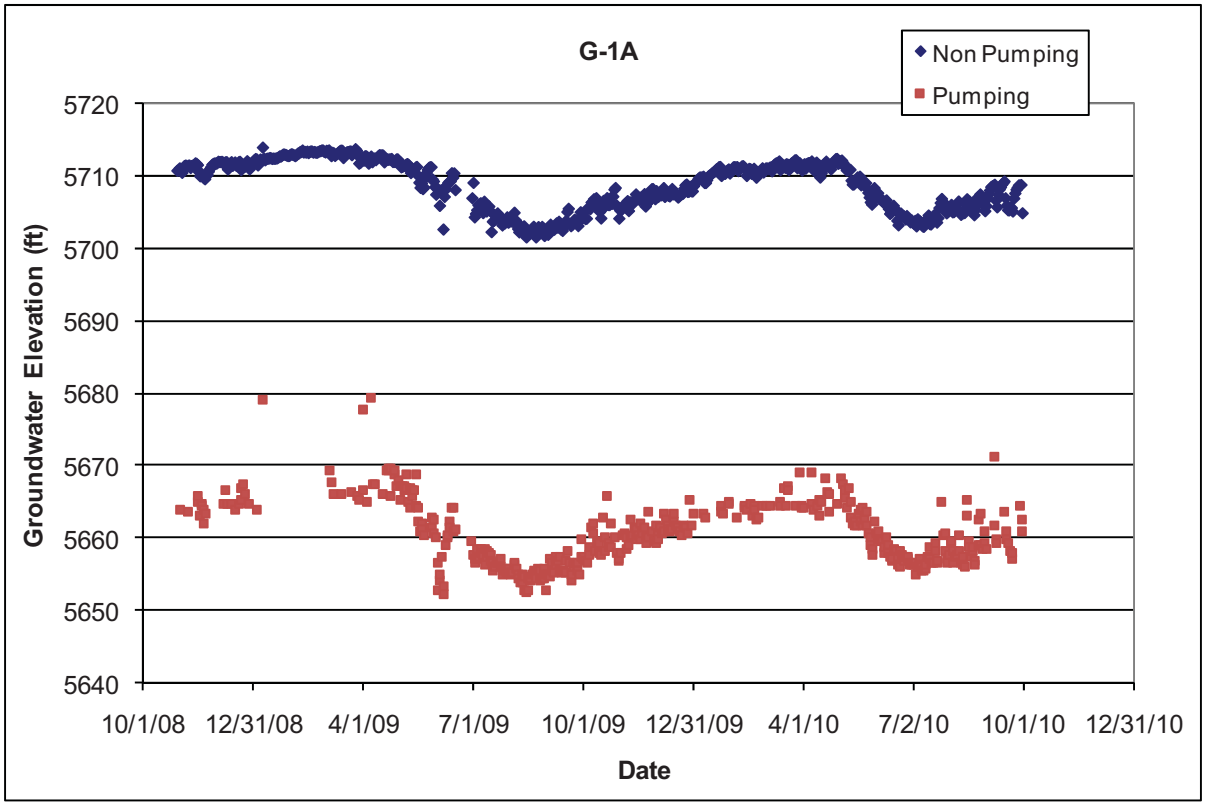
6.1 G-1A

Location: G-1A is located in Guaje Canyon and is the easternmost well in the Guaje well field.
Completion Type: Single completion in the Santa Fe Group.
Period of Record: Well completed in 1954, periodic manual measurements (Koch and Rogers 2003). Transducer installed in bubbler pressure line October 29, 2008; data through June 2010.
Remarks: G-1A was constructed without gage lines so manual measurements are not possible while the pump is installed. The transducer is connected to a bubble pressure line installed to the depth of the top of the pump. Drawdown during pumping is about 45 ft.

G-1A Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	272	1513	5742	4501	1241	496	5518	1513	4501	1519	6	93	RT	Tsf

Note: Ground Elevation: 6014.0 ft; all measurements from this elevation



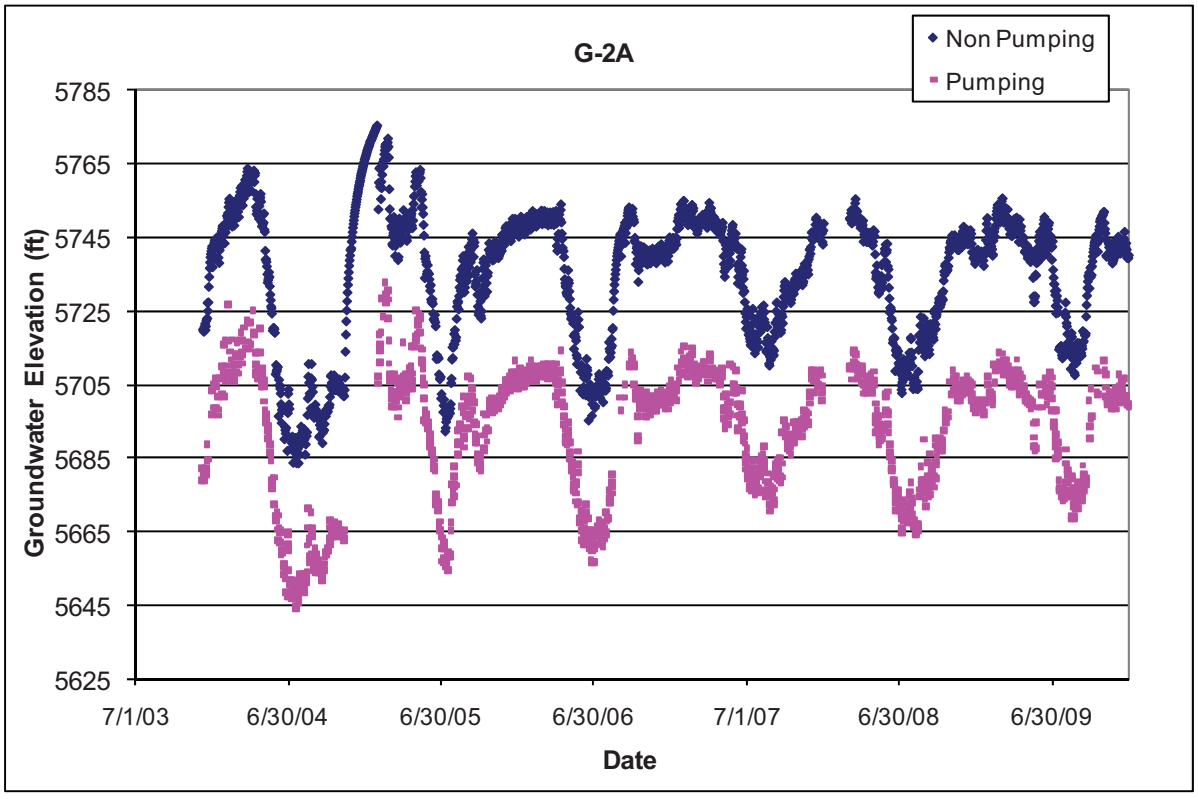
6.2 G-2A

Location: G-2A is located in Guaje Canyon about 300 ft east of monitoring well G-3.
Completion Type: Single completion in the Santa Fe Group.
Period of Record: Well completed in 1998, transducer installed December 2003; data through 2010.
Remarks: The pumping and non-pumping water levels overlap depending on pumping stress to the aquifer. The drawdown is about 40 ft.

G-2A Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	565	1980	5573	4158	1415	540	5598	1980	4158	2000	20	444.8	RT	Tsf

Note: Ground Elevation: 6138.0 ft; all depths are from this elevation



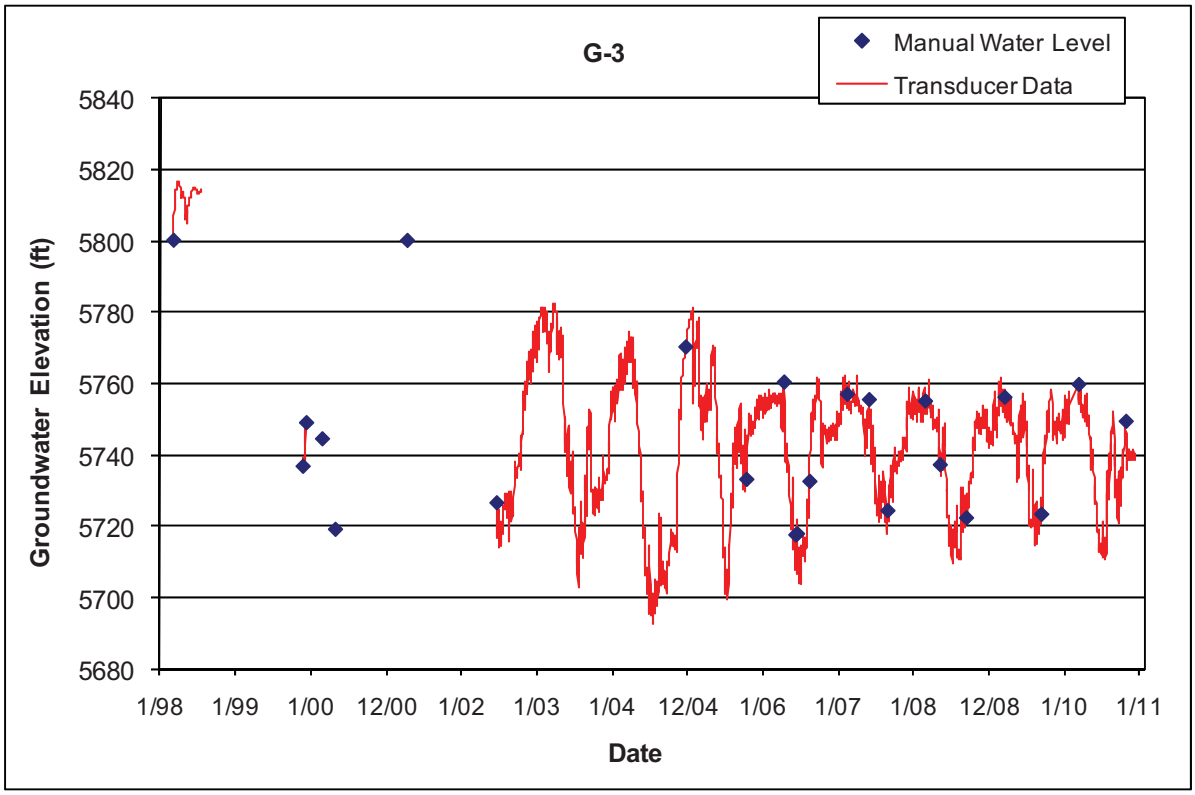
6.3 G-3

Location: G-3 is located in Guaje Canyon about 300 ft west of supply well G-2A.
Completion Type: Single completion in the Santa Fe Group.
Period of Record: Well originally completed as a supply well in July 1951; plugged back to 1103 ft and converted to a monitoring well in 1998, transducer installed June 2002; data through 2010.
Remarks: G-3 responds primarily to pumping at supply well G-2A; daily water level fluctuation is about 8 ft. The aquifer in the Guaje well field fluctuates seasonally 40 to 70 ft depending on pumping stresses.

G-3 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	441	1100	5698	5039	659	None	None	1100	5039	1103	3	66.7	RT	Tsf

Note: Ground Elevation: 6139.0 ft; all depths are from this elevation



Note: mean daily water level values displayed

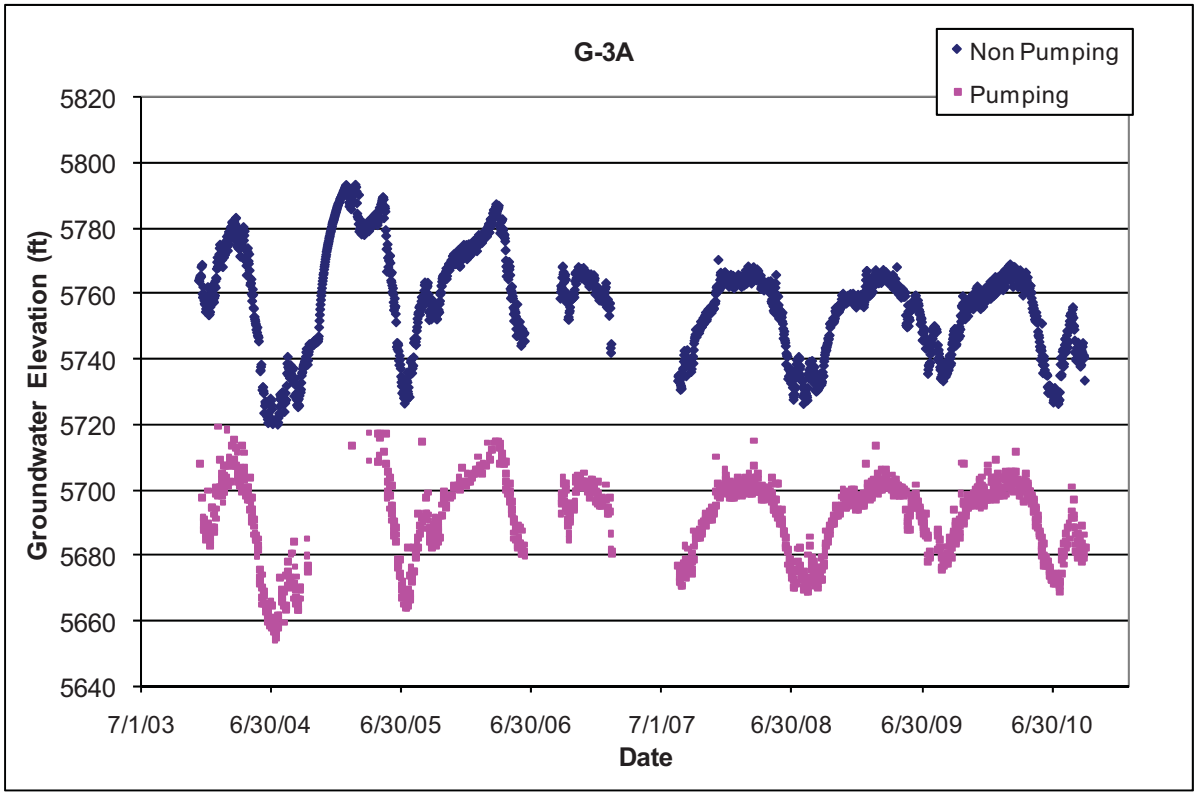
6.4 G-3A

Location: G-3A is located in Guaje Canyon about 1.5 mi west of monitoring well G-3.
Completion Type: Single completion in the Santa Fe Group.
Period of Record: Well completed as a supply well in May 1998; transducer installed December 2003; intermittent data through June 2010.
Remarks: Drawdown is 60 to 65 ft.

G-3A Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Dept (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	590	1980	5622	4232	1390	560	5652	1980	4232	2000	20	853.7	RT	Tsf

Note: Ground Elevation: 6212.0 ft; all measurements are from this elevation



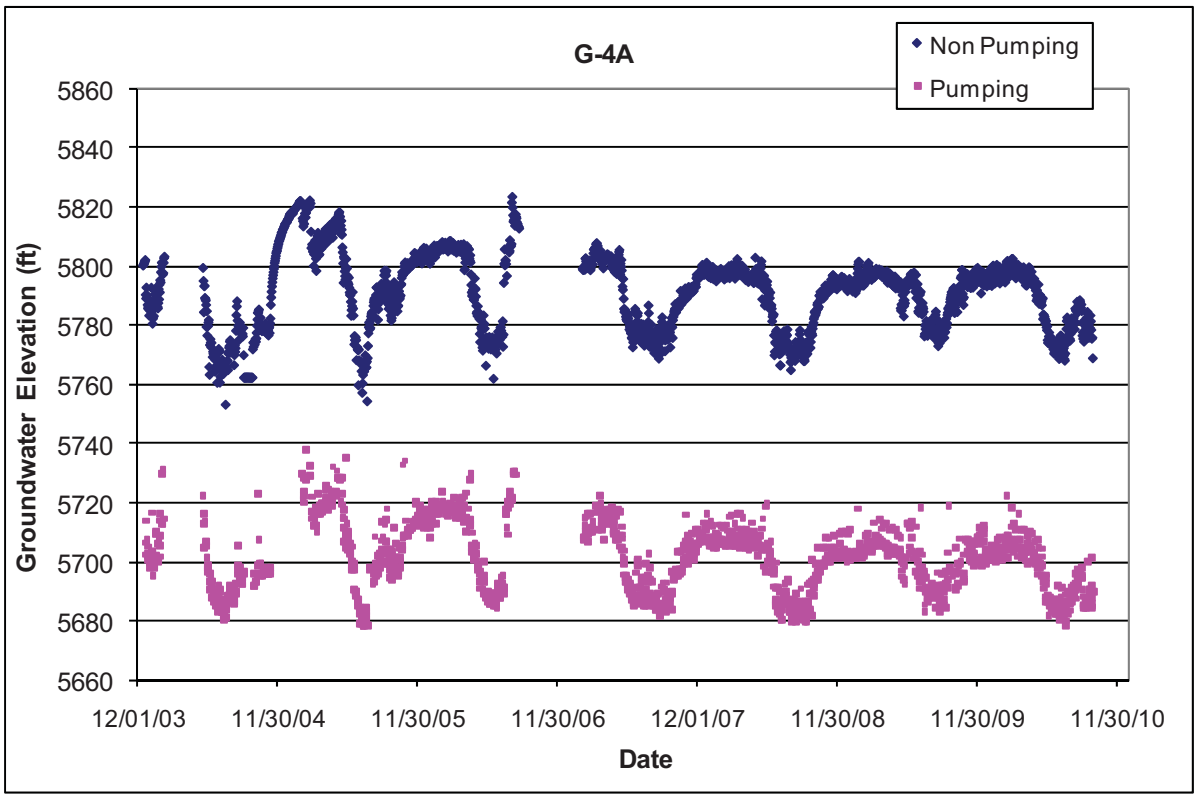
6.5 G-4A

Location: G-4A is located in lower Rendija Canyon near the confluence with Guaje Canyon and about 0.5 mi west of supply well G-3A.
Completion Type: Single completion in the Santa Fe Group.
Period of Record: Well completed as a supply well in April 1998; transducer installed December 2003; intermittent data through 2010.
Remarks: Drawdown is 80 to 85 ft.

G-4A Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	655	1980	5644	4319	1325	630	5669	1980	4319	2000	20.0	853.7	RT	Tsf

Note: Ground Elevation: 6299.0 ft; all measurements are from this elevation



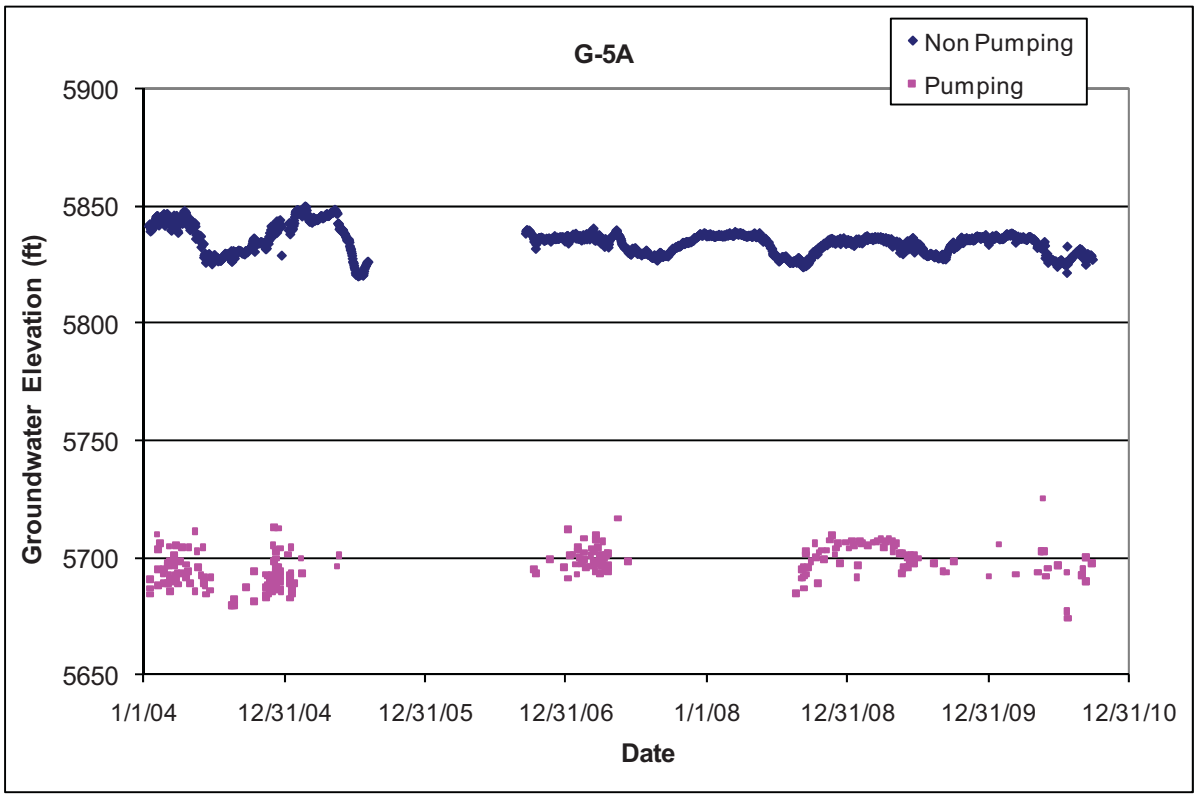
6.6 G-5A

Location: G-5A is located in Guaje Canyon upstream of Rendija Canyon and about 1.9 mi northwest of supply well G-4A.
Completion Type: Single completion in the Santa Fe Group.
Period of Record: Well completed as a supply well in May 1998; transducer installed January 2004; data through 2010.
Remarks: G-5A is not used on a regular basis. Drawdown is 140 to 150 ft.

G-5A Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code	Comment
1	765	1980	5649	4434	1215	740	5674	1980	4434	2000	20	853.7	RT	Tsf	Supply Well

Note: Ground Elevation: 6414.0 ft; all measurements are from this elevation



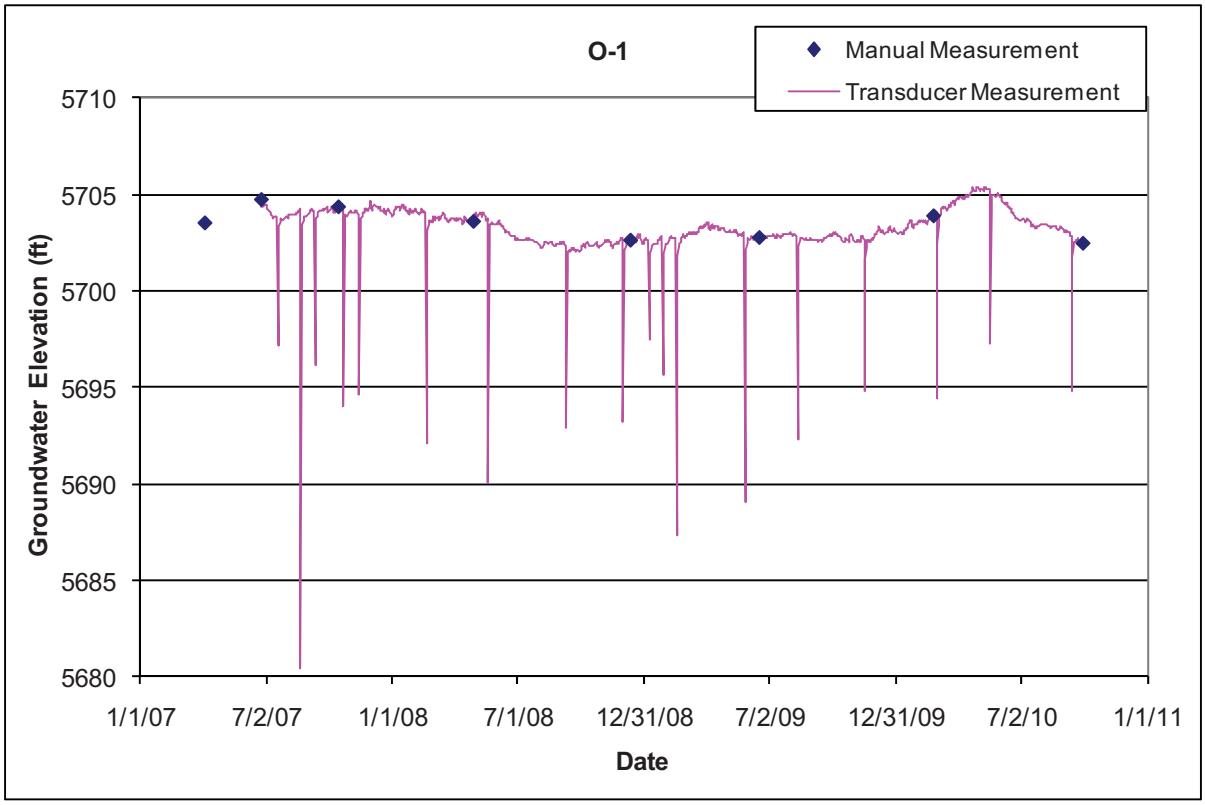
6.7 O-1

Location: O-1 is located in lower Pueblo Canyon about 0.5 mi downstream of monitoring well R-5.
Completion Type: Single completion in the Santa Fe Group.
Period of Record: Well completed as a supply well in August 1990; transducer installed June 2007; data through June 2010.
Remarks: O-1 has not been used on a regular basis except for periodic groundwater sampling. Drawdown is about 100 ft. O-1 responds to pumping of supply well PM-1.

O-1 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1017	2477	5379	3919	1460	877	5519	2477	2477	2497	20	790.8	RT	Tsf

Note: Ground Elevation: 6396 ft; all measurements are from this elevation

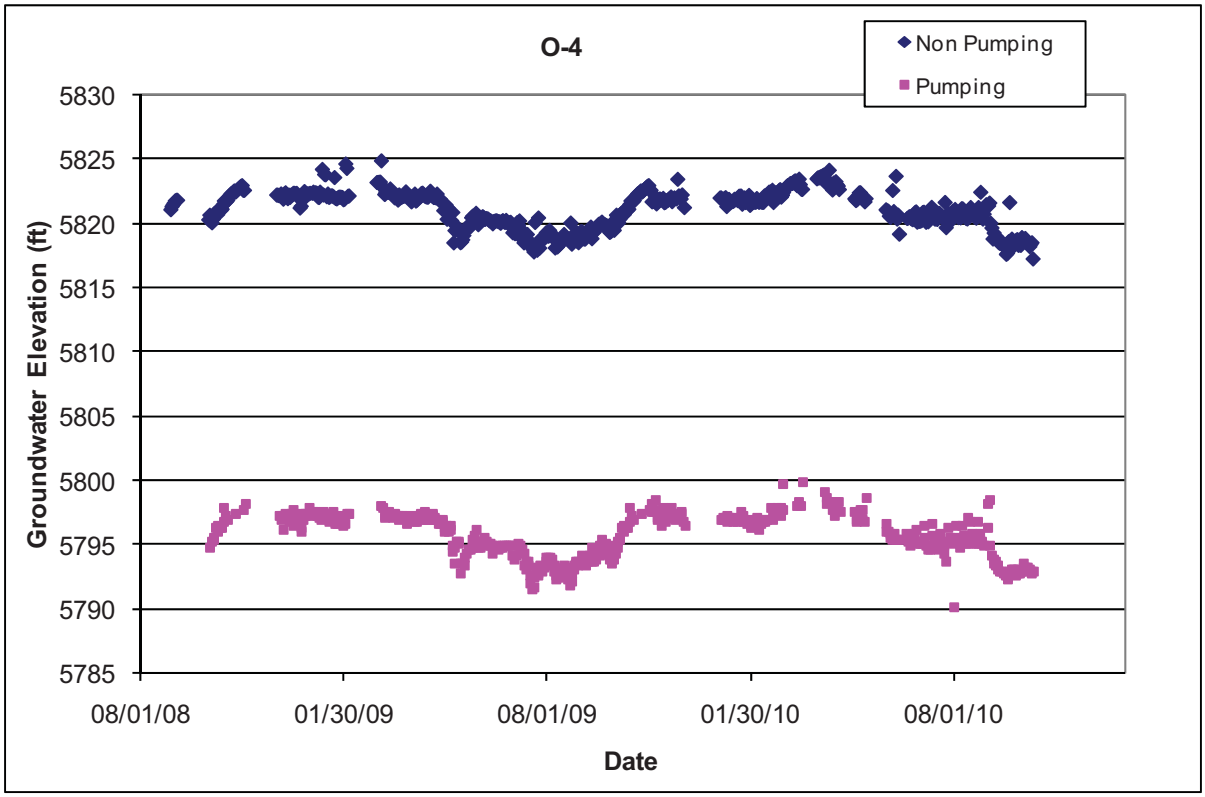


Note: Hydrograph shows mean daily values

6.8 O-4

Location: O-4 is located in Los Alamos Canyon above the confluence with DP Canyon and about 1500 ft southeast of monitoring well R-6.
Completion Type: Single completion in the Santa Fe Group.
Period of Record: Well completed as a supply well in March 1990; transducer installed August 2008; data through 2010.
Remarks: O-4 drawdown is about 25 ft.

O-4 Construction Information														
Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1115	2575	5512	4052	1460	928	5699	2575	4052	2575	0	0	RT	Tsf
Note: Ground Elevation: 6627 ft; all Measurements are from this elevation														



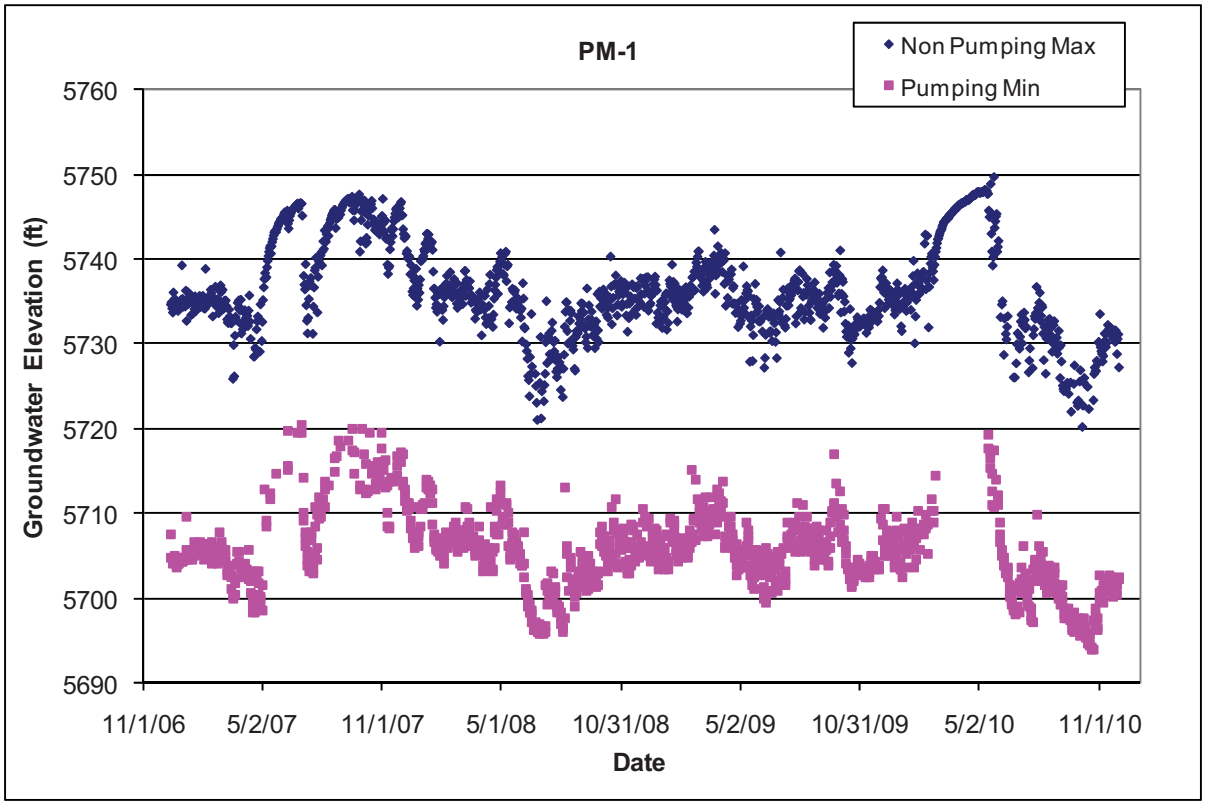
6.9 PM-1

Location: PM-1 is located in lower Sandia Canyon near the eastern Laboratory boundary and about 360 ft northeast of monitoring well R-12.
Completion Type: Single completion in the Santa Fe Group.
Period of Record: Well completed as a supply well in February 1965; transducer installed December 2006; data through 2010.
Remarks: Drawdown is about 30 ft.

PM-1 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	945	2479	5575	4041	1534	877	5643	2479	2479	2499	20.0	790.8	RT	Tsf

Note: Ground Elevation: 6520 ft; all measurements are from this elevation



6.10 PM-2

Location: PM-2 is located in Pajarito Canyon about 0.25 mi west of monitoring well R-20 and about 220 ft southwest of recently installed monitoring well R-40.

Completion Type: Single completion in the Puye Formation and Santa Fe Group.

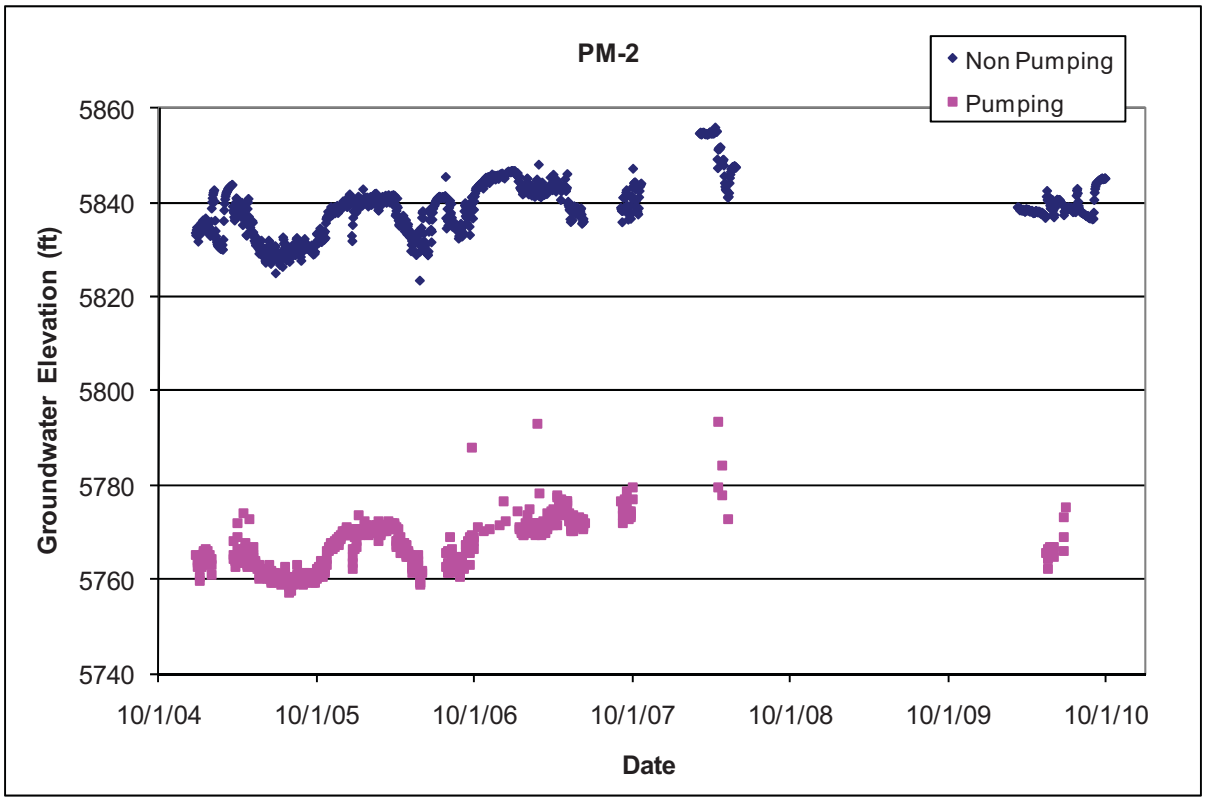
Period of Record: Well completed as a supply well in July 1965; transducer installed December 2004; data to October 23, 2007. The transducer was removed in October 2007 during pump removal and well rehabilitation. Data during April and May 2008 during pump testing. Transducer removed May 30, 2008, for well repairs, reinstalled March 8, 2010; data through 2010.

Remarks: Drawdown is about 70 ft. PM-2 responds to pumping at PM-4 (McLin 2006). PM-2 was not operated for most of 2008, 2009, and 2010 because of well maintenance and repairs.

PM-2 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Vol (L)	Hydro Zone Code	Geo Unit Code
1	1004	2280	5711	4435	1276	980	5735	2280	4435	2300	20.0	790.8	RT	Tp

Note: Ground Elevation: 6715 ft; all measurements are from this elevation



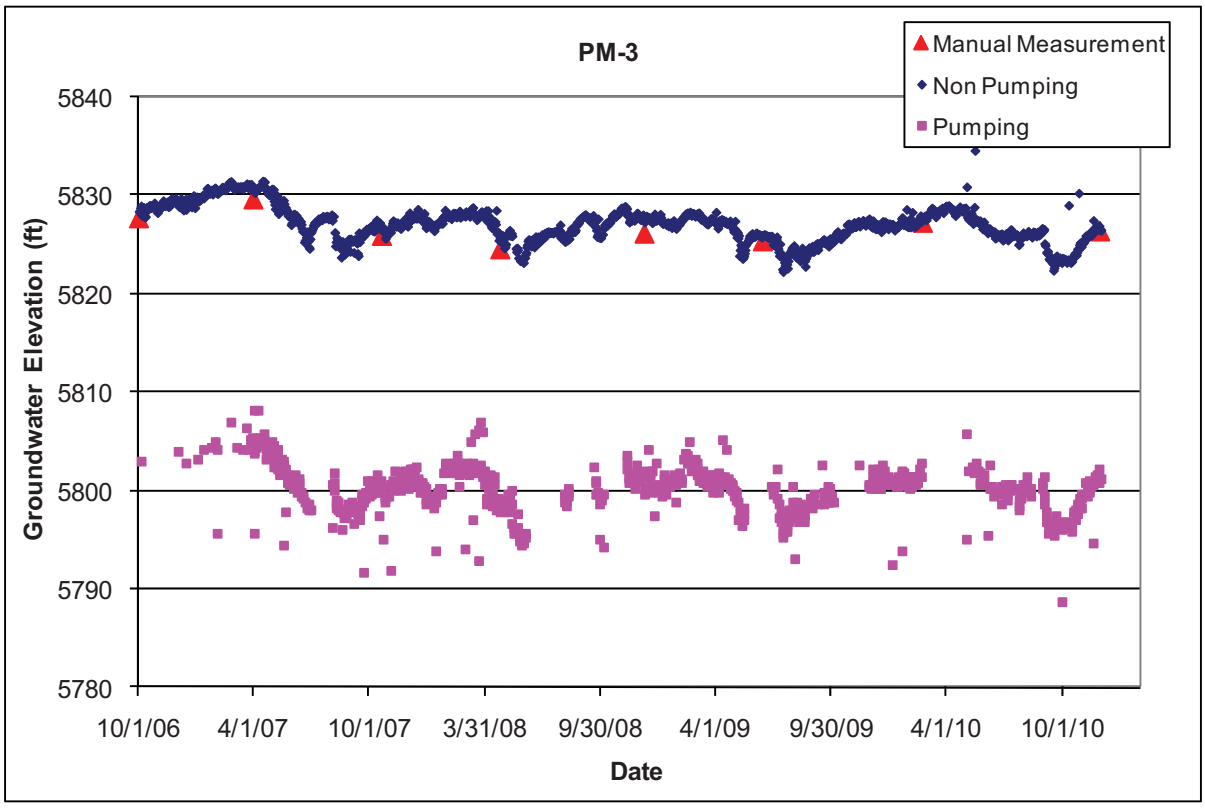
6.11 PM-3

Location: PM-3 is located in Sandia Canyon about 1 mi west of PM-1 and about 330 ft northeast of monitoring well R-35a.
Completion Type: Single completion in Santa Fe Group.
Period of Record: Well completed as a supply well in November 1966; transducer installed October 2006; data through 2010.
Remarks: Drawdown is about 27 ft. PM-3 responds to pumping at O-4.

PM-3 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	956	2532	5654	4078	1576	830	5780	2532	4078	2552	20	605.4	RT	Tsf

Note: Ground Elevation: 6610 ft; all measurements are from this elevation



6.12 PM-4

Location: PM-4 is located on Mesita del Buey about midway between supply wells PM-2 and PM-5. The nearest monitoring well is R-52 about 0.45 mi to the southeast. R-15 in Mortandad Canyon is about 0.67 mi to the north.

Completion Type: Single completion in the Puye Formation and Santa Fe Group.

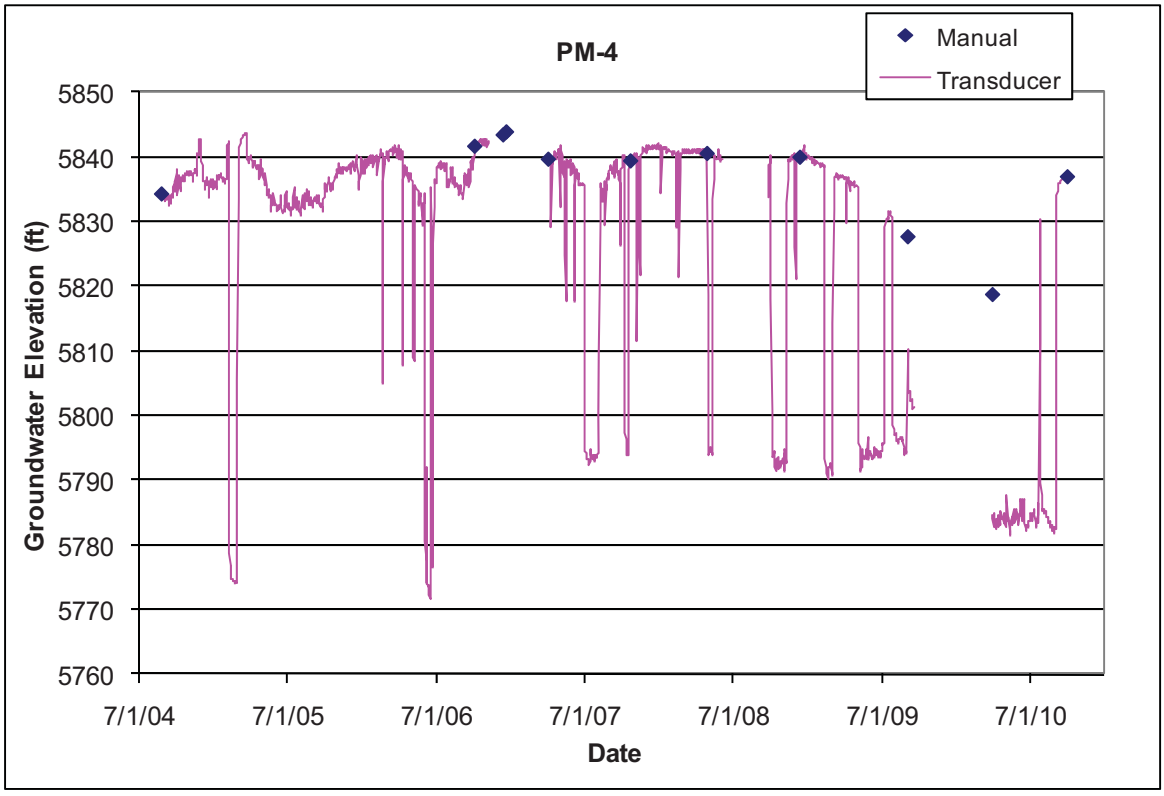
Period of Record: Well completed as a supply well in August 1981; transducer installed August 2004. The transducer failed in November 2006 and was replaced in April 2007, failed again June 2008, replaced September 2008, and failed again September 2009; replaced March 2010; data through 2010.

Remarks: Well is powered by a natural gas motor and when used is operated continuously. Drawdown in 2008 was about 48 ft and in 2010 about 54 ft. PM-4 responds to pumping at PM-2.

PM-4 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1260	2854	5660	4066	1594	1210	5710	2854	4066	2874	20	790.8	RT	Tp

Note: Ground Elevation: 6920 ft; all measurements are from this elevation



Note: mean daily water level values shown

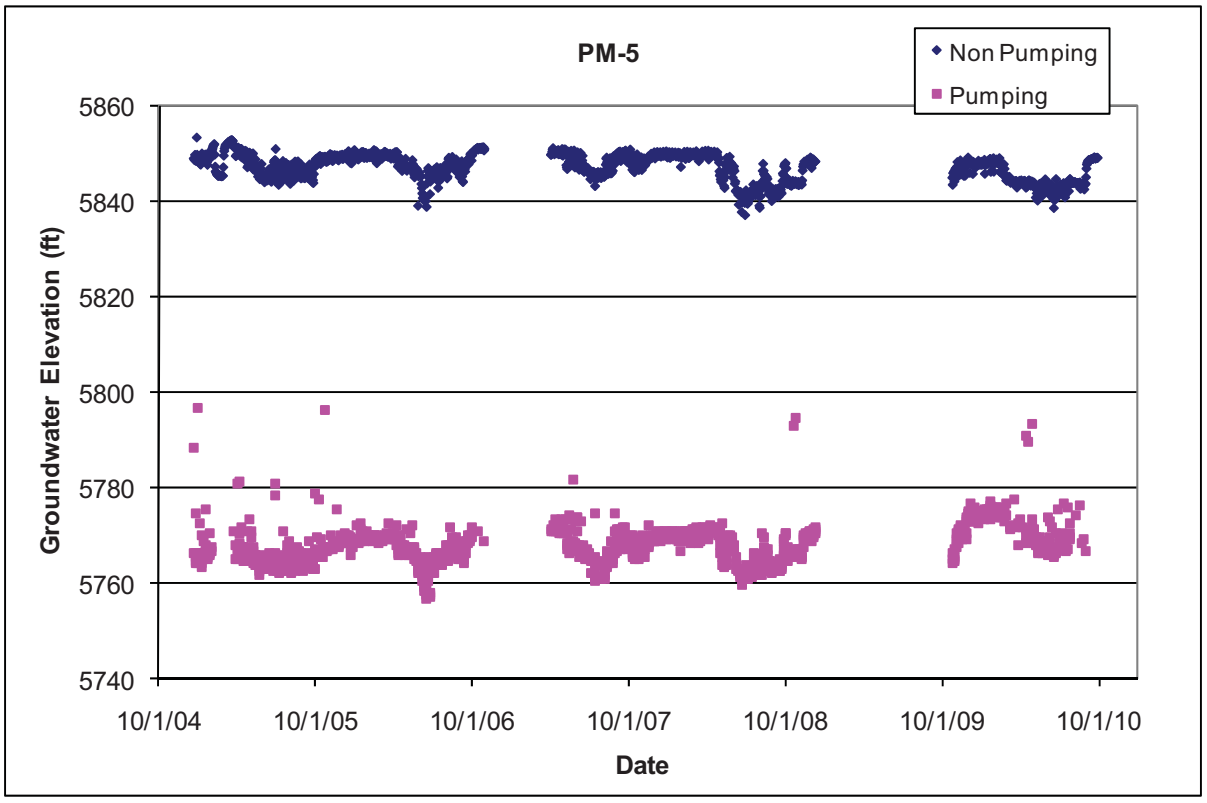
6.13 PM-5

Location: PM-5 is located on a mesa south of Ten Site and Mortandad canyons. The nearest monitoring well is R-33 in Ten Site Canyon about 1500 ft to the northeast.
Completion Type: Single completion in the Puye Formation and Santa Fe Group.
Period of Record: Well completed as a supply well in September 1982; transducer installed December 2004. The transducer failed in October 2006 and was replaced in April 2007; transducer failed again December 2008 and was replaced October 2009; data through 2010.
Remarks: PM-5 responds to pumping PM-4. Drawdown is about 80 ft.

PM-5 Construction Information

Screen	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Screen Top Elev (ft)	Screen Bottom Elev (ft)	Screen Length (ft)	Pump Intake Depth (ft)	Pump Intake Elev (ft)	Top of Sump Depth (ft)	Top of Sump Elev (ft)	Sump Bottom Depth (ft)	Sump Length (ft)	Sump Volume (L)	Hydro Zone Code	Geo Unit Code
1	1440	3072	5655	4023	1632	1384	5711	3072	3072	3092	20	790.8	RT	Tp

Note: Ground Elevation: 7095 ft; all measurements are from this elevation



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Appendix A. Geologic Unit Codes

Table A-1. Geologic Unit Codes

Geologic Unit Code	Geologic Unit Description
P	Polvadera Group
Qal	Quaternary alluvium
Qb	Bandelier Tuff, undivided
Qbo	Otowi Member of the Bandelier Tuff, undivided
Qbof	Otowi Member of the Bandelier Tuff, ash flows
Qbog	Otowi Member of the Bandelier Tuff, Guaje Pumice Bed
Qbt	Tshirege Member of the Bandelier Tuff, undivided
Qbt1	Tshirege Member of the Bandelier Tuff, Unit 1, undivided
Qbt1g	Tshirege Member of the Bandelier Tuff, Unit 1, glassy
Qbt1v	Tshirege Member of the Bandelier Tuff, Unit 1, vapor phase
Qbt2	Tshirege Member of the Bandelier Tuff, Unit 2
Qbt3	Tshirege Member of the Bandelier Tuff, Unit 3
Qbt3nw	Tshirege Member of the Bandelier Tuff, Unit 3, nonwelded
Qbt3t	Tshirege Member of the Bandelier Tuff, Unit 3, transitional
Qbt4	Tshierge Member of the Bandelier Tuff , Unit 4
Qbt5	Tshierge Member of the Bandelier Tuff , Unit 5
Qbtt	Tshierge Member of the Bandelier Tuff, Tsankawi Pumice Bed
Qct	Cerro Toledo Interval
T	Tewa Group
Tb	Tertiary Basalts
Tb1	Middle Miocene Basalts, ~12.8 - 12.9 Ma
Tb2	Late Miocene Basalts, ~8.4 - 11.4 Ma
Tb4	Cerros del Rio Basaltic Rocks, Pliocene Lavas and associated tephra of the Cerro
Tcar	Chamita Formation, axial river deposits
Tch	Chamita Formation
Tf	Puye Formation, Older fanglomerate
Tjfp	Bearhead Rhyolie and Fanglomerats
Tk	Keres Group, undivided
Tp	Puye Formation, undivided
Tpf	Puye Formation, fanglomerates
Tpp	Puye Formation, pumiceous fanglomerates
Tpt	Puye Formation, Totavi river gravels
Tsf	Santa Fe Group, undivided
Tsfb	Santa Fe Group basalt
Tsfu	Santa Fe Group, excluding Tsfuv
Tsfuv	Santa Fe Group, upper unit with volcanic detritus
Tt	Tschicoma Formation, undivided
Tt1	Tschicoma Formation, older flows
Tt2	Tschicoma Formation, younger flows

Appendix B. Mean Annual Water Level Data

Table B-1. Mean Annual Groundwater Levels at the Top of the Regional Aquifer in 2010

Well Name	Top of Regional Aquifer (ft)	No. of Data Values	Std. Dev. (ft)	Last Data Date	Well Name	Top of Regional Aquifer (ft)	No. of Data Values	Std. Dev. (ft)	Last Data Date
CDV-R-15-3	6019.1	4958	0.05	08/02/10	R-35b	5835.6	7718	0.26	11/18/10
CDV-R-37-2	6136.7	5242	0.07	08/09/10	R-36	5839.7	7719	0.20	11/18/10
G-3	5737.9	7241	13.39	12/09/10	R-37	5856.0	14054	0.69	11/29/10
R-1	5877.8	8052	0.29	12/02/10	R-38	5857.5	7743	0.16	11/19/10
R-10a	5739.7	8144	0.49	12/06/10	R-39	5753.4	10694	0.39	12/07/10
R-11	5836.2	7718	0.33	11/18/10	R-4	5829.7	7159	0.63	10/26/10
R-13	5834.7	6971	0.38	10/18/10	R-40	5864.7	7835	0.73	11/23/10
R-14	5879.1	7015	0.44	10/20/10	R-41	5699.3	10696	0.19	12/07/10
R-15	5847.5	7042	1.30	10/21/10	R-42	5838.3	8075	0.35	12/03/10
R-16r	5692.1	7738	0.18	11/19/10	R-43	5838.0	7717	0.39	11/18/10
R-17	5884.4	6007	0.31	11/23/10	R-44	5835.3	8009	0.39	12/03/10
R-18	6116.9	6829	0.24	10/12/10	R-45	5835.0	8074	0.38	12/03/10
R-19	5887.2	5940	0.14	10/26/10	R-46	5884.9	7743	0.41	11/19/10
R-2	5869.3	8193	0.23	12/08/10	R-48	6133.8	6872	1.05	10/14/10
R-20	5863.3	6848	1.28	10/29/10	R-49	5774.9	8172	1.80	12/07/10
R-21	5854.4	7741	0.62	11/19/10	R-5	5765.4	8217	0.11	12/16/10
R-22	5761.6	3403	0.18	04/13/09	R-50	5835.4	15468	2.72	12/03/10
R-23	5696.7	7208	0.17	10/28/10	R-51	5871.3	9618	0.66	11/22/10
R-24	5828.6	7161	1.66	10/26/10	R-52	5864.6	17409	0.55	12/31/10
R-25	6232.5	17995	1.72	12/16/10	R-53	5859.6	11191	0.68	12/31/10
R-26	6534.1	5359	2.33	08/13/10	R-54	5862.8	9737	0.55	12/31/10
R-27	5898.0	6826	0.23	10/12/10	R-57	5757.8	3398	0.37	12/21/10
R-28	5836.6	6971	0.39	10/18/10	R-6	5836.8	8218	0.45	12/09/10
R-29	5948.0	5405	0.29	12/09/10	R-7	5876.3	7063	0.05	12/09/10
R-3	5735.2	5466	2.21	12/08/10	R-8	5852.1	6242	0.80	12/16/10
R-30	5948.2	4853	0.19	12/09/10	R-9	5691.1	7981	0.16	11/29/10
R-31	5827.0	7426	0.13	12/07/10	Test Well DT-10	5918.2	8223	0.13	12/09/10
R-32	5851.8	7232	1.25	10/29/10	Test Well DT-5A	5957.5	8222	0.22	12/09/10
R-33	5870.6	8052	0.35	12/02/10	Test Well DT-9	5914.6	8220	0.13	12/09/10
R-34	5833.1	8145	0.30	12/06/10					

Table B-2. Mean Annual Groundwater Levels in Intermediate Wells in 2010

Well Name	Screen	Average 2010 Water Level (ft)	No. Data Points	Std. Dev. (ft)	Date Last Data
16-26644	Single	7458.0	7723	3.86	12/10/10
CdV-16-1(i)	Single	6804.3	22563	1.66	12/10/10
CdV-16-2(i)r	Single	6619.4	17641	0.45	12/31/10
CDV-37-1(i)	Single	6198.5	7318	0.21	12/07/10
LADP-3	Single	6434.7	6665	0.99	12/09/10
LAOI(A)-1.1	Single	6541.7	8223	0.30	12/09/10
LAOI-3.2	Single	6498.8	8221	0.22	12/09/10
LAOI-3.2a	Single	6441.1	6520	0.20	12/09/10
LAOI-7	Single	6241.0	8197	1.98	12/08/10
MCOI-4	Single	6315.7	8006	0.78	12/02/10
MCOI-5	Single	6139.3	8071	0.52	12/03/10
MCOI-6	Single	6157.5	8070	0.68	12/03/10
PCI-2	Single	6407.7	7815	0.20	11/22/10
POI-4	Single	6213.1	8195	0.71	12/08/10
R-12	1	6073.6	7718	0.84	11/18/10
R-12	2	6073.8	7718	0.82	11/18/10
R-19	2	6169.9	4991	0.10	10/26/10
R-23i	1	6121.7	7303	0.39	12/31/10
R-23i	2	6075.3	15077	2.38	12/31/10
R-23i	3	6071.3	13551	4.16	12/31/10
R-25	1	6780.1	17997	0.20	12/16/10
R-25	2	6742.4	17996	0.45	12/16/10
R-25	4	6344.9	17997	0.19	12/16/10
R-25b	Single	6765.6	21033	1.63	11/03/10
R-26	1	7034.4	5357	0.05	08/13/10
R-26 PZ-2	PZ-2	7467.6	7667	3.90	12/10/10
R-27i	Single	6100.9	5712	0.17	12/07/10
R-37	1	5961.6	14057	0.29	11/29/10
R-3i	Single	6201.1	8193	8.37	12/08/10
R-40	R-40i	5953.4	7836	2.76	11/23/10
R-40	1	6079.9	7837	0.11	11/23/10
R-47i	Single	6529.4	8169	0.32	12/07/10
R-5	2	6136.7	8217	0.60	12/16/10
R-6i	Single	6403.4	8218	0.17	12/09/10
R-9i	1	6242.7	6866	2.87	12/09/10
R-9i	2	6131.4	6866	0.60	12/09/10
SCI-1	Single	6370.9	7066	0.54	10/22/10
SCI-2	Single	6206.4	7717	0.33	11/18/10
TA-53i	Single	6386.8	7718	0.17	11/18/10
TW-2Ar	Single	6553.4	4056	0.17	12/08/10

Appendix C. Summary of Transient Responses

Table C-1. Summary of Transient Responses to Supply Well Pumping in LANL Monitoring Wells

Well	Screen	Seasonal Response	Guaje	O-1	O-4	PM-1	PM-2	PM-3	PM-4	PM-5	Comment
CdV-R-15-3	4	Yes	NE	NE	NE	NE	No	NE	No	No	Seasonal response not related to pumping
CdV-R-15-3	5	Yes	NE	NE	NE	NE	No	NE	No	No	Seasonal response not related to pumping
CdV-R-15-3	6	Yes	NE	NE	NE	NE	No	NE	No	Possible	Seasonal response not related to pumping
CdV-R-37-2	2	Yes	NE	NE	NE	NE	No	NE	No	No	Seasonal response not related to pumping
CdV-R-37-2	3	Yes	NE	NE	NE	NE	No	NE	No	No	Seasonal response not related to pumping
CdV-R-37-2	4	Yes	NE	NE	NE	NE	No	NE	No	No	Seasonal response not related to pumping
G-3	Single	Yes	Yes	NE	NE	NE	NE	NE	NE	NE	Guaje well field monitoring well
R-1	Single	Yes	NE	NE	Possible	NE	No	No	Possible	Yes	Primarily responds to PM-5
R-2	Single	No	No	NE	No	NE	NE	NE	NE	NE	Gradual decline of about 0.5 ft/yr
R-4	Single	Yes	Possible	No	Possible	NE	NE	Yes	NE	NE	Seasonal response but not to a specific well
R-5	3	No	No	No	No	No	NE	No	NE	NE	Gradual decline of about 0.6 ft/yr
R-5	4	Yes	No	Possible	No	Yes	NE	No	NE	NE	Seasonal response but not to a specific well
R-6	Single	Yes	No	No	Possible	NE	NE	Yes	NE	No	Seasonal response but not to a specific well
R-7	3	No	No	No	No	NE	NE	No	NE	NE	Gradual decline of about 0.5 ft/yr
R-8	1	Yes	No	NE	Possible	No	NE	Yes	NE	NE	Responds primarily to pumping at PM-3
R-8	2	Yes	No	NE	Possible	No	NE	Yes	NE	NE	Responds primarily to pumping at PM-3
R-9	Single	Yes	No	No	NE	No	NE	No	NE	NE	Gradual decline of about 0.4 ft/yr
R-10	1	ID	NE	NE	NE	Yes	NE	NE	NE	NE	Responds primarily to PM-1
R-10	2	ID	ID	ID	ID	ID	ID	ID	ID	ID	No water level data as of 01/08
R-10a	Single	No	NE	NE	NE	No	NE	No	NE	NE	No apparent response to pumping
R-11	Single	Yes	NE	NE	No	NE	Possible	No	No	Possible	Seasonal response but not to a specific well
R-12	3	No	No	No	No	No	NE	No	No	No	No apparent response to nearby well PM-1
R-13	Single	Yes	NE	NE	No	No	Possible	No	Yes	Possible	Seasonal response but not to a specific well
R-14	1	Yes	NE	NE	Possible	NE	Possible	NE	No	Yes	Responds primarily to PM-5
R-14	2	Yes	NE	NE	Possible	NE	Possible	NE	No	Yes	Responds primarily to PM-5
R-15	Single	Yes	NE	NE	Possible	NE	No	No	Yes	Yes	Responds primarily to pumping at PM-4 and PM-5
R-16	2	No	NE	NE	NE	No	No	NE	NE	NE	No apparent response to Buckman pumping
R-16	3	No	NE	NE	NE	No	No	NE	NE	NE	No apparent response to Buckman pumping
R-16	4	No	NE	NE	NE	No	No	NE	NE	NE	No apparent response to Buckman pumping
R-16r	Single	No	No	No	No	No	No	No	No	No	No apparent response to Buckman pumping
R-17	1	Yes	NE	NE	NE	NE	No	NE	No	No	Seasonal response but not to a specific well
R-17	2	Yes	NE	NE	NE	NE	Possible	NE	Possible	Yes	Responds primarily to pumping at PM-5
R-18	Single	No	NE	NE	NE	NE	No	NE	No	No	No apparent response to pumping
R-19	3	Yes	NE	NE	NE	NE	Possible	NE	No	Possible	Muted response
R-19	4	Yes	NE	NE	NE	NE	Yes	NE	Yes	Possible	Responds primarily to PM-2
R-19	5	Yes	NE	NE	NE	NE	Yes	NE	Yes	Possible	Responds primarily to PM-2
R-19	6	Yes	NE	NE	NE	NE	Yes	NE	Yes	Possible	Responds primarily to PM-2
R-19	7	Yes	NE	NE	NE	NE	Yes	NE	Yes	Possible	Responds primarily to PM-2
R-20	1	Yes	NE	NE	NE	NE	Yes	NE	Yes	NE	Highly muted response
R-20	2	Yes	NE	NE	NE	NE	Yes	NE	Yes	NE	Muted response
R-20	3	Yes	NE	NE	NE	NE	Yes	NE	Yes	NE	Responds primarily to PM-2 but also to PM-4
R-21	Single	Yes	NE	NE	NE	No	Yes	No	Possible	NE	Seasonal response but not to a specific well

NE = not evaluated; ID = insufficient Data

Table C-1. Summary of Transient Responses to Supply Well Pumping in LANL Monitoring Wells (Continued)

Well	Screen	Seasonal Response	Guaje	O-1	O-4	PM-1	PM-2	PM-3	PM-4	PM-5	Comment
R-22	1	Yes	NE	NE	NE	No	No	No	No	NE	Seasonal response but not to a specific well
R-22	2	Yes	NE	NE	NE	No	No	No	No	NE	Seasonal response but not to a specific well
R-22	3	Yes	NE	NE	NE	No	No	No	No	NE	Seasonal response but not to a specific well
R-22	4	Yes	NE	NE	NE	No	No	No	No	NE	Seasonal response but not to a specific well
R-22	5	Yes	NE	NE	NE	No	No	No	No	NE	Seasonal response but not to a specific well
R-23	Single	No	NE	NE	NE	No	No	NE	NE	NE	No apparent response to pumping
R-24	Single	Yes	Possible	No	Possible	No	NE	Yes	NE	NE	Responds primarily to pumping at PM-3
R-25	5	No	NE	NE	NE	NE	No	No	No	No	No apparent response to pumping
R-25	6	No	NE	NE	NE	NE	No	No	No	No	No apparent response to pumping
R-25	7	No	NE	NE	NE	NE	No	No	No	No	No apparent response to pumping
R-25	8	No	NE	NE	NE	NE	No	No	No	No	No apparent response to pumping
R-26	2	No	NE	NE	NE	NE	No	No	No	No	No apparent response to pumping
R-27	Single	Yes	NE	NE	NE	NE	NE	NE	NE	NE	Seasonal response but not to a specific well
R-28	Single	Yes	NE	NE	NE	NE	Possible	No	Yes	Possible	Seasonal response but not to a specific well
R-31	2	No	NE	NE	NE	No	No	No	No	NE	No apparent response to pumping
R-31	3	No	NE	NE	NE	No	No	No	No	NE	No apparent response to pumping
R-31	4	No	NE	NE	NE	No	Possible	No	No	NE	Limited data for evaluation
R-31	5	Yes	NE	NE	NE	No	Yes	No	Possible	NE	Appears to respond seasonally like PM-2
R-32	1	No	NE	NE	NE	NE	No	No	No	NE	No apparent response to pumping
R-32	2	Yes	NE	NE	NE	No	Yes	No	Yes	NE	Responds primarily to pumping at PM-2 and PM-4
R-32	3	Yes	NE	NE	NE	No	Yes	No	Yes	NE	Responds primarily to pumping at PM-2 and PM-4
R-33	1	No	NE	NE	NE	NE	NE	NE	NE	No	No apparent response to PM-5
R-33	2	Yes	NE	NE	NE	NE	NE	No	Yes	Yes	Responds primarily to pumping at PM-5
R-34	Single	Yes	NE	NE	NE	No	No	No	No	NE	Seasonal response but not to a specific well
R-35a	Single	Yes	NE	NE	Yes	NE	NE	Yes	NE	NE	Responds primarily to nearby supply well PM-3
R-35b	Single	Yes	NE	NE	NE	NE	NE	No	NE	NE	Gradual decline of about 0.6 ft/yr
R-36	Single	No	NE	NE	NE	NE	NE	NE	NE	NE	Gradual decline of about 0.5 ft/yr
R-37	2	Yes	NE	NE	ID	NE	ID	ID	Yes	ID	Responds primarily to pumping at PM-4
R-38	Single	Yes	NE	NE	ID	ID	ID	ID	Possible	ID	Sseasonal response in 2010 larger than in 2009
R-39	Single	Yes	NE	NE	ID	ID	ID	ID	Possible	ID	Sseasonal response in 2010 larger than in 2009
R-40	2	Yes	NE	NE	NE	NE	Yes	NE	Yes	NE	Responds to pumping PM-4 and PM-2
R-41	2	No	NE	NE	No	No	ID	No	No	No	Unusual fluctuations not related to pumping?
R-42	Single	Yes	NE	NE	No	NE	ID	ID	Yes	Possible	Primary response to PM-4 in 2010
R-43	1	Yes	NE	NE	ID	NE	ID	No	Yes	ID	Primary response to PM-4 in 2010
R-43	2	Yes	NE	NE	ID	NE	ID	No	Yes	ID	Primary response to PM-4 in 2010
R-44	1	Yes	NE	NE	ID	NE	ID	No	Yes	ID	Primary response to PM-4 in 2010
R-44	2	Yes	NE	NE	ID	NE	ID	No	Yes	ID	Primary response to PM-4 in 2010
R-45	1	Yes	NE	NE	ID	NE	ID	No	Yes	ID	Primary response to PM-4 in 2010
R-45	2	Yes	NE	NE	ID	NE	ID	No	Yes	ID	Primary response to PM-4 in 2010
R-46	Single	Yes	NE	NE	ID	NE	ID	ID	Yes	Yes	Primary response to PM-4 and PM-5 in 2010
R-48	Single	No	No	No	No	No	ID	No	No	No	No apparent response to pumping
R-49	1	Yes	NE	NE	NE	NE	ID	NE	Possible	Possible	Seasonal response but not to a specific well
R-49	2	Yes	NE	NE	NE	NE	ID	NE	Yes	Yes	Primary response to PM-4 and PM-5 in 2010
R-50	1	Yes	NE	NE	NE	NE	ID	ID	Yes	Possible	Primary response to PM-4 in 2010
R-50	2	Yes	NE	NE	NE	NE	ID	ID	Yes	Possible	Primary response to PM-4 in 2010
R-51	1	Yes	NE	NE	ID	NE	ID	NE	Yes	ID	Primary response to PM-4 in 2010
R-51	2	Yes	NE	NE	ID	NE	ID	NE	Yes	ID	Primary response to PM-4 in 2010
R-52	1	Yes	NE	NE	ID	NE	ID	NE	Yes	ID	Primary response to PM-4 in 2010
R-52	2	Yes	NE	NE	ID	NE	ID	NE	Yes	ID	Primary response to PM-4 in 2010
R-53	1	No	NE	NE	ID	NE	ID	NE	No	ID	No apparent response to pumping
R-53	2	Yes	NE	NE	ID	NE	ID	NE	Yes	ID	Primary response to PM-4 in 2010
R-54	1	No	NE	NE	ID	NE	No	NE	No	Possible	No apparent response to pumping
R-54	2	Yes	NE	NE	ID	NE	Yes	NE	Yes	ID	Primary response to PM-4 in 2010
R-55	1	ID	ID	ID	ID	ID	ID	ID	ID	ID	Insufficient data
R-55	2	ID	ID	ID	ID	ID	ID	ID	ID	ID	Insufficient data
R-56	1	ID	ID	ID	ID	ID	ID	ID	ID	ID	Insufficient data
R-56	2	ID	ID	ID	ID	ID	ID	ID	ID	ID	Insufficient data
R-57	1	ID	ID	ID	ID	ID	ID	ID	ID	ID	Insufficient data
R-57	2	ID	ID	ID	ID	ID	ID	ID	ID	ID	Insufficient data
R-60	1	ID	ID	ID	ID	ID	ID	ID	ID	ID	Insufficient data
TW-3	Single	Yes	No	NE	No	NE	NE	No	NE	NE	Gradual decline of about 0.8 ft/yr

NE = not evaluated; ID = insufficient Data

Appendix D. Summary of Intermediate Groundwater Level Responses to Runoff

D.1. Intermediate Groundwater Responses in Cerros del Rio Basalt (Tb4)

Figure D-1 shows the intermediate groundwater hydrographs for wells completed in the Cerros del Rio basalt. These wells are located in lower Los Alamos Canyon, lower Pueblo Canyon, middle Mortandad Canyon, and lower Pajarito Canyon (see Figure 4-1). Note the water levels in R-12 and R-23i are lower than in the other wells (scale on the right side of the hydrograph). Perched intermediate groundwater levels in the Cerros del Rio basalt in some wells show seasonal variations that are evaluated as probable response to large runoff events in Los Alamos Canyon.

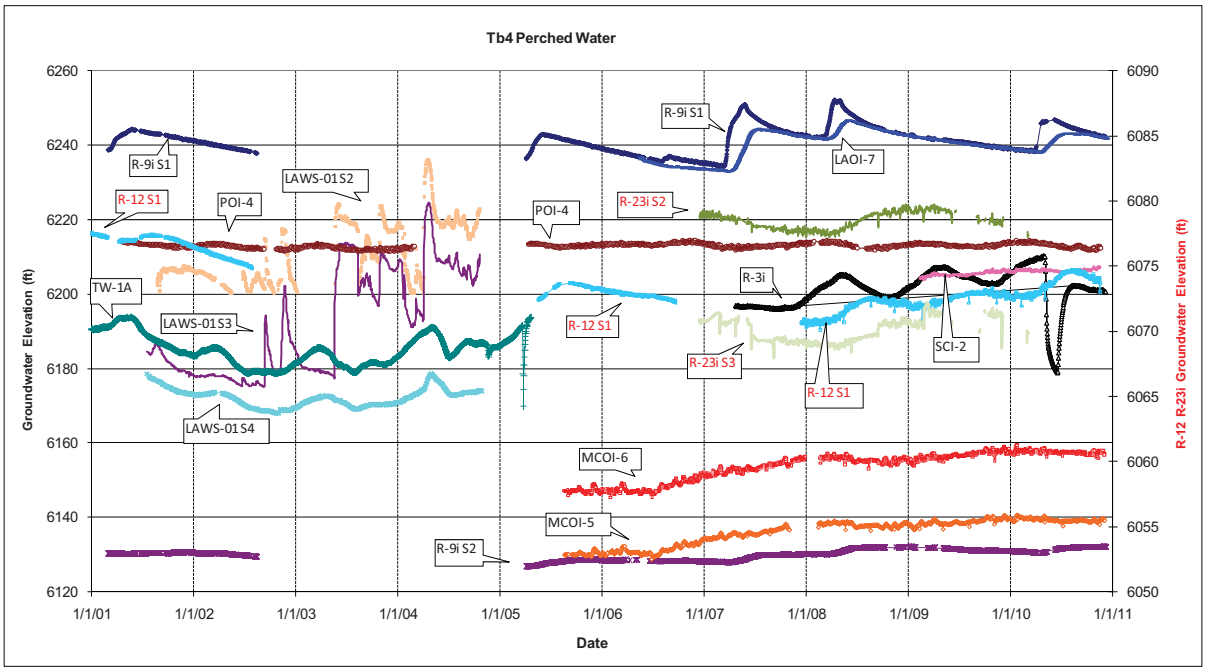

Figure D-1. Intermediate groundwater levels in Cerros del Rio basalt.

Figure D-2 shows the intermediate groundwater level in Cerros del Rio basalt in wells in lower Los Alamos Canyon and lower Pueblo Canyon and the mean daily flow at gaging station E042 in lower Los Alamos Canyon. From 2001 to 2004 screens 2 and 3 in LAWS-01 in lower Los Alamos Canyon (Stone et al. 2004) show responses to small and large runoff events. During this period LAWS-01 screen 4 and nearby well TW-1A in lower Pueblo Canyon show similar responses, generally higher water levels in the winter and lower levels in the summer. From 2006 through 2010, similar seasonal responses are observed in POI-4 and R-3i. The perched water at R-3i declined during drilling of adjacent well R-3 during the summer of 2010 and recovered when R-3 construction was completed.

Large snowmelt runoff events occurred in Los Alamos Canyon in the spring of 2001, 2005, 2007, 2008, and 2010 as observed in lower Los Alamos Canyon at stream gage E042 (Figure D-2). No significant snowmelt runoff occurred in 2002, 2003, 2006, and 2009. Concurrent with the large snowmelt runoff in lower Los Alamos Canyon, intermediate groundwater levels in wells R-9i, R-12, and LAOI-7 show groundwater level rises that appear to be related to the snowmelt runoff events.

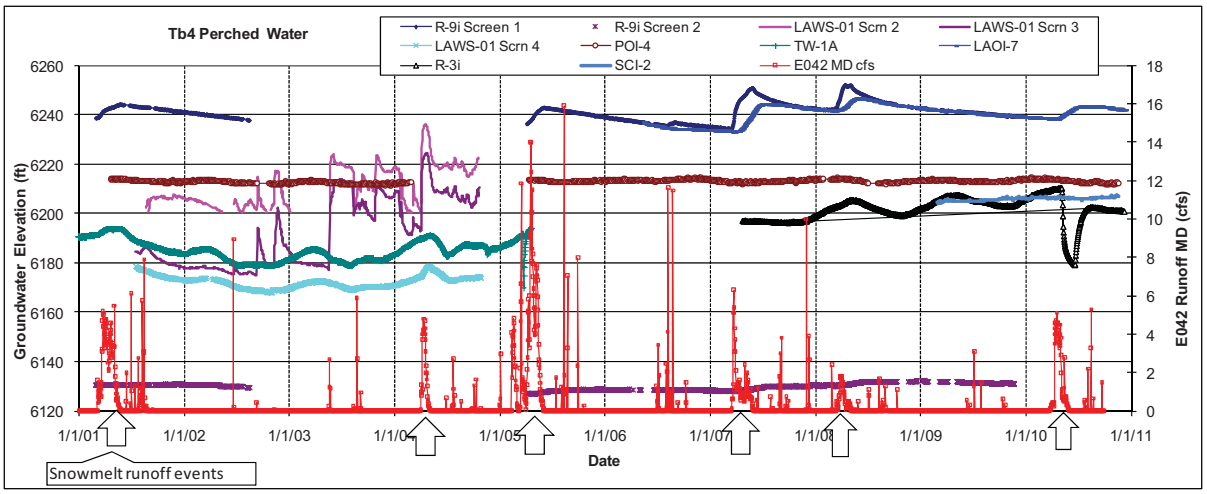

Figure D-2. Intermediate groundwater levels in Cerros del Rio basalt in Los Alamos and Pueblo canyons and mean daily flow at Gaging Station E042.

Figure D-3 shows the runoff at gage E042 from 2007 to 2010 and the water level responses in the Cerros del Rio basalt in wells R-9i screen 1, LAOI-7, and R-12 screen 1. The earliest water level response to snowmelt runoff is typically at R-9i screen 1, followed by LAOI-7 with a slightly reduced total response, and then followed possibly by a much subdued response at R-12 screen 1; again, note that the groundwater elevation at screen 1 in R-12 is about 170 ft lower than R-9i and LAOI-7. A significantly smaller and delayed response is also observed in R-9i screen 2. Additionally, two large storm runoff events in the summer of 2006 caused a rise in the groundwater level at R-9i screen 1 but little if any response at LAOI-7. With no snowmelt runoff in 2009, the groundwater levels at R-9i and LAOI-7 show a continued decline through 2009. However, the groundwater at R-12 screen 1 showed a rising trend in 2009, suggesting that the groundwater at R-12 may not be responding to the large runoff events in lower Los Alamos Canyon, or is possibly responding at a lag period greater than a few months. Additional monitoring is needed to understand the groundwater level fluctuations at R-12. The intermediate perched groundwater at all three wells again appear to have responded to snowmelt runoff in the spring of 2010.

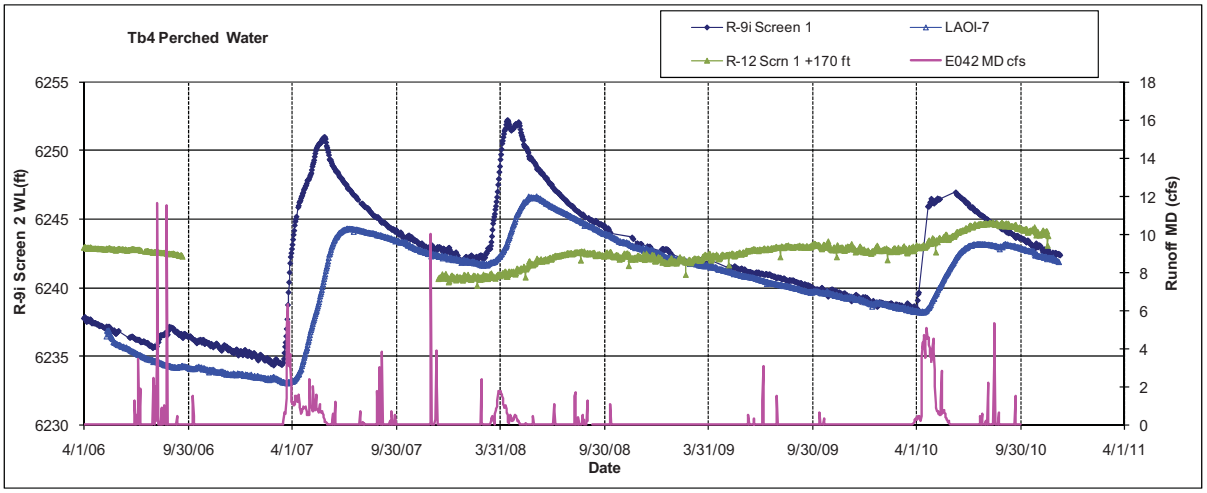

Figure D-3. Intermediate groundwater responses to snowmelt runoff in 2007, 2008, 2009, and 2010 in Cerros del Rio basalt and mean daily flow at Gaging Station E042.

Figure D-4 shows the hydrographs for intermediate perched groundwater in R-12 in lower Sandia Canyon and R-23i in lower Pajarito Canyon and the runoff at stream gages E042 in Los Alamos Canyon and E250 in lower Pajarito Canyon. As indicated above, the groundwater level fluctuations at R-12 may not be the result of snowmelt runoff infiltration below Los Alamos Canyon. The groundwater level rise in R-23i in 2008 follows a large snowmelt runoff period in the spring of 2008 and may similarly be associated with snowmelt runoff in Pajarito Canyon. Following no runoff in lower Pajarito Canyon in 2009, the water levels in R-23i showed a declining trend. The groundwater at R-23i screen 2 in 2010 do not show an obvious response to snowmelt runoff in the spring of 2010. The water levels measured at R-23i screen 3 in 2010 appear to have been compromised by possible leakage from screen 2. Additional runoff monitoring in lower Pajarito Canyon and groundwater level data from R-23i are necessary to determine if groundwater at R-23i responds to runoff events.

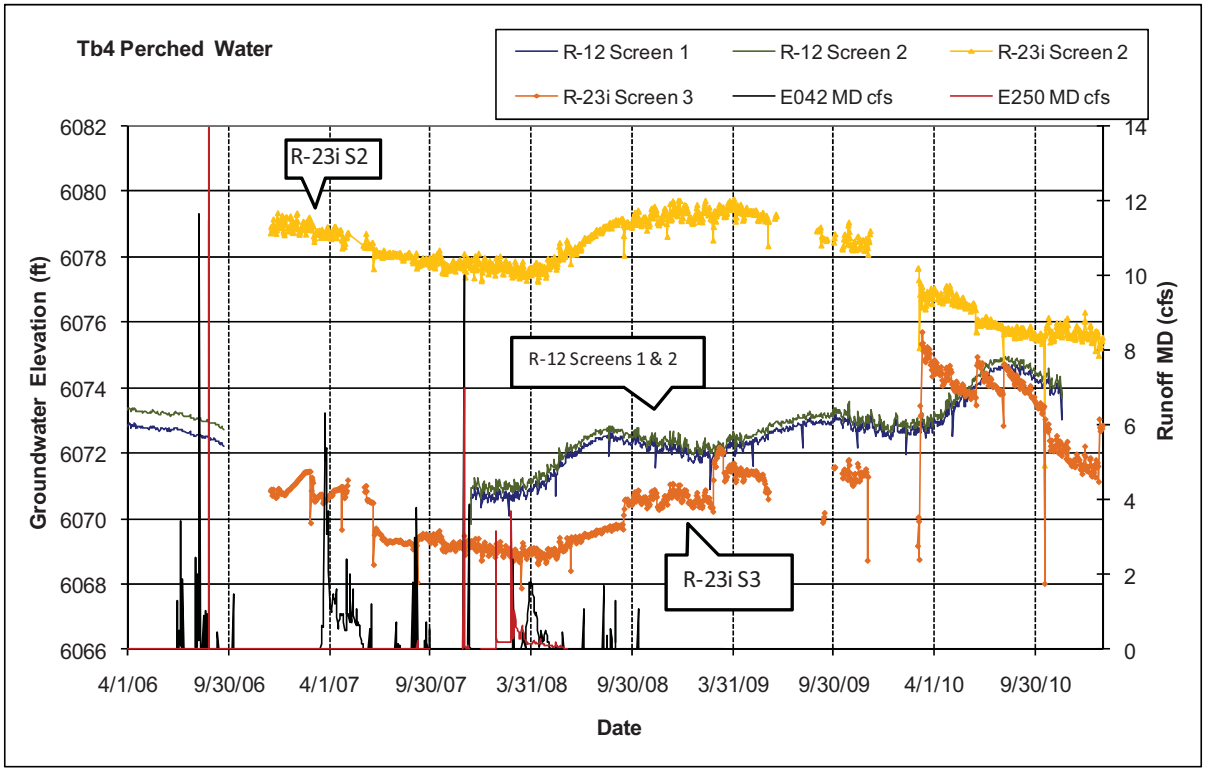

Figure D-4. Intermediate groundwater levels at R-12 and R-23i and mean daily flow at Gaging Stations E042 and E250.

Perched intermediate groundwater in the Cerros del Rio basalt beneath Mortandad Canyon in wells MCOI-5 and MCOI-6 (Figure D-1) shows a rising trend from mid 2006 to early 2008 when the water levels in both wells rose about 10 ft. A small rising trend continued at these wells in 2009 but the water levels were approximately stable in 2010. The trends in the groundwater levels in these wells do not appear to be related to specific runoff events; additional monitoring is needed to determine if the intermediate groundwater in these wells is influenced by runoff.

D.2. Intermediate Groundwater in Guaje Pumice Bed (Qbog)

Figure D-5 shows the hydrographs of perched intermediate groundwater in wells screened in the Guaje pumice bed and the mean daily runoff recorded in lower Los Alamos Canyon at stream gage E042. These wells are located in middle Los Alamos Canyon where the intermediate groundwater in the Guaje pumice bed is 100 to 300 ft below the canyon floor and is stratigraphically higher than the intermediate groundwater in the Puye Formation and Cerros del Rio basalts. The Guaje pumice bed is about 100 ft above the Cerros del Rio basalt in this area. There is no apparent correlation between trends in the groundwater levels in the Guaje pumice bed and runoff in Los Alamos Canyon.

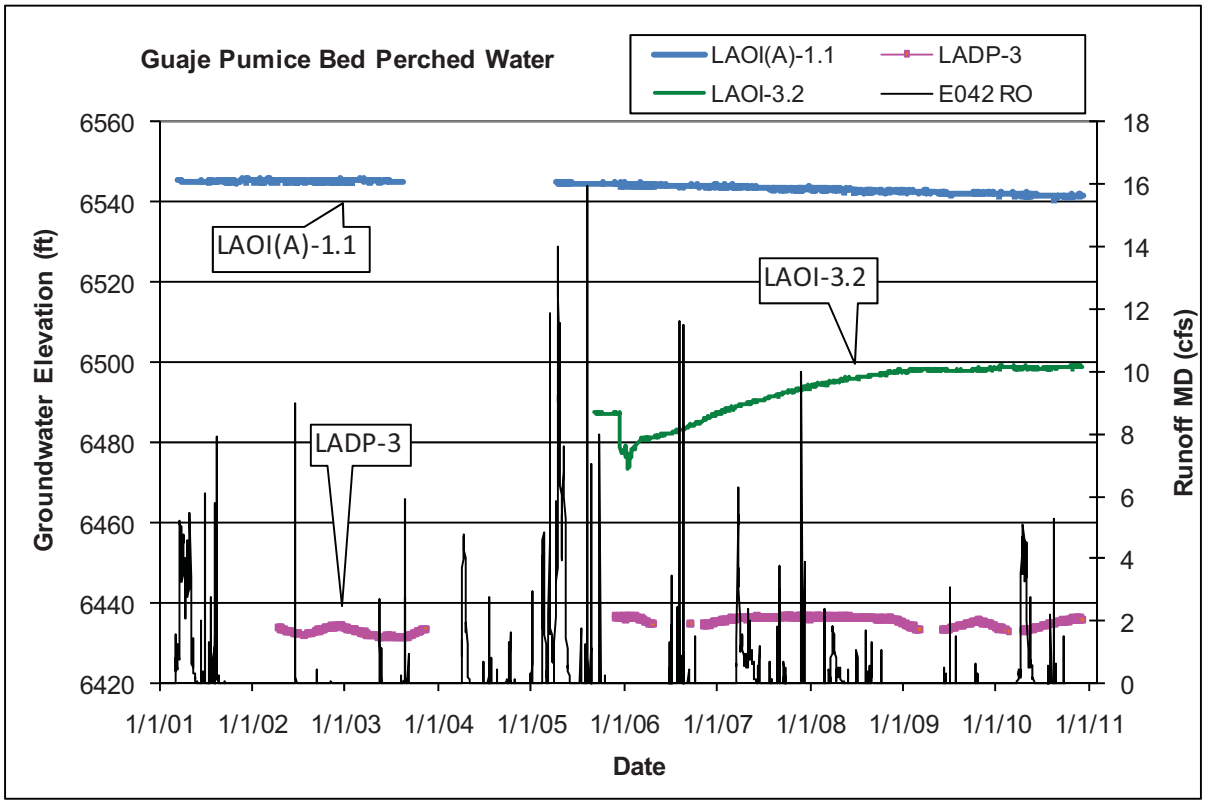

Figure D-5. Intermediate groundwater levels in the Guaje pumice bed at LAOI(A)-1.1, LADP-3, and LAOI-3.2 and mean daily flow at Gaging Station E042.

D.3. Intermediate Groundwater in the Puye Formation (Tp)

Screens in monitoring wells LAOI-3.2a, SCI-1, MCOI-4, R-5 screen 2, R-6i, R0-47i, and TA-53i monitor perched intermediate groundwater in the Puye Formation (see Section 4). There is no apparent relationship between runoff and groundwater levels in these wells.

D.4. Intermediate Groundwater at TA-16

Intermediate groundwater is monitored in the TA-16 area at wells CdV-16(i)-1, R-25 screens 1, 2, and 4, R-25b, CdV-16-2(i)r, R-26 screen 1, R-26 PZ-2, and 16-26644. Figures D-6 and D-7 show the groundwater levels from these wells and the mean daily runoff at gage E252 in upper Water Canyon. Snowmelt runoff occurred at gage E252 in 2005, 2007, and 2008, and presumably in 2010 (data not yet available), but no significant runoff occurred in 2006 and 2009. The groundwater at CdV-16-1(i) and R-25 screens 1 and 2 show an apparent response to snowmelt runoff in 2007, 2008, and 2010 ranging from a few tenths of a foot in 2007 at R-25 screen 1 up to about 5 ft at CdV-16-1(i) in 2010. The screen at R-25b is at a similar elevation as R-25 screen 1, and showed a similar response to snowmelt runoff in 2010, although a sampling event at the beginning of runoff obscured some of the response at R-25b. In 2010 the groundwater at R-25 screen 2 rose about 1.5 ft in response to snowmelt runoff, while at screen 1, the rise was about 0.8 ft (Figure D-6).

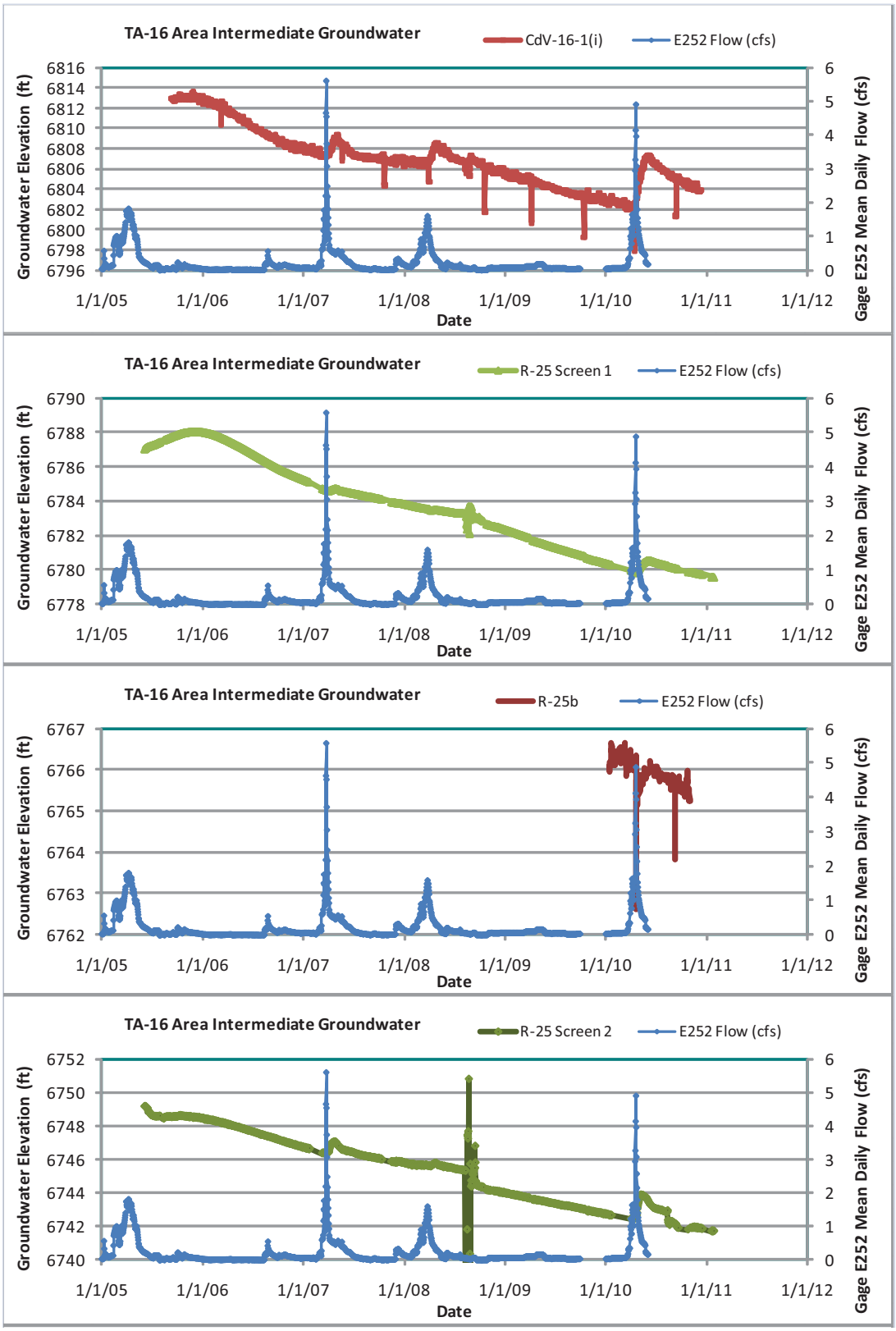

Figure D-6. Intermediate groundwater levels in TA-16 wells and mean daily flow at Gaging Station E252.

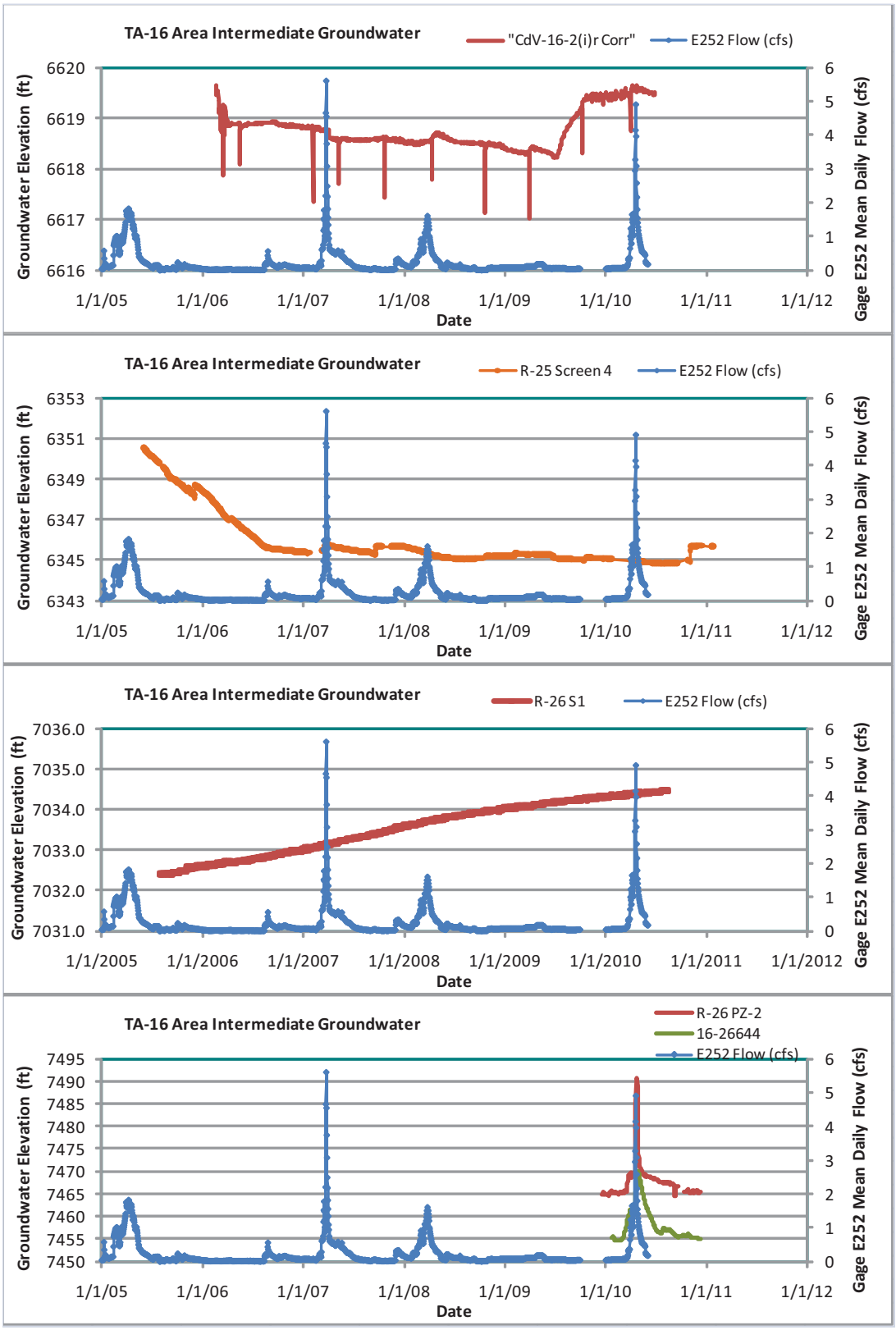

Figure D-7. Intermediate groundwater levels in TA-16 wells and mean daily flow at Gaging Station E252.

R-25 screen 4 may have shown a slight response to runoff in 2007 (Figure D-7), but there was no apparent response in 2008 and 2010, although there was an abrupt rise at screen 4 in November 2010, which may have been a delayed response to drilling nearby well CDV-16-4ip. Note that R-25 screens 1 and 2 and CdV-16-1(i) showed water level responses to drilling and installing monitoring wells R-25b and R-25c in August and September 2008 and R-25 screen 2 showed an abrupt water level decline in 2010 during drilling of CDV-16-4ip.

There was no apparent response to snowmelt runoff at CdV-16-2(i)r in 2007 and 2010 (Figure D-7), but there may have been a response in 2008. After dry well CdV-16i-2(i) was plugged and abandoned in 2009, the groundwater level at CdV-16-2(i)r showed a recovery of greater than 1 ft (see Section 3).

The perched intermediate groundwater at R-26 screen 1 in Cerro Toledo interval sediments has shown a continuing rise from 2005 to 2010, but no apparent response to snowmelt runoff. The monitoring of groundwater levels at nearby piezometer R-26 PZ-2 began in late 2009. This piezometer is screened in Unit 3 of the Bandelier Tuff and showed a total groundwater level rise of about 25 ft during snowmelt runoff in 2010 (Figure D-7). Similarly, the groundwater at monitoring well 16-26644 (also screened in Unit 3 of the Bandelier Tuff) rose about 15 ft during the spring of 2010, apparently in response to snowmelt runoff.

D.5. Summary of Runoff Impacts to Intermediate Perched Groundwater

Large snowmelt and storm runoff events in Los Alamos Canyon that extend eastward as far as the LANL boundary appear to infiltrate into subsurface units and impact groundwater levels in wells completed in the Cerros del Rio basalt. Intermediate perched groundwater in other geologic units beneath the middle part of Los Alamos Canyon and the surrounding Pajarito Plateau does not appear to be impacted by runoff events.

Similarly, intermediate perched groundwater in some wells at TA-16 appears to respond to large snowmelt runoff events. With no significant runoff events in 2009, the intermediate groundwater levels in most of the TA-16 area showed a continued decline. Reid et al. (2008) observed that the rapid infiltration to intermediate zones occurred at both the eastern and western side of the plateau in two contrasting hydrogeologic settings: runoff over fractured basalt in lower Los Alamos Canyon and possibly in lower Pajarito Canyon, and runoff crossing the Pajarito fault and associated fractured bedrock in the western part of the Pajarito Plateau. Reid et al. (2008) concluded that the key feature associated with the large runoff events and response in intermediate groundwater zones was persistent runoff and brittle bedrock near the surface that provided a conduit for infiltration.

Appendix E. Summary of Regional and Intermediate Groundwater Temperature

Table E-1. Groundwater Temperature in Regional Aquifer Wells

Regional Aquifer Temperature									
Well	Screen	T (C)	Hyro Unit	Geo Unit	Well	Screen	T (C)	Hyro Unit	Geo Unit
CDV-R-15-3	4	16.3	RT	Tpf	R-29	Single	17.3	RT	Tpf
CDV-R-15-3	5	16.7	RD	Tpf	R-3	Single	23.2	RT	Tsf
CDV-R-15-3	6	19.0	RD	Tpf	R-30	Single	19.1	RT	Tpf
CDV-R-37-2	2	20.1	RT	Tt	R-31	2	19.3	RT	Tb4
CDV-R-37-2	3	20.7	RD	Tt	R-31	3	20.4	RD	Tb4
CDV-R-37-2	4	21.8	RD	Tt	R-31	4	22.2	RD	Tpt
G-2A	Single	27.2	RT	Tsf	R-31	5	23.8	RD	Tpt
G-3	Single	24.8	RT	Tsf	R-32	1	19.7	RT	Tpt
G-3A	Single	26.6	RT	Tsf	R-33	1	21.2	RT	Tpp
O-1	Single	23.0	RT	Tsf	R-35a	Single	25.0	RD	Tsfu
PM-1	Single	26.5	RT	Tsf	R-35b	Single	23.5	RT	Tpf
PM-2	Single	20.8	RT	Tp	R-36	Single	22.9	RT	Tsfu
PM-3	Single	24.9	RT	Tsf	R-37	2	20.6	RT	Tpf
PM-4	Single	24.6	RT	Tp	R-38	Single	20.0	RT	Tpf
PM-5	Single	23.2	RT	Tp	R-39	Single	21.5	RT	Tpf
R-10	1	20.9	RD	Tsf	R-4	Single	24.5	RT	Tp
R-10a	Single	20.4	RT	Tsf	R-40	2	20.1	RT	Tpf
R-11	Single	21.3	RT	Tp	R-41	2	22.5	RT	Tpt
R-13	Single	19.8	RT	Tp	R-42	1	19.6	RT	Tsfuv
R-14	Single	22.7	RT	Tp	R-43	1	20.3	RT	Tsfu
R-16	2	20.6	RD	Tsf	R-44	1	19.2	RT	Tpf
R-16r	Single	19.8	RT	Tpt	R-45	1	19.6	RT	Tpf
R-17	1	21.4	RT	Tpf	R-46	1	23.0	RT	Tpf
R-18	Single	14.8	RT	Tpf	R-48	Single	19.9	RT	Tt
R-19	3	20.4	RT	Tpf	R-49	1	21.2	RT	Tb4
R-19	4	21.5	RD	Tpf	R-5	3	22.8	RT	Tsf
R-19	5	21.5	RD	Tpf	R-5	4	25.1	RD	Tsfb
R-19	6	25.7	RD	Tpf	R-50	1	20.0	RT	Tpf
R-19	7	26.4	RD	Tpf	R-51	1	19.8	RT	Tpf
R-2	Single	23.6	RT	Tpf	R-52	1	20.9	RT	Tpf
R-20	1	20.7	RT	Tb4	R-53	1	20.5	RT	Tpf
R-21	Single	20.4	RT	Tp	R-54	1	20.3	RT	Tpf
R-23	Single	21.6	RT	Tpt	R-57	1	22.3	RT	Tb4
R-24	Single	28.4	RT	Tsf	R-6	Single	21.9	RT	Tf
R-25	5	12.4	RT	Tpf	R-7	3	16.1	RT	Tp
R-25	6	13.7	RD	Tpf	R-8	1	20.5	RT	Tp
R-25	7	16.7	RD	Tpf	R-8	2	22.9	RD	Tp
R-25	8	20.2	RD	Tpf	R-9	Single	22.2	RT	Tsfb
R-26	2	26.7	RT	Tp	DT-10	Single	18.4	RT	Tb4
R-27	Single	17.7	RT	Tpf	DT-5A	Single	19.5	RT	Tb4
R-28	Single	24.2	RT	Tpf	DT-9	Single	20.7	RT	Tb4

Multiple completion wells equipped with Westbay® sampling systems employ transducers with temperature sensors at each screen, which appropriately measure the in-situ water temperature at each screen; these data are shown on Tables E-1 and E-2 for each screen. Multiple completion wells equipped with Baski sampling systems employ transducers that are installed above the packer. The water level for the lower screen zones is appropriately measured via a small diameter tube that extends below the packer. However, the temperature sensors in transducers that measure the lower screen water levels in the Baski-equipped wells record the water temperature of the upper screen zone and not that of the lower screen zone. Thus the temperature of the water in the lower screens is

not appropriately measured and temperature data recorded by the transducers for the lower screen zones in Baski-equipped wells are not shown in Tables E-1 and E-2.

Table E-2. Groundwater Temperature in Intermediate Groundwater Wells

Intermediate Groundwater Temperature				
Well	**Screen**	**T (C)**	**Hyro Unit**	**Geo Unit**
16-26644	Single	11.9	I	Qbt3
CdV-16-1(i)	Single	10.8	I	Qbo
CdV-16-2(i)r	Single	11.1	I	Tpf
CDV-37-1(i)	Single	12.7	I	Tpf
LADP-3	Single	9.9	I	Qbog
LAOI(A)-1.1	Single	9.6	I	Qbog
LAOI-3.2	Single	11.7	I	Qbog
LAOI-3.2a	Single	12.1	I	Tpf
LAOI-7	Single	13.8	I	Tb4
MCOI-4	Single	14.5	I	Tpf
MCOI-5	Single	16.0	I	Tb4
MCOI-6	Single	14.9	I	Tb4
PCI-2	Single	14.5	I	Tpf
POI-4	Single	11.6	I	Tb4
R-12	1	18.8	I	Tb4
R-19	2	18.0	I	Tp
R-23i	1	15.8	I	Tb4
R-25	1	11.2	I	Qbo
R-25b	Single	10.7	I	Qbo
R-26	1	15.5	I	Qct
R-26 PZ-2	PZ-2	10.7	I	Qbt3
R-27i	Single	14.7	I	Tpf
R-37	1	19.9	I	Tpf
R-3i	Single	13.7	I	Tb4
R-40	1	19.0	I	Tb4
R-47i	Single	12.5	I	Tpf
R-5	2	17.7	I	Tp
R-6i	Single	16.5	I	Tpf
R-9i	1	9.3	I	Tb4
SCI-1	Single	10.9	I	Tpf
SCI-2	Single	16.0	I	Tb4
TA-53i	Single	14.5	I	Tpf
TW-2Ar	Single	11.5	I	Tpf

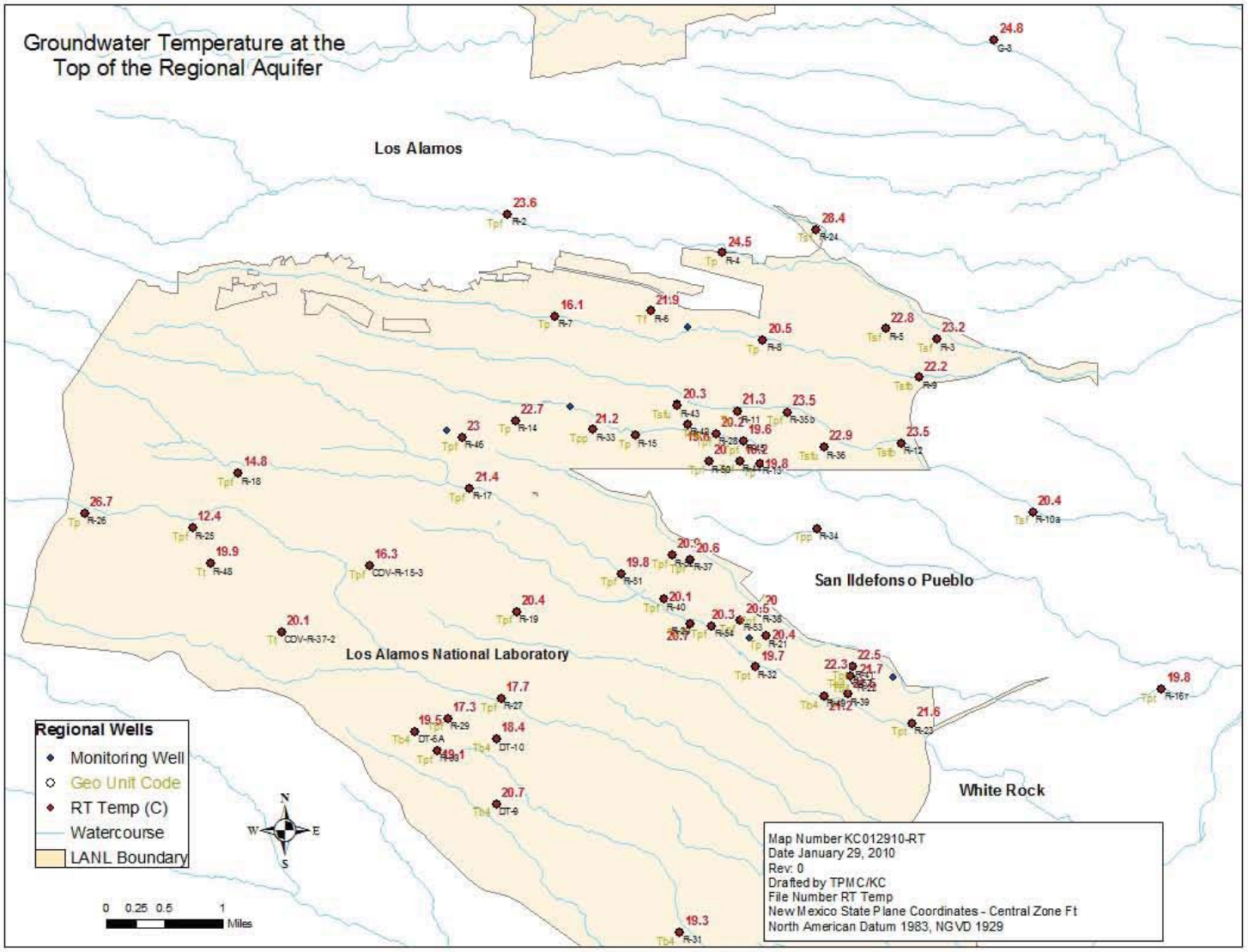

Figure E-1. Temperature of groundwater at the top of the regional aquifer.

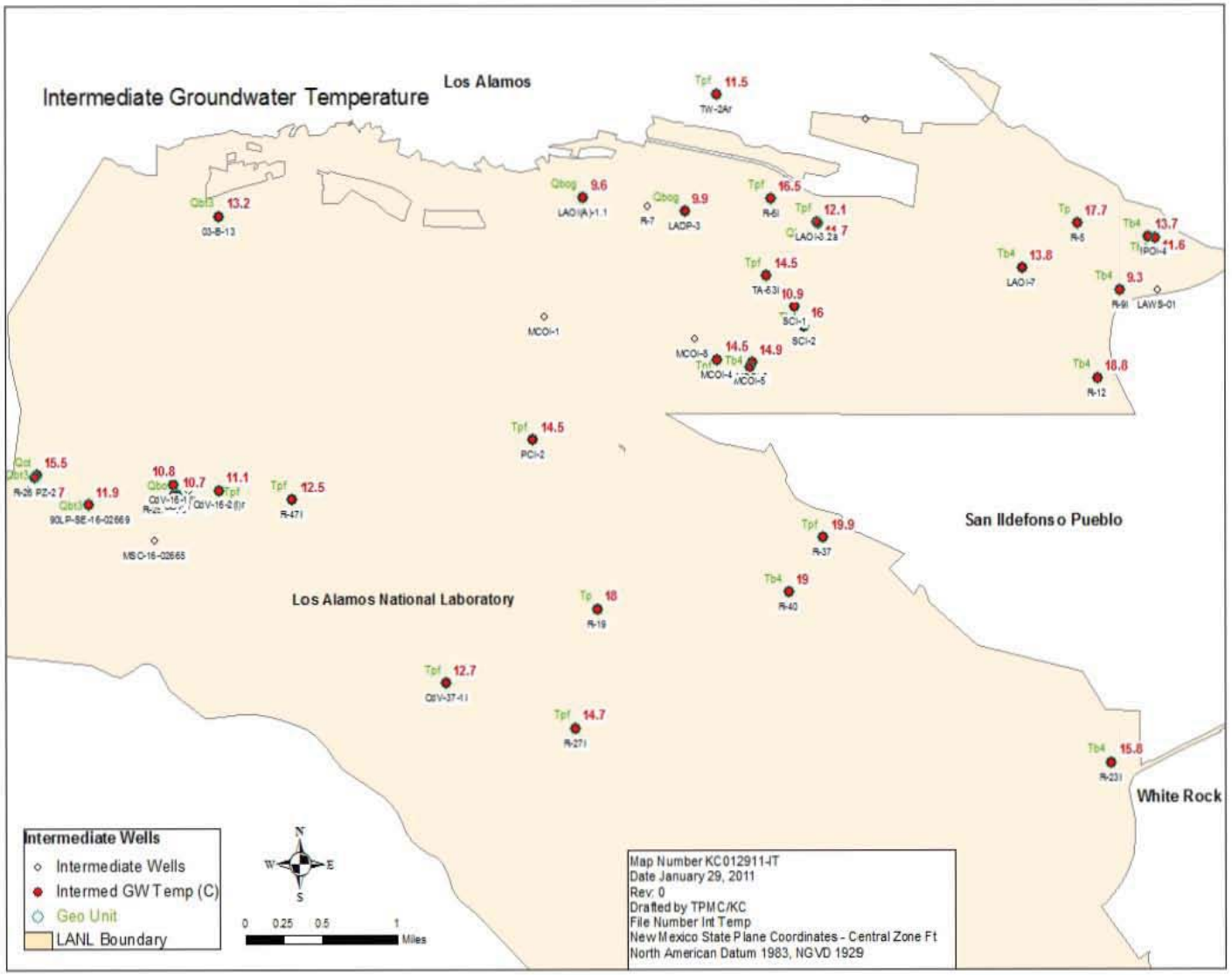

Figure E-2. Temperature of intermediate groundwater.

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2011 Interim Facility-Wide Groundwater Monitoring Plan, Revision 1



Prepared by the Environmental Programs Directorate

Los Alamos National Laboratory, operated by Los Alamos National Security, LLC, for the U.S. Department of Energy under Contract No. DE-AC52-06NA25396, has prepared this document pursuant to the Compliance Order on Consent, signed March 1, 2005. The Compliance Order on Consent contains requirements for the investigation and cleanup, including corrective action, of contamination at Los Alamos National Laboratory. The U.S. government has rights to use, reproduce, and distribute this document. The public may copy and use this document without charge, provided that this notice and any statement of authorship are reproduced on all copies.

EP2011-0375

2011 Interim Facility-Wide Groundwater Monitoring Plan, Revision 1

December 2011

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EXECUTIVE SUMMARY

This Interim Facility-Wide Groundwater Monitoring Plan (hereafter, the Interim Plan) fulfills a requirement of the Compliance Order on Consent (hereafter, the Consent Order). Los Alamos National Laboratory (the Laboratory) will collect and analyze groundwater and surface water samples at specific locations and for specific constituents to fulfill the requirements of the Consent Order. Groundwater-level data will also be collected because they are critical to understanding groundwater occurrence and movement. Four types of water are monitored: base flow (persistent surface water), alluvial groundwater, intermediate-perched groundwater, and regional aquifer groundwater. This Interim Plan is updated annually and submitted to the New Mexico Environment Department (NMED) for its approval. The 2011 Interim Plan applies to the monitoring year (MY) from October 1, 2011, to September 30, 2012. This revision of the Interim Plan will supplement the first quarter implemented under the initial 2011 Interim Plan and be in effect starting January 1, 2012.

The monitoring conducted under this plan is designed to enhance the general understanding of the groundwater within and beneath the Laboratory. These data are used for characterization purposes to support corrective measures work conducted at numerous sites around the Laboratory and to support ongoing operations. The monitoring is conducted both inside and outside of current Laboratory boundaries. Monitoring within current Laboratory boundaries takes place in seven major watershed groupings: Los Alamos Canyon/Pueblo Canyon, Sandia Canyon, Mortandad Canyon, Pajarito Canyon, Water Canyon/Cañon de Valle, Ancho/Chaquehui/Frijoles Canyons, and White Rock Canyon/Rio Grande.

Most of the monitoring wells discussed in the Interim Plan are assigned to area-specific monitoring groups related to project areas that may be located in more than one watershed. Area-specific monitoring groups are defined for Technical Area 54 (TA-54) in Pajarito and Mortandad Canyons; TA-21, primarily in Los Alamos Canyon; Material Disposal Area (MDA) AB, primarily in Ancho Canyon; MDA C, primarily in Mortandad Canyon; the chromium investigation area in Sandia and Mortandad Canyons; and the TA-16 260 Outfall in Water Canyon/Cañon de Valle. Locations that are not included within one of these six area-specific monitoring groups are assigned to the general surveillance monitoring group.

Monitoring outside the Laboratory boundaries is conducted in areas (1) where Laboratory operations have been conducted in the past (e.g., Guaje and Rendija Canyons) or (2) that historically have not been affected by Laboratory operations. To ensure water leaving the Laboratory does not pose an unacceptable risk to human and ecological receptors, this plan also includes monitoring in areas downgradient of the Laboratory and outside Laboratory boundaries (e.g., the Rio Grande and springs in White Rock Canyon).

Monitoring locations were initially derived from Table XII-5 of the Consent Order, but the current list of monitoring locations represents the most recent results of subsequent annual updates to the 2005 Interim Plan. The locations, analytical suites, and frequency of monitoring reflect the technical and regulatory status of each area-specific monitoring group.

The monitoring data collected under this plan are published in periodic monitoring reports submitted to NMED and analytical results are made available to the public in the Risk Analysis, Communication, Evaluation, and Reduction database (http://racernm.com). In addition, groundwater data collected by the Laboratory are reviewed monthly, and constituents exceeding any of the seven screening criteria laid out in the Consent Order, modified May 13, 2008, are reported monthly to the NMED Hazardous Waste Bureau.

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Plate

Plate 1 Monitoring Group Overview

1.0 INTRODUCTION

The 2011 Interim Facility-Wide Groundwater Monitoring Plan (hereafter, the Interim Plan) for Los Alamos National Laboratory (LANL or the Laboratory) fulfills the groundwater monitoring requirement in Section IV.A.3.b of the March 1, 2005, Compliance Order on Consent (Consent Order). Section IV.A.3.b requires the Interim Plan to be updated annually and anticipates that monitoring plans for specific areas will change as the groundwater investigation objectives in Section IV.A.3.a are met. The monitoring year (MY) for the Interim Plan is from October 1, 2011, to September 30, 2012. This revision of the Interim Plan will supplement the first quarter implemented under the initial 2011 Interim Plan and be in effect starting January 1, 2012.

Groundwater monitoring has been conducted at the Laboratory for over 60 yr, starting with U.S. Geological Survey (USGS) water-supply studies in 1945 and Laboratory groundwater quality monitoring in 1949. The first groundwater-monitoring network consisted of water-supply wells, several observation wells, and springs. The monitoring network continued to evolve through the years as various environmental investigations installed additional wells, primarily in the shallow alluvial systems, as potential monitoring points.

Between 1997 and 2005, the Laboratory implemented a sitewide hydrogeologic characterization program, described in the Laboratory's "Hydrogeologic Workplan" (LANL 1998, 059599). The primary objective of this characterization program was to refine the Laboratory's understanding of the area's hydrogeologic systems and to improve its ability to design and implement an integrated sitewide groundwater monitoring plan. Building upon information obtained from this and other programs, the Laboratory has subsequently refined the monitoring-network design and implementation through a series of monitoring-well network evaluation reports and the delineation of area-specific monitoring groups in this plan.

This plan consists of nine sections, including this introduction, with supporting appendixes. Sections 2 through 7 describe the monitoring and site activities conducted in six area-specific monitoring groups: Technical Area 21 (TA-21); chromium investigation; MDA C; MDAs G, H, and L at TA-54; TA-16 260 Outfall; and MDA AB. Section 8 describes general surveillance monitoring in seven major watersheds or watershed groupings: Los Alamos Canyon/Pueblo Canyon, Sandia Canyon, Mortandad Canyon, Pajarito Canyon, Water Canyon/Cañon de Valle, the combined watersheds of Ancho/Chaquehui/Frijoles Canyons, and White Rock Canyon/Rio Grande. Section 9 includes a list of references cited in this report and the map data sources.

Appendix A is the list of acronyms and abbreviations used in the report, a metric conversion table, and the definitions of data qualifiers. Appendix B presents screening results for data collected in the six area-specific monitoring groups and seven watershed groupings. Appendix C summarizes the methods and procedures used to conduct monitoring and the management of investigation-derived waste (IDW). Appendix D summarizes the objectives of the monitoring performed and the sampling frequencies and analytical suites for each monitoring group. Appendix E summarizes how field quality assurance (QA)/quality control (QC) results are used and the types of corrective actions that may be taken to address exceedances of target measures for each QA/QC sample type. Appendix F assesses the reliability of water-quality data collected from specific monitoring-network wells. Appendix G presents geologic cross-sections of the watersheds.

Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to the New Mexico Environment Department (NMED) in accordance with U.S. Department of Energy (DOE) policy.

1.1 Purpose

The Interim Plan will address monitoring to

- determine the fate and transport of known legacy-waste contaminants,
- detect the arrival of potential contaminants to groundwater from previous releases,
- evaluate efficacies of corrective-action remedies,
- support proposed corrective measures,
- meet groundwater discharge permit requirements, and
- meet the monitoring requirements of DOE Orders 436.1 and 458.1.

These objectives collectively assist the Laboratory in determining any potential adverse impacts to surface water and groundwater resulting from Laboratory operations.

In addition, monitoring produces data required to evaluate risk and to assess regulatory compliance. Although the Interim Plan does not specifically address how the data collected will be used in those evaluations, the design of the monitoring network is based on conceptual models of potential sources, hydrogeologic pathways, and receptors. The data collected are intended to be useful in meeting reporting requirements under the Consent Order.

This revised Interim Plan presents an increased focus of monitoring activities on area-specific monitoring groups and key analytes for TA-54, TA-21, MDA AB, MDA C, TA-16 260 Outfall, and the chromium investigation. Monitoring of alluvial wells and springs that show a history of nondetects, that are located near other springs being monitored, or that are located in outlying areas away from Laboratory operations will be discontinued under the new focused approach.

The scope of this focused monitoring approach includes the following key elements to ensure groundwater protection.

- *The spatial coverage of the current monitoring program will be maintained*. The monitoring footprint in perched-intermediate and regional wells at all monitoring groups is retained.
- *The selection of monitoring frequency and appropriate analytes will be tailored to each specific area.* The monitoring frequency for each monitoring group was selected based on the contamination status at each site, the rate of change in contaminant concentrations, the historical monitoring data, and the hydrogeological conditions governing contaminant fate and transport for the area.
- *The groundwater monitoring program will continue to be fully protective of the regional aquifer beneath the Pajarito Plateau and of water-supply wells.* Monitoring of key sentinel wells is maintained.
- *Monitoring of key alluvial monitoring wells and springs will continue.* The alluvial wells were selected at locations downgradient of ongoing Laboratory operations. Continued monitoring of these alluvial wells will enable detection of contaminant releases, should any occur.

Section 1.6 summarizes basic sets of analytical suites and frequencies for locations assigned to area-specific monitoring groups or to general surveillance monitoring in each watershed.

Updates to monitoring within each watershed or monitoring group, including changes in monitoring frequency, analytical suites, and monitoring locations, are based on the following:

- Summaries of contaminant frequency of detections (FDs) (Attachment B-1 in Appendix B on CD)
- Conceptual models in watershed investigation reports (IRs)
- Completed canyons investigations whose results show contributions to risk from surface water are low
- Reviews of existing analytical data and trends for individual watersheds
- Reviews of water-level data to identify wells that are consistently dry and are candidates for removal from the sampling plan (section 1.10)
- Changes to the monitoring-well networks over time, including the addition of newly installed monitoring wells, the rehabilitation and conversion of multiscreen wells, and the removal of wells recently plugged and abandoned or planned for plugging and abandonment in the near-term
- Monitoring objectives for the area-specific monitoring groups

1.2 Scope

The Interim Plan describes the objectives for monitoring, the locations of sampling stations, the frequency of sampling, the field measurements taken at each location, and the analytical suites included in the monitoring plan for each watershed or monitoring group.

Four occurrences of water are monitored in this plan:

- Base flow—persistent surface water that is maintained by precipitation, snowmelt, effluent, and other sources
- Alluvial groundwater—water within the alluvium in the bottom of the canyons
- Intermediate-perched groundwater—localized saturated zones within the unsaturated zone
- Regional groundwater—deep, laterally continuous groundwater beneath the Pajarito Plateau

Groundwater will be routinely monitored by collecting samples at wells and springs and by analyzing them for specific constituents. Groundwater monitoring refers to gathering data not only for water-quality analysis but also for water-level measurements. Water-level data are critical to understanding groundwater occurrence and movement and the responses of groundwater levels to recharge and to pumping of water-supply wells.

Surface water at the Laboratory is divided into the following three flow types:

- Base flow—persistent, but not necessarily perennial, stream flow. This stream flow is present for periods of weeks or longer. The water source may be effluent, springs, or shallow groundwater in canyons.
- Snowmelt—flowing water that is present because of melting snow. This type of water often may be present for several weeks or more (persistent) but in some years may not be present at all.
- Storm runoff—flowing water that is present in response to rainfall. These flow events are generally short-lived, with flows lasting from less than an hour to several days.

In some cases, depending on weather conditions, each flow type may be collected at a single location within a time span of a few days. At other times, the flow may represent a combination of these types.

Storm runoff and snowmelt monitoring is not addressed in this plan but rather through the National Pollutant Discharge Elimination System (NPDES) Individual Permit and under DOE Orders 436.1 and 458.1 for surveillance. Base flow (persistent water) and, in some cases, persistent flow derived from snowmelt are monitored under the Interim Plan.

Monitoring under the Interim Plan will take place in area-specific monitoring groups within seven major watershed groupings: Los Alamos Canyon/Pueblo Canyon, Sandia Canyon, Mortandad Canyon, Pajarito Canyon, Water Canyon/Cañon de Valle, the combined watersheds of Ancho/Chaquehui/Frijoles Canyons, and White Rock Canyon. Monitoring outside the Laboratory boundary is conducted to collect baseline data in areas that have been affected by past Laboratory operations (e.g., Guaje and Rendija Canyons) or that have not been affected by Laboratory operations. To ensure water leaving the Laboratory boundaries does not pose an unacceptable risk, this plan also includes monitoring in areas off-site that have the potential to be impacted by the Laboratory (e.g., the Rio Grande and springs in White Rock Canyon). Figure 1.2-1 shows the areas included in this Interim Plan.

The Interim Plan is updated annually to incorporate new information collected during the previous year. Locations, analytes, and sampling frequencies will be evaluated and updated as appropriate to ensure adequate monitoring and to ensure monitoring objectives for the individual monitoring groups continue to be met. Information gained through characterization efforts, aquifer test results, water-level monitoring, network assessments, and water-quality data will be used to refine the monitoring plan for each monitoring group. In addition, the need for sampling of analytes previously eliminated from sampling in various monitoring groups will be reevaluated during the development of the annual updates to the Interim Plan.

1.3 Reporting

The data collected under this Interim Plan are submitted to NMED in periodic monitoring reports (PMRs) in accordance with Section IV.A.6 of the Consent Order and per subsequent agreements with NMED on the frequency of reporting. The data in reports submitted to NMED are independently maintained and are made available to the public in the Risk Analysis, Communication, Evaluation, and Reduction (RACER) database as the data are received from the analytical laboratory (available at http://racernm.com/). Subject to the protocol stipulated in the memorandum of understanding (MOU) regarding the release of monitoring data collected from locations on Pueblo of San Ildefonso lands.

The PMRs present groundwater and base-flow data and are submitted to NMED in accordance with Consent Order requirements. Each PMR includes all available watershed monitoring data, along with the previous three rounds of data. In addition, groundwater data collected by the Laboratory are reviewed monthly, and constituents exceeding any of the seven screening criteria described in the Consent Order, modified May 13, 2008, are reported monthly to the NMED Hazardous Waste Bureau.

1.4 Regulatory Context

This Interim Plan fulfills groundwater monitoring requirements of the Consent Order as described in section 1.0. In addition to the Consent Order, the Laboratory is required to perform groundwater monitoring to satisfy other regulatory requirements, as summarized below. The Laboratory has an integrated approach to monitoring groundwater, and many of the other regulatory requirements discussed below are fulfilled through the implementation of the monitoring performed under the Interim Plan.

1.4.1 New Mexico Water Quality Control Commission Regulations

Currently, the TA-46 Sanitary Wastewater Systems (SWWS) Plant operates under a groundwater discharge permit (discharge plan number DP-857) issued by NMED pursuant to 20.6.2 New Mexico Administrative Code (NMAC). Sampling locations, monitoring frequencies, and reporting requirements are specified in the NMED-approved DP-857, under which the Laboratory conducts quarterly sampling at two NPDES outfalls, the SWWS Plant reuse wet well, and CdBO-6, an alluvial monitoring well located in Cañada del Buey. Monitoring under DP-857 began when the SWWS Plant opened in 1993 and is expected to continue indefinitely, with appropriate modifications made as discharge conditions change over time. The plan was renewed in 1998, and a second request for plan renewal was submitted to the NMED in 2002.

1.4.2 DOE Environmental Protection Programs

Groundwater monitoring has been conducted in compliance with DOE orders related to environmental protection. DOE Orders 436.1 and 458.1 require an environmental management system at DOE facilities that includes surveillance groundwater monitoring and reporting. Surveillance monitoring has been conducted at the Laboratory since the 1970s under previous DOE orders, and the results are documented in annual reports. Currently, the Laboratory conducts groundwater-surveillance monitoring from wells located within the Laboratory boundary and at off-site locations. These wells include alluvial, perched-intermediate, and regional aquifer wells. Some of the off-site monitoring is performed under cooperative agreements with Los Alamos County, which owns and operates water-supply wells within and near the Laboratory, and with the City of Santa Fe. Additional monitoring is performed under an MOU among DOE, the Bureau of Indian Affairs, and the Pueblo of San Ildefonso. The results of surveillance monitoring are reported in annual environmental reports and the RACER database. The environmental reports contain descriptions of the surveillance monitoring network, key results and trends, and the QA/QC program.

1.4.3 Hazardous Waste Facility Permit

Section III.W of the Consent Order describes the integration of the current and any future Hazardous Waste Facility Permits (hereafter, the Permits) with the Consent Order. All corrective action for releases of hazardous waste or hazardous constituents required by Sections 3004(u), 3004 (v), and 3008(h) of the federal Resource Conservation and Recovery Act (RCRA); Sections 74-4-4(A)(5)(h) and (i), 74-4-4.2(B) and 7-7-10(E) of the Hazardous Waste Act (HWA); and the federal and state implementing regulations at 40 Code of Federal Regulations (CFR) Part 264, Subpart F and 20.6.2.3103 NMAC shall be conducted solely under the Consent Order, with the following four exceptions:

1. New releases of hazardous wastes or hazardous constituents from operating units at the Laboratory;
2. Closure and postclosure care requirements as they apply to operating units at the Laboratory;
3. Implementation of controls, including long-term monitoring, for any solid waste management units (SWMUs) and areas of concern (AOCs) on the Permit's Corrective Action Complete with Controls list; and
4. Any releases of hazardous wastes or hazardous constituents that occur after the termination of the Consent Order.

Groundwater-monitoring requirements for SWMUs, AOCs, and regulated units that satisfy the alternative requirements provisions in 40 CFR 264.90(a)(2) are addressed under the groundwater-monitoring provisions of the Consent Order, including implementation of the Interim Plan.

1.5 Integration of Groundwater Monitoring at the Laboratory

All groundwater monitoring under the Interim Plan is conducted as an integrated activity that uses the same operating procedures, field sampling and analytical contracts, and data-management systems. For chemical analysis of water samples, the Laboratory uses commonly accepted analytical methods called for under federal regulations (such as the Clean Water Act) and approved by the U.S. Environmental Protection Agency (EPA). The Laboratory is responsible for obtaining analytical services that support monitoring activities. Samples for laboratory analysis are submitted to accredited contract laboratories. The analytical laboratory statement of work provides contract laboratories the general QA guidelines and includes specific requirements and guidelines for analyzing water samples. The contract laboratories are required to establish method detection limits (MDLs) and practical quantitation limits (PQLs) for target analytes.

Appendix C includes summaries of the procedures followed to measure water levels and collect water samples (sections C-1.0 and C-2.0) and to measure field parameters (section C-3.0). Field procedures follow guidelines from USGS water sample collection methods and industrial standards common to environmental sample collection and field measurements. The analytical methods, PQLs, and applicable background or screening levels used for each analyte are listed in section C-4.0. The management of IDW is discussed in section C-5.0.

1.6 Approach to Monitoring Network Design

The interim nature of this monitoring plan reflects an evolving monitoring network at the Laboratory. The groundwater data collected under this plan are used for subsurface characterization, groundwater monitoring network evaluation, and support of corrective measures.

For the 2010 Interim Plan, monitoring groups were established to address monitoring requirements for locations within specific project areas (LANL 2010, 109830). These monitoring groups are shown in Plate 1 and include the following (the watersheds in which the monitoring area is located are given in parentheses):

- TA-21 (Los Alamos Canyon)
- TA-54 (Pajarito and Mortandad Canyons)
- MDA C (Pajarito and Mortandad Canyons)
- Chromium investigation (Sandia and Mortandad Canyons)
- TA-16 260 Outfall (Pajarito and Water Canyons and Cañon de Valle)
- MDA AB (Ancho and Water Canyons)

Monitoring locations outside of the seven area-specific monitoring groups delineated above are included in a general surveillance monitoring group, which includes locations in all seven major watershed groupings (Los Alamos Canyon/Pueblo Canyon, Sandia Canyon, Mortandad Canyon, Pajarito Canyon, Water Canyon/Cañon de Valle, the combined watersheds of Ancho/Chaquehui/Frijoles Canyons, and White Rock Canyon).

The locations, analytical suites, and frequency of monitoring for each monitoring group reflect the state of knowledge for a given project area, including what contaminants have been released and the nature and extent of the contaminants released. Much of the information underlying the design of the monitoring plan is presented in IRs and is supported by the FD tables in Appendix B of this Interim Plan. Recommendations for the analytical suites for each watershed and locations within the watershed were determined by evaluating past Laboratory operations, investigation-derived information, and monitoring results. For this Interim Plan, updates to monitoring are made for all monitoring groups based on the adequacy of data to support the modifications to suite and the frequency. Data from 2005 to 2010 were screened to compare with one-half the lowest applicable standard (see Table 1.6-1). This period of record was selected for this version of the plan to provide a sufficiently robust data set to evaluate FD and time-series trends, if applicable. The analytical data screening results are summarized in tables in Attachment B-1 of Appendix B (on CD).

Table 1.6-2 summarizes analytical suites, and sampling frequencies for each type of sampling location (e.g., base flow, alluvial, intermediate, regional, or springs) within each area-specific monitoring group. Table 1.6-3 summarizes the analytical suites and sampling frequencies for general surveillance monitoring locations (locations not assigned to area-specific monitoring groups). In this sampling table, the northern locations (including Los Alamos/Pueblo, Sandia, and Mortandad Canyons) and the southern locations (including Pajarito, Water/Cañon de Valle, Frijoles, Ancho, and Chaquehui Canyons) are distinguished because the analytical suites differ, based primarily on the presence of high explosives (HE) in the southern canyons and their absence in the northern canyons. The analytical suites and frequencies are tailored to each watershed and sampling location based on the adequacy of the data record, the status of investigations and maturity of the conceptual model, the nature of watershed contaminant sources, and the history of detections, as documented in more detail in sections 2 to 8. Analytical suites assigned to existing (pre-2010) wells within watersheds and investigation areas are based on the results of applicable IRs and a review of ongoing monitoring data, as presented in the statistical summaries of detections in Attachment B-1 of Appendix B (on CD). The assignment of specific analytical suites to a well also reflects data needs for pending corrective measures evaluations (CMEs). Tables 1.6-2 and 1.6-3 also list characterization suites and sampling frequencies for newly installed wells (wells installed on or after October 1, 2010). New wells will be sampled for at least four rounds for the monitoring-group specific characterization suites for new wells presented in Tables 1.6-2 and 1.6-3.

Exceptions to the analytical suites and sampling frequencies presented in Tables 1.6-2 and 1.6-3 occur in some cases. These exceptions may be the result of a number of factors such as additional regulatory or permit requirements and sampling commitments outlined in the MOU with the Pueblo of San Ildefonso.

Exceptions to the default analytical suites and sampling frequencies may also be made for wells affected by residual drilling or construction products, recently rehabilitated wells, and other wells known to produce nonrepresentative water-quality data or for which the reliability of the data has not yet been established or may be questioned (Appendix F). Additionally, some wells may be monitored for a limited set of constituents tailored to address monitoring objectives or performance issues with the well.

Appendix D summarizes the sampling frequencies and analytical suites for each monitoring group and explains how the monitoring objectives are protective of groundwater.

1.7 Data-Screening Process

This section describes the process for screening the monitoring data. The purpose of the screening is to identify analytical parameters that guide the assignment of analytical suites and monitoring frequencies in each monitoring group.

The results of the screening for all locations in each monitoring group are used to update the monitoring for that group. The results of the data-screening process and statistical summaries are presented in Appendix B. The data-screening process consists of compiling the water-quality data set, determining detection status, screening the data against applicable standards, and producing summary statistics to identify constituents of potential concern in each watershed. Table B1-1 (groundwater) and Table B1-2 (surface water) in Attachment B-1 of Appendix B (on CD) present summary statistics for each water type and analytical suites based on data compiled for individual locations in Table B1-3 (groundwater) and Table B1-4 (surface water).

Table 1.6-1 presents the regulatory standards for the various water sample types by screening category. The data results were screened against the lowest applicable regulatory standard or risk-based value in the tables in Attachment B-1 of Appendix B. The standards that apply depend on the type of field preparation conducted during collection (filtered or unfiltered) and the type of the water (i.e., groundwater or persistent surface water). Each combination of water type/field preparation is referred to as a screening category. The standards for filtered samples are those applicable to the dissolved fraction, and standards for unfiltered samples are those applicable to the total concentration in nonfiltered samples. The terms “nonfiltered” and “unfiltered” are used interchangeably in this document.

For screening purposes, laboratory and field QC samples were removed from the statistical analysis. The detection status for an analytical result was established using the combined set of laboratory-assigned validation qualifiers and reason codes assigned during data validation (Appendix E).

The screening tables presented in Attachment B-1 of Appendix B (on CD) were used to identify constituents of potential concern and to optimize the monitoring strategy for each watershed. Groundwater and base-flow data from 2005 to 2010 are screened against one-half the lowest applicable regulatory standards or other risk-based screening levels (presented in Table 1.6-1) and against appropriate groundwater background values, if available. The screening tables are organized by contaminant type in each water type (e.g., spring, perennial base flow, regional aquifer) within each monitoring group.

The screening tables in Attachment B-1 include summary information such as the total number of samples collected for each analyte; the numbers of detections and nondetects; the minimum, mean, and maximum values for detections of each analyte; and comparisons with background values (if available) and with regulatory standards. The tables also list sampling locations where the lowest applicable regulatory standards are exceeded. Additional details regarding the screening tables are presented in the introduction to Appendix B.

1.8 Sampling Frequency and Schedule

The Interim Plan proposes monitoring frequencies for each monitoring group as described in the sampling tables in sections 2 through 8. For newly installed wells (i.e., those installed on or after October 1, 2010), the monitoring frequency and characterization suite are quarterly or semiannually for target analyte (TAL) metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), tritium, general inorganics, and perchlorate. Less mobile constituents for which there is no reasonable migration scenario to the regional aquifer (including pesticides, polychlorinated biphenyls [PCBs], and dioxins/furans) are no longer sampled in new deep wells completed in perched-intermediate groundwater or in the regional aquifer. HE compounds may be sampled quarterly or semiannually if known or suspected to be present.

Monitoring locations that are being used or are candidates for the determination of background water quality for the regional and perched-intermediate aquifers are indicated as such in the sampling table for each monitoring group.

The MY for the Interim Plan is from October 2011 to September 2012. This revision of the Interim Plan will supplement the first quarter implemented under the initial 2011 Interim Plan and will be in effect starting January 1, 2012. Table 1.8-1 presents a proposed sampling schedule. Following submittal of this Interim Plan to NMED, a finalized sampling schedule for each monitoring group or watershed will be established to ensure the monitoring frequency is met during the implementation year of the plan. A PMR for the periodic monitoring event conducted during first quarter of MY2012 (sampling conducted from October to December 2011) will be submitted on May 31, 2012. A PMR for second quarter of MY2012 (sampling conducted from January to March 2012) will be submitted on August 31, 2012. A PMR for the third quarter MY2012 (sampling conducted from April to June 2012) will be submitted on November 30, 2012. A PMR for the fourth quarter MY2012 (sampling conducted from July to September 2012) will be submitted on February 28, 2013.

The Consent Order requires all monitoring wells within a watershed be sampled within 21 d of the start of the groundwater sampling event. For the 2011 Interim Plan, monitoring groups for project areas have effectively replaced the watersheds, and monitoring for the individual monitoring groups, with the exception of the general surveillance monitoring group, will be completed within 21 d. Monitoring of the White Rock Canyon general surveillance group will be completed within 21 d. The other general surveillance locations will be monitored in conjunction with other monitoring activities at nearby locations or watersheds.

1.9 Water-Level Monitoring

The majority of monitoring wells sampled are equipped with pressure transducers to measure and record water levels to aid in understanding the hydrologic system. Pressure transducers are typically set to record on an hourly basis. Manual water-level measurements are also collected on a regular basis to verify the pressure transducer data.

The water-level data collected using the automated pressure transducers address the requirement of Section IX.B.2.h.i of the Consent Order to measure groundwater levels in all wells in a given watershed within 24 h. These data are available for any 24-h period and, therefore, meet the requirement for these measurements to be completed across all watersheds within 14 d of the commencement of the specified water-level measuring event as required by the Consent Order. Water levels are monitored in a number of wells and/or well screens that are not sampled under the Interim Plan to collect data to develop and validate the conceptual models (Table 1.9-1). Groundwater levels are also monitored in Los Alamos County water-supply wells in cooperation with Los Alamos County utilities personnel and in the Buckman Well Field in cooperation with the City of Santa Fe.

1.10 Wells That Are Historically Dry

Wells that are historically dry are generally no longer monitored for water levels, except for a few wells in key locations (Table 1.9-1). Wells that intermittently show water (in response to large snowmelt years or precipitation events) may continue to be monitored for water levels using transducers and will be sampled if sufficient water is present during their respective watershed's sampling campaign. New wells that are dry may be retained in the monitoring plan to evaluate potential wetting responses and temporal changes in water levels.

2.0 TA-21 MONITORING GROUP

2.1 Introduction

The TA-21 monitoring group is located in and around TA-21 and is primarily located in upper Los Alamos Canyon (Figure 2.1-1). The group includes monitoring wells completed in the perched-intermediate groundwater and in the regional aquifer.

TA-21 is located on the mesa north of Los Alamos Canyon, which is joined by DP Canyon, east of TA-21. TA-21 consists of two historically operational areas, DP West and DP East, both of which produced liquid and solid radioactive wastes. The operations at DP West included plutonium processing, while the operations at DP East included the production of weapons initiators and tritium research.

2.2 Background

The occurrence of surface water and alluvial, perched-intermediate, and regional groundwater in Los Alamos Canyon is discussed in detail in section 7.2 of the Los Alamos and Pueblo Canyons IR (LANL 2004, 087390).

In upper Los Alamos Canyon, perennial flow originates from springs and interflow through hillslope soils. The downgradient extent of perennial flow varies but generally terminates in the upper portions of Los Alamos Canyon west of TA-41. The remainder of upper Los Alamos Canyon down to the confluence with Pueblo Canyon is characterized by intermittent surface water flow that is seasonally dependent. Within the vicinity of TA-21, surface water occurs predominantly as ephemeral flow in Los Alamos and DP Canyons. Ephemeral surface water flows generally occur during runoff associated with thunderstorms and snowmelt.

In the vicinity of TA-21, alluvial groundwater occurs in Los Alamos Canyon and in stretches of DP Canyon. DP Canyon is typical of other dry canyons (Birdsell et al. 2005, 092048) based on its small drainage area and low-elevation headwaters. However, it previously received effluent discharges operations at TA-21 [SWMU 21-011(k)]. It currently receives surface runoff from paved parking lots and roadways from within the Los Alamos townsite. These townsite runoff sources contribute to locally persistent alluvial groundwater beneath parts of the canyon floor, specifically the portion adjacent to TA-21. There, alluvial deposits are thin (approximately 2 m [6 ft]) and are periodically recharged by surface water flows that reach this part of the canyon. Surface water infiltrates the canyon bottom alluvial sediments until its downward movement is impeded by strata of lower permeability, typically welded tuff at the top of unit Qbt 2 of the Tshirege Member. Despite the episodic nature of surface water flow and thin nature of the alluvial deposits, transducer readings at alluvial well LAUZ-1 indicate the alluvium in this part of the canyon was continuously saturated from January 2008 to January 2010 (Koch and Schmeer 2010, 108926), suggesting the underlying welded tuffs are an effective perching horizon that inhibits deeper infiltration.

Appendix D of the Technical Area 21 Groundwater and Vadose-Zone Monitoring Well Network Evaluation and Recommendations report (LANL 2010, 109947) describes known occurrences of intermediate-perched water beneath Los Alamos and Pueblo Canyons. Perched-intermediate zones nearest TA-21 are shown on the geologic cross-sections presented in Appendix G.

Perched-intermediate groundwater beneath Los Alamos and Pueblo Canyons results from infiltration of surface water and alluvial groundwater derived from snowmelt and seasonal rainfall. Surface water in Pueblo Canyon was previously augmented by effluent released from the Pueblo Canyon wastewater treatment plant (WWTP) from 1951 to 1991 and the Central WWTP from 1947 to 1961. Perched-

intermediate groundwater beneath lower Pueblo Canyon includes contributions of canyon-floor effluent infiltration from the Bayo WWTP that operated from 1963 to 2007 and the Los Alamos WWTP that began operations in 2007.

The most significant perched-intermediate groundwater in the vicinity of TA-21 occurs within the Guaje Pumice Bed and the underlying Puye Formation beneath Los Alamos Canyon. Near TA-21, saturated thicknesses for these occurrences range from about 9 ft at LADP-3 to more than 31 ft at LAOI-3.2a. The depth to perched-intermediate groundwater ranges from 124 ft to 746 ft. These perched groundwater occurrences are probably part of a larger integrated system that extends over 3.5 mi along the axis of Los Alamos Canyon from H-19 to LAOI-3.2 and LAOI-3.2a and may extend locally to the south (Appendix G).

Based on these observations, it appears an important control of intermediate-zone groundwater flow in the vicinity of TA-21 is the contact between the Guaje Pumice Bed and the underlying Puye Formation. Structure contours indicate the downdip direction for the base of the Guaje Pumice Bed is towards the south, southeast, and southwest in the vicinity of TA-21. The control exerted on groundwater flow by the Guaje Pumice Bed suggests that perched water beneath Los Alamos Canyon should move generally southward away from TA-21.

The occurrence of thicker perched-intermediate zones in the eastern part of Los Alamos Canyon may be the result of enhanced infiltration where the canyon floor is underlain by Cerros del Rio basalts rather than by the Bandelier Tuff. Because the Cerros del Rio basalt does not extend as far west as the developed portion of TA-21, it is unlikely the eastern perched zones of Los Alamos Canyon extend beneath the TA-21 area. No perched-intermediate groundwater has been encountered to date during drilling on DP Mesa.

The regional aquifer includes confined and unconfined zones. The shallow portion of the regional aquifer is predominantly unconfined, and the deeper portion of the aquifer is predominantly confined. Groundwater flow in the shallow portion of the regional aquifer generally follows the gradient of the water table. The deep portion of the regional aquifer is predominantly under confined conditions that are affected by Pajarito Plateau water-supply pumping.

In the vicinity of TA-21, the upper surface of the regional aquifer is located in the Puye Formation and in the Santa Fe Group. The depths to water range from 707 ft to 1159 ft below ground surface (bgs) (Koch and Schmeer 2011, 201566). The regional aquifer beneath the east end of DP Mesa occurs at a depth of 1159 ft bgs, based on water levels measured in well R-6. Shallow regional groundwater in the vicinity of TA-21 generally flows to the east-northeast.

Contaminant Sources and Distributions

Primary sources of contaminants in the vicinity of the TA-21 monitoring group include SWMU 21-011(k), the adsorption beds and disposal shafts at MDA T, DP West, and waste lines and sumps. Other potential sources include DP East and a diesel spill.

Mobile contaminants, such as tritium, nitrate, and perchlorate, released at the SWMU 21-011(k) outfall have dispersed down DP and Los Alamos Canyons by surface water and alluvial groundwater. They are present in perched-intermediate groundwater near the confluence of DP and Los Alamos Canyons (at wells R-6i, LAOI-3.2, and LAOI-3.2a), farther down Los Alamos Canyon (at LAOI-7 and R-9i), and beneath Mesita de Los Alamos (at R-53i).

The lower reach of DP Canyon is the likely infiltration location for mobile contaminants such as tritium, nitrate, and perchlorate that are detected in perched groundwater at R-6i, LAOI-3.2, and LAOI-3.2a. Infiltration at the confluence with DP Canyon (near wells LAOI-3.2/LAOI-3.2a) may be further enhanced by surface water runoff and alluvial groundwater in Los Alamos Canyon, contributing to the deeper, perched-intermediate zones observed beneath the confluence of the two canyons. The zones of perched-intermediate groundwater occur within the Guaje Pumice Bed and the underlying Puye Formation near the confluence of the two canyons.

Contaminant concentrations are at background levels in regional groundwater monitoring wells in the near vicinity of TA-21 (e.g., R-6, R-8, and R-64), suggesting deep infiltration through the vadose zone, including migration from perched groundwater, does not reach the regional aquifer near TA-21. This observation is also supported by the absence of tritium in the regional screen in R-7, although the absence of nitrate and perchlorate at this location is not conclusive because of reducing conditions in the screened interval that may be attributed to residual organic drilling products. The regional aquifer at Test Well (TW) 3 shows levels of contamination above background, but this may be related to leakage around the well casing from the absence of annular seal in this older well. The well is scheduled to be plugged and abandoned. Tritium and perchlorate are slightly elevated in the regional aquifer at R-9, which is located farther down Los Alamos Canyon. These far-field contaminants may have originated at SWMU 21-011(k).

2.3 Monitoring Objectives

The monitoring objectives for the TA-21 monitoring group presented in this Interim Plan are based in part on the results and conclusions presented in the Los Alamos and Pueblo Canyons IR (LANL 2004, 087390) as well as on the NMED-approved Los Alamos and Pueblo Canyons Groundwater Monitoring Well Network Evaluation and Recommendations, Revision 1 (LANL 2008, 101330).

Sampling over the last few years has generated a substantial data set from perched-intermediate and regional groundwater wells located in and next to Los Alamos Canyon. Data from these wells indicate the importance of lateral migration of perched-intermediate groundwater and regional groundwater flow directions. This information can lead to a groundwater monitoring domain that may extend beyond the footprint of a watershed where the initial release occurred.

Monitoring for TA-21 is focused on intermediate-perched and regional wells surrounding the TA-21 area that monitor for potential releases from mesa-top sites and the fate of mobile constituents historically released into DP Canyon from SWMU 21-011(k). The key constituents detected in nearby perched-intermediate and regional groundwater wells include nitrate, perchlorate, and tritium. Base-flow and alluvial-groundwater wells near and downgradient of TA-21 are not part of the TA-21 monitoring group because the source(s) of constituents detected in these wells is terminated or controlled and residual concentrations are stable, declining, or no longer present.

2.4 Scope of Activities

Active monitoring locations in the TA-21 monitoring group include intermediate-perched groundwater wells and regional groundwater wells, which are shown in Figure 2.1-1. All the monitoring locations are in the Los Alamos Canyon/Pueblo Canyon watershed.

Table 2.4-1 presents sampling locations, the rationale for these locations, analytical suites, and frequencies for the TA-21 monitoring group. Analytical suites and frequencies assigned to individual locations listed in Table 2.4-1 generally follow the high-level monitoring design presented in Table 1.6-2 for the TA-21 monitoring group. These analytical suites and frequencies are based on the results of

applicable IRs and a review of ongoing monitoring data, such as the statistical summaries for locations in the TA-21 monitoring group provided in the FD screening tables in Attachment B-1 of Appendix B (on CD).

Exceptions to the analytical suites and sampling frequencies presented in Table 1.6-2 may occur for some locations listed in Table 2.4-1. The majority of the wells in the TA-21 monitoring group are sampled annually. New wells R-64 (completed July 11, 2011) and R-66 (following installation of its sampling system) will be sampled quarterly. The objectives for the sampling frequency and analytical suites are presented in Table D-1.

3.0 CHROMIUM INVESTIGATION MONITORING GROUP

3.1 Introduction

The chromium investigation monitoring group is located in Sandia and Mortandad Canyons (Figure 3.1-1). Monitoring focuses on the characterization and fate and transport of chromium contamination in perched-intermediate groundwater and within the regional aquifer. The distribution of wells in the monitoring group also addresses historical releases from Outfall 051, which discharges from the Radioactive Liquid Waste Treatment Facility (RLWTF) in the Mortandad Canyon watershed. Effluent volumes were considerably reduced in 2010 and 2011 because process changes at the RLWTF have significantly reduced discharges to the outfall.

Sandia Canyon heads on Laboratory property within TA-03 at an elevation of approximately 7300 ft and trends east-southeast across the Laboratory, Bandelier National Monument, and San Ildefonso Pueblo. Sandia Canyon empties into the Rio Grande in White Rock Canyon at an elevation of 5450 ft. The area of Sandia Canyon watershed is approximately 5.5 mi^2. The head of the canyon is located on the Pajarito Plateau at TA-03. Perennial stream flow and saturated alluvial aquifer conditions occur in the upper and middle portions of the canyon system because sanitary wastewater and cooling tower effluent discharge to the canyon from operating facilities. A wetland of approximately 7 acres has developed as a result of the wastewater and cooling tower effluent discharge. The only known perennial spring in the watershed (Sandia Spring) is located in lower Sandia Canyon near the Rio Grande. TAs located in the Sandia Canyon watershed include TA-03, TA-53, TA-60, TA-61, TA-72, and former TA-20. A total of 264 SWMUs and AOCs are located within these TAs.

Mortandad Canyon is an east-to-southeast trending canyon that heads on the Pajarito Plateau near the main Laboratory complex at TA-03 at an elevation of 7380 ft (Figure 1.2-1). The drainage extends about 9.6 mi from its headwaters to its confluence with the Rio Grande at an elevation of 5440 ft. The canyon crosses Pueblo of San Ildefonso land for several miles before joining the Rio Grande (LANL 1997, 056835). The Mortandad Canyon watershed is located in the central portion of the Laboratory and covers approximately 10 mi^2. Pueblo of San Ildefonso lies immediately next to a portion of the Laboratory's eastern boundary and includes the eastern end of Mortandad Canyon. The Mortandad Canyon watershed contains several tributary canyons that have received contaminants released during Laboratory operations. The most prominent tributary canyons include Ten Site Canyon, Pratt Canyon, Effluent Canyon, and Cañada del Buey.

3.2 Background

Sources of surface water in the Sandia watershed are currently dominated by effluent releases. Effluent water releases to Sandia Canyon have occurred since the early 1950s and continue today, with the primary source being treated sanitary wastewater and steam plant discharges at Outfall 001 and lesser

sources being cooling tower blowdown. Data from 2007 and 2008 indicate the NPDES outfalls contribute approximately 75% of the total surface water flow in Sandia Canyon, with stormwater runoff and snowmelt contributing the remainder (LANL 2008, 102996, Appendix C).

The long-term discharges and runoff support a wetland near the head of Sandia Canyon. Persistent surface flow occurs through the wetland and into the narrow, bedrock portion of the upper canyon. Surface water flows past gage E124 typically only during times of high alluvial groundwater levels, increased effluent volume, or during stormwater runoff events.

Surface water in Mortandad Canyon is ephemeral and occurs infrequently in lower Mortandad Canyon. Effluent releases from the RLWTF have historically supported surface water in middle Mortandad Canyon, but those contributions are currently minimal. The lower canyon is characterized by a broad flat canyon floor with an indistinct drainage channel. It contains thick alluvial deposits (up to 30 m [100 ft]) that rapidly accommodate the rare surface water flows that reach this part of the canyon. Surface water is rarely observed below the confluence with Ten Site Canyon.

Alluvial groundwater in Sandia Canyon is recharged daily by surface-water flow, largely supplied by effluent from Outfall 001 and periodically by stormwater. This groundwater generally accumulates in the lower part of the alluvial deposits that fill the canyon bottom, most often perching on or within shallow bedrock units. The alluvial groundwater body extends farther downcanyon (roughly more than 1 km [0.6 mi] farther east) than do the daily stream-flow events. Alluvial saturation occurs approximately between alluvial wells SCA-2 and well SCA-5, with the most persistent perched alluvial groundwater occurring between alluvial wells SCA-2 and SCA-4.

In Mortandad Canyon (LANL 2006, 094161), alluvial groundwater storage is limited in the upper reaches but increases downcanyon in wider, thicker alluvial deposits (LANL 2006, 094161). Small outfall and runoff sources in upper Effluent Canyon create localized areas of surface water and possibly minor alluvial groundwater. The extent of alluvial saturation in Mortandad Canyon is historically variable and depends primarily on variations in runoff and effluent volume; the extent has decreased recently with the decrease of effluent from RLWTF.

A zone of perched-intermediate groundwater occurs within the Puye Formation on top of the Cerros del Rio basalt between well SCI-1 and borehole SCC-4, where it ranged from approximately 1 ft to 25 ft thick, and generally thinned to the west. This perched zone is probably recharged by percolation of alluvial groundwater through the underlying bedrock units before perching on top of the basalt. The perching layer for this perched-intermediate groundwater is the top of the Cerros del Rio basalt. A local depression occurs in the upper basalt surface in the vicinity of nearby well SCI-2, which may control the accumulation of perched water in this area. The top of the Cerros del Rio basalt also acts as a perching horizon at perched-intermediate wells MCOI-4 and MCOBT-4.4 in Mortandad Canyon, indicating this contact has favorable characteristics for perching groundwater over a wide area.

A second perched-intermediate zone is penetrated by well SCI-2 within fractured lavas and interflow breccias in the lower part of the Cerros del Rio basalt. The thickness of the perched zone is uncertain but ranges between 45 ft and 100 ft. The lava flows hosting the perched groundwater at well SCI-2 were deposited over a south to south-southeast dipping surface that developed on top of the Puye Formation. The nature of the perching horizon at the base of these basalts is poorly understood but may include relatively impermeable sedimentary rock of the Puye Formation and clay altered flow-base volcanic sediment at the base of the Cerros del Rio basalt that occurs at a depth of 629 ft (LANL 2009, 105296).

Lack of perched water in the Cerros del Rio basalt at wells R-28 and R-42 in Mortandad Canyon may indicate that the perched groundwater drained from the basalts and infiltrated the underlying Puye Formation, eventually reaching the regional aquifer in the area between wells SCI-2 and R-28/R-42.

During drilling of well R-10a, intermediate-perched groundwater was encountered between 330 ft and 370 ft depth in silts and arkosic sands sandwiched between thick massive lavas of the Cerros del Rio basalt. The water level in this zone was 304 ft, indicating the groundwater was confined. Well R-10a and its companion well R-10 were completed in the regional aquifer. However, perched-intermediate groundwater was not encountered at regional wells R-11, R-35a, R-35b, R-36, R-28, R-44, or R-45, indicating that the perched zones at wells SCI-1 and SCI-2 are not connected with those observed in R-12 and R-10/10a. The inferred connection between the perched-intermediate systems at wells R-10/10a and R-12 is based on their similar settings within the Cerros del Rio basalt, their similar groundwater elevations, and their relatively close proximity.

The regional aquifer beneath Sandia Canyon (and canyons to the north and south) includes confined and unconfined zones. The shallow portion of the regional aquifer is predominantly unconfined, and the deeper portion of the aquifer is predominantly confined. Groundwater flow in the shallow portion of the regional aquifer generally follows the gradient of the water table. Groundwater flow and water levels within the deeper portion of the regional aquifer are impacted by water-supply pumping, with the largest fluctuations in water levels observed at well R-35a, located close to water supply well PM-3.

In the vicinity of the chromium investigation monitoring group, the water table is located in the Puye Formation and in the Santa Fe Group.

Contaminant Sources and Distributions

Chromium concentrations exceed NMED groundwater standards and EPA maximum contaminant levels (MCLs) in the regional aquifer at wells R-28, R-42, and R-50 located in Mortandad Canyon. Other constituents observed above background in wells in the monitoring group include nitrate, perchlorate, and tritium. A conceptual model for the sources and distribution of these contaminants is presented in the Investigation Report for Sandia Canyon (hereafter, the Sandia Canyon IR) (LANL 2009, 107453). The Sandia Canyon IR presents the results of all the chromium and related studies conducted to date to address the nature and extent and the fate and transport of chromium and other contaminants originating in the Sandia Canyon watershed.

The conceptual model hypothesizes that chromium and other contaminants originate from releases into Sandia Canyon with lateral migration pathways that move contamination to locations beneath Mortandad Canyon. For this reason, perched-intermediate and regional wells beneath Mortandad Canyon are included in the chromium investigation monitoring group. Other sources of contamination beneath Sandia and Mortandad Canyons are from Mortandad Canyon sources, particularly historical releases from the RLWTF outfall. Lateral migration from Los Alamos Canyon sources appears to also be detected in the chromium monitoring group. These sources and the migration pathways are described in the Sandia Canyon IR (LANL 2009, 107453).

3.3 Monitoring Objectives

The objective of the chromium investigation monitoring group is to further refine the nature and extent of contamination originating from various sources principally within Sandia and Mortandad Canyons, and to monitor the fate and transport of observed contaminants. For the past 6 yr, the monitoring in and beneath Sandia Canyon and adjacent canyons has focused on acquiring a fundamental understanding of the

nature and extent of contaminants originating in the Sandia Canyon watershed, with an emphasis on chromium contamination because its concentration exceeds groundwater standards in the regional aquifer. This work has been coupled with sediment and biota investigations to refine the conceptual model for the fate and transport of contaminants. Several new wells have also been installed and have been undergoing initial characterization monitoring on a quarterly basis.

Base-flow locations and alluvial wells in Sandia Canyon are excluded from the chromium monitoring group because the primary contaminants of concern are at low and very stable concentrations in these media (LANL 2009, 107453). In Mortandad Canyon, contaminants in the surface water and alluvial groundwater have shown a marked decrease in concentration as a result of improvements in the treatment processes at the TA-50 RLWTF (see Figures 7.2-17, 7.2-18, and 7.2-25 in the Mortandad Canyon IR [LANL 2006, 094161]). The steadily decreasing trend of the contaminant concentrations in the surface water and alluvial groundwater supports inclusion of the locations within the general surveillance monitoring group (section 8.0). These data should provide sufficient information to continue verifying the decreasing trends in contaminant concentrations in alluvial groundwater.

Perched-intermediate and regional wells in Mortandad Canyon are included in the chromium investigation monitoring group because they are located along the contaminant-transport pathway that includes the southerly diversion of groundwater within the vadose zone beneath Sandia and Mortandad Canyons. The predominant contaminants monitored in this group of wells include chromium, other metals, nitrate, perchlorate, 1,4-dioxane, and tritium. The monitoring recommendations for perched-intermediate and regional groundwater beneath Mortandad Canyon reflect the updated conceptual model for these zones as presented in the Sandia Canyon IR (LANL 2009, 107453).

3.4 Scope of Activities

Active monitoring locations in the chromium investigation monitoring group include perched-intermediate and regional aquifer wells, which are shown in Figure 3.1-1. The monitoring group includes locations in Sandia Canyon as well as in Mortandad Canyon.

Table 3.4-1 presents sampling locations, the rationale for these locations, analytical suites, and monitoring frequencies. Analytical suites and frequencies assigned to individual locations in Table 3.4-1 generally follow the high-level monitoring design presented in Table 1.6-2 for the chromium investigation monitoring group. These analytical suites and frequencies are based on the results of applicable IRs and a review of ongoing monitoring data, such as the statistical summaries for locations in the Sandia and Mortandad Canyon watersheds provided in the FD screening tables in Attachment B-1 of Appendix B (on CD).

Following submittal of the Sandia Canyon IR (LANL 2009, 107453), more intensive monitoring is now focused on the perched-intermediate and regional groundwater, with an emphasis on chromium and general inorganic chemicals (particularly nitrate), as presented in Table 1.6-2. The sampling frequency for the wells in the chromium monitoring group is based primarily on the chromium concentrations compared with groundwater standards. Wells with concentrations exceeding standards are sampled quarterly, well with concentrations above background levels but below standards are sampled semiannually, and wells with concentrations at background levels are sampled annually. New well R-62 will be sampled quarterly after the sampling system is installed. Exceptions to the analytical suites and sampling frequencies presented in Table 1.6-2 may occur for some locations listed in Table 3.4-1. The objectives for the sampling frequency and analytical suites are presented in Table D-1.

4.0 MDA C MONITORING GROUP

4.1 Introduction

The MDA C monitoring group includes nearby regional monitoring wells on the mesa top and in Mortandad Canyon (Figure 4.1-1). MDA C is located on Mesita del Buey in TA-50, at the head of Ten Site Canyon. TA-50 is bounded on the north by Effluent and Mortandad Canyons, on the east by the upper reaches of Ten Site Canyon, on the south by Twomile Canyon, and on the west by TA-55.

MDA C is an inactive 11.8-acre landfill consisting of 7 disposal pits and 108 shafts. Solid low-level radioactive wastes and chemical wastes were disposed of in the landfill between 1948 and 1974. The depths of the seven pits at MDA C range from 12 ft to 25 ft below the original ground surface. The depths of the 108 shafts range from 10 ft to 25 ft below the original ground surface. The original ground surface is defined as beneath the cover that was placed over the site in 1984. The pits and shafts are constructed in the Tshirege Member of the Bandelier Tuff. The regional aquifer is estimated to be approximately 1330 ft deep based on the water level in well R-46 (LANL 2009, 105592). The topography of MDA C is relatively flat, although the slope steepens to the north where the northeast corner of MDA C abuts the south wall of Ten Site Canyon.

4.2 Background

MDA C is located on a mesa top, so no shallow alluvial groundwater is present in the immediate vicinity. The nearest surface water is found in Effluent Canyon to the north and in Pajarito Canyon and Twomile Canyon to the south.

No perched groundwater or intermediate-depth saturated horizons were encountered during previous investigations at MDA C (LANL 1998, 059599; LANL 2005, 091493, p. 6) or in any of the boreholes drilled during the Phase III investigation at MDA C (LANL 2011, 204370). No perched groundwater was encountered during the drilling of regional wells R-46 or R-60.

Regional monitoring wells R-46 and R-60 are located downgradient of MDA C (Figure 4.1-1) (LANL 2009, 105592; LANL 2011, 111798). The upper surface of the regional aquifer is located within the lower Puye Formation or the upper pumiceous deposits of the Santa Fe Group, and the depths to water range from approximately 1320 ft to 1330 ft bgs (Koch and Schmeer 2011, 201566). Near MDA C, the direction of shallow groundwater flow in the regional aquifer is to the east-southeast.

Contaminant Sources and Distributions

Vapor-phase VOCs and tritium are present in the upper 500 ft of the unsaturated zone beneath MDA C (LANL 2011, 204370). The primary vapor-phase contaminants beneath MDA C are trichloroethene (TCE), tetrachloroethene, and tritium. There is no evidence of groundwater contamination in the regional aquifer (Attachment B-1 of Appendix B of this report). MDA C is located on a mesa top above thick, unsaturated units of the Bandelier Tuff, and therefore present-day aqueous-phase transport is generally believed to be minimal.

4.3 Monitoring Objectives

Monitoring objectives for the MDA C monitoring group are to supplement existing vadose zone pore-gas monitoring to refine and nature and extent of contamination and assess the fate and transport of the current vadose zone contaminant distribution. The monitoring will also support upcoming CME activities.

4.4 Scope of Activities

The MDA C Area monitoring group consists of three regional groundwater monitoring wells, R-14, R-46, and R-60, as shown in Figure 4.1-1. Table 4.4-1 presents sampling locations, the rationale for these locations, analytical suites, and frequencies for the MDA C monitoring group. Analytical suites and frequencies assigned to individual locations listed in Table 4.4-1 generally follow the high-level monitoring design presented in Table 1.6-2 for the MDA C monitoring group. These analytical suites and frequencies are based on the results of applicable IRs and a review of ongoing monitoring data, such as the statistical summaries for locations in the MDA C monitoring group provided in the FD screening tables in Attachment B-1 of Appendix B (on CD).

Exceptions to the analytical suites and sampling frequencies presented in Table 1.6-2 may occur for some locations listed in Table 4.4-1. The wells in the MDA C monitoring group are sampled semiannually. The objectives for the sampling frequency and analytical suites are presented in Table D-1.

5.0 TA-54 MONITORING GROUP

5.1 Introduction

At TA-54, groundwater monitoring is being conducted to support both the corrective measures process for SWMUs and AOCs (particularly the MDAs G, H, and L) under the Consent Order and in support of the RCRA permit. The TA-54 monitoring group was established to address the monitoring requirements for all portions and aspects of TA-54 (Figure 5.1-1). The TA-54 monitoring group includes both perched-intermediate and regional wells in the near vicinity. Other downgradient wells have general relevance to TA-54 and other upgradient sources but are not considered part of the TA-54 monitoring network and are not discussed in this section.

TA-54 is situated in the east-central portion of the Laboratory on Mesita del Buey. TA-54 includes four MDAs designated as G, H, J, and L; a waste characterization, container storage, and transfer facility (TA-54 West); active radioactive waste storage and disposal operations at Area G; hazardous and mixed-waste storage operations at Area L; and administrative and support areas. The transfer facility is located at the western end of TA-54. MDAs H and J are located approximately 500 ft and 1000 ft (150 m and 305 m) southeast of the transfer facility, respectively. MDA L is located approximately 1 mi (1.6 km) southeast of the transfer facility. MDA G subsurface units are located within Area G approximately 0.5 mi (0.8 km) southeast of MDA L.

Mesita del Buey is a 100-ft to 140-ft-high finger-shaped mesa that trends southeast. The elevation of Mesita del Buey ranges from 6750 ft to 6670 ft at Area G. The mesa is approximately 500 ft wide and is bounded by the basin of Cañada del Buey (450 ft to the north) and the basin of Pajarito Canyon (360 ft to the south) (Figure 5.1-1).

5.2 Background

The TA-54 monitoring group is located predominantly in the Pajarito Canyon watershed, and the occurrence of surface water, alluvial groundwater, and perched-intermediate and regional groundwater is discussed in detail in section 7.2 of the Pajarito Canyon IR (LANL 2009, 106939).

Sources of surface water in the Pajarito watershed currently include snowmelt, stormwater runoff, and discharges at several springs. Perennial surface water flow within the TA-54 monitoring group area occurs in within Pajarito Canyon.

The primary alluvial groundwater body in Pajarito Canyon extends east from below the confluence with Twomile Canyon to approximately regional well R-23, a distance of 4.4 mi (7 km). Spatially restricted bodies of alluvial groundwater are also present west of the Twomile Canyon confluence and extend upcanyon to springs in the south fork of Pajarito Canyon (Upper Starmer Spring) and Pajarito Canyon above the south fork confluence (Homestead Spring). The alluvial groundwater is recharged by stream flow and some local precipitation. It accumulates in the alluvial deposits that fill the canyon bottom, often perching on shallow bedrock units. The alluvial groundwater extends farther down canyon than does stream flow because some downcanyon, lateral flow occurs within the alluvium. Alluvial groundwater acts as a source of infiltrating water into the deeper tuff units and transiently into the Cerros del Rio basalt, which is very near the surface at well R-23. The extent of this groundwater helps define deeper infiltration zones within the canyon. Overall, lateral flow within the alluvium and deeper infiltration of alluvial groundwater into underlying bedrock may provide a driving force for subsurface transport of soluble contaminants along the length of the canyon and into the deeper subsurface.

Perched-intermediate groundwater occurs in a variety of settings beneath the Pajarito watershed. Occurrences are known from deep groundwater investigations and from more localized SWMU investigations. Intermediate-perched horizons are present in the Bandelier Tuff in the upper portion of the watershed and in the Cerro Toledo interval, Puye Formation, dacitic lavas, and Cerros del Rio lavas in the middle and lower portions of Pajarito Canyon. The location and nature of most of these occurrences are consistent with, and indicative of, known or suspected canyon reaches with higher infiltration, such as nearby wells R-17 and R-23. At well R-37, relic regional groundwater may have become disconnected or stranded from the current regional groundwater as drawdown associated with water-supply production has occurred. There is no indication that the perched-intermediate zones are laterally continuous over large areas.

In the vicinity of TA-54, perched-intermediate groundwater occurs in wells R-55, R-55i and R-23/R-23i (LANL 2003, 079601; Kleinfelder 2006, 092495; LANL 2011, 111611) at depths ranging from 406 ft to 498 ft bgs. Perched-intermediate groundwater also occurs in wells R-40/40i and R-37 (LANL 2009, 106432; LANL 2009, 107116) at depths ranging from 639 ft to 909 ft. This water is thought to be localized beneath the canyon floor, and to result from localized canyon floor infiltration.

The regional aquifer in the vicinity of TA-54 includes confined and unconfined zones. The shallow portion of the regional aquifer is predominantly unconfined, and the deeper portion of the aquifer is predominantly confined. Groundwater flow in the shallow portion of the regional aquifer is generally eastward beneath the western section of Pajarito watershed and southeastward beneath the eastern section of Pajarito watershed. In the vicinity of TA-54, the upper surface of the regional aquifer is located within the Cerros del Rio basalts and the underlying sediments of the Puye Formation, and the depths to water range from 785 to 1020 ft bgs (Koch and Schmeer 2011, 201566).

Groundwater flow in the upper part of the regional aquifer beneath TA-54 appears to be substantially impacted by the Cerros del Rio lavas (LANL 2010, 111362). These lavas are more than 150 ft thick beneath the regional water table. Groundwater flow in the regional aquifer beneath TA-54 is impacted by (1) water-supply pumping, (2) the local-scale infiltration recharge along Pajarito Canyon, (3) the lateral propagation of large-scale mountain-front aquifer recharge occurring to the west of TA-54, and (4) the discharge of the regional aquifer to the southwest towards the White Rock Canyon springs and the Rio Grande.

Contaminant Sources and Distributions

Pore-gas monitoring data show that vapor-phase transport of contaminants occurs in the upper portion of the unsaturated zone, and that vapor-phase VOCs are present beneath MDAs G and L. The primary contaminants that have transported in the vapor phase at TA-54 are 1,1,1-trichloroethane (1,1,1,-TCA); TCE; Freon-113; and tritium (LANL 2005, 090513; LANL 2006, 091888; LANL 2007, 096409).

Data from the groundwater monitoring network around TA-54 show sporadic detections of a variety of contaminants including, most notably, several VOCs. The temporal and spatial nature of the occurrences do not, however, clearly indicate the presence of a source related to potential sources at TA-54 (LANL 2009, 106939). Further evaluations of existing groundwater data near TA-54, and detailed descriptions of organic and inorganic contaminants detected in perched-intermediate and regional groundwater at TA-54 are presented in the CMEs for MDAs G, H, and L (LANL 2011, 205756; LANL 2011, 206319; LANL 2011, 206324).

5.3 Monitoring Objectives

Monitoring at TA-54 focuses on perched-intermediate and regional groundwater zones beneath TA-54 (Figure 5.1-1). The monitoring suite for perched-intermediate and regional groundwater addresses RCRA monitoring requirements and also reflects the data collected to date from wells in the TA-54 network.

Characterization of groundwater under MDAs G, H, and L is underway as data are collected from the completed network of new and existing wells. Groundwater monitoring for TA-54 is conducted with perched-intermediate well screens at R-40i, R-40 screen 1, R-23i, and R-37 screen 1, R-55i and regional wells: R-20, R-21, R-22, R-23, R-32, R-37, R-38, R-39, R-40, R-41, R-49, R-51, R-52, R-53, R-54, R-55, R-56, and R-57 (Figure 5.1-1). R-22 is not currently being sampled. The actively sampled wells have one or two screens, all of which are equipped with purgeable sampling systems.

The monitoring at TA-54 provides the basis for accurately describing the groundwater conditions beneath TA-54. The sampling plan for each of the wells within the TA-54 monitoring group is presented in Table 5.4-1. Base-flow and alluvial groundwater wells near and downgradient of TA-54 are not included in the TA-54 monitoring group because no evidence was found of a hydrologic connection between the subsurface contamination beneath TA-54 and adjacent canyons, as discussed in the Pajarito Canyon and Cañada del Buey IRs (LANL 2009, 106939; LANL 2009, 107497).

The regional monitoring-well network downgradient of the MDAs in TA-54 is a system that includes redundancy and is designed to provide reliable detection of potential contaminants reaching the regional aquifer. The wells are located both near the facility boundary and at more distal locations along the dominant regional flow direction as well as along potential local flow directions to the northeast. The locations of wells also address potential complex pathways for contaminants in the vadose zone. Because of the difficulties associated with monitoring groundwater that occurs in lavas beneath TA-54, the network is made up of two-screen wells with an upper well screen placed as close to the water table as possible to monitor the first arrival of contaminants in the aquifer and a lower screen placed in permeable aquifer sediments to monitor the primary groundwater pathways downgradient of the facility.

5.4 Scope of Activities

Active monitoring locations of the TA-54 monitoring group are focused on intermediate-perched and regional groundwater wells. These locations are shown in Figure 5.1-1.

Sampling locations, frequencies, analytical suites, and the rationale for these locations are presented in Table 5.4-1. The FD screening tables for the TA-54 monitoring group are presented in Attachment B-1 of Appendix B (on CD).

Exceptions to the analytical suites and sampling frequencies presented in Tables 1.6-2 may occur for some locations listed in Table 5.4-1. The wells in the TA-54 monitoring group are sampled semiannually. The objectives for the sampling frequency and analytical suites are presented in Table D-1.

6.0 TA-16 260 MONITORING GROUP

6.1 Introduction

The TA-16 260 monitoring group (Figure 6.1-1) was established for the upper Water Canyon/ Cañon de Valle watershed to detect and monitor contaminants released from Consolidated Unit 16-021(c)-99, the TA-16 260 Outfall (hereafter, the 260 Outfall), and other sites at TA-16. The 260 Outfall is a former HE machining outfall that discharged HE-bearing water to Cañon de Valle for almost 50 yr and is the predominant source of contaminants detected in groundwater in the Water Canyon/ Cañon de Valle area. These discharges contaminated soils, sediments, surface waters, spring waters, and deep-perched and regional groundwater at TA-16.

The TA-16 260 monitoring group includes springs, alluvial wells, and wells completed in several deep perched-intermediate groundwater zones and in the regional aquifer. Shallow monitoring locations such as the springs and alluvial wells are included in this monitoring group because they contain HE, barium, and VOC contamination related to past activities at the 260 Outfall and other sites in the area.

TA-16 is located in the southwest corner of the Laboratory and was established to develop explosive formulations, cast and machine explosive charges, and assemble and test explosive components for the nuclear weapons program. TA-16 is bordered by Bandelier National Monument along NM 4 to the south and by the Santa Fe National Forest along NM 501 to the west. To the north and east, it is bordered by TA-08, TA-09, TA-11, TA-14, TA-15, TA-37, and TA-49. Water Canyon, a 200-ft-deep ravine with steep walls, separates NM 4 from active sites at TA-16. Cañon de Valle forms the northern border of TA-16.

6.2 Background

Surface water in the area consists of stormwater and snowmelt runoff that flows in canyon drainages, including Cañon de Valle, Fishladder Canyon, and Martin Spring (S-Site) Canyon. Fishladder Canyon also receives snowmelt and stormwater runoff. Alluvial groundwater occasionally discharges at Fishladder Spring. The surface flow in Fishladder Canyon decreased significantly once the TA-16 340 Outfall was deactivated.

The TA-16 260 monitoring group includes alluvial monitoring wells in Cañon de Valle (CdV-16-02659), in Fish Ladder Canyon (FLC-16-25280), and in Martin Spring Canyon (MSC-16-06295). Groundwater in these alluvial systems is shallow, and water levels generally show responses to snowmelt runoff.

The vadose zone at TA-16 is approximately 1000 ft to 1300 ft thick and is recharged by mountain-front precipitation and subsequent infiltration along the Pajarito fault zone east of TA-16 and along canyons (e.g., infiltration along upper Cañon de Valle). The vadose zone contains one shallow suite of perched water zones (less than 200 ft depth from the mesa top) and two significant deep- perched-intermediate groundwater zones between approximately 750 ft and 1200 ft bgs. The shallow perched zones are heterogeneous and controlled by fractures and surge beds near the Tshirege unit 3/4 contact. They

manifest as three springs (SWSC, Burning Ground, and Martin), as intermittently saturated zones in several boreholes in the northern portions of TA-16, and in a continuously-saturated borehole near the 90s Line Pond. The deep perched-intermediate groundwater zones are believed to extend from west to east for more than 6500 ft and from north to south for approximately 3280 ft. Perched-intermediate groundwater was encountered at R-26 screen 1; R-25b, R-25 screens 1, 2, 4; CdV-16-1i; CdV-16-2ir; and R-47i. No perched groundwater was observed at R-18 and R-48, limiting its north-south extent. The low permeability Tschicoma dacite observed in R-48 (approximately 2000 ft south of Cañon de Valle) may impede the southward flow of water in the deep-perched system. The perched zones are present both within the Otowi Member of the Bandelier Tuff (R-25, R-25b, and CdV-16-1[i]) and within the Puye Formation (CdV-16-4ip and CdV-16-2[i]r). In the vicinity of CdV-16-4ip, the two perched zones are separated by a 100 ft to 150 ft of Puye sediments under variable saturation (LANL 2011, 203711). The degree of hydraulic connection between the perched horizons and the regional aquifer has not been fully analyzed to date, but will be assessed in future reports.

Water-level data indicate groundwater within the perched horizons generally flows from west to east. There is some evidence of a southerly component of flow within the Otowi Member of the Bandelier Tuff in the vicinity of R-25, possibly from recharge along Cañon de Valle. Water-level data from multiple screens in R-25 and from the two screens of CdV-16-4ip indicate water levels within the deep-perched system are lower with depth, suggesting significant vertical anisotropy, with vertical hydraulic conductivities perhaps orders of magnitude lower than horizontal hydraulic conductivities in some strata (LANL 2011, 203711).

The regional aquifer in the vicinity of northern TA-16 is predominantly unconfined, with the water table located within the Puye Formation at a depth of approximately 1108 ft to1353 ft bgs. Groundwater flow in the shallow portion of the regional aquifer is generally eastward, with some perturbation near R-25, perhaps reflecting local recharge. Downgradient (east) of R-25, the regional groundwater flow direction incorporates a northerly component of flow near R-18 and R-17. Water levels in regional wells near TA-16 show little influence from transient effects of deeper water-supply pumping (LANL 2006, 091450).

Contaminant Sources and Distributions

Discharges from the former 260 Outfall during the past 50 yr at Consolidated Unit 16-021(c)-99 served as a primary source of source of HE and inorganic contamination found throughout the site (LANL 1998, 059891; LANL 2003, 085531). Results of the 260 Outfall CME (LANL 2007, 098734) show the drainage channel below the outfall and the canyon bottom as well as surface water, alluvial groundwater, and deep-perched groundwater, are contaminated with explosive compounds, including RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine); HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine); TNT (2,4,6 trinitrotoluene); and barium. In addition, the VOCs tetrachloroethane and TCE have been detected in springs, alluvial groundwater, and perched-intermediate groundwater. Low concentrations of PCE have also been detected in the regional aquifer in R-25 (screen 5).

The primary migration pathway for these contaminants is believed to consist of (1) discharge as effluent from the 260 Outfall, (2) surface flow to Cañon de Valle via a small tributary drainage, (3) downcanyon transport by surface water flow and alluvial groundwater, (4) and infiltration through the vadose zone as recharge to the deep-perched groundwater zones and potentially into the regional aquifer.

Groundwater in the perched horizons contains the largest inventory of HE in the environment on a mass basis; estimates range from as low as approximately 700 kg of RDX to as high as approximately 8000 kg of RDX. Investigations of vadose zone and regional groundwater at TA-16 have been conducted during the past several years, and the results of these investigations are discussed in several reports

(e.g., Longmire 2005, 088510; LANL 2006, 093798; LANL 2007, 096003; LANL 2007, 095787; LANL 2011, 203711).

6.3 Monitoring Objectives

The objective for the TA-16 260 monitoring group is to further refine nature and extent for contamination originating from the area and to monitor fate and transport for observed contaminants. These data will support the pending CME for perched-intermediate and regional groundwater (Plate 1) (LANL 2007, 098734; LANL 2008, 103165). This group's monitoring focuses on HE, barium, and VOC contamination in the upper Cañon de Valle watershed (Table 1.6-2).

Characterization sampling for a wide range of potential contaminants in groundwater from TA-16 (e.g., fission-product radionuclides, SVOCs, pesticides, PCBs, dioxins/furans) has been completed for the majority of wells in the group. These constituents have not been detected beyond sporadic, low-level detections that can be attributed to infrequent but normal analytical issues, as summarized in the FD tables in Attachment B-1 of Appendix B (on CD).

6.4 Scope of Activities

Active monitoring locations in the TA-16 260 monitoring group include alluvial groundwater wells, perched-intermediate groundwater wells, regional groundwater wells, and springs. These locations are shown in Figure 6.1-1.

Sampling locations, frequencies, analytical suites, and the rationale for these locations are presented in Table 6.4-1. The FD screening tables for Water Canyon/Cañon de Valle are presented in Attachment B-1 of Appendix B (on CD).

Additional base-flow, spring, and alluvial groundwater monitoring is conducted as general surveillance in the watershed (section 8.6). Monitoring of deep groundwater from the perched-intermediate and regional aquifers reflects a long-term data set that indicates what constituents are present and their trends and variability. Additional rounds are maintained for some constituents in the perched-intermediate groundwater as an early-detection location for potential migration of those constituents from secondary sources in the vadose zone.

Exceptions to the analytical suites and sampling frequencies presented in Table 1.6-2 may occur for some locations listed in Table 6.4-1. The sampling frequency for the wells in the TA-16 260 monitoring group is based on the presence of RDX contamination; those locations consistently showing RDX are sampled semiannually, while those locations that do not show significant contamination are sampled annually. Sampling at new well R-63 will transition from quarterly to semiannually during MY2011. The objectives for the sampling frequency and analytical suites are presented in Table D-1.

7.0 MDA AB MONITORING GROUP

7.1 Introduction

The MDA AB monitoring group is located in TA-49 and includes one monitoring well completed in perched-intermediate groundwater and three wells completed in the regional aquifer. TA-49, also known as the Frijoles Mesa Site, is located on a mesa in the upper part of the Ancho Canyon drainage and part of the area drains into Water Canyon. The MDA AB monitoring group is shown in Figure 7.1-1.

TA-49 was used for underground hydronuclear testing in the early 1960s. The testing consisted of criticality, equation-of-state, and calibration experiments involving special nuclear materials. The testing produced large inventories of radioactive and hazardous materials: isotopes of uranium and plutonium, lead, and beryllium; explosives such as TNT, RDX, HMX; and barium nitrate. Much of this material remains in shafts on the mesa top. Further information about activities and SWMUs and AOCs at TA-49 can be found in recent Laboratory reports (LANL 2010, 109318; LANL 2010, 109319). The RCRA facility investigation work plan also describes the planned investigations that focus on identifying and quantifying migration of contaminants from the shafts.

7.2 Background

Both main Ancho Canyon and the north fork of Ancho Canyon head on the Pajarito Plateau in the south-central part of the Laboratory. Approximately 2.2 mi^2 (5.6 km^2 is drained by the north fork of Ancho Canyon and, above the confluence with the north fork, approximately 2.3 mi^2 (5.8 km^2) is drained by main Ancho Canyon. Surface-water flow is ephemeral and occurs as runoff, primarily following infrequent, intense thunderstorms or during snowmelt. Its source is direct precipitation and runoff from surrounding mesa tops. No perennial sources of surface water exist at TA-49.

In 1960, the USGS drilled three deep wells (test wells DT-5A, DT-9, and DT-10) to monitor regional aquifer water quality. No contaminants were found in these wells at concentrations near or above standards. As with other wells installed around the Laboratory using mild carbon steel during that period, samples from these three test wells have shown elevated metals concentrations related to corrosion or flaking of well components. In 2010, the total lead concentration in a sample from test well DT-9 of 20.1 µg/L was above the EPA drinking water system action level of 15 µg/L. Another sample during the year had a total lead result of less than 2 µg/L. Some results during the 1990s were above 50 µg/L.

Several deep mesa-top boreholes and wells have been drilled to intermediate depths of 300 ft to 700 ft bgs (49-CH-1 through 49-CH-4, 49-2-700) and to the regional aquifer (DT-5A, DT-9, DT-10, R-29, and R-30). No perched-intermediate groundwater zones were encountered when these wells were drilled (LANL 2006, 093714; LANL 2010, 110478; LANL 2010, 110518). A moisture profile for the 700-ft deep mesa-top borehole 49-2-700-1 (Figure B-2.0-1) shows low moisture content (<17% by weight) throughout the profile; the profile is similar to those beneath other dry mesas and indicates that infiltration along neighboring canyons does not impact moisture beneath the mesa at TA-49. In addition, 49-Gamma was drilled to 54 ft bgs in upper Ancho Canyon, and wells 49-9M-2 through 49-9M-4 were drilled in the drainage of the upper north fork of Ancho Canyon; these boreholes were dry when drilled. These observations show a lack of shallow perched groundwater in the upper portions of the Ancho watershed.

Perched-intermediate groundwater was encountered in Water Canyon, approximately 3500 ft northeast of MDA AB during the drilling of R-27 in 2005. The perched zone was detected at 628 ft bgs in the Puye Formation immediately above the Cerros del Rio basalt. Monitoring well R-27i was subsequently installed in September 2009 with a single screen to evaluate water quality and measure water levels in the perched zone.

Springs and seeps are known to occur in the lower reaches of Water and Ancho Canyons, far downgradient of TA-49 (near the Rio Grande), but none have been identified within the boundaries of TA-49 (LANL 2007, 098492).

The top of the regional aquifer occurs approximately 1126 ft to 1153 ft bgs, based on water levels in monitoring wells R-29 and R-30. The potentiometric surface of the regional aquifer beneath TA-49 lies completely within the Puye Formation and the Cerros del Rio basalt. Groundwater flow in the upper portion of the regional aquifer at TA-49 is generally eastward.

Contaminant Sources and Distributions

The primary contaminants at MDA AB and other disposal areas in TA-49 include tritium, radionuclides (plutonium-238, plutonium-239/240, americium-241, and cesium-137), arsenic, chromium, copper, lead, and perchlorate. Radionuclides have been detected in canyon sediments, but no elevated levels of contaminants have been detected in groundwater in the wells that comprise the MDA AB monitoring group. Three decades of water-quality records from regional wells in this area (test wells DT-5A, DT-9, and DT-10) show no substantial changes in water chemistry or the presence of Laboratory contaminants in the regional aquifer. Perchlorate has been detected slightly above background in R-27i.

7.3 Monitoring Objectives

The monitoring objectives for the MDA AB monitoring group are to characterize the groundwater beneath MDA AB and ultimately to support the MDA AB CME process. New regional aquifer wells R-29 and R-30 have been drilled immediately downgradient of MDA AB at TA-49. The older test wells, DT-5A, DT-9, and DT-10, will no longer be monitored because of their potential for nonrepresentative data associated with well casing and screen materials, the long well screened intervals (617 ft, 681 ft, and 329.6 ft, respectively) and because they have been effectively replaced by R-29 and R-30.

7.4 Scope of Activities

Frequency, analytical suites, and the rationale for monitoring at each location are presented in Table 7.4-1. Groundwater monitoring for MDA AB has historically been conducted primarily at the DT-series regional aquifer wells. Recently installed wells R-29 and R-30 have been incorporated into the monitoring network for MDA AB and will be monitored annually to support the corrective action process for MDA AB.

Exceptions to the analytical suites and sampling frequencies presented in Table 1.6-2 may occur for some locations listed in Table 7.4-1. The objectives for the sampling frequency and analytical suites are presented in Table D-1.

8.0 GENERAL SURVEILLANCE MONITORING GROUP

8.1 Overview

Monitoring locations not associated with project-specific monitoring groups are included in the general surveillance monitoring group. This group includes base-flow locations, alluvial monitoring wells, and springs, except for those assigned to the TA-16 260 monitoring group. The general surveillance group also includes some wells completed in perched-intermediate zones or in the regional aquifer that are not associated with area-specific monitoring groups.

General surveillance monitoring locations are sited across the Pajarito Plateau in all the major watersheds. Some are upgradient of project specific areas or are in areas where contamination was historically present, but where concentrations have since fallen and are stable and below standards. General surveillance monitoring locations for Los Alamos/Pueblo Canyons, Sandia Canyon, Mortandad Canyon, Pajarito Canyon, Water Canyon/Cañon de Valle, and Frijoles, Ancho and Chaquehui Canyons are shown in Figure 8.1-1. General surveillance monitoring locations for White Rock Canyon are shown in Figure 8.1-2.

Most general surveillance locations are well-characterized and have a long history of sampling data. Some locations show little or no contamination, while others show residual contamination from past operations or effluent releases. The residual contamination may be present in surface water, alluvial groundwater, and occasionally in perched-intermediate groundwater. In many cases, contaminant concentrations at these locations are fairly steady over time or decreasing as a result of reductions in sources over the years.

8.2 Monitoring Objectives

The primary monitoring objectives for the general surveillance locations are

- to continue monitoring long-term water quality trends;
- to continue verifying decreasing contaminant trends at general surveillance locations in some watersheds (Los Alamos, Sandia, and Mortandad);
- to monitor for potential impacts from ongoing operations under DOE requirements for environmental surveillance; and
- to continue surveillance for potential Laboratory impacts to the groundwater, as expressed at the springs in White Rock Canyon.

8.3 Scope of Activities

These objectives can be met at all general surveillance locations through annual monitoring at the majority of all general surveillance locations, with a few exceptions. Semiannual monitoring is proposed at two locations, monitoring well 03-B-13 (because of elevated and highly variable VOC and SVOC concentrations) and at Basalt Spring (to meet monitoring requirements under the MOU). Quarterly monitoring is proposed at R-34 to meet monitoring requirements under the MOU.

Base-flow locations will be monitored using dedicated probes to measure field parameters. Specific conductance and pH will be logged hourly. Base-flow locations monitored under general surveillance (Figure 8.1-1) will include the following:

- Water Canyon between E252 and Water at Beta (existing location)
- Pajarito below TA-14 (new location)
- Two Mile Canyon below TA-64 (new location)
- Sandia above Wetlands (new location)
- Sandia below Wetlands (existing location)

New locations will be sited based on the presence of persistent surface water. The probes will be installed by April 1, 2012. Water, Twomile, and Pajarito Canyons may be prone to flooding during the summer months because of the changed hydrology in these watersheds following the 2011 Las Conchas fire. The monitoring probes may be removed from these watersheds during the summer months (June 15 through September 30) to avoid damage or loss.

Tables 8.3-1 and 8.3-2 list the sampling locations, the rationale for these locations, the analytical suites, and frequencies for the general surveillance group. The locations in the general surveillance monitoring group are sampled annually, with the exceptions noted above. The objectives for the sampling frequency and analytical suites are presented in Table D-1.

9.0 REFERENCES AND MAP DATA SOURCES

9.1 References

The following list includes all documents cited in this plan. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Record Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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LANL (Los Alamos National Laboratory), September 2011. "Corrective Measures Evaluation Report for Material Disposal Area L, Solid Waste Management Unit 54-006, at Technical Area 54, Revision 2," Los Alamos National Laboratory document LA-UR-11-4798, Los Alamos, New Mexico. (LANL 2011, 205756)

LANL (Los Alamos National Laboratory), September 2011. "Corrective Measures Evaluation Report for Material Disposal Area G, Solid Waste Management Unit 54-013(b)-99, at Technical Area 54, Revision 3," Los Alamos National Laboratory document LA-UR-11-4910, Los Alamos, New Mexico. (LANL 2011, 206324)

LANL (Los Alamos National Laboratory), September 2011. "Corrective Measures Evaluation Report for Material Disposal Area H, Solid Waste Management Unit 54-004, at Technical Area 54, Revision 1," Los Alamos National Laboratory document LA-UR-11-5079, Los Alamos, New Mexico. (LANL 2011, 206319)

Longmire, P., May 2005. "Characterization Well R-25 Geochemistry Report," Los Alamos National Laboratory report LA-14198-MS, Los Alamos, New Mexico. (Longmire 2005, 088510)

9.2 Map Data Sources

Water sampling locations: ER Project Locations; Los Alamos National Laboratory, ESH&Q Waste and Environmental Services Division, 2010-2E; 1:2,500 Scale Data; 04 October 2010.

Primary drainage: Watercourse; Los Alamos National Laboratory, ENV Water Quality & Hydrology Group; 05 April 2005.

Paved road: Road Centerlines for the County of Los Alamos; County of Los Alamos, Information Services; as published 04 March 2009.

MDA: Materials Disposal Areas; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program; ER2004-0221; 1:2,500 Scale Data; 23 April 2004.

LANL boundary: LANL Areas Used and Occupied; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; 19 September 2007; as published 13 August 2010.

Land ownership: LANL Areas Used and Occupied; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; 19 September 2007; as published 13 August 2010.

TA boundary: Technical Area Boundaries; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Office; September 2007; as published 13 August 2010.

LANL structure: Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 29 November 2010.

Watershed: Watersheds; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program; EP2006-0942; 1:2,500 Scale Data; 27 October 2006.

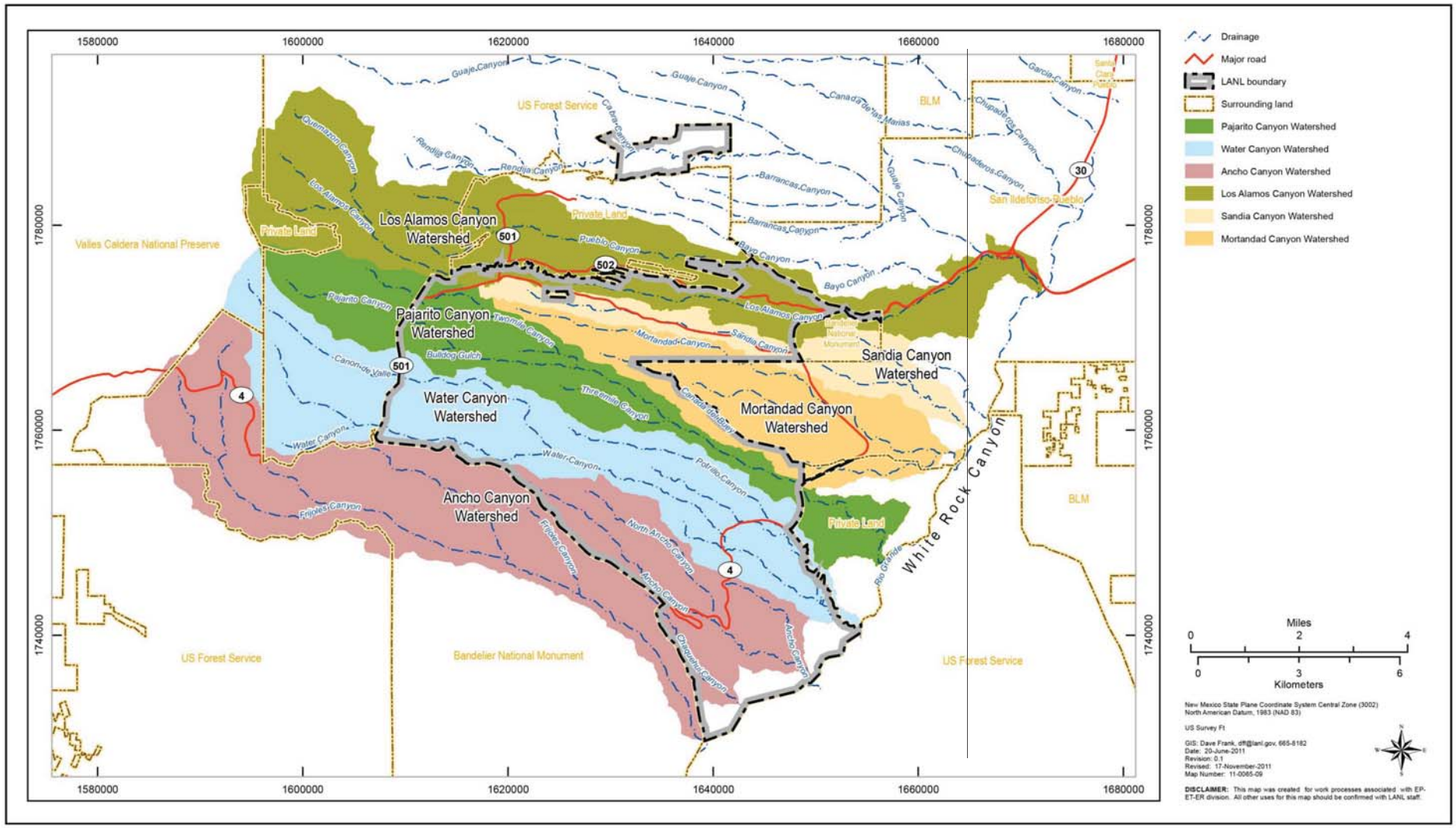


Figure 1.2-1 Watersheds at Los Alamos National Laboratory

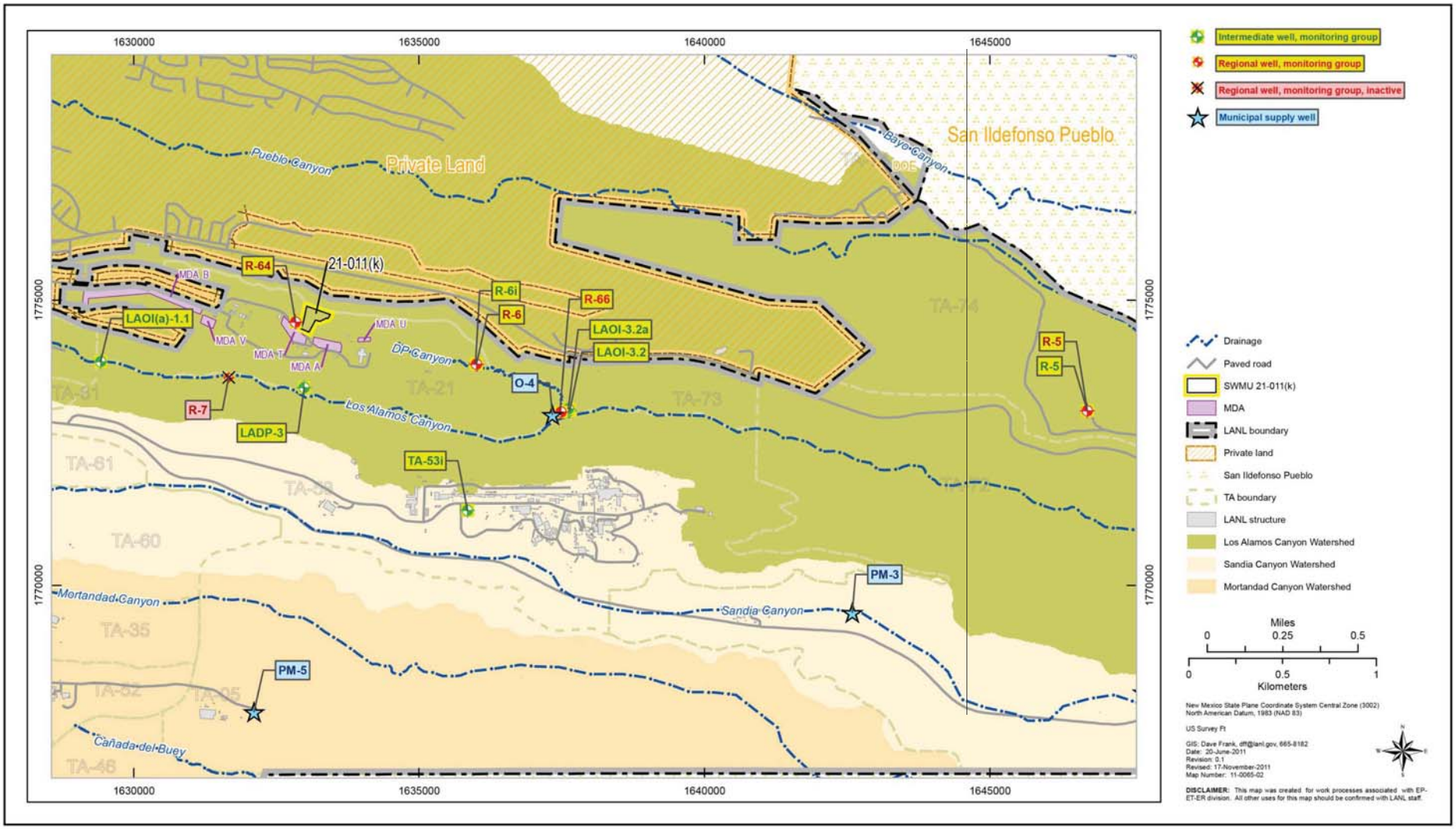


Figure 2.1-1 TA-21 monitoring group

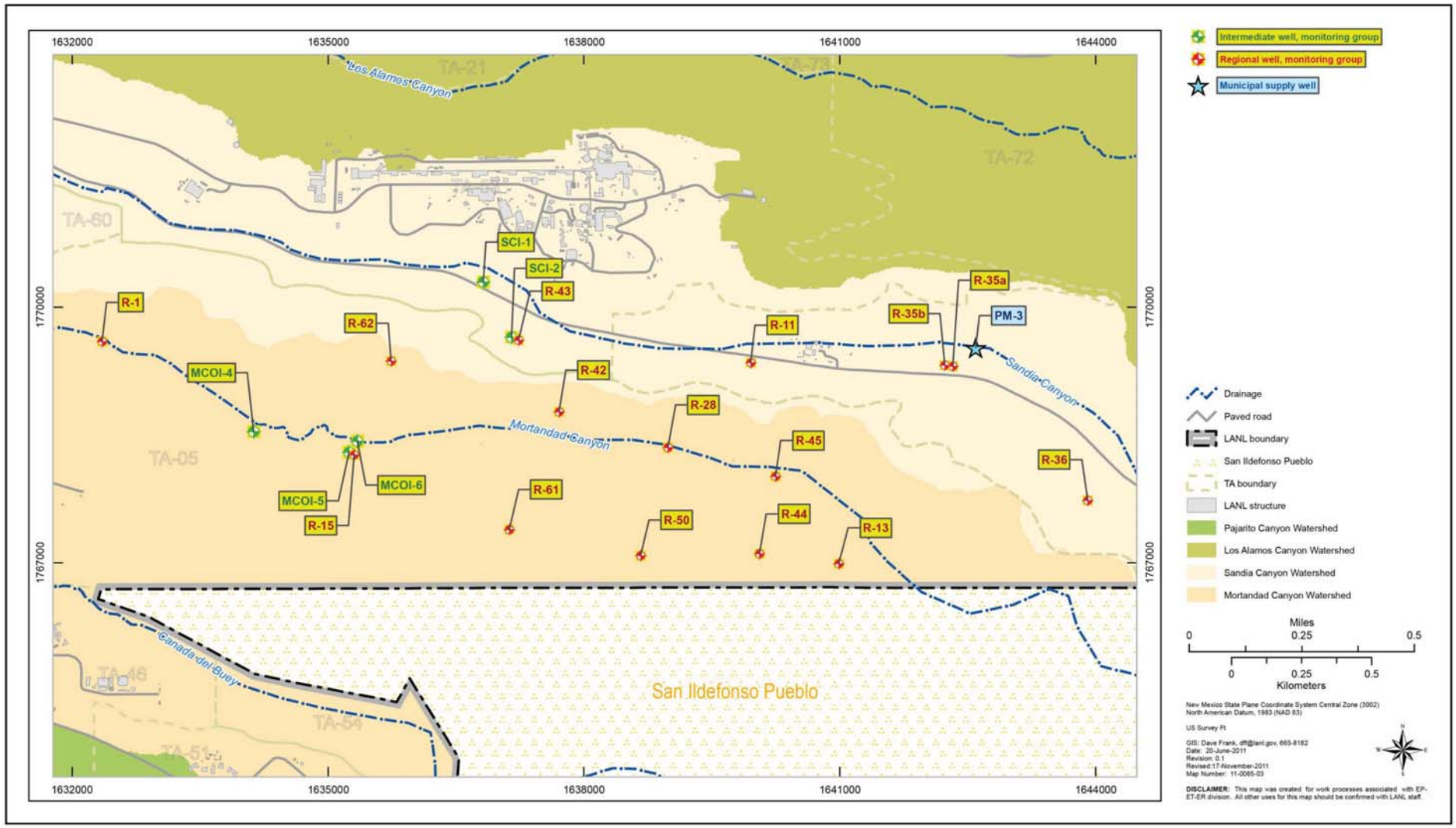


Figure 3.1-1 Chromium investigation monitoring group

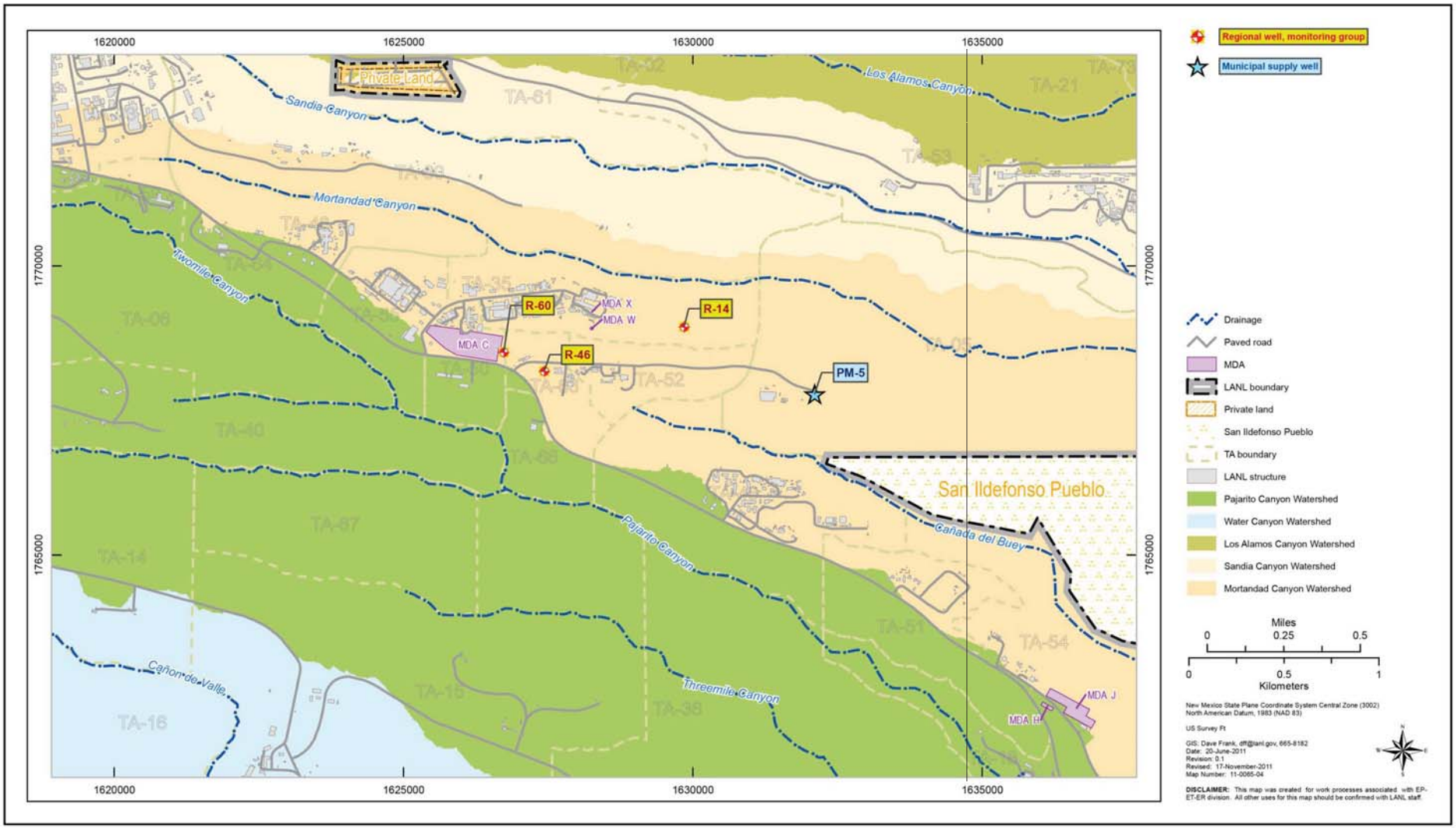


Figure 4.1-1 MDA C monitoring group

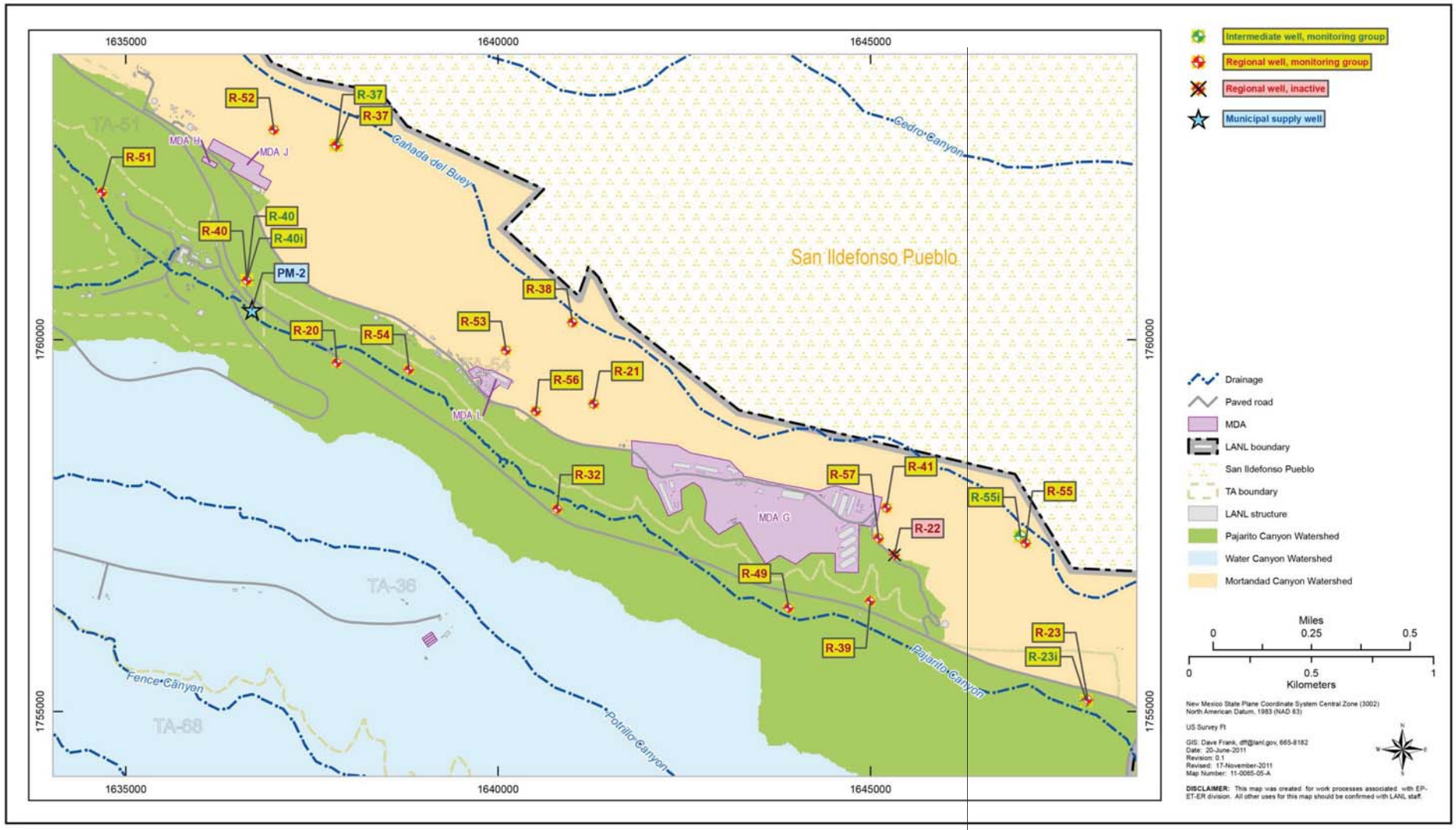


Figure 5.1-1 Monitoring well network for TA-54 MDAs H, L, and G

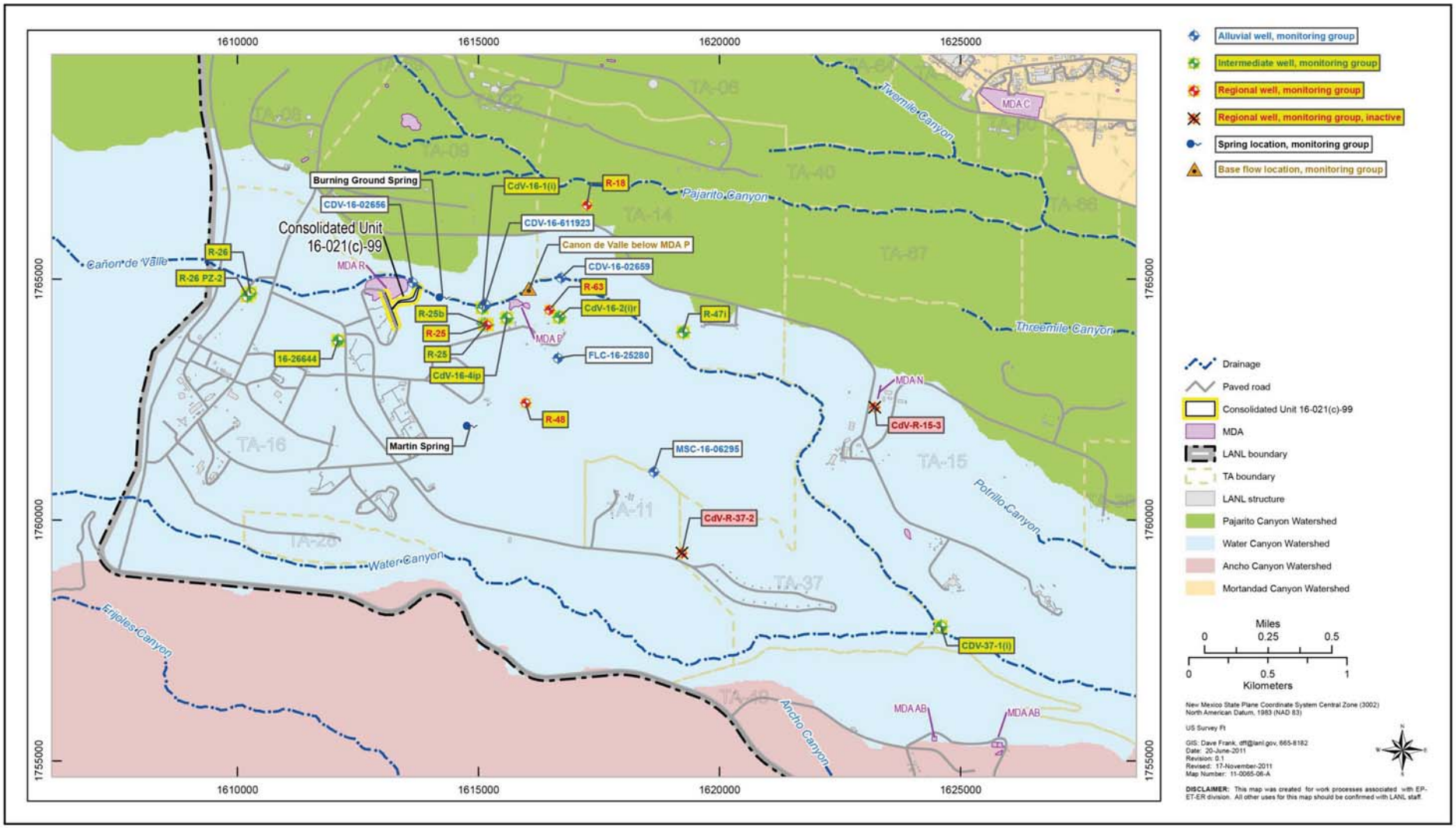


Figure 6.1-1 TA-16 260 Outfall monitoring group

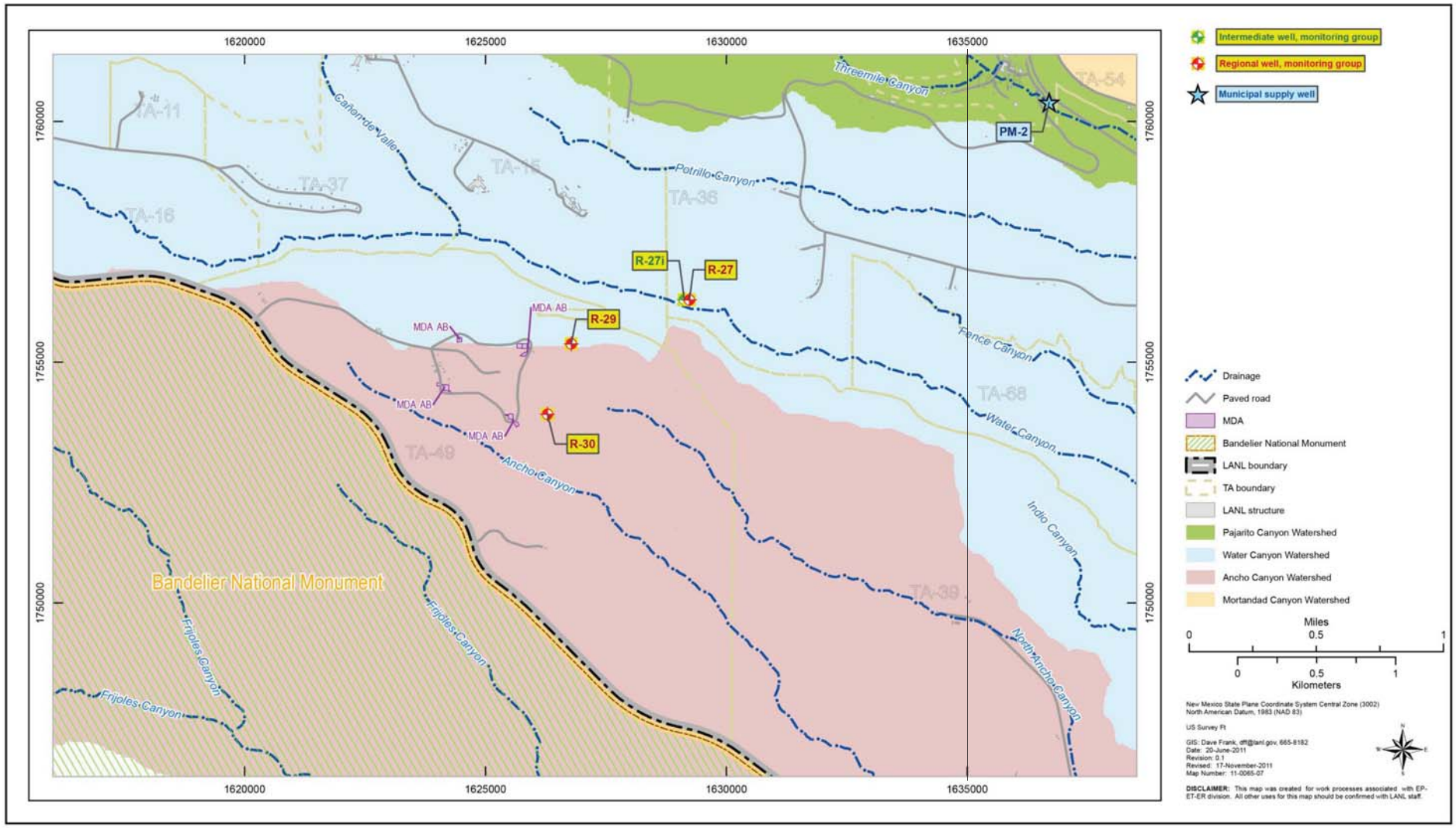


Figure 7.1-1 MDA AB monitoring group

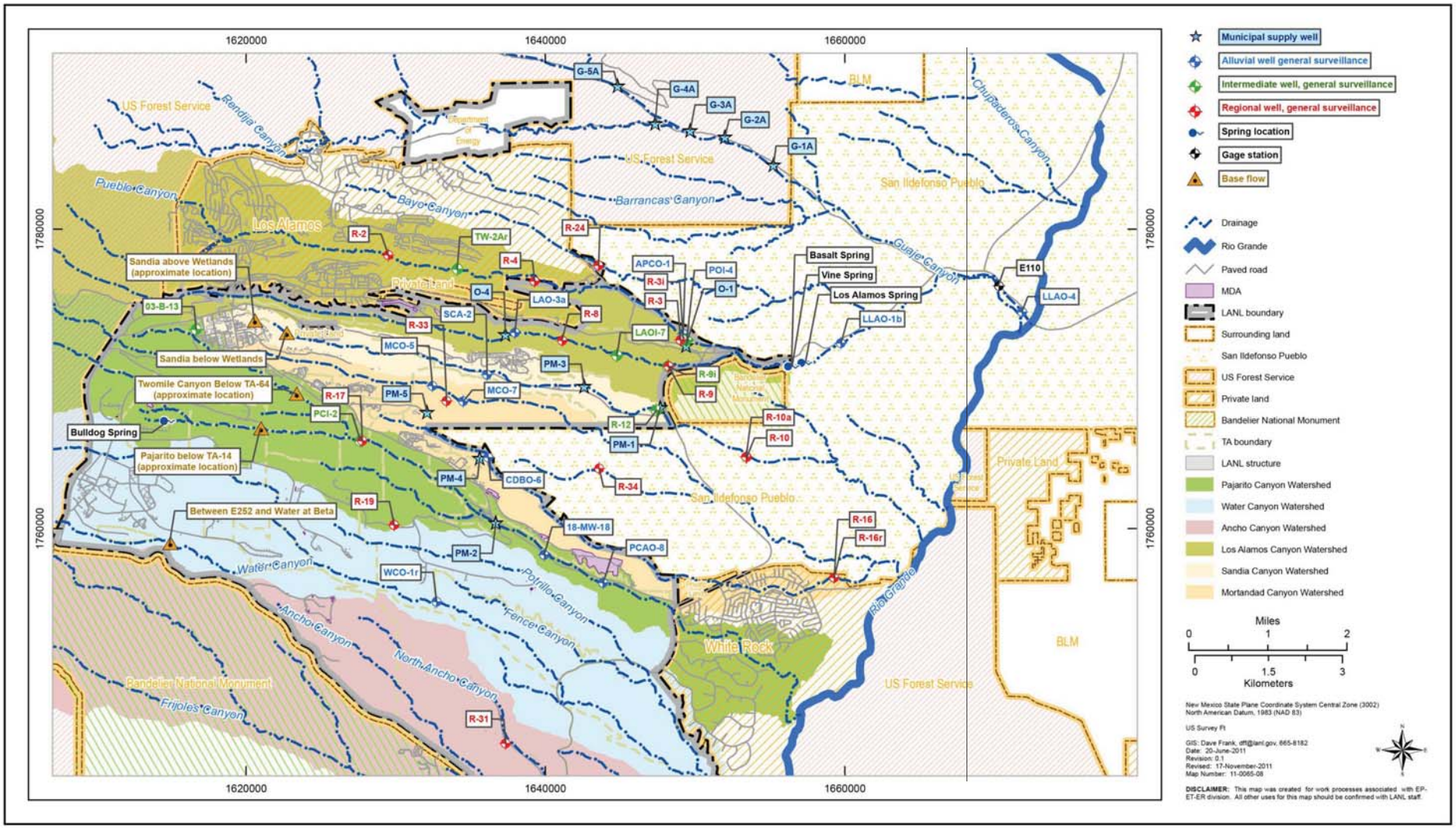


Figure 8.1-1 General surveillance

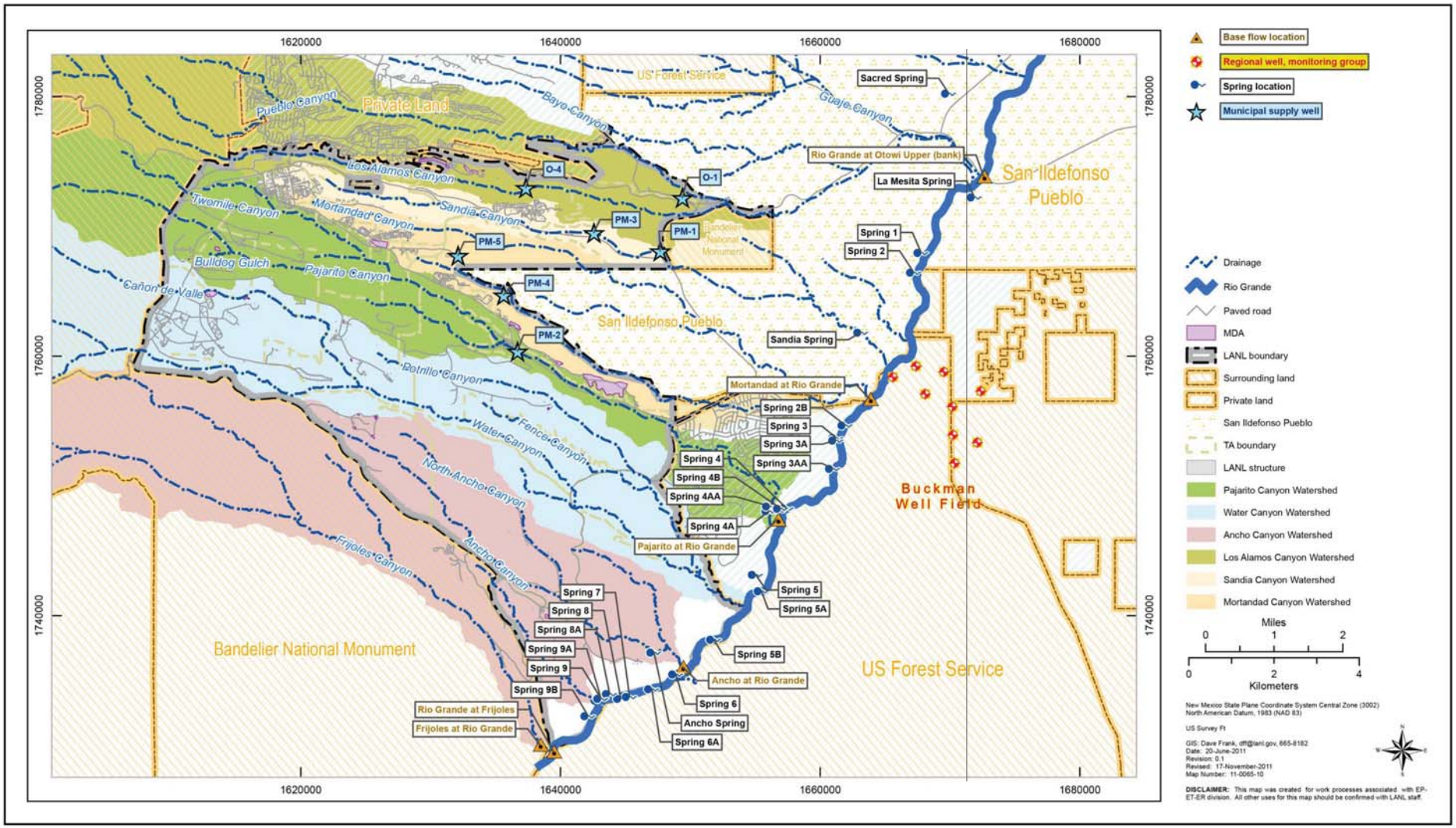


Figure 8.1-2 General surveillance, White Rock Canyon

Table 1.6-1
Potentially Applicable Standards Used to Select Base-Flow and Groundwater Screening Levels

Type	Source	Description	Abbreviation[a]	Potential Applicability[b]					
				Perennial Surface Water		Ephemeral Surface Water		Groundwater (Includes Springs)	
				F[c]	UF[d]	F	UF	F	UF
State of New Mexico Water Quality Control Commission (NMWQCC)									
Standard	NMAC 20.6.4	Livestock Watering	NM LVSTK WTR STD	X	X	X	X		
Standard	NMAC 20.6.4	Wildlife Habitat	NM WQCC WLDLF HAB		X		X		
Standard	NMAC 20.6.4	Aquatic Life Acute	NM Aqu Acute *x* mg[e]			X	X		
Standard	NMAC 20.6.4	Aquatic Life Chronic	NM Aqu Chronic *x* mg[e]	X	X				
Standard	NMAC 20.6.4	Human Health Standard	NM HH OO	X	X	X	X		
Standard	NMAC 20.6.2	Groundwater Human Health Standards, Other Standards for Domestic Water Supply and Standards for Irrigation Use	NM GW STD					X	X
Consent Order									
Screening level	Consent Order	Screening Level for Perchlorate in Groundwater	NM GW CONS					X	X
EPA									
Standard	40 CFR 141	EPA maximum contaminant levels	EPA MCL					X	X
Risk—human	EPA Regional Screening Levels[f]	EPA Regional Screening Levels for Tap Water	EPA TAP SCRN LVL					X	X
DOE									
Risk—ecological	DOE Order 458.1	DOE Biota Concentration Guides	DOE BCG WATER	X	X	X	X		
Risk—human	DOE Order 458.1	DOE 4-mrem Drinking Water Derived Concentration Guidelines	DOE DW DCG					X	X

[a] Abbreviations used in the screening tables in Attachment B-1 of Appendix B.

[b] The protocol for selecting the lowest applicable screening levels for groundwater and surface water is described in Appendix B. The description includes assumptions and rationale for hardness-dependent metals. Blank cells indicate the screening level is not applicable to the water type.

[c] F = Filtered.

[d] UF = Unfiltered.

[e] *x* indicates the hardness concentration (as mg/L) used to calculate screening levels for hardness-dependent trace metals.

[f] EPA Regional Screening Levels (EPA 2011, 204336).

Table 1.6-2
Analytical Suites and Frequencies for Locations Assigned to Area-Specific Monitoring Groups

Surface-Water Body or Source Aquifer	Metals[a] (filtered)	Organics			Radionuclides			General Inorganics		
	TAL Metals	VOCs[b]	SVOCs[b]	HEXP[c]	Radionuclides[d]	Tritium[e]	Low-Level Tritium[e]	General Inorganics[f]	Perchlorate	Field Data[g]
TA-21 Monitoring Group (Upper Los Alamos and Sandia Canyons)										
Intermediate	—[h]	—	—	—	A	A	A	A	A	A
Regional	—	—	—	—	A	—	A	A	A	A
Characterization of new deep groundwater wells[i]	Q	Q	Q	S	Q	—	Q	Q	Q	Q
Chromium Investigation Monitoring Group (Sandia and Mortandad Canyons)										
Intermediate (Sandia)	S	—	—	—	A	A	—	S	S	S
Intermediate (Mortandad)	A	A	A	—	A	A	—	A	A	A
Regional	A	—	—	—	B	—	A	A	A	A
Characterization of new deep groundwater wells	Q	S	S	S	S	—	S	Q	Q	Q
MDA C Monitoring Group (Mortandad and Pajarito Canyons)										
Regional	—	S	S	—	A	—	S	A	—	S
TA-54 Monitoring Group (Mortandad Canyon/Cañada del Buey and Pajarito Canyons)										
Intermediate	A	S	A	—	A	—	S	A	—	S
Regional	A	S	A	—	A	—	S	A	—	S
TA-16 260 Monitoring Group (Water Canyon/Cañon de Valle and Pajarito Canyon)										
Base flow	S	S	—	S	B	—	—	S	—	S
Springs	S	S	—	S	B	—	—	S	—	S
Alluvial	S	S	—	S	B	—	—	A	—	S
Intermediate	S	S	—	S	B	—	—	A	—	S
Regional	A	A	—	A	B	—	—	A	—	A
Characterization of new deep groundwater wells	S	S	S	S	A	—	S	S	S	S

Table 1.6-2 (continued)

Surface-Water Body or Source Aquifer	Metals[a] (filtered)	Organics			Radionuclides			General Inorganics		Field Data[g]
	TAL Metals	VOCs[b]	SVOCs[b]	HEXP[c]	Radionuclides[d]	Tritium[e]	Low-Level Tritium[e]	General Inorganics[f]	Perchlorate	
MDA AB Monitoring Group (Ancho and Water Canyons)										
Intermediate	A	A	A	A	A	—	A	A	—	A
Regional	A	A	A	A	A	—	A	A	—	A

Notes: Sampling suites and frequencies: Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); B = biennial (1 time every 2 yr). Some locations assigned to an area-specific monitoring group may be assigned analytical suites or frequencies that differ from those shown in this table for site-specific reasons documented in Appendixes D and F.

[a] Metals analysis includes the 23 TAL metals (Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn), plus boron, molybdenum, silicon dioxide, strontium, tin, and uranium.

[b] VOCs = Volatile organic compounds; SVOCs = semivolatile organic compounds.

[c] The analytical suite of explosive compounds (HEXP) includes the Consent Order list of the normal SW-846:8330 analytes plus pentaerythritol tetranitrate (PETN); triaminotrinitrobenzene (TATB); 3,5-dinitroaniline, tri(o-cresyl)phosphate (TOCP); 2,4-diamino-6-nitrotoluene; and 2,6-diamino-4-nitrotoluene.

[d] The radionuclide suite includes gross alpha, gross beta, strontium-90, and radionuclides analyzed by alpha and gamma spectroscopy.

[e] Tritium samples may be submitted for analysis by liquid scintillation if the average activities are anticipated to exceed 200 pCi/L. Low-level tritium is analyzed using electrolytic enrichment or direct counting.

[f] General inorganic analysis includes major anions (bromide, chloride, fluoride, sulfate); major cations (calcium, magnesium, sodium, potassium); nitrate plus nitrite (as N); total Kjeldahl nitrogen (TKN); ammonia; total phosphorus; total organic carbon (TOC); total dissolved solids (TDS); alkalinity; specific conductivity; pH; and hardness. TKN, TOC and total cyanide are analyzed only in unfiltered samples.

[g] Field parameters include pH, turbidity, specific conductance, dissolved oxygen, and temperature at all locations. Oxidation-reduction potential (ORP) will be measured if a flow-through cell is used and will not be measured in surface water, spring water, or water collected from Westbay sampling systems unless specified. Alkalinity will be measured for all samples either in the field or at the on-site Earth Systems Observations (EES-14) laboratory.

[h] — = This analytical suite is not scheduled to be collected for this type of water at locations assigned to this monitoring group.

[i] Characterization suites and frequencies apply to new intermediate perched or regional groundwater wells assigned to this monitoring group. “New” wells are defined as those completed or converted on or after October 1, 2010.

Table 1.6-3
Analytical Suites and Frequencies for Locations Assigned to General Surveillance Monitoring

Surface-Water Body or Source Aquifer	Metals[a] (filtered)	Organics			Radionuclides			General Inorganics		Suspended Sediments	Field Data[g]
	Metals (filtered)	VOCs[b]	SVOCs[b]	HEXP[c]	Radionuclides[d]	Tritium[e]	Low-Level Tritium[e]	General Inorganics[f]	Perchlorate		
Characterization of New Deep Groundwater Wells[h]											
Characterization	Q	Q	Q	S	Q	—[i]	Q	Q	Q	—	Q
Northern locations (Los Alamos/Pueblo, Sandia, and Mortandad Canyons)											
Springs	A	—	—	—	A	—	—	A	A	A	A
Alluvial	A	—	—	—	A	—	—	A	A	—	A
Intermediate	A	—	—	—	A	—	—	A	A	—	A
Regional	A	—	—	—	A	—	—	A	A	—	A
Southern locations (Pajarito, Water Canyon/Cañon de Valle, Frijoles, Ancho, and Chaquehui Canyons)											
Springs	A	—	—	A	A	—	—	A	A	A	A
Alluvial	A	—	—	A	A	—	—	A	A	—	A
Intermediate	A	—	—	A	A	—	—	A	A	—	A
Regional	A	—	—	A	A	—	—	A	A	—	A
White Rock Canyon and Rio Grande Watershed											
Base flow north of confluence with Mortandad Canyon	A	—	—	—	A	—	—	A	A	A	A
Base flow south of confluence with Mortandad Canyon	A	A	T	—	A	—	—	A	A	A	A

Table 1.6-3 (continued)

Surface-Water Body or Source Aquifer	Metals[a] (filtered)	Organics			Radionuclides			General Inorganics		Suspended Sediments	Field Data[g]
	Metals (filtered)	VOCs[b]	SVOCs[b]	HEXP[c]	Radionuclides[d]	Tritium[e]	Low-Level Tritium[e]	General Inorganics[f]	Perchlorate		
Springs north of confluence with Mortandad Canyon	A	A	T	T	A	—	A	A	A	A	A
Springs south of confluence with Mortandad Canyon	A	A	A	A	A	—	A	A	A	A	A

Notes: Sampling suites and frequencies: Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); B = biennial (1 time every 2 yr). Some locations assigned to an area-specific monitoring group may be assigned analytical suites or frequencies that differ from those shown in this table for site-specific reasons documented in Appendixes D and F.

[a] Metals analysis includes the 23 TAL metals (Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn), plus boron, molybdenum, silicon dioxide, strontium, tin, and uranium.

[b] VOCs = Volatile organic compounds; SVOCs = semivolatile organic compounds.

[c] The analytical suite of explosive compounds (HEXP) includes the Consent Order list of the normal SW-846:8330 analytes plus pentaerythritol tetranitrate (PETN); triaminotrinitrobenzene (TATB); 3,5-dinitroaniline, tri(o-cresyl)phosphate (TOCP); 2,4-diamino-6-nitrotoluene; and 2,6-diamino-4-nitrotoluene.

[d] The radionuclide suite includes gross alpha, gross beta, strontium-90, and radionuclides analyzed by alpha and gamma spectroscopy.

[e] Tritium samples may be submitted for analysis by liquid scintillation if the average activities are anticipated to exceed 200 pCi/L. Low-level tritium is analyzed using electrolytic enrichment or direct counting.

[f] General inorganic analysis includes major anions (bromide, chloride, fluoride, sulfate); major cations (calcium, magnesium, sodium, potassium); nitrate plus nitrite (as N); total Kjeldahl nitrogen (TKN); ammonia; total phosphorus; total organic carbon (TOC); total dissolved solids (TDS); alkalinity; specific conductivity; pH; and hardness. TKN, TOC and total cyanide are analyzed only in unfiltered samples.

[g] Field parameters include pH, turbidity, specific conductance, dissolved oxygen, and temperature at all locations. Oxidation-reduction potential (ORP) will be measured if a flow-through cell is used and will not be measured in surface water, spring water, or water collected from Westbay sampling systems unless specified. Alkalinity will be measured for all samples either in the field or at the on-site Earth Systems Observations (EES-14) laboratory.

[h] Characterization suites and frequencies apply to new intermediate perched or regional groundwater wells assigned to this monitoring group. “New” wells are defined as those completed or converted on or after October 1, 2010.

[i] — = This analytical suite is not scheduled to be collected for this type of water at locations assigned to this monitoring group.

Table 1.8-1
Sampling Schedule for MY2011: October 1, 2011–September 30, 2012

Monitoring Group or Watershed	Location Type	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
		Oct–Dec 2011	Jan–Mar 2012	Apr–Jun 2012	Jul–Sep 2012
Monitoring Groups					
TA-54	Routine	T, A, S, Q	—	S	—
Chromium Investigation	Routine	T, A, S, Q	Q	S, Q	Q
MDA C	Routine	A, S	—	S	—
TA-21	Routine	Q[a]	S, Q[b]	Q[b]	A, S, Q[b]
MDA AB	Routine	—	A	—	—
TA-16 260	Routine	Q[c]	A, B, S, Q[c]	—	S
General Surveillance					
Los Alamos and Pueblo Canyons	Routine	S[d]	—	A, S[d]	—
Mortandad and Sandia Canyons	Routine	Q	Q, S[e]	Q	Q, T, A, S[e]
Pajarito Canyon	Routine	S[f]	—	A, S[f]	—
Frijoles, Ancho, and Chaquehui Canyons	Routine	—	A	—	
Water Canyon	Routine	—	—	—	A
White Rock Canyon	Routine	A	—	—	—
Characterization					
All Watersheds	Characterization	Q	Q	Q	Q

Notes: Sampling frequencies: Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); B = biennial (1 time every 2 yr); T= triennial (1 time every 3 yr); — = no samples are scheduled to be collected from this monitoring group during this period.

[a] R-64.

[b] R-64 and R-66.

[c] R-26 screen 1 and R-63.

[d] Basalt or Vine Tree Spring.

[e] R-34.

[f] 03-B-13.

Table 1.9-1
Frequencies for Locations Assigned to Water-Level Monitoring Only

Assigned Monitoring Group	Location	Rationale for Selection of Location	Source Aquifer	Water Level*
Los Alamos/Pueblo Canyons Watershed				
TA-21 Monitoring Group	R-5 screen 1	Well located downgradient of upper Pueblo and Acid Canyons. Screen has been dry since well installation (2001) although water was observed in the sump below the screen (Koch and Schmeer 2011, 201566). Automated monitoring of water levels maintained to determine if the zone wets up.	Intermediate	C^{HD}
	R-7 screen 1	Well located in middle Los Alamos Canyon. Screen 1 went dry during sampling in December 2003 (Koch and Schmeer 2011, 201566). The zone produced water during drilling, and the screen produced small amounts of water for a short period following installation. Water was detected in the sump below the screen since 2005. Automated monitoring of water levels maintained to determine if either zone recovers.	Intermediate	C^{HD}
	R-7 screen 2	Well located in middle Los Alamos Canyon. Screen 2 has been dry since well installation in 2001 although water has been observed in the sump since mid-2008 (Koch and Schmeer 2011, 201566). Automated monitoring of water levels maintained to determine if either zone recovers.	Intermediate	C^{HD}
	R-7 screen 3	Well located in middle Los Alamos Canyon. The collection of water-quality samples from this screen is suspended because it remains impacted by drilling products. Automated monitoring of water levels should be maintained to monitor the top of the regional aquifer	Regional	C
General Surveillance	LAO-4.5c	Monitors location down canyon below Los Alamos/DP Canyon confluence.	Alluvial	C
	LAUZ-1	Well is located downgradient of Reach DP 2. Continue monitoring water levels and specific conductance using Aqua Troll transducer to collect data on salinity impacts from snowmelt runoff.	Alluvial	C
	PAO-2	Well is located approximately mid-way between SCA-3 and the easternmost drainage from the TA-53 complex. Continue monitoring water levels and specific conductance using Aqua Troll transducer to collect data on salinity impacts from snowmelt runoff.	Alluvial	C
Sandia Canyon Watershed				
General Surveillance	SCA-1	Well located in wetland in upper Sandia Canyon. Sampling events were moved to nearby drive point well SCA-1-DP because of silting in of the screen in SCA-1. Continuous water levels are monitored in SCA-1, and manual measurements are taken at SCA-1-DP during sampling events (Koch and Schmeer 2011, 201566).	Alluvial	C
	SCA-4	Well located in lower Sandia Canyon approximately mid-way between SCA-3 and the easternmost drainage from the TA-53 complex. Water-level monitoring will provide data regarding impacts from Sandia wetlands mitigation activities.	Alluvial	C

Table 1.9-1 (continued)

Assigned Monitoring Group	Location	Rationale for Selection of Location	Source Aquifer	Water Level*
Mortandad Canyon Watershed				
General Surveillance	MCO-2	Well monitors Effluent Canyon above the TA-50 outfall. Continue monitoring water levels and specific conductance using Aqua Troll transducer to collect data on salinity impacts from snowmelt runoff.	Alluvial	C
	MCO-3	Well monitors upper part of Mortandad Canyon. Water-level data from MCO-3 will be used to document hydrologic characteristics of the alluvial groundwater following reduction of discharges from the TA-50 RLWTF outfall since 2010. Aqua Troll transducer will be used to assess salinity impacts from snowmelt runoff.	Alluvial	C
TA-54 Monitoring Group	R-41 screen 1	Well located east of MDA G at TA-54. Screen 1 has been dry since well installation (March 2009) (Koch and Schmeer 2011, 201566). Water level should be checked annually during sampling of R-41.	Intermediate	A^{HD}
Pajarito Canyon Watershed				
General Surveillance	PCAO-7b2	Well characterizes potential impacts from TA-18. Continue monitoring water levels and specific conductance using Aqua Troll transducer to collect data on salinity impacts from snowmelt runoff.	Alluvial	C
	R-19 screen 1	Well located on a mesa south of Threemile Canyon and downgradient of TA-16. Screen 1 has been dry since installation of the Westbay sampling system in September 2000 (Koch and Schmeer 2011, 201566). Water-level data will continue to be monitored in this screen.	Intermediate	C^{HD}
	R-19 screen 5 R-19 screen 6 R-19 screen 7	Well located on a mesa south of Threemile Canyon and downgradient of TA-16. The collection of water-quality samples from these screens is suspended because they remain impacted by drilling products. Water-level data will continue to be collected from these screens until well R-19 is reconfigured or replaced.	Regional	C
Water Canyon/Cañon de Valle Watershed				
TA-16 260 Monitoring Group	R-25 screen 3	Located at TA-16 within the Cañon de Valle watershed. Screen 3 has always been dry but the screen was damaged during installation and is not reliable for water-level monitoring (Koch and Schmeer 2011, 201566). Pump water at screen 3 responded to drilling and installation of adjacent well R-25c (replacement for R-25 screen 3) in August 2008.	Intermediate	C
Ancho Canyon Watershed				
General Surveillance	R-31 screen 1	Located in the north Ancho Canyon tributary. Zone initially showed water during drilling but has been dry since installation of the Westbay system in April 2000 (Koch and Schmeer 2011, 201566). Water-level data will continue to be monitored in this screen.	Intermediate	C^{HD}

Table 1.9-1 (continued)

Assigned Monitoring Group	Location	Rationale for Selection of Location	Source Aquifer	Water Level*
	R-31 screen 2 R-31 screen 3	The collection of water-quality samples from these screens is suspended because they remain impacted by drilling products. Water-level data will continue to be monitored in these screens.	Regional	C
Water-Level Data from Water-Supply Wells (Koch and Schmeer 2011, 201566)				
Cooperative Agreement	G-1A, G-2A, G-3A, G-5A	Water-supply wells located in Guaje Canyon	Regional	C
	G-4A	Water-supply well located in lower Rendija Canyon near its confluence with Guaje Canyon	Regional	C
	O-1	Water-supply well located in lower Pueblo Canyon	Regional	C
	O-4	Water-supply well located in Los Alamos Canyon above confluence with DP Canyon	Regional	C
	PM-1 and PM-3	Water-supply wells located in Sandia Canyon	Regional	C
	PM-2	Water-supply well located in Pajarito Canyon	Regional	C
	PM-4	Water-supply well located on Mesita del Buey south of Mortandad Canyon	Regional	C
	PM-5	Water-supply well located on a mesa south of Ten Site and Mortandad Canyons	Regional	C

* Sampling frequency: C = continuous; Q = quarterly (4 times/yr at set time periods); S = semiannual (2 times/yr); A = annual (1 time/yr). The superscript HD indicates this sampling location is historically dry. Continuous monitoring for groundwater refers to the measurement of groundwater-level measurements by a transducer placed in a well and programmed to collect groundwater-level measurements at highly frequent intervals (e.g., every 60 min daily throughout the year).

Table 2.4-1
Interim Monitoring Plan for TA-21 Monitoring Group

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
LADP-3	LADP-3	Los Alamos	Monitors downgradient location for potential contaminants from upper Los Alamos Canyon, DP Canyon, and TA-21.	Intermediate	C	—[j]	—	—	—	A	—	A	A	A	A
LAOI(a)-1.1	LAOI(a)-1.1	Los Alamos	Monitors for potential contaminants from upper Los Alamos Canyon, DP Canyon, and TA-21. Background location in Groundwater Background Investigation Report, Revision 3 (GBIR R3) (LANL 2007, 095817) and Groundwater Background Investigation Report, Revision 4 (GBIR R4) (LANL 2010, 110535).	Intermediate	C	—	—	—	—	A	—	A	A	A	A
LAOI-3.2	LAOI-3.2	Los Alamos	Monitors for potential contaminants from upper Los Alamos Canyon, DP Canyon, and TA-21.	Intermediate	C	—	—	—	—	A	A	—	A	A	A
LAOI-3.2a	LAOI-3.2a	Los Alamos	Monitors for potential contaminants from upper Los Alamos Canyon, DP Canyon, and TA-21.	Intermediate	C	—	—	—	—	A	A	—	A	A	A

Table 2.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-5 screen 2	R-5 S2	Los Alamos	Monitors for potential contaminants from upper Pueblo and Acid Canyons.	Intermediate	C	—	—	—	—	A	—	A	A	A	A
R-6i	R-6i	Los Alamos	Monitors for potential contaminants from upper Los Alamos Canyon, DP Canyon, and TA-21.	Intermediate	C	—	A	A	—	A	A	—	A	A	A
TA-53i	TA-53i	Los Alamos	Monitors for potential southward migration of contaminants from sources in Los Alamos Canyon. Located within TA-53 on the mesa separating Los Alamos and Sandia Canyons.	Intermediate	C	—	—	—	—	A	A	—	A	A	A
R-5 screen 3	R-5 S3	Los Alamos	Monitors for potential contaminants from upper Pueblo and Acid Canyons.	Regional	C	—	—	—	—	A	—	A	A	A	A
R-5 screen 4	R-5 S4	Los Alamos	Monitors for potential contaminants from upper Pueblo and Acid Canyons.	Regional	C	—	—	—	—	A	—	A	A	A	A

Table 2.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-6	R-6	Los Alamos	Monitors for potential contaminants from upper Los Alamos Canyon, DP Canyon, and TA-21. Background location in GBIR R4.	Regional	C	—	—	—	—	A	A	—	A	A	A
R-64	R-64	Los Alamos	New single-screen regional well. Monitors downgradient location for potential contaminants from upper Los Alamos and DP Canyons and at TA-21. Completed July 15, 2011.[k]	Regional	C	Q	Q	Q	S	Q	—	Q	Q	Q	Q
R-66	R-66	Los Alamos	New regional well to replace TW-3, located near Otowi-4. Monitors for potential contaminants from upper Los Alamos and DP Canyons and TA-21. Completed 11/16/11.	Regional	C	Q	Q	Q	S	Q	—	Q	Q	Q	Q

Table 2.4-1 (continued)

Notes: Sampling suites and frequencies: C = continuous; Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); T= triennial (1 time every 3 yr). Nonfiltered and filtered samples will be collected for general inorganics (excluding anions). Metals, anions, and perchlorate samples will be filtered. Samples collected for radionuclide analysis will be nonfiltered only for all water media. Organic and HEXP constituents are nonfiltered for all water media.

[a] Continuous monitoring for groundwater refers to the measurement of groundwater levels by a transducer placed in a well and programmed to collect groundwater-level measurements at highly frequent intervals (e.g., every 60 min daily throughout the year). Continuous stream-flow monitoring refers to the measurement of stream flow by a base-flow stream gage that is programmed to collect stream-flow measurements at highly frequent intervals.

[b] Metals analysis includes the 23 TAL metals (Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn), plus boron, molybdenum, silicon dioxide, strontium, tin, and uranium.

[c] VOC = Volatile organic compounds; SVOC = semivolatile organic compounds.

[d] HEXP = High explosive (compounds). The HEXP analytical suite includes the Consent Order list of the normal SW-846:8330 analytes plus pentaerythritol tetranitrate (PETN); triaminotrinitrobenzene (TATB); 3,5-dinitroaniline, tri(o-cresyl)phosphate (TOCP); 2,4-diamino-6-nitrotoluene; and 2,6-diamino-4-nitrotoluene. These additional analytes are analyzed by SW-846:8321A.

[e] The radionuclide suite includes gross alpha, gross beta, alpha spectroscopy, gamma spectroscopy, and strontium-90.

[f] Tritium samples may be submitted for analysis by liquid scintillation if average activities are anticipated to exceed 200 pCi/L. Low-level tritium is analyzed using electrolytic enrichment or direct counting.

[g] General inorganic analysis includes major anions (bromide, chloride, fluoride, sulfate); major cations (calcium, magnesium, sodium, potassium); nitrate plus nitrite (as N); total Kjeldahl nitrogen (TKN); ammonia; total phosphorus, total organic carbon (TOC); total dissolved solids (TDS); alkalinity; specific conductivity; pH; and hardness.

[h] Analysis for perchlorate using high-performance liquid chromatography coupled with electrospray ionization mass spectrometry or tandem mass spectrometry (EPA Method 6850).

[i] Field parameters include pH, turbidity, specific conductance, dissolved oxygen, and temperature at all locations. Oxidation-reduction potential (ORP) will be measured if a flow-through cell is used and will not be measured in surface water, spring water, or water collected from Westbay sampling systems unless specified otherwise..

[j] — = This analytical suite is not scheduled to be collected for this type of water at locations assigned to this monitoring group.

[k] Characterization suites and frequencies apply to new perched-intermediate or regional groundwater wells. “New” wells are defined as those completed, rehabilitated, or converted on or after October 1, 2010.

Table 3.4-1
Interim Monitoring Plan for Chromium Investigation Monitoring Group

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
SCI-1	SCI-1	Sandia	Monitors the first perched-intermediate groundwater encountered along the key infiltration pathway in Sandia Canyon.	Intermediate	C	S	—[j]	—	—	A	A	—	S	S	S
SCI-2	SCI-2	Sandia	Monitors key infiltration pathway in Sandia Canyon.	Intermediate	C	Q	—	—	—	A	A	—	Q	Q	Q
R-11	R-11	Sandia	Monitors for potential contaminants from Sandia Canyon and possibly Los Alamos Canyon.	Regional	C	Q	—	—	—	B	—	A	Q	Q	Q
R-35a	R-35a	Sandia	Sentinel monitoring location for chromium contamination in regional groundwater. Located within the same stratigraphic zone as the upper louvered section of water-supply well PM-3.	Regional	C	A	—	—	—	B	—	A	A	A	A
R-35b	R-35b	Sandia	Sentinel monitoring location for chromium contamination in the regional groundwater. Located near the water table above the louvered section of water-supply well PM-3.	Regional	C	A	—	—	—	B	—	A	A	A	A

Table 3.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-36	R-36	Sandia	Monitors for potential contaminants from the Sandia Canyon source and other potential sources from canyons to the north. Also serves as a sentinel well for water-supply well PM-1.	Regional	C	A	—	—	—	B	—	A	A	A	A
R-43 screen 1	R-43 S1	Sandia	Monitors downgradient extent of contamination originating in Sandia Canyon and possibly canyons to the north.	Regional	C	Q	—	—	—	B	—	A	Q	Q	Q
R-43 screen 2	R-43 S2	Sandia	Monitors downgradient extent of contamination originating in Sandia Canyon and possibly canyons to the north.	Regional	C	Q	—	—	—	B	—	A	Q	Q	Q
MCOI-4	MCOI-4	Mortandad	Monitors for potential contaminants from upper Mortandad and Ten Site Canyons or possibly Sandia Canyon.	Intermediate	C	S	A	A	—	A	A	—	S	S	S
MCOI-5	MCOI-5	Mortandad	Monitors for potential contaminants from upper Mortandad and Ten Site Canyons or possibly Sandia Canyon.	Intermediate	C	A	A	A	—	A	A	—	A	A	A
MCOI-6	MCOI-6	Mortandad	Monitors for potential contaminants from upper Mortandad and Ten Site Canyons or possibly Sandia Canyon.	Intermediate	C	Q	A	A	—	A	A	—	Q	Q	Q
R-1	R-1	Mortandad	Monitors for potential contaminants from upper Mortandad Canyon or possibly Sandia Canyon. Background location in GBIR R3.	Regional	C	A	—	—	—	B	—	A	A	A	A

Table 3.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-13	R-13	Mortandad	Monitors for nature and extent of contaminants originating in Mortandad and Sandia Canyons. Key lower boundary well. Background location in GBIR R3.	Regional	C	A	—	—	—	B	—	A	A	A	A
R-15	R-15	Mortandad	Monitors for potential contaminants from upper Ten Site or Mortandad Canyons.	Regional	C	S	—	—	—	B	—	A	S	S	S
R-28	R-28	Mortandad	Monitors for potential contaminants from upper Sandia, Mortandad, or Ten Site Canyons or possibly sources in canyons to the north.	Regional	C	Q	—	—	—	B	A	—	Q	Q	Q
R-42	R-42	Mortandad	Key characterization and monitoring point located upgradient of R-28.	Regional	C	Q	—	—	—	B	A	—	Q	Q	Q
R-44 screen 1	R-44 S1	Mortandad	Monitors near the water table for nature and extent of contaminants from sources in Sandia Canyon and possibly sources in canyons to the north.	Regional	C	S	—	—	—	B	—	A	S	A	S
R-44 screen 2	R-44 S2	Mortandad	Monitors for nature and extent of contaminants from sources in Sandia Canyon and possibly sources in canyons to the north.	Regional	C	S	—	—	—	B	—	A	S	A	S

Table 3.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-45 screen 1	R-45 S1	Mortandad	Monitors near the water table for nature and extent of contaminants from sources in Sandia Canyon and possibly sources in canyons to the north.	Regional	C	S	—	—	—	B	—	A	S	A	S
R-45 screen 2	R-45 S2	Mortandad	Monitors for nature and extent of contaminants from sources in Sandia Canyon and possibly sources in canyons to the north.	Regional	C	S	—	—	—	B	—	A	S	A	S
R-50 screen 1	R-50 S1	Mortandad	Monitoring well located on the mesa south of Mortandad Canyon to define the southern extent of chromium contamination in the regional aquifer.	Regional	C	Q	—	—	—	B	—	S	Q	Q	Q
R-50 screen 2	R-50 S2	Mortandad	Monitoring well located on the mesa south of Mortandad Canyon to define the southern extent of chromium contamination in the regional aquifer.	Regional	C	Q	—	—	—	B	—	S	Q	Q	Q
R-61 screen 1	R-61 S1	Mortandad	New well located on the mesa south of Mortandad Canyon to define the western extent of the flow path for chromium migration. Completed May 3, 2011.[k]	Regional	C	Q	S	S	S	S	—	S	Q	Q	Q
R-61 screen 2	R-61 S2	Mortandad	New well located on the mesa south of Mortandad Canyon to define the western extent of the flow path for chromium migration. Completed May 3, 2011.[k]	Regional	C	Q	S	S	S	S	—	S	Q	Q	Q

Table 3.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-62 screen 1	R-62 S1	Mortandad	New well located on a ridge between Sandia and Mortandad Canyon at the east end of Sigma Mesa. Completed October 3, 2011.[k]	Regional	C	Q	S	S	S	S	—	S	Q	Q	Q
R-62 screen 2	R-62 S2	Mortandad	New well located on a ridge between Sandia and Mortandad Canyon at the east end of Sigma Mesa. Completed October 3, 2011.[k]	Regional	C	Q	S	S	S	S	—	S	Q	Q	Q

Table 3.4-1 (continued)

Notes: Sampling suites and frequencies: C = continuous; Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); T= triennial (1 time every 3 yr). Nonfiltered and filtered samples will be collected for general inorganics (excluding anions). Metals, anions, and perchlorate samples will be filtered. Samples collected for radionuclide analysis will be nonfiltered only for all water media. Organic and HEXP constituents are nonfiltered for all water media.

[a] Continuous monitoring for groundwater refers to the measurement of groundwater levels by a transducer placed in a well and programmed to collect groundwater-level measurements at highly frequent intervals (e.g., every 60 min daily throughout the year). Continuous stream-flow monitoring refers to the measurement of stream flow by a base-flow stream gage that is programmed to collect stream-flow measurements at highly frequent intervals.

[b] Metals analysis includes the 23 TAL metals (Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn), plus boron, molybdenum, silicon dioxide, strontium, tin, and uranium.

[c] VOC = Volatile organic compounds; SVOC = semivolatile organic compounds.

[d] HEXP = High explosive (compounds). The HEXP analytical suite includes the Consent Order list of the normal SW-846:8330 analytes plus pentaerythritol tetranitrate (PETN); triaminotrinitrobenzene (TATB); 3,5-dinitroaniline, tri(o-cresyl)phosphate (TOCP); 2,4-diamino-6-nitrotoluene; and 2,6-diamino-4-nitrotoluene. These additional analytes are analyzed by SW-846:8321A.

[e] The radionuclide suite includes gross alpha, gross beta, alpha spectroscopy, gamma spectroscopy, and strontium-90.

[f] Tritium samples may be submitted for analysis by liquid scintillation if average activities are anticipated to exceed 200 pCi/L. Low-level tritium is analyzed using electrolytic enrichment or direct counting.

[g] General inorganic analysis includes major anions (bromide, chloride, fluoride, sulfate); major cations (calcium, magnesium, sodium, potassium); nitrate plus nitrite (as N); total Kjeldahl nitrogen (TKN); ammonia; total phosphorus, total organic carbon (TOC); total dissolved solids (TDS); alkalinity; specific conductivity; pH; and hardness.

[h] Analysis for perchlorate using high-performance liquid chromatography coupled with electrospray ionization mass spectrometry or tandem mass spectrometry (EPA Method 6850).

[i] Field parameters include pH, turbidity, specific conductance, dissolved oxygen, and temperature at all locations. Oxidation-reduction potential (ORP) will be measured if a flow-through cell is used and will not be measured in surface water, spring water, or water collected from Westbay sampling systems unless specified otherwise.

[j] — = This analytical suite is not scheduled to be collected for this type of water at locations assigned to this monitoring group.

[k] Characterization suites and frequencies apply to new perched-intermediate or regional groundwater wells. “New” wells are defined as those completed, rehabilitated, or converted on or after October 1, 2010.

Table 4.4-1
Interim Monitoring Plan for MDA C Monitoring Group

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites							
						Metals	Organics			Radionuclides		Inorganics	Field[h]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Low-Level Tritium[f]	Gen Inorganics[g]	DO, ORP, pH, SC, T, Turb
R-14	R-14	Mortandad	Monitors for potential contaminants from Ten Site Canyon or upper Mortandad Canyon, including MDA C. Background location in GBIR R4.	Regional	C	—[i]	S	S	—	A	S	A	S
R-46	R-46	Mortandad	Monitors groundwater quality downgradient of MDA C.	Regional	C	—	S	S	—	A	S	A	S
R-60	R-60	Mortandad	New monitoring well installed east of MDA C. Monitors for potential contaminant releases from MDA C. Completed October 18, 2010.[j]	Regional	C	S	S	S	—	A	S	S	S

Table 4.4-1 (continued)

Notes: Sampling suites and frequencies: C = continuous; Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); T= triennial (1 time every 3 yr). Nonfiltered and filtered samples will be collected for general inorganics (excluding anions). Metals, anions, and perchlorate samples will be filtered. Samples collected for radionuclide analysis will be nonfiltered only for all water media. Organic and HEXP constituents are nonfiltered for all water media.

[a] Continuous monitoring for groundwater refers to the measurement of groundwater levels by a transducer placed in a well and programmed to collect groundwater-level measurements at highly frequent intervals (e.g., every 60 min daily throughout the year). Continuous stream-flow monitoring refers to the measurement of stream flow by a base-flow stream gage that is programmed to collect stream-flow measurements at highly frequent intervals.

[b] Metals analysis includes the 23 TAL metals (Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn), plus boron, molybdenum, silicon dioxide, strontium, tin, and uranium.

[c] VOC = Volatile organic compounds; SVOC = semivolatile organic compounds.

[d] HEXP = High explosive (compounds). The HEXP analytical suite includes the Consent Order list of the normal SW-846:8330 analytes plus pentaerythritol tetranitrate (PETN); triaminotrinitrobenzene (TATB); 3,5-dinitroaniline, tri(o-cresyl)phosphate (TOCP); 2,4-diamino-6-nitrotoluene; and 2,6-diamino-4-nitrotoluene. These additional analytes are analyzed by SW-846:8321A.

[e] The radionuclide suite includes gross alpha, gross beta, alpha spectroscopy, gamma spectroscopy, and strontium-90.

[f] Tritium samples may be submitted for analysis by liquid scintillation if average activities are anticipated to exceed 200 pCi/L. Low-level tritium is analyzed using electrolytic enrichment or direct counting.

[g] General inorganic analysis includes major anions (bromide, chloride, fluoride, sulfate); major cations (calcium, magnesium, sodium, potassium); nitrate plus nitrite (as N); total Kjeldahl nitrogen (TKN); ammonia; total phosphorus, total organic carbon (TOC); total dissolved solids (TDS); alkalinity; specific conductivity; pH; and hardness.

[h] Field parameters include pH, turbidity, specific conductance, dissolved oxygen, and temperature at all locations. Oxidation-reduction potential (ORP) will be measured if a flow-through cell is used and will not be measured in surface water, spring water, or water collected from Westbay sampling systems unless specified otherwise.

[i] — = This analytical suite is not scheduled to be collected for this type of water at locations assigned to this monitoring group.

[j] Characterization suites and frequencies apply to new perched-intermediate or regional groundwater wells. “New” wells are defined as those completed, rehabilitated, or converted on or after October 1, 2010.

Table 5.4-1
Interim Monitoring Plan for TA-54 Monitoring Group

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-23i piezometer (port 1)	R-23i PIEZ	Pajarito	Downgradient monitoring location for TA-54. Monitors potential sources in Pajarito watershed and potential sources in canyons to the north.	Intermediate	A	A	S	A	—[j]	A	A	—	A	—	S
R-23i screen 1 (port 2)	R-23i S2	Pajarito	Downgradient monitoring location for TA-54. Also monitors potential sources in Pajarito watershed and potential sources in canyons to the north.	Intermediate	C	A	S	A	—	A	—	S	A	—	S
R-23i screen 2 (port 3)	R-23i S3	Pajarito	Downgradient monitoring location for TA-54. Monitors potential sources in Pajarito watershed and potential sources in canyons to the north.	Intermediate	C	A	S	A	—	A	—	S	A	—	S
R-40i	R-40 Si	Pajarito	Monitors TA-54 and potential sources in Pajarito watershed. Screen impacted by drilling fluids.	Intermediate	C	A	S	A	—	A	—	S	A	—	S
R-20 screen 1	R-20 S1	Pajarito	Monitors TA-54 and potential sources in Pajarito watershed.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-20 screen 2	R-20 S2	Pajarito	Monitors TA-54 and potential sources in Pajarito watershed.	Regional	C	A	S	A	—	A	—	S	A	—	S

Table 5.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-23	R-23	Pajarito	Downgradient monitoring location for TA-54. Also monitors potential sources in Pajarito watershed and possible sources from canyons to the north.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-32	R-32	Pajarito	Monitors TA-54 and potential sources in Pajarito watershed.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-39	R-39	Pajarito	Monitors TA-54 and potential sources in Pajarito watershed.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-40 screen 1	R-40 S1	Pajarito	Monitors TA-54 and potential sources in Pajarito watershed.	Intermediate	C	—	S	—	—	—	—	S	—	—	S
R-40 screen 2	R-40 S2	Pajarito	Monitors TA-54 and potential sources in Pajarito watershed.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-49 screen 1	R-49 S1	Pajarito	Monitors groundwater south of Area G in Pajarito Canyon.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-49 screen 2	R-49 S2	Pajarito	Monitors groundwater south of Area G in Pajarito Canyon. Background location in GBIR R4.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-51 screen 1	R-51 S1	Pajarito	Monitoring well installed west of MDAs H and J and northwest of TA-18. Monitors TA-54 and other potential contaminant sources in Pajarito Canyon. Completed February 8, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S

Table 5.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-51 screen 2	R-51 S2	Pajarito	Monitoring well installed west of MDAs H and J and northwest of TA-18. Monitors TA-54 and other potential contaminant sources in Pajarito Canyon. Completed February 8, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-54 screen 1	R-54 S1	Pajarito	Monitoring well installed immediately west of MDA L in Pajarito Canyon; monitors for potential releases from MDA L. Completed January 29, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-54 screen 2	R-54 S2	Pajarito	Monitoring well installed immediately west of MDA L in Pajarito Canyon; monitors for potential releases from MDA L. Completed January 29, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-37 screen 1	R-37 S1	Mortandad	Monitors perched-intermediate groundwater downgradient of MDA H.	Intermediate	C	A	S	S	—	A	—	S	A	—	S
R-55i	R-55i	Mortandad	Intermediate well located downgradient of MDA G. Monitors for potential contaminant releases from MDA G and other sources in Pajarito Canyon. Completed January 18, 2011.[k]	Intermediate	C	S	S	S	S	A	—	S	S	S	S

Table 5.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-21	R-21	Mortandad	Monitors regional groundwater in Mortandad Canyon. Background location in GBIR R3 and GBIR R4.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-37 screen 2	R-37 S2	Mortandad	Monitors regional groundwater downgradient of MDA H.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-38	R-38	Mortandad	Monitors groundwater downgradient of MDA L in the north fork of Cañada del Buey in the Mortandad watershed.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-41 screen 2	R-41 S2	Pajarito	Monitors groundwater near northeast corner of MDA G.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-52 screen 1	R-51 S1	Pajarito	Located north-northeast of MDAs H and J on mesa south of Cañada del Buey. Monitors for potential releases of contaminants from MDA H. Completed March 31, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-52 screen 2	R-51 S2	Pajarito	Located north-northeast of MDAs H and J on mesa south of Cañada del Buey. Monitors for potential releases of contaminants from MDA H. Completed March 31, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-53 screen 1	R-53 S1	Pajarito	Located north of MDA L in Cañada del Buey; monitors for potential releases from MDA L. Completed March 29, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S

Table 5.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-53 screen 2	R-53 S2	Pajarito	Located north of MDA L in Cañada del Buey; monitors for potential releases from MDA L. Completed March 29, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-55 screen 1	R-55 S1	Mortandad	Located downgradient of MDA G. Monitors for potential contaminant releases from MDA G and other sources in Pajarito Canyon. Completed August 25, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-55 screen 2	R-55 S2	Mortandad	Located downgradient of MDA G. Monitors for potential contaminant releases from MDA G and other sources in Pajarito Canyon. Completed August 25, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-56 screen 1	R-56 S1	Pajarito	Located on Mesita del Buey between MDAs G and L. Monitors for potential contaminant releases from MDAs G and L and other sources in Pajarito Canyon. Completed July 19, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-56 screen 2	R-56 S2	Pajarito	Located on Mesita del Buey between MDAs G and L. Monitors for potential contaminant releases from MDAs G and L and other sources in Pajarito Canyon. Completed July 19, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S

Table 5.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides			Inorganics		Field[i]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	DO, ORP, pH, SC, T, Turb
R-57 screen 1	R-57 S1	Pajarito	Located downgradient of MDA G at the eastern end of TA-54; monitors for potential releases from MDA G. Completed June 8, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S
R-57 screen 2	R-57 S2	Pajarito	Located downgradient of MDA G at the eastern end of TA-54; monitors for potential releases from MDA G. Completed June 8, 2010.	Regional	C	A	S	A	—	A	—	S	A	—	S

Table 5.4-1 (continued)

Notes: Sampling suites and frequencies: C = continuous; Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); T= triennial (1 time every 3 yr). Nonfiltered and filtered samples will be collected for general inorganics (excluding anions). Metals, anions, and perchlorate samples will be filtered. Samples collected for radionuclide analysis will be nonfiltered only for all water media. Organic and HEXP constituents are nonfiltered for all water media.

[a] Continuous monitoring for groundwater refers to the measurement of groundwater levels by a transducer placed in a well and programmed to collect groundwater-level measurements at highly frequent intervals (e.g., every 60 min daily throughout the year). Continuous stream-flow monitoring refers to the measurement of stream flow by a base-flow stream gage that is programmed to collect stream-flow measurements at highly frequent intervals.

[b] Metals analysis includes the 23 TAL metals (Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn), plus boron, molybdenum, silicon dioxide, strontium, tin, and uranium.

[c] VOC = Volatile organic compounds; SVOC = semivolatile organic compounds.

[d] HEXP = High explosive (compounds). The HEXP analytical suite includes the Consent Order list of the normal SW-846:8330 analytes plus pentaerythritol tetranitrate (PETN); triaminotrinitrobenzene (TATB); 3,5-dinitroaniline, tri(o-cresyl)phosphate (TOCP); 2,4-diamino-6-nitrotoluene; and 2,6-diamino-4-nitrotoluene. These additional analytes are analyzed by SW-846:8321A.

[e] The radionuclide suite includes gross alpha, gross beta, alpha spectroscopy, gamma spectroscopy, and strontium-90.

[f] Tritium samples may be submitted for analysis by liquid scintillation if average activities are anticipated to exceed 200 pCi/L. Low-level tritium is analyzed using electrolytic enrichment or direct counting.

[g] General inorganic analysis includes major anions (bromide, chloride, fluoride, sulfate); major cations (calcium, magnesium, sodium, potassium); nitrate plus nitrite (as N); total Kjeldahl nitrogen (TKN); ammonia; total phosphorus, total organic carbon (TOC); total dissolved solids (TDS); alkalinity; specific conductivity; pH; and hardness.

[h] Analysis for perchlorate using high-performance liquid chromatography coupled with electrospray ionization mass spectrometry or tandem mass spectrometry (EPA Method 6850).

[i] Field parameters include pH, turbidity, specific conductance, dissolved oxygen, and temperature at all locations. Oxidation-reduction potential (ORP) will be measured if a flow-through cell is used and will not be measured in surface water, spring water, or water collected from Westbay sampling systems unless specified otherwise.

[j] — = This analytical suite is not scheduled to be collected for this type of water at locations assigned to this monitoring group.

[k] Characterization suites and frequencies apply to new perched-intermediate or regional groundwater wells. “New” wells are defined as those completed, rehabilitated, or converted on or after October 1, 2010.

Table 6.4-1
Interim Monitoring Plan for TA-16 260 Monitoring Group

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
Cañon de Valle below MDA P (E256)	Cañon de Valle below MDA P	Water	Downgradient surface water location for 260 Outfall. Monitors HE and other contaminants in support of surface CME.	Base flow	C	S	S	—[k]	S	B	—	A	—	S	S
Martin Spring	Martin Spring	Water	Spring located in upper Martin/S-Site Canyon.	Spring	C	S	S	—	S	B	—	A	—	S	S
Burning Ground Spring	Burning Ground Spring	Water	Spring downgradient of TA-16 260 Outfall [Consolidated Unit 16-021(c)-99].	Spring	C	S	S	—	S	B	—	A	—	S	S
CdV-16-02656	CdV-16-02656	Water	Alluvial well location nearest to 260 Outfall drainage/Cañon de Valle confluence. Downgradient of MDA R. Monitors HE and other contaminants in support of surface CME.	Alluvial	C	S	S	—	S	B	—	A	—	S	S
CdV-16-02659	CDV-16-02659	Water	Downgradient alluvial well from 260 Outfall drainage confluence. Monitors HE and other contaminants in support of surface CME.	Alluvial	C	S	S	—	S	B	—	A	—	—	S
CdV-16-611923	CdV-16-611923	Water	Key location downgradient of 260 Outfall.	Alluvial	C	S	S	—	S	B	—	A	—	—	S

Table 6.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
FLC-16-25280	16-25280	Water	Alluvial well downgradient of Fishladder and Burning Ground.	Alluvial	C	S	S	—	S	B	—	A	—	—	S
MSC-16-06295	MSC-16-06295	Water	Alluvial well in S-Site/Martin Canyon downgradient of Martin Spring and several TA-16 SWMU sites.	Alluvial	C	A	A	—	A	B	—	A	—	—	A
16-26644	16-26644	Water	Intermediate well located at TA-16 southeast and downgradient of the 90s Line Pond.	Intermediate	C	S	S	—	S	B	—	A	—	—	S
CdV-16-1(i)	CdV-16-1(i)	Water	Located downgradient of the 260 Outfall.	Intermediate	C	S	S	—	S	B	—	A	—	—	S
CdV-16-2(i)r	CdV-16-2(i)r	Water	Located downgradient of the 260 Outfall.	Intermediate	C	S	S	—	S	B	—	A	—	—	S
CdV-16-4ip screen 1	CDV-16-4ip S1	Water	Hydrologic test well installed downgradient of the 260 Outfall to evaluate the hydrologic properties of the deep perched-intermediate aquifer in TA-16. Completed August 23, 2010.	Intermediate	C	S	S	S	S	A	S	S	S	—	S

Table 6.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
Cdv-37-1(i)	CDV-37-1(i)	Water	Located near the confluence of Water Canyon and Cañon de Valle. Monitors groundwater contamination in the perched-intermediate zone downgradient of TA-16.	Intermediate	C	A	A	—	A	B	—	A	—	—	A
R-25 screen 1	R-25 S1	Water	Downgradient monitoring location for the 260 Outfall.	Intermediate	C	—	S	—	S	B	—	A	—	—	S
R-25 screen 2	R-25 S2	Water	Downgradient monitoring location for the 260 Outfall.	Intermediate	C	S	S	—	S	B	—	A	—	—	S
R-25 screen 4	R-25 S4	Water	Downgradient monitoring location for the 260 Outfall.	Intermediate	C	S	S	—	S	B	—	A	—	—	S
R-25b	R-25b	Water	Located immediately west of R-25 on the mesa top in TA-16. Monitors perched-intermediate groundwater for potential contamination associated with effluent from the 260 Outfall. Installed as a replacement for screen 1 in R-25.	Intermediate	C	A	A	—	A	B	—	A	—	—	A
R-26 PZ-2	R-26 PZ-2	Water	Piezometer installed near R-26. Provides data for perched-intermediate groundwater upgradient of TA-16.	Intermediate	C	S	S	—	S	B	—	A	—	—	S

Table 6.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
R-26 screen 1	R-26 S1	Water	Provides site-specific background data for perched-intermediate groundwater upgradient of TA-16. Background location in GBIR R3. Converted to single-screen well.	Intermediate	C	S	S	S	S	A	S	S	S	—	S
R-47i	R-47i	Water	Located northeast of the 260 Outfall. Provides data in support of the 260 Outfall CME.	Intermediate	C	A	A	—	A	B	—	A	—	—	A
R-25 screen 5	R-25 S5	Water	Downgradient monitoring location for the 260 Outfall.	Regional	C	A	A	—	A	B	—	A	—	—	A
R-25 screen 6	R-25 S6	Water	Downgradient monitoring location for the 260 Outfall.	Regional	C	A	A	—	A	B	—	A	—	—	A
R-25 screen 7	R-25 S7	Water	Downgradient monitoring location for the 260 Outfall.	Regional	C	A	A	—	A	B	—	A	—	—	A
R-48	R-48	Water	Completed by deepening open borehole CdV-16-3(i). Monitors historical TA-16 sources.	Regional	C	A	A	—	A	B	—	A	—	—	A
R-63	R-63	Water	New single-screen regional well installed as a replacement for R-25 screen 5. Completed February 9, 2011.	Regional	C	S+Q	S+Q	S+Q	S+Q	A	S+Q	S+Q	S+Q	—	S+Q

Table 6.4-1 (continued)

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Low-Level Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
R-18	R-18	Pajarito	Monitors for potential contaminants from sources in TA-16.	Regional	C	S	S	—	S	B	—	A	—	—	S

Notes: Sampling suites and frequencies: C = continuous; Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); T= triennial (1 time every 3 yr). Nonfiltered and filtered samples will be collected for general inorganics (excluding anions). Metals, anions, and perchlorate samples will be filtered. Samples collected for radionuclide analysis will be nonfiltered only for all water media. Organic and HEXP constituents are nonfiltered for all water media.

[a] Continuous monitoring for groundwater refers to the measurement of groundwater levels by a transducer placed in a well and programmed to collect groundwater-level measurements at highly frequent intervals (e.g., every 60 min daily throughout the year). Continuous stream-flow monitoring refers to the measurement of stream flow by a base-flow stream gage that is programmed to collect stream-flow measurements at highly frequent intervals.

[b] Metals analysis includes the 23 TAL metals (Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn), plus boron, molybdenum, silicon dioxide, strontium, tin, and uranium.

[c] VOC = Volatile organic compounds; SVOC = semivolatile organic compounds.

[d] HEXP = High explosive (compounds). The HEXP analytical suite includes the Consent Order list of the normal SW-846:8330 analytes plus pentaerythritol tetranitrate (PETN); triaminotrinitrobenzene (TATB); 3,5-dinitroaniline, tri(o-cresyl)phosphate (TOCP); 2,4-diamino-6-nitrotoluene; and 2,6-diamino-4-nitrotoluene. These additional analytes are analyzed by SW-846:8321A.

[e] The radionuclide suite includes gross alpha, gross beta, alpha spectroscopy, gamma spectroscopy, and strontium-90.

[f] Tritium samples may be submitted for analysis by liquid scintillation if average activities are anticipated to exceed 200 pCi/L. Low-level tritium is analyzed using electrolytic enrichment or direct counting.

[g] General inorganic analysis includes major anions (bromide, chloride, fluoride, sulfate); major cations (calcium, magnesium, sodium, potassium); nitrate plus nitrite (as N); total Kjeldahl nitrogen (TKN); ammonia; total phosphorus, total organic carbon (TOC); total dissolved solids (TDS); alkalinity; specific conductivity; pH; and hardness.

[h] Analysis for perchlorate using high-performance liquid chromatography coupled with electrospray ionization mass spectrometry or tandem mass spectrometry (EPA Method 6850).

[i] Suspended sed = Suspended sediment concentration.

[i] Field parameters include pH, turbidity, specific conductance, dissolved oxygen, and temperature at all locations. Oxidation-reduction potential (ORP) will be measured if a flow-through cell is used and will not be measured in surface water, spring water, or water collected from Westbay sampling systems unless specified otherwise.

[k] — = This analytical suite is not scheduled to be collected for this type of water at locations assigned to this monitoring group.

Table 7.4-1
Interim Monitoring Plan for MDA AB Monitoring Group

Old Location Name	New Location Name	Watershed	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites							
						Metals	Organics			Radionuclides		Inorganics	Field[h]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Low-Level Tritium[f]	Gen Inorganics[g]	DO, ORP, pH, SC, T, Turb
R-29	R-29	Ancho	Located downgradient of TA-49 MDA AB. Installed to determine whether zones of perched-intermediate groundwater occur under MDA AB. Completed March 12, 2010.	Regional	C	A	A	A	A	A	A	A	A
R-30	R-30	Ancho	Located at the eastern edge of TA-49 and downgradient of MDA AB. Installed to determine whether zones of perched-intermediate groundwater occur under MDA AB. Completed April 3, 2010.	Regional	C	A	A	A	A	A	A	A	A
R-27i	R-27i	Water	Monitors potential contamination associated with the perched-intermediate zone downgradient of historical TA-16 sources.	Intermediate	C	A	A	A	A	A	A	A	A
R-27	R-27	Water	Monitors TA-16 in support of the TA-16 260 Outfall CME. Background location in GBIR R4.	Regional	C	A	A	A	A	A	A	A	A

Table 7.4-1 (continued)

Notes: Sampling suites and frequencies: C = continuous; Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); T= triennial (1 time every 3 yr). Nonfiltered and filtered samples will be collected for general inorganics (excluding anions). Metals, anions, and perchlorate samples will be filtered. Samples collected for radionuclide analysis will be nonfiltered only for all water media. Organic and HEXP constituents are nonfiltered for all water media.

[a] Continuous monitoring for groundwater refers to the measurement of groundwater levels by a transducer placed in a well and programmed to collect groundwater-level measurements at highly frequent intervals (e.g., every 60 min daily throughout the year). Continuous stream-flow monitoring refers to the measurement of stream flow by a base-flow stream gage that is programmed to collect stream-flow measurements at highly frequent intervals.

[b] Metals analysis includes the 23 TAL metals (Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn), plus boron, molybdenum, silicon dioxide, strontium, tin, and uranium.

[c] VOC = Volatile organic compounds; SVOC = semivolatile organic compounds.

[d] HEXP = High explosive (compounds). The HEXP analytical suite includes the Consent Order list of the normal SW-846:8330 analytes plus pentaerythritol tetranitrate (PETN); triaminotrinitrobenzene (TATB); 3,5-dinitroaniline, tri(o-cresyl)phosphate (TOCP); 2,4-diamino-6-nitrotoluene; and 2,6-diamino-4-nitrotoluene. These additional analytes are analyzed by SW-846:8321A.

[e] The radionuclide suite includes gross alpha, gross beta, alpha spectroscopy, gamma spectroscopy, and strontium-90.

[f] Tritium samples may be submitted for analysis by liquid scintillation if average activities are anticipated to exceed 200 pCi/L. Low-level tritium is analyzed using electrolytic enrichment or direct counting.

[g] General inorganic analysis includes major anions (bromide, chloride, fluoride, sulfate); major cations (calcium, magnesium, sodium, potassium); nitrate plus nitrite (as N); total Kjeldahl nitrogen (TKN); ammonia; total phosphorus, total organic carbon (TOC); total dissolved solids (TDS); alkalinity; specific conductivity; pH; and hardness.

[h] Field parameters include pH, turbidity, specific conductance, dissolved oxygen, and temperature at all locations. Oxidation-reduction potential (ORP) will be measured if a flow-through cell is used and will not be measured in surface water, spring water, or water collected from Westbay sampling systems unless specified otherwise.

Table 8.3-1
Interim Monitoring Plan for General Surveillance Monitoring

Old Location Name	New Location Name	Watershed	Comment	Zone	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
LAO-3a	LAO-3a	Upper Los Alamos Canyon	Monitors net effect of mixing of alluvial groundwater from Los Alamos and DP Canyons. Located just downcanyon of the confluence of Los Alamos and DP Canyons.	Alluvial	C	A	—[k]	—	—	A	—	A	A	—	A
LAOI-7	LAOI-7	Upper Los Alamos Canyon	Monitors downgradient location for potential contaminants from upper Los Alamos and DP Canyons and TA-21.	Intermediate	C	A	—	—	—	A	A	A	A	—	A
R-9i screen 1	R-9i S1	Upper Los Alamos Canyon	Monitors downgradient location for potential contaminants from upper Los Alamos and DP Canyons and TA-21 and possible southward perched-zone migration from Pueblo Canyon.	Intermediate	C	A	—	—	—	A	—	A	A	—	A
R-9i screen 2	R-9i S2	Upper Los Alamos Canyon	Monitors downgradient location for potential contaminants from upper Los Alamos and DP Canyons and TA-21 and possible southward perched-zone migration from Pueblo Canyon.	Intermediate	C	A	—	—	—	A	—	A	A	—	A

Table 8.3-1 (continued)

Old Location Name	New Location Name	Watershed	Comment	Zone	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
R-8 screen 1	R-8 S1	Upper Los Alamos Canyon	Monitors downgradient location for potential contaminants from upper Los Alamos and DP Canyons and TA-21.	Regional	C	A	—	—	—	A	—	A	A	—	A
R-8 screen 2	R-8 S2	Upper Los Alamos Canyon	Monitors downgradient location for potential contaminants from upper Los Alamos and DP Canyons and TA-21.	Regional	C	A	—	—	—	A	—	A	A	—	A
R-9	R-9	Upper Los Alamos Canyon	Monitors downgradient location for potential contaminants from upper Los Alamos and DP Canyons and TA-21 and or possible southward perched-zone migration from Pueblo Canyon.	Regional	C	A	—	—	—	A	—	A	A	—	A
APCO-1	APCO-1	Pueblo	Monitors within the wetland below the Pueblo WWTP. Most downcanyon monitoring point in Pueblo Canyon.	Alluvial	C	A	—	—	—	A	—	A	A	—	A
POI-4	POI-4	Pueblo	Monitors for potential contaminants from upper Pueblo and Acid Canyons sources.	Intermediate	C	A	—	—	—	A	—	A	A	—	A
R-3i	R-3i	Pueblo	Monitors along the potential infiltration pathway originating in lower Pueblo Canyon.	Intermediate	C	A	A	A	—	A	—	A	A	—	A

Table 8.3-1 (continued)

Old Location Name	New Location Name	Watershed	Comment	Zone	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
TW-2Ar	TW-2Ar	Pueblo	Replacement monitoring well for TW-2A. Monitors perched-intermediate groundwater in lower Pueblo Canyon. Completed March 4, 2010.	Intermediate	C	A	—	—	—	A	A	A	A	—	A
R-2	R-2	Pueblo	Monitors for potential contaminants from upper Pueblo and Acid Canyons. Background location in GBIR R4.	Regional	C	A	—	—	—	A	—	A	A	—	A
R-3	R-3	Pueblo	Located in Pueblo Canyon, near the eastern boundary of TA-74. Monitors potential contaminant flow paths near municipal production well Otowi 1. Completed June 21, 2010.	Regional	C	A	—	—	—	A	—	A	A	—	A
R-4	R-4	Pueblo	Monitors for potential contaminants from upper Pueblo and Acid Canyons.	Regional	C	A	—	—	—	A	—	A	A	—	A
R-24	R-24	Pueblo	Monitors for potential contaminants from upper Pueblo and Acid Canyons and Guaje Canyon. Background location in GBIR R4.	Regional	C	A	—	—	—	A	—	A	A	—	A

Table 8.3-1 (continued)

Old Location Name	New Location Name	Watershed	Comment	Zone	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
Los Alamos Canyon near Otowi Bridge (E110)	LA Canyon near Otowi Bridge	Lower Los Alamos Canyon	Measures quality of persistent surface water in Los Alamos Canyon above the confluence of Los Alamos Canyon and Rio Grande. Located on San Ildefonso land and sampled under the MOU.	Base flow	A	A	A	A	T	A	—	A	A	A	A
Basalt Spring/Vine Tree Spring	Basalt Spring	Lower Los Alamos Canyon	Basalt Spring water quality indicates a relation to perched-intermediate groundwater in lower Pueblo Canyon. Located on San Ildefonso land immediately downgradient of the Laboratory boundary and sampled under the MOU. Sample Basalt Spring; if not possible, sample Vine Tree Spring.	Spring	S	S	S	T	T	S	—	S	S	S	S
Los Alamos Spring	Los Alamos Spring	Lower Los Alamos Canyon	Los Alamos Spring water quality indicates a relation to perched-intermediate groundwater, possibly originating beneath Los Alamos Canyon. Located on San Ildefonso land and sampled under the MOU.	Spring	A	A	A	T	T	A	—	A	A	A	A

Table 8.3-1 (continued)

Old Location Name	New Location Name	Watershed	Comment	Zone	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
LLAO-1b	LLAO-1b	Lower Los Alamos Canyon	Monitors upper portion of San Ildefonso Pueblo reach in lower Los Alamos Canyon. Water quality is consistent with recharge of water that emerges at Basalt Spring. Located on San Ildefonso land and sampled under the MOU.	Alluvial	C	A	A	T	T	A	—	A	A	—	A
LLAO-4	LLAO-4	Lower Los Alamos Canyon	Monitors lower San Ildefonso Pueblo reach in lower Los Alamos Canyon near the confluence with Rio Grande. Water quality appears to reflect mixing with regional groundwater near the Rio Grande. Located on San Ildefonso land and sampled under the MOU.	Alluvial	C	A	A	T	T	A	—	A	A	—	A
SCA-2	SCA-2	Sandia	Located at the upper portion of the lower canyon where the valley floor first opens up and the first significant alluvial storage is present along the canyon.	Alluvial	C^{MP}	A	—	—	—	A	—	A	A	—	A
R-12 screen 1	R-12 S1	Sandia	Monitors for potential contaminants from Sandia Canyon or possibly Los Alamos or Pueblo Canyons.	Intermediate	C	A	—	—	—	A	—	A	A	—	A

Table 8.3-1 (continued)

Old Location Name	New Location Name	Watershed	Comment	Zone	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
R-12 screen 2	R-12 S2	Sandia	Monitors for potential contaminants from Sandia Canyon or possibly Los Alamos or Pueblo Canyons.	Intermediate	C	A	—	—	—	A	—	A	A	—	A
R-10 screen 1	R-10 S1	Sandia	Monitors for potential contaminants from Sandia Canyon and possibly Los Alamos or Pueblo Canyons. Located on San Ildefonso land and sampled under the MOU. Background location in GBIR R4.	Regional	C	A	A	A	T	A	—	A	A	—	A
R-10 screen 2	R-10 S2	Sandia	Monitors for potential contaminants from Sandia Canyon and possibly Los Alamos or Pueblo Canyons. Located on San Ildefonso land and sampled under the MOU. Background location in GBIR R4.	Regional	C	A	A	A	T	A	—	A	A	—	A
R-10a	R-10a	Sandia	Monitors for potential contaminants from Sandia Canyon and possibly Los Alamos or Pueblo Canyons. Located on San Ildefonso land and sampled under the MOU.	Regional	C	A	A	A	T	A	—	A	A	—	A

Table 8.3-1 (continued)

Old Location Name	New Location Name	Watershed	Comment	Zone	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
CDBO-6	CDBO-6	Mortandad	Located in a small spatially limited saturated zone below Cañada del Buey in shallow bedrock. Monitors infiltration of runoff through the canyon floor.	Alluvial	C	A	—	—	—	A	—	A	A	—	A
MCO-5	MCO-5	Mortandad	Monitors trends in alluvial groundwater quality following upgrades to the RLWTF.	Alluvial	C	A	—	—	—	A	A	A	A	—	A
MCO-7	MCO-7	Mortandad	Near recent downcanyon extent of alluvial saturation. Monitors trends in alluvial groundwater quality following upgrades to the RLWTF. Monitoring required for RLWTF Discharge Permit DP-1132.	Alluvial	C	A	—	—	—	A	A	A	A	—	A
R-16 screen 2	R-16 S2	Mortandad	Downgradient monitoring location for TA-54 or other possible sources in Pajarito Canyon or canyons to the north.	Regional	C	A	—	—	—	A	—	A	A	—	A
R-16 screen 4	R-16 S4	Mortandad	Downgradient monitoring location for TA-54 or other possible sources in Pajarito Canyon or canyons to the north.	Regional	C	A	—	—	—	A	—	A	A	—	A

Table 8.3-1 (continued)

Old Location Name	New Location Name	Watershed	Comment	Zone	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
R-16r	R-16r	Mortandad	Downgradient monitoring location for TA-54 or other possible sources in Pajarito Canyon or canyons to the north. Replaces screen 1 in R-16. Background location in GBIR R4.	Regional	C	A	—	—	—	A	—	A	A	—	A
R-33 screen 1	R-33 S1	Mortandad	Monitors for potential contaminants from upper Ten Site or Mortandad Canyons. Background location in GBIR R4.	Regional	C	A	—	—	—	A	—	A	A	—	A
R-33 screen 2	R-33 S2	Mortandad	Monitors for potential contaminants from upper Ten Site or Mortandad Canyons. Background location in GBIR R4.	Regional	C	A	—	—	—	A	—	A	A	—	A
R-34	R-34	Mortandad	Monitors regional groundwater for potential contaminants originating beneath Los Alamos, Sandia, or Mortandad Canyons. Key monitoring location for San Ildefonso and Buckman Well Field. Located on San Ildefonso land and sampled under the MOU. Background location in GBIR R4.	Regional	C	Q	A	A	T	A	—	Q	A	—	Q
Bulldog Spring	Bulldog Spring	Pajarito	Monitors HE contamination downgradient of TA-09.	Spring	A	A	—	—	A	A	—	A	A	A	A

Table 8.3-1 (continued)

Old Location Name	New Location Name	Watershed	Comment	Zone	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
18-MW-18	18-MW-18	Pajarito	Part of a group of alluvial wells within the former TA-18 complex. Monitoring point for potential releases associated with historical sewage lagoons on lower Pajarito Canyon.	Alluvial	C^{MP}	A	—	—	A	A	—	A	A	—	A
PCAO-8	PCAO-8	Pajarito	Characterizes potential impacts from runoff associated with TA-54 near PCTH-5 (between PCO 2 and PCO-3).	Alluvial	C	A	—	—	A	A	—	A	A	—	A
03-B-13	03-B-13	Pajarito	Near TA-03, building SM-30. Monitored in support of project at SWMU 03-010(a).	Intermediate	C	S	S	S	A	A	A	S	A	—	S
R-19 screen 2	R-19 S2	Pajarito	Monitors for potential contaminants from TA-16. Also provides baseline characterization data for downgradient areas, including TA-54.	Intermediate	C	A	—	—	A	A	—	A	A	—	A
PCI-2	PCI-2	Pajarito	Monitors perched-intermediate groundwater at the confluence of Twomile and Pajarito Canyons. Provides baseline characterization data for areas upgradient of TA-54. Background location in GBIR R4.	Intermediate	C	A	—	—	A	A	—	A	A	—	A

Table 8.3-1 (continued)

Old Location Name	New Location Name	Watershed	Comment	Zone	Water Level or Flow[a]	Analytical Suites									
						Metals	Organics			Radionuclides		Inorganics			Field[j]
						Metals (Filtered)[b]	VOCs[c]	SVOCs[c]	HEXP[d]	Radionuclide[e]	Tritium[f]	Gen Inorganics[g]	Perchlorate[h]	Suspended Sed[i]	DO, ORP, pH, SC, T, Turb
R-17 screen 1	R-17 S1	Pajarito	Monitors MDA C, TA-16, and potential sources in upper Pajarito watershed. Background location in GBIR R4.	Regional	C	A	—	—	A	A	—	A	A	—	A
R-17 screen 2	R-17 S2	Pajarito	Monitors MDA C, TA-16, and potential sources in upper Pajarito watershed. Background location in GBIR R4.	Regional	C	A	—	—	A	A	—	A	A	—	A
R-19 screen 3	R-19 S3	Pajarito	Monitors for potential contaminants from TA-16. Also provides baseline characterization data for downgradient areas including TA-54.	Regional	C	A	—	—	A	A	—	A	A	—	A
R-19 screen 4	R-19 S4	Pajarito	Monitors for potential contaminants from TA-16. Also provides baseline characterization data for downgradient areas including TA-54.	Regional	C	A	—	—	A	A	—	A	A	—	A
WCO-1r	WCO-1r	Water	Replacement well for MCO-1.	Alluvial	C	A	—	—	A	A	—	A	A	—	A
R-31 screen 4	R-31 S4	Frijoles, Ancho, and Chaquehui	Part of interim monitoring network pending well network assessment for MDA AB.	Regional	C	A	—	—	A	A	—	A	A	—	A
R-31 screen 5	R-31 S5	Frijoles, Ancho, and Chaquehui	Part of interim monitoring network pending well network assessment for MDA AB.	Regional	C	A	—	—	A	A	—	A	A	—	A

Table 8.3-1 (continued)

Notes: Sampling suites and frequencies: C = continuous; Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); T= triennial (1 time every 3 yr). Nonfiltered and filtered samples will be collected for general inorganics (excluding anions). Metals, anions, and perchlorate samples will be filtered. Samples collected for radionuclide analysis will be nonfiltered only for all water media. Organic and HEXP constituents are nonfiltered for all water media.

[a] Continuous monitoring for groundwater refers to the measurement of groundwater levels by a transducer placed in a well and programmed to collect groundwater-level measurements at highly frequent intervals (e.g., every 60 min daily throughout the year). Continuous stream-flow monitoring refers to the measurement of stream flow by a base-flow stream gage that is programmed to collect stream-flow measurements at highly frequent intervals. The superscript MP indicates water levels will be monitored at highly frequent intervals using a multiparameter probe that measures specific conductance, water level, and temperature. Spring discharge is measured during semiannual (S) or annual (A) sampling.

[b] Metals analysis includes the 23 TAL metals (Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn), plus boron, molybdenum, silicon dioxide, strontium, tin, and uranium.

[c] VOC = Volatile organic compounds; SVOC = semivolatile organic compounds.

[d] HEXP = High explosive (compounds). The HEXP analytical suite includes the Consent Order list of the normal SW-846:8330 analytes plus pentaerythritol tetranitrate (PETN); triaminotrinitrobenzene (TATB); 3,5-dinitroaniline, tri(o-cresyl)phosphate (TOCP); 2,4-diamino-6-nitrotoluene; and 2,6-diamino-4-nitrotoluene. These additional analytes are analyzed by SW-846:8321A.

[e] The radionuclide suite includes gross alpha, gross beta, alpha spectroscopy, gamma spectroscopy, and strontium-90.

[f] Tritium samples may be submitted for analysis by liquid scintillation if average activities are anticipated to exceed 200 pCi/L. Low-level tritium is analyzed using electrolytic enrichment or direct counting.

[g] General inorganic analysis includes major anions (bromide, chloride, fluoride, sulfate); major cations (calcium, magnesium, sodium, potassium); nitrate plus nitrite (as N); total Kjeldahl nitrogen (TKN); ammonia; total phosphorus, total organic carbon (TOC); total dissolved solids (TDS); alkalinity; specific conductivity; pH; and hardness.

[h] Analysis for perchlorate using high-performance liquid chromatography coupled with electrospray ionization mass spectrometry or tandem mass spectrometry (EPA Method 6850).

[i] Suspended sed = Suspended sediment concentration.

[i] Field parameters include pH, turbidity, specific conductance, dissolved oxygen, and temperature at all locations. Oxidation-reduction potential (ORP) will be measured if a flow-through cell is used and will not be measured in surface water, spring water, or water collected from Westbay sampling systems unless specified otherwise.

[k] — = This analytical suite is not scheduled to be collected for this type of water at locations assigned to this monitoring group.

Table 8.3-2
Interim Monitoring Plan for White Rock Canyon and Rio Grande Watershed

Location	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites														
				Metals	Organics						Radionuclides			Inorganics				Field[l]
				Metals[b]	VOCs[c]	SVOCs[c]	Pesticides	PCB[d]	HEXP[e]	Dioxins/Furans	Radionuclide[f]	Tritium[g]	Low-Level Tritium[g]	Gen Inorganics[h]	Perchlorate[i]	Stable Isotopes[j]	Suspended Sed[k]	DO, ORP, pH, SC, T, Turb, ALK
Ancho at Rio Grande	Historical annual sampling site. Monitors base flow from Ancho at Rio Grande. If base flow is not reaching the Rio Grande, a surface water sample will be collected at the first upstream location with sufficient flow that is no farther than 1000 ft from the confluence with the Rio Grande.	Base flow	A	A	A	T	T	T	T	T	A	—[m]	—	A	A	—	A	A
Frijoles at Rio Grande	Perimeter station for the Laboratory. Sampled in fall, during White Rock and Rio Grande watershed sampling event. If base flow is not reaching the Rio Grande, a surface water sample will be collected at the first upstream location with sufficient flow that is no farther than 1000 ft from the confluence with the Rio Grande.	Base flow	A	A	A	T	T	T	T	T	A	—	—	A	A	—	A	A
Mortandad at Rio Grande	Located on San Ildefonso land and sampled under the MOU. If base flow is not reaching the Rio Grande, a surface water sample will be collected at the first upstream location with sufficient flow that is no farther than 1000 ft from the confluence with the Rio Grande.	Base flow	A	A	A	A	T	A	A	T	A	—	A	A	A	—	A	A

Table 8.3-2 (continued)

Location	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites															
				Metals	Organics						Radionuclides			Inorganics				Field[l]
				Metals[b]	VOCs[c]	SVOCs[c]	Pesticides	PCB[d]	HEXP[e]	Dioxins/Furans	Radionuclide[f]	Tritium[g]	Low-Level Tritium[g]	Gen Inorganics[h]	Perchlorate[i]	Stable Isotopes[j]	Suspended Sed[k]	DO, ORP, pH, SC, T, Turb, ALK
Pajarito at Rio Grande	Monitors base flow from Pajarito at the Rio Grande. If base flow is not reaching the Rio Grande, a surface water sample will be collected at the first upstream location with sufficient flow that is no farther than 1000 ft from the confluence with the Rio Grande.	Base flow	A	A	A	T	T	T	T	T	A	—	—	A	A	—	A	A
Rio Grande at Frijoles	Monitors base flow in the Rio Grande at Frijoles Canyon.	Base flow	A	A	A	T	T	T	T	T	A	—	—	A	A	—	A	A
Rio Grande at Otowi Upper	Monitors base flow in the Rio Grande at Otowi Bridge. Located on San Ildefonso land and sampled under the MOU.	Base flow	A	A	A	A	T	A	A	T	A	—	A	A	A	—	A	A
La Mesita Spring	Monitors regional aquifer downgradient of the Laboratory. Located on San Ildefonso land and sampled under the MOU.	Spring	A	A	A	T	T	T	T	T	A	—	A	A	A	—	A	A
Sacred Spring	Off-site spring that monitors regional aquifer downgradient of the Laboratory. Background location. Located on San Ildefonso land and sampled under the MOU. Background location in GBIR R3 and GBIR R4.	Spring	A	A	A	T	T	T	T	T	A	—	A	A	A	—	A	A
Sandia Spring	Monitors regional aquifer downgradient of the Laboratory. Located on San Ildefonso land and sampled under the MOU. Background location in GBIR R4.	Spring	A	A	A	T	T	T	T	T	A	—	A	A	A	—	A	A

Table 8.3-2 (continued)

Location	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites															
				Metals	Organics						Radionuclides			Inorganics				Field[l]
				Metals[b]	VOCs[c]	SVOCs[c]	Pesticides	PCB[d]	HEXP[e]	Dioxins/Furans	Radionuclide[f]	Tritium[g]	Low-Level Tritium[g]	Gen Inorganics[h]	Perchlorate[i]	Stable Isotopes[j]	Suspended Sed[k]	DO, ORP, pH, SC, T, Turb, ALK
Spring 1	Monitors regional aquifer downgradient of the Laboratory. Background location. Located on San Ildefonso land and sampled under the MOU. Background location in GBIR R3 and GBIR R4.	Spring	A	A	A	T	T	T	T	T	A	—	A	A	A	—	A	A
Spring 2	Monitors regional aquifer downgradient of the Laboratory. Located on San Ildefonso land and sampled under the MOU.	Spring	A	A	A	T	T	T	T	T	A	—	A	A	A	—	A	A
Spring 2B	Monitors regional aquifer downgradient of the Laboratory.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A
Spring 3	Monitors regional aquifer downgradient of the Laboratory.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A
Spring 3A	Monitors regional aquifer downgradient of the Laboratory.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A
Spring 3AA	Monitors regional aquifer downgradient of the Laboratory.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A
Spring 4	Monitors regional aquifer downgradient of the Laboratory.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A
Spring 4A	Monitors regional aquifer downgradient of the Laboratory.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A
Spring 4AA	Monitors regional aquifer downgradient of the Laboratory.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A
Spring 4B	Monitors regional aquifer downgradient of the Laboratory.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A

Table 8.3-2 (continued)

Location	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites															
				Metals	Organics						Radionuclides			Inorganics				Field[l]	
				Metals[b]	VOCs[c]	SVOCs[c]	Pesticides	PCB[d]	HEXP[e]	Dioxins/Furans	Radionuclide[f]	Tritium[g]	Low-Level Tritium[g]	Gen Inorganics[h]	Perchlorate[i]	Stable Isotopes[j]	Suspended Sed[k]	DO, ORP, pH, SC, T, Turb, ALK	
Ancho Spring	Monitors regional aquifer downgradient of the Laboratory. Background location in GBIR R3 and GBIR R4.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A	
Spring 5	Monitors regional aquifer downgradient of the Laboratory.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A	
Spring 5A	Monitors regional aquifer downgradient of the Laboratory.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A	
Spring 5B	Monitors regional aquifer downgradient of the Laboratory. Background location in GBIR R3.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A	
Spring 6	Monitors regional aquifer downgradient of the Laboratory. Background location in GBIR R3 and GBIR R4.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A	
Spring 6A	Monitors regional aquifer downgradient of the Laboratory. Background location in GBIR R3 and GBIR R4.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A	
Spring 8A	Monitors regional aquifer downgradient of the Laboratory. Background location in GBIR R3.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A	
Spring 9	Monitors regional aquifer downgradient of the Laboratory. Background location in GBIR R3 and GBIR R4.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A	

Table 8.3-2 (continued)

Location	Rationale for Selection of Location	Surface Water Body or Source Aquifer	Water Level or Flow[a]	Analytical Suites															
				Metals	Organics						Radionuclides			Inorganics				Field[l]	
				Metals[b]	VOCs[c]	SVOCs[c]	Pesticides	PCB[d]	HEXP[e]	Dioxins/Furans	Radionuclide[f]	Tritium[g]	Low-Level Tritium[g]	Gen Inorganics[h]	Perchlorate[i]	Stable Isotopes[j]	Suspended Sed[k]	DO, ORP, pH, SC, T, Turb, ALK	
Spring 9A	Monitors regional aquifer downgradient of the Laboratory. Background location in GBIR R3 and GBIR R4.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A		
Spring 9B	Monitors regional aquifer downgradient of the Laboratory. Background location in GBIR R3 and GBIR R4.	Spring	A	A	A	A	T	T	A	T	A	—	A	A	A	—	A	A	

Table 8.3-2 (continued)

Notes: Sampling suites and frequencies: C = continuous; Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); T= triennial (1 time every 3 yr). Some locations may be assigned analytical suites or frequencies that differ from those indicated for the general surveillance monitoring group in Table 1.6-3 for site-specific reasons summarized in Table D-8.8-3.

Nonfiltered and filtered samples will be collected for general inorganics (excluding anions) and metals. Anions and perchlorate samples will be filtered. Samples collected for radionuclide analysis will be nonfiltered only for all water media. Organic and HEXP constituents are nonfiltered for all water media. Stable isotope samples for nitrogen isotopes are filtered; stable isotope samples for deuterium and oxygen isotopes are not filtered.

[a] Continuous monitoring for groundwater refers to the measurement of groundwater levels by a transducer placed in a well and programmed to collect groundwater-level measurements at highly frequent intervals (e.g., every 60 min daily throughout the year). Continuous stream-flow monitoring refers to the measurement of stream flow by a base-flow stream gage that is programmed to collect stream-flow measurements at highly frequent intervals. The superscript MP indicates water levels will be monitored at highly frequent intervals using a multiparameter probe that measures specific conductance, water level, and temperature. The superscript HD indicates that this sampling location is historically dry.

[b] Metals analysis includes the 23 TAL metals, plus boron, molybdenum, silicon dioxide, strontium, tin, and uranium.

[c] VOC = Volatile organic compounds; SVOC = semivolatile organic compounds.

[d] PCB = Polychlorinated biphenyl (compound).

[e] HEXP = High explosive (compounds). The HEXP analytical suite includes the Consent Order list of the normal SW-846:8330 analytes plus pentaerythritol tetranitrate (PETN); triaminotrinitrobenzene (TATB); 3,5-dinitroaniline, tri(o-cresyl)phosphate (TOCP); 2,4-diamino-6-nitrotoluene; and 2,6-diamino-4-nitrotoluene. These additional analytes are analyzed by SW-846:8321A.

[f] The radionuclide suite includes gross alpha, gross beta, alpha spectroscopy, gamma spectroscopy, and strontium-90.

[g] Tritium samples may be submitted for analysis by liquid scintillation if average activities are anticipated to exceed 200 pCi/L. Low-level tritium is analyzed using electrolytic enrichment or direct counting.

[h] General inorganic analysis includes major anions (bromide, chloride, fluoride, sulfate); major cations (calcium, magnesium, sodium, potassium); nitrate plus nitrite (as N); total Kjeldahl nitrogen (TKN); ammonia; total phosphorus, total organic carbon (TOC); total dissolved solids (TDS); alkalinity; specific conductivity; pH; and hardness.

[i] Analysis for perchlorate using high-performance liquid chromatography coupled with electrospray ionization mass spectrometry or tandem mass spectrometry (EPA Method 6850).

[j] Analysis for stable nitrogen, deuterium, and oxygen isotopes. The collection of samples for stable isotopic analysis is considered a special sampling campaign that is outside the scope of the regulatory process. In general, samples for isotopic analysis are collected semiannually from “new” wells (those which completed construction, rehabilitation, or conversion on or after October 1, 2010) until at least four sets of data have been collected. Any subsequent sampling for stable isotope analysis will be decided on the basis of site-specific conditions.

[k] Suspended sed = Suspended sediment concentration.

[l] Field parameters include pH, turbidity, specific conductance, dissolved oxygen, and temperature at all locations. Oxidation-reduction potential (ORP) will be measured if a flow-through cell is used and will not be measured in surface water, spring water, or water collected from Westbay sampling systems unless specified otherwise. Alkalinity (ALK) will be measured for all samples either in the field or at the on-site EES-14 laboratory.

[m] — = This analytical suite is not scheduled to be collected for this type of water at locations assigned to this monitoring group.

Appendix A

Acronyms and Abbreviations,
Metric Conversion Table, and Data Qualifier Definitions

A-1.0 ACRONYMS AND ABBREVIATIONS

ALK	alkalinity
AK	acceptable knowledge
AOC	area of concern
BCG	Biota Concentration Guides (DOE)
bgs	below ground surface
cfs	cubic feet per second
CFR	Code of Federal Regulations
CME	corrective measures evaluation
CMI	corrective measures implementation
Consent Order	Compliance Order on Consent
COPC	chemical of potential concern
CV	casing volume
DCG	Derived Concentration Guidelines (DOE)
DO	dissolved oxygen
DOE	Department of Energy (U.S.)
EES-14	Earth Systems Observations (Laboratory group)
EP	Environmental Programs (Directorate)
EPA	Environmental Protection Agency (U.S.)
F	filtered
FD	frequency of detection
FY	fiscal year
GBIR	Groundwater Background Investigation Report
GFM	geologic framework model
GW	groundwater
HE	high explosives (also HEXP)
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
IDW	investigation-derived waste
Interim Plan	Interim Facility-Wide Groundwater Monitoring Plan
IR	investigation report
LANL	Los Alamos National Laboratory
MCL	maximum contaminant level
MDA	material disposal area
MDL	method detection limit

meq	milliequivalents
MOU	memorandum of understanding
MP	multiport system (Westbay)
MY	monitoring year
NIST	National Institute of Standards and Technology
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMWQCC	New Mexico Water Quality Control Commission
NOI	notice of intent
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
ORP	oxygen-reduction potential
PCB	polychlorinated biphenyl
PEB	performance evaluation blank
PETN	pentaerythritol tetranitrate
PMR	periodic monitoring report
PQL	practical quantitation limit
QA	quality assurance
QC	quality control
RACER	Risk Analysis, Communication, Evaluation, and Reduction (database)
RCRA	Resource Conservation and Recovery Act
RDX	hexahydro-1,3,5,trinitro-1,3,5-triazine
RFI	RCRA facility investigation
RLWTF	Radioactive Liquid Waste Treatment Facility
RPF	Records Processing Facility
RSL	Regional Screening Level (EPA)
SC	specific conductance
SMO	Sample Management Office
SOP	standard operating procedure
SU	standard unit
SVOC	semivolatile organic compound
SWMU	solid waste management unit
SWSC	Sanitary Wastewater Systems Consolidation
SWWS	Sanitary Wastewater Systems
TA	technical area

TAL	target analyte list (EPA)
TATB	triaminotrinitrobenzene
TBD	to be determined
TCE	trichloroethene
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TNT	trinitrotoluene(2,4,6)
TNX	hexahydro-1,3,5-trinitroso-1,3,5-triazine
TOC	total organic carbon
TOCP	tri(o-cresyl)phosphate
TW	Test Well
UF	unfiltered
USGS	U.S. Geological Survey
USFS	U.S. Forest Service
VOC	volatile organic compound
WCSF	waste characterization strategy form
WWTP	waste water treatment plant

A-2.0 METRIC CONVERSION TABLE

Multiply SI (Metric) Unit	by	To Obtain U.S. Customary Unit
kilometers (km)	0.622	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.281	feet (ft)
meters (m)	39.37	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.394	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns (µm)	0.0000394	inches (in.)
square kilometers (km^2)	0.3861	square miles (mi^2)
hectares (ha)	2.5	acres
square meters (m^2)	10.764	square feet (ft^2)
cubic meters (m^3)	35.31	cubic feet (ft^3)
kilograms (kg)	2.2046	pounds (lb)
grams (g)	0.0353	ounces (oz)
grams per cubic centimeter (g/cm^3)	62.422	pounds per cubic foot (lb/ft^3)
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
micrograms per gram (µg/g)	1	parts per million (ppm)
liters (L)	0.26	gallons (gal.)
milligrams per liter (mg/L)	1	parts per million (ppm)
degrees Celsius (°C)	9/5 + 32	degrees Fahrenheit (°F)

A-3.0 DATA QUALIFIER DEFINITIONS

Data Qualifier	Definition
U	The analyte was analyzed for but not detected.
J	The analyte was positively identified, and the associated numerical value is estimated to be more uncertain than would normally be expected for that analysis.
J+	The analyte was positively identified, and the result is likely to be biased high.
J-	The analyte was positively identified, and the result is likely to be biased low.
UJ	The analyte was not positively identified in the sample, and the associated value is an estimate of the sample-specific detection or quantitation limit.
R	The data are rejected as a result of major problems with quality assurance/quality control (QA/QC) parameters.

Appendix B

Screening Information

B-1.0 OVERVIEW

Attachment B-1 to this appendix presents screening tables for groundwater and base-flow water-quality data used to optimize monitoring strategies for watersheds and area-specific monitoring groups in the Interim Facility-Wide Groundwater Monitoring Plan (the Interim Plan, prepared by Los Alamos National Laboratory (the Laboratory). Selection of the screening values for groundwater data follows the approach prescribed for the development of groundwater cleanup levels in Section VIII of the Compliance Order on Consent (the Consent Order). An analogous protocol is used to select screening values for base-flow surface-water data. The process used to select the cleanup levels from applicable standards or screening levels (Table B-1.0-1) is described in section B-2.0 for groundwater and section B-3.0 for base flow.

Groundwater and base-flow data from 2006 to 2010 are screened against one-half of the groundwater or base-flow cleanup level. Groundwater data are also screened against the Laboratory's groundwater background values (LANL 2007, 095817), where available.

The screening implemented in the tables (Attachment B-1 on CD) serves as a high-level screening tool consistent with U.S. Environmental Protection Agency (EPA) regulatory guidance (EPA 1996, 065402). The screening does not trigger actions or define unacceptable levels of contaminants in water. In this appendix, "screening" refers to identification of locations in a watershed or area-specific monitoring group where contaminant concentrations fall below screening levels and therefore do not require additional evaluation. On the other hand, where contaminant concentrations exceed a screening level, additional evaluation may be needed to determine actions. The screening levels include assumptions—such as residential land-use scenarios—that are protective for a wide range of site conditions but are generally more stringent than site-specific levels.

Attachment B-1 (on CD) presents screening tables organized by the six area-specific monitoring groups plus the general surveillance monitoring group in seven watersheds. Within each watershed or area-specific monitoring group, these screening tables are organized by analytical suite for each water type sampled. Groundwater types include springs, alluvial groundwater, intermediate-perched groundwater, and regional groundwater; surface water types are ephemeral and perennial base flow. Four screening tables are included in Attachment B-1:

- Table B1-1, Analytical Data Screening for Frequency of Detection in Each Watershed or Area-Specific Monitoring Group: Groundwater (Including Springs)
- Table B1-2, Analytical Data Screening for Frequency of Detection in Each Watershed or Area-Specific Monitoring Group: Base Flow
- Table B1-3, Analytical Data Screening for Frequency of Detection at Locations in Each Watershed or Area-Specific Monitoring Group: Groundwater (Including Springs)
- Table B1-4, Analytical Data Screening for Frequency of Detection at Locations in Each Watershed or Area-Specific Monitoring Group: Base Flow

For each water type in each watershed or area-specific monitoring group, the screening tables report statistics for analytes categorized by analytical suite, with statistics tabulated separately for filtered (F) and unfiltered (UF) samples:

- diesel range organics (DRO)
- dioxin/furans (DIOX/FUR)
- gasoline range organics (GRO)

- general inorganics (GENINORG)
- herbicides (HERB)
- high explosives (HEXP)
- metals (METALS)
- polychlorinated biphenyls (PCB)
- PCB congeners (PCB CONGENER or PCB CONG)
- pesticides (PEST)
- radioactivity (RAD)
- semivolatile organic analytes (SVOA)
- volatile organic analytes (VOA)

The list of analytical suites and water types compiled for individual watersheds or area-specific monitoring group varies according to the availability of sampling locations and analytical data in that watershed for 2006 to 2010, the period of time covered by these tables. Table columns in Tables B1-1 and B1-2 summarize the following types of information:

- Analyte—the name of the analyte screened
- Method—analytical method(s)
- Units—unit of measurement
- Number of analyses—number of analyses available for screening, preceded by the less-than symbol (<) if all of the available analyses are classified as not detected
- Number of Detects—number of values classified as detected
- Number of Nondetects—number of values classified as not detected
- Min, Mean, and Max—minimum, mean, and maximum of detected values (or if in italics, minimum, mean, and maximum of the minimum detection levels)
- BV—applicable numerical background value, if available, used for screening
- Number >BV—number of detections greater than the background value
- Std—numerical value for the groundwater or base-flow cleanup level used for screening, if available
- Number>Std—number of detected values greater than the groundwater or base-flow cleanup level
- 1/2 Std—one-half of the numerical value for the groundwater or base-flow cleanup level
- Number >1/2 Std—number of detected values greater than one-half the groundwater or base-flow cleanup level
- Std Type—a reference for the groundwater or base-flow cleanup level

Abbreviations used for standards and screening levels in the table column “Std Type” are provided in Table B-1.0-1.

B-2.0 PROTOCOL FOR SELECTING SCREENING LEVELS FOR GROUNDWATER DATA

Water quality data for groundwater (including springs) are compared to the groundwater cleanup levels, determined according to the process described in Section VIII of the Consent Order. The cleanup levels are selected from the lowest applicable standard or screening level (Table B-1.0-1):

- New Mexico Water Quality Control Commission (NMWQCC) Standards for Ground Water (20.6.2.3103 New Mexico Administrative Code [NMAC])
- EPA National Primary Drinking Water Regulations: maximum contaminant levels (MCLs) (40 Code of Federal Regulations [CFR] Part 141 through July 1, 2007)
- Consent Order groundwater screening level for perchlorate (Section VIII.A.1)
- U.S. Department of Energy (DOE) Derived Concentration Guidelines (DCGs) for radionuclides (ingested-water DCG based on a target limit of 4 mrem/yr) (DOE 5400.5, Figure III-1)

If no standard exists for a chemical analyte, groundwater data are compared against the EPA's Regional screening levels (RSLs) for tap water (EPA 2011, 204336). For compounds with screening levels based on cancer risk, the EPA's screening values in the RSL tables are based on a cancer risk of 10^{-6}. These risk levels are adjusted to a cancer risk of 10^{-5}, consistent with requirements in the Consent Order, by moving the decimal point one place to the right.

The screening process for groundwater also compares each analyte against background values for naturally occurring metals and general chemical parameters at or near the Laboratory. The background values for each groundwater zone (alluvial, intermediate, or regional) are from the groundwater background investigation report (LANL 2007, 094856; LANL 2010, 110535).

B-3.0 PROTOCOL FOR SCREENING BASE-FLOW SURFACE WATER DATA

The NMWQCC establishes surface water standards in the State of New Mexico Standards for Interstate and Intrastate Surface Waters (20.6.4 NMAC). Certain reaches of watercourses may have specific classification and have segment-specific designated uses. The designated uses for surface water are associated with use-specific water-quality criteria, including numeric criteria. Nonclassified surface waters are described as ephemeral, intermittent, or perennial, each of which also has corresponding designated uses described in 20.6.4 NMAC.

The Laboratory's sitewide monitoring program includes base-flow stations in reaches that are assigned to different watercourse classifications in 20.6.4 NMAC, each of which has its own set of water-quality criteria. In addition, the Laboratory collects samples from surface waters under tribal regulatory jurisdiction. Although these waters are specifically excluded from state regulation (20.6.4.7[DD] NMAC), they are nonetheless included in the screening in this Interim Plan.

The base-flow monitoring locations are assigned to one of two screening categories—perennial or ephemeral (Table B-3.0-1). Along with a hardness value, this category determines the screening levels used for data at each monitoring location. Water-quality data from these locations are compared with the base-flow cleanup level, determined as the lowest numeric standard among the designated uses.

Hardness-dependent screening levels used to screen data at each base-flow monitoring location in the 2011 Interim Plan are the geometric mean of hardness data (mg/L as $CaCO_3$) collected since 2006 at each location (Table B-3.0-1). Hardness-dependent acute and chronic criteria for dissolved aluminum, cadmium, chromium, copper, lead, manganese, nickel, silver, and zinc were used in accordance with the requirements of 20.6.4 NMAC.

Radionuclide data for ephemeral and perennial surface-water locations are compared with the DOE Biota Concentration Guides (BCGs) (DOE 2002, 085637), as modified by site-specific BCGs for selected radionuclides (McNaughton et al. 2008, 106501).

B-4.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

DOE (U.S. Department of Energy), July 2002. "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota," DOE Standard No. DOE-STD-1153-2002, U.S. Department of Energy, Washington, D.C. (DOE 2002, 085637)

EPA (U.S. Environmental Protection Agency), April 1996. "Soil Screening Guidance: User's Guide," EPA/540/R-96/018, Office of Solid Waste and Emergency Response, Washington, D.C. (EPA 1996, 065402)

EPA (U.S. Environmental Protection Agency), June 3011. "Regional Screening Level (RSL) Composite Table June 2011," Regional Screening Levels for Chemical Contaminants at Superfund Sites screening level/preliminary remediation goal website, tables available online at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm, Washington, D.C. (EPA 2011, 204336)

LANL (Los Alamos National Laboratory), May 2007. "Groundwater Background Investigation Report, Revision 3," Los Alamos National Laboratory document LA-UR-07-2853, Los Alamos, New Mexico. (LANL 2007, 095817)

LANL (Los Alamos National Laboratory), February 2007. "Groundwater Background Investigation Report, Revision 2," Los Alamos National Laboratory document LA-UR-07-0755, Los Alamos, New Mexico. (LANL 2007, 094856)

LANL (Los Alamos National Laboratory), August 2010. "Groundwater Background Investigation Report, Revision 4," Los Alamos National Laboratory document LA-UR-10-4827, Los Alamos, New Mexico. (LANL 2010, 110535)

McNaughton, M., P. Fresquez, and W. Eisele, May 2008. "Site-Representative Biota Concentration Guides at Los Alamos," Los Alamos National Laboratory document LA-UR-08-2783, Los Alamos, New Mexico. (McNaughton et al. 2008, 106501)

Table B-1.0-1
Potentially Applicable Standards Used to Select Screening Levels

Type	Source	Description	Abbreviation[a]	Potential Applicability					
				Perennial Surface Water		Ephemeral Surface Water		Groundwater (Includes Springs)	
				F	UF	F	UF	F	UF
NMWQCC									
Standard	NMAC 20.6.4	Livestock Watering	NM LVSTK WTR STD	X	X	X	X		
Standard	NMAC 20.6.4	Wildlife Habitat	NM WQCC WLDLF HAB		X		X		
Standard	NMAC 20.6.4	Aquatic Life Acute	NM Aqu Acute[b]			X	X		
Standard	NMAC 20.6.4	Aquatic Life Chronic	NM Aqu Chronic[b]	X	X				
Standard	NMAC 20.6.4	Human Health Standard	NM HH OO	X	X	X	X		
Standard	NMAC 20.6.2	Groundwater Human Health Standards, Other Standards for Domestic Water Supply and Standards for Irrigation Use	NM GW STD					X	X
Consent Order									
Screening Level	Consent Order	Screening Level for Perchlorate in Groundwater	NM GW CONS					X	X
EPA									
Standard	40 CFR 141	EPA maximum contaminant levels	EPA MCL					X	X
Risk—human	EPA RSLs[c]	EPA Regional Screening Levels for Tapwater	EPA TAP SCRN LVL					X	X
DOE									
Risk—ecological	DOE Order 5400.5	DOE Biota Concentration Guides	DOE BCG WATER	X	X	X	X		
Risk—human	DOE Order 5400.5	DOE 4-mrem Drinking Water Derived Concentration Guidelines	DOE DW DCG					X	X

[a] Abbreviations used here and in the screening tables in Attachment B-1.

[b] Hardness-dependent.

[c] EPA RSLs (EPA 2011, 204336).

Table B-3.0-1
Hardness Assignments Used to Select Screening Levels

Watershed	Location	Stream Type	Hardness (mg/L as $CaCO_3$)
Guaje	Guaje above Rendija	Ephemeral	40
Pueblo	Acid above Pueblo	Ephemeral	50
Pueblo	Pueblo 3	Ephemeral	80
Pueblo	Pueblo above Acid	Ephemeral	80
Pueblo	Pueblo above SR-502	Perennial	70
Los Alamos	DP above TA-21	Ephemeral	100
Los Alamos	DP below Meadow at TA-21	Ephemeral	100
Los Alamos	Los Alamos above DP Canyon	Ephemeral	50
Los Alamos	Los Alamos above SR-4	Ephemeral	60
Los Alamos	Los Alamos below Ice Rink	Perennial	40
Los Alamos	Los Alamos below LA Weir	Ephemeral	60
Los Alamos	Los Alamos Canyon near Otowi Bridge	Ephemeral	100
Sandia	Middle Sandia Canyon at terminus of persistent baseflow	Ephemeral	90
Sandia	Sandia below Wetlands	Perennial	100
Sandia	Sandia left fork at Asphalt Plant	Perennial	100
Sandia	Sandia right fork at Power Plant	Perennial	100
Sandia	South Fork of Sandia Canyon at E122	Ephemeral	100
Mortandad	E-1E	Ephemeral	90
Mortandad	E-1FW	Ephemeral	80
Mortandad	E-1W	Ephemeral	100
Mortandad	M-1E	Ephemeral	60
Mortandad	M-1W	Ephemeral	50
Mortandad	M-2E	Ephemeral	90
Mortandad	Mortandad below Effluent Canyon	Ephemeral	60
Mortandad	TS-1W	Ephemeral	60
Mortandad	TS-2E	Ephemeral	70
Pajarito	Pajarito 0.5 mi above SR-501	Perennial	30
Pajarito	Pajarito above Twomile	Ephemeral	50
Pajarito	Pajarito at Rio Grande	Ephemeral	70
Pajarito	Pajarito below confluences of South and North Anchor East Basin	Perennial	50
Pajarito	Pajarito below TA-18	Ephemeral	70
Pajarito	Two Mile Canyon below TA-59	Ephemeral	50
Pajarito	Twomile above Pajarito	Ephemeral	50
Water	Between E252 and Water at Beta	Perennial	50
Water	Canon de Valle below MDA P	Perennial	70
Water	Water above SR-501	Perennial	40
Water	Water at Beta	Perennial	50

Table B-3.0-1 (continued)

Watershed	Location	Stream Type	Hardness (mg/L as $CaCO_3$)
Ancho	Ancho at Rio Grande	Ephemeral	50
Frijoles	Frijoles at Rio Grande	Perennial	40
Frijoles	Rio de los Frijoles at Bandelier	Perennial	30
White Rock	Rio Grande at Otowi Bridge	Perennial	100
White Rock	Buckman Diversion SW	Perennial	100
White Rock	Mortandad at Rio Grande	Ephemeral	100
White Rock	Rio Grande at Frijoles	Perennial	100

Attachment B-1

Tables B1-1 to B1-4
(on CD included with this document)

Appendix C

Procedures, Methods, and
Investigation-Derived Waste Management

C-1.0 PROCEDURES FOR MEASURING GROUNDWATER LEVELS AND COLLECTING WATER SAMPLES

This section summarizes Los Alamos National Laboratory (LANL or the Laboratory) standard operating procedures (SOPs) used to measure groundwater levels and to collect groundwater, base-flow, and spring samples. These procedures are listed in the table below and are summarized in subsequent sections. These (or equivalent) procedures (or equivalent) will be used during sampling activities conducted in accordance with the revised 2011 Interim Facility-Wide Groundwater Monitoring Plan (the Interim Plan).

Procedure Identifier	Procedure Title	Applicability
Measurement of Groundwater Levels		
SOP-5223	Manual Groundwater Level Measurements	Procedure for measuring depth to groundwater and determining groundwater elevation in a monitoring well or an open borehole
EP-DIV-SOP-10010 (supersedes SOP-5227, R0)	Pressure Transducer Installation, Removal, and Maintenance	Procedure to install, remove, and maintain pressure transducers to monitor and record water-level data in monitoring wells and piezometers
SOP-5226	Westbay Pressure Transducer Installation, Removal, and Maintenance	Procedure to install, remove, and maintain pressure transducers to monitor and record water-level data in Westbay monitoring wells
SOP-5230	Groundwater Level Data Processing	Procedure to review and validate groundwater level data obtained from pressure transducers
EP-DIV-SOP-20006 (supersedes SOP-5260)	Pressure Monitoring of Packer Systems in Monitoring Wells	Procedure for monitoring and maintenance of Baski sampling system packers and temporary packers installed in water wells
Collection of Groundwater Samples		
EP-DIV-SOP-20032 (supersedes SOP-5232, R1)	Groundwater Sampling	Procedure for sampling groundwater using a dedicated submersible pump, Baski sampling system, or a portable pump
SOP-5225	Groundwater Sampling Using Westbay MP System	Procedure for sampling groundwater using the Westbay multiport (MP) system
EP-ERSS-SOP-5061	Field Decontamination of Equipment	Procedure for field decontamination of equipment
SOP-06.03	Sampling for Volatile Organic Compounds in Groundwater	Procedure for collecting groundwater samples for volatile organic compound (VOC) analysis
Collection of Surface Water and Spring Samples		
SOP-5224	Spring and Surface Water Sampling	Procedure for sampling springs and surface water
Measuring Field Parameters		
ENV-DO-203	Field Water Quality Analyses	Procedure for measuring field analytical water-quality parameters
Sample Preparation, Preservation, and Transportation		
EP-ERSS-SOP-5059	Field Quality Control Samples	Procedure for collection of field quality control (QC) samples, including field duplicates, equipment rinsate blanks, and trip blanks
SOP-219	Sample Control and Field Documentation	Procedure for establishing and maintaining sample traceability using sample control and field documentation
EP-ERSS-SOP-5056	Sample Containers and Preservation	Procedure specifying sample containers, collection and preservation techniques, and holding times

Procedure Identifier	Procedure Title	Applicability
SOP-066	Filtering and Chemical Preservation of Water Samples	Procedure describes the process for the chemical preservation of storm water and groundwater samples
EP-ERSS-SOP-5057	Handling, Packaging, and Transporting Field Samples	Procedure for sample packaging and shipping
ENV-WQH-QP-029	Creating and Maintaining Chain of Custody	Procedure for generating an analytical request and maintaining chain of custody in the collection, management, and processing of water-quality samples
SOP-5255	Shipping of Environmental Samples by the WES SMO	Procedure for receiving, packaging, and shipping samples to analytical laboratories.
Field Activities Documentation		
SOP-5181	Notebook and Logbook Documentation for Environmental Directorate Technical and Field Activities	Procedure for documenting technical work and field activities in a notebook or logbook.
Waste Management		
SOP-5238	Characterization and Management of Environmental Program Waste	Procedure for characterizing and managing generated waste

C-2.0 SUMMARY OF FIELD INVESTIGATION METHODS

Method	Summary
General	The objective of this sampling program is to collect samples from wells, springs, or base-flow stations that are representative of physical and geochemical conditions in the targeted hydrogeologic unit. To meet this objective, sampling equipment, sampling methods, monitoring-well operation and maintenance, and sample-handling procedures are implemented such that the chemistry of the sample is not altered. The procedures summarized below have been developed to meet the above objective and to be consistent with the requirements of the Compliance Order on Consent.
Groundwater Level Measurements Referenced Procedures: • EP-DIV-SOP-10010, Pressure Transducer Installation, Removal, and Maintenance • SOP-5226, Westbay Pressure Transducer Installation, Removal and Maintenance • SOP-5223, Manual Groundwater Level Measurements • SOP-5230, Groundwater Level Data Processing	This summary applies to the collection of groundwater-level data. Groundwater levels are manually measured at predetermined intervals. Additionally, data is downloaded at wells with pressure transducers installed after each sampling event. Water levels cannot be manually measured in wells equipped with the Westbay sampling system; however, data from these wells are downloaded before and after each sampling event. Westbay transducers must be removed before sampling and reinstalled after each sampling event. Two methods are used to collect water-level data: • Pressure transducers are used to measure water levels in individual wells or well screens at specified intervals. Most wells sampled under the Interim Plan are monitored with pressure transducers. • Manual water-level measurements are routinely measured in wells not instrumented with pressure transducers. These measurements are also taken before purging and sampling alluvial wells. Manual water level measurements are also taken periodically to verify transducer readings. Data from pressure transducers are automatically recorded in a data logger for later retrieval and processing to calculate water levels. Information collected during manual water level measurements is documented on the Groundwater Level Measurement Form or Groundwater Level Project Field Form. Pressure transducers are periodically bench-tested to verify calibration.

<table>
<tr><th>Method</th><th>Summary</th></tr>
<tr><td>Collection of Groundwater Samples Using Dedicated Submersible or Portable Pumping Systems

Referenced Procedures:
• EP-DIV-SOP-20032 Groundwater Sampling
• ENV-DO-203, Field Water Quality Analyses
• EP-ERSS-SOP-5056, Sample Containers and Preservation
• SOP-5238, Characterization and Management of Environmental Program Waste
• SOP-5181, Notebook and Logbook Documentation for Environmental Directorate Technical Field Activities</td><td>This summary applies to the use of an electric gear-driven Submersible Pump system, a bladder-pump system, a Bennett pump system, a Baski pump system, a hand-bailer system, and portable versions of the bladder pump and Bennett pump to sample wells.
• Wells are purged sufficiently before sample collection to ensure samples will be representative of formation water.
• The pumping rate should be adjusted, if possible, during purging so that excessive drawdown does not occur. Field crews may have limited ability to restrict flow, depending on the pumping system. Turning off the pump while purging regional and intermediate wells should be avoided unless absolutely necessary. Instead, the pumping rate should be slowed to prevent drawdown into the screen, whenever possible.
• The discharge rate is calculated either by using an in-line flow meter or by filling a bucket or bottle of known volume and dividing by the fill time. Flow rate is monitored at regular intervals during the purge, preferably once per casing volume and while the drop pipe is being cleared.
• In general, a well may be sampled once the following criteria have been met (see EP-DIV-SOP-20032 or details):
❖ A minimum of one casing volume (CV) has been removed for alluvial wells and a minimum of three CVs (plus drop pipe) have been removed for intermediate or regional wells (unless otherwise requested)
❖ The field indicator parameters have stabilized within their allowable ranges (as listed below) for at least three consecutive measurements taken a minimum of 3 or 5 min apart.

<table>
<tr><th>Field Parameter</th><th>Stabilization Criteria
(Yeskis and Zavala 2002, 204429)</th></tr>
<tr><td>Turbidity</td><td>± 10% when turbidity is greater than 10 nephelometric turbidity units (NTUs)</td></tr>
<tr><td>Dissolved Oxygen</td><td>± 0.3 mg/L,</td></tr>
<tr><td>pH</td><td>± 0.1 Standard Unit (SU)</td></tr>
<tr><td>Specific Conductance</td><td>± 3%</td></tr>
<tr><td>Temperature</td><td>± 10% (per the Compliance Order on Consent)</td></tr>
</table>

• Purge water is discharged under the notice of intent (NOI) with the New Mexico Environment Department (NMED) or containerized pending waste determination.
• Sample labels and documentation are completed for each sample following procedures referenced in this Interim Plan. All activities are documented in the field logbook and appropriate field forms.
• Chain-of-custody seals are applied to each sample container before samples are transported from the site.
• All samples are submitted to the Sample Management Office (SMO) and then shipped to the designated off-site analytical laboratory in a timely manner to allow the laboratory to conduct analyses within proper holding times.</td></tr>
</table>

Method	Summary
Collection of Groundwater Samples Using Westbay System Referenced Procedures: • SOP-5225, Groundwater Sampling Using Westbay Sampling System • SOP-5226, Westbay Pressure Transducer Installation, Removal and Maintenance • ENV-DO-203, Field Water Quality Analyses • EP-ERSS-SOP-5056, Sample Containers and Preservation	This summary applies to the sampling of wells equipped with the Westbay multiport (MP) system, a multilevel groundwater monitoring system. Samples are collected using a dedicated closed-access tube with valved ports that provide access to multiple levels of a borehole through a single well casing. The Westbay system is designed to allow for sampling without purging under normal aquifer conditions and takes samples at an in situ pressure. • The Westbay MP system consists of casing components that are permanently installed in the final casing, portable pressure measurement and sampling probes, and specialized tools. • The sampling probes are lowered to a precise port depth from which the sample is collected. This sampling system is a non-purge system so no purge water is generated. • Samples are collected directly into the sampling probe's sample containers and are transferred into the appropriate sample containers as soon as possible. • Data collected during sampling, including port pressures and field parameters, are documented on the appropriate forms in SOP-5225. • The sample probe and sample containers are the only equipment or materials that are reused and are decontaminated between sampling each port, as described in SOP-5225. • Sample labels and documentation are completed for each sample following procedures referenced in this Interim Plan. Samples are delivered to SMO and shipped to the designated off-site analytical laboratory in a timely manner to allow the samples to be analyzed within proper holding times.
Collection of Spring and Surface Water Samples Referenced Procedures: • ENV-DO-203, Field Water Quality Analyses • SOP-5224, Spring and Surface Water Sampling • EP-ERSS-SOP-5056, Sample Containers and Preservation • ENV-WQH-SOP-009, Operation and Maintenance of Stream Gauge Stations	This summary applies to collecting water-quality samples from base-flow sites and springs. • Permanent spring and base-flow sampling sites are usually identified by posts or gaging stations. However, this may not be possible at some sites. • Ideally, samples are collected from flowing water. In some cases, the samples may need to be collected from pooled or ponded water. Samples are collected far enough upstream of a confluence so the sample is not influenced by water from another stream. If there is any question about whether a representative sample can be collected, field personnel are instructed to contact the requestor before proceeding. • Samples may be collected using either the direct containment method, or by using a peristaltic pump. Filtered samples must be collected using a peristaltic pump. • Where both field conditions and flow conditions allow, take a discharge measurement using one of the methods outlined in SOP-5224. Discharge may be estimated where quantitative measurements are not possible. • Sample labels and documentation are completed for each sample following procedures referenced in this Interim Plan. All activities are documented in the field logbook and appropriate field forms. • Samples are delivered to SMO and shipped to the designated off-site analytical laboratory in a timely manner to allow the samples to be analyzed within proper holding times.

Method	Summary
Sample Bottles and Preservation of Samples Referenced Procedure: • EP-ERSS-SOP-5056, Sample Containers and Preservation • SOP-066, Filtering and Chemical Preservation of Water Samples	This summary applies to requirements for sampling containers, sample pretreatment, and sample preservation requirements that are applicable to all water-quality samples. • All samples are collected in containers specifically prepared for that given parameter. • Sample containers are pre-cleaned to a 300 Series (I-Chem, ESS) and are commercially available through a number of vendors. • For filtered samples for the analysis of dissolved constituents, the following systems will be used: ❖ in-line 0.45-µm disposable filter capsules, ❖ in-line filter holders with 0.45-µm filter membranes, or ❖ in-line 0.02-µm disposable filter capsules (for samples requiring microfiltration only). • Samples are preserved in accordance with Attachment 1 to SOP-5056. Samples are preserved and pH tested immediately after collection.
Handling, Packaging, and Shipping of Samples Referenced Procedures: • EP-ERSS-SOP-5057, Handling, Packaging, and Transporting Field Samples • SOP-5255, Shipping of Environmental Samples by the WES SMO	This summary applies to requirements for handling, packaging, and shipping of samples. • After all samples are collected and preserved, the sample containers are wiped off and custody tape is applied before packaging. • Samples for off-site analysis are transported to the SMO for shipment to off-site analytical laboratories. • The sampling personnel will coordinate with the SMO regarding shipment of all samples.
Sample Documentation Referenced Procedures: • SOP-219, Sample Control and Field Documentation • ENV-WQH-QP-028, Creating and Maintaining Chain-of-Custody • EP-ERSS-SOP-5057, Handling, Packaging, and Transporting Field Samples • SOP-5181, Notebook and Logbook Documentation for Environmental Directorate Technical Field Activities	This summary applies to requirements for documentation of sample collection. • The requested parameters, preservation and bottle type, chain-of-custody, required field parameters, and any other additional information are included on the analytical request generated from the database. • All sampling activities are documented in the field logbooks and appropriate field forms. • Chain of custody is documented on the analytical request form and signed to verify that the samples were not left unattended. • All field information, date and time of sample, purging and final field parameters, field conditions, and sampling personnel are included in the specific sampling method field sheets.

Method	Summary
Field Quality Assurance/Quality Control Samples Referenced Procedure: • ENV-WQH-QP-028, Creating and Maintaining Chain-of-Custody	Field quality assurance (QA)/QC samples are required by the Consent Order, and are discussed in detail in Appendix E. Field QA/QC samples to be collected are summarized below. • Field blanks are collected at a frequency of 10% of all samples collected. • Equipment rinsate blanks are collected at a minimum frequency of 1 per day when non-dedicated sampling equipment is used. • Field duplicates are collected at a rate of 10% of all samples by media type, with a minimum of one duplicate collected per sample batch. • Trip blanks are included with any coolers containing samples submitted for VOC analysis. • Performance evaluation blanks will be submitted on an as-needed basis to evaluate the reagent-grade water used for decontamination and preparation of blanks.

C-3.0 METHODS AND INSTRUMENTS USED FOR FIELD MEASUREMENTS

Field Parameter	Method Description	U.S. Environmental Agency–-Approved Methods	Primary Field Instrument(s)	Primary Flow-Through Cell Used/Type	Description
pH	Hydrogen ion, pH (pH units): electrometric measurement	EPA: Method 150.1 Standard Methods,* 4500-H^+ B Editions 18th, 19th, 20th	YSI 650 Handheld Multiparameter Instrument	YSI 650 cell	Samples will be analyzed for pH and temperature in the field using a flow-through cell during well purging and at the time of sample collection. The listed instrument is commercially available with a temperature sensor for automatic compensation. A calibration check is performed on the meter using the manufacturer's instructions with standard buffers traceable to National Institute of Standards and Technology (NIST) and recorded. Standards are purchased from commercial vendors.
Temperature	Temperature, thermometric (°C)	EPA: Method 170.1 Standard Methods, 2550 B Editions 18th, 19th, 20th	YSI 650 Handheld Multiparameter Instrument	YSI 650 cell	Samples will be analyzed for temperature concurrently with pH measurement in the field using a flow-through cell during well purging and at the time of sample collection. The listed instruments are commercially available with a temperature sensor for automatic compensation.
Specific Conductance	Electrical conductance (micromhos/cm at 25°C): Wheatstone bridge	EPA: Method 120.1 Standard Methods, 2510 B Editions 18th, 19th, 20th	YSI 650 Handheld Multiparameter Instrument	YSI 650 cell	Samples will be analyzed for specific conductance in the field using a flow-through cell during well purging and at the time of sample collection. The listed instruments are commercially available with a temperature sensor for automatic compensation. A calibration check is performed on the meter using the manufacturer's instructions with standard buffers traceable to NIST and is recorded. Standards are purchased from commercial vendors.
Dissolved Oxygen	Oxygen, dissolved (mg/L): electrode	EPA: Method 360.1 Standard Methods, 4500-O G Editions 18th, 19th, 20th	YSI 650 Handheld Multiparameter Instrument	YSI 650 cell	Samples will be analyzed for dissolved oxygen in the field using a flow-through cell during well purging and at the time of sample collection. The listed instruments are commercially available with a temperature sensor for automatic compensation. The meter is calibrated using the manufacturer's instructions and is recorded.

Field Parameter	Method Description	U.S. Environmental Agency–-Approved Methods	Primary Field Instrument(s)	Primary Flow-Through Cell Used/Type	Description
Turbidity	NTU	EPA: Method 180.1 Standard Methods, 2130 B Editions 18th, 19th, 20th	Hach 2100P, YSI 650 Handheld Multiparameter Instrument	Single sample aliquot application	Samples will be analyzed for turbidity in the field using a single aliquot during well purging and at the time of sample collection. The listed instruments are commercially available, and a calibration check is performed on the meter using the manufacturer's instructions. The YSI 650 Handheld Multiparameter Instrument serves as a back-up in case the primary instrument fails.
Oxidation Reduction Potential	Reduction-oxidation potential (mV): electrode method	Standard Methods, 2580 A Editions 18th, 19th, 20th	YSI 650 Handheld Multiparameter Instrument	YSI 650 cell	Samples will be analyzed for oxidation-reduction potential in the field using a flow-through cell during well purging and at the time of sample collection. The listed instruments are commercially available with a temperature sensor for automatic compensation. A calibration check is performed on the meter using the manufacturer's instructions and is recorded.

* "Standard Methods" refers to editions of the Standard Methods for the Examination of Water and Wastewater, published by the American Public Health Association (Washington, D.C.).

C-4.0 ANALYTICAL METHODS—GROUNDWATER ANALYTICAL SUITES

C-4.1 Analyses by Accredited Contract Laboratories

Samples for laboratory analysis are submitted to accredited contract laboratories. The contract laboratories are required to establish method detection limits (MDLs) and practical quantitation limits (PQLs) for target analytes.

The MDL is the minimum concentration of an analyte that can be measured and reported with a 99% confidence that the concentration is greater than zero, as determined by the procedure set forth at Appendix B of 40 Code of Federal Regulations Part 136. The MDL is based on prepared spiked samples that go through the entire sample preparation scheme before they are analyzed. Most often, the MDL samples are analyzed by the contract laboratories under ideal conditions when the analytical instrumentation has been recently serviced, cleaned, and calibrated.

The PQL is the lowest concentration that can be reliably measured within specified limits of precision, accuracy, representativeness, completeness, and comparability during *routine* laboratory operating conditions using approved U.S. Environmental Protection Agency (EPA) methods. In most cases the contract laboratories define the low spike on their initial calibration curve as the PQL. Generally, the PQL is 3 to 5 times higher than the MDL and should not be more than 10 times the MDL.

Tables C-4.1-1 and C-4.1-2 provide the mode (that is, most frequent value) for MDL and PQLs reported for 2010 analyses of groundwater and base-flow samples for the Laboratory by contract laboratories, organized by analytical suite and method. The number of sample analyses and detections (that is, results greater than the MDL) for the period from 2006 to 2010 are given. The tables include values for applicable cleanup and/or background levels for each analyte listed. The cleanup levels are derived as described in Appendix B-2.0, Protocol for Selecting Cleanup Levels. The background values are from the most recent NMED-approved report (LANL 2009, 106115, Table 4.2-3; NMED 2010, 109327).

A subset of Tables C-4.1-1 and C-4.1-2 appears in three tables that compare the PQLs with cleanup or background levels.

Table C-4.1-3 shows analytes with a PQL above the applicable groundwater cleanup level.

Table C-4.1-4 shows analytes with a PQL above the background values for alluvial, intermediate, and regional groundwater from Laboratory guidance (LANL 2009, 106115).

Table C-4.1-5 shows analytes with a PQL above the base-flow cleanup level.

Comments in these tables indicate the cases where the MDL is below the cleanup level for the analyte, thus meeting the Consent Order requirement (Section IX).

The background levels for seldom-detected analytes were based on the MDL. In some cases, background values were determined using data from an internal analytical laboratory. As a result of differences in analytical methods and variation of reported MDLs over time, some MDL values are slightly above a groundwater background level.

For comparison, the lowest of background values for intermediate and regional groundwater identified in the Groundwater Background Investigation Report, Revision 4 (LANL 2010, 110535) are also shown in Table C-4.1-4. These background values are substantially higher for several analytes.

For most of the organic compounds where the MDL is higher than the cleanup level, the compound has seldom or never been detected in years of water samples, as indicated in Table C-4.1-3 for groundwater and Table C-4.1-5 for base flow.

The analytical services provided under contract to the Laboratory meet EPA requirements. Based on EPA 530-R-09-007 Unified Guidance (p. 2-7), "Any practical quantification limit (PQL) approved by the Regional Administrator under §264.97(h) [or §258.53(g)] that is used in the statistical method shall be the lowest concentration level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions available to the facility."

The Laboratory's primary analytical services provider is GEL Laboratories, LLC. GEL's client base includes 15 U.S. Department of Energy sites, 8 districts of the U.S. Army Corps of Engineers, the southern division of the U.S. Navy, several of the largest industrial manufacturers in southeastern U.S., and over 50 nuclear power plants in the U.S.

For the few instances where MDLs for analytes are higher than the cleanup levels for results reported in 2010, the MDLs are based on routine laboratory operating conditions available to the Laboratory. Most of these cases involve volatile or semivolatile organic compounds analyzed by EPA Methods SW-846:8260B and SW-846:8270C. Eighty compounds are analyzed by volatile organic Method SW-846:8260B. Of these 80 compounds, 67 have groundwater cleanup levels, and in 61 of these cases the MDL is below the cleanup level. The Laboratory also receives 80 analytes analyzed by semivolatile organic Method SW-846:8270C. Of these 80 compounds, 69 have groundwater cleanup levels, and in 55 of these cases the MDL is below the cleanup level.

C-4.2 Analyses by On-Site Laboratories

Regulatory analyses that support Laboratory's characterization, cleanup, and monitoring programs are provided by external contract analytical laboratories. However, in some specific situations, samples are most appropriately submitted for on-site analysis by the Geochemistry and Geomaterials Research Laboratories (GGRL) in the Laboratory's Earth Systems Observations Group (EES-14). In-house analyses are often used in the following cases:

- When rapid turnaround data (e.g., less than 24 h) are required to support activities such as drilling, well development, or well rehabilitation. Such rapid turnaround analyses are unavailable (at reasonable cost) from external laboratories.
- When special studies are undertaken to develop and refine conceptual models for contaminant transport in the environment. Examples of such studies are stable isotope analyses and filtration studies.
- When a well screen is impacted by residual effects of drilling and construction and is not producing reliable or representative water-quality data that fully meet monitoring objectives.

Table C-4.2-1 lists the analytical methods, PQLs, and MDLs for analytes reported by GGRL in recent data packages submitted to the Laboratory. The analytical methods used by GGRL are the most recent EPA and industry-accepted extraction and analytical methods for chemical analyses of these analytes.

C-5.0 INVESTIGATION-DERIVED WASTE MANAGEMENT

This section describes how investigation-derived waste (IDW) generated during the groundwater monitoring activities conducted under this Interim Plan will be managed. IDW is waste generated as a

result of field-investigation activities and may include, but is not limited to, purge water, contact waste, decontamination fluids, and all other wastes that has potentially come into contact with contaminants. IDW generated during implementation of the Interim Plan will be managed to protect human health and the environment, comply with applicable regulatory requirements, and adhere to Laboratory waste minimization goals.

All IDW generated during groundwater-monitoring activities will be managed in accordance with applicable Environmental Programs Directorate SOPs, which incorporate the requirements of all applicable EPA and NMED regulations, DOE orders, and Laboratory requirements. The SOP applicable to the characterization and management of IDW is

- SOP-5238, Characterization and Management of Environmental Program Waste, available at http://www.lanl.gov/environment/all/qa/adep.shtml.

The Los Alamos National Security, LLC, Hazardous Waste Minimization Plan (LANL 2009, 109324) will be implemented during groundwater monitoring to minimize waste generation. This document is updated annually as a requirement of Permit Section 2.9 of the Laboratory's Hazardous Waste Facility Permit.

The IDW waste streams associated with groundwater monitoring are identified in the table below and are briefly described below. The estimated volumes of these waste streams that may be generated during the implementation of this Interim Plan are summarized in Table C-5.0-1.

A waste characterization strategy form (WCSF) will be prepared and approved per requirements of SOP-5238. The WCSF will provide detailed information on IDW characterization methods, management, containerization, and potential volumes. IDW characterization is completed through review of sampling data and/or documentation or by direct sampling of the IDW or the media being investigated (e.g., groundwater, surface soil, subsurface soil). Waste characterization may include a review of historical information and process knowledge to identify whether listed hazardous waste may be present (i.e., due diligence reviews). If low levels of hazardous waste from a listed source are identified, a "contained in" determination may be submitted for approval to NMED.

Wastes will be containerized and placed in clearly marked, appropriately constructed waste accumulation areas. Waste accumulation area postings, regulated storage duration, and inspection requirements will be based on the type of IDW and its classification. Container and storage requirements will be detailed in the WCSF and approved before the waste is generated. Transportation and disposal requirements will also be detailed in the WCSF and approved before waste is generated.

Waste Determinations

The number of sampling events needed to make Resource Conservation and Recovery Act (RCRA) waste determinations will be based on acceptable knowledge (AK) of groundwater conditions within a watershed at the well or surface sample location. AK includes a review of historical information and process knowledge to identify whether hazardous waste, from a listed source, may be present (i.e., due diligence reviews).

The number of sampling events needed to make the waste determination for a given location is summarized as follows:

- For locations where existing AK demonstrates no RCRA hazardous waste or hazardous constituents above RCRA regulatory limits, a minimum of one sampling event will be used annually to confirm the nonhazardous waste determination. This waste determination will be reevaluated with data from subsequent sampling campaigns.
- For new wells with no existing AK, two consecutive sampling events will be conducted to ensure reproducibility and to establish reliable AK. Wastes generated during the first sampling event will be characterized by the data collected during the event. These wastes will be managed in accordance with the regulatory classification.
- For locations where RCRA hazardous constituents are suspected to exhibit a characteristic or sporadic, but not confirmed, the waste will initially be managed as hazardous. Once data is received from the first sampling event, waste will be managed and disposed of according to the analytical results. Waste generated from subsequent sampling events will be managed using AK from previous events until analytical data is available.

For new locations at or near a known listed hazardous waste source, that does not have a “contained in” determination, waste will be managed as hazardous until a due diligence can be performed. If a listed hazardous waste source is identified and low levels of listed hazardous waste constituents are detected, a “contained in” determination may be submitted to NMED for approval.

- For locations where IDW has been identified as RCRA hazardous waste, subsequent IDW generated at the location will be managed as hazardous waste until the data from four consecutive sampling events contain no RCRA hazardous waste or hazardous constituents above RCRA regulatory limits. At this point, the waste will be managed as nonhazardous.

Where RCRA constituents are detected, the following steps may be taken to complete the waste determination:

- Where duplicate groundwater samples are collected during the same sampling event and one is a nondetect and the other is detected, the Laboratory assumes the detection is the result of laboratory or field contamination. The detection will not be used for waste determination.
- When an F-, U-, P-, or K-listed contaminant is detected, the sources contributing to the watershed will be evaluated (i.e., due diligence reviews). If there is no documentation that these contaminants are from listed processes, the waste will be managed as nonhazardous.
- Sampling purge water will be managed in accordance with the most current version of ENV-RCRA-SOP-010, Land Application of Groundwater, as amended by the NMED-approved LANL Drilling, Development, Rehabilitation and Sampling Purge Water Decision Tree—Revised 03/12/2010 (NMED 2010, 109025).

Waste Management

Purge water: This waste stream consists of water purged from wells before and during sampling. The management of nonhazardous purge water will comply with ENV-RCRA-SOP-010, Land Application of Groundwater. If the purge water is hazardous, it will be managed in accordance with hazardous waste management requirements.

Purge water will be characterized based on the results of the analysis of water samples from the well from which the purge water originated or by direct sampling and analysis of the purge water. Purge water will be land applied if it meets the criteria in the NMED-approved NOI for land application of groundwater.

Contact waste: The contact waste stream consists of potentially contaminated wastes that "contacted" purge water during sampling. This waste stream consists primarily of, but is not limited to, personal protective equipment such as gloves; decontamination wastes such as paper wipes; and disposable sampling supplies. Characterization of this waste stream will be performed through AK from analytical results for the environmental media (i.e., purge water) with which it came into contact or direct sampling of the containerized waste and a review of any potentially RCRA Hazardous Listed Waste sources. The Laboratory expects most of these contact wastes will be nonhazardous waste that will be disposed of at a New Mexico solid waste landfill or low-level waste that will be disposed of at Area G at Technical Area 54 (TA-54).

Decontamination fluids: The decontamination fluids waste stream will consist of liquid wastes from decontamination activities (i.e., decontamination solutions and rinse waters). Consistent with waste minimization practices, the Laboratory employs dry decontamination methods to the extent possible. If dry decontamination cannot be performed, liquid decontamination wastes will be collected in containers at the point of generation. The decontamination fluids will be characterized through AK of the waste materials, the levels of contamination observed in the environmental media (e.g., purge water) and, if necessary, direct sampling of the containerized waste. The Laboratory expects most of these wastes to be nonhazardous liquid waste or radioactive liquid waste that will be sent to one of its wastewater treatment facilities or a LANL approved offsite treatment facility.

C-6.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

LANL (Los Alamos National Laboratory), May 2007. "Groundwater Background Investigation Report, Revision 3," Los Alamos National Laboratory document LA-UR-07-2853, Los Alamos, New Mexico. (LANL 2007, 095817)

LANL (Los Alamos National Laboratory), May 2009. "2009 Interim Facility-Wide Groundwater Monitoring Plan," Los Alamos National Laboratory document LA-UR-09-1340, Los Alamos, New Mexico. (LANL 2009, 106115)

LANL (Los Alamos National Laboratory), November 2009. "Los Alamos National Security, LLC, Hazardous Waste Minimization Plan," Los Alamos National Laboratory document LA-UR-09-07682, Los Alamos, New Mexico. (LANL 2009, 109324)

LANL (Los Alamos National Laboratory), August 2010. "Groundwater Background Investigation Report, Revision 4," Los Alamos National Laboratory document LA-UR-10-4827, Los Alamos, New Mexico. (LANL 2010, 110535)

NMED (New Mexico Environment Department), March 12, 2010. "LANL Drilling, Development, Rehabilitation and Sampling Purge Water Decision Tree Revision," New Mexico Environment Department letter to G. Turner (DOE-LASO) and T. George (LANL) from J.P. Bearzi (NMED-HWB) and W.C. Olsen (NMED-GWQB), Santa Fe, New Mexico. (NMED 2010, 109025)

NMED (New Mexico Environment Department), May 4, 2010. "Approval with Direction, 2009 Interim Facility-Wide Groundwater Monitoring Plan," New Mexico Environment Department letter to G.J. Rael (DOE-LASO) and M.J. Graham (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2010, 109327)

Yeskis, D., and B. Zavala, May 2002. "Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers," a *Ground Water Forum Issue Paper*, EPA 542-S-02-001, Office of Solid Waste and Emergency Response, Washington, D.C. (Yeskis and Zavala 2002, 204429)

Table C-4.1-1
Analytes, Analytical Methods, and MDLs and PQLs Obtained for 2010 Analyses of
Groundwater Samples by Contract Laboratories and Number of Sample Analyses and Detections for the Period 2006 to 2010

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Unit	Cleanup-Level Type
Diox/Fur	35822-46-9	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	525	44	SW-846:8290		0.00005			µg/L	
Diox/Fur	37871-00-4	Heptachlorodibenzodioxins (Total)	525	91	SW-846:8290		0.00005			µg/L	
Diox/Fur	67562-39-4	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	525	28	SW-846:8290		0.00005			µg/L	
Diox/Fur	55673-89-7	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	525	0	SW-846:8290		0.00005			µg/L	
Diox/Fur	38998-75-3	Heptachlorodibenzofurans (Total)	525	47	SW-846:8290		0.00005			µg/L	
Diox/Fur	39227-28-6	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	525	1	SW-846:8290		0.00005			µg/L	
Diox/Fur	57653-85-7	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	525	2	SW-846:8290		0.00005			µg/L	
Diox/Fur	19408-74-3	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	525	2	SW-846:8290		0.00005			µg/L	
Diox/Fur	34465-46-8	Hexachlorodibenzodioxins (Total)	525	8	SW-846:8290		0.00005			µg/L	
Diox/Fur	70648-26-9	Hexachlorodibenzofuran[1,2,3,4,7,8-]	525	11	SW-846:8290		0.00005			µg/L	
Diox/Fur	57117-44-9	Hexachlorodibenzofuran[1,2,3,6,7,8-]	525	4	SW-846:8290		0.00005			µg/L	
Diox/Fur	72918-21-9	Hexachlorodibenzofuran[1,2,3,7,8,9-]	525	0	SW-846:8290		0.00005			µg/L	
Diox/Fur	60851-34-5	Hexachlorodibenzofuran[2,3,4,6,7,8-]	525	2	SW-846:8290		0.00005			µg/L	
Diox/Fur	55684-94-1	Hexachlorodibenzofurans (Total)	525	32	SW-846:8290		0.00005			µg/L	
Diox/Fur	3268-87-9	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	525	79	SW-846:8290		0.0001			µg/L	
Diox/Fur	39001-02-0	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	525	35	SW-846:8290		0.0001			µg/L	
Diox/Fur	40321-76-4	Pentachlorodibenzodioxin[1,2,3,7,8-]	525	2	SW-846:8290		0.00005			µg/L	
Diox/Fur	36088-22-9	Pentachlorodibenzodioxins (Total)	525	5	SW-846:8290		0.00005			µg/L	
Diox/Fur	57117-41-6	Pentachlorodibenzofuran[1,2,3,7,8-]	525	3	SW-846:8290		0.00005			µg/L	
Diox/Fur	57117-31-4	Pentachlorodibenzofuran[2,3,4,7,8-]	525	5	SW-846:8290		0.00005			µg/L	
Diox/Fur	30402-15-4	Pentachlorodibenzofurans (Totals)	525	26	SW-846:8290		0.00005			µg/L	
Diox/Fur	1746-01-6	Tetrachlorodibenzodioxin[2,3,7,8-]	525	0	SW-846:8290		0.00001	0.00003		µg/L	EPA MCL
Diox/Fur	41903-57-5	Tetrachlorodibenzodioxins (Total)	525	1	SW-846:8290		0.00001			µg/L	
Diox/Fur	51207-31-9	Tetrachlorodibenzofuran[2,3,7,8-]	525	1	SW-846:8290		0.00001			µg/L	
Diox/Fur	55722-27-5	Tetrachlorodibenzofurans (Totals)	525	7	SW-846:8290		0.00001			µg/L	
DRO	TPH-DRO	Total Petroleum Hydrocarbons Diesel Range Organics	64	25	SW-846:8015M	65	200			µg/L	
Geninorg	ALK-CO3	Alkalinity-CO3	2678	351	EPA:310.1	0.73	1			mg/L	
Geninorg	ALK-CO3+HCO3	Alkalinity-CO3+HCO3	2680	2677	EPA:310.1	0.73	1		52	mg/L	
Geninorg	NH3-N	Ammonia as Nitrogen	2706	497	EPA:350.1	0.016	0.05		0.04	mg/L	
Geninorg	Br(-1)	Bromide	2699	669	EPA:300.0	0.066	0.2		0.03	mg/L	
Geninorg	Ca	Calcium	4761	4756	SW-846:6010B	0.05	0.2		17.3	mg/L	
Geninorg	Cl(-1)	Chloride	2733	2727	EPA:300.0	0.066	0.2	250	3.57	mg/L	NM GW STD
Geninorg	CN(TOTAL)	Cyanide (Total)	2169	222	EPA:335.4	0.0017	0.005	0.2		mg/L	EPA MCL
Geninorg	F(-1)	Fluoride	2748	2647	EPA:300.0	0.033	0.1	1.6	0.23	mg/L	NM GW STD
Geninorg	HARDNESS	Hardness	4733	4727	SM:A2340B	0.35	1.24			mg/L	

Table C-4.1-1 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Unit	Cleanup-Level Type
Geninorg	Mg	Magnesium	4761	4748	SW-846:6010B	0.085	0.3		4.15	mg/L	
Geninorg	NO3+NO2-N	Nitrate-Nitrite as Nitrogen	2700	2343	EPA:353.2	0.01	0.05	10	0.57	mg/L	EPA MCL
Geninorg	C2O4	Oxalate	7	0	EPA:300.0	0.33	1			mg/L	
Geninorg	ClO4	Perchlorate	3364	2541	SW-846:6850	0.05	0.2	4	0.05	µg/L	NM GW CONS
Geninorg	pH	pH	2671	2671	EPA:150.1	0.01	0.1			SU	
Geninorg	K	Potassium	4761	4748	SW-846:6010B	0.05	0.15		2.63	mg/L	
Geninorg	Na	Sodium	4761	4756	SW-846:6010B	0.1	0.3		12.2	mg/L	
Geninorg	SO4(-2)	Sulfate	2731	2712	EPA:300.0	0.1	0.4	600	7.2	mg/L	NM GW STD
Geninorg	SSC	Suspended Sediment Concentration	502	245	EPA:160.2	0.76	3.33			mg/L	
Geninorg	TDS	Total Dissolved Solids	2708	2703	EPA:160.1	2.4	10	1000	127	mg/L	NM GW STD
Geninorg	TKN	Total Kjeldahl Nitrogen	3142	1084	EPA:351.2	0.033	0.1		0.04	mg/L	
Geninorg	TOC	Total Organic Carbon	2273	1898	SW-846:9060	0.33	1		0.33	mg/L	
Geninorg	PO4-P	Total Phosphate as Phosphorus	2606	821	EPA:365.4	0.015	0.05		0.05	mg/L	
Geninorg	TSS	Total Suspended Solids	116	65	EPA:160.2	2.3	10			mg/L	
GRO	TPH-GRO	Total Petroleum Hydrocarbons Gasoline Range Org	11	7	SW-846:8015M	11	50			µg/L	
Herb	94-75-7	D[2,4-]	388	0	SW-846:8151A	0.087	0.26	70		µg/L	EPA MCL
Herb	75-99-0	Dalapon	388	0	SW-846:8151A	1.3	5.3	200		µg/L	EPA MCL
Herb	94-82-6	DB[2,4-]	388	2	SW-846:8151A	0.087	0.26	290		µg/L	EPA TAP SCRN LVL
Herb	1918-00-9	Dicamba	388	0	SW-846:8151A	0.087	0.26	1100		µg/L	EPA TAP SCRN LVL
Herb	120-36-5	Dichlorprop	388	0	SW-846:8151A	0.087	0.26			µg/L	
Herb	88-85-7	Dinoseb	388	0	SW-846:8151A	0.087	0.26	7		µg/L	EPA MCL
Herb	94-74-6	MCPA	388	0	SW-846:8151A	12	53	18		µg/L	EPA TAP SCRN LVL
Herb	93-65-2	MCPP	388	0	SW-846:8151A	11	53	37		µg/L	EPA TAP SCRN LVL
Herb	93-76-5	T[2,4,5-]	388	0	SW-846:8151A	0.087	0.26	370		µg/L	EPA TAP SCRN LVL
Herb	93-72-1	TP[2,4,5-]	388	0	SW-846:8151A	0.087	0.26	50		µg/L	EPA MCL
Hexp	6629-29-4	2,4-Diamino-6-nitrotoluene	1739	17	SW-846:8321	0.39	1.3			µg/L	
Hexp	59229-75-3	2,6-Diamino-4-nitrotoluene	1739	9	SW-846:8321	0.39	1.3			µg/L	
Hexp	618-87-1	3,5-Dinitroaniline	1739	25	SW-846:8321	0.39	1.3			µg/L	
Hexp	19406-51-0	Amino-2,6-dinitrotoluene[4-]	1740	121	SW-846:8321	0.1	0.33	73		µg/L	EPA TAP SCRN LVL
Hexp	35572-78-2	Amino-4,6-dinitrotoluene[2-]	1740	97	SW-846:8321	0.1	0.33	73		µg/L	EPA TAP SCRN LVL
Hexp	99-65-0	Dinitrobenzene[1,3-]	1740	1	SW-846:8321	0.1	0.33	3.7		µg/L	EPA TAP SCRN LVL
Hexp	121-14-2	Dinitrotoluene[2,4-]	1740	14	SW-846:8321	0.1	0.33	2.2		µg/L	EPA TAP SCRN LVL
Hexp	606-20-2	Dinitrotoluene[2,6-]	1740	2	SW-846:8321	0.1	0.33	37		µg/L	EPA TAP SCRN LVL
Hexp	DNX	DNX	1234	42	SW-846:8330	0.069	0.5			µg/L	
Hexp	2691-41-0	HMX	1742	231	SW-846:8321	0.1	0.33	1800		µg/L	EPA TAP SCRN LVL
Hexp	MNX	MNX	1234	80	SW-846:8330	0.091	0.5			µg/L	
Hexp	98-95-3	Nitrobenzene	1740	2	SW-846:8321	0.1	0.33	1.2		µg/L	EPA TAP SCRN LVL

Table C-4.1-1 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Unit	Cleanup-Level Type
Hexp	88-72-2	Nitrotoluene[2-]	1740	7	SW-846:8321	0.1	0.33	3.1		µg/L	EPA TAP SCRN LVL
Hexp	99-08-1	Nitrotoluene[3-]	1740	1	SW-846:8321	0.1	0.33	3.7		µg/L	EPA TAP SCRN LVL
Hexp	99-99-0	Nitrotoluene[4-]	1740	0	SW-846:8321	0.1	0.65	42		µg/L	EPA TAP SCRN LVL
Hexp	78-11-5	PETN	1740	0	SW-846:8321	0.13	1.3			µg/L	
Hexp	121-82-4	RDX	1742	260	SW-846:8321	0.1	0.33	6.1		µg/L	EPA TAP SCRN LVL
Hexp	3058-38-6	TATB	1739	3	SW-846:8321	0.39	1.3			µg/L	
Hexp	479-45-8	Tetryl	1740	0	SW-846:8321	0.13	0.65	150		µg/L	EPA TAP SCRN LVL
Hexp	TNX	TNX	1234	43	SW-846:8330	0.082	0.5			µg/L	
Hexp	99-35-4	Trinitrobenzene[1,3,5-]	1740	54	SW-846:8321	0.1	0.33	1100		µg/L	EPA TAP SCRN LVL
Hexp	118-96-7	Trinitrotoluene[2,4,6-]	1740	42	SW-846:8321	0.1	0.33	22		µg/L	EPA TAP SCRN LVL
Hexp	78-30-8	Tris (o-cresyl) phosphate	1739	0	SW-846:8321	0.39	1.3			µg/L	
Metals	Al	Aluminum	4766	1573	SW-846:6010B	68	200	5000	68	µg/L	NM GW STD
Metals	Sb	Antimony	4757	130	SW-846:6020	0.5	3	6	0.5	µg/L	EPA MCL
Metals	As	Arsenic	4758	1054	SW-846:6020	1.5	5	10	4.32	µg/L	EPA MCL
Metals	Ba	Barium	4761	4747	SW-846:6010B	1	5	1000	56.8	µg/L	NM GW STD
Metals	Be	Beryllium	4761	59	SW-846:6010B	1	5	4	1	µg/L	EPA MCL
Metals	B	Boron	4752	3373	SW-846:6010B	15	50	750	15.1	µg/L	NM GW STD
Metals	Cd	Cadmium	4756	183	SW-846:6020	0.11	1	5	1	µg/L	EPA MCL
Metals	Cr	Chromium	5093	3290	SW-846:6020	2.5	10	50	1	µg/L	NM GW STD
Metals	Co	Cobalt	4761	458	SW-846:6010B	1	5	50	0.5	µg/L	NM GW STD
Metals	Cu	Copper	4761	702	SW-846:6010B	3	10	1000	3	µg/L	NM GW STD
Metals	Fe	Iron	4766	2600	SW-846:6010B	30	100	1000	21	µg/L	NM GW STD
Metals	Pb	Lead	4756	857	SW-846:6020	0.5	2	15	0.5	µg/L	EPA MCL
Metals	Mn	Manganese	4766	2632	SW-846:6010B	2	10	200	2	µg/L	NM GW STD
Metals	Hg	Mercury	4732	103	EPA:245.2	0.066	0.2	2	0.06	µg/L	EPA MCL
Metals	Mo	Molybdenum	4730	2929	SW-846:6020	0.1	0.5	1000	2	µg/L	NM GW STD
Metals	Ni	Nickel	4756	3849	SW-846:6020	0.5	2	200	1	µg/L	NM GW STD
Metals	Se	Selenium	4756	269	SW-846:6020	1	5	50	6	µg/L	EPA MCL
Metals	SiO2	Silicon Dioxide	1718	1710	SW-846:6010B	0.053	0.213		50.7	mg/L	
Metals	Ag	Silver	4756	157	SW-846:6020	0.2	1	50	1	µg/L	NM GW STD
Metals	Sr	Strontium	4733	4728	SW-846:6010B	1	5	22000	120	µg/L	EPA TAP SCRN LVL
Metals	Tl	Thallium	4756	372	SW-846:6020	0.3	1	2	1	µg/L	EPA MCL
Metals	Sn	Tin	4733	84	SW-846:6010B	2.5	10	22000	3.26	µg/L	EPA TAP SCRN LVL
Metals	U	Uranium	4732	3954	SW-846:6020	0.05	0.2	30	0.72	µg/L	EPA MCL
Metals	V	Vanadium	4761	3819	SW-846:6010B	1	5	180	1	µg/L	EPA TAP SCRN LVL
Metals	Zn	Zinc	4763	2777	SW-846:6010B	3.3	10	10000	2	µg/L	NM GW STD
PCB	12674-11-2	Aroclor-1016	1170	1	SW-846:8082	0.033	0.1	0.5		µg/L	EPA MCL

Table C-4.1-1 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Unit	Cleanup-Level Type
PCB	11104-28-2	Aroclor-1221	1170	0	SW-846:8082	0.033	0.1	0.5		µg/L	EPA MCL
PCB	11141-16-5	Aroclor-1232	1170	0	SW-846:8082	0.033	0.1	0.5		µg/L	EPA MCL
PCB	53469-21-9	Aroclor-1242	1170	5	SW-846:8082	0.033	0.1	0.5		µg/L	EPA MCL
PCB	12672-29-6	Aroclor-1248	1170	0	SW-846:8082	0.033	0.1	0.5		µg/L	EPA MCL
PCB	11097-69-1	Aroclor-1254	1171	9	SW-846:8082	0.033	0.1	0.5		µg/L	EPA MCL
PCB	11096-82-5	Aroclor-1260	1170	8	SW-846:8082	0.033	0.1	0.5		µg/L	EPA MCL
PCB	37324-23-5	Aroclor-1262	1169	0	SW-846:8082	0.033	0.1	0.5		µg/L	EPA MCL
Pest	309-00-2	Aldrin	1229	4	SW-846:8081A	0.005	0.02	0.04		µg/L	EPA TAP SCRN LVL
Pest	319-84-6	BHC[alpha-]	1229	1	SW-846:8081A	0.005	0.02	0.11		µg/L	EPA TAP SCRN LVL
Pest	319-85-7	BHC[beta-]	1229	1	SW-846:8081A	0.006	0.02	0.37		µg/L	EPA TAP SCRN LVL
Pest	319-86-8	BHC[delta-]	1229	4	SW-846:8081A	0.005	0.02			µg/L	
Pest	58-89-9	BHC[gamma-]	1229	4	SW-846:8081A	0.005	0.02	0.2		µg/L	EPA MCL
Pest	5103-71-9	Chlordane[alpha-]	1229	0	SW-846:8081A	0.005	0.02			µg/L	
Pest	5103-74-2	Chlordane[gamma-]	1229	3	SW-846:8081A	0.005	0.02			µg/L	
Pest	72-54-8	DDD[4,4'-]	1229	14	SW-846:8081A	0.01	0.04	2.8		µg/L	EPA TAP SCRN LVL
Pest	72-55-9	DDE[4,4'-]	1229	15	SW-846:8081A	0.005	0.04	2		µg/L	EPA TAP SCRN LVL
Pest	50-29-3	DDT[4,4'-]	1229	8	SW-846:8081A	0.01	0.04	2		µg/L	EPA TAP SCRN LVL
Pest	60-57-1	Dieldrin	1229	8	SW-846:8081A	0.01	0.04	0.042		µg/L	EPA TAP SCRN LVL
Pest	959-98-8	Endosulfan I	1229	4	SW-846:8081A	0.005	0.02			µg/L	
Pest	33213-65-9	Endosulfan II	1229	5	SW-846:8081A	0.011	0.045			µg/L	
Pest	1031-07-8	Endosulfan Sulfate	1229	6	SW-846:8081A	0.01	0.04			µg/L	
Pest	72-20-8	Endrin	1229	5	SW-846:8081A	0.01	0.04	2		µg/L	EPA MCL
Pest	7421-93-4	Endrin Aldehyde	1229	3	SW-846:8081A	0.005	0.04			µg/L	
Pest	53494-70-5	Endrin Ketone	1229	0	SW-846:8081A	0.01	0.04			µg/L	
Pest	76-44-8	Heptachlor	1229	10	SW-846:8081A	0.005	0.02	0.4		µg/L	EPA MCL
Pest	1024-57-3	Heptachlor Epoxide	1229	3	SW-846:8081A	0.005	0.02	0.2		µg/L	EPA MCL
Pest	72-43-5	Methoxychlor[4,4'-]	1229	0	SW-846:8081A	0.05	0.2	40		µg/L	EPA MCL
Pest	8001-35-2	Toxaphene (Technical Grade)	1229	1	SW-846:8081A	0.15	0.5	3		µg/L	EPA MCL
Rad	Am-241	Americium-241	2578	61	Alpha Spectroscopy	0.05		1.2	0.04	pCi/L	DOE DW DCG
Rad	Cs-137	Cesium-137	2552	3	Gamma Spectroscopy	8		120	5.8	pCi/L	DOE DW DCG
Rad	Co-60	Cobalt-60	2552	0	Gamma Spectroscopy	8		200		pCi/L	DOE DW DCG
Rad	GROSSA	Gross alpha	1821	377	Gas Proportional Counting	3		15	2.98	pCi/L	EPA MCL
Rad	GROSSB	Gross beta	1817	1079	Gas Proportional Counting	3			4	pCi/L	
Rad	GROSSG	Gross gamma	2552	145	Gamma Spectroscopy	120			648	pCi/L	
Rad	Np-237	Neptunium-237	2649	1	Alpha Spectroscopy	0.05		1.2		pCi/L	DOE DW DCG
Rad	Pu-238	Plutonium-238	2551	18	Alpha Spectroscopy	0.05		1.6	0.06	pCi/L	DOE DW DCG
Rad	Pu-239/240	Plutonium-239/240	2551	57	Alpha Spectroscopy	0.05		1.2		pCi/L	DOE DW DCG

Table C-4.1-1 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Unit	Cleanup-Level Type
Rad	K-40	Potassium-40	2552	12	Gamma Spectroscopy	10		280		pCi/L	DOE DW DCG
Rad	Ra-226	Radium-226	612	187	Gas Proportional Counting	1		4		pCi/L	DOE DW DCG
Rad	Ra-226	Radium-226	612	187	Alpha Spectroscopy	1		4		pCi/L	DOE DW DCG
Rad	Ra-228	Radium-228	615	216	Gas Proportional Counting	1		4		pCi/L	DOE DW DCG
Rad	Na-22	Sodium-22	2552	0	Gamma Spectroscopy	10		400		pCi/L	DOE DW DCG
Rad	Sr-90	Strontium-90	2585	184	Gas Proportional Counting	0.5		8	0.29	pCi/L	EPA MCL
Rad	Tc-99	Technetium-99	60	0	Gas Proportional Counting	1		4000		pCi/L	DOE DW DCG
Rad	Th-228	Thorium-228	163	16	Alpha Spectroscopy	0.05				pCi/L	
Rad	Th-230	Thorium-230	163	10	Alpha Spectroscopy	0.05				pCi/L	
Rad	Th-232	Thorium-232	163	21	Alpha Spectroscopy	0.05				pCi/L	
Rad	H-3	Tritium	2454	1197	Liquid Scintillation Counting	250		20000	0.32	pCi/L	EPA MCL
Rad	U-234	Uranium-234	2559	2177	Alpha Spectroscopy	0.05		20	0.18	pCi/L	DOE DW DCG
Rad	U-235/236	Uranium-235/236	2559	360	Alpha Spectroscopy	0.05		24		pCi/L	DOE DW DCG
Rad	U-238	Uranium-238	2559	2144	Alpha Spectroscopy	0.05		24	0.19	pCi/L	DOE DW DCG
SVOA	83-32-9	Acenaphthene	2074	2	SW-846:8270C	0.33	1.1	2200		µg/L	EPA TAP SCRN LVL
SVOA	208-96-8	Acenaphthylene	2074	3	SW-846:8270C	0.21	1.1			µg/L	
SVOA	62-53-3	Aniline	2074	0	SW-846:8270C	2.5	10	120		µg/L	EPA TAP SCRN LVL
SVOA	120-12-7	Anthracene	2074	4	SW-846:8270C	0.21	1.1	11000		µg/L	EPA TAP SCRN LVL
SVOA	1912-24-9	Atrazine	2074	0	SW-846:8270C	3	10	3		µg/L	EPA MCL
SVOA	103-33-3	Azobenzene	2074	0	SW-846:8270C	2	10	1.3		µg/L	EPA TAP SCRN LVL
SVOA	92-87-5	Benzidine	2074	0	SW-846:8270C	3	10	0.00094		µg/L	EPA TAP SCRN LVL
SVOA	56-55-3	Benzo(a)anthracene	2074	6	SW-846:8270C	0.2	1	0.29		µg/L	EPA TAP SCRN LVL
SVOA	50-32-8	Benzo(a)pyrene	2074	9	SW-846:8270C	0.2	1	0.2		µg/L	EPA MCL
SVOA	205-99-2	Benzo(b)fluoranthene	2074	10	SW-846:8270C	0.2	1	0.29		µg/L	EPA TAP SCRN LVL
SVOA	191-24-2	Benzo(g,h,i)perylene	2074	6	SW-846:8270C	0.2	1			µg/L	
SVOA	207-08-9	Benzo(k)fluoranthene	2074	9	SW-846:8270C	0.2	1	2.9		µg/L	EPA TAP SCRN LVL
SVOA	65-85-0	Benzoic Acid	2074	28	SW-846:8270C	6	20	150000		µg/L	EPA TAP SCRN LVL
SVOA	100-51-6	Benzyl Alcohol	2074	0	SW-846:8270C	2	10	3700		µg/L	EPA TAP SCRN LVL
SVOA	111-91-1	Bis(2-chloroethoxy)methane	2074	0	SW-846:8270C	3	10	110		µg/L	EPA TAP SCRN LVL
SVOA	111-44-4	Bis(2-chloroethyl)ether	2074	0	SW-846:8270C	2	10	0.12		µg/L	EPA TAP SCRN LVL
SVOA	117-81-7	Bis(2-ethylhexyl)phthalate	2074	128	SW-846:8270C	2	10	6		µg/L	EPA MCL
SVOA	101-55-3	Bromophenyl-phenylether[4-]	2074	0	SW-846:8270C	2	10			µg/L	
SVOA	85-68-7	Butylbenzylphthalate	2074	0	SW-846:8270C	2	10	350		µg/L	EPA TAP SCRN LVL
SVOA	59-50-7	Chloro-3-methylphenol[4-]	2074	0	SW-846:8270C	2	10	3700		µg/L	EPA TAP SCRN LVL
SVOA	106-47-8	Chloroaniline[4-]	2074	0	SW-846:8270C	2	10	3.4		µg/L	EPA TAP SCRN LVL
SVOA	91-58-7	Chloronaphthalene[2-]	2074	2	SW-846:8270C	0.3	1	2900		µg/L	EPA TAP SCRN LVL
SVOA	95-57-8	Chlorophenol[2-]	2074	0	SW-846:8270C	2	10	180		µg/L	EPA TAP SCRN LVL

Table C-4.1-1 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Unit	Cleanup-Level Type
SVOA	7005-72-3	Chlorophenyl-phenyl[4-] Ether	2074	0	SW-846:8270C	2	10			µg/L	
SVOA	218-01-9	Chrysene	2074	5	SW-846:8270C	0.2	1	29		µg/L	EPA TAP SCRN LVL
SVOA	53-70-3	Dibenz(a,h)anthracene	2074	4	SW-846:8270C	0.2	1	0.029		µg/L	EPA TAP SCRN LVL
SVOA	132-64-9	Dibenzofuran	2074	0	SW-846:8270C	2	10	37		µg/L	EPA TAP SCRN LVL
SVOA	95-50-1	Dichlorobenzene[1,2-]	2074	1	SW-846:8270C	2	10	600		µg/L	EPA MCL
SVOA	541-73-1	Dichlorobenzene[1,3-]	2074	16	SW-846:8270C	2	10			µg/L	
SVOA	106-46-7	Dichlorobenzene[1,4-]	2074	0	SW-846:8270C	2	10	75		µg/L	EPA MCL
SVOA	91-94-1	Dichlorobenzidine[3,3'-]	2074	0	SW-846:8270C	2	10	1.5		µg/L	EPA TAP SCRN LVL
SVOA	120-83-2	Dichlorophenol[2,4-]	2074	0	SW-846:8270C	2	10	110		µg/L	EPA TAP SCRN LVL
SVOA	84-66-2	Diethylphthalate	2074	48	SW-846:8270C	2	10	29000		µg/L	EPA TAP SCRN LVL
SVOA	131-11-3	Dimethyl Phthalate	2074	0	SW-846:8270C	2	10			µg/L	
SVOA	105-67-9	Dimethylphenol[2,4-]	2074	0	SW-846:8270C	2	10	730		µg/L	EPA TAP SCRN LVL
SVOA	84-74-2	Di-n-butylphthalate	2074	0	SW-846:8270C	2	10	3700		µg/L	EPA TAP SCRN LVL
SVOA	534-52-1	Dinitro-2-methylphenol[4,6-]	2074	0	SW-846:8270C	3	10	2.9		µg/L	EPA TAP SCRN LVL
SVOA	51-28-5	Dinitrophenol[2,4-]	2074	0	SW-846:8270C	5	20	73		µg/L	EPA TAP SCRN LVL
SVOA	121-14-2	Dinitrotoluene[2,4-]	2074	14	SW-846:8270C	2	10	2.2		µg/L	EPA TAP SCRN LVL
SVOA	606-20-2	Dinitrotoluene[2,6-]	2073	2	SW-846:8270C	2	10	37		µg/L	EPA TAP SCRN LVL
SVOA	117-84-0	Di-n-octylphthalate	2074	5	SW-846:8270C	3	10			µg/L	
SVOA	88-85-7	Dinoseb	2074	0	SW-846:8270C	2	10	7		µg/L	EPA MCL
SVOA	123-91-1	Dioxane[1,4-]	2010	119	SW-846:8270C	2	10	6.7		µg/L	EPA TAP SCRN LVL
SVOA	122-39-4	Diphenylamine	2069	0	SW-846:8270C	3	10	910		µg/L	EPA TAP SCRN LVL
SVOA	206-44-0	Fluoranthene	2074	4	SW-846:8270C	0.2	1	1500		µg/L	EPA TAP SCRN LVL
SVOA	86-73-7	Fluorene	2074	3	SW-846:8270C	0.2	1	1500		µg/L	EPA TAP SCRN LVL
SVOA	118-74-1	Hexachlorobenzene	2074	0	SW-846:8270C	2	10	1		µg/L	EPA MCL
SVOA	87-68-3	Hexachlorobutadiene	2074	0	SW-846:8270C	2	10	8.6		µg/L	EPA TAP SCRN LVL
SVOA	77-47-4	Hexachlorocyclopentadiene	2074	0	SW-846:8270C	3	10	50		µg/L	EPA MCL
SVOA	67-72-1	Hexachloroethane	2074	0	SW-846:8270C	2	10	48		µg/L	EPA TAP SCRN LVL
SVOA	193-39-5	Indeno(1,2,3-cd)pyrene	2074	5	SW-846:8270C	0.2	1	0.29		µg/L	EPA TAP SCRN LVL
SVOA	78-59-1	Isophorone	2074	0	SW-846:8270C	3	10	710		µg/L	EPA TAP SCRN LVL
SVOA	90-12-0	Methylnaphthalene[1-]	2072	3	SW-846:8270C	0.3	1	23		µg/L	EPA TAP SCRN LVL
SVOA	91-57-6	Methylnaphthalene[2-]	2074	2	SW-846:8270C	0.3	1	150		µg/L	EPA TAP SCRN LVL
SVOA	95-48-7	Methylphenol[2-]	2074	2	SW-846:8270C	2	10	1800		µg/L	EPA TAP SCRN LVL
SVOA	106-44-5	Methylphenol[4-]	1341	2	SW-846:8270C	3	10	180		µg/L	EPA TAP SCRN LVL
SVOA	91-20-3	Naphthalene	2074	3	SW-846:8270C	0.3	1	30		µg/L	NM GW STD
SVOA	88-74-4	Nitroaniline[2-]	2074	0	SW-846:8270C	2	10	370		µg/L	EPA TAP SCRN LVL
SVOA	99-09-2	Nitroaniline[3-]	2074	0	SW-846:8270C	2	10			µg/L	
SVOA	100-01-6	Nitroaniline[4-]	2074	0	SW-846:8270C	3	10	34		µg/L	EPA TAP SCRN LVL

Table C-4.1-1 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Unit	Cleanup-Level Type
SVOA	98-95-3	Nitrobenzene	2074	2	SW-846:8270C	3	10	1.2		µg/L	EPA TAP SCRN LVL
SVOA	88-75-5	Nitrophenol[2-]	2074	0	SW-846:8270C	2	10			µg/L	
SVOA	100-02-7	Nitrophenol[4-]	2074	0	SW-846:8270C	2	10			µg/L	
SVOA	55-18-5	Nitrosodiethylamine[N-]	2074	0	SW-846:8270C	2	10	0.0014		µg/L	EPA TAP SCRN LVL
SVOA	62-75-9	Nitrosodimethylamine[N-]	2074	0	SW-846:8270C	2	10	0.0042		µg/L	EPA TAP SCRN LVL
SVOA	924-16-3	Nitroso-di-n-butylamine[N-]	2074	0	SW-846:8270C	3	10	0.024		µg/L	EPA TAP SCRN LVL
SVOA	621-64-7	Nitroso-di-n-propylamine[N-]	2074	0	SW-846:8270C	2	10	0.096		µg/L	EPA TAP SCRN LVL
SVOA	930-55-2	Nitrosopyrrolidine[N-]	2074	0	SW-846:8270C	2	10	0.32		µg/L	EPA TAP SCRN LVL
SVOA	108-60-1	Oxybis(1-chloropropane)[2,2'-]	2074	0	SW-846:8270C	2	10	3.2		µg/L	EPA TAP SCRN LVL
SVOA	608-93-5	Pentachlorobenzene	2074	0	SW-846:8270C	3	10	29		µg/L	EPA TAP SCRN LVL
SVOA	87-86-5	Pentachlorophenol	2074	1	SW-846:8270C	2	10	1		µg/L	EPA MCL
SVOA	85-01-8	Phenanthrene	2074	5	SW-846:8270C	0.2	1			µg/L	
SVOA	108-95-2	Phenol	2074	5	SW-846:8270C	1	10	5		µg/L	NM GW STD
SVOA	129-00-0	Pyrene	2074	2	SW-846:8270C	0.3	1	1100		µg/L	EPA TAP SCRN LVL
SVOA	110-86-1	Pyridine	1564	0	SW-846:8270C	3	10	37		µg/L	EPA TAP SCRN LVL
SVOA	95-94-3	Tetrachlorobenzene[1,2,4,5]	2074	0	SW-846:8270C	3	10	11		µg/L	EPA TAP SCRN LVL
SVOA	58-90-2	Tetrachlorophenol[2,3,4,6-]	2074	1	SW-846:8270C	2	10	1100		µg/L	EPA TAP SCRN LVL
SVOA	120-82-1	Trichlorobenzene[1,2,4-]	2074	1	SW-846:8270C	2	10	70		µg/L	EPA MCL
SVOA	95-95-4	Trichlorophenol[2,4,5-]	2074	0	SW-846:8270C	2	10	3700		µg/L	EPA TAP SCRN LVL
SVOA	88-06-2	Trichlorophenol[2,4,6-]	2074	0	SW-846:8270C	2	10	61		µg/L	EPA TAP SCRN LVL
VOA	67-64-1	Acetone	2543	253	SW-846:8260B	3.5	10	22000		µg/L	EPA TAP SCRN LVL
VOA	75-05-8	Acetonitrile	2543	5	SW-846:8260B	6.3	25	130		µg/L	EPA TAP SCRN LVL
VOA	107-02-8	Acrolein	2543	2	SW-846:8260B	1.3	5	0.042		µg/L	EPA TAP SCRN LVL
VOA	107-13-1	Acrylonitrile	2543	0	SW-846:8260B	1	5	0.45		µg/L	EPA TAP SCRN LVL
VOA	71-43-2	Benzene	2543	10	SW-846:8260B	0.3	1	5		µg/L	EPA MCL
VOA	108-86-1	Bromobenzene	2543	0	SW-846:8260B	0.25	1	88		µg/L	EPA TAP SCRN LVL
VOA	74-97-5	Bromochloromethane	2543	0	SW-846:8260B	0.3	1			µg/L	
VOA	75-27-4	Bromodichloromethane	2543	0	SW-846:8260B	0.25	1	80		µg/L	EPA MCL
VOA	75-25-2	Bromoform	2543	1	SW-846:8260B	0.25	1	80		µg/L	EPA MCL
VOA	74-83-9	Bromomethane	2543	2	SW-846:8260B	0.3	1	8.7		µg/L	EPA TAP SCRN LVL
VOA	71-36-3	Butanol[1-]	2004	6	SW-846:8260B	15	50	3700		µg/L	EPA TAP SCRN LVL
VOA	78-93-3	Butanone[2-]	2543	75	SW-846:8260B	1.3	5	7100		µg/L	EPA TAP SCRN LVL
VOA	104-51-8	Butylbenzene[n-]	2543	0	SW-846:8260B	0.25	1			µg/L	
VOA	135-98-8	Butylbenzene[sec-]	2543	0	SW-846:8260B	0.25	1			µg/L	
VOA	98-06-6	Butylbenzene[tert-]	2543	0	SW-846:8260B	0.25	1			µg/L	
VOA	75-15-0	Carbon Disulfide	2543	14	SW-846:8260B	1.3	5	1000		µg/L	EPA TAP SCRN LVL
VOA	56-23-5	Carbon Tetrachloride	2543	0	SW-846:8260B	0.3	1	5		µg/L	EPA MCL

Table C-4.1-1 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Unit	Cleanup-Level Type
VOA	126-99-8	Chloro-1,3-butadiene[2-]	2543	0	SW-846:8260B	0.3	1	0.16		µg/L	EPA TAP SCRN LVL
VOA	107-05-1	Chloro-1-propene[3-]	2543	0	SW-846:8260B	1.5	5	6.5		µg/L	EPA TAP SCRN LVL
VOA	108-90-7	Chlorobenzene	2543	0	SW-846:8260B	0.25	1	100		µg/L	EPA MCL
VOA	124-48-1	Chlorodibromomethane	2543	1	SW-846:8260B	0.3	1	80		µg/L	EPA MCL
VOA	75-00-3	Chloroethane	2543	0	SW-846:8260B	0.3	1	21000		µg/L	EPA TAP SCRN LVL
VOA	67-66-3	Chloroform	2543	127	SW-846:8260B	0.25	1	80		µg/L	EPA MCL
VOA	74-87-3	Chloromethane	2543	77	SW-846:8260B	0.3	1	190		µg/L	EPA TAP SCRN LVL
VOA	95-49-8	Chlorotoluene[2-]	2543	0	SW-846:8260B	0.25	1	730		µg/L	EPA TAP SCRN LVL
VOA	106-43-4	Chlorotoluene[4-]	2543	0	SW-846:8260B	0.25	1	2600		µg/L	EPA TAP SCRN LVL
VOA	96-12-8	Dibromo-3-Chloropropane[1,2-]	2543	0	SW-846:8260B	0.3	1	0.2		µg/L	EPA MCL
VOA	106-93-4	Dibromoethane[1,2-]	2543	0	SW-846:8260B	0.25	1	0.05		µg/L	EPA MCL
VOA	74-95-3	Dibromomethane	2543	0	SW-846:8260B	0.3	1	8.2		µg/L	EPA TAP SCRN LVL
VOA	95-50-1	Dichlorobenzene[1,2-]	2543	1	SW-846:8260B	0.25	1	600		µg/L	EPA MCL
VOA	541-73-1	Dichlorobenzene[1,3-]	2543	16	SW-846:8260B	0.25	1			µg/L	
VOA	106-46-7	Dichlorobenzene[1,4-]	2543	0	SW-846:8260B	0.25	1	75		µg/L	EPA MCL
VOA	75-71-8	Dichlorodifluoromethane	2543	0	SW-846:8260B	0.3	1	390		µg/L	EPA TAP SCRN LVL
VOA	75-34-3	Dichloroethane[1,1-]	2543	66	SW-846:8260B	0.3	1	25		µg/L	NM GW STD
VOA	107-06-2	Dichloroethane[1,2-]	2543	6	SW-846:8260B	0.25	1	5		µg/L	EPA MCL
VOA	75-35-4	Dichloroethene[1,1-]	2543	65	SW-846:8260B	0.3	1	5		µg/L	NM GW STD
VOA	156-59-2	Dichloroethene[cis-1,2-]	2543	8	SW-846:8260B	0.3	1	70		µg/L	EPA MCL
VOA	156-60-5	Dichloroethene[trans-1,2-]	2543	0	SW-846:8260B	0.3	1	100		µg/L	EPA MCL
VOA	78-87-5	Dichloropropane[1,2-]	2543	0	SW-846:8260B	0.25	1	5		µg/L	EPA MCL
VOA	142-28-9	Dichloropropane[1,3-]	2543	0	SW-846:8260B	0.3	1	730		µg/L	EPA TAP SCRN LVL
VOA	594-20-7	Dichloropropane[2,2-]	2543	0	SW-846:8260B	0.3	1			µg/L	
VOA	563-58-6	Dichloropropene[1,1-]	2543	0	SW-846:8260B	0.25	1			µg/L	
VOA	10061-01-5	Dichloropropene[cis-1,3-]	2543	0	SW-846:8260B	0.25	1			µg/L	
VOA	10061-02-6	Dichloropropene[trans-1,3-]	2543	0	SW-846:8260B	0.25	1			µg/L	
VOA	60-29-7	Diethyl Ether	2004	5	SW-846:8260B	0.3	1	7300		µg/L	EPA TAP SCRN LVL
VOA	97-63-2	Ethyl Methacrylate	2543	0	SW-846:8260B	1	5	3300		µg/L	EPA TAP SCRN LVL
VOA	100-41-4	Ethylbenzene	2543	4	SW-846:8260B	0.25	1	700		µg/L	EPA MCL
VOA	87-68-3	Hexachlorobutadiene	2543	0	SW-846:8260B	0.3	1	8.6		µg/L	EPA TAP SCRN LVL
VOA	591-78-6	Hexanone[2-]	2543	1	SW-846:8260B	1.3	5	47		µg/L	EPA TAP SCRN LVL
VOA	74-88-4	Iodomethane	2543	1	SW-846:8260B	1.3	5			µg/L	
VOA	78-83-1	Isobutyl alcohol	2543	1	SW-846:8260B	13	50	11000		µg/L	EPA TAP SCRN LVL
VOA	98-82-8	Isopropylbenzene	2543	11	SW-846:8260B	0.25	1	680		µg/L	EPA TAP SCRN LVL
VOA	99-87-6	Isopropyltoluene[4-]	2543	4	SW-846:8260B	0.25	1			µg/L	
VOA	126-98-7	Methacrylonitrile	2542	0	SW-846:8260B	1	5	1		µg/L	EPA TAP SCRN LVL

Table C-4.1-1 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Unit	Cleanup-Level Type
VOA	80-62-6	Methyl Methacrylate	2543	1	SW-846:8260B	1	5	1400		µg/L	EPA TAP SCRN LVL
VOA	1634-04-4	Methyl tert-Butyl Ether	2004	32	SW-846:8260B	0.25	1	120		µg/L	EPA TAP SCRN LVL
VOA	108-10-1	Methyl-2-pentanone[4-]	2543	8	SW-846:8260B	1.3	5	2000		µg/L	EPA TAP SCRN LVL
VOA	75-09-2	Methylene Chloride	2543	15	SW-846:8260B	3	10	5		µg/L	EPA MCL
VOA	91-20-3	Naphthalene	2543	7	SW-846:8260B	0.25	1	30		µg/L	NM GW STD
VOA	107-12-0	Propionitrile	2543	0	SW-846:8260B	1.5	5			µg/L	
VOA	103-65-1	Propylbenzene[1-]	2543	0	SW-846:8260B	0.25	1	1300		µg/L	EPA TAP SCRN LVL
VOA	100-42-5	Styrene	2543	5	SW-846:8260B	0.25	1	100		µg/L	EPA MCL
VOA	630-20-6	Tetrachloroethane[1,1,1,2-]	2543	0	SW-846:8260B	0.3	1	5.2		µg/L	EPA TAP SCRN LVL
VOA	79-34-5	Tetrachloroethane[1,1,2,2-]	2543	0	SW-846:8260B	0.25	1	10		µg/L	NM GW STD
VOA	127-18-4	Tetrachloroethene	2543	86	SW-846:8260B	0.3	1	5		µg/L	EPA MCL
VOA	108-88-3	Toluene	2543	245	SW-846:8260B	0.25	1	750		µg/L	NM GW STD
VOA	76-13-1	Trichloro-1,2,2-trifluoroethane[1,1,2-]	2541	1	SW-846:8260B	1	5	59000		µg/L	EPA TAP SCRN LVL
VOA	87-61-6	Trichlorobenzene[1,2,3-]	2543	2	SW-846:8260B	0.33	1	29		µg/L	EPA TAP SCRN LVL
VOA	120-82-1	Trichlorobenzene[1,2,4-]	2543	1	SW-846:8260B	0.3	1	70		µg/L	EPA MCL
VOA	71-55-6	Trichloroethane[1,1,1-]	2543	54	SW-846:8260B	0.33	1	60		µg/L	NM GW STD
VOA	79-00-5	Trichloroethane[1,1,2-]	2543	9	SW-846:8260B	0.25	1	5		µg/L	EPA MCL
VOA	79-01-6	Trichloroethene	2543	150	SW-846:8260B	0.25	1	5		µg/L	EPA MCL
VOA	75-69-4	Trichlorofluoromethane	2543	0	SW-846:8260B	0.3	1	1300		µg/L	EPA TAP SCRN LVL
VOA	96-18-4	Trichloropropane[1,2,3-]	2543	0	SW-846:8260B	0.3	1	0.0072		µg/L	EPA TAP SCRN LVL
VOA	95-63-6	Trimethylbenzene[1,2,4-]	2543	3	SW-846:8260B	0.25	1	15		µg/L	EPA TAP SCRN LVL
VOA	108-67-8	Trimethylbenzene[1,3,5-]	2543	0	SW-846:8260B	0.25	1	370		µg/L	EPA TAP SCRN LVL
VOA	108-05-4	Vinyl acetate	2543	0	SW-846:8260B	1.5	5	410		µg/L	EPA TAP SCRN LVL
VOA	75-01-4	Vinyl Chloride	2543	0	SW-846:8260B	0.5	1	1		µg/L	NM GW STD
VOA	95-47-6	Xylene[1,2-]	2543	4	SW-846:8260B	0.3	1	1200		µg/L	EPA TAP SCRN LVL
VOA	Xylene[1,3 and 1,4]	Xylene[1,3-]+Xylene[1,4-]	2541	20	SW-846:8260B	0.5	2			µg/L	

Note: Blank cells indicate there are no values.

[a] Mode (most frequent) of values reported for 2010 data.

[b] This value is derived as result of logic provided in Appendix B-2.0, Protocol for Selecting Cleanup Levels.

[c] Lowest of background values for alluvial, intermediate, and regional groundwater as identified in the Laboratory's 2007 groundwater background report (LANL 2007, 095817).

Table C-4.1-2
Analytes, Analytical Methods, and MDLs and PQLs Obtained for 2010 Analyses of
Base-Flow Samples by Contract Laboratories and Number of Sample Analyses and Detections for the Period 2006 to 2010

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
Diox/Fur	35822-46-9	Heptachlorodibenzodioxin[1,2,3,4,6,7,8-]	75	27	SW-846:8290		0.00005		µg/L	
Diox/Fur	37871-00-4	Heptachlorodibenzodioxins (Total)	75	45	SW-846:8290		0.00005		µg/L	
Diox/Fur	67562-39-4	Heptachlorodibenzofuran[1,2,3,4,6,7,8-]	75	16	SW-846:8290		0.00005		µg/L	
Diox/Fur	55673-89-7	Heptachlorodibenzofuran[1,2,3,4,7,8,9-]	75	6	SW-846:8290		0.00005		µg/L	
Diox/Fur	38998-75-3	Heptachlorodibenzofurans (Total)	75	28	SW-846:8290		0.00005		µg/L	
Diox/Fur	39227-28-6	Hexachlorodibenzodioxin[1,2,3,4,7,8-]	75	4	SW-846:8290		0.00005		µg/L	
Diox/Fur	57653-85-7	Hexachlorodibenzodioxin[1,2,3,6,7,8-]	75	5	SW-846:8290		0.00005		µg/L	
Diox/Fur	19408-74-3	Hexachlorodibenzodioxin[1,2,3,7,8,9-]	75	4	SW-846:8290		0.00005		µg/L	
Diox/Fur	34465-46-8	Hexachlorodibenzodioxins (Total)	75	14	SW-846:8290		0.00005		µg/L	
Diox/Fur	70648-26-9	Hexachlorodibenzofuran[1,2,3,4,7,8-]	75	5	SW-846:8290		0.00005		µg/L	
Diox/Fur	57117-44-9	Hexachlorodibenzofuran[1,2,3,6,7,8-]	75	4	SW-846:8290		0.00005		µg/L	
Diox/Fur	72918-21-9	Hexachlorodibenzofuran[1,2,3,7,8,9-]	75	1	SW-846:8290		0.00005		µg/L	
Diox/Fur	60851-34-5	Hexachlorodibenzofuran[2,3,4,6,7,8-]	75	6	SW-846:8290		0.00005		µg/L	
Diox/Fur	55684-94-1	Hexachlorodibenzofurans (Total)	75	22	SW-846:8290		0.00005		µg/L	
Diox/Fur	3268-87-9	Octachlorodibenzodioxin[1,2,3,4,6,7,8,9-]	75	37	SW-846:8290		0.0001		µg/L	
Diox/Fur	39001-02-0	Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	75	21	SW-846:8290		0.0001		µg/L	
Diox/Fur	40321-76-4	Pentachlorodibenzodioxin[1,2,3,7,8-]	75	2	SW-846:8290		0.00005		µg/L	
Diox/Fur	36088-22-9	Pentachlorodibenzodioxins (Total)	75	10	SW-846:8290		0.00005		µg/L	
Diox/Fur	57117-41-6	Pentachlorodibenzofuran[1,2,3,7,8-]	75	6	SW-846:8290		0.00005		µg/L	
Diox/Fur	57117-31-4	Pentachlorodibenzofuran[2,3,4,7,8-]	75	4	SW-846:8290		0.00005		µg/L	
Diox/Fur	30402-15-4	Pentachlorodibenzofurans (Totals)	75	17	SW-846:8290		0.00005		µg/L	
Diox/Fur	1746-01-6	Tetrachlorodibenzodioxin[2,3,7,8-]	75	3	SW-846:8290		0.00001	5.1E-08	µg/L	NM HH OO
Diox/Fur	41903-57-5	Tetrachlorodibenzodioxins (Total)	75	10	SW-846:8290		0.00001		µg/L	
Diox/Fur	51207-31-9	Tetrachlorodibenzofuran[2,3,7,8-]	75	6	SW-846:8290		0.00001		µg/L	
Diox/Fur	55722-27-5	Tetrachlorodibenzofurans (Totals)	75	11	SW-846:8290		0.00001		µg/L	
DRO	TPH-DRO	Total Petroleum Hydrocarbons Diesel Range Organics	1	1	SW-846:8015M	65	200		µg/L	
Geninorg	ALK-CO3	Alkalinity-CO3	399	81	EPA:310.1	0.73	1		mg/L	
Geninorg	ALK-CO3+HCO3	Alkalinity-CO3+HCO3	399	396	EPA:310.1	0.73	1		mg/L	
Geninorg	NH3-N	Ammonia as Nitrogen	404	197	EPA:350.1	0.016	0.05		mg/L	
Geninorg	Br(-1)	Bromide	399	135	EPA:300.0	0.066	0.2		mg/L	
Geninorg	Ca	Calcium	724	724	SW-846:6010B	0.05	0.2		mg/L	
Geninorg	Cl(-1)	Chloride	395	395	EPA:300.0	0.066	0.2		mg/L	
Geninorg	CN(TOTAL)	Cyanide (Total)	338	71	EPA:335.4	0.0017	0.005		mg/L	
Geninorg	F(-1)	Fluoride	402	380	EPA:300.0	0.033	0.1		mg/L	
Geninorg	HARDNESS	Hardness	721	721	SM:A2340B	0.35	1.24		mg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
Geninorg	Mg	Magnesium	724	724	SW-846:6010B	0.085	0.3		mg/L	
Geninorg	NO3+NO2-N	Nitrate-Nitrite as Nitrogen	404	247	EPA:353.2	0.01	0.05	132	mg/L	NM LVSTK WTR STD
Geninorg	ClO4	Perchlorate	460	305	SW-846:6850	0.05	0.2		µg/L	
Geninorg	pH	pH	395	395	EPA:150.1	0.01	0.1		SU	
Geninorg	K	Potassium	724	724	SW-846:6010B	0.05	0.15		mg/L	
Geninorg	Na	Sodium	724	724	SW-846:6010B	0.1	0.3		mg/L	
Geninorg	SO4(-2)	Sulfate	402	400	EPA:300.0	0.1	0.4		mg/L	
Geninorg	SSC	Suspended Sediment Concentration	339	262	EPA:160.2	0.76	3.33		mg/L	
Geninorg	TDS	Total Dissolved Solids	392	390	EPA:160.1	2.4	10		mg/L	
Geninorg	TKN	Total Kjeldahl Nitrogen	487	380	EPA:351.2	0.033	0.1		mg/L	
Geninorg	TOC	Total Organic Carbon	353	352	SW-846:9060	0.33	1		mg/L	
Geninorg	PO4-P	Total Phosphate as Phosphorus	398	233	EPA:365.4	0.015	0.05		mg/L	
Geninorg	TSS	Total Suspended Solids	19	15	EPA:160.2	2.3	10		mg/L	
Herb	94-75-7	D[2,4-]	42	0	SW-846:8151A	0.087	0.26		µg/L	
Herb	75-99-0	Dalapon	42	0	SW-846:8151A	1.3	5.3		µg/L	
Herb	94-82-6	DB[2,4-]	42	0	SW-846:8151A	0.087	0.26		µg/L	
Herb	1918-00-9	Dicamba	42	0	SW-846:8151A	0.087	0.26		µg/L	
Herb	120-36-5	Dichlorprop	42	0	SW-846:8151A	0.087	0.26		µg/L	
Herb	88-85-7	Dinoseb	42	0	SW-846:8151A	0.087	0.26		µg/L	
Herb	94-74-6	MCPA	42	0	SW-846:8151A	12	53		µg/L	
Herb	93-65-2	MCPP	42	0	SW-846:8151A	11	53		µg/L	
Herb	93-76-5	T[2,4,5-]	42	0	SW-846:8151A	0.087	0.26		µg/L	
Herb	93-72-1	TP[2,4,5-]	42	0	SW-846:8151A	0.087	0.26		µg/L	
Hexp	6629-29-4	2,4-Diamino-6-nitrotoluene	175	4	SW-846:8321	0.39	1.3		µg/L	
Hexp	59229-75-3	2,6-Diamino-4-nitrotoluene	175	2	SW-846:8321	0.39	1.3		µg/L	
Hexp	618-87-1	3,5-Dinitroaniline	175	1	SW-846:8321	0.39	1.3		µg/L	
Hexp	19406-51-0	Amino-2,6-dinitrotoluene[4-]	175	12	SW-846:8321	0.1	0.33		µg/L	
Hexp	35572-78-2	Amino-4,6-dinitrotoluene[2-]	175	14	SW-846:8321	0.1	0.33		µg/L	
Hexp	99-65-0	Dinitrobenzene[1,3-]	175	0	SW-846:8321	0.1	0.33		µg/L	
Hexp	121-14-2	Dinitrotoluene[2,4-]	175	0	SW-846:8321	0.1	0.33		µg/L	
Hexp	606-20-2	Dinitrotoluene[2,6-]	175	0	SW-846:8321	0.1	0.33		µg/L	
Hexp	DNX	DNX	131	8	SW-846:8330	0.069	0.5		µg/L	
Hexp	2691-41-0	HMX	175	46	SW-846:8321	0.1	0.33		µg/L	
Hexp	MNX	MNX	131	9	SW-846:8330	0.091	0.5		µg/L	
Hexp	98-95-3	Nitrobenzene	175	0	SW-846:8321	0.1	0.33	690	µg/L	NM HH OO
Hexp	88-72-2	Nitrotoluene[2-]	175	0	SW-846:8321	0.1	0.33		µg/L	
Hexp	99-08-1	Nitrotoluene[3-]	175	0	SW-846:8321	0.1	0.33		µg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
Hexp	99-99-0	Nitrotoluene[4-]	175	0	SW-846:8321	0.1	0.65		µg/L	
Hexp	78-11-5	PETN	175	0	SW-846:8321	0.13	1.3		µg/L	
Hexp	121-82-4	RDX	175	30	SW-846:8321	0.1	0.33		µg/L	
Hexp	3058-38-6	TATB	175	0	SW-846:8321	0.39	1.3		µg/L	
Hexp	479-45-8	Tetryl	175	0	SW-846:8321	0.13	0.65		µg/L	
Hexp	TNX	TNX	131	7	SW-846:8330	0.082	0.5		µg/L	
Hexp	99-35-4	Trinitrobenzene[1,3,5-]	175	0	SW-846:8321	0.1	0.33		µg/L	
Hexp	118-96-7	Trinitrotoluene[2,4,6-]	175	0	SW-846:8321	0.1	0.33		µg/L	
Hexp	78-30-8	Tris (o-cresyl) phosphate	175	0	SW-846:8321	0.39	1.3		µg/L	
Metals	Al	Aluminum	724	519	SW-846:6010B	68	200	391	µg/L	NM Aqu Chronic 30 mg/L hardness
Metals	Sb	Antimony	724	36	SW-846:6020	0.5	3	640	µg/L	NM HH OO
Metals	As	Arsenic	730	205	SW-846:6020	1.5	5	9	µg/L	NM HH OO
Metals	Ba	Barium	724	724	SW-846:6010B	1	5		µg/L	
Metals	Be	Beryllium	724	20	SW-846:6010B	1	5		µg/L	
Metals	B	Boron	716	540	SW-846:6010B	15	50	5000	µg/L	NM LVSTK WTR STD
Metals	Cd	Cadmium	724	70	SW-846:6020	0.11	1	0.23	µg/L	NM Aqu Chronic 30 mg/L hardness
Metals	Cr	Chromium	728	419	SW-846:6020	2.5	10	35	µg/L	NM Aqu Chronic 30 mg/L hardness
Metals	Co	Cobalt	724	117	SW-846:6010B	1	5	1000	µg/L	NM LVSTK WTR STD
Metals	Cu	Copper	724	264	SW-846:6010B	3	10	4	µg/L	NM Aqu Chronic 30 mg/L hardness
Metals	Fe	Iron	724	627	SW-846:6010B	30	100		µg/L	
Metals	Pb	Lead	724	286	SW-846:6020	0.5	2	1	µg/L	NM Aqu Chronic 30 mg/L hardness
Metals	Mn	Manganese	724	660	SW-846:6010B	2	10	1216	µg/L	NM Aqu Chronic 30 mg/L hardness
Metals	Hg	Mercury	719	17	EPA:245.2	0.066	0.2	0.77	µg/L	NM WQCC WLDLF HAB
Metals	Mo	Molybdenum	724	495	SW-846:6020	0.1	0.5		µg/L	
Metals	Ni	Nickel	724	643	SW-846:6020	0.5	2	24	µg/L	NM Aqu Chronic 30 mg/L hardness
Metals	Se	Selenium	724	45	SW-846:6020	1	5	5	µg/L	NM WQCC WLDLF HAB
Metals	SiO2	Silicon Dioxide	225	225	SW-846:6010B	0.053	0.213		mg/L	
Metals	Ag	Silver	724	78	SW-846:6020	0.2	1	0.7	µg/L	NM Aqu Chronic 30 mg/L hardness
Metals	Sr	Strontium	716	716	SW-846:6010B	1	5		µg/L	
Metals	Tl	Thallium	724	69	SW-846:6020	0.3	1	0.47	µg/L	NM HH OO
Metals	Sn	Tin	716	10	SW-846:6010B	2.5	10		µg/L	
Metals	U	Uranium	716	524	SW-846:6020	0.05	0.2		µg/L	
Metals	V	Vanadium	724	603	SW-846:6010B	1	5	100	µg/L	NM LVSTK WTR STD
Metals	Zn	Zinc	724	490	SW-846:6010B	3.3	10	53	µg/L	NM Aqu Chronic 30 mg/L hardness
PCB	12674-11-2	Aroclor-1016	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO
PCB	11104-28-2	Aroclor-1221	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO
PCB	11141-16-5	Aroclor-1232	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
PCB	53469-21-9	Aroclor-1242	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO
PCB	12672-29-6	Aroclor-1248	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO
PCB	11097-69-1	Aroclor-1254	216	6	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO
PCB	11096-82-5	Aroclor-1260	216	7	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO
PCB	37324-23-5	Aroclor-1262	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO
PCB Cong	2051-60-7	PCB-1	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	33146-45-1	PCB-10	10	0	EPA:1668A		0.000035		µg/L	
PCB Cong	39485-83-1	PCB-100	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	60145-21-3	PCB-103	53	1	EPA:1668A		0.000028		µg/L	
PCB Cong	56558-16-8	PCB-104	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	32598-14-4	PCB-105	53	7	EPA:1668A		0.000035		µg/L	
PCB Cong	70424-69-0	PCB-106	35	3	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-106/118	PCB-106/PCB-118	18	3	EPA:1668A		0.0000097		µg/L	
PCB Cong	70424-68-9	PCB-107	35	3	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-107/109	PCB-107/PCB-109	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-108/112	PCB-108/PCB-112	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-108/124	PCB-108/PCB-124	10	1	EPA:1668A		0.0000139		µg/L	
PCB Cong	2050-67-1	PCB-11	53	4	EPA:1668A		0.000056		µg/L	
PCB Cong	38380-03-9	PCB-110	43	5	EPA:1668A		0.000028		µg/L	
PCB Cong	39635-32-0	PCB-111	35	0	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-111/115	PCB-111/PCB-115	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	74472-36-9	PCB-112	10	0	EPA:1668A		0.000007		µg/L	
PCB Cong	68194-10-5	PCB-113	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	74472-37-0	PCB-114	53	1	EPA:1668A		0.000007		µg/L	
PCB Cong	56558-17-9	PCB-119	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-12/13	PCB-12/PCB-13	53	0	EPA:1668A		0.000056		µg/L	
PCB Cong	68194-12-7	PCB-120	53	1	EPA:1668A		0.000028		µg/L	
PCB Cong	56558-18-0	PCB-121	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	76842-07-4	PCB-122	53	1	EPA:1668A		0.000028		µg/L	
PCB Cong	65510-44-3	PCB-123	53	1	EPA:1668A		0.000035		µg/L	
PCB Cong	70424-70-3	PCB-124	43	1	EPA:1668A		0.000028		µg/L	
PCB Cong	57465-28-8	PCB-126	53	1	EPA:1668A		0.000007		µg/L	
PCB Cong	39635-33-1	PCB-127	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-128/162	PCB-128/PCB-162	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	55215-18-4	PCB-129	43	1	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-66-8	PCB-130	53	5	EPA:1668A		0.000028		µg/L	
PCB Cong	61798-70-7	PCB-131	53	1	EPA:1668A		0.000028		µg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
PCB Cong	PCB-132/161	PCB-132/PCB-161	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	35694-04-3	PCB-133	35	2	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-133/142	PCB-133/PCB-142	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	52704-70-8	PCB-134	35	2	EPA:1668A		0.000035		µg/L	
PCB Cong	PCB-134/143	PCB-134/PCB-143	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	52744-13-5	PCB-135	43	1	EPA:1668A		0.000028		µg/L	
PCB Cong	38411-22-2	PCB-136	53	6	EPA:1668A		0.000028		µg/L	
PCB Cong	35694-06-5	PCB-137	53	3	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-139/140	PCB-139/PCB-140	10	1	EPA:1668A		0.0000139		µg/L	
PCB Cong	PCB-139/149	PCB-139/PCB-149	18	1	EPA:1668A		0.000028		µg/L	
PCB Cong	34883-41-5	PCB-14	53	0	EPA:1668A		0.000056		µg/L	
PCB Cong	59291-64-4	PCB-140	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	52712-04-6	PCB-141	53	8	EPA:1668A		0.000028		µg/L	
PCB Cong	41411-61-4	PCB-142	10	0	EPA:1668A		0.000007		µg/L	
PCB Cong	68194-15-0	PCB-143	10	0	EPA:1668A		0.000007		µg/L	
PCB Cong	68194-14-9	PCB-144	53	5	EPA:1668A		0.000028		µg/L	
PCB Cong	74472-40-5	PCB-145	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-146/165	PCB-146/PCB-165	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	68194-13-8	PCB-147	43	1	EPA:1668A		0.000028		µg/L	
PCB Cong	74472-41-6	PCB-148	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	2050-68-2	PCB-15	53	3	EPA:1668A		0.000056		µg/L	
PCB Cong	68194-08-1	PCB-150	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-63-5	PCB-151	43	2	EPA:1668A		0.000028		µg/L	
PCB Cong	68194-09-2	PCB-152	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	60145-22-4	PCB-154	53	1	EPA:1668A		0.000028		µg/L	
PCB Cong	33979-03-2	PCB-155	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	38380-08-4	PCB-156	43	5	EPA:1668A		0.000004		µg/L	
PCB Cong	PCB-156/157	PCB-156/PCB-157	10	4	EPA:1668A		0.0000138		µg/L	
PCB Cong	69782-90-7	PCB-157	43	1	EPA:1668A		0.000005		µg/L	
PCB Cong	PCB-158/160	PCB-158/PCB-160	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	39635-35-3	PCB-159	53	1	EPA:1668A		0.000028		µg/L	
PCB Cong	38444-78-9	PCB-16	10	0	EPA:1668A		0.000035		µg/L	
PCB Cong	PCB-16/32	PCB-16/PCB-32	43	2	EPA:1668A		0.000028		µg/L	
PCB Cong	41411-62-5	PCB-160	10	0	EPA:1668A		0.000007		µg/L	
PCB Cong	74472-43-8	PCB-161	10	0	EPA:1668A		0.000007		µg/L	
PCB Cong	39635-34-2	PCB-162	10	0	EPA:1668A		0.000007		µg/L	
PCB Cong	74472-46-1	PCB-165	10	0	EPA:1668A		0.000007		µg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
PCB Cong	41411-63-6	PCB-166	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-72-6	PCB-167	53	6	EPA:1668A		0.000007		µg/L	
PCB Cong	59291-65-5	PCB-168	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	32774-16-6	PCB-169	53	0	EPA:1668A		0.000007		µg/L	
PCB Cong	37680-66-3	PCB-17	53	2	EPA:1668A		0.000028		µg/L	
PCB Cong	35065-30-6	PCB-170	53	7	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-71-5	PCB-171	43	1	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-171/173	PCB-171/PCB-173	10	4	EPA:1668A		0.0000138		µg/L	
PCB Cong	52663-74-8	PCB-172	53	5	EPA:1668A		0.000028		µg/L	
PCB Cong	68194-16-1	PCB-173	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	38411-25-5	PCB-174	53	8	EPA:1668A		0.000028		µg/L	
PCB Cong	40186-70-7	PCB-175	53	2	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-65-7	PCB-176	53	5	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-70-4	PCB-177	53	6	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-67-9	PCB-178	53	3	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-64-6	PCB-179	53	7	EPA:1668A		0.000028		µg/L	
PCB Cong	37680-65-2	PCB-18	43	2	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-18/30	PCB-18/PCB-30	10	3	EPA:1668A		0.0000138		µg/L	
PCB Cong	PCB-180/193	PCB-180/PCB-193	10	1	EPA:1668A		0.0000139		µg/L	
PCB Cong	74472-47-2	PCB-181	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	60145-23-5	PCB-182	35	3	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-182/187	PCB-182/PCB-187	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-69-1	PCB-183	43	2	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-183/185	PCB-183/PCB-185	10	3	EPA:1668A		0.0000139		µg/L	
PCB Cong	74472-48-3	PCB-184	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	52712-05-7	PCB-185	43	1	EPA:1668A		0.000028		µg/L	
PCB Cong	74472-49-4	PCB-186	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	74487-85-7	PCB-188	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	39635-31-9	PCB-189	53	3	EPA:1668A		0.000007		µg/L	
PCB Cong	38444-73-4	PCB-19	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	41411-64-7	PCB-190	53	5	EPA:1668A		0.000028		µg/L	
PCB Cong	74472-50-7	PCB-191	53	3	EPA:1668A		0.000028		µg/L	
PCB Cong	74472-51-8	PCB-192	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	69782-91-8	PCB-193	43	1	EPA:1668A		0.000028		µg/L	
PCB Cong	35694-08-7	PCB-194	53	7	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-78-2	PCB-195	53	5	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-196/203	PCB-196/PCB-203	18	0	EPA:1668A		0.000028		µg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
PCB Cong	33091-17-7	PCB-197	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-197/200	PCB-197/PCB-200	10	0	EPA:1668A		0.0000139		µg/L	
PCB Cong	68194-17-2	PCB-198	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-75-9	PCB-199	43	2	EPA:1668A		0.000028		µg/L	
PCB Cong	2051-61-8	PCB-2	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-20/21/33	PCB-20/PCB-21/PCB-33	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-73-7	PCB-200	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	40186-71-8	PCB-201	53	3	EPA:1668A		0.000028		µg/L	
PCB Cong	2136-99-4	PCB-202	53	4	EPA:1668A		0.000028		µg/L	
PCB Cong	74472-52-9	PCB-204	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	74472-53-0	PCB-205	53	1	EPA:1668A		0.000028		µg/L	
PCB Cong	40186-72-9	PCB-206	53	6	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-79-3	PCB-207	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-77-1	PCB-208	53	1	EPA:1668A		0.000028		µg/L	
PCB Cong	2051-24-3	PCB-209	53	1	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-21/33	PCB-21/PCB-33	10	1	EPA:1668A		0.0000139		µg/L	
PCB Cong	38444-85-8	PCB-22	53	4	EPA:1668A		0.000028		µg/L	
PCB Cong	55720-44-0	PCB-23	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	55702-45-9	PCB-24	35	0	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-24/27	PCB-24/PCB-27	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	55712-37-3	PCB-25	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	38444-81-4	PCB-26	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-26/29	PCB-26/PCB-29	10	0	EPA:1668A		0.0000139		µg/L	
PCB Cong	38444-76-7	PCB-27	10	0	EPA:1668A		0.000007		µg/L	
PCB Cong	7012-37-5	PCB-28	43	2	EPA:1668A		0.000028		µg/L	
PCB Cong	15862-07-4	PCB-29	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	2051-62-9	PCB-3	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	35693-92-6	PCB-30	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	16606-02-3	PCB-31	53	7	EPA:1668A		0.000028		µg/L	
PCB Cong	38444-77-8	PCB-32	10	1	EPA:1668A		0.000007		µg/L	
PCB Cong	37680-68-5	PCB-34	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	37680-69-6	PCB-35	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	38444-87-0	PCB-36	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	38444-90-5	PCB-37	53	4	EPA:1668A		0.000028		µg/L	
PCB Cong	53555-66-1	PCB-38	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	38444-88-1	PCB-39	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	13029-08-8	PCB-4	35	0	EPA:1668A		0.000035		µg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
PCB Cong	PCB-4/10	PCB-4/PCB-10	18	0	EPA:1668A		0.000056		µg/L	
PCB Cong	38444-93-8	PCB-40	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-40/71	PCB-40/PCB-71	10	1	EPA:1668A		0.0000139		µg/L	
PCB Cong	52663-59-9	PCB-41	35	1	EPA:1668A		0.000035		µg/L	
PCB Cong	PCB-41/64/71/72	PCB-41/PCB-64/PCB-71/PCB-72	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	36559-22-5	PCB-42	35	1	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-42/59	PCB-42/PCB-59	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	70362-46-8	PCB-43	35	1	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-43/49	PCB-43/PCB-49	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	41464-39-5	PCB-44	43	2	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-44/47/65	PCB-44/PCB-47/PCB-65	10	1	EPA:1668A		0.00002		µg/L	
PCB Cong	70362-45-7	PCB-45	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-45/51	PCB-45/PCB-51	10	0	EPA:1668A		0.0000139		µg/L	
PCB Cong	41464-47-5	PCB-46	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	70362-47-9	PCB-48	35	0	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-48/75	PCB-48/PCB-75	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-49/69	PCB-49/PCB-69	10	4	EPA:1668A		0.0000138		µg/L	
PCB Cong	16605-91-7	PCB-5	53	2	EPA:1668A		0.000056		µg/L	
PCB Cong	62796-65-0	PCB-50	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-50/53	PCB-50/PCB-53	10	0	EPA:1668A		0.0000139		µg/L	
PCB Cong	68194-04-7	PCB-51	43	13	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-52/69	PCB-52/PCB-69	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	41464-41-9	PCB-53	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	15968-05-5	PCB-54	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	74338-24-2	PCB-55	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	41464-43-1	PCB-56	35	5	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-56/60	PCB-56/PCB-60	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	70424-67-8	PCB-57	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	41464-49-7	PCB-58	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-59/62/75	PCB-59/PCB-62/PCB-75	10	0	EPA:1668A		0.00002		µg/L	
PCB Cong	25569-80-6	PCB-6	53	0	EPA:1668A		0.000056		µg/L	
PCB Cong	33025-41-1	PCB-60	10	3	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-61/70	PCB-61/PCB-70	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	54230-22-7	PCB-62	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	74472-34-7	PCB-63	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	52663-58-8	PCB-64	10	4	EPA:1668A		0.000007		µg/L	
PCB Cong	33284-54-7	PCB-65	43	0	EPA:1668A		0.000028		µg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
PCB Cong	32598-10-0	PCB-66	10	3	EPA:1668A		0.000035		µg/L	
PCB Cong	PCB-66/PCB-76	PCB-66/PCB-76	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	73575-53-8	PCB-67	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	73575-52-7	PCB-68	53	2	EPA:1668A		0.000028		µg/L	
PCB Cong	33284-50-3	PCB-7	35	0	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-7/9	PCB-7/PCB-9	18	0	EPA:1668A		0.000056		µg/L	
PCB Cong	41464-42-0	PCB-72	10	1	EPA:1668A		0.000007		µg/L	
PCB Cong	74338-23-1	PCB-73	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	32690-93-0	PCB-74	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	32598-13-3	PCB-77	53	5	EPA:1668A		0.000007		µg/L	
PCB Cong	70362-49-1	PCB-78	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	41464-48-6	PCB-79	53	1	EPA:1668A		0.000028		µg/L	
PCB Cong	34883-43-7	PCB-8	10	2	EPA:1668A		0.0000114		µg/L	
PCB Cong	33284-52-5	PCB-80	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	70362-50-4	PCB-81	53	0	EPA:1668A		0.000007		µg/L	
PCB Cong	52663-62-4	PCB-82	53	5	EPA:1668A		0.000028		µg/L	
PCB Cong	60145-20-2	PCB-83	53	2	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-84/PCB-92	PCB-84/PCB-92	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-85/116	PCB-85/PCB-116	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-85/116/117	PCB-85/PCB-116/PCB-117	10	1	EPA:1668A		0.00002		µg/L	
PCB Cong	55312-69-1	PCB-86	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-87/117/125	PCB-87/PCB-117/PCB-125	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	55215-17-3	PCB-88/91	53	3	EPA:1668A		0.000028		µg/L	
PCB Cong	73575-57-2	PCB-89	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	34883-39-1	PCB-9	10	0	EPA:1668A		0.000007		µg/L	
PCB Cong	PCB-90/101	PCB-90/PCB-101	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	73575-56-1	PCB-93	43	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-93/100	PCB-93/PCB-100	10	0	EPA:1668A		0.0000139		µg/L	
PCB Cong	73575-55-0	PCB-94	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-95/98/102	PCB-95/PCB-98/PCB-102	18	0	EPA:1668A		0.000028		µg/L	
PCB Cong	73575-54-9	PCB-96	53	0	EPA:1668A		0.000028		µg/L	
PCB Cong	41464-51-1	PCB-97	43	1	EPA:1668A		0.000028		µg/L	
PCB Cong	PCB-98/102	PCB-98/PCB-102	10	1	EPA:1668A		0.0000139		µg/L	
PCB Cong	38380-01-7	PCB-99	53	6	EPA:1668A		0.000035		µg/L	
PCB Cong	DECACB(Total)	Total decaCB	53	1	EPA:1668A		0.000028		µg/L	
PCB Cong	25512-42-9	Total diCB	53	8	EPA:1668A		0.000056		µg/L	
PCB Cong	27323-18-8	Total monoCB	53	0	EPA:1668A		0.000028		µg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
PCB Cong	53742-07-7	Total nonaCB	53	6	EPA:1668A		0.000028		µg/L	
PCB Cong	55722-26-4	Total octaCB	53	7	EPA:1668A		0.000028		µg/L	
PCB Cong	25429-29-2	Total pentaCB	53	13	EPA:1668A		0.00003		µg/L	
PCB Cong	25323-68-6	Total triCB	53	7	EPA:1668A		0.000028		µg/L	
Pest	309-00-2	Aldrin	197	1	SW-846:8081A	0.005	0.02	0.0005	µg/L	NM HH OO
Pest	319-84-6	BHC[alpha-]	197	1	SW-846:8081A	0.005	0.02		µg/L	
Pest	319-85-7	BHC[beta-]	197	1	SW-846:8081A	0.006	0.02		µg/L	
Pest	319-86-8	BHC[delta-]	197	4	SW-846:8081A	0.005	0.02		µg/L	
Pest	58-89-9	BHC[gamma-]	197	1	SW-846:8081A	0.005	0.02	0.95	µg/L	NM Aqu Acute
Pest	5103-71-9	Chlordane[alpha-]	197	1	SW-846:8081A	0.005	0.02	0.0043	µg/L	NM Aqu Chronic
Pest	5103-74-2	Chlordane[gamma-]	197	2	SW-846:8081A	0.005	0.02	0.0043	µg/L	NM Aqu Chronic
Pest	72-54-8	DDD[4,4'-]	197	3	SW-846:8081A	0.01	0.04	0.001	µg/L	NM WQCC WLDLF HAB
Pest	72-55-9	DDE[4,4'-]	197	5	SW-846:8081A	0.005	0.04	0.001	µg/L	NM WQCC WLDLF HAB
Pest	50-29-3	DDT[4,4'-]	197	4	SW-846:8081A	0.01	0.04	0.001	µg/L	NM WQCC WLDLF HAB
Pest	60-57-1	Dieldrin	197	2	SW-846:8081A	0.01	0.04	0.00054	µg/L	NM HH OO
Pest	959-98-8	Endosulfan I	197	2	SW-846:8081A	0.005	0.02	0.056	µg/L	NM Aqu Chronic
Pest	33213-65-9	Endosulfan II	197	2	SW-846:8081A	0.011	0.045	0.056	µg/L	NM Aqu Chronic
Pest	1031-07-8	Endosulfan Sulfate	197	2	SW-846:8081A	0.01	0.04	89	µg/L	NM HH OO
Pest	72-20-8	Endrin	197	2	SW-846:8081A	0.01	0.04	0.036	µg/L	NM Aqu Chronic
Pest	7421-93-4	Endrin Aldehyde	197	3	SW-846:8081A	0.005	0.04	0.3	µg/L	NM HH OO
Pest	53494-70-5	Endrin Ketone	197	1	SW-846:8081A	0.01	0.04		µg/L	
Pest	76-44-8	Heptachlor	197	2	SW-846:8081A	0.005	0.02	0.0038	µg/L	NM Aqu Chronic
Pest	1024-57-3	Heptachlor Epoxide	197	2	SW-846:8081A	0.005	0.02	0.0038	µg/L	NM Aqu Chronic
Pest	72-43-5	Methoxychlor[4,4'-]	197	1	SW-846:8081A	0.05	0.2		µg/L	
Pest	8001-35-2	Toxaphene (Technical Grade)	197	0	SW-846:8081A	0.15	0.5	0.0002	µg/L	NM Aqu Chronic
Rad	Am-241	Americium-241	434	25	Alpha Spectroscopy	0.05		400	pCi/L	DOE BCG WATER
Rad	Cs-137	Cesium-137	427	9	Gamma Spectroscopy	8		40	pCi/L	DOE BCG WATER
Rad	Co-60	Cobalt-60	427	0	Gamma Spectroscopy	8		4000	pCi/L	DOE BCG WATER
Rad	GROSSA	Gross alpha	292	71	Gas Proportional Counting	3		15	pCi/L	NM LVSTK WTR STD
Rad	GROSSB	Gross beta	292	237	Gas Proportional Counting	3			pCi/L	
Rad	GROSSG	Gross gamma	427	1	Gamma Spectroscopy	120			pCi/L	
Rad	Np-237	Neptunium-237	437	0	Alpha Spectroscopy	0.05			pCi/L	
Rad	Pu-238	Plutonium-238	433	30	Alpha Spectroscopy	0.05			pCi/L	
Rad	Pu-239/240	Plutonium-239/240	433	44	Alpha Spectroscopy	0.05		200	pCi/L	DOE BCG WATER
Rad	K-40	Potassium-40	427	5	Gamma Spectroscopy	10			pCi/L	
Rad	Ra-226	Radium-226	73	11	Alpha Spectroscopy	1		30	pCi/L	NM LVSTK WTR STD
Rad	Ra-226	Radium-226	73	11	Gas Proportional Counting	1		30	pCi/L	NM LVSTK WTR STD

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
Rad	Ra-228	Radium-228	69	15	Gas Proportional Counting	1		30	pCi/L	NM LVSTK WTR STD
Rad	Na-22	Sodium-22	427	0	Gamma Spectroscopy	10			pCi/L	
Rad	Sr-90	Strontium-90	427	59	Gas Proportional Counting	0.5		300	pCi/L	DOE BCG WATER
Rad	Th-228	Thorium-228	69	21	Alpha Spectroscopy	0.05			pCi/L	
Rad	Th-230	Thorium-230	69	16	Alpha Spectroscopy	0.05			pCi/L	
Rad	Th-232	Thorium-232	69	23	Alpha Spectroscopy	0.05		300	pCi/L	DOE BCG WATER
Rad	H-3	Tritium	195	190	Liquid Scintillation Counting	250		20000	pCi/L	NM LVSTK WTR STD
Rad	U-234	Uranium-234	431	295	Alpha Spectroscopy	0.05		200	pCi/L	DOE BCG WATER
Rad	U-235/236	Uranium-235/236	431	39	Alpha Spectroscopy	0.05			pCi/L	
Rad	U-238	Uranium-238	431	309	Alpha Spectroscopy	0.05		200	pCi/L	DOE BCG WATER
SVOA	83-32-9	Acenaphthene	281	1	SW-846:8270C	0.33	1.1	990	µg/L	NM HH OO
SVOA	208-96-8	Acenaphthylene	281	1	SW-846:8270C	0.21	1.1		µg/L	
SVOA	62-53-3	Aniline	281	0	SW-846:8270C	2.5	10		µg/L	
SVOA	120-12-7	Anthracene	281	2	SW-846:8270C	0.21	1.1	40000	µg/L	NM HH OO
SVOA	1912-24-9	Atrazine	281	0	SW-846:8270C	3	10		µg/L	
SVOA	103-33-3	Azobenzene	281	0	SW-846:8270C	2	10		µg/L	
SVOA	92-87-5	Benzidine	281	0	SW-846:8270C	3	10		µg/L	
SVOA	56-55-3	Benzo(a)anthracene	281	2	SW-846:8270C	0.2	1		µg/L	
SVOA	50-32-8	Benzo(a)pyrene	281	3	SW-846:8270C	0.2	1	0.18	µg/L	NM HH OO
SVOA	205-99-2	Benzo(b)fluoranthene	281	1	SW-846:8270C	0.2	1		µg/L	
SVOA	191-24-2	Benzo(g,h,i)perylene	281	3	SW-846:8270C	0.2	1		µg/L	
SVOA	207-08-9	Benzo(k)fluoranthene	281	3	SW-846:8270C	0.2	1		µg/L	
SVOA	65-85-0	Benzoic Acid	281	3	SW-846:8270C	6	20		µg/L	
SVOA	100-51-6	Benzyl Alcohol	281	1	SW-846:8270C	2	10		µg/L	
SVOA	111-91-1	Bis(2-chloroethoxy)methane	281	1	SW-846:8270C	3	10		µg/L	
SVOA	111-44-4	Bis(2-chloroethyl)ether	281	1	SW-846:8270C	2	10		µg/L	
SVOA	117-81-7	Bis(2-ethylhexyl)phthalate	281	13	SW-846:8270C	2	10		µg/L	
SVOA	101-55-3	Bromophenyl-phenylether[4-]	281	1	SW-846:8270C	2	10		µg/L	
SVOA	85-68-7	Butylbenzylphthalate	281	0	SW-846:8270C	2	10	1900	µg/L	NM HH OO
SVOA	59-50-7	Chloro-3-methylphenol[4-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	106-47-8	Chloroaniline[4-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	91-58-7	Chloronaphthalene[2-]	281	1	SW-846:8270C	0.3	1	1600	µg/L	NM HH OO
SVOA	95-57-8	Chlorophenol[2-]	281	0	SW-846:8270C	2	10	150	µg/L	NM HH OO
SVOA	7005-72-3	Chlorophenyl-phenyl[4-] Ether	281	0	SW-846:8270C	2	10		µg/L	
SVOA	218-01-9	Chrysene	281	2	SW-846:8270C	0.2	1		µg/L	
SVOA	53-70-3	Dibenz(a,h)anthracene	281	3	SW-846:8270C	0.2	1		µg/L	
SVOA	132-64-9	Dibenzofuran	281	0	SW-846:8270C	2	10		µg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
SVOA	95-50-1	Dichlorobenzene[1,2-]	281	0	SW-846:8270C	2	10	1300	µg/L	NM HH OO
SVOA	541-73-1	Dichlorobenzene[1,3-]	281	0	SW-846:8270C	2	10	960	µg/L	NM HH OO
SVOA	106-46-7	Dichlorobenzene[1,4-]	281	1	SW-846:8270C	2	10	190	µg/L	NM HH OO
SVOA	91-94-1	Dichlorobenzidine[3,3'-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	120-83-2	Dichlorophenol[2,4-]	281	0	SW-846:8270C	2	10	290	µg/L	NM HH OO
SVOA	84-66-2	Diethylphthalate	281	3	SW-846:8270C	2	10	44000	µg/L	NM HH OO
SVOA	131-11-3	Dimethyl Phthalate	281	0	SW-846:8270C	2	10	1100000	µg/L	NM HH OO
SVOA	105-67-9	Dimethylphenol[2,4-]	281	0	SW-846:8270C	2	10	850	µg/L	NM HH OO
SVOA	84-74-2	Di-n-butylphthalate	281	0	SW-846:8270C	2	10	4500	µg/L	NM HH OO
SVOA	534-52-1	Dinitro-2-methylphenol[4,6-]	281	0	SW-846:8270C	3	10	280	µg/L	NM HH OO
SVOA	51-28-5	Dinitrophenol[2,4-]	281	0	SW-846:8270C	5	20	5300	µg/L	NM HH OO
SVOA	121-14-2	Dinitrotoluene[2,4-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	606-20-2	Dinitrotoluene[2,6-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	117-84-0	Di-n-octylphthalate	281	0	SW-846:8270C	3	10		µg/L	
SVOA	88-85-7	Dinoseb	281	0	SW-846:8270C	2	10		µg/L	
SVOA	123-91-1	Dioxane[1,4-]	270	6	SW-846:8270C	2	10		µg/L	
SVOA	122-39-4	Diphenylamine	281	0	SW-846:8270C	3	10		µg/L	
SVOA	206-44-0	Fluoranthene	281	2	SW-846:8270C	0.2	1	140	µg/L	NM HH OO
SVOA	86-73-7	Fluorene	281	2	SW-846:8270C	0.2	1	5300	µg/L	NM HH OO
SVOA	118-74-1	Hexachlorobenzene	281	0	SW-846:8270C	2	10	0.0029	µg/L	NM HH OO
SVOA	87-68-3	Hexachlorobutadiene	281	0	SW-846:8270C	2	10		µg/L	
SVOA	77-47-4	Hexachlorocyclopentadiene	281	0	SW-846:8270C	3	10	1100	µg/L	NM HH OO
SVOA	67-72-1	Hexachloroethane	281	0	SW-846:8270C	2	10		µg/L	
SVOA	193-39-5	Indeno(1,2,3-cd)pyrene	281	4	SW-846:8270C	0.2	1		µg/L	
SVOA	78-59-1	Isophorone	281	0	SW-846:8270C	3	10		µg/L	
SVOA	90-12-0	Methylnaphthalene[1-]	281	1	SW-846:8270C	0.3	1		µg/L	
SVOA	91-57-6	Methylnaphthalene[2-]	281	2	SW-846:8270C	0.3	1		µg/L	
SVOA	95-48-7	Methylphenol[2-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	106-44-5	Methylphenol[4-]	161	0	SW-846:8270C	3	10		µg/L	
SVOA	91-20-3	Naphthalene	281	1	SW-846:8270C	0.3	1		µg/L	
SVOA	88-74-4	Nitroaniline[2-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	99-09-2	Nitroaniline[3-]	281	1	SW-846:8270C	2	10		µg/L	
SVOA	100-01-6	Nitroaniline[4-]	281	1	SW-846:8270C	3	10		µg/L	
SVOA	98-95-3	Nitrobenzene	281	0	SW-846:8270C	3	10	690	µg/L	NM HH OO
SVOA	88-75-5	Nitrophenol[2-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	100-02-7	Nitrophenol[4-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	55-18-5	Nitrosodiethylamine[N-]	281	1	SW-846:8270C	2	10		µg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
SVOA	62-75-9	Nitrosodimethylamine[N-]	281	1	SW-846:8270C	2	10		µg/L	
SVOA	924-16-3	Nitroso-di-n-butylamine[N-]	281	1	SW-846:8270C	3	10		µg/L	
SVOA	621-64-7	Nitroso-di-n-propylamine[N-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	930-55-2	Nitrosopyrrolidine[N-]	281	1	SW-846:8270C	2	10		µg/L	
SVOA	108-60-1	Oxybis(1-chloropropane)[2,2'-]	281	0	SW-846:8270C	2	10	65000	µg/L	NM HH OO
SVOA	608-93-5	Pentachlorobenzene	281	1	SW-846:8270C	3	10		µg/L	
SVOA	87-86-5	Pentachlorophenol	281	0	SW-846:8270C	2	10	15	µg/L	NM Aqu Chronic
SVOA	85-01-8	Phenanthrene	281	3	SW-846:8270C	0.2	1		µg/L	
SVOA	108-95-2	Phenol	281	0	SW-846:8270C	1	10	860000	µg/L	NM HH OO
SVOA	129-00-0	Pyrene	281	1	SW-846:8270C	0.3	1	4000	µg/L	NM HH OO
SVOA	110-86-1	Pyridine	185	0	SW-846:8270C	3	10		µg/L	
SVOA	95-94-3	Tetrachlorobenzene[1,2,4,5]	281	1	SW-846:8270C	3	10		µg/L	
SVOA	58-90-2	Tetrachlorophenol[2,3,4,6-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	120-82-1	Trichlorobenzene[1,2,4-]	281	0	SW-846:8270C	2	10	70	µg/L	NM HH OO
SVOA	95-95-4	Trichlorophenol[2,4,5-]	281	0	SW-846:8270C	2	10		µg/L	
SVOA	88-06-2	Trichlorophenol[2,4,6-]	281	0	SW-846:8270C	2	10		µg/L	
VOA	67-64-1	Acetone	309	64	SW-846:8260B	3.5	10		µg/L	
VOA	75-05-8	Acetonitrile	309	0	SW-846:8260B	6.3	25		µg/L	
VOA	107-02-8	Acrolein	309	2	SW-846:8260B	1.3	5	9	µg/L	NM HH OO
VOA	107-13-1	Acrylonitrile	309	0	SW-846:8260B	1	5		µg/L	
VOA	71-43-2	Benzene	309	2	SW-846:8260B	0.3	1	510	µg/L	NM HH OO
VOA	108-86-1	Bromobenzene	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	74-97-5	Bromochloromethane	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	75-27-4	Bromodichloromethane	309	9	SW-846:8260B	0.25	1		µg/L	
VOA	75-25-2	Bromoform	309	7	SW-846:8260B	0.25	1		µg/L	
VOA	74-83-9	Bromomethane	309	0	SW-846:8260B	0.3	1	1500	µg/L	NM HH OO
VOA	71-36-3	Butanol[1-]	219	0	SW-846:8260B	15	50		µg/L	
VOA	78-93-3	Butanone[2-]	309	7	SW-846:8260B	1.3	5		µg/L	
VOA	104-51-8	Butylbenzene[n-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	135-98-8	Butylbenzene[sec-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	98-06-6	Butylbenzene[tert-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	75-15-0	Carbon Disulfide	309	0	SW-846:8260B	1.3	5		µg/L	
VOA	56-23-5	Carbon Tetrachloride	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	126-99-8	Chloro-1,3-butadiene[2-]	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	107-05-1	Chloro-1-propene[3-]	294	0	SW-846:8260B	1.5	5		µg/L	
VOA	108-90-7	Chlorobenzene	309	0	SW-846:8260B	0.25	1	1600	µg/L	NM HH OO
VOA	124-48-1	Chlorodibromomethane	309	10	SW-846:8260B	0.3	1		µg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
VOA	75-00-3	Chloroethane	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	67-66-3	Chloroform	309	14	SW-846:8260B	0.25	1		µg/L	
VOA	74-87-3	Chloromethane	309	2	SW-846:8260B	0.3	1		µg/L	
VOA	95-49-8	Chlorotoluene[2-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	106-43-4	Chlorotoluene[4-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	96-12-8	Dibromo-3-Chloropropane[1,2-]	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	106-93-4	Dibromoethane[1,2-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	74-95-3	Dibromomethane	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	95-50-1	Dichlorobenzene[1,2-]	309	0	SW-846:8260B	0.25	1	1300	µg/L	NM HH OO
VOA	541-73-1	Dichlorobenzene[1,3-]	309	0	SW-846:8260B	0.25	1	960	µg/L	NM HH OO
VOA	106-46-7	Dichlorobenzene[1,4-]	309	1	SW-846:8260B	0.25	1	190	µg/L	NM HH OO
VOA	75-71-8	Dichlorodifluoromethane	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	75-34-3	Dichloroethane[1,1-]	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	107-06-2	Dichloroethane[1,2-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	75-35-4	Dichloroethene[1,1-]	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	156-59-2	Dichloroethene[cis-1,2-]	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	156-60-5	Dichloroethene[trans-1,2-]	309	0	SW-846:8260B	0.3	1	10000	µg/L	NM HH OO
VOA	78-87-5	Dichloropropane[1,2-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	142-28-9	Dichloropropane[1,3-]	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	594-20-7	Dichloropropane[2,2-]	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	563-58-6	Dichloropropene[1,1-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	10061-01-5	Dichloropropene[cis-1,3-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	10061-02-6	Dichloropropene[trans-1,3-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	60-29-7	Diethyl Ether	219	3	SW-846:8260B	0.3	1		µg/L	
VOA	97-63-2	Ethyl Methacrylate	309	0	SW-846:8260B	1	5		µg/L	
VOA	100-41-4	Ethylbenzene	309	0	SW-846:8260B	0.25	1	2100	µg/L	NM HH OO
VOA	87-68-3	Hexachlorobutadiene	309	0	SW-846:8260B	0.3	1	180	µg/L	NM HH OO
VOA	591-78-6	Hexanone[2-]	309	0	SW-846:8260B	1.3	5		µg/L	
VOA	74-88-4	Iodomethane	309	0	SW-846:8260B	1.3	5		µg/L	
VOA	78-83-1	Isobutyl alcohol	309	0	SW-846:8260B	13	50		µg/L	
VOA	98-82-8	Isopropylbenzene	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	99-87-6	Isopropyltoluene[4-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	126-98-7	Methacrylonitrile	309	0	SW-846:8260B	1	5		µg/L	
VOA	80-62-6	Methyl Methacrylate	309	0	SW-846:8260B	1	5		µg/L	
VOA	1634-04-4	Methyl tert-Butyl Ether	219	0	SW-846:8260B	0.25	1		µg/L	
VOA	108-10-1	Methyl-2-pentanone[4-]	309	0	SW-846:8260B	1.3	5		µg/L	
VOA	75-09-2	Methylene Chloride	309	2	SW-846:8260B	3	10		µg/L	

Table C-4.1-2 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Unit	Cleanup-Level Type
VOA	91-20-3	Naphthalene	309	1	SW-846:8260B	0.25	1		µg/L	
VOA	107-12-0	Propionitrile	309	0	SW-846:8260B	1.5	5		µg/L	
VOA	103-65-1	Propylbenzene[1-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	100-42-5	Styrene	309	1	SW-846:8260B	0.25	1		µg/L	
VOA	630-20-6	Tetrachloroethane[1,1,1,2-]	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	79-34-5	Tetrachloroethane[1,1,2,2-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	127-18-4	Tetrachloroethene	309	0	SW-846:8260B	0.3	1	33	µg/L	NM HH OO
VOA	108-88-3	Toluene	309	5	SW-846:8260B	0.25	1	15000	µg/L	NM HH OO
VOA	76-13-1	Trichloro-1,2,2-trifluoroethane[1,1,2-]	309	0	SW-846:8260B	1	5		µg/L	
VOA	87-61-6	Trichlorobenzene[1,2,3-]	309	0	SW-846:8260B	0.33	1		µg/L	
VOA	120-82-1	Trichlorobenzene[1,2,4-]	309	0	SW-846:8260B	0.3	1	70	µg/L	NM HH OO
VOA	71-55-6	Trichloroethane[1,1,1-]	309	2	SW-846:8260B	0.33	1		µg/L	
VOA	79-00-5	Trichloroethane[1,1,2-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	79-01-6	Trichloroethene	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	75-69-4	Trichlorofluoromethane	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	96-18-4	Trichloropropane[1,2,3-]	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	95-63-6	Trimethylbenzene[1,2,4-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	108-67-8	Trimethylbenzene[1,3,5-]	309	0	SW-846:8260B	0.25	1		µg/L	
VOA	108-05-4	Vinyl acetate	309	0	SW-846:8260B	1.5	5		µg/L	
VOA	75-01-4	Vinyl Chloride	309	0	SW-846:8260B	0.5	1		µg/L	
VOA	95-47-6	Xylene[1,2-]	309	0	SW-846:8260B	0.3	1		µg/L	
VOA	Xylene[1,3 and 1,4]	Xylene[1,3-]+Xylene[1,4-]	308	0	SW-846:8260B	0.5	2		µg/L	

Note: Blank cells indicate there are no values.

[a] Mode (most frequent) of values reported for 2010 data.

[b] This value is derived as a result of logic provided in Appendix B-2.0, Protocol for Selecting Cleanup Levels.

Table C-4.1-3
Analytes with PQLs above Groundwater Cleanup Levels

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Background[d]	Unit	Cleanup-Level Type	Comment
Herb	94-74-6	MCPA	388	0	SW-846:8151A	12	53	18			µg/L	EPA TAP SCRN LVL	Although the PQL is higher, the MDL is less than the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Herb	93-65-2	MCPP	388	0	SW-846:8151A	11	53	37			µg/L	EPA TAP SCRN LVL	Although the PQL is higher, the MDL is less than the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	Be	Beryllium	4761	59	SW-846:6010B	1	5	4	1	1	µg/L	EPA MCL	Although the PQL is higher, the MDL is less than the EPA maximum contaminant level (MCL). The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	1912-24-9	Atrazine	2074	0	SW-846:8270C	3	10	3			µg/L	EPA MCL	Although the PQL is higher, the MDL is equal to the EPA MCL. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	103-33-3	Azobenzene	2074	0	SW-846:8270C	2	10	1.3			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	92-87-5	Benzidine	2074	0	SW-846:8270C	3	10	0.00094			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	56-55-3	Benzo(a)anthracene	2074	6	SW-846:8270C	0.2	1	0.29			µg/L	EPA TAP SCRN LVL	Although the PQL is higher, the MDL is less than the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	50-32-8	Benzo(a)pyrene	2074	9	SW-846:8270C	0.2	1	0.2			µg/L	EPA MCL	Although the PQL is higher, the MDL is equal to the EPA MCL. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	205-99-2	Benzo(b)fluoranthene	2074	10	SW-846:8270C	0.2	1	0.29			µg/L	EPA TAP SCRN LVL	Although the PQL is higher, the MDL is less than the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	111-44-4	Bis(2-chloroethyl)ether	2074	0	SW-846:8270C	2	10	0.12			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	117-81-7	Bis(2-ethylhexyl)phthalate	2074	128	SW-846:8270C	2	10	6			µg/L	EPA MCL	Although the PQL is higher, the MDL is less than the EPA MCL. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	106-47-8	Chloroaniline[4-]	2074	0	SW-846:8270C	2	10	3.4			µg/L	EPA TAP SCRN LVL	Although the PQL is higher, the MDL is less than the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	53-70-3	Dibenz(a,h)anthracene	2074	4	SW-846:8270C	0.2	1	0.029			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	91-94-1	Dichlorobenzidine[3,3'-]	2074	0	SW-846:8270C	2	10	1.5			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	534-52-1	Dinitro-2-methylphenol[4,6-]	2074	0	SW-846:8270C	3	10	2.9			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.

Table C-4.1-3 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Background[d]	Unit	Cleanup-Level Type	Comment
SVOA	121-14-2	Dinitrotoluene[2,4-]	2074	14	SW-846:8270C	2	10	2.2			µg/L	EPA TAP SCRN LVL	The Laboratory also analyzes this compound by SW-846:8321; that PQL is below the EPA tap water screening level.
SVOA	88-85-7	Dinoseb	2074	0	SW-846:8270C	2	10	7			µg/L	EPA MCL	The Laboratory also analyzes this compound by SW-846:8151A; that PQL is below the EPA MCL.
SVOA	123-91-1	Dioxane[1,4-]	2010	119	SW-846:8270C	2	10	6.7			µg/L	EPA TAP SCRN LVL	Although the PQL is higher, the MDL is less than the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	118-74-1	Hexachlorobenzene	2074	0	SW-846:8270C	2	10	1			µg/L	EPA MCL	The MDL exceeds the EPA MCL. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	87-68-3	Hexachlorobutadiene	2074	0	SW-846:8270C	2	10	8.6			µg/L	EPA TAP SCRN LVL	The Laboratory also analyzes this compound by SW-846:8260B; that PQL is below the EPA tap water screening level
SVOA	193-39-5	Indeno(1,2,3-cd)pyrene	2074	5	SW-846:8270C	0.2	1	0.29			µg/L	EPA TAP SCRN LVL	Although the PQL is higher, the MDL is less than the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	98-95-3	Nitrobenzene	2074	2	SW-846:8270C	3	10	1.2			µg/L	EPA TAP SCRN LVL	The Laboratory also analyzes this compound by SW-846:8321; that PQL is below the EPA tap water screening level
SVOA	55-18-5	Nitrosodiethylamine[N-]	2074	0	SW-846:8270C	2	10	0.0014			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	62-75-9	Nitrosodimethylamine[N-]	2074	0	SW-846:8270C	2	10	0.0042			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	924-16-3	Nitroso-di-n-butylamine[N-]	2074	0	SW-846:8270C	3	10	0.024			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	621-64-7	Nitroso-di-n-propylamine[N-]	2074	0	SW-846:8270C	2	10	0.096			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	930-55-2	Nitrosopyrrolidine[N-]	2074	0	SW-846:8270C	2	10	0.32			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	108-60-1	Oxybis(1-chloropropane)[2,2'-]	2074	0	SW-846:8270C	2	10	3.2			µg/L	EPA TAP SCRN LVL	Although the PQL is higher, the MDL is less than the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	87-86-5	Pentachlorophenol	2074	1	SW-846:8270C	2	10	1			µg/L	EPA MCL	The MDL exceeds the EPA MCL. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	108-95-2	Phenol	2074	5	SW-846:8270C	1	10	5			µg/L	NM GW STD	Although the PQL is higher, the MDL is less than the NM groundwater standard. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
VOA	107-02-8	Acrolein	2543	2	SW-846:8260B	1.3	5	0.042			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.

Table C-4.1-3 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Background[d]	Unit	Cleanup-Level Type	Comment
VOA	107-13-1	Acrylonitrile	2543	0	SW-846:8260B	1	5	0.45			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
VOA	126-99-8	Chloro-1,3-butadiene[2-]	2543	0	SW-846:8260B	0.3	1	0.16			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
VOA	96-12-8	Dibromo-3-Chloropropane[1,2-]	2543	0	SW-846:8260B	0.3	1	0.2			µg/L	EPA MCL	The MDL exceeds the EPA MCL. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
VOA	106-93-4	Dibromoethane[1,2-]	2543	0	SW-846:8260B	0.25	1	0.05			µg/L	EPA MCL	The MDL exceeds the EPA MCL. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
VOA	126-98-7	Methacrylonitrile	2542	0	SW-846:8260B	1	5	1			µg/L	EPA TAP SCRN LVL	Although the PQL is higher, the MDL is equal to the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
VOA	75-09-2	Methylene Chloride	2543	15	SW-846:8260B	3	10	5			µg/L	EPA MCL	Although the PQL is higher, the MDL is less than the EPA MCL. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
VOA	96-18-4	Trichloropropane[1,2,3-]	2543	0	SW-846:8260B	0.3	1	0.0072			µg/L	EPA TAP SCRN LVL	The MDL exceeds the EPA tap water screening level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.

Note: Blank cells indicate there are no values.

[a] Mode (most frequent) of values reported for 2010 data.

[b] This value is derived as result of logic provided in Appendix B-2.0, Protocol for Selecting Cleanup Levels.

[c] Lowest of background values for alluvial, intermediate, and regional groundwater as identified in the Laboratory's 2007 groundwater background report (LANL 2007, 095817).

[d] Lowest of background values for intermediate and regional groundwater as identified in the Laboratory's 2010 groundwater background report (LANL 2010, 110535).

Table C-4.1-4
Analytes with PQLs above Groundwater Background Levels

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Background[d]	Unit	Cleanup-Level Type	Comment
Geninorg	NH3-N	Ammonia as Nitrogen	2706	497	EPA:350.1	0.016	0.05		0.04	0.07	mg/L		The PQL exceeds the background. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Geninorg	Br(-1)	Bromide	2699	669	EPA:300.0	0.066	0.2		0.03	0.07	mg/L		The MDL exceeds the background. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Geninorg	ClO4	Perchlorate	3364	2541	SW-846:6850	0.05	0.2	4	0.05	0.48	µg/L	NM GW CONS	While the PQL is above background, the MDL and the PQL are less than the Consent Order screening value
Geninorg	TKN	Total Kjeldahl Nitrogen	3142	1084	EPA:351.2	0.033	0.1		0.04	0.29	mg/L		The PQL exceeds the background. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Geninorg	TOC	Total Organic Carbon	2273	1898	SW-846:9060	0.33	1		0.33	0.07	mg/L		The PQL exceeds the background. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	Al	Aluminum	4766	1573	SW-846:6010B	68	200	5000	68	68	µg/L	NM GW STD	While the PQL is above background, the MDL and the PQL are less than the NM groundwater standard.
Metals	Sb	Antimony	4757	130	SW-846:6020	0.5	3	6	0.5	0.5	µg/L	EPA MCL	While the PQL is above background, the MDL and the PQL are less than the EPA MCL.
Metals	As	Arsenic	4758	1054	SW-846:6020	1.5	5	10	4.32	3.43	µg/L	EPA MCL	While the PQL is above background, the MDL and the PQL are less than the EPA MCL.
Metals	Be	Beryllium	4761	59	SW-846:6010B	1	5	4	1	1	µg/L	EPA MCL	The MDL is less than the EPA MCL. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	B	Boron	4752	3373	SW-846:6010B	15	50	750	15.1	35.42	µg/L	NM GW STD	While the PQL is above background, the MDL and the PQL are less than the NM groundwater standard.
Metals	Cr	Chromium	5093	3290	SW-846:6020	2.5	10	50	1	4.74	µg/L	NM GW STD	The MDL is less than the New Mexico groundwater standard. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	Co	Cobalt	4761	458	SW-846:6010B	1	5	50	0.5	1	µg/L	NM GW STD	The MDL is less than the New Mexico groundwater standard. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	Cu	Copper	4761	702	SW-846:6010B	3	10	1000	3	3	µg/L	NM GW STD	While the PQL is above background, the MDL and the PQL are less than the NM groundwater standard
Metals	Fe	Iron	4766	2600	SW-846:6010B	30	100	1000	21	30	µg/L	NM GW STD	The MDL is less than the New Mexico groundwater standard. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	Pb	Lead	4756	857	SW-846:6020	0.5	2	15	0.5	0.5	µg/L	EPA MCL	While the PQL is above background, the MDL and the PQL are less than the EPA MCL.
Metals	Mn	Manganese	4766	2632	SW-846:6010B	2	10	200	2	36	µg/L	NM GW STD	While the PQL is above background, the MDL and the PQL are less than the NM groundwater standard.
Metals	Hg	Mercury	4732	103	EPA:245.2	0.066	0.2	2	0.06	0.07	µg/L	EPA MCL	The MDL is less than the EPA MCL. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	Ni	Nickel	4756	3849	SW-846:6020	0.5	2	200	1	2.98	µg/L	NM GW STD	While the PQL is above background, the MDL and the PQL are less than the NM groundwater standard.
Metals	Sn	Tin	4733	84	SW-846:6010B	2.5	10	22000	3.26	25	µg/L	EPA TAP SCRN LVL	While the PQL is above background, the MDL and the PQL are less than the EPA tap water screening level
Metals	V	Vanadium	4761	3819	SW-846:6010B	1	5	180	1	15.21	µg/L	EPA TAP SCRN LVL	While the PQL is above background, the MDL and the PQL are less than the EPA tap water screening level

Table C-4.1-4 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Cleanup Level[b]	Background[c]	Background[d]	Unit	Cleanup-Level Type	Comment
Metals	Zn	Zinc	4763	2777	SW-846:6010B	3.3	10	10000	2	3.3	µg/L	NM GW STD	The MDL is less than the New Mexico groundwater standard. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Rad	Am-241	Americium-241	2578	61	Alpha Spectroscopy	0.05		1.2	0.04	0.05	pCi/L	DOE DW DCG	The MDA is less than the DOE Derived Concentration Guidelines (DCG). The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Rad	Cs-137	Cesium-137	2552	3	Gamma Spectroscopy	8		120	5.8	6.92	pCi/L	DOE DW DCG	The minimum detectable activity is less than the DOE DCG. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Rad	GROSSA	Gross alpha	1821	377	Gas Proportional Counting	3		15	2.98	2.75	pCi/L	EPA action level	The minimum detectable activity is less than the EPA action level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Rad	Sr-90	Strontium-90	2585	184	Gas Proportional Counting	0.5		8	0.29	0.51	pCi/L	EPA action level	The minimum detectable activity is less than the EPA action level. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Rad	H-3	Tritium	2454	1197	Liquid Scintillation Counting	250		20000	0.32	6.26	pCi/L	EPA action level	The MDL exceeds the background but is below the EPA action level. This background value was determined using data from a laboratory no longer under contract. The Laboratory uses a routine analytical method for this compound under its contract analytical program.

Note: Blank cells indicate there are no values.

[a] Mode (most frequent) of values reported for 2010 data.

[b] This value is derived as result of logic provided in Appendix B-2.0, Protocol for Selecting Cleanup Levels.

[c] Lowest of background values for alluvial, intermediate, and regional groundwater as identified in the Laboratory's 2007 groundwater background report (LANL 2007, 095817).

[d] Lowest of background values for intermediate and regional groundwater as identified in the Laboratory's 2010 groundwater background report (LANL 2010, 110535).

Table C-4.1-5
Analytes with a PQL above Base-Flow Cleanup Levels

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Screening Level[b]	Unit	Screening-Level Type	Comment
Diox/Fur	1746-01-6	Tetrachlorodibenzodioxin[2,3,7,8-]	75	3	SW-846:8290		0.00001	5.1E-08	µg/L	NM HH OO	The PQL exceeds the New Mexico human health numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	Cd	Cadmium	724	70	SW-846:6020	0.11	1	0.23	µg/L	NM Aqu Chronic 30 mg/L hardness	Although the PQL is higher, the MDL is less than the New Mexico aquatic chronic numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	Cu	Copper	724	264	SW-846:6010B	3	10	4	µg/L	NM Aqu Chronic 30 mg/L hardness	Although the PQL is higher, the MDL is less than the New Mexico aquatic chronic numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	Pb	Lead	724	286	SW-846:6020	0.5	2	1	µg/L	NM Aqu Chronic 30 mg/L hardness	Although the PQL is higher, the MDL is less than the New Mexico aquatic chronic numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	Ag	Silver	724	78	SW-846:6020	0.2	1	0.7	µg/L	NM Aqu Chronic 30 mg/L hardness	Although the PQL is higher, the MDL is less than the New Mexico aquatic chronic numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Metals	Tl	Thallium	724	69	SW-846:6020	0.3	1	0.47	µg/L	NM HH OO	Although the PQL is higher, the MDL is less than the New Mexico human health numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
PCB	12674-11-2	Aroclor-1016	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO	The Laboratory also analyzes PCBs by EPA:1668A; the PQL for that method is less than the New Mexico human health numerical criterion.
PCB	11104-28-2	Aroclor-1221	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO	The Laboratory also analyzes PCBs by EPA:1668A; the PQL for that method is less than the New Mexico human health numerical criterion.
PCB	11141-16-5	Aroclor-1232	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO	The Laboratory also analyzes PCBs by EPA:1668A; the PQL for that method is less than the New Mexico human health numerical criterion.
PCB	53469-21-9	Aroclor-1242	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO	The Laboratory also analyzes PCBs by EPA:1668A; the PQL for that method is less than the New Mexico human health numerical criterion.
PCB	12672-29-6	Aroclor-1248	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO	The Laboratory also analyzes PCBs by EPA:1668A; the PQL for that method is less than the New Mexico human health numerical criterion.
PCB	11097-69-1	Aroclor-1254	216	6	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO	The Laboratory also analyzes PCBs by EPA:1668A; the PQL for that method is less than the New Mexico human health numerical criterion.
PCB	11096-82-5	Aroclor-1260	216	7	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO	The Laboratory also analyzes PCBs by EPA:1668A; the PQL for that method is less than the New Mexico human health numerical criterion.
PCB	37324-23-5	Aroclor-1262	216	0	SW-846:8082	0.033	0.1	0.00064	µg/L	NM HH OO	The Laboratory also analyzes PCBs by EPA:1668A; the PQL for that method is less than the New Mexico human health numerical criterion.
Pest	309-00-2	Aldrin	197	1	SW-846:8081A	0.005	0.02	0.0005	µg/L	NM HH OO	The MDL exceeds the New Mexico human health numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Pest	5103-71-9	Chlordane[alpha-]	197	1	SW-846:8081A	0.005	0.02	0.0043	µg/L	NM Aqu Chronic	The MDL exceeds the New Mexico aquatic chronic numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Pest	5103-74-2	Chlordane[gamma-]	197	2	SW-846:8081A	0.005	0.02	0.0043	µg/L	NM Aqu Chronic	The MDL exceeds the New Mexico aquatic chronic numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Pest	72-54-8	DDD[4,4'-]	197	3	SW-846:8081A	0.01	0.04	0.001	µg/L	NM WQCC WLDLF HAB	The MDL exceeds the New Mexico wildlife habitat numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Pest	72-55-9	DDE[4,4'-]	197	5	SW-846:8081A	0.005	0.04	0.001	µg/L	NM WQCC WLDLF HAB	The MDL exceeds the New Mexico wildlife habitat numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.

Table C-4.1-5 (continued)

Suite	Analyte or CAS No.	Analyte Name	Total Samples 2006–2010	Total Detects 2006–2010	Method	MDL[a]	PQL[a]	Screening Level[b]	Unit	Screening-Level Type	Comment
Pest	50-29-3	DDT[4,4'-]	197	4	SW-846:8081A	0.01	0.04	0.001	µg/L	NM WQCC WLDLF HAB	The MDL exceeds the New Mexico wildlife habitat numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Pest	60-57-1	Dieldrin	197	2	SW-846:8081A	0.01	0.04	0.00054	µg/L	NM HH OO	The MDL exceeds the New Mexico human health numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Pest	72-20-8	Endrin	197	2	SW-846:8081A	0.01	0.04	0.036	µg/L	NM Aqu Chronic	Although the PQL is higher, the MDL is less than the New Mexico aquatic chronic numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Pest	76-44-8	Heptachlor	197	2	SW-846:8081A	0.005	0.02	0.0038	µg/L	NM Aqu Chronic	The MDL exceeds the New Mexico aquatic chronic numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Pest	1024-57-3	Heptachlor Epoxide	197	2	SW-846:8081A	0.005	0.02	0.0038	µg/L	NM Aqu Chronic	The MDL exceeds the New Mexico aquatic chronic numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
Pest	8001-35-2	Toxaphene (Technical Grade)	197	0	SW-846:8081A	0.15	0.5	0.0002	µg/L	NM Aqu Chronic	The MDL exceeds the New Mexico aquatic chronic numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	50-32-8	Benzo(a)pyrene	281	3	SW-846:8270C	0.2	1	0.18	µg/L	NM HH OO	The MDL exceeds the New Mexico human health numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.
SVOA	118-74-1	Hexachlorobenzene	281	0	SW-846:8270C	2	10	0.0029	µg/L	NM HH OO	The MDL exceeds the New Mexico human health numerical criterion. The Laboratory uses a routine analytical method for this compound under its contract analytical program.

Note: Blank cells indicate there are no values.

[a] Mode (most frequent) of values reported for 2010 data.

[b] This value is derived as result of logic provided in Appendix B-2.0, Protocol for Selecting Screening Levels.

Table C-4.2-1
Analytical Methods, PQLs, and MDLs for Analytes Reported by GGRL

Analyte	Analytical Method	Method Description	MDL	PQL	Unit
General Inorganics					
Alkalinity-CO_3	EPA:310.1	Titrimetric	0.8	4	mg/L
Alkalinity-CO_3+HCO_3	EPA:310.1	Titrimetric	0.8	4	mg/L
Ammonia as Nitrogen	EPA:350.3	Ion selective electrode	0.1	0.5	mg/L
Bromide	EPA:300.0	Ion chromatography	0.01	0.05	mg/L
Calcium	EPA:200.7	ICP-AES[a]	0.01	0.05	mg/L
Chloride	EPA:300.0	Ion chromatography	0.01	0.05	mg/L
Fluoride	EPA:300.0	Ion chromatography	0.01	0.05	mg/L
Magnesium	EPA:200.7	ICP-AES	0.01	0.05	mg/L
Nitrite as Nitrogen	EPA:300.0	Ion chromatography	0.003	0.015	mg/L
Nitrate as Nitrogen	EPA:300.0	Ion chromatography	0.002	0.01	mg/L
Oxalate	EPA:300.0	Ion chromatography	0.01	0.05	mg/L
Perchlorate	EPA:314.0	Ion chromatography	2	10	µg/L
pH	EPA:150.1	pH meter	—[b]	—	SU
Phosphorus, Orthophosphate (Expressed as PO_4)	EPA:300.0	Ion chromatography	0.01	—	mg/L
Potassium	EPA:200.7	ICP-AES	0.01	—	mg/L
Sodium	EPA:200.7	ICP-AES	0.01	0.05	mg/L
Sulfate	EPA:300.0	Ion chromatography	0.01	0.05	mg/L
Total Organic Carbon	SW-846:9060	Carbonaceous analyzer	0.2	1	mg/L
Sulfide, Total	EPA:376.2	Colorimetric	0.01	0.05	mg/L
Metals					
Aluminum	EPA:200.7	ICP-AES	1	5	µg/L
Antimony	EPA:200.8	ICP-MS[c]	1	5	µg/L
Arsenic	EPA:200.8	ICP-MS	0.2	1	µg/L
Barium	EPA:200.7	ICP-AES	1	5	µg/L
Beryllium	EPA:200.8	ICP-MS	1	5	µg/L
Boron	EPA:200.7	ICP-AES	2	10	µg/L
Cadmium	EPA:200.8	ICP-MS	1	5	µg/L
Cesium	EPA:200.8	ICP-MS	1	5	µg/L
Chromium	EPA:200.8	ICP-MS	1	5	µg/L
Chromium Hexavalent Ion	SW-846:7196A	Ultraviolet–Visible Spectrophotometry	0.05	0.25	µg/L
Cobalt	EPA:200.8	ICP-MS	1	5	µg/L
Copper	EPA:200.8	ICP-MS	1	5	µg/L
Iron	EPA:200.7	ICP-AES	10	50	µg/L
Lithium	EPA:200.7	ICP-AES	1	5	µg/L
Lead	EPA:200.8	ICP-MS	0.2	1	µg/L
Manganese	EPA:200.7	ICP-AES	1	5	µg/L
Mercury	EPA:200.8	ICP-MS	0.05	0.25	µg/L

Table C-4.2-1 (continued)

Analyte	Analytical Method	Method Description	MDL	PQL	Unit
Molybdenum	EPA:200.8	ICP-MS	1	5	µg/L
Nickel	EPA:200.8	ICP-MS	1	5	µg/L
Selenium	EPA:200.8	ICP-MS	1	5	µg/L
Silicon Dioxide	EPA:200.7	ICP-AES	0.0214	0.107	mg/L
Silver	EPA:200.8	ICP-MS	1	5	µg/L
Strontium	EPA:200.7	ICP-AES	1	5	µg/L
Thallium	EPA:200.8	ICP-MS	1	5	µg/L
Tin	EPA:200.8	ICP-MS	1	5	µg/L
Titanium	EPA:200.7	ICP-AES	2	10	µg/L
Uranium	EPA:200.8	ICP-MS	0.2	1	µg/L
Vanadium	EPA:200.8	ICP-MS	1	5	µg/L
Zinc	EPA:200.7	ICP-AES	1	5	µg/L
Isotope					
Deuterium Ratio	Generic:Deuterium Ratio	Isotope ratio mass spectrometry	—	—	permil
Oxygen-18/Oxygen-16 Ratio	Generic:Oxygen Isotope Ratio	Isotope ratio mass spectrometry	—	—	permil
Nitrogen-15/Nitrogen-14 Ratio	Generic:Nitrogen Isotope Ratio	Isotope ratio mass spectrometry	—	—	permil

[a] ICP-AES = inductively coupled plasma atomic emission spectroscopy.

[b] — = Not applicable.

[c] ICP-MS = inductively coupled mass spectrometry.

Table C-5.0-1
Waste Stream, Estimated Volumes, and Management of IDW

Waste Stream	Estimated Volume	On-Site Management and Final Disposition
Purge water	5 to 3000 gal. per well per sampling event	Land application per ENV-RCRA-SOP-010, Land Application of Groundwater
Contact waste	Less than 110 gal. per watershed monitoring campaign	Accumulation in 55-gal. drums with drum liners. Disposal off-site at a New Mexico solid waste landfill or on-site disposal at TA-54, Area G
Decontamination fluids	Less than 55 gal. per watershed monitoring campaign	Treatment at an on-site or Laboratory-approved off-site wastewater treatment facility for which waste meets waste acceptance criteria

Appendix D

Supplemental Information for
Assigned Sampling Suites and Frequencies

Appendix D provides supplemental information relevant to sampling frequencies and analytical suites assigned to locations in each area-specific monitoring group or watershed. The following are primary considerations used to define sampling frequencies and analytical suites that are protective of groundwater:

- general types of contaminants released from upgradient sources
- extent to which contaminant nature and extent have been defined
- expected transport characteristics of the released contaminants
- frequency of detection of contaminants in the monitoring group
- magnitude of concentrations relative to the lowest applicable standard
- nature and rate of change of contaminant concentrations

The highest sampling frequencies apply to areas in which a mobile contaminant has been detected above a standard but where its nature and extent may not be characterized sufficiently to support decisions about potential remedial actions to be taken. Lower sampling frequencies apply to analytes that are not of significance for a given monitoring group, are relatively immobile in the subsurface, and have not been detected or have been detected infrequently.

The following general rules of thumb were used to define the lowest sampling frequencies for specific analytical suites (excluding those locations undergoing characterization sampling).

Inorganic Constituents. General inorganics and metals are sampled annually if these suites contain one or more significant contaminants for a monitoring group, the nature and extent of those constituents are well characterized, and additional data are not needed to support regulatory decision-making, such as an investigation report or a corrective measures evaluation (CME). To the extent that additional data are needed to meet project objectives or for new wells, the relevant analytical suite is sampled more frequently. Metals are not sampled from areas that have no evidence of metals migration. Perchlorate is sampled annually or more frequently in new wells and in the northern monitoring groups where it is a potentially significant constituent. Perchlorate is no longer sampled for in wells from the southern monitoring groups where it was not used.

Organic Constituents. The main characteristic used to determine the lowest sampling frequency for an organic analytical suite is the mobility of its constituents. Suites containing organic constituents with moderate to high mobility in the environment (volatile organic compounds [VOCs] and, to a lesser extent, semivolatile organic compounds [SVOCs]) are sampled annually or not sampled in areas for which there is a history of nondetections and where additional data are not needed to support regulatory decision-making, such as an investigation report or a CME. If consistently detected or if additional data are needed to meet project objectives, then the relevant suite is sampled annually or more frequently. Data from across Los Alamos National Laboratory show a history of nondetections for dioxins/furans, pesticides, and polychlorinated biphenyls (PCBs) in deeper groundwater zones. This is consistent with the expected inability for these highly adsorptive constituents to migrate to deeper groundwater zones. Therefore, these constituents have been eliminated from the groundwater sampling suite. Similarly, high explosives (HEXP) are not present in the northern watersheds (those north of Pajarito Canyon) and are not part of the analytical suite after initial characterization sampling of new wells has been completed.

Radionuclides (Excluding Tritium). If there is a history of nondetections or if detections fall within the range of natural background (for naturally occurring radionuclides), then the lowest sampling frequency applies, which is quarterly or semiannually for new wells, annual if radionuclides are among the significant

constituents for an area being monitored, and biennial otherwise. The frequency is increased to semiannual if one or more radionuclides is detected above background, if the nature and extent of radionuclide constituents are not well characterized, or if additional data are needed to support decision-making.

Tritium. Tritium samples are collected only from springs and deep groundwater. Annual or higher frequencies apply except where tritium is not a significant contaminant, such as in the Technical Area 16 (TA-16) 260 monitoring group and in some general surveillance locations. Samples are collected for low-level tritium analysis at locations where a very low minimum detectable activity is useful to support a conceptual model for fate and transport.

Table D-1 provides background information and the objectives used to generally define the sampling frequencies and analytical suites for the area-specific monitoring groups. The specific sampling frequencies and analytical suites for individual sampling locations are provided in Tables 2.4-1 through 8.3-2 of the monitoring plan.

Table D-1
Background Information and Objectives Used to Determine
Sampling Frequencies and Analytical Suites for Area-Specific Monitoring Groups

Monitoring Group	Background*	Proposed Frequency	Proposed Analyte Suites	Objectives
TA-21	• Nature and extent of groundwater contamination generally understood • No concentrations exceed standards or screening levels (SLs) in regional groundwater	• Quarterly sampling of new regional wells • Annual sampling of all other intermediate and regional wells	• Metals, VOCs, SVOCs, radionuclides, low-level tritium, general inorganics, and perchlorate analyses for all quarterly samples from new wells; HEXP semiannually at new wells • Radionuclides, tritium or low-level tritium, and general inorganics and perchlorate analyses annually for other wells • Annual VOC and SVOC analysis at R-6i	• Focus on mobile constituents and radionuclides
Chromium (Cr)	• Nature and extent of groundwater contamination generally understood • Cr concentrations in regional aquifer exceed New Mexico Groundwater Standard (NM GW STD) • Perchlorate concentrations in regional aquifer exceed Consent Order SL • No constituent concentrations exceed standards or SLs in regional groundwater • Cr concentrations at the down-gradient portion of the plume below NM GW STD and stable, especially in deeper screens where concentrations are at background concentrations	• Quarterly sampling of new regional wells • Quarterly sampling of intermediate and regional wells with chromium (Cr) concentrations that exceed 25 µg/L (half the NM GW STD) • Quarterly sampling of intermediate and regional wells with significant rate of change in Cr concentrations • Semiannual sampling of intermediate and regional wells with Cr concentrations that are above 10.44 µg/L (background upper tolerance limit) but less than 25 µg/L (half the NM GW STD) • Annual sampling of intermediate and regional with Cr concentrations at background levels	• Metals, general inorganics, and perchlorate analyses for all quarterly samples from new regional wells; VOCs, SVOCs, HEXP, radionuclides, and low-level tritium semiannually from new regional wells • Metals, general inorganics, and perchlorate analyses for all samples; perchlorate annually at R-44 and R-45 because of low concentrations • Annual VOC and SVOC analysis for samples from intermediate Mortandad Canyon wells with consistently detected 1,4-dioxane • Annual analysis for radionuclides at intermediate wells; biennial for regional wells that are not new	• Focus highest frequency sampling and analysis for mobile constituents, including perchlorate • Focus highest frequency sampling and analysis at locations with highest Cr concentrations • Monitor wells located where potential for greatest rate of change is possible because of the presence of Cr in the vadose zone • Monitor wells located at downgradient edge of Cr plume • Monitor wells located between Cr plume and water-supply wells

Table D-1 (continued)

Monitoring Group	Background*	Proposed Frequency	Proposed Analyte Suites	Objectives
MDA C	• Current data sufficient to support remedy selection for Material Disposal Area (MDA) C CME • No concentrations of constituents exceed standards or SLs in regional groundwater • Determination that groundwater is protected is supported by vapor-phase VOC sampling conducted to date	• Semiannual sampling of all wells	• VOC, SVOC, and low-level tritium analyses for all samples • Metals analysis for all R-60 samples • Annual analysis for radionuclides and general inorganics for all locations	• Focus highest frequency analysis for mobile constituents known to be present beneath MDA C
TA-54	• Current data sufficient to support remedy selection; CMEs for MDAs G, H and L submitted to the New Mexico Environment Department (09/09/2011) • No constituent concentrations exceed standards or SLs in regional groundwater • Determination that groundwater is protected is supported by vapor-phase VOC sampling conducted to date	• Semiannual sampling of all intermediate and regional wells	• Metals, VOCs, SVOCs, HEXP, low-level tritium, general inorganics, and perchlorate analyses for all samples from new well R-55i; radionuclides annually • VOC and low-level tritium analyses for all other samples • Semiannual SVOC analysis for R-37 screen 1 (consistently detected 1,4-dioxane) • VOCs and low-level tritium analysis only at R-40 screen 1 because of low yield • Annual metals, SVOCs, radionuclides, general inorganics, and perchlorate analyses for all other locations	• Focus highest frequency analysis for mobile constituents known to present beneath TA-54 MDAs

Table D-1 (continued)

Monitoring Group	Background*	Proposed Frequency	Proposed Analyte Suites	Objectives
TA-16-260	• Increased runoff following Las Conchas fire may impact near-surface hydrology and contaminant distributions • Nature and extent of groundwater contamination generally understood • RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) exceeds U.S. Environmental Protection Agency tap water SL in intermediate groundwater • No constituent concentrations exceed standards or SLs in regional groundwater • Historical rate of change in RDX concentrations doesn't require high-frequency (e.g., quarterly) sampling	• Monitor semiannually or annually at key base-flow location, alluvial monitoring wells, and springs • Semiannual sampling of new or reconfigured wells with an extra quarterly round in R-63 • Semiannual sampling of springs, and alluvial, intermediate, and regional wells with elevated RDX concentrations • Annual sampling of springs and wells without significant RDX detections	• Metals, VOCs, SVOCs, HEXP, low-level tritium, general inorganics, and perchlorate analyses for all samples from new or reconfigured wells; annual analysis for radionuclides • Metals, VOCs, and HEXP analyses for all other samples • Annual analysis for general inorganics and biennial analysis for radionuclides for all other locations	• Reestablish baseline conditions for shallow system following Las Conchas fire • Focus highest frequency analysis for mobile constituents known to be released at the 260 Outfall
MDA AB	• No constituent concentrations exceed standards or SLs in regional groundwater	• Annual sampling of all intermediate and regional wells	• Metals, VOCs, SVOCs, HEXP, radionuclides, low-level tritium, and general inorganics analyses for all samples	• General analyte suite for constituents that may have been released from MDA AB

Table D-1 (continued)

Monitoring Group	Background*	Proposed Frequency	Proposed Analyte Suites	Objectives
General Surveillance	• Number of outfalls significantly reduced and remaining outfalls have improved water quality • Nature and extent of groundwater contamination generally understood • Canyons investigations are complete and show contribution to risk from surface water is low and within acceptable limits • Generally, constituent concentrations are below standards or SLs	• Continuous field-parameters sampling at key base-flow locations • Annual monitoring at key alluvial monitoring wells and springs to capture unexpected near-surface conditions • Annual sampling of all intermediate and regional wells	• Metals, radionuclides, general inorganics, and perchlorate analyses for all samples • Analysis of additional constituents at monitoring well 03-B-13 • HEXP analysis for southern watersheds • VOCs and SVOCs analysis for selected areas	• Focus highest frequency analysis for mobile constituents known to be present in particular watershed • Limit monitoring in the alluvial groundwater because of limited contamination • Focus on intermediate and regional locations for groundwater protection

* Constituents discussed in this column do not include detections of spurious organic constituents, naturally occurring constituents, or constituents related to well corrosion or to potential drilling effects.

Appendix E

Field Quality Assurance/Quality Control Samples

Sample Type	Summary
General	This appendix summarizes field quality assurance/quality control (QA/QC) samples to be collected during interim facility-wide groundwater monitoring activities. Field QA/QC samples are collected in accordance with the Compliance Order on Consent, Section IX.B and include field blanks, equipment rinsate blanks, performance evaluation blanks, field duplicates, and field trip blanks. Field QA/QC samples are used to detect possible field or analytical laboratory contamination and to track analytical laboratory performance. Differences in analytical results between field-duplicate samples, for example, may indicate the samples were not uniform or significant variation occurred during analyses. Detection of analytes in deionized water field blanks may indicate contamination of the deionized water source or sample bottles or contamination from the analytical laboratory. This summary also addresses how field QA/QC results are used and the types of corrective actions that may be taken to address exceedances of target measures for each QA/QC sample type.
Field Blanks	Field blanks are used to monitor for contamination during sampling and are collected at a minimum frequency of 10% of all samples collected in a sampling campaign. Field blanks are collected by filling sample containers in the field with deionized water to check for sources of sample contamination in the field. Field blanks are analyzed for the organic constituents sampled for during the sampling campaign, with the exception of high explosive compounds, which are not analyzed in field or equipment rinsate blanks. Field-blank results are evaluated as part of the secondary data validation process by using the results to validate the associated sample results. If any analytes are detected in the field blank, the result from the associated sample is qualified as undetected if the result is less than 5 times the amount for the analyte found in the associated field blank. A validation reason code is also assigned to describe why the data were qualified.
Equipment Rinsate Blanks	Equipment rinsate blanks are used to detect any contamination resulting from contaminated equipment or poor decontamination techniques. The equipment rinsate blank is prepared by passing deionized water through unused or decontaminated sampling equipment, including Westbay sample bottles. Equipment rinsate blanks are collected before a well is sampled with a nondedicated pump. An equipment rinsate blank is also collected before sampling each well equipped with a Westbay sampling system for which samples are being collected for off-site analysis. Equipment rinsate blanks are not required for wells equipped with Westbay sampling systems from which samples are being collected only for on-site analysis. Equipment rinsate blanks are analyzed for the organic constituents sampled for in the associated well, with the exception of high explosive compounds, which are not analyzed in rinsate blanks. During the secondary data validation process, equipment rinsate blanks are evaluated in the same manner as field blanks, and any detected analytes are qualified in the samples associated with the equipment rinsate blank.
Performance Evaluation Blanks	Performance evaluation blanks (PEBs) are deionized water blanks submitted as regular samples, without any indication that they are QC samples. PEBs are used to evaluate the reagent-grade deionized water used to decontaminate sampling equipment and to prepare the blank samples discussed above. One PEB is collected per sampling campaign and analyzed for total organic carbon and for the full suite of constituents analyzed during the watershed sampling campaign, including metals, organic chemicals, general inorganics, and radionuclides. PEBs are not analyzed for stable isotopes or specialized analytes that may be requested for the sampling campaign.

Sample Type	Summary
Field Duplicates	Field duplicates are split samples that provide information about field variation of sampling results as well as analytical laboratory variation. They may reveal sampling techniques with poor reproducibility and provide information on the reproducibility of the sampling process. Field duplicates are collected at a rate of 10% of all samples collected in a sampling campaign. Field-duplicate samples should be distributed proportionally among surface water, alluvial groundwater, and intermediate/regional groundwater to the relative number of samples collected for each type of media. Field-duplicate samples are selected from robust sampling locations requiring full analytical suites and yielding plenty of sample volume. Field-duplicate samples should be analyzed for the same suite of analytes for which the primary samples are analyzed. However, field-duplicate samples need not be analyzed for specialized nonroutine analytes that may be requested for a sampling campaign, unless directed by the project leader. These analytes include stable isotopes and parameters for which microfiltration is requested. Field-duplicate results are compared with the associated sample results, and a relative percent difference is calculated. The acceptable threshold for relative percent differences is 20% for data greater than 5 times the reporting limit.
Field Trip Blanks	Field trip blanks accompany samples collected for volatile organic compound (VOC) analyses and are used to identify potential VOC contamination that may occur during sample handling, shipping, and storage or at the analytical laboratory. Field trip blanks consist of organic-free deionized water prepared by an independent off-site laboratory and are analyzed only for VOCs. A minimum of one trip blank is required for each cooler containing samples for VOC analyses. However, to facilitate data validation and verification, one trip blank may be included with each sample submitted for VOC analysis. During the secondary data validation process, field trip blanks are evaluated the same as field blanks, and any detected analytes are qualified in the samples associated with the trip blank. If any analytes are detected in the field trip blank, the result from the associated sample is qualified as undetected if the result is less than 5 times the amount of the concentration of the analyte found in the associated field blank. These results are given a validation reason code to describe why the data were qualified.
QA/QC Corrective Actions	Exceedances of target measures for each of the QA/QC sections summarized above triggers any number of potential corrective actions. Potential corrective actions are considered on a case-by-case basis and generally follow a graded approach. Corrective actions to be considered include the following. **Data review/focused validation:** A typical first step is to review field paperwork (e.g., chains-of-custody forms, sample collection logs) to ensure sample identifiers align with analytical results. Detailed data review and focused validation may also provide insights into improper use of sample preservatives and other similar errors in sample collection. **Reanalysis:** Review of QA/QC results sometimes detects problems that occur with sample analysis. In these instances, reanalysis of an aliquot of the original sample may be requested of the analytical laboratory, assuming no holding-time issues are associated with the sample aliquot. **Resampling:** If the QA/QC problem is not resolved using the approaches described above, resampling may be necessary. The decision to resample depends largely on the schedule for the subsequent sampling round. For instance, if a site is sampled quarterly, the sample collected for that round should suffice in filling the data gap. If the site is sampled annually, it may be necessary to resample after the discovery of a QA/QC concern if it would result in an important data gap. If an unacceptable QA/QC condition persists, then determining the source of the problem and making root-level corrections in a specific portion of the process will be initiated. For example, corrections or modifications may be made to an equipment decontamination process.

Appendix F

Protocols for Assessing
the Performance of Deep Groundwater Monitoring Wells

F-1.0 OBJECTIVES AND SCOPE

This appendix establishes a "watch list" identifying perched-intermediate and regional groundwater monitoring wells (hereafter referred to as the deep monitoring wells) for which the representativeness of water-quality data for certain constituents is questionable. These deep monitoring wells are sampled at Los Alamos National Laboratory (the Laboratory) under the Interim Facility-Wide Groundwater Monitoring Plan (the Interim Plan). Table F-1.0-1 lists the preliminary watch list of deep monitoring wells for the 2011 Interim Monitoring Plan, and describes the reason for this condition.

This appendix describes approaches for tracking the performance of deep monitoring wells at the Laboratory under the Interim Monitoring Plan.

- Section F-2.0 identifies deep monitoring wells that are purged less than 3 casing volumes (CVs).
- Section F-3.0 defines a protocol for assigning deep monitoring wells to watch lists with appropriate follow-up actions when questions arise concerning the reliability and representativeness of water-quality data from those wells.
- Section F-4.0 outlines an approach for conducting reliability assessments of deep monitoring wells to determine their capability for producing representative water-quality samples and to identify any potential effects of well installation, rehabilitation, or sampling protocol on data quality.

One well is also included on the watch list because of possible construction issues. In addition to wells described in Table F-1.0-1, the representativeness of new water quality samples from other wells is continually reviewed for possible addition to the watch list. The results from newly drilled wells and recently converted Westbay wells are part of this evaluation.

Inclusion of a well on the watch list is intended to be used as a general indicator of data quality and should not be construed as a definitive identification of data usability. The watch list is also dynamic insofar as it will be updated as conditions evolve. Changes will occur when additional water-quality data justify the removal or addition of wells from the list.

F-2.0 DEEP WELLS WITH LIMITED PURGE VOLUMES

Water that remains in a monitoring well for a period of time may not be representative of formation water because of physical, chemical, or biological changes that may occur as the water remains in contact with the well casing, dedicated sampling equipment, and the air space in the upper casing. This stagnant water may not represent formation water at the time of sampling. To ensure samples collected from a monitoring well are representative of formation water, stagnant water in the casing is generally removed (i.e., purged) from the sampling zone within the well before it is sampled. As prescribed in Standard Operating Procedure (SOP) EP-DIV-SOP-20032, Groundwater Sampling, the Laboratory's standard practice is to purge perched-intermediate and regional wells a minimum of 3 CVs plus the volume of the drop pipe and to continue purging until water-quality parameters stabilize. Once the parameters stabilize, it is presumed that all stagnant water has been removed from the well and that fresh formation water is available for sampling.

However, purging 3 CVs is not always possible or feasible, particularly in low-producing monitoring wells that purge dry at low pumping rates. SOP-EP-DIV-SOP-20032 allows deviation from the 3-CV purge requirement for such conditions. However, data users may want to be aware of deep wells at which the 3-CV purge requirement generally cannot be met to consider potential impacts for data reliability. Table F-1.0-1 lists deep well screens which cannot meet the 3-CV purge requirement and describes the reason for this condition.

F-3.0 WATCH LIST ASSIGNMENTS

This appendix section discusses additional watch list criteria for deep monitoring wells in this Interim Plan for which the representativeness of water-quality data is questionable.

Data examined for the assessment includes field parameters monitored during purging before sample collection, field parameters associated with samples at the time of collection, major-ion concentrations, trace-metal concentrations, and detections of organic constituents. The assessments are based on site-specific geochemical criteria. The assessment may result in recommendations concerning the well's configuration, sampling protocols (such as purging volumes), extension or limitation of the analytical suites to be collected from the well screen, or caveats about data usability.

The specific objective of a reliability assessment is to determine the current reliability of a well (including its sampling system) as it relates to the water-quality data objectives of the specific monitoring network to which it is assigned. In general, reliability assessments may be conducted for a subset of the wells assigned to the watch list described in the preceding section or for deep wells within the context of a specific monitoring network.

The watch list presented in Table F-1.0-1 includes deep well screens for which field parameters monitored during purging consistently fail to meet stability criteria as well as deep well screens which show anomalous chemistry data suggesting groundwater in the screened interval may not be fully equilibrated following construction or rehabilitation. Table F-1.0-1 also provides the rationale for each listed well screen and lists recommended follow-up actions.

F-4.0 RELIABILITY ASSESSMENT PROTOCOL

The specific objective of a reliability assessment is to determine the current reliability of a well (including its sampling system) as it relates to the water-quality data objectives of the specific monitoring network to which it is assigned. In general, reliability assessments may be conducted for a subset of the wells assigned to the watch lists described in the preceding section or for deep wells within the context of a specific monitoring network.

Data examined for the assessment includes field parameters monitored during purging before sample collection, field parameters associated with samples at the time of collection, major-ion concentrations, trace-metal concentrations, and detections of organic constituents. The assessments are based on site-specific geochemical criteria and generally focus on data obtained for the four most recent sampling events. The assessment may result in recommendations concerning the well's configuration, sampling protocols (such as purging volumes), extension or limitation of the analytical suites to be collected from the well screen, or caveats about data usability.

Field parameters. Time-series data for field parameters monitored during purging before sample collection are examined for attainment of stable values by the end of purging. Stabilization criteria are prescribed in SOP EP-DIV-SOP-20032, Groundwater Sampling, and are derived from the stabilization criteria recommended by EPA (Yeskis and Zavala 2002, 204429) and from the Compliance Order on Consent (the Consent Order). The most sensitive indicator parameters are dissolved oxygen (DO) and turbidity. Other parameters such as water temperature, specific conductance, pH, and oxidation-reduction potential (ORP) are also monitored but are considered less sensitive indicators of formation water.

Field parameters are examined for stability during individual sampling events, and trends are compared for a sequence of events at the same location. Final field-parameter values associated with the sample at the time of collection are compared with the range observed in background locations for perched-intermediate groundwater and regional groundwater.

Inorganic analytes. Analytical data for common inorganic ions and trace metals are examined for stability and for excursions from background concentrations as follows:

- trends in concentrations of key indicators for the presence of the specific materials used in the screened interval, such as sodium, sulfate, and total organic carbon (TOC);
- trends in relative concentrations of major ions; and
- comparison of concentrations for major ions and selected trace metals with lower and upper concentration ranges for plateau-scale and site-specific background groundwater, as described below.

Concentration trends may be depicted using time-series plots, standard trilinear diagrams, or modified Schoeller plots.

- Trilinear diagrams, also called Piper plots, show major ions as percentages of milliequivalents (meq) in two base triangles. The total cations and the total anions are set equal to 100%, and the data points in the two triangles are projected onto an adjacent grid. The main purpose of the Piper diagram is to show clustering of data points to indicate samples that have similar compositions.
- Schoeller plots are semilogarithmic diagrams originally developed to represent major ion analyses in meq/L and to demonstrate different hydrochemical water types on the same diagram. This type of graphical representation has the advantage that, unlike the trilinear diagrams, actual sample concentrations are displayed and compared. The modified Schoeller plot used for the reliability assessment represents analyses as mg/L or µg/L to avoid the need to make assumptions about ion speciation, which may be particularly problematic for trace metals.

Organic analytes. Detections of volatile and semivolatile organic compounds are compiled for examination of temporal trends and comparison against area-specific chemicals of potential concern.

Field documentation. As appropriate, field notes, groundwater sampling logs, and sample collection logs for each sampling event are also examined for observations about unusual odors, colors, or other indications of impacted water samples.

Plateau-scale background values for assessment. For naturally occurring analytes, statistical summaries of water-quality data for background groundwater locations establish a range of concentrations against which data from the assessed wells are compared for a preliminary assessment step. Lower and upper bounds of plateau-scale background ranges used in the reliability assessments are derived primarily from statistical tables in the most recent New Mexico Environment Department– (NMED-) approved Groundwater Background Investigation Report.

Site-specific background values for assessment. Representativeness may be assessed with greater specificity by comparing analytical concentrations with those in groundwater from other deep wells in sufficiently similar hydrogeologic settings and at which effects from downhole materials or local contaminants are known to be absent or negligible. The approach allows for the inclusion of wells not hydraulically upgradient of the well being assessed. This is similar to the interwell comparison approach described in sections 5.2.4 and 6.3.2 of the EPA guidance document, “Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities” (“Unified Guidance”) (EPA 2009, 110369). The development and use of site-specific background values is illustrated in the Reliability Assessment of Well R-47i (LANL 2011, 201564).

Under some conditions, some or all of the constituents measured in the sample collected at the end of development may also be appropriate to use as the basis of site-specific background values or to augment

the background dataset compiled for the interwell comparison. This is similar to the intrawell comparison approach described in sections 5.2.4 and 6.3.2 of EPA's Unified Guidance (EPA 2009, 110369).

F-5.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

EPA (U.S. Environmental Protection Agency), March 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance," EPA 530-R-09-007, Office of Resource Conservation and Recovery, Washington, D.C. (EPA 2009, 110369)

LANL (Los Alamos National Laboratory), March 2011. "Reliability Assessment for Well R-47i," Los Alamos National Laboratory document LA-UR-11-0933, Los Alamos, New Mexico. (LANL 2011, 201564)

Yeskis, D., and B. Zavala, May 2002. "Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers," a *Ground Water Forum Issue Paper*, EPA 542-S-02-001, Office of Solid Waste and Emergency Response, Washington, D.C. (Yeskis and Zavala 2002, 204429)

Table F-1.0-1
Preliminary Watch List of Deep Monitoring Wells in the 2011 Interim Plan

Location	Monitoring Group	Watch List Rationale	Description of Condition	Action
Limited Water Volume				
MCOI-4	Cr Investigation	Limited water volume	Low volume of water. Field parameters do not stabilize.	Prioritize analytical suites for collection
SCI-1	Cr Investigation	Limited water volume	Low volume of water. Field parameters do not stabilize.	Prioritize analytical suites for collection
R-26 PZ-2	TA-16 260	Limited water volume	Sampled with bailer. Often bails dry. High turbidity.	Prioritize analytical suites for collection
R-40 S1	TA-54	Limited water volume	Low volume of water. Typically yields only 1 CV	Prioritize analytical suites for collection
Water-Quality Issues				
R-61 S1	Cr Investigation	High iron and manganese	Two sample events, concentrations rising.	Track performance and propose action if appropriate
R-61 S2	Cr Investigation	High iron and manganese	Two sample events, concentrations rising.	Track performance and propose action if appropriate
R-25 S1	TA-16 260	Steel corrosion	Westbay screen. Unreliable metal data from steel corrosion.	Do not sample for metals. Final disposition will be proposed in TA-16 monitoring well network evaluation.
R-40 Si (formerly R-40i)	TA-54	High iron, manganese	Residual drilling effects	Track performance and propose action if appropriate
R-54 S1	TA-54	High iron and manganese	Seven sampling events, concentrations high	Track performance and propose action if appropriate

Appendix G

Geologic Cross-Sections

This appendix presents six east-west and three north-south geologic cross-sections that show the relationship of sampling locations in this Interim Facility-Wide Groundwater Monitoring Plan (the Interim Plan) to the hydrogeologic setting of the Los Alamos National Laboratory (the Laboratory) site. Figure G-1 is an overview of the cross-section locations.

The east-west cross-sections follow the stream channel in the following canyons:

- A–A' Water Canyon/Cañon de Valle (Figure G-2)
- B–B' Pajarito Canyon (Figure G-3)
- C–C' Mortandad Canyon (Figure G-4)
- D–D' Sandia Canyon (Figure G-5)
- E–E' Los Alamos Canyon (Figure G-6)
- F–F' Pueblo Canyon (Figure G-7)

The north-south cross-sections are distributed across the Laboratory site and include the following:

- G–G' in the eastern part of the Laboratory (Figure G-8)
- H–H' in the central part of the Laboratory (Figure G-9)
- I–I' in the western part of the Laboratory (Figure G-10)

The cross-sections are based on the three-dimensional geologic framework model (GFM) for the Laboratory that was developed using borehole and outcrop map data. The geologic model used in this report is an updated version of the Laboratory's fiscal year (FY) 2009 three-dimensional geologic framework model (Cole et al. 2010, 106101). The GFM was developed using the geospatial modeling software EarthVision, developed by Dynamic Graphics, Inc., in 2008. The updated GFM model is designated WC11a and incorporates new regional and perched intermediate wells installed since 2009, reinterpretation of stratigraphic contacts in a few existing well logs, and the addition of shallow Technical Area 21 (TA-21) and data that were not incorporated into the FY2009 model. The cross-sections were generated using the updated WC11a model to best represent the current conceptual understanding of the Laboratory's hydrogeology.

No faults are presented on the cross-sections because no known or mapped faults lie within the GFM domain used to develop these geologic cross-sections. Buried, inferred, and possible faults have not yet been incorporated into the WC11a model.

The cross-sections show sampling locations that fall within a 1500-ft buffer on both sides of the respective transect lines. Perched-intermediate and regional monitoring wells are shown as vertical lines, and the locations of well screens are shown as boxes presented to actual scale. Wells located within 500 ft of transects are indicated by solid lines, and wells offset more than 500 ft are demarcated by a dashed pattern. Because of their offset from the transect, some well screens in the outer portions of the buffer zones may not appear to plot within the proper geologic unit because of dipping geologic contacts. The relative positions of alluvial wells, surface-water sampling stations, and springs located along the transects are arrayed horizontally above the cross-sections to show the spatial relationship between the shallow, intermediate, and deep water-quality monitoring network and the GFM. Only sampling locations in the 2011 Interim Plan are shown on the cross-sections.

REFERENCE

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

Cole, G., D. Coblentz, E. Jacobs, D. Koning, D. Broxton, D. Vaniman, F. Goff, and G. WoldeGabriel, April 2010. "The 2009 Three-Dimensional Geologic Models of the Los Alamos National Laboratory Site, Southern Española Basin, and Española Basin," Los Alamos National Laboratory document LA-UR-09-3701, Los Alamos, New Mexico. (Cole et al. 2010, 106101)

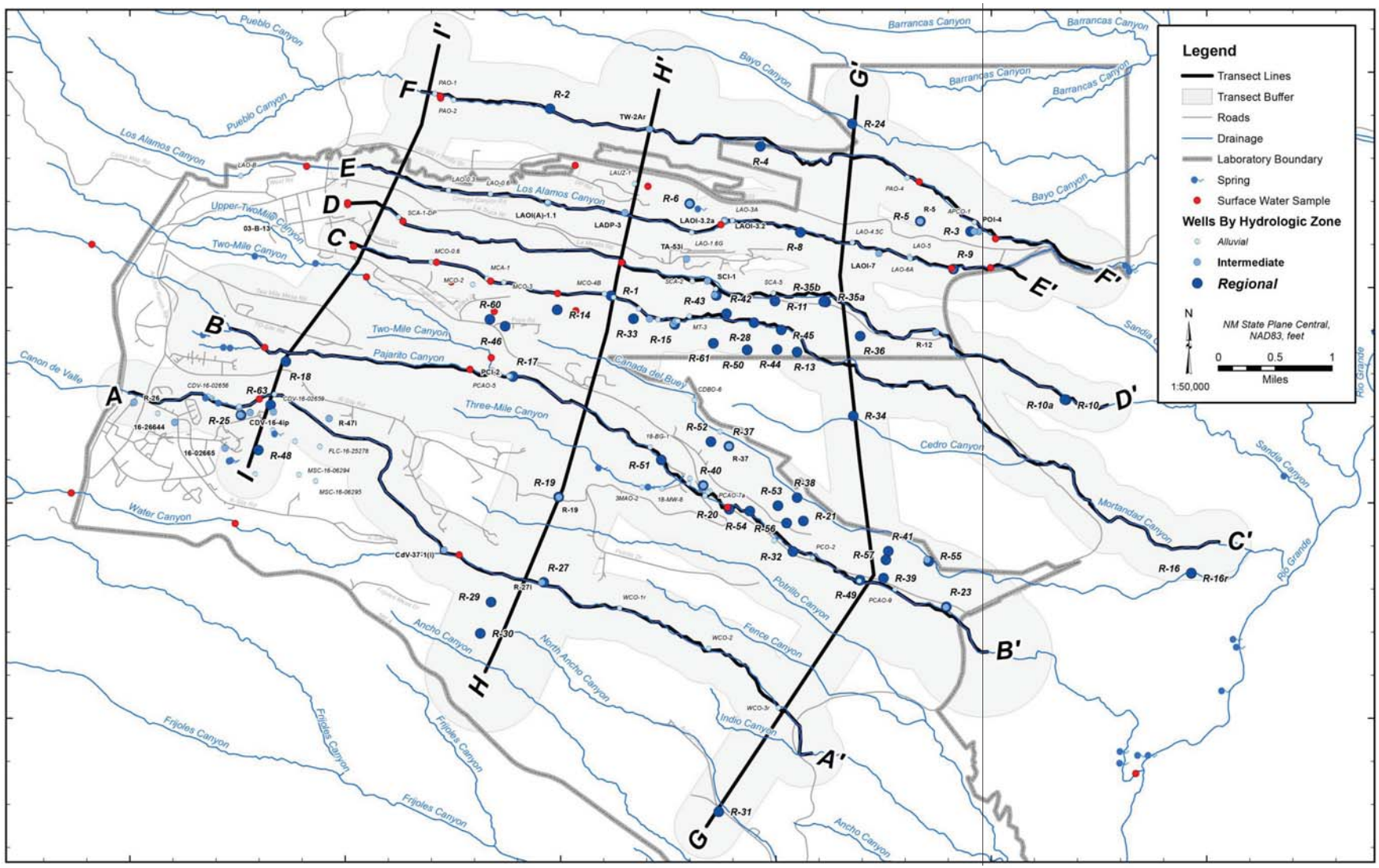


Figure G-1 Transect location map

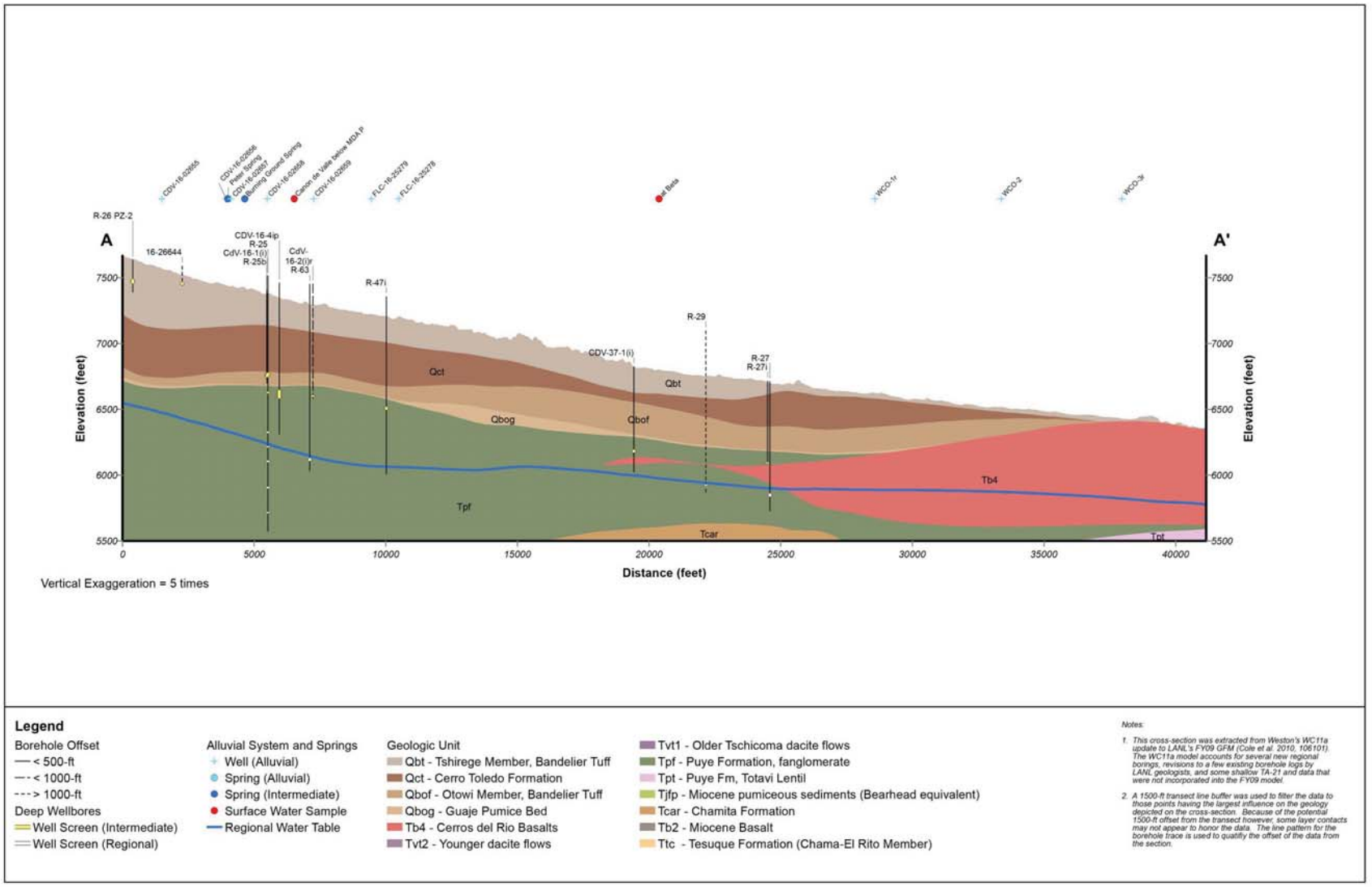


Figure G-2 Cross-section A–A' Water Canyon/Cañon de Valle

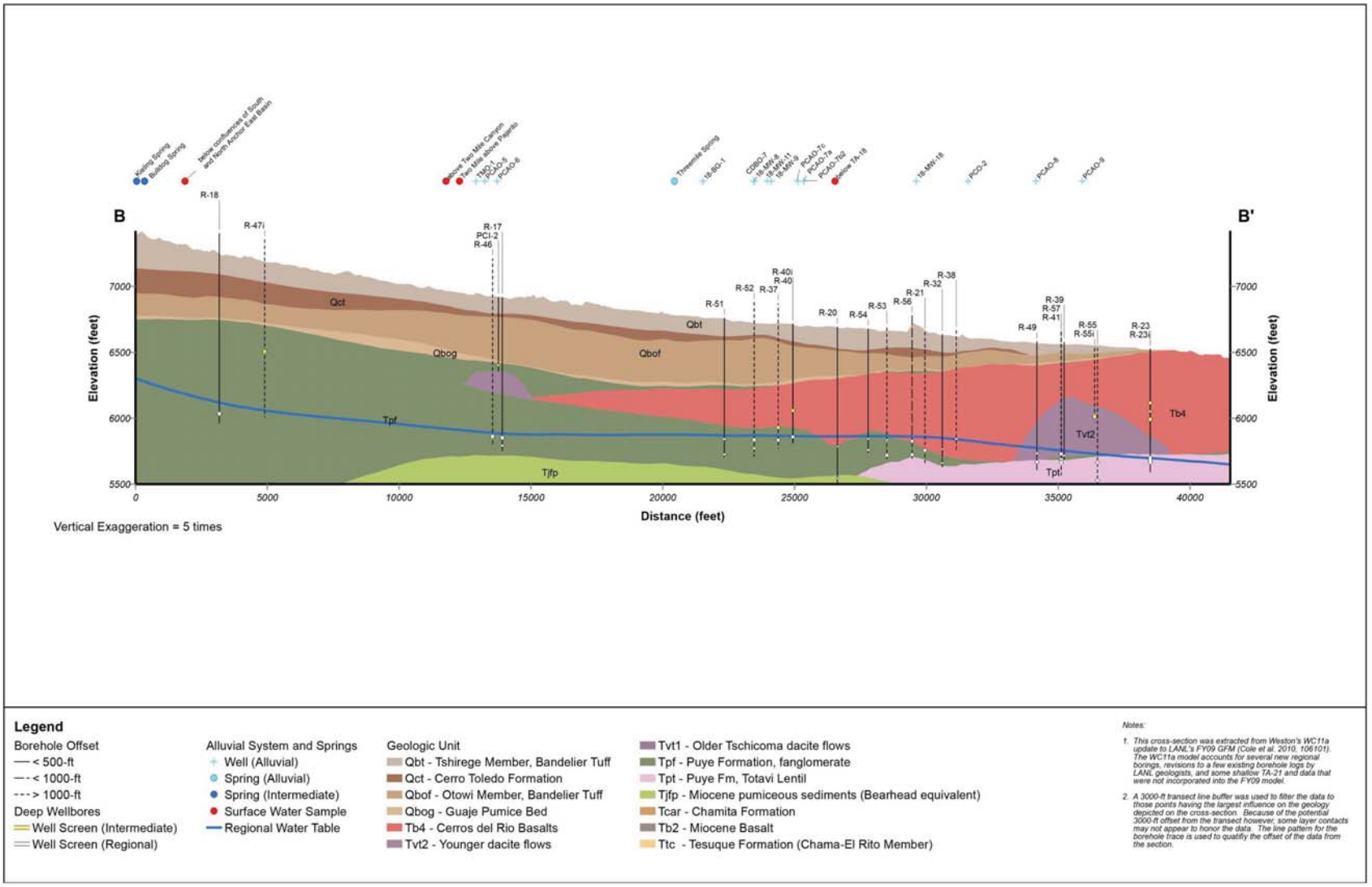
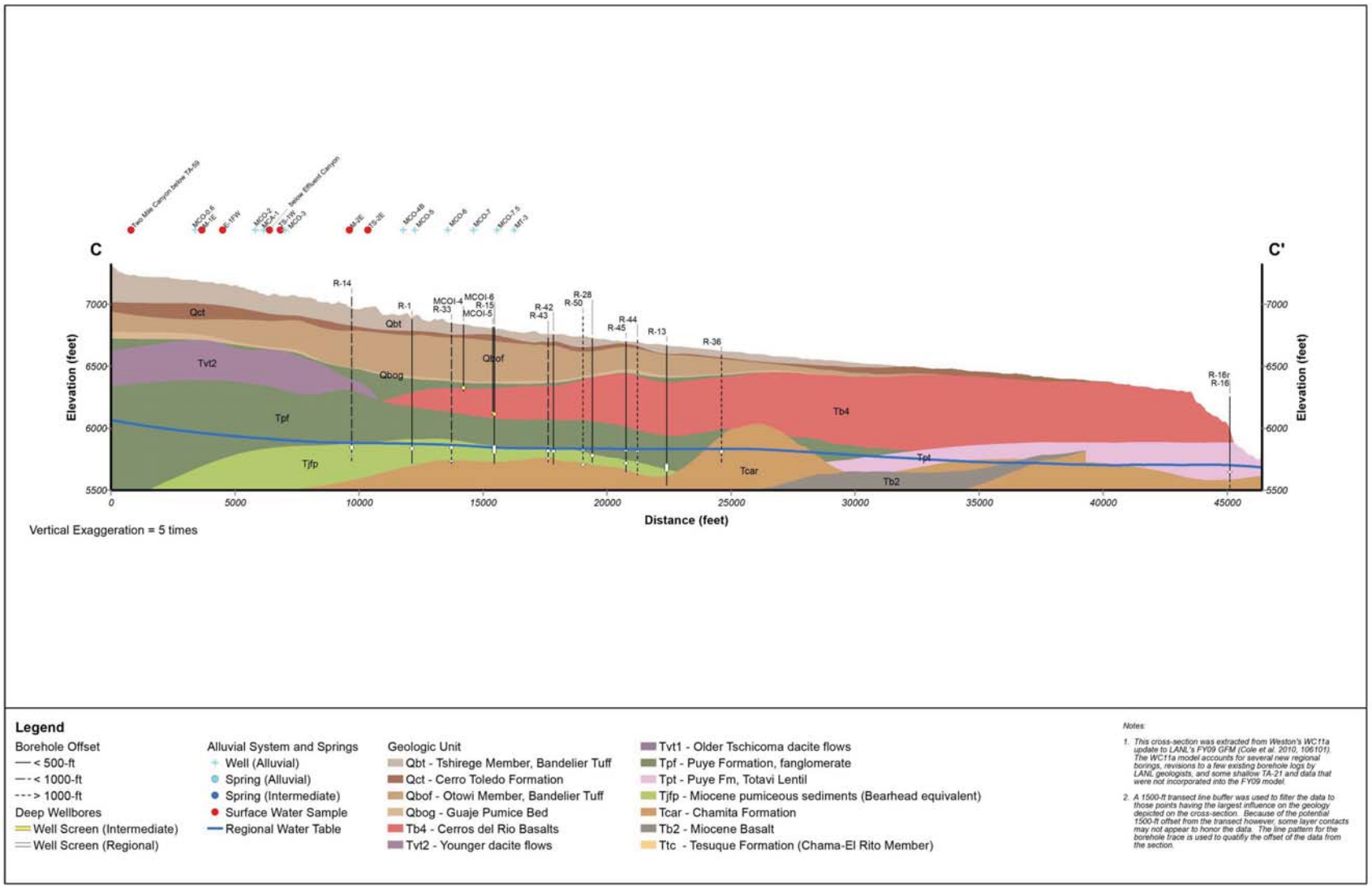


Figure G-3 Cross-section B–B′ Pajarito Canyon



Legend

Borehole Offset
- < 500-ft
- < 1000-ft
- > 1000-ft

Deep Wellbores
- Well Screen (Intermediate)
- Well Screen (Regional)

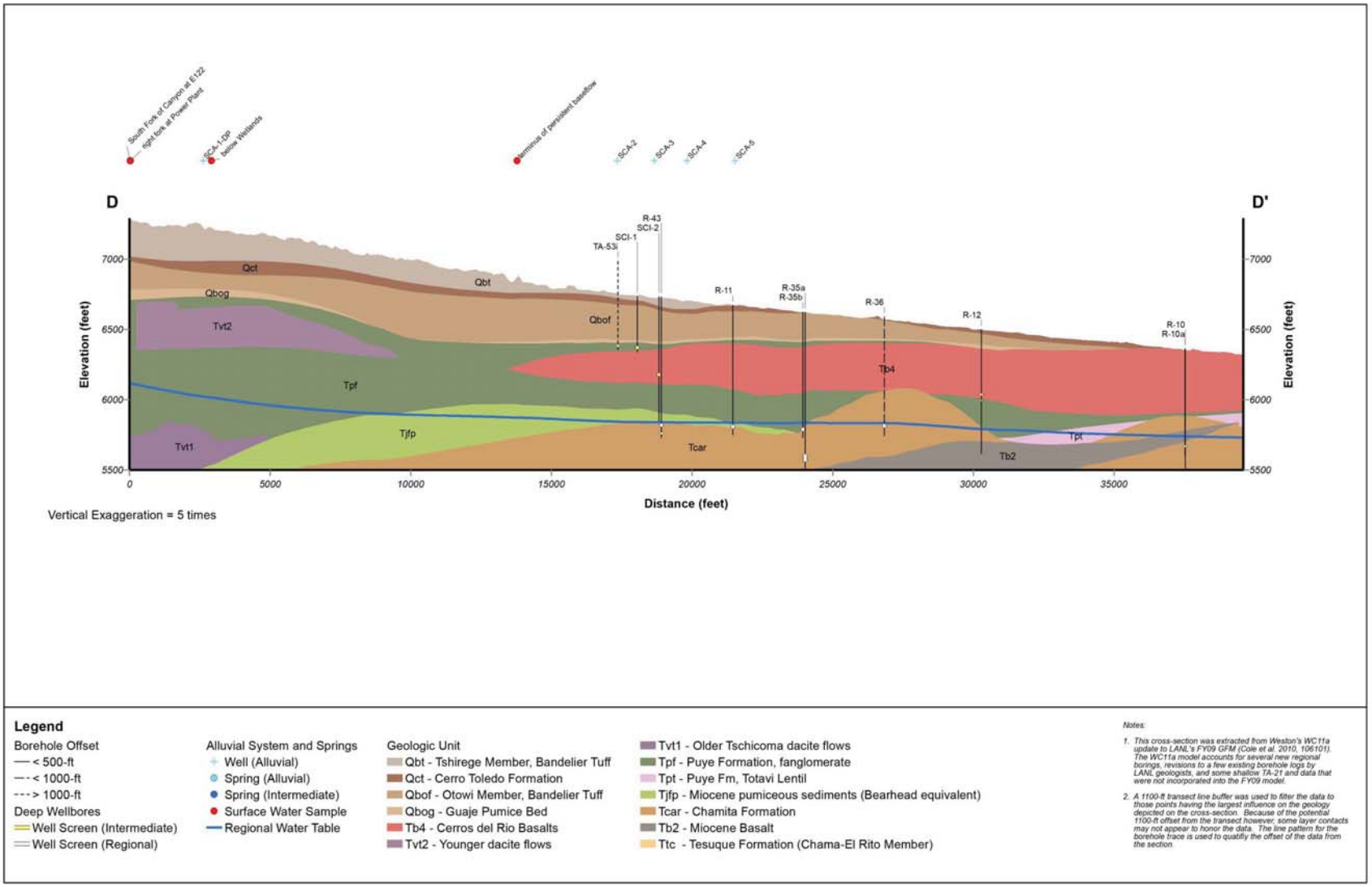
Alluvial System and Springs
- Well (Alluvial)
- Spring (Alluvial)
- Spring (Intermediate)
- Surface Water Sample
- Regional Water Table

Geologic Unit
- Qbt - Tshirege Member, Bandelier Tuff
- Qct - Cerro Toledo Formation
- Qbof - Otowi Member, Bandelier Tuff
- Qbog - Guaje Pumice Bed
- Tb4 - Cerros del Rio Basalts
- Tvt2 - Younger dacite flows
- Tvt1 - Older Tschicoma dacite flows
- Tpf - Puye Formation, fanglomerate
- Tpt - Puye Fm, Totavi Lentil
- Tjfp - Miocene pumiceous sediments (Bearhead equivalent)
- Tcar - Chamita Formation
- Tb2 - Miocene Basalt
- Ttc - Tesuque Formation (Chama-El Rito Member)

Notes:

1. This cross-section was extracted from Weston's WC11a update to LANL's FY09 GFM (Cole et al. 2010, 106101). The WC11a model accounts for several new regional borings, revisions to a few existing borehole logs by LANL geologists, and some shallow TA-21 and data that were not incorporated into the FY09 model.
2. A 1500-ft transect line buffer was used to filter the data to those points having the largest influence on the geology depicted on the cross-section. Because of the potential 1500-ft offset from the transect however, some layer contacts may not appear to honor the data. The line pattern for the borehole trace is used to quatify the offset of the data from the section.

Figure G-4 Cross-section C–C′ Mortandad Canyon



Legend

Borehole Offset
- < 500-ft
- < 1000-ft
- > 1000-ft

Deep Wellbores
- Well Screen (Intermediate)
- Well Screen (Regional)

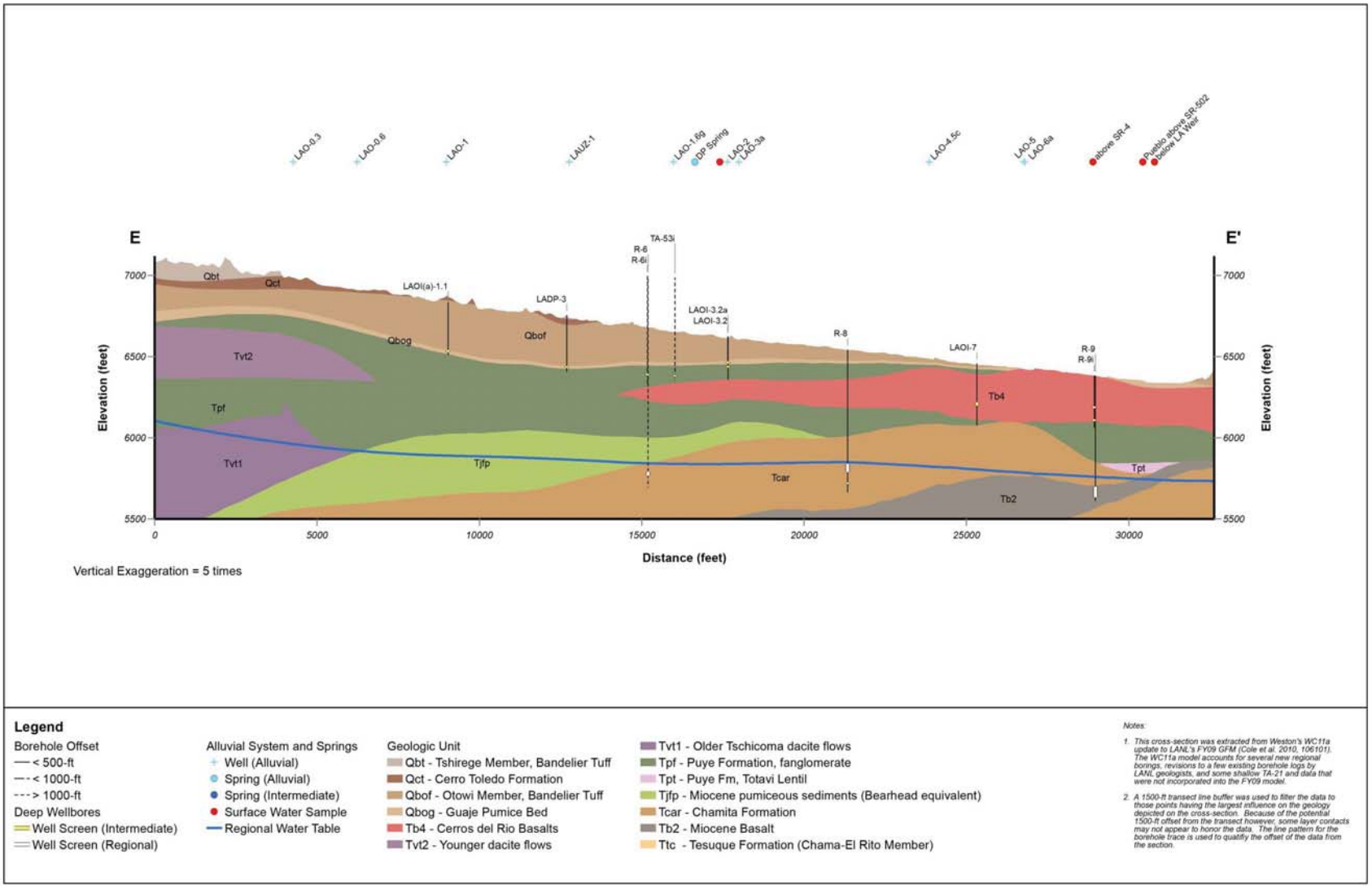
Alluvial System and Springs
- Well (Alluvial)
- Spring (Alluvial)
- Spring (Intermediate)
- Surface Water Sample
- Regional Water Table

Geologic Unit
- Qbt - Tshirege Member, Bandelier Tuff
- Qct - Cerro Toledo Formation
- Qbof - Otowi Member, Bandelier Tuff
- Qbog - Guaje Pumice Bed
- Tb4 - Cerros del Rio Basalts
- Tvt2 - Younger dacite flows
- Tvt1 - Older Tschicoma dacite flows
- Tpf - Puye Formation, fanglomerate
- Tpt - Puye Fm, Totavi Lentil
- Tjfp - Miocene pumiceous sediments (Bearhead equivalent)
- Tcar - Chamita Formation
- Tb2 - Miocene Basalt
- Ttc - Tesuque Formation (Chama-El Rito Member)

Notes:

1. This cross-section was extracted from Weston's WC11a update to LANL's FY09 GFM (Cole et al. 2010, 106101). The WC11a model accounts for several new regional borings, revisions to a few existing borehole logs by LANL geologists, and some shallow TA-21 and data that were not incorporated into the FY09 model.
2. A 1100-ft transect line buffer was used to filter the data to those points having the largest influence on the geology depicted on the cross-section. Because of the potential 1100-ft offset from the transect however, some layer contacts may not appear to honor the data. The line pattern for the borehole trace is used to quatify the offset of the data from the section.

Figure G-5 Cross-section D–D′ Sandia Canyon



Legend

Borehole Offset
- — < 500-ft
- — - < 1000-ft
- - - > 1000-ft

Deep Wellbores
- Well Screen (Intermediate)
- Well Screen (Regional)

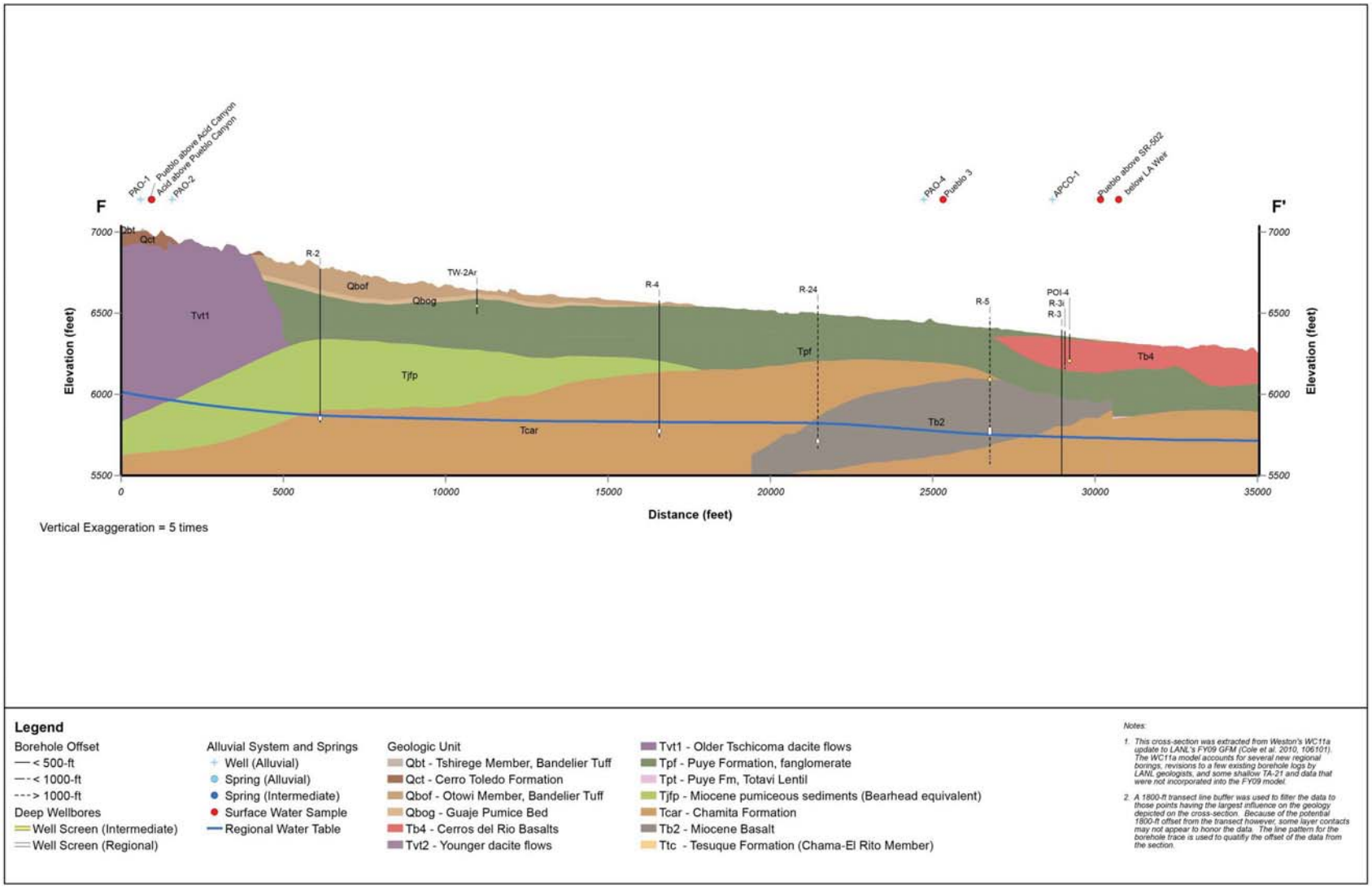
Alluvial System and Springs
- Well (Alluvial)
- Spring (Alluvial)
- Spring (Intermediate)
- Surface Water Sample
- Regional Water Table

Geologic Unit
- Qbt - Tshirege Member, Bandelier Tuff
- Qct - Cerro Toledo Formation
- Qbof - Otowi Member, Bandelier Tuff
- Qbog - Guaje Pumice Bed
- Tb4 - Cerros del Rio Basalts
- Tvt2 - Younger dacite flows
- Tvt1 - Older Tschicoma dacite flows
- Tpf - Puye Formation, fanglomerate
- Tpt - Puye Fm, Totavi Lentil
- Tjfp - Miocene pumiceous sediments (Bearhead equivalent)
- Tcar - Chamita Formation
- Tb2 - Miocene Basalt
- Ttc - Tesuque Formation (Chama-El Rito Member)

Notes:

1. This cross-section was extracted from Weston's WC11a update to LANL's FY09 GFM (Cole et al. 2010, 106101). The WC11a model accounts for several new regional borings, revisions to a few existing borehole logs by LANL geologists, and some shallow TA-21 and data that were not incorporated into the FY09 model.
2. A 1500-ft transect line buffer was used to filter the data to those points having the largest influence on the geology depicted on the cross-section. Because of the potential 1500-ft offset from the transect however, some layer contacts may not appear to honor the data. The line pattern for the borehole trace is used to qualify the offset of the data from the section.

Figure G-6 Cross-section E–E′ Los Alamos Canyon



Legend

Borehole Offset
- < 500-ft
- < 1000-ft
- > 1000-ft

Deep Wellbores
- Well Screen (Intermediate)
- Well Screen (Regional)

Alluvial System and Springs
- Well (Alluvial)
- Spring (Alluvial)
- Spring (Intermediate)
- Surface Water Sample
- Regional Water Table

Geologic Unit
- Qbt - Tshirege Member, Bandelier Tuff
- Qct - Cerro Toledo Formation
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- Qbog - Guaje Pumice Bed
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- Tpf - Puye Formation, fanglomerate
- Tpt - Puye Fm, Totavi Lentil
- Tjfp - Miocene pumiceous sediments (Bearhead equivalent)
- Tcar - Chamita Formation
- Tb2 - Miocene Basalt
- Ttc - Tesuque Formation (Chama-El Rito Member)

Notes:

1. This cross-section was extracted from Weston's WC11a update to LANL's FY09 GFM (Cole et al. 2010, 106101). The WC11a model accounts for several new regional borings, revisions to a few existing borehole logs by LANL geologists, and some shallow TA-21 and data that were not incorporated into the FY09 model.
2. A 1800-ft transect line buffer was used to filter the data to those points having the largest influence on the geology depicted on the cross-section. Because of the potential 1800-ft offset from the transect however, some layer contacts may not appear to honor the data. The line pattern for the borehole trace is used to quatify the offset of the data from the section.

Figure G-7 Cross-section F–F′ Pueblo Canyon

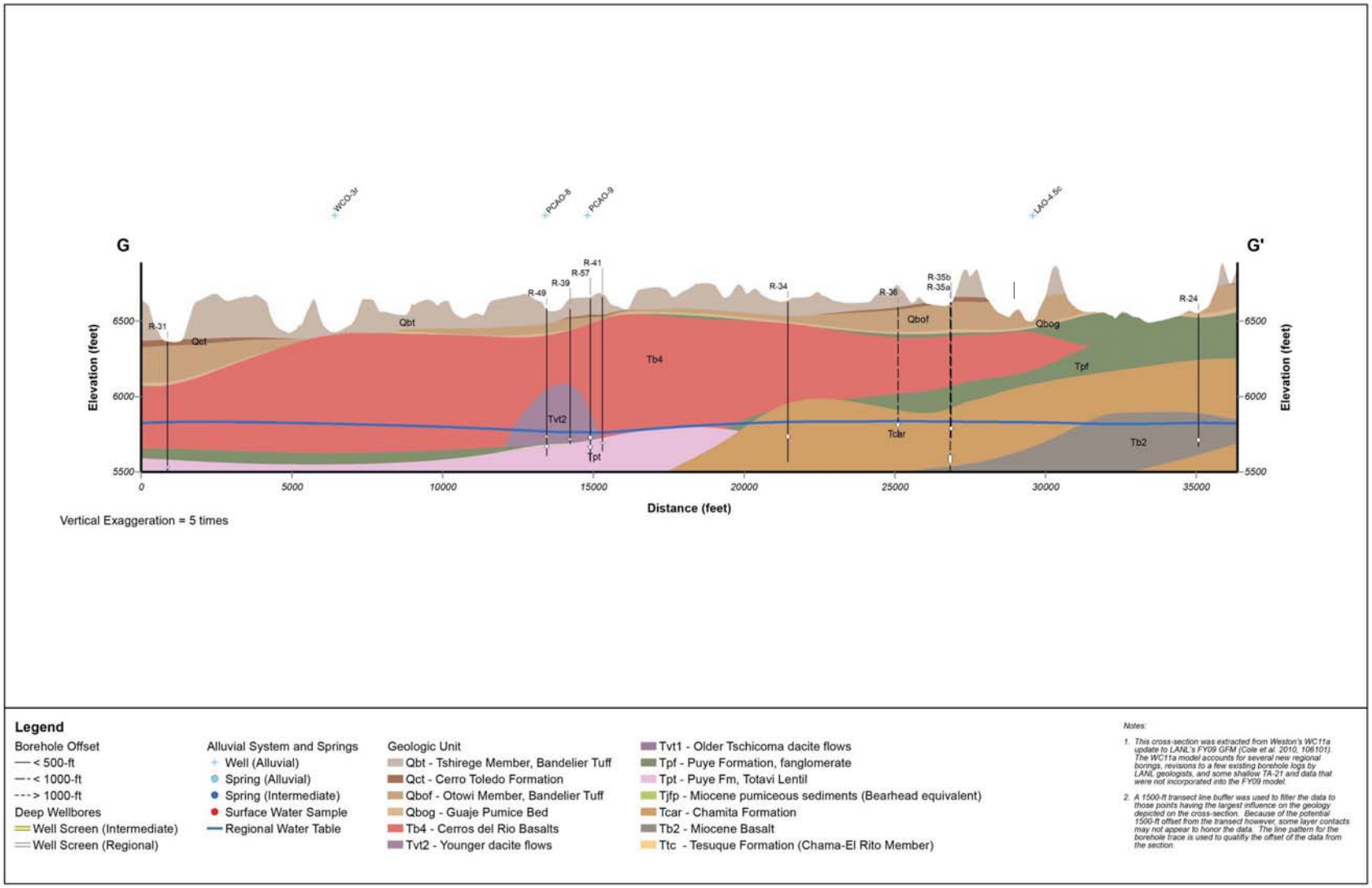


Figure G-8 Cross-section G–G′ in the eastern part of the Laboratory (north-south)

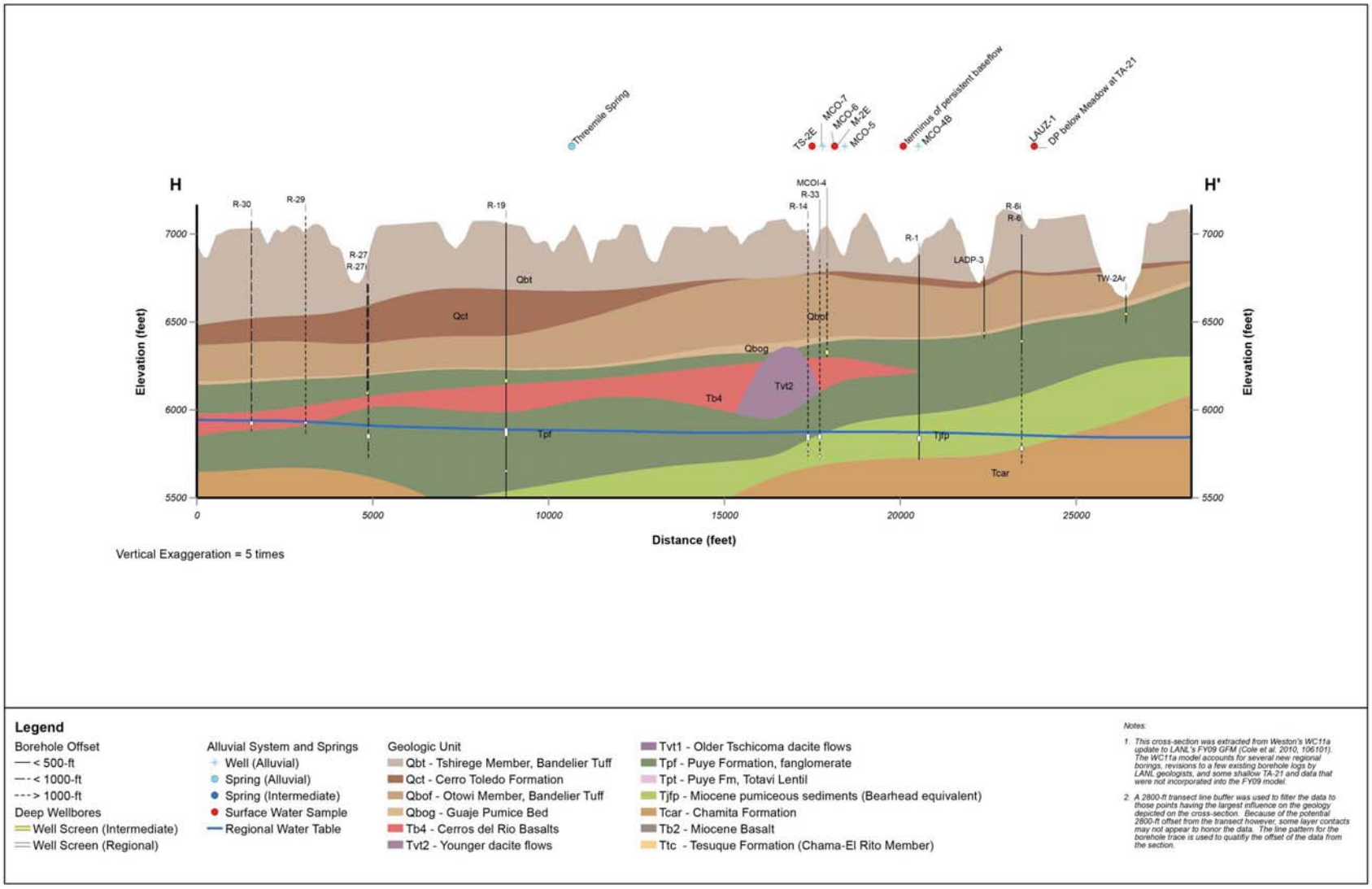
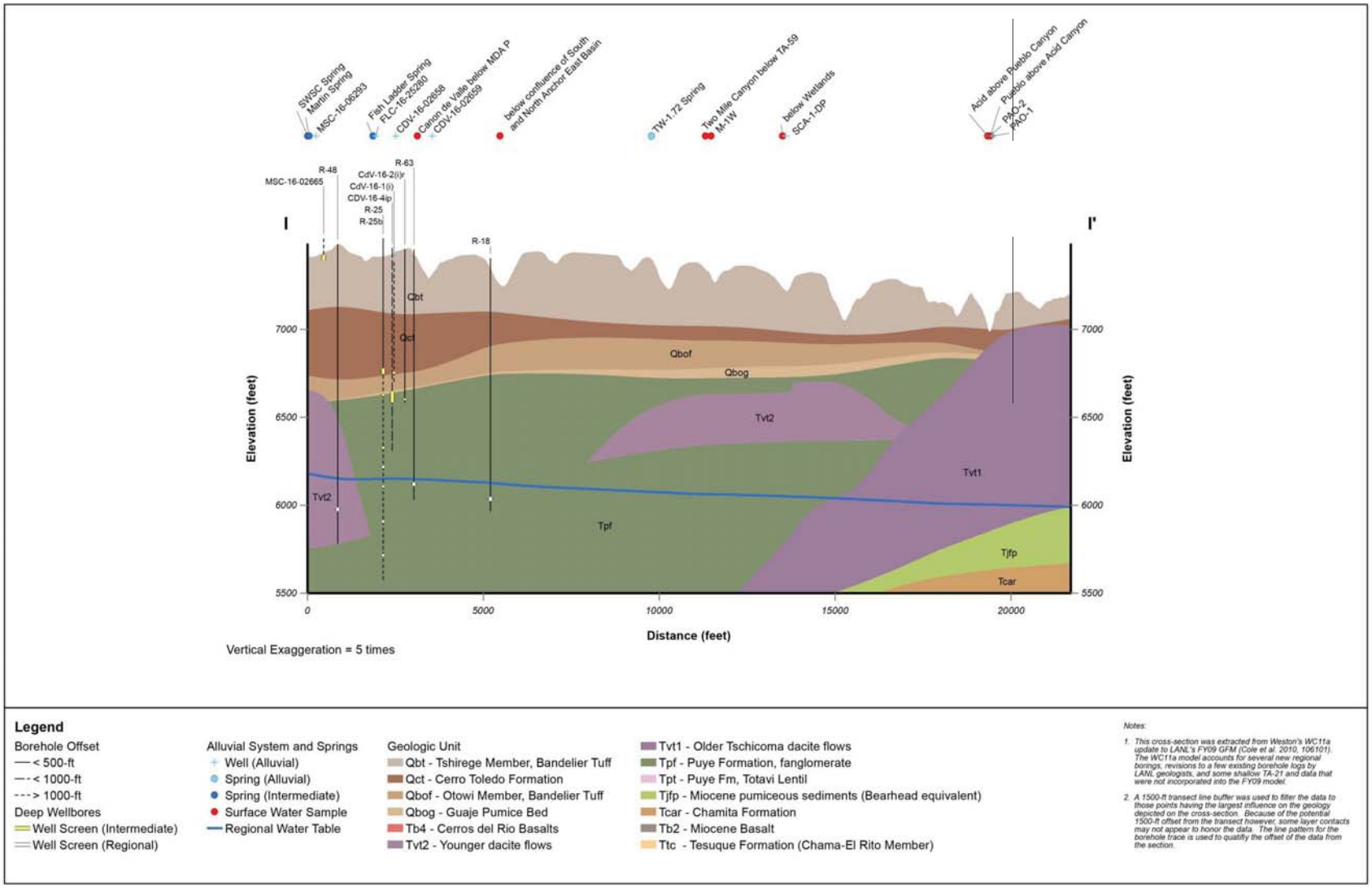


Figure G-9 Cross-section H–H′ in the central part of the Laboratory (north-south)



Legend

Borehole Offset
- < 500-ft
- < 1000-ft
- > 1000-ft

Deep Wellbores
- Well Screen (Intermediate)
- Well Screen (Regional)

Alluvial System and Springs
- Well (Alluvial)
- Spring (Alluvial)
- Spring (Intermediate)
- Surface Water Sample
- Regional Water Table

Geologic Unit
- Qbt - Tshirege Member, Bandelier Tuff
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- Tpt - Puye Fm, Totavi Lentil
- Tjfp - Miocene pumiceous sediments (Bearhead equivalent)
- Tcar - Chamita Formation
- Tb2 - Miocene Basalt
- Ttc - Tesuque Formation (Chama-El Rito Member)

Notes:

1. This cross-section was extracted from Weston's WC11a update to LANL's FY09 GFM (Cole et al. 2010, 106101). The WC11a model accounts for several new regional borings, revisions to a few existing borehole logs by LANL geologists, and some shallow TA-21 and data that were not incorporated into the FY09 model.
2. A 1500-ft transect line buffer was used to filter the data to those points having the largest influence on the geology depicted on the cross-section. Because of the potential 1500-ft offset from the transect however, some layer contacts may not appear to honor the data. The line pattern for the borehole trace is used to quatify the offset of the data from the section.

Figure G-10 Cross-section I–I' in the western part of the Laboratory (north-south)

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Conceptual Models of Vadose Zone Flow and Transport beneath the Pajarito Plateau, Los Alamos, New Mexico

Kay H. Birdsell,* Brent D. Newman, David E. Broxton, and Bruce A. Robinson

ABSTRACT

The Pajarito Plateau in northern New Mexico, on which the Los Alamos National Laboratory is situated, is characterized by a thick vadose zone overlying the regional aquifer of the western Espanola Basin. In this study, conceptual models of vadose zone flow and transport processes are presented and then supported through the interpretation of field data, including synthesis with numerical models. The conceptual models differentiate the rate of percolation by their location and surface hydrologic setting, including wet and dry canyons, and wet, dry, and disturbed mesas. Net infiltration beneath wet canyons is the highest, with rates on the order of a meter per year (100–1000 mm yr^{-1}). Transport to the regional aquifer beneath the wettest canyons is likely on the order of several years to several decades, depending on the thicknesses of the various hydrostratigraphic layers. Perched water is sometimes found beneath wetter canyons and is associated with near-surface alluvial systems and at intermediate depths along low-permeability interfaces such as buried soils or unfractured regions of basalt flows. Percolation through the volcanic tuffs is generally considered to be via matrix-dominated flow, whereas fracture flow may play a key role in contaminant transport through densely welded tuffs or basalt units beneath wet canyons. Infiltration beneath dry canyons and dry mesas is much slower (10 mm yr^{-1} or less), yielding transport times to the aquifer of hundreds to several thousands of years. However, long-term surface disturbances at mesa-top locations may alter infiltration rates such that at a local scale, the infiltration rates temporarily approach those of wetter canyons.

"A CONCEPTUAL MODEL is an evolving hypothesis identifying the important features, processes, and events controlling fluid flow and contaminant transport of consequence at a specific field site in the context of a recognized problem" (National Research Council, 2001). A well-defined site conceptual model is a useful tool for compiling and interpreting site data, focusing characterization work, developing the framework for numerical models, conveying information about the site to interested parties, and determining possible receptors that may be affected by disposal operations at the site. In fact, at a workshop sponsored by the National Research Council (2001), a panel of experts concluded that conceptual model development is the most important step in the overall modeling process used for site evaluation. They also pointed out that appropriate controlling processes can be identified through the development of alternative conceptual models accompanied by the evaluation of these alternatives through comparison with field observations. To best develop and test conceptual models, supporting data should be derived using a number of observational techniques and include a variety of data types.

Los Alamos National Laboratory (the Laboratory or LANL; Fig. 1) has performed research and development in nuclear weapons technologies and other national defense activities for more than 60 yr, beginning with the Manhattan Project in the 1940s. During this time, Laboratory operations have been accompanied by both disposal of and intentional or accidental releases of chemical contaminants into the environment at a variety of sites. Contaminants with possible negative impacts to groundwater include high explosives, radionuclides, chemical solvents, and metals. Today, the Laboratory is responsible for ensuring that none of its past contaminant releases pose a threat to human health now or in the future, and to carry out remediation activities to clean up contaminated sites. One of the key potential risks is groundwater contamination, possibly affecting drinking water quality in municipal or private wells. Contaminants must travel through a thick vadose zone to reach the regional aquifer. Therefore, a well-developed conceptual model describing vadose zone flow and transport beneath the Pajarito Plateau is key to assessing groundwater risk.

The conceptual models for vadose zone flow and transport for the plateau are used to characterize the hydrologic setting located between the ground surface and the regional aquifer and to help determine the fate, transport, and potential future risk of contaminants that have been released into the environment by the Laboratory. Because the Laboratory is large (>100 km^2) and covers complex terrain (Fig. 1), hydrologic conditions vary by location. For this reason, we have chosen to present the conceptual model for the plateau as multiple conceptual models that vary by location to more easily make distinctions between the varying hydrologic conditions. The ideas are based on ongoing observations of hydrologic processes that have been made since the mid 1940s (Griggs, 1964; Abrahams et al., 1961). Refinement of the conceptual models has occurred over the years and especially recently with the interpretation of data collected across the entire thickness of the vadose zone during the drilling of well-characterized regional aquifer wells (Vaniman et al., 2002; Broxton et al., 2002a; Ball et al., 2002; Longmire, 2002).

Our main purpose here is to describe the conceptual models of vadose zone flow and transport for the Pajarito Plateau and then to support these models by providing comprehensive sets of evidence from across the plateau. Toward that purpose, we briefly characterize the

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Abbreviations: ET, evapotranspiration; LANL, Los Alamos National Laboratory; MDA, material disposal area; RLWTF, radioactive liquid-waste treatment facility; TA, technical area.

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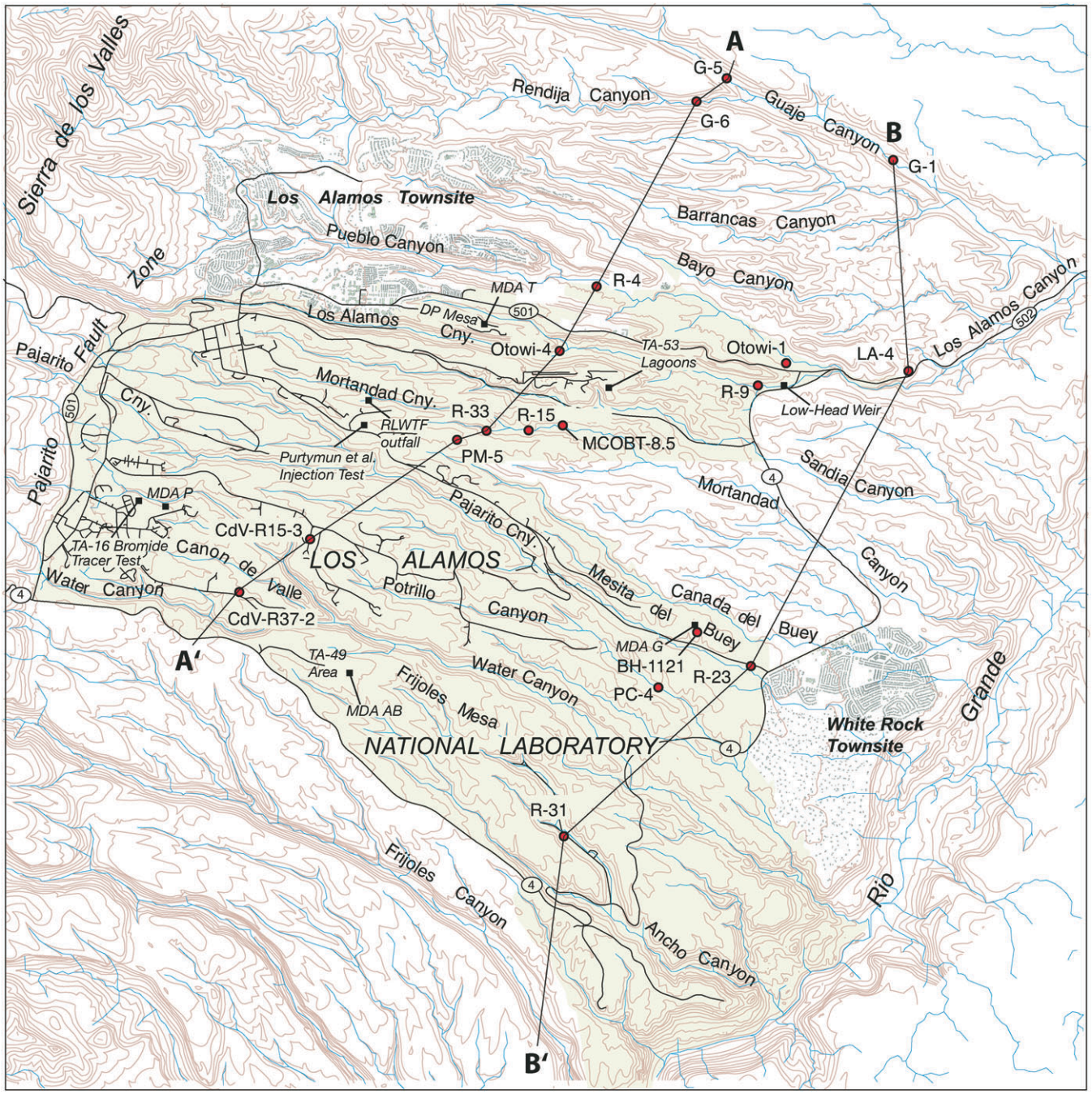

Fig. 1. Site map showing topography, Los Alamos National Laboratory boundary, and locations of cross sections, canyons, mesas, and other example sites discussed in text.

geohydrologic setting of the Pajarito Plateau, describe the hydrologic conceptual models, and then provide supporting evidence. The evidence consists of data sets, observations, and interpretation through numerical simulations. By compiling these sets of evidence into a comprehensive explanation of the processes that occur across the plateau, the credibility of the conceptual models is enhanced.

SITE DESCRIPTION

Topography and Stratigraphy

The Pajarito Plateau is a high, east-tilted tableland eroded into a series of narrow mesas separated by deep canyons. The map view in Fig. 1 and the two cross sections in Fig. 2 illustrate the topographic contrast between the mesa and canyons across the plateau. Mesa-top elevations range from approximately 2400 m on the west to about 1900 m on the east. About 1.22 and 1.61 Ma (Izett and Obradovich, 1994; Spell et al., 1990, 1996) cataclysmic eruptions from calderas in the central part of the Jemez Mountains deposited thick blankets of tuff over the area. Intense heat and hot volcanic gases welded these tuffs into hard, resistant deposits that make up the upper surface of the plateau. Streams flowing eastward across the plateau from the Jemez Mountains to the Rio Grande have cut canyons deep into the tuff, forming the striking mesas and canyons that character-

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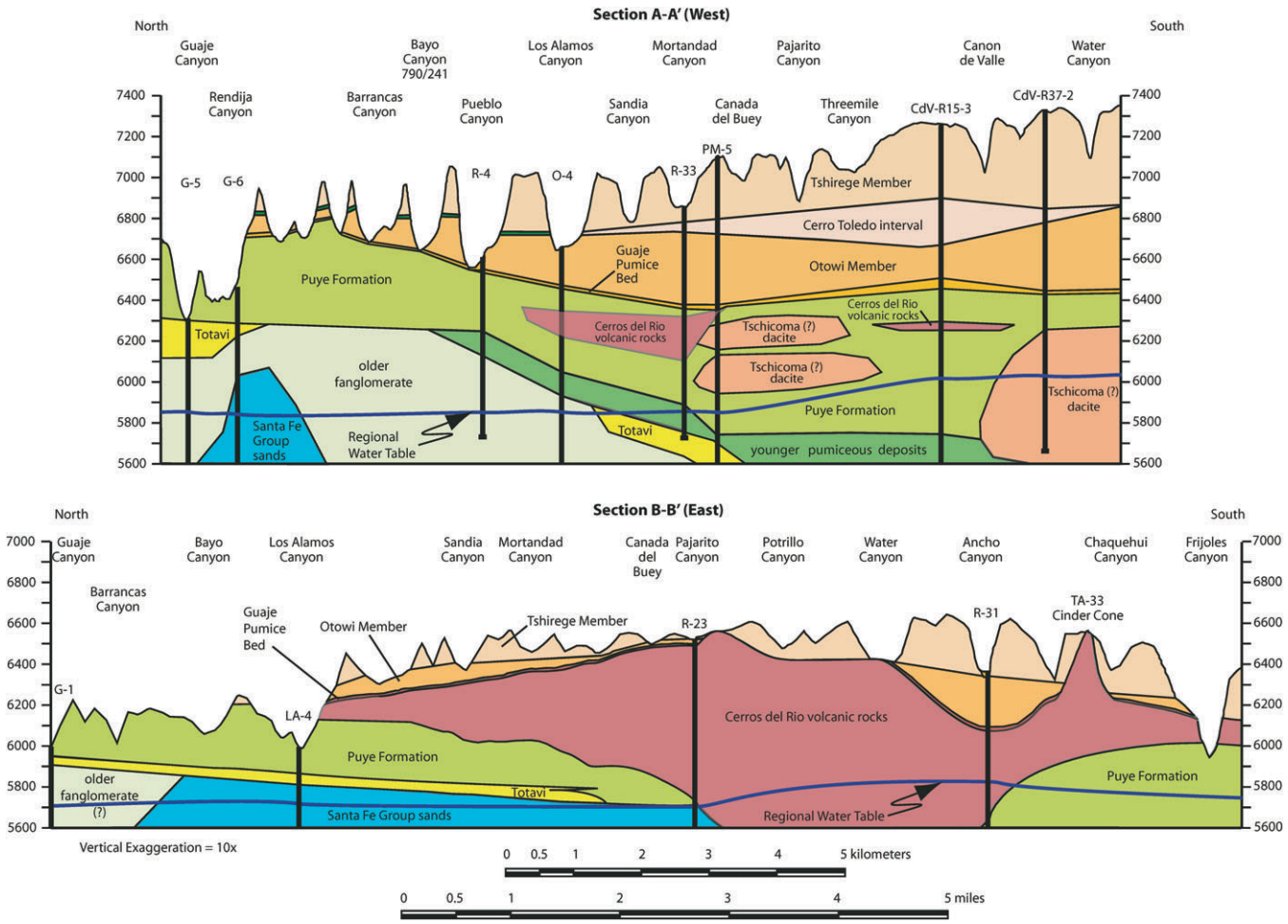

Fig. 2. Cross sections on the Pajarito Plateau, (a) A–A′ on the western end, (b) B–B′ on the eastern end, as indicated in Fig. 1.

ize the landscape. The canyons tend to be deep and narrow in the western part of the plateau where streams are incised in the most strongly welded tuff units (Fig. 2a). The canyons become wider and shallower eastward, where thinner, less-welded tuffs overlie resistant basalt and coarse volcaniclastic deposits (Fig. 2b).

A comprehensive description of the regional hydrogeologic setting of the Pajarito Plateau is given in a companion paper by Broxton and Vaniman (2005). This section provides a brief overview of vadose zone stratigraphy that establishes a geologic framework for discussing conceptual models of contaminant transport. The two cross sections in Fig. 2 illustrate the lateral variations in vadose zone geology. The principal geologic units include, in descending order, the Tshirege and Otowi Members of the Bandelier Tuff, Puye Formation, and Cerros del Rio basalt. Descriptions of alluvial deposits and of other relatively minor bedrock units can be found in Broxton and Vaniman (2005).

The upper part of the vadose zone consists of an eastward-thinning wedge of Bandelier Tuff. The Bandelier Tuff is subdivided into two stratigraphic members, each consisting of a basal pumice fall overlain by a succession of rhyolitic ash-flow tuffs (Bailey et al., 1969). The Tshirege Member, which forms the surface outcrops throughout the plateau, is a compound-cooling unit consisting of alternating layers of nonwelded to moderately welded rhyolitic ash-flow tuffs. Welding within subunits of the Tshirege increases from east to west across the plateau, with some tuffs becoming densely welded near the western mountain front where they are thicker and more proximal to their source area. Within the Tshirege Member, welded tuffs are typically more highly fractured than the nonwelded tuffs that separate them. Fractures originating in welded zones, which include both cooling joints and tectonic fractures, commonly die out in overlying and underlying nonwelded tuffs. The Tshirege Member is up to 170 m thick in the south-central part of the Laboratory (Stimac et al., 2002). The Tsankawi Pumice Bed, a 0.3- to 1.2-m-thick fall deposit, marks the base of the Tshirege Member. The Otowi Member underlies the Tshirege Member and is exposed in lower canyon slopes in the northern part of the plateau. It is a multiple-flow unit made up of a relatively uniform sequence of nonwelded ash-flow tuffs. The maximum thickness of the Otowi Member is 128 m in the southwest part of the Laboratory. The Guaje Pumice Bed is a 2- to 15-m-thick stratified fall deposit at the base of the Otowi Member. The nonwelded portions of the Tshirege Member and all of the tuffs within the Otowi Member lack the pervasive cooling joints that characterize the welded portions of the Tshirege Member. Although high-

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angle fractures tend to be rare in nonwelded tuffs, a few were documented by borehole videos and core samples (Broxton et al., 2002a).

The Puye Formation commonly underlies the Guaje Pumice Bed and consists of highly stratified, poorly cemented gravels and conglomerates consisting of subrounded dacitic and andesitic lava clasts in a poorly sorted, sandy to silty matrix. Debris flows, ash beds, pumiceous volcaniclastic sediments, and beds of fluvial sand and silt are interbedded with the gravels and conglomerates. Basaltic ash and lacustrine deposits are present in the upper part of the Puye Formation on the eastern side of the plateau. The formation reaches a maximum thickness of >335 m beneath the western part of the plateau but thins to 15 m in the northeast part of the plateau near the Rio Grande. Ancestral Rio Grande deposits called the Totavi Lentil are interbedded with the lower part of the Puye Formation on the east side of the plateau. These riverine deposits contain subangular dacitic detritus derived from volcanic sources to the west and rounded cobbles and boulders of quartzite, granite, and pegmatite derived from Precambrian highlands to the north and east. In some parts of the plateau, a distinctive pumice-rich rock unit beneath the Puye Formation, labeled younger pumiceous deposits in Fig. 2, overlies the Totavi Lentil. Borehole geophysical logs show that these pumiceous deposits typically have a higher porosity and lower bulk density than overlying fanglomerates. Thick deposits of older fanglomerate occur beneath the pumiceous deposits. These deposits, which are similar to but predate rocks normally assigned to the Puye Formation, are informally called older fanglomerate (Broxton and Vaniman, 2005).

Basaltic rocks of the Cerros del Rio volcanic field are intercalated with the upper part of the Puye Formation in the central and eastern part of the Pajarito Plateau. These basalts occur as numerous lava flows separated by interflow breccia, scoria, ash, and fluvial deposits. The lava flows typically contain highly brecciated tops and bottoms that provide zones of highly interconnected porosity over distances of tens to hundreds of meters. In some areas, the permeability of these zones is reduced by clays deposited in the pores of the breccias. Studies of basalts on the Columbia River Plateau found that, under saturated conditions, groundwater is most readily transmitted through the breccia zones at the tops and bottoms of basalt flows (Whiteman et al., 1994). The interiors of the flows are made up of dense, impermeable basalt. Fractures provide the primary source of permeability for the transport of liquid water and vapor in the dense flow interiors. Fracture patterns vary vertically within a flow unit with vertical columnar joints commonly occurring in the lower part of flow and irregular, complexly fanning fractures occurring in the upper part. Horizontal platy joints are also present near the base of some flow units.

Sources of Contamination

Many of the processes used to carry out the Laboratory's past and present missions use hazardous and radioactive materials. Throughout the Laboratory's history, some of these materials have been disposed of on Laboratory property or released into the environment. Since World War II, environmental legislation has evolved to become increasingly protective, and the Laboratory's operations have evolved with the legislation.

The Laboratory's Environmental Restoration Program is actively working to identify and restore contaminated sites. Original contaminant sources include, for example, septic tanks and lines, wastewater outfalls, material disposal areas (MDAs), firing ranges, and surface spills. In this paper, the focus is largely on contaminants associated with wastewater outfalls and MDAs. Wastewater from Laboratory technical areas (TAs) was historically drained through pipes and allowed to discharge into nearby canyons or mesa top lagoons. The outfalls are those areas below these effluent pipes and are a source of potential contamination for local canyons. Material disposal areas are generally mesa-top sites where waste was historically placed in near-surface pits or shafts. A variety of contaminants were disposed of in MDAs, including solid and liquid radioactive wastes, heavy metals, and organic wastes. These sites were intended to be permanent disposal facilities, and assessments are underway to determine whether any of these facilities pose long-term risks.

Climate and Near-Surface Hydrology

Arid and semiarid regions have common characteristics, such as thick vadose zones, infiltration that is often focused in topographic lows or beneath surface water bodies, and average annual potential evapotranspiration (ET) rates that far exceed precipitation rates. Under these conditions, infiltration events that propagate beneath the root zone are sporadic and occur only when the short-term infiltration rate exceeds the ET rate, such as during snowmelt or after large rainstorms. Consequently, the rates for deeper infiltration are difficult to quantify through traditional water balance studies because this component of the water balance can be orders of magnitude less than the other components (de Vries and Simmers, 2002; Scanlon et al., 2002; Sophocleous, 2002; Sanford, 2002; Flint et al., 2002). These generalities apply to the Pajarito Plateau, which has a semiarid climate and a vadose zone that ranges in thickness between approximately 100 and 400 m (Fig. 2).

Average annual precipitation across the Pajarito Plateau ranges from >0.5 m along the western boundary near the Jemez Mountains to <0.36 m to the east at the Rio Grande (Bowen, 1990). Most precipitation occurs either as winter and spring snow or as summer "monsoonal" rains. As a result, infiltration occurs episodically during spring snowmelts or the intense summer thunderstorm season and is often focused by runoff into the canyons.

Surface water flow in the canyons is generally ephemeral or intermittent, although a few canyons have short stretches with perennial surface flow. Anthropogenic discharges from water treatment outfalls can be a significant source of water in some canyons. Infiltration of

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these surface sources form shallow perched alluvial groundwater systems in many of the canyons (Stone et al., 2001). These alluvial groundwaters are not sufficiently extensive for domestic use, but nevertheless, they are an important component of the subsurface hydrologic system. Because of their close association with surface waters, these shallow perched systems generally show the earliest and most pronounced impacts of laboratory contamination of all groundwaters. They also serve as lateral pathways for the down-canyon migration of contaminants and provide storage for groundwater infiltrating to deeper parts of the vadose zone.

VADOSE ZONE CONCEPTUAL MODELS OF THE PAJARITO PLATEAU

The conceptual models for vadose zone flow and transport beneath the Pajarito Plateau identify wet canyons as being hydrologically different from dry canyons and dry mesas (LANL, 1998a; Rogers et al., 1996; Neeper and Gilkeson, 1996; Turin and Rosenberg, 1996; Birdsell et al., 2000). Table 1 shows a compilation of infiltration rates estimated using a variety of interpretive techniques for locations across the plateau. These data begin to illustrate the difference in infiltration rate depending on location (i.e., mesa or canyon). In addition, Kwicklis et al. (2005) developed a map of average annual "net infiltration" in the Los Alamos area, on the basis of physical features such as elevation, vegetation, surface geology, and stream flow. They defined net infiltration as that water remaining after accounting for evapotranspiration in the shallow subsurface (i.e., the root zone). The highest net infiltration rates occur in the larger canyon systems, especially those that head in the mountains, with magnitudes of up to a few hundred millimeters per year caused by channelized runoff. In contrast, much lower net infiltration rates occur across mesas and in the smaller canyons that head on the plateau. These geographic variations in infiltration rates are key components of the site conceptual models.

In the subsections that follow, conceptual models are presented for (i) wet canyons, (ii) dry canyons, (iii) dry and disturbed mesas, and (iv) mountain-front mesas. First, however, a comparison of porous matrix flow and transport with more rapid fracture flow and transport is presented because this topic is relevant to the four location-specific conceptual models. Then, the location-specific conceptual models are given. Each conceptual model includes field observations and interpretations that support the application of these models to the Pajarito Plateau. Finally, a contrast between subsurface observations at mesa top and canyon sites is presented that further supports the distinction between canyons and mesas.

Along with each conceptual model description, field observations and/or interpretation are presented as evidence to support the model. Many of these cases are interpreted through numerical simulation using the Finite Element Heat and Mass (FEHM) code (Zyvoloski et al., 1997). This code has been used extensively to model unsaturated and saturated flow and contaminant transport in porous and fractured media (Robinson and Bussod, 2000; Robinson et al., 2005a; Keating et al., 2005). The numerical studies that follow employ the water characteristic-curve formulation of van Genuchten (1980) because that formulation was used to fit the available site data measured on core samples.

Matrix vs. Fracture Flow and Transport

Vadose zone flow through nonwelded to moderately welded units of the Bandelier Tuff is thought to occur through the porous matrix. Within densely welded tuffs and dense basalts, the vadose zone flow regime may be dominated by fracture flow. In contrast, matrix flow may occur within the more porous, brecciated zones in the basalt. The following evidence supports these hypotheses.

Matrix Flow in Nonwelded and Moderately Welded Tuffs

Across most of the plateau, the uppermost vadose zone consists of nonwelded to moderately welded Tshirege

Table 1. Estimated net infiltration rates across the Pajarito Plateau. (Negative infiltration rate implies upward flow.)

Location	Classification	Estimated net infiltration rate	Technique used for estimation	Reference
		mm yr^{-1}		
Los Alamos Canyon	wet canyon (natural with previous discharges)	213–1076	water balance study	Gray, 1997
Mortandad Canyon	wet canyon (anthropogenic recharge)	0.13, 0.25, and 1.5	analyzed vertical head gradients	Rogers et al., 1996
		transient, decreasing from 2400 to 150	depths of subsurface tritium peaks	Kwicklis et al., 2005
Cañada del Buey	dry canyon	−0.22 and 2.0	analyzed vertical head gradients	Rogers et al., 1996
Potrillo Canyon	dry canyon	0.12	analyzed vertical head gradients	Rogers et al., 1996
Mesita del Buey	dry mesa	6.9,-7.0, 0.07, −0.06, and 0.26	analyzed vertical head gradients	Rogers et al., 1996
		0.2 and 3.3	chloride mass-balance approach	Bergfeld and Newman, 2001
		1–5	moisture matching	Birdsell et al., 2000
MDA G on Mesita del Buey	disturbed dry mesa site with waste disposal	9	chloride mass-balance approach	Newman et al., 2005
Frijoles Mesa, 210-m hole near MDA AB	dry mesa	0.3–2.0	chloride mass-balance approach	Newman et al., 1997
MDA AB on Frijoles Mesa	disturbed mesa site with asphalt cover	300	water balance based on subsurface moisture	Rofer et al., 1999
MDA P	disturbed mesa site with waste disposal	95	analyzed vertical head gradients	Rogers et al., 1996
TA-53 Lagoons on Mesita de los Alamos	disturbed mesa site with liquid waste disposal	230	analyzed vertical head gradients	Rogers et al., 1996

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Member ash-flow tuffs and nonwelded Otowi Member ash-flow tuffs (Fig. 2). Unsaturated flow and transport through these tuffs is assumed to occur predominantly through the porous matrix. These units have typical porosities of 40 to 50%, moderate saturated hydraulic conductivities (e.g., 10^{-4} cm s^{-1}), and water contents that are generally far below saturated conditions (2–25%) (Abrahams et al., 1961; Rogers et al., 1996; Birdsell et al., 2000; Springer, 2005). Although these tuffs are often fractured, water flow is expected to be matrix dominated unless conditions approach full saturation (Soll and Birdsell, 1998), such as beneath liquid-waste disposal pits or outfalls. In contrast, under background conditions where the fractured tuffs form the dry finger mesas on the eastern side of the plateau, air is thought to circulate freely through the fractures resulting in evaporation of pore water (Neeper, 2002; Stauffer et al., 2005).

Field observations and analyses support the matrix-flow hypothesis. Robinson et al. (2005a) modeled a vadose zone, wellbore injection test that was performed on a mesa north of Pajarito Canyon in moderately welded tuffs of the Tshirege Member (Purtymun et al., 1989) (Fig. 1). Through a numerical analysis incorporating different conceptual models of fracture flow behavior, they showed that the observed moisture distribution was consistent with a continuum model without fractures. The agreement between the numerical model and the observations was acceptable, both qualitatively and quantitatively. Dual-permeability and discrete-fracture conceptual models could also reproduce the observations, but only by muting the effect of the fractures. They estimated an equivalent infiltration rate during the injection phase of about 2.7×10^4 mm yr^{-1}, which is greater than most estimates of infiltration across the plateau (Kwicklis et al., 2005). They concluded that if matrix-dominated flow is observed at the high effective infiltration rate of this injection test, then it is even more likely to be the case under natural conditions on the plateau.

Evidence of fracture transport in a nonwelded to partially welded tuff exists beneath an historic liquid-waste disposal facility at MDA T on DP Mesa (Fig. 1). The disposal facility consisted of four adsorption beds dug 1.2 m deep into the mesa top and filled with cobbles and gravel. The beds received liquid wastes primarily between 1945 and 1950, with occasional disposals through 1967. Subsurface contaminant data from 1960, 1978, and 1996 collected beneath the adsorption beds show evidence of contaminant transport associated with fractures, while subsurface data collected in boreholes adjacent to the beds shows none (Nyhan et al., 1984; LANL, 2004b). However, the 1978 study, which targeted data collection in fractures beneath the adsorption beds, concluded that most fractures (8 of 10) did not enhance contaminant transport. The two observations of transport in fractures in that investigation occurred at similar depths (<7 m below the ground surface) to those cited in the 1960 study, even though the four investigative boreholes drilled in 1978 extended deeper (to 30 m) (Nyhan et al., 1984). Although the 1996 data show contamination in a 20-m-deep fracture, the general assumption is that fracture transport occurred while the beds actively received liquid waste and that the contaminants associated with the fractures are remnants of previous fracture flow episodes (LANL, 2004b). These data support the idea that some fractures in the nonwelded to moderately welded tuff will flow when the matrix is saturated.

Fracture Flow in Densely Welded Tuffs

In areas near the mountain front on the western edge of the plateau, the majority of tuffs making up the Tshirege Member are moderately to densely welded. These strongly welded tuffs are characterized by porosities ranging from 17 to 40%, unsaturated volumetric water contents from 3 to 12%, and low saturated hydraulic conductivities (e.g., 10^{-6} to 10^{-9} cm s^{-1}) (LANL, 2003b). These tuffs are also more fractured in the vicinity of the Pajarito fault zone along the western mountain front and can support fracture flow and transport when sufficient water is present. A bromide tracer test and high explosives contaminant distributions suggest that both fracture-dominated and matrix-dominated flow occur near the mountain front, depending on the degree of welding of the tuff (LANL, 1998b; LANL, 2003b).

Fracture Flow in Dense Basalts; Matrix Flow in Brecciated Basalts

Like the densely welded tuff units, fracture flow is hypothesized to occur through the dense, low-porosity flow interiors of the Cerros del Rio basalt. Evidence for fracture flow in basalt comes from a field experiment on the upstream side of a low-head weir located in lower Los Alamos Canyon (Fig. 1; Stone and Newell, 2002; Stone et al., 2004). The objective of the experiment was to monitor water flow and bromide tracer transport through fractured basalt under transient, unsaturated and periodically ponded conditions using three observation boreholes. Following three ponding events, the bromide tracer advanced quickly downward to a depth of several tens of meters within 10 to 14 d after the first ponding event (Stone et al., 2004). The rapid advance of bromide indicates that fracture flow and transport occur through basalts under ponded conditions. Model calibration of bromide transport yields an effective fracture porosity in the range of 10^{-2} to 10^{-3} and saturated hydraulic conductivity in the range of 10^{-2} to 10^{-3} cm s^{-1} (Stauffer and Stone, 2005; Stone et al., 2004). The data and simulations both indicate that the bromide continued to advance through the fractured system even after the ponds had drained.

Perched groundwater has been identified in a number of boreholes on the plateau (Robinson et al., 2005b; Broxton and Vaniman, 2005) and is often located beneath the larger wet canyons and within the more porous, breccia zones in basalt. An example of perched water in basalt occurs at Well R-9 in lower Los Alamos Canyon (Fig. 1), where groundwater was found from 55 to 70 m deep in the middle of the 86-m sequence of stacked lava flows (Broxton et al., 2001). The groundwater is located within a breccia zone and an underlying highly fractured basalt flow. The base of the perched zone occurs where the highly fractured basalt grades

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downward into a massive flow interior with few fractures. Tritium concentrations in the perched water reveal that it is no more than a few decades old (Broxton et al., 2001).

It is apparent that groundwater flow in basalts occurs both as porous flow through breccia zones and as fracture flow where dense flow interiors are broken by interconnected fracture systems. Flow direction is likely controlled by the geometry of the interflow breccias and by fracture orientation, both of which are heterogeneous. Perched zones may be stagnant or may flow laterally. For contaminant transport calculations, water flow through the basalt is commonly purposely predicted to be via fast-flowing vertical fractures because so little is known about the true nature of flow through the basalt units (Birdsell et al., 2000).

Wet Canyons

Wet Canyon Conceptual Model

Figure 3 is a photograph of Cañon de Valle, a wet canyon on the western boundary of the plateau. Several features characterize the large, deep naturally wet canyons on the Pajarito Plateau, such as Los Alamos and Pueblo Canyons (Fig. 1 and 2). Their headwaters are in the mountains, they have large catchment areas (13–26 km^2), surface flow occurs frequently, and perched alluvial groundwaters exist beneath the canyon floors. In some cases, discharges from anthropogenic sources such as outfalls and wastewater treatment plants increase flows sufficiently that smaller dry canyons that head on the plateau act like wet canyons (e.g., Mortandad Canyon, Fig. 1 and 2). Often, deeper, intermediate perched zones are associated with wet canyons. The geometry of wet canyons promotes hydrologic conditions that yield relatively fast, unsaturated flow and transport as described in the paragraphs that follow.

Wet canyons collect large runoff volumes, either through channeling of mountain-front precipitation from large contributing areas or through wastewater discharges. This runoff, in turn, creates surface water flow along canyon bottoms, which subsequently infiltrates to form perched alluvial water bodies. Lateral flow and transport through surface water and in the alluvial systems are rapid compared with other subsurface hydrologic processes on the plateau. Rates of lateral transport are most rapid during surface flow events, which occur more frequently in the larger wet watersheds than in other areas of the plateau. Sorbing species transport slowly in alluvial waters and more commonly migrate down the canyon floor by sediment transport (LANL, 2004a; Lopes and Dionne, 1998; Solomons and Forstner, 1984; Watters et al., 1983). Since some of the wet canyons received liquid-waste discharges from outfalls, the alluvial systems then act as line sources for both water and contaminants to deeper parts of the vadose zone beneath the canyon floor. The resulting net percolation rates beneath the perched alluvial systems to the underlying unsaturated zone are expected to be among the highest across the plateau, approaching a meter per year (100–1000 mm yr^{-1}) (Gray, 1997; Kwicklis et al., 2005; Table 1).



Fig. 3. Photograph of Cañon de Valle, a wet canyon on the western edge of the plateau.

From west to east, the vadose zone becomes progressively thinner and the geology becomes dominated by pre-Bandelier rock units, as can be seen by comparing Fig. 2a and 2b. This is especially true for the deep wet canyons, which are deeply incised into the underlying strata. In the eastern part of the plateau, contaminants transported laterally down canyon via surface flow or in alluvial groundwater often percolate through a geologic column consisting primarily of basalt and fanglomerate with little or no overlying tuff. Downward percolation is believed to be more rapid in the basalt than through porous tuff, as discussed in the matrix vs. fracture flow section above. Thus, especially along the eastern end of the plateau, the wet canyons have thinner vadose zones (compare, e.g., Los Alamos Canyon in Fig. 2a and 2b) and a shorter portion of the flow path that has matrix-dominated flow (compare, e.g., Pajarito Canyon in Fig. 2a and 2b) than for the less eroded areas of the plateau. These stratigraphic factors compounded by the relatively high net infiltration rates in wet canyons likely yield the fastest vadose zone travel times for contaminants from the land surface of the plateau to the regional aquifer. Transport to the regional aquifer beneath wet canyons is predicted to be on the order of decades to hundreds of years (LANL, 2003b; Nylander et al., 2003).

Wet Canyon Examples

Mortandad Canyon has the physical features of a dry canyon (Fig. 1 and 2). However, this canyon is classified as wet because it has received significant effluent discharge since the late 1950s. Since 1963, a radioactive liquid-waste treatment facility (RLWTF, Fig. 1) has released treated effluent in excess of 10^7 L yr^{-1} to Mortandad Canyon via a small side canyon (LANL, 1997). Discharge volumes and contaminant masses for the RLWTF outfall are well documented. As such, data for this canyon prove useful for conceptual model validation. Discharge volumes have declined steadily since 1982.

A perched alluvium system fills the canyon floor and varies in thickness from near zero to more than 30 m near the eastern boundary of the Laboratory (McLin

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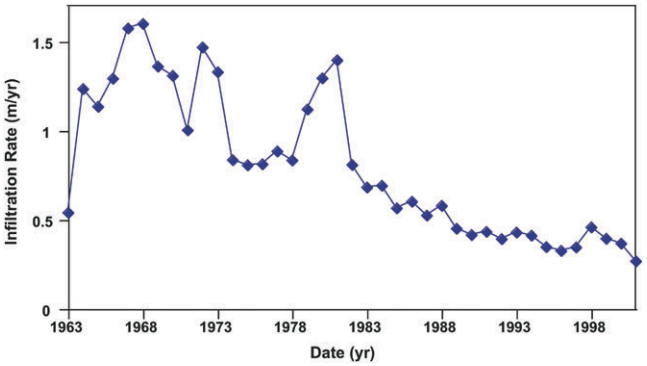

Fig. 4. Time-varying percolation rate at the alluvium–tuff interface, estimated for Mortandad Canyon near Well R-15 (Hollis et al., 2005).

et al., 1997). Purtymun (1974) observed that lateral transport of tritium and chloride was rapid through the alluvial system. He estimated lateral transport velocities between alluvial wells varying from 620 to 7300 m yr^{-1}. The alluvial wells in Mortandad Canyon cover more than a 3-km distance downstream from the RLWTF and have been monitored for nitrate and radionuclides regularly since 1963 (LANL, 1997, 2001). Nitrate and tritium concentrations at the wells are roughly within a factor of two to three of each other, indicating that these nonsorbing species are well mixed throughout the alluvial groundwater. The rapid lateral transport and mixing of nonsorbing species support the concept that the wet alluvial systems spread contaminants down canyon such that they act as a line source of water and well-mixed contaminants to the deeper vadose zone. In contrast, the concentrations of adsorbing species, such as strontium and plutonium, in the alluvial water decline by an order of magnitude or more as the water flows down canyon (LANL, 1997). This variation in concentration with distance would need to be considered when predicting transport of adsorbing species from the alluvial aquifer.

A series of one-dimensional vadose zone flow and transport simulations, using 38 columns to represent the canyon bottom, were performed to support a probabilistic risk assessment of Mortandad Canyon (Hollis et al., 2005). As an upper-boundary condition, the simulations apply a water balance to the alluvial aquifer to estimate recharge from the alluvial aquifer to the deeper vadose zone. The water balance approach assumes that the volume of water entering the canyon is a function of the discharge volume from the RLWTF, the main anthropogenic water source to the canyon, and that recharge is a function of the distance from the source. An estimate of the time-varying percolation rate at the alluvium–tuff interface in the vicinity of Well R-15 (Fig. 1) developed for the stochastic analysis is shown in Fig. 4. This particular example uses mean values for the three parameters in the study that define the distribution of infiltrating water throughout the canyon floor, with the main control being the assumed dilution of the recorded RLWTF discharge volumes (Hollis et al., 2005). The percolation estimates are indicative of rates expected in wet canyons; they range from 300 mm yr^{-1} to >1.5 m yr^{-1}.

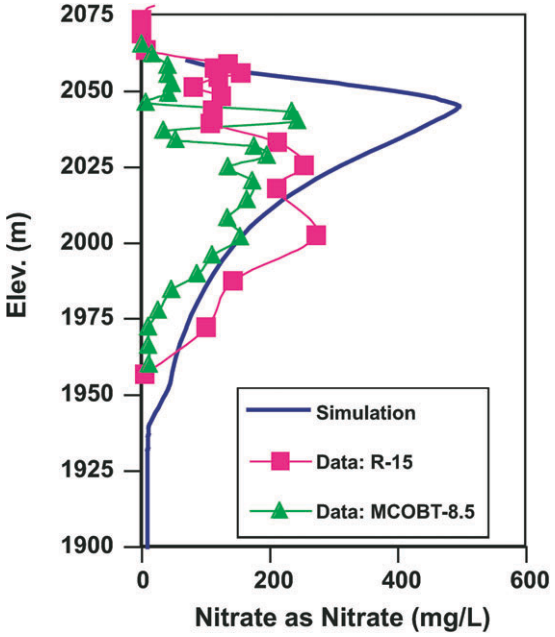

Fig. 5. Nitrate concentration profiles as a function of elevation in Wells R-15 (Longmire et al., 2001) and MCOBT-8.5 (Broxton et al., 2002b) and for a one-dimensional simulation (Hollis et al., 2005).

Nitrate concentration data collected in core from two vadose zone boreholes, R-15 and MCOBT-8.5 (Longmire et al., 2001; Broxton et al., 2002b), also confirm wet canyon behavior in Mortandad Canyon. Here nitrate has migrated to a depth of at least 100 m in the vadose zone in approximately 40 yr, as shown in Fig. 5. An example nitrate concentration profile predicted at the location of Well R-15 with the transient one-dimensional, vadose zone simulation described above agrees well with the concentration data (Fig. 5). The simulation uses the transient percolation rate shown in Fig. 4 and measured nitrate releases from the RLWTF (LANL, 1997), although one-half the nitrate mass is assumed to be degraded due to denitrification (Hollis et al., 2005). The simulation also assumes that water flow through the tuff units is matrix dominated, and flow through the basalt is fracture dominated.

Nitrate has also been observed in the regional aquifer at levels near 2 mg L^{-1} (LANL, 2003a) in Well R-15. This well is 337 m deep and extends 44 m into the regional aquifer. These nitrate levels are elevated relative to background levels in regional groundwater and are believed to be the result of Laboratory liquid-effluent discharges to Mortandad Canyon (Longmire, 2002).

Los Alamos Canyon is a large canyon that is both naturally wet and has previously received wastewater discharges. Laboratory derived contaminants (tritium, perchlorate) released in liquid effluents into this canyon and the adjacent Pueblo Canyon have reached the regional aquifer and are present in one municipal water supply well (Otowi-1) (LANL, 2004c). Well Otowi-1, located in Pueblo Canyon near the confluence with Los Alamos Canyon (Fig. 1), is in an area in which alluvium sits directly on top of basalts and the Puye formation. Further up Los Alamos and Pueblo Canyons, significant thicknesses of Bandelier Tuff are present. In contrast to

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Fig. 6. Photograph of a dry canyon, lower Sandia Canyon.

Otowi-1, no contaminants have been detected in water supply well Otowi-4 (LANL, 2004c), located in a region in which more than 50 m of Bandelier Tuff is present (Fig. 1). Thus, the Otowi-4 result is consistent with a conceptual model of matrix-dominated flow and longer travel times through the nonwelded Bandelier Tuff, and the Otowi-1 observation is consistent with fracture flow through the basalt units. The numerical model of Los Alamos Canyon developed in Robinson et al. (2005c) yielded results consistent with these observations.

To summarize, these data and interpretation demonstrate several of the features included in the wet canyon conceptual model. First, lateral transport by both surface water and perched alluvial groundwater spreads nonsorbing contaminants down canyon to create a line source of contamination to the deeper vadose zone. Next, wastewater discharges can cause wet-canyon hydrologic behavior in small canyons that would otherwise likely have little net infiltration, as discussed in the upcoming section. Also, a matrix-flow model for the tuff units appears to adequately capture infiltration beneath Mortandad Canyon even though a perched system sits atop the tuff, and the transient percolation rate is estimated to have been on the order of a meter per year. In contrast, near Otowi-1, at the confluence of Los Alamos and Pueblo Canyons, little or no tuff is present, and a rapid fracture flow model through the basalts best explains the contaminant observations. Finally, the presence of anthropogenic contaminants in regional groundwater confirms that beneath wet canyons some vadose zone pathways have travel times on the order of a few decades.

Dry Canyons

Dry Canyon Conceptual Model

Figure 6 is a photograph of lower Sandia Canyon (Fig. 1), which is considered a dry canyon. In contrast to wet canyons, dry canyons head on the plateau, have smaller catchment areas (<13 km^2), experience infrequent surface flows, and have limited or no saturated alluvial systems in their floors. If anthropogenic sources are present, they are small volume sources. These hydrologic factors yield little lateral near-surface contaminant migration and slower unsaturated flow and transport from the surface to the regional aquifer. For example, because surface and alluvial waters are less common, contaminants remain near their original sources. Pathways through the vadose zone tend to be longer in the shallow dry canyons, which have thicker sections of nonwelded to moderately welded tuff than in the deeper-cut wet canyons; see, for example, Cañada del Buey in Fig. 2. Net infiltration beneath dry canyons is much slower, with rates generally believed to be less than tens of millimeters per year and commonly on the order of 1 mm yr^{-1}. Finally, transport times to the aquifer beneath dry canyons are expected to be from hundreds to several thousands of years (Nylander et al., 2003).

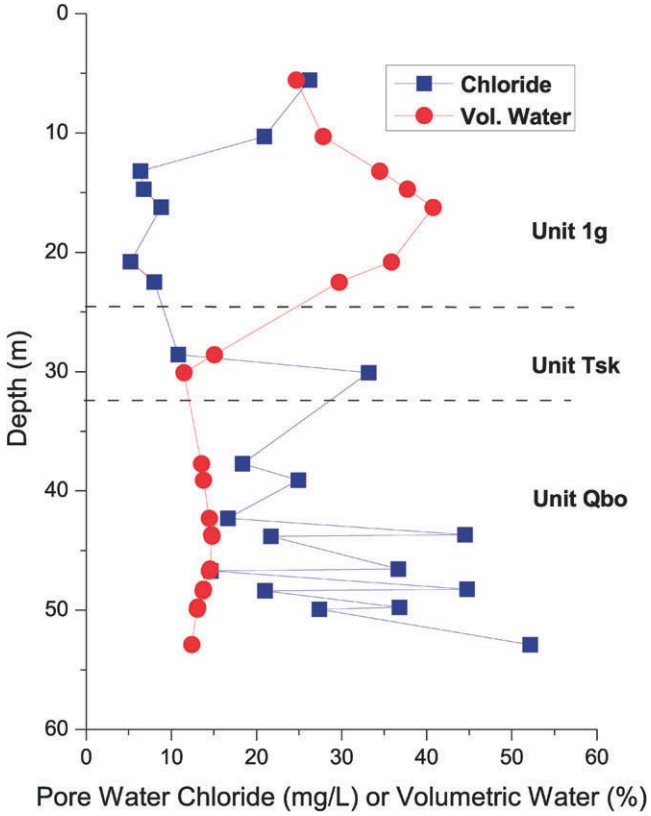

Fig. 7. Pore water chloride and volumetric water content profiles in Potrillo Canyon for Borehole PC-4 (Newman, 2002, unpublished data). Stratigraphic contacts are also shown (Qbt-1g is the Tshierege 1g unit, Tsk is the Tsankawi Pumice Bed, and Qbo is the Otowi Member of the Bandelier Tuff).

Dry Canyon Examples

Estimated net infiltration rates by Rogers et al. (1996) (Table 1) suggest fluxes of a few millimeters per year or less for two dry canyon locations, Potrillo Canyon and Cañada del Buey. Water content and chloride profiles from Potrillo Canyon Borehole PC-4 are presented in Fig. 7. The example shows that even in a "dry" canyon there can be zones of high water content (i.e., water contents are in the 40% range at about 17 m). However, the chloride mass-balance estimate of flux from this borehole is only 4.5 mm yr^{-1}, and the chloride-based vadose zone residence time exceeds 1700 yr.

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Fig. 8. Photo of a dry mesa located north of Cañada del Buey, on the eastern side of the Laboratory.

Dry Mesas

Dry and Disturbed Mesa Conceptual Model

Dry finger mesas constitute most of the mesa coverage on the plateau. The hydrologic conditions on the surface and within these dry mesas lead to slow unsaturated flow and transport. Figure 8 is a photograph of a dry mesa near the eastern boundary of the laboratory. Dry mesas shed precipitation as surface runoff to the surrounding canyons such that most deep infiltration occurs episodically following snowmelt. Much of the water that does enter the soil zone is lost through evapotranspiration. In fact, potential ET was estimated to exceed precipitation at a climate station on the eastern portion of the plateau by a ratio of 6:1 (LANL, 2003c). As a result, annual net infiltration rates for dry mesas are <10 mm yr^{-1} and are more often estimated to be on the order of 1 mm yr^{-1} or less (Kwicklis et al., 2005). Since the dry mesas are generally comprised of nonwelded to moderately welded tuffs with low water content, flow is matrix dominated. Travel times for contaminants migrating through mesas to the regional aquifer are expected to be several hundred to thousands of years (Newman, 1996; Newman et al., 1997b; Birdsell et al., 2000; Nylander et al., 2003).

The topographic relief of these steep-sided mesas influences their internal hydrologic conditions as well. High solar radiation, strong winds, and fluctuations in barometric pressure cause temperature and pressure gradients between the surface of the mesa and its interior. These gradients enhance air circulation through the mesas, which is thought to enhance deep evaporation (Neeper, 2002; Neeper and Gilkeson, 1996; Newman, 1996; Newman et al., 1997b). This additional drying in the mesa-top units further slows downward water flow and transport of dissolved species. However, these same conditions enhance vapor transport of volatile species (Stauffer et al., 2005).

Anthropogenic discharges and surface disturbances from laboratory operations can drive infiltration rates higher in normally dry mesas. In some cases, multiyear disturbances of mesa sites through liquid waste disposal, asphalt covers, and/or devegetation have temporarily caused mesa infiltration rates to increase to near wet canyon levels (Table 1). Even with elevated infiltration, at most sites flow remains matrix dominated. Fracture flow has occurred beneath a long-term liquid disposal site with ponded conditions, as discussed above. However, fracture flow is thought to cease once liquid disposals stop (Soll and Birdsell, 1998). Infiltration rates are expected to return to low, near-background levels when the surface and vegetation return to native conditions.

Dry and Disturbed Mesa Examples

Two examples of vadose zone conditions from dry and disturbed mesas are discussed. The first example uses volumetric water content and chloride profiles from four boreholes (Fig. 9) from Mesita del Buey located near the eastern boundary of the laboratory (Fig. 1). In this mesa, vadose zone water contents above the level of the adjacent canyon bottoms are variable, but a large fraction of the mesa has extremely low water contents of $<5\%$ ($<12\%$ saturation). Chloride accumulation in the vadose zone is also variable, but all four boreholes have significant chloride inventories. Some samples have pore water chloride concentrations that exceed 1000 mg L^{-1}. The chloride data (Newman, 1996) and numerical modeling (Birdsell et al., 2000) indicate that downward fluxes vary with depth and across the mesa. Chloride mass-balance flux estimates range from 0.03 to 6 mm yr^{-1}, with the highest fluxes associated with the upper 6 to 9 m. However, all four boreholes have a depth interval where fluxes are <1 mm yr^{-1}. Chloride-based residence times range from 1300 to 17 000 yr (Newman, 1996). The low fluxes and long residence times suggest that there is little water movement through the mesa.

Even though the natural conditions in dry mesas result in low downward fluxes, disturbance can alter how quickly water moves through the vadose zone. Rogers et al. (1996) showed that addition of water or focusing of flow on mesa tops (e.g., waste water lagoons or storm water diversion ditches) can result in flux increases of tens to hundreds of millimeters per year (Table 1). Another example of how rapidly dry mesa conditions can shift from disturbance is provided by periodic water content monitoring of Borehole 1121 on Mesita del Buey. When the borehole was drilled, chloride and water content data reflected the native conditions in the mesa (Fig. 10). Subsequently, focused runoff from an asphalt pad resulted in transient ponding in a localized area around Borehole 1121. Periodic water content monitoring in Borehole 1121 using neutron probe revealed increasing water contents down to about 24 m in <10 yr (Fig. 10; Newell, 1996 and 2000, unpublished data). This example shows that transient ponding can affect deep portions of dry-mesa vadose zones in less than a decade.

The second dry or disturbed mesa example is from Frijoles Mesa, located at the south-central portion of the Laboratory (Fig. 1). Explosives experiments were conducted at MDA AB on Frijoles Mesa in 1960 and

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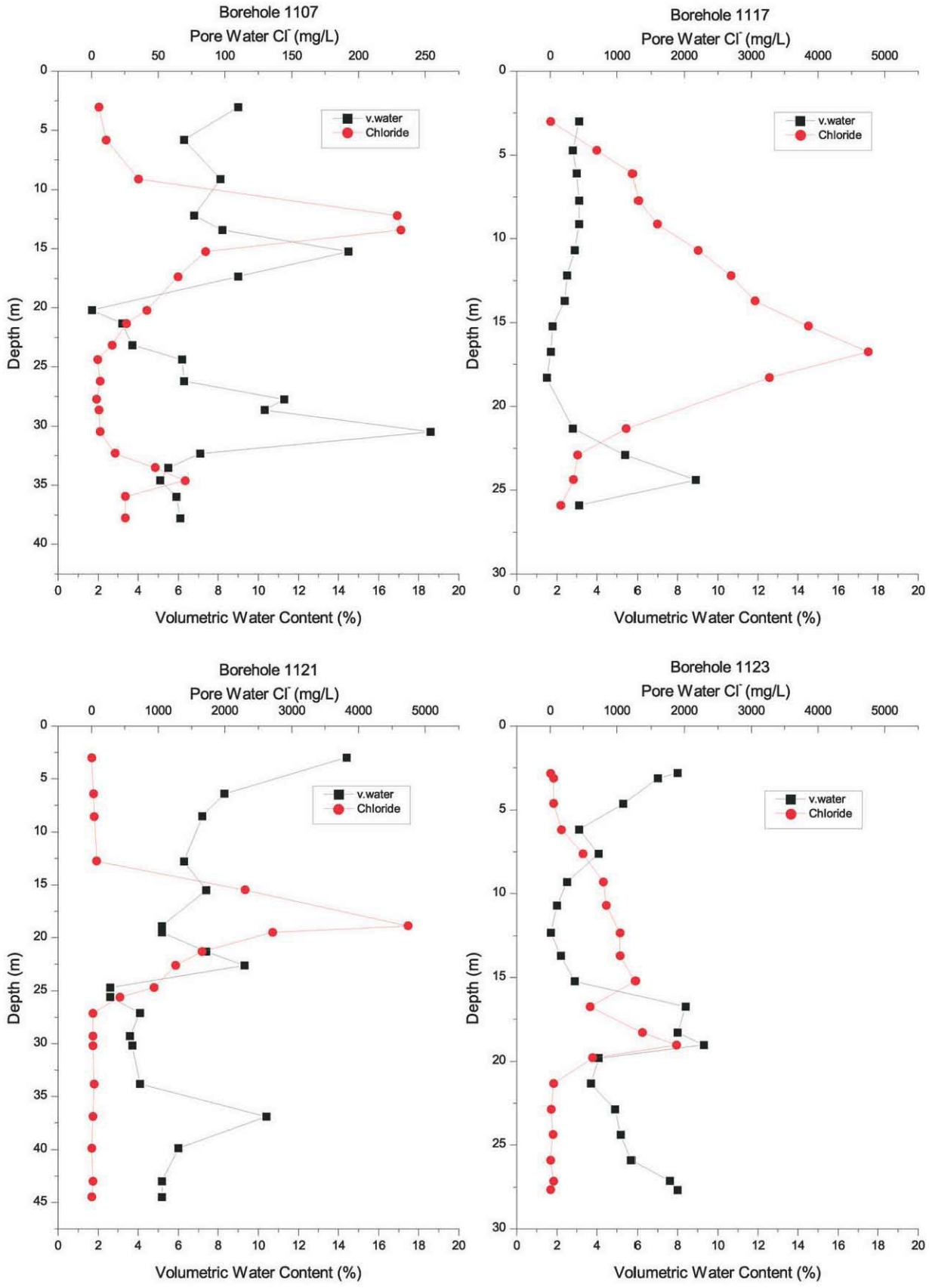

Fig. 9. Water content and chloride profiles from MDA G (Newman, 1996).

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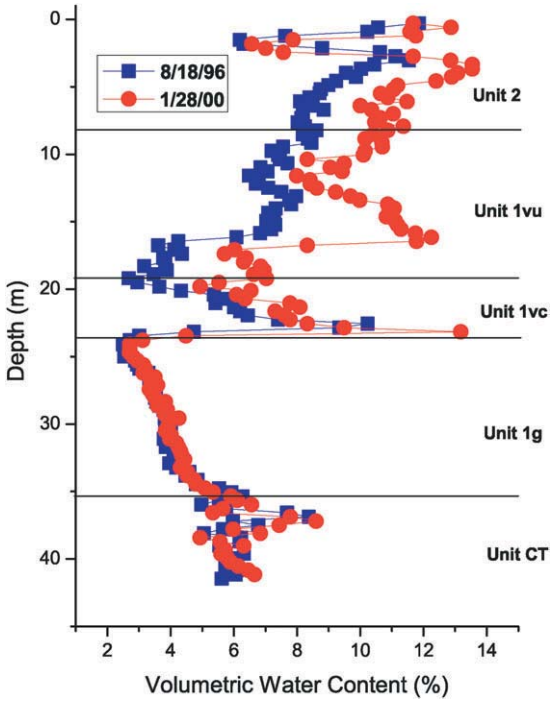

Fig. 10. Changes in volumetric water content in borehole 1121 as a result of episodic ponding (Newell, 1996 and 2000, unpublished data). Ponding occurred from focused runoff from an asphalted area.

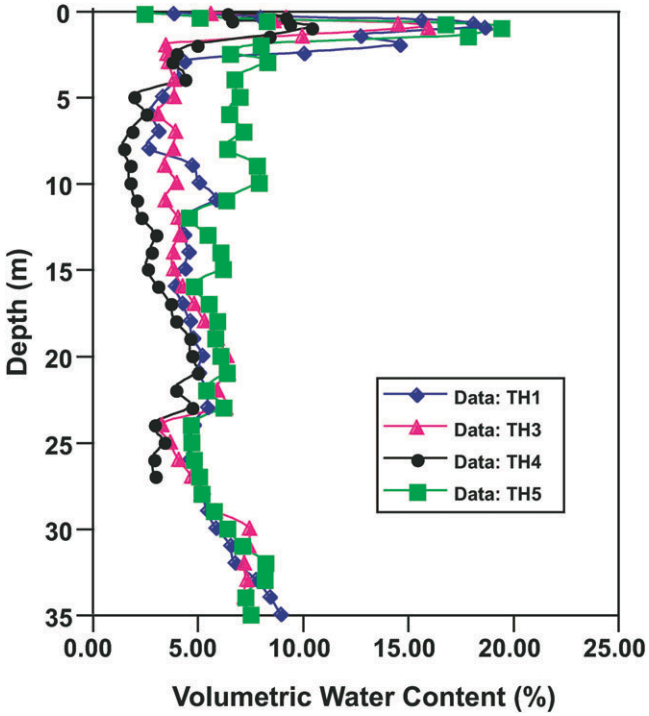

Fig. 11. Volumetric Water Content in four boreholes for background conditions at TA-49 near MDA AB (Levitt et al., 2005).

1961 at the bottom of shafts dug approximately 20 to 24 m into the Tshirege Member of the Bandelier Tuff. One area at the site was paved with asphalt in 1961 to minimize the spread of accidental surface contamination. It was later found that the elevated asphalt pad unfavorably altered the naturally dry hydrologic characteristics of the site by inhibiting evapotranspiration and by damming surface water along its edge. At several times, the asphalt was found to be in disrepair, and estimates of leakage through the cracked asphalt pad ranged from 60 to 388 mm yr^{-1} (Table 1; LANL, 1992; Rofer et al., 1999).

Background water content profiles measured in four 37-m boreholes (Fig. 11) and a 210-m borehole (Levitt et al., 2005) illustrate the site's dry background conditions. Water content of the tuff below about 3 m is <10%. Newman et al. (1997b) estimated infiltration rates in the range 0.3 to 2.0 mm yr^{-1} based on the chloride profile from the 210-m borehole at the site (Table 1). Water content profiles from beneath the asphalt were measured in two 46-m boreholes in 1994 (Fig. 12). These data clearly show elevated water contents to a depth of 18 m.

Two-dimensional numerical simulations, assuming matrix properties for the tuff units, were run to determine the asphalt's effect on the subsurface water balance and to predict the possible recovery of the site following asphalt removal (Birdsell et al., 1999). A simulated background infiltration rate of 0.1 mm yr^{-1} fits the background, water content data well and was used as an initial condition for transient simulations of the paved area. The transient simulations assumed an immediate increase in the infiltration rate in 1961, when the site was paved, to a new steady value of 60, 150, or 388 mm yr^{-1}, based on the leakage estimate cited above. Figure 12 shows the predicted water content profiles for the 60 and 150 mm yr^{-1} infiltration rate cases for a simulation time equivalent to 1994. The water content profile, based on a net infiltration rate of 60 mm yr^{-1} (a 600-

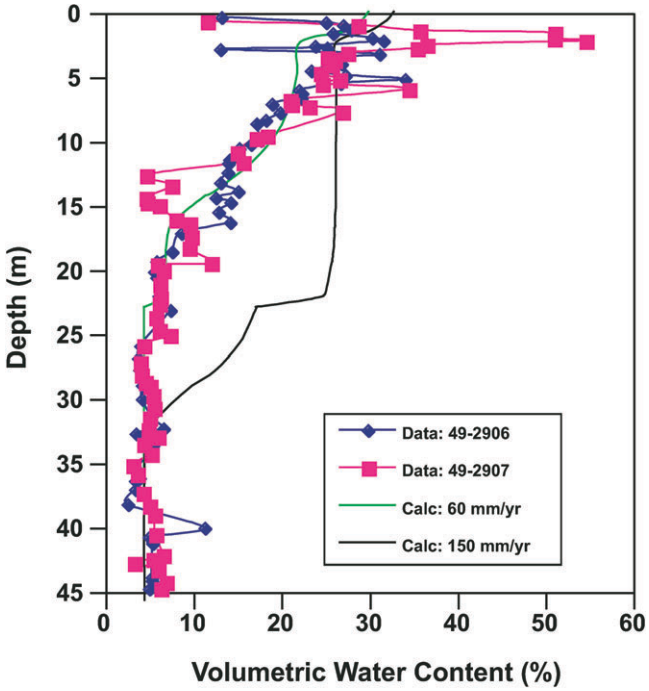

Fig. 12. Volumetric water content for disturbed conditions at TA-49, MDA AB. Data are for two boreholes beneath an asphalt area (Farley, 1994, unpublished data). Simulation results are for transient simulations with increased deep percolation during asphalt lifetime (Birdsell et al., 1999).

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Fig. 13. Photograph of mountain-front mesa at TA-16.

fold increase) applied from 1961 through 1994, matches the 1994 water content data well. The simulations indicate that if the site returned to a 0.1 mm yr^{-1} infiltration rate, the soil would show detectable signs of drying in a 5-yr period. However, the water content of the uppermost tuff unit might increase slightly as the steep gradient in the top few meters, as seen in Fig. 12, relaxes downward.

To return the site to a more natural state, the asphalt was removed in 1998. The site was then regraded, capped with an ET cover, and revegetated. From 2000 through 2004, monitoring has shown slow drying in the upper 6 m of the soil layer beneath the ET cover (Levitt et al., 2005). Water contents at 12-m to 18-m depths show a slight increase in time (Levitt et al., 2005), as predicted, because of the steep water content profile that existed before removal of the asphalt is relaxing.

Data and simulations for MDA AB support several of the assumptions of the dry mesa conceptual model under both background and disturbed conditions. First, the matrix flow model adequately matches water content data at both background and enhanced infiltration conditions. Second, native conditions of this mesa are dry with predicted infiltration rates between 0.1 mm yr^{-1} (simulations) and 2.0 mm yr^{-1} (chloride). Third, the surface disturbance significantly enhanced net infiltration. Finally, the site seems to be returning to a drier condition. However, since the asphalt was in place for several decades, water accumulation in the disturbed area is significant. The simulations indicate that it may take hundreds of years for water content levels within the tuff units to return to near-background conditions.

Mountain-Front Mesas

Mountain-Front Mesa Conceptual Model

Mesas along the mountain front of the plateau are classified as being naturally wet mesas. Figure 13 shows a photograph of a mountain-front mesa area at TA-16 (Fig. 1). In contrast to the dry mesas, these mesas receive greater precipitation (e.g., 500 mm yr^{-1}) and increased runoff and infiltration. The wet, mountain-front mesas contain numerous perennial and ephemeral springs. Such springs are rare in the dry mesas of the eastern part of the plateau, except where the regional groundwater aquifer discharges along the Rio Grande. Duffy (2004) discusses the importance of mountain-front processes and conditions in semiarid landscapes and suggests that the mountain block and mountain-front areas are the dominant recharge zones in semiarid landscapes. Thus, hydrologic conditions are quite different along the wet mountain-front mesas. One other important difference is that the upper tuff units along the mountain front are often moderately to strongly welded because of the close proximity to the caldera source. Welding results in increased fracturing during cooling, and because the mountain-front mesas lie within the Pajarito Fault Zone, additional fracturing and minor faulting of the tuff units have resulted. The welded tuffs create a hydraulic condition where matrix hydraulic conductivities are low (e.g., 10^{-7} to 10^{-9} cm s^{-1}), but fracture densities are relatively high. Thus, there is a propensity for significant fracture flow. Fracturing appears to control the locations of natural springs along the mountain-front mesas. Also, fracture flow related to outfalls and wastewater lagoons is suggested by water content and contaminant distributions (LANL, 2003b).

Mountain-Front Mesa Examples

To illustrate how rapidly vadose zone flow and transport can occur in wet, mountain-front mesas, a bromide tracer test is described. This tracer experiment was conducted in a former high explosives outfall pond at TA-16. Use of the outfall had been discontinued, and ponded water conditions no longer existed at the site. In 1997, 100 kg of potassium bromide were applied to the outfall pond with 3028 L of water. The main goal of the study was to determine whether there was a connection between the mesa-top outfall pond and two high explosives–contaminated springs that flowed along the north side of the mesa. Except for the tracer solution, no additional water was added to the site. Thus, precipitation was the dominant driver for tracer transport. Borehole monitoring and drilling during the test showed that the vadose zone was largely unsaturated. Tracer was observed in the first spring after only 4 mo. These observations indicate more than 300 m of lateral transport and 33 m of vertical transport. Tracer was observed in the second spring after about 7 mo. Such rapid movement of tracer to the springs is inconsistent with fluxes that would be expected under unsaturated, matrix-type flow conditions (LANL, 1998b, 2003b). Thus, rapid movement along locally saturated fractures (possibly in combination with matrix flow) is implied. It is also worth noting that <2% of the applied tracer mass actually made it to the springs. Subsequent drilling and sampling in the application area 3 yr after the tracer was released suggests nearly all of the tracer mass was still in the top 1.2 m of the vadose zone (LANL, 2003b). This result illustrates that vadose fluxes in the mountain-front zone are not always large and that there can be a great deal

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Table 2. Comparison of canyon and mesa hydrogeochemical characteristics.

	Max. Cl^-	Avg. Cl^-	Max. SO_4^{2-}	Avg. SO_4^{2-}	Max. $\delta^{18}O$	Avg. $\delta^{18}O$	Max. θ_v	Avg. θ_v
	mg L^{-1}				‰		%	
Canyons	172	30	641	78	−7	−10	52	20
Mesas	1761	398	8913	766	−1	−8	18	7
Difference	1589	368	8272	688	6	2	−33	−13

of variation in fluxes, depending on whether fracture or matrix flow (or both) occur.

Mesa–Canyon Comparison

To further demonstrate the pronounced difference between the subsurface hydrologic conditions beneath mesas and canyons, a direct comparison of data collected at a variety of mesa and canyon sites is presented in this section. A statistical examination of vadose zone water content, anion concentrations (e.g., chloride), and stable isotopes ($\delta^{18}O$ and δD) supports the hypothesis that canyons are hydrologically different from mesas. These characteristics serve as sensitive indicators for differences in recharge through the vadose zones. Cores from nine canyon and 13 mesa boreholes from relatively undisturbed locations were examined. Water content and anion and stable isotope data from the core samples were collected following Newman et al. (1997a). For each borehole, the average and maximum values of pore water chloride and sulfate concentrations, pore water $\delta^{18}O$ values, and volumetric water contents were determined. Data for each characteristic (averaged for all canyon and mesa boreholes, respectively) are shown in Table 2 along with the difference between the values. The differences between the canyons and mesas are substantial in most cases.

To test whether these differences were significant, the nonparametric Mann–Whitney U test was run using the various mesa and canyon borehole values. The nonparametric test was used primarily because of the small number of analyses available. For a p value of 0.05, the tests showed that all of the characteristics for both the maximum and average values were significantly different for the mesas and canyons. The dramatic differences between the mesa and canyon characteristics can also be seen from box and whisker plots of water content and chloride concentration shown in Fig. 14 and 15. These comparisons of mesa and canyon vadose zone characteristics support the conceptual model that there are significant differences between the mesas and the canyons in hydrologic behavior and in downward fluxes. Unfortunately, there are not enough data to test for significant differences between dry and wet canyons.

SUMMARY AND CONCLUSIONS

Field observations, data and numerical models were used in conjunction to develop and test the conceptual models of vadose zone hydrology beneath the Pajarito Plateau. Many of our findings have relevance to studies being conducted in other arid and semiarid regions and provide insights into flow and transport mechanisms, the role of hydrogeology in controlling vadose zone flow, and the influence of topographic and surface water flow conditions on infiltration and deep percolation. Therefore, understanding of the unsaturated zone hydrologic processes studied here should have a general applicability and interest that goes beyond the characterization of the Pajarito Plateau in north-central New Mexico. Our principle findings and the means for reaching these conclusions are summarized below.

Topography and Surface-Water Setting. The conceptual models distinguish differences among wet canyons, dry canyons and mesas, and mountain-front mesas. Wet canyons receive larger quantities of deep infiltration due to surface and shallow groundwater flow in alluvium. In contrast, little net infiltration occurs beneath dry canyons and mesas. Mountain-front mesas receive consid-

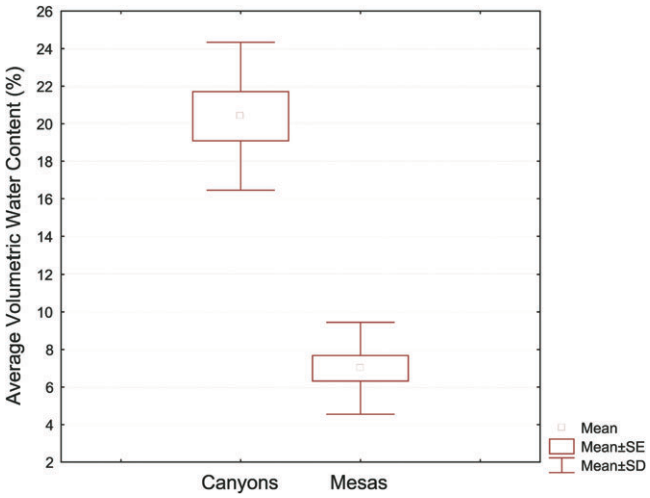

Fig. 14. Box and whisker plot comparing canyon and mesa volumetric water contents.

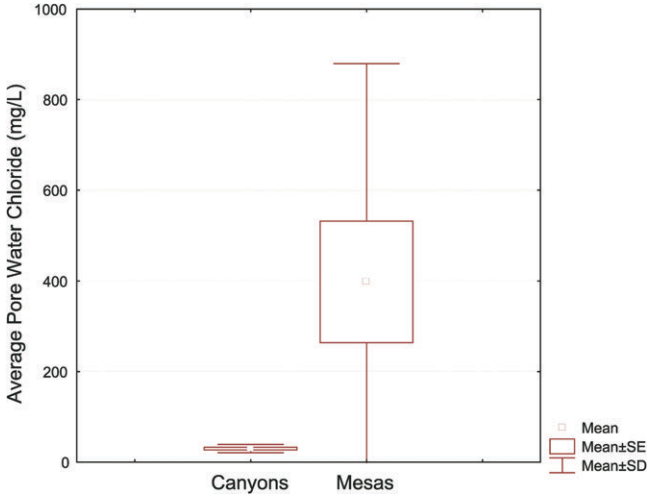

Fig. 15. Box and whisker plot comparing canyon and mesa pore water chloride concentrations.

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erably more infiltration, and the particular hydrostratigraphic conditions give rise to localized perched water, and lateral flow through fractures to nearby springs. These ideas are supported by the following observations and interpretations of data from across the plateau:

- Moisture profile measurements and numerical simulation of vadose zone flow
- Major ion, stable-isotope, and contaminant concentration measurements
- Water budget studies in individual canyons (Gray, 1997; Kwicklis et al., 2005)
- Tracer tests in perched water for the mountain-front mesa case

Anthropogenic Impacts. Both canyons and mesas can be significantly changed from their natural conditions by human activities. On mesas, asphalt pavements on mesas reduce ET, and moisture builds up underneath. If the asphalt focuses runoff or subsequently cracks, localized high infiltration can take place in a location where it ordinarily would not. In canyons, effluent discharges from LANL or Los Alamos County sources can significantly increase surface and alluvial groundwater flow, which in turns typically increases the infiltration rate to the deeper vadose zone. These ideas are supported by the following observations and interpretations:

- Measurements and numerical modeling of water contents beneath and adjacent to areas paved to support LANL facilities
- Water content and contaminant transport measurements and numerical modeling of canyons impacted by LANL facilities

Flow and Transport Mechanisms. The two principle stratigraphic units of interest for vadose zone flow and transport beneath the Pajarito Plateau are the Bandelier Tuff and Cerros del Rio basalt. Water percolates through the porous and permeable matrix of most subunits of the Bandelier Tuff. Many of these units are sparsely fractured, but even for those with fractures, water quickly imbibes into the matrix. An exception is the uppermost units of the Tshirege Member, present in the western part of the Laboratory, near the mountain front, where rapid lateral transport through fractures has been observed. The basaltic rocks exhibit rapid flow and transport through fractures. These ideas are supported by the following observations and interpretations:

- Water content, major ion, and contaminant transport measurements and numerical modeling
- Field measurements at an instrumented site in basalt (Stauffer and Stone, 2005)
- Fluid injection tests in the Bandelier Tuff (Robinson et al., 2005a)

Vadose Zone Travel Times. Travel times of contaminants from wet canyons to the regional aquifer can be as short as several years to several decades. The shortest travel times occur when water infiltrates directly into fractured basalt. When significant thickness of Bandelier tuff is present, travel times on the order of decades are more common. Travel times to the water table for dry canyons or undisturbed mesas are much longer; times in excess of thousands of years are consistent with the available data. These ideas are supported by the following observations and interpretations:

- Numerical modeling of wet canyons (Robinson et al., 2005c)
- Contaminant profiles in vadose zone boreholes
- Chloride and isotope profiles in mesa-top boreholes
- Regional aquifer contaminant concentrations from groundwater surveillance activities (LANL, 2004c, 2003a)

In conclusion, the conceptual models provide a general picture of the relevant processes controlling vadose zone flow and transport at the LANL site. Preliminary assessments of a particular site on the Pajarito Plateau can be based on the results presented herein. More detailed, site-specific investigations may be required to develop in-depth understanding and models with predictive capability. In those cases, the conceptual models serve as guiding sets of principles on which site-specific data-collection programs can be based.

ACKNOWLEDGMENTS

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United States Department of Agriculture

Natural Resources Conservation Service

In cooperation with the United States Department of the Interior, Bureau of Land Management and Bureau of Indian Affairs; and the New Mexico Agricultural Experiment Station

Soil Survey of Sandoval County Area, New Mexico,

Parts of Los Alamos, Sandoval, and Rio Arriba Counties



How To Use This Soil Survey

General Soil Map

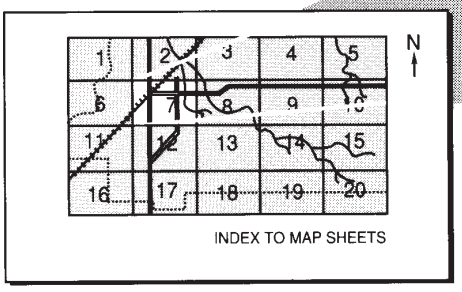
The general soil map, which is a color map, shows the survey area divided into groups of associated soils called general soil map units. This map is useful in planning the use and management of large areas.

To find information about your area of interest, locate that area on the map, identify the name of the map unit in the area on the color-coded map legend, then refer to the section **General Soil Map Units** for a general description of the soils in your area.

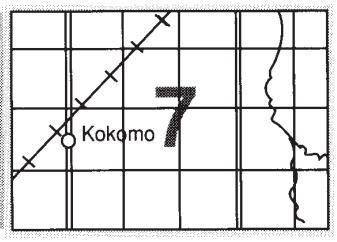
Detailed Soil Maps

The detailed soil maps can be useful in planning the use and management of small areas.

To find information about your area of interest, locate that area on the **Index to Map Sheets**. Note the number of the map sheet and turn to that sheet.

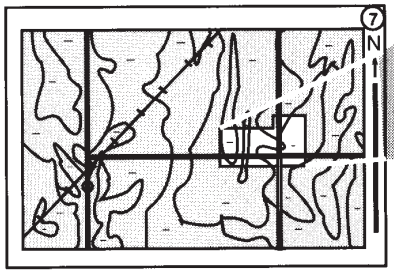


INDEX TO MAP SHEETS

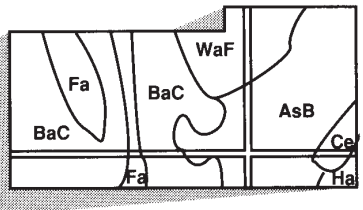


MAP SHEET

Locate your area of interest on the map sheet. Note the map unit symbols that are in that area. Turn to the **Contents**, which lists the map units by symbol and name and shows the page where each map unit is described.



MAP SHEET



AREA OF INTEREST

NOTE: Map unit symbols in a soil survey may consist only of numbers or letters, or they may be a combination of numbers and letters.

The **Contents** shows which table has data on a specific land use for each detailed soil map unit. Also see the **Contents** for sections of this publication that may address your specific needs.

This soil survey is a publication of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (formerly the Soil Conservation Service) has leadership for the Federal part of the National Cooperative Soil Survey.

Major fieldwork for this soil survey was completed in 1977-1985. Soil names and descriptions were approved in 1987. Unless otherwise indicated, statements in this publication refer to conditions in the survey area in 1982. This survey was made cooperatively by the Natural Resources Conservation Service and the United States Department of Interior, Bureau of Land Management and Bureau of Indian Affairs; and the New Mexico Agricultural Experiment Station. The survey is part of the technical assistance furnished to the San Juan, Cuba, Coronado, Ciudad, and Santa Fe-Pojoaque Soil and Water Conservation Districts.

Soil maps in this survey may be copied without permission. Enlargement of these maps, however, could cause misunderstanding of the detail of mapping. If enlarged, maps do not show the small areas of contrasting soils that could have been shown at a larger scale.

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Cover: "Valle Grande," is the Spanish term for "great valley." Depicted here is a typical landscape of the Cosey-Jarmillo association, 2 to 20 percent slopes, in the foreground; Panlon very cobbly sandy loam, 35 to 65 percent slopes, is on the steep mountain slopes in the far background.

Additional information about the Nation's natural resources is available online from the Natural Resources Conservation Service at http://www.nrcs.usda.gov.

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Foreword

This soil survey contains information that affects land use planning in this survey area. It contains predictions of soil behavior for selected land uses. The survey also highlights soil limitations, improvements needed to overcome the limitations, and the impact of selected land uses on the environment.

This soil survey is designed for many different users. Farmers, ranchers, foresters, and agronomists can use it to evaluate the potential of the soil and the management needed for maximum food and fiber production. Planners, community officials, engineers, developers, builders, and home buyers can use the survey to plan land use, select sites for construction, and identify special practices needed to ensure proper performance. Conservationists, teachers, students, and specialists in recreation, wildlife management, waste disposal, and pollution control can use the survey to help them understand, protect, and enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. The information in this report is intended to identify soil properties that are used in making various land use or land treatment decisions. Statements made in this report are intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are shallow to bedrock. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

These and many other soil properties that affect land use are described in this soil survey. Broad areas of soils are shown on the general soil map. The location of each soil is shown on the detailed soil maps. Each soil in the survey area is described. Information on specific uses is given for each soil. Help in using this publication and additional information are available at the local office of the Natural Resources Conservation Service or the Cooperative Extension Service.



Dennis Alexander
State Conservationist

Soil Survey of Sandoval County Area, New Mexico,

Parts of Los Alamos, Sandoval, and Rio Arriba Counties

By Leroy Hacker, Natural Resources Conservation Service and Christopher Banet, Bureau of Indian Affairs

Fieldwork by Leroy Hacker, Dale Swanson, Mark Seyfried, Tommie Parham, and Javier Ruiz, Natural Resources Conservation Service, and Christopher Banet and William Rigdon, Bureau of Indian Affairs

United States Department of Agriculture, Natural Resources Conservation Service
in cooperation with United States Department of the Interior, Bureau of Land Management, Bureau of Indian Affairs, and New Mexico Agricultural Experiment Station

General Nature of the Survey Area

Sandoval County Area is in north-central New Mexico. The survey area is bordered on the north by the Jicarilla Apache Area, Rio Arriba County Area, and the Santa Fe National Forest; on the east by Santa Fe County; on the south by Bernalillo County; and on the west by Cabezon Area, Cibola Area, McKinley County Area, and San Juan County, Eastern Part. It has a total of 1,550,000 acres or about 2,422 square miles, and includes parts of Sandoval and Los Alamos Counties.

Bernalillo, the county seat of Sandoval County, is on the Rio Grande in the south-central part of the survey area. Los Alamos, the county seat of Los Alamos County, is in the north-eastern corner of the survey area. Highways N.M. 550, 96, and 4, U.S. 85, Interstate 25, and the Santa Fe railway traverse the survey area.

The Rio Grande, the only perennial stream, traverses the eastern part of the survey area from north to south. The Rio Puerco and Jemez River are intermittent streams in the west and central parts of the survey area.

Elevation ranges from about 11,252 feet on Redondo Peak, the highest point in the survey area, to about 5,000 feet where the Rio Grande enters Bernalillo County.

Principal land uses in the survey area are livestock grazing, wood and timber harvesting, recreation, wildlife production, high-intensity irrigated farming, and urban development. The irrigated farming is in the Rio Grande and Jemez River Valleys. Urban development is concentrated in the Rio Rancho area.

Descriptions, names and delineations of the soils in this survey area do not fully agree with those of Bernalillo, Cabezon, San Juan, or Santa Fe Counties. This is the result of new concepts of soil classification, changes in series concepts, different needs and uses, and the time the soil survey work was performed. Map unit differences are noted in the map unit descriptions. Updated correlations are in progress for these older surveys.

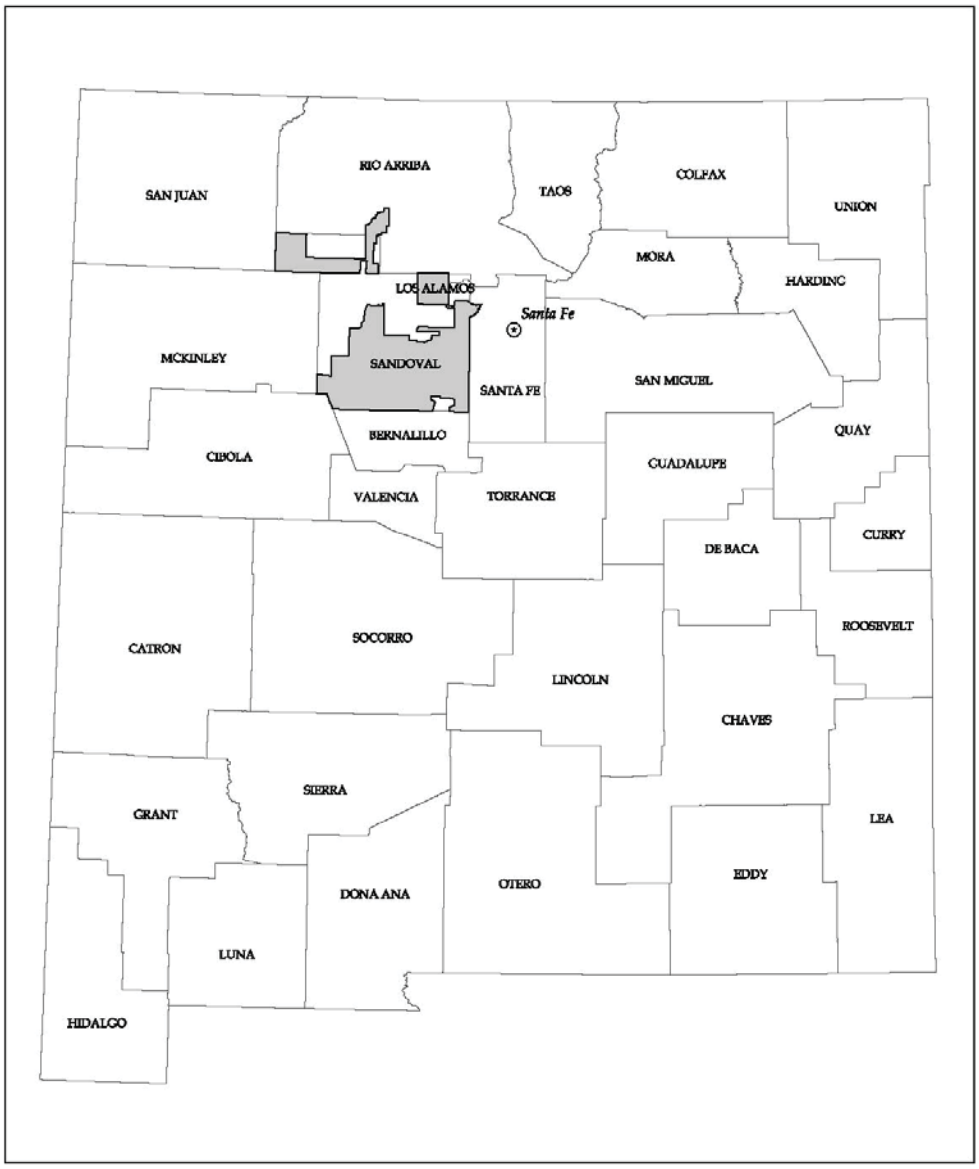

Figure 1.—Location of Sandoval County Area, New Mexico.

Agriculture

Agriculture in Sandoval and Los Alamos counties is many centuries old. Records indicate that Pueblo Indians were irrigating land and growing crops when first encountered by the Spaniards in 1540. They have continued to irrigate their lands up to the present time. Although there are a number of small and widely separated tracts of irrigated land in the valleys of the Jemez River, Rio Puerco, and their tributaries, most of the land now irrigated is in the Rio Grande Valley.

These lands along the Rio Grande are in an organized irrigation district known as the Middle Rio Grande Conservancy District. It was formed in 1925 to consolidate the many old ditch and diversion headings into major diversion dams and irrigation systems.

Water supplies generally are not as dependable for the small and scattered tracts of irrigated land that lie outside the Rio Grande Valley. Irrigation water for these lands

comes from the smaller streams originating in the mountains, and generally is available only in the spring or following periods of heavy rainfall.

The 16,000 acres of irrigated land is all within Sandoval County. Although this is a very small percentage of the total land area, it contributes much to the economy of the area. Wide varieties of crops are grown; however, many are of extremely limited acreage. Alfalfa, corn, and small grains, which are the principal crops, are grown on approximately 50 percent of the irrigated land.

Dryland farming, which was practiced to a limited extent in the western and northern parts of Sandoval County, has declined to the point that little land is now used for this purpose. Between 1920 and 1940, homesteaders settled in the more suitable parts of this area and acquired tracts of 320 to 640 acres on which they grew beans and corn successfully in some years. The low and erratic rainfall, however, made dryland farming extremely hazardous, and raising livestock gradually replaced the production of crops.

A high percentage of the land in this area is used for grazing livestock, and ranching is the principal type of agricultural enterprise. Livestock operations range from small flocks of sheep to medium-sized cow-calf-yearling operations.

Wildlife and recreation are also important land uses in this survey area. The high mountainous parts of this area, as well as adjacent foothills, provide good habitat for many species of wildlife and many opportunities for outdoor recreation such as camping, fishing, hunting, and other outdoor activities.

History of the Survey Area

The region has had continuous habitation since the Ice Age (Sandia Man Cave), and is presently the home of eight Indian pueblos.

Near Los Alamos, Bandelier National Monument is a spectacular open record of sporadic farming dating almost 3,000 years ago. In the next thousand years (nearly 2000 B.C.), a more established type of farming was taking place by people inhabiting the cave shelters of the canyon.

Further down river, the distinctive natural river crossing of the Rio Grande just north of the Sandia Mountains is the geographic crossroads of the area. North, south, east, and west traffic was centered in and around Bernalillo, which is now the County Seat of Sandoval County.

The first land to be settled by Spanish colonists in the winter of 1540 was near Bernalillo. Like the Pueblo Indians, they farmed the flat lands along the river and throughout the next century, settlers began establishing ranches there.

In the 1620s, the Spanish built mission churches in the Rio Grande pueblos. By 1680, there were 3,000 Spaniards in this region called New Spain, and ten times that many Indians. In 1680, the Indians rose up and drove the Spanish out of the valley back to Mexico, where they stayed for 15 years before returning to New Mexico.

Bernalillo was established as a village in 1695. Vineyards and orchards were planted and were an important industry in the central valley. Sheep ranching in the 18th and 19th centuries was an important occupation of the Spanish land grant families.

In 1848, General Kearney took possession of New Mexico for the United States. In 1849, Sandoval was called Santa Ana County and by 1852, another change established the county borders running across Arizona to the California line. In 1876, Santa Ana County was abolished and the area was annexed to Bernalillo County. In 1903, it was named Sandoval County for a prominent family in the area at the time. Finally on March 16, 1949, the County of Los Alamos was formed from portions of Sandoval and Santa Fe Counties.

In 1942, the Federal government purchased most of what is now Los Alamos County for use in developing the world's first atomic fission weapon. The Atomic

Energy Commission, predecessor to the Department of Energy, took control of Los Alamos Scientific Laboratory (LASL) in 1947. The area became an “open city” in 1957 when restrictive access was lifted. In 1980, the lab’s name was changed to Los Alamos National Laboratory (LANL). LANL continues to be one of the outstanding research centers of the world today, and operates in cooperation with the University of California.

In 2000, the population of Sandoval County was about 89,908 and that of Los Alamos County was about 18,343.

The Geology and Geomorphology of Sandoval County

The geology and geomorphology of Sandoval County is a complex area including portions of two major physiographic divisions. A portion of the northwestern corner of the county falls within the Rocky Mountain System major division, and more specifically within the Southern Rocky Mountains physiographic province. This area is characterized by complex mountains of various types and intermountain basins. The remainder of the county is included within the Intermontane Plateaus major division. Within this division are portions of the Colorado Plateaus physiographic province, Navajo and Datil sections; and the Basin and Range physiographic province, Mexican Highland section.

The Southern Rocky Mountain physiographic province includes the Jemez and Nacimiento mountains. The Nacimiento Mountains are the surface expression of the Nacimiento uplift and fault zone. The western edge of the Nacimiento Mountains is bordered by the westerly dipping Mesozoic rocks of the San Juan Basin. The Nacimiento uplift has been slightly overthrust to the west and formed a prominent hogback between the east edge of the San Juan Basin and the west edge of the uplift. The Nacimiento Fault escarpment extends north to south from northeast of Cuba to a point west of San Ysidro. Most of this escarpment is composed of Precambrian age granite. The granite is overlain by upper Paleozoic rocks in an irregular, 3 to 6 mile wide band along its eastern edge. These are in turn overlain by the younger deposits of volcanic flows and pyroclastics that form the broad based cone surrounding the Jemez volcanic center. The cone extends south to the Jemez Pueblo, and to the west bank of the Rio Grande.

The Jemez Mountains are the dominant physical feature in this area. These mountains were created through volcanic activity. The remnant volcanic caldera is one of the largest caldera features on the earth. Several resurgent domes have risen in the interior of the caldera with the largest cone rising to an elevation of 11,252 feet above sea level. Within the Jemez Mountains, large volumes of volcanic tuff and pumice are found. These materials represent two large eruptions that shaped the form of these mountains. Huge amounts of volcanic gases and ash representing 50 cubic miles of rock materials were ejected from the destroyed composite volcano. Ash clouds drifted as far north and east as Iowa. The welded ash known as the Bandelier Tuff was deposited by these eruptions. Geothermal springs are well represented in these mountains. The source of the hot water is shallow, hot rocks bearing evidence to the areas volcanic past.

The Colorado Plateau physiographic province covers the northwest portion of the county. This area is represented by the southeastern portion of the San Juan Basin. Tertiary aged rocks of the San Jose Formation and the Nacimiento Formation are found at the ground surface. These units consist of sandstone, siltstone, and claystone. Some of the clays have high shrink-swell potential. Some Cretaceous aged marine sandstones and shale are also found on the flanks of the San Juan Basin. Some of the marine deposited shale are quite thick and contribute to water quality issues due to the large amounts of salts found in these units.

The Navajo Section of the Colorado Plateau physiographic province is found in the southwest corner of the survey area. It is characterized by a young plateau with minor relief. The plateau is formed from Cretaceous aged marine sandstone and shale. The landforms represented include mesas and canyons with eroded shale plains. Exposures of underlying Triassic and Jurassic aged rocks are scattered across the area but generally concentrated on the western flanks of the Nacimiento Mountains. These exposures in some cases are the result of erosion of the overlying, relatively soft Cretaceous rocks, but more commonly due to the movement of deep seated faults. Volcanic necks and lava flows are found in the westernmost portion of this area. These Tertiary aged rocks and flows are scattered through the Rio Puerco valley. The western extent of these flows form Mesa Chivato. Cabezon Peak is the largest and best known volcanic neck in the region. Its prominent profile is due to the erosion of softer Cretaceous aged rocks that surround the more erosive resistant volcanic materials.

The Navajo Section is drained by the Rio Puerco. The river is deeply incised within the highly erosive silty to sandy soils. Some of the extent of the erosion was caused by relocation of the channel south of Cuba by the highway department. The relocation of the channel caused a shortening and steepening of the channel geomorphology. The result of these changes caused the river to downcut in excess of 20 feet in some areas. The remainder of the watershed was forced to adjust to the newly created base level. The result of this adjustment was large-scale erosion and the movement of extreme amounts of sediment down the Rio Puerco and into the Rio Grande.

The Basin and Range physiographic province located within Sandoval County is found in the southeast corner of the county. The Mexican Highland section is characterized by isolated mountain ranges separated by aggraded desert plains. From the southern and southeastern boundary of the Jemez volcanic deposits, the land surface is covered with the poorly indurated rocks of the Tertiary aged Santa Fe Group. These basin fill deposits are associated with materials moving from surrounding mountains and highlands and filling the down-dropped basins that formed the ancestral Rio Grande River corridor. The extreme southeastern corner of the survey includes the northern end of the Sandia Mountains. The Sandia Mountains are the uplifted portion of a massive fault block that exposes Precambrian aged granite to the west, and is capped with easterly dipping Pennsylvanian aged limestone and sandstone. Geologic hazards, including radon gas and collapsible soils, are associated with alluvial fans and channels draping off the flanks of the Sandia Mountains. The mode of deposition of much of the alluvial fans makes them favorable to the development of collapsible soils.

How This Survey Was Made

This survey was made to provide information about the soils and miscellaneous areas in the survey area. The information includes a description of the soils and miscellaneous areas and their location and a discussion of their suitability, limitations, and management for specified uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They dug many holes to study the soil profile, which is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

The soils and miscellaneous areas in the survey area are in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous

areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept or model of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Mapping Unit Composition

Soils in this survey area were mapped at two levels of detail. The detail of mapping in an area was selected based on the area's anticipated long term use.

At the most detailed level, mapping units are narrowly defined. Soil boundaries are plotted and verified at closely spaced intervals. Agricultural areas along the Rio Grande Valley were mapped at this level of detail.

Most of the survey area is used as rangeland, and mapping was performed at a less detailed level. The mapping units in this area are broadly defined. Soil boundaries were plotted and verified at widely spaced intervals. In general, these mapping units are less homogeneous and contain more minor soil components areas than the more detailed mapping units. These units are designed primarily for planning the management of large tracts of land as rangeland. They provide general information for development, but the information should be used with caution. Onsite investigation is essential to provide the detail needed for planning intensive land uses.

Climate

Prepared by the Natural Resources Conservation Service National Water and Climate Center, Portland, Oregon.

Climate tables are created from climate stations Cuba, Jemez Springs, Torreon Navajo Mission, and Wolf Canyon, New Mexico.

Thunderstorm days, relative humidity, percent sunshine, and wind information are estimated from First Order station in Albuquerque, New Mexico.

Table 1 gives data on temperature and precipitation for the survey area as recorded at these four climate stations in the period 1971 to 2000. Table 2 shows probable dates of the first freeze in fall and the last freeze in spring. Table 3 provides data on the length of the growing season.

In winter, average temperatures are 27.2, 34.9, 30.9 and 24.0 degrees F at Cuba, Jemez Springs, Torreon, and Wolf Canyon, respectively. Average daily minimum temperatures are 10.5, 21.5, 17.4, and 9.3 degrees, respectively. The lowest temperatures on record were -40 degrees at Cuba on February 1, 1951; and -18 degrees at Jemez Springs, -33 degrees at Torreon, and –36 degrees at Wolf Canyon, all on January 6, 1971.

In summer, average temperatures are 64.5, 70.1, 70.0, and 56.7 degrees, respectively, at Cuba, Jemez Springs, Torreon, and Wolf Canyon. Average daily maximum temperatures are 83.1, 86.8, 87.0, and 73.9 degrees, respectively. The highest temperatures ever recorded were 102 degrees at Cuba on July 3, 1953; 101 degrees at Jemez Springs on July 28, 1995; 107 degrees at Torreon on August 9, 1962; and 90 degrees at Wolf Canyon on July 11, 1958.

Growing degree days are shown in Table 1. They are equivalent to “heat units.” During the month, growing degree days accumulate by the amount that the average temperature each day exceeds a base temperature (40 degrees F). The normal monthly accumulation is used to schedule single or successive plantings of a crop between the last freeze in spring and the first freeze in fall.

Average annual total precipitation is variable across this soil survey area. In general, lower elevations, mostly in the south and west, receive between 8 and 12 inches of annual precipitation, while to the north amounts increase with elevation, and are generally between 11 and 18 inches. Elevations above 7,000 feet receive up to 30 inches or more, depending on slope and other factors. Average annual precipitation at these four stations is 12.57 inches at Cuba, 17.63 inches at Jemez Springs, 10.80 inches at Torreon, and 24.28 inches at Wolf Canyon (at 8,220 feet in elevation). Generally, about half of the annual precipitation falls between June and September at elevations below 7,500 feet, but in the higher mountainous elevations a greater percentage of precipitation falls as snow during the winter. The heaviest 1-day precipitation amounts during the periods of record were 2.25 inches at Cuba on October 31, 1998; 2.78 inches at Jemez Springs on October 16, 1960; 1.89 inches at

Torreon on August 15, 1994; and 3.35 inches at Wolf Canyon on July 25, 1962. Thunderstorms occur on about 40 days each year (with slightly more at the higher elevations), and most occur between May and September, with more than 22 in July and August.

Average seasonal snowfall over the area also is quite dependent on elevation and location relative to the mountains. Average annual snowfall is 27.6, 32.5, 20.5, and 128.1 inches, respectively, at Cuba, Jemez Springs, Torreon, and Wolf Canyon. The greatest snow depths at any one time during the periods of record were 22 inches at Cuba, recorded on December 20, 1967; 20 inches at Jemez Springs, on January 16, 1987; 16 inches at Torreon on March 22, 2000; and 46 inches at Wolf Canyon on February 2, 1979. On average, about 15 to 25 days per year have at least 1 inch of snow on the ground at lower elevations, while at higher elevations up to 90 days or more are snow-covered. For these four stations, number of days ranges from 18 at Cuba and Torreon, to 25 at Jemez Springs, and 96 days at Wolf Canyon. The heaviest 1-day snowfalls on record were 13.5 inches at Cuba, recorded on March 4, 1964; 19.8 inches at Jemez Springs on January 16, 1987; 14.0 inches at Torreon on March 21, 2000; and 26.0 at Wolf Canyon on January 16, 1987.

The average relative humidity in mid-afternoon is about 40 percent in the winter and between 15 and 20 percent in the summer. Humidity is higher at night, and the average at dawn is about 70 percent in the winter and 45 percent in the summer. The sun shines about 75 to 80 percent of the time in summer and around 65 to 70 percent in winter. The prevailing wind is from the northwest in the winter and early spring and from the south and southeast the remainder of the year. Average wind speed is highest, around 12 miles per hour, in April.

General Soil Map Unit Descriptions

The general soil map in this publication shows broad areas that have a distinctive pattern of soils, relief, and drainage. Each map unit on the general soil map is a unique natural landscape. Typically, it consists of one or more major soils or miscellaneous areas and some minor soils or miscellaneous areas. It is named for the major soils or miscellaneous areas. The components of one map unit can occur in another but in a different pattern.

The general soil map can be used to compare the suitability of large areas for general land uses. Areas of suitable soils can be identified on the map. Likewise, areas where the soils are not suitable can be identified.

Because of its small scale, the map is not suitable for planning the management of a farm or field or for selecting a site for a road or building or other structure. The soils in any one map unit differ from place to place in slope, depth, drainage, and other characteristics that affect management.

Soil Descriptions

Dry soils on plateaus and flood plains

This group consists of two map units and makes up about 9 percent of the survey area. The slopes range from 0 to 15 percent, but included areas range to 40 percent. The present vegetation consists of grass and shrubs. Elevation is 5,000 to 6,000 feet. The average annual precipitation is 8 to 10 inches; the average annual air temperature is 53 to 55 degrees F., and the average frost-free period is 140 to 160 days.

The soils in this group formed in alluvium and eolian material derived from sediment of mixed sources.

The soils in this group are used for irrigated farming, urban development, and wildlife habitat.

1. Gilco-Trail-Peralta

Very deep soils on the flood plain of the Rio Grande River

This map unit is in the east-central part of the survey area along the Rio Grande River. The slopes range from 0 to 4 percent. The native vegetation on this unit consists mainly of grasses and shrubs. Elevation is 5,000 to 6,000 feet. The average annual precipitation is 8 to 10 inches; the average annual air temperature is 53 to 55 degrees F., and the average frost-free period is 140 to 160 days.

This unit makes up about 3 percent of the survey area. It is about 34 percent Gilco and similar soils, 26 percent Trail and similar soils, and 15 percent Peralta soils. The remaining 25 percent is comprised of components of minor extent.

Gilco soils are on the flood plain of the Rio Grande River. These soils are very deep, moderately well drained, and moderately permeable. They formed in stream alluvium. The surface layer is brown loam about 4 inches thick. The underlying material is light yellowish brown stratified silt loam, loam, and fine sandy loam to a depth of 60 inches or more.

Trail soils are on the flood plain of the Rio Grande. These soils are very deep, moderately well drained, and moderately rapidly permeable. They formed in eolian material and stream alluvium. The surface layer is light yellowish brown fine sandy loam about 9 inches thick. The upper 27 inches of the underlying material is very pale brown loamy sand. The lower part is very pale brown sandy loam to a depth of 60 inches or more.

Peralta soils are on the flood plain of the Rio Grande. These soils are very deep, somewhat poorly drained, and moderately permeable. They formed in stream alluvium. The surface layer is brown loam about l0 inches thick. The underlying layer is stratified brown, light yellowish brown, pale brown, and yellowish brown very fine sandy loam, fine sandy loam, loamy sand, and loamy fine sand, with thin lenses of silt loam, and clay loam to a depth of 60 inches or more.

Other soils and miscellaneous areas in this unit are Jocity and Sparham soils and Riverwash along the Rio Grande channel.

This unit is used mainly for irrigated crops. It is also used for wildlife habitat, urban development, and livestock grazing. The hazard of soil blowing and seepage are the main limitations for most uses.

This unit supports a diversity of wildlife habitats, including riparian trees, river, and wetland; irrigated croplands, orchards, and rural residential.

Characteristic wildlife includes raccoon, striped skunk, cottontail rabbit, pocket gopher, mourning dove, pheasant, swallow, bullsnake, and woodhouse toad. The aquatic and wetland habitats support beaver, muskrat, and bullfrogs. This unit is an important migratory corridor for sandhill cranes, snow geese, and ducks.

2. Sheppard-Grieta

Very deep soils on dunes and ridges

This map unit is in the south-central part of the survey area. The slopes range from 1 to 15 percent. The vegetation on this unit consists mainly of grasses and shrubs. Elevation is 5,000 to 6,000 feet. The average annual precipitation is 8 to 10 inches; the average annual air temperature is 53 to 55 degrees F., and the average frost-free period is 140 to 160 days.

This unit makes up about 6 percent of the survey area. It is about 45 percent Sheppard soils and 43 percent Grieta soils. The remaining 12 percent is comprised of components of minor extent.

Sheppard soils are on dunes. These soils are very deep, somewhat excessively drained, and rapidly permeable. They formed in eolian sands. The surface layer is light brown loamy fine sand about 3 inches thick. The upper 24 inches of the underlying material is strong brown loamy fine sand. The lower part is pink loamy fine sand to a depth of 60 inches or more.

Grieta soils are on ridges. These soils are very deep, well drained, and moderately permeable. They formed in eolian material and fan alluvium. The surface layer is brown loamy fine sand about 7 inches thick. The subsoil is yellowish brown and pale brown sandy clay loam about 14 inches thick. The substratum is light yellowish brown, white, and very pale brown coarse sandy loam to a depth of 60 inches or more.

Other soils in this unit are Cascajo, Embudo, and Tijeras soils.

This unit is used mainly for urban development. It is also used for wildlife habitat and livestock grazing. A hazard of soil blowing due to the sandy surface layers is the main limitation to most uses. Vegetative cover aids in the control of soil blowing.

This unit furnishes a desert grassland wildlife habitat which has been heavily impacted by human activities. While the vegetative base is in fair or good condition, the habitat has been degraded.

Characteristic wildlife includes coyote, badger, kit fox, scaled quail, horned lark, western kingbird, collared lizard, and prairie rattlesnake.

Moist soils on valley floors, valley sides, plateaus, cuestas, and mesas

This group consists of 11 map units. It makes up about 82 percent of the survey area. The slopes range from 0 to 60 percent but may climb to 70 percent. The present vegetation consists of grass and trees. Elevation is dominantly 5,500 to 6,500 feet, but ranges from 5,000 to 7,500 feet. The average annual precipitation is 10 to 16 inches; the average annual air temperature is 48 to 54 degrees F., and the average frost-free period is 110 to 140 days.

The soils formed in alluvium, colluvium, and eolian materials derived from volcanic rocks, gypsum, limestone, sandstone, and shale.

This group is used for livestock grazing, fuel wood, and wildlife habitat.

3. Harvey-Cascajo-Ildefonso

Very deep soils on mesas, hills, and fan terraces

This map unit is in the eastern part of the survey area. The slopes range from 1 to 45 percent. The vegetation on this unit consists mainly of grasses and shrubs. Elevation is 6,300 to 6,500 feet. The average annual precipitation is 10 to 13 inches; the average annual air temperature is 52 to 54 degrees F.; and the average frost-free period is 120 to 140 days.

This unit makes up about 9 percent of the survey area. It is about 30 percent Harvey and similar soils, 23 percent Cascajo and similar soils, and 22 percent Ildefonso and similar soils. The remaining 25 percent is comprised of components of minor extent.

Harvey soils are on mesas. These soils are very deep, well drained, and moderately permeable. They formed in eolian material and fan alluvium. The surface layer is pinkish gray loam about 4 inches thick. The subsoil is pinkish gray loam about 6 inches thick. The upper 31 inches of the substratum is pinkish gray and pink clay loam. The lower part is reddish yellow sandy clay loam to a depth of 60 inches or more.

Cascajo soils are on hills. These soils are very deep, excessively drained, and rapidly permeable. They formed in fan alluvium. The surface layer is pale brown and very pale brown very gravelly sandy loam about 5 inches thick. The upper 6 inches of the underlying material is very pale brown very gravelly sandy loam. The next 19 inches is pale and light brown very gravelly loamy sand. The lower part is light brown extremely cobbly loamy sand to a depth of 60 inches or more.

Ildefonso soils are on fan terraces. These soils are very deep, well drained, and moderately rapidly permeable. They formed in colluvium and fan alluvium. The surface layer is brown cobbly loam about 2 inches thick. The subsoil is brown and pale brown very gravelly loam about 11 inches thick. The upper 27 inches of the substratum is very pale brown very cobbly sandy loam. The lower part is very pale brown extremely cobbly sand to a depth of 60 inches or more.

Other soils and miscellaneous areas in this unit are Skyvillage, Pastura, and Placitas soils, and Riverwash.

This unit is used mainly for livestock grazing. It is also used for wildlife habitat and urban development. Slope and droughtiness are the main limitations to most uses. Overgrazing is an important concern of management because it increases the risk of water erosion, and promotes an increase of undesirable plants.

This unit contains both desert grassland and juniper grassland wildlife habitats. There is little habitat diversity other than shrub thickets in the drainage ways.

Characteristic wildlife includes coyote, kit fox, blacktailed jackrabbit, kangaroo rat, spotted ground squirrel, horned lark, burrowing owl, scaled quail, striped whiptail lizard, bullsnake, and western rattlesnake.

4.Pinavetes-Clovis-Zia
Very deep soils on dunes, plains, alluvial fans, and stream terraces

This map unit is in the central part of the survey area. The slopes range from 1 to 35 percent. The vegetation on this unit consists mainly of grasses and shrubs with scattered trees. Elevation is 5,100 to 7,200 feet. The average annual precipitation is 10 to 13 inches. The average annual air temperature is 52 to 54 degrees F.; the average frost-free period is 120 to 140 days.

This unit makes up about 9 percent of the survey area. It is about 32 percent Pinavetes soils, 25 percent Clovis soils, and similar soils, and 23 percent Zia soils. The remaining 20 percent is comprised of components of minor extent.

Pinavetes soils are on dunes. These soils are very deep, excessively drained, and rapidly permeable. They formed in eolian sands derived dominantly from sandstone. The surface layer is light yellowish brown loamy sand about 10 inches thick. The underlying material is light yellowish brown sand to a depth of 60 inches or more.

Clovis soils are on plains. These soils are very deep, well drained, and moderately permeable. They formed in eolian material and slope alluvium. The surface layer is pale brown fine sandy loam about 3 inches thick. The subsoil is brown sandy clay loam about 19 inches thick. The substratum is light brown and reddish yellow sandy clay loam to a depth of 60 inches or more.

Zia soils are on alluvial fans and stream terraces. These soils are very deep, well drained, and moderately rapidly permeable. They formed in eolian material and fan and stream alluvium. The surface layer is pale brown sandy loam about 5 inches thick. The upper 9 inches of the underlying material is pale brown sandy loam. The lower part is light gray, very pale brown, and light yellowish brown sandy loam and sandy clay loam to a depth of 60 inches or more.

Other soils and miscellaneous areas in this unit are Sandoval and Skyvillage soils, Rock outcrop, and Riverwash.

This unit is used mainly for livestock grazing. It is also used for wildlife habitat and urban development. Soil blowing is the main limitation for most uses. Overgrazing is an important concern of management because it increases the risk of soil blowing and promotes an increase in undesirable plants.

This unit consists of desert shrub, and desert grassland wildlife habitat is interspersed by thin shrub thickets along drainageways. Habitats have been rated as fair for pronghorn and poor for mule deer.

Characteristic wildlife include coyote, kit fox, pronghorn antelope, blacktailed jackrabbit, spotted ground squirrel, horned lark, prairie falcon, meadowlark, horned lizard, bullsnake, and prairie rattlesnake.

5. Sparank
Very deep soils on alluvial fans

This map unit is in the west-central part of the survey area. The slopes range from 0 to 3 percent. The vegetation on this unit consists mainly of grasses and shrubs. Elevation is 5,500 to 6,400 feet. The average annual precipitation is 10 to 13 inches; the average annual air temperature is 52 to 54 degrees F., and the average frost-free period is 120 to l40 days.

This unit makes up about 3 percent of the survey area. It is about 82 percent Sparank and similar soils. The remaining 18 percent is comprised of components of minor extent.

Sparank soils are on alluvial fans. These soils are very deep, well drained, and very slowly permeable. They formed in stream alluvium. The surface layer is brown clay loam about 2 inches thick. The upper 22 inches of the underlying material is brown silty clay. The lower part is pale brown and dark grayish brown silty clay and silty clay loam to a depth of 60 inches or more.

Other soils and miscellaneous areas in this unit are Orlie, Pinavetes, and Zia soils, and Riverwash.

This unit is used mainly for livestock grazing. It is also used for wildlife habitat, irrigated crops, and urban development. A hazard of flooding, slow permeability, and gullying are the main limitations for most uses. Overgrazing is an important concern of management because it increased the risk of flooding and gullying and promotes an increase in undesirable plants.

This unit consists of valley and bottomland grasslands wildlife habitats which are mostly in poor vegetative condition. Diversity of vegetation is provided by seasonal streamflow, wetlands, salt flats, and scattered thickets of trees or shrubs.

Characteristic wildlife includes blacktailed jackrabbit, pocket gopher, prairie dog, scaled quail, sandpiper, woodhouse toad, and garter snake.

6. Rock outcrop-Frijoles-Hackroy

Rock outcrop and deep to shallow soils on narrow mesas and plateaus formed from tuff and pumice

This map unit is in the northeastern part of the survey area. The slopes range from 1 to 8 percent. The vegetation consists mainly of pinyon and juniper. Elevation is 6,000 to 7,500 feet. The average annual precipitation is 13 to 16 inches; the average annual air temperature is 48 to 52 degrees F.; and the average frost-free period is 110 to 130 days.

This unit makes up about 3 percent of the survey area. It is about 52 percent Rock outcrop, 14 percent Frijoles soils, and 14 percent Hackroy soils. The remaining 20 percent is comprised of components of minor extent.

Rock outcrop is found on the edges and sides of mesas.

Frijoles soils are on mesas. These soils are deep, well drained, and moderately permeable. They formed in eolian material and alluvium. The surface layer is brown very fine sandy loam about 3 inches thick. The subsoil is brown very gravelly clay loam about 10 inches thick. The upper 7 inches of the substratum is pinkish gray extremely gravelly sandy loam. The lower part is pinkish white pumice pebbles to a depth of 60 inches or more.

Hackroy soils are on plateaus. These soils are very shallow or shallow, well drained, and slowly permeable. They formed in residuum. The surface layer is brown sandy loam about 3 inches thick. The subsoil is reddish brown clay about 10 inches thick. Tuff is at a depth of 13 inches.

Other soils in this unit are Hagerman, Nyjack, Penistaja, and Totavi.

This unit is used mainly for wildlife habitat. It is also used for urban development. Depth to tuff and pumice are the main limitations for most uses.

This unit contains a complex of wildlife habitat types. The valley is a combination of juniper grassland and shrub-forb grassland. Upslope there are valuable browse plants such as oak, sumac, saltbush, and sagebrush. There are pinyon-juniper woodlands on mesa tops and northern slopes. Stringers of ponderosa pine follow drainages and eastern slopes at higher elevations.

Characteristic wildlife includes mountain cottontail, coyote, woodrat, valley pocket gopher, scrub jay, raven, fence lizard, and western diamondback rattlesnake. The band-tailed pigeon uses this unit when foraging for oak acorns and pinyon nuts. The prominent rock outcrops furnish habitat for the ringtail, bats, and several hawks.

7. Bamac-Espiritu-Cochiti

Very deep soils on fan remnants, mountain slopes, and fan terraces

This map unit is in the east-central part of the survey area. The slopes range from 1 to 50 percent. The vegetation on this unit consists mainly of pinyon and juniper with an understory of grasses and shrubs. Elevation is 5,400 to 6,500 feet. The average

annual precipitation is 13 to 16 inches; the average annual air temperature is 48 to 52 degrees F.; and the average frost-free period is 110 to 130 days.

This unit makes up about 5 percent of the survey area. It is about 38 percent Bamac, 30 percent Espiritu and similar soils, and 13 percent Cochiti and similar soils. The remaining 19 percent is comprised of components of minor extent.

Bamac soils are on fan remnants. These soils are very deep, excessively drained, and very rapidly permeable. They formed in slope and fan alluvium. The surface layer is light yellowish brown very gravelly loamy sand about 4 inches thick. The upper 6 inches of the underlying material is light yellowish brown loamy sand. The lower part is very pale brown, pale brown, and pink very gravelly loamy coarse sand to a depth of 60 inches or more.

Espiritu soils are on mountain slopes. These soils are very deep, well drained, and moderately permeable. They formed in slope alluvium and colluvium. The surface layer is brown very gravelly fine sandy loam about 6 inches thick. The subsoil is brown and light brown very gravelly sandy clay loam about 16 inches thick. The substratum is stratified pale brown, strong brown, and reddish yellow very cobbly sandy clay loam, fine sandy loam, and very gravelly sandy loam to a depth of 60 inches or more.

Cochiti soils are on fan terraces. These soils are very deep, well drained, and slowly permeable. They formed in gravelly alluvium. The surface layer is dark yellowish brown gravelly loam about 7 inches thick. The upper 13 inches of the subsoil is reddish brown gravelly clay loam and very gravelly clay. The lower 9 inches is light reddish brown very gravelly clay loam. The substratum is light reddish brown very gravelly sandy loam to a depth of 60 inches or more.

Other soils and miscellaneous areas in this unit are Elpedro, Flugle, and Montecito soils, and Rock outcrop.

This unit is used mainly for livestock grazing. It is also used for wildlife habitat and fuel wood production. A hazard of droughtiness, slope, and sandy surface layer are the main limitations for most uses. Overgrazing is an important concern of management because it increases the risk of water erosion and promotes an increase in undesirable plants.

This unit provides pinyon-juniper wildlife habitat which furnishes winter range for elk and mule deer.

Characteristic wildlife includes coyote, gray fox, rock squirrel, pinyon jay, plain titmouse, redtail hawk, short horned lizard, and blacktailed rattlesnake.

8. Silver-Ildefonso-Clovis

Very deep soils on mesas, fan terraces, and plains

This map unit is in the central part of the survey area. The slopes range from 1 to 15 percent. The vegetation on this unit consists mainly of grasses and shrubs. Elevation is 5,600 to 7,300 feet. The average annual precipitation is 10 to 13 inches; the average annual air temperature is 52 to 54 degrees F.; and the average frost-free period is 120 to 140 days.

This unit makes up about 8 percent of the survey area. It is about 43 percent Silver and similar soils, 20 percent Ildefonso and similar soils, and 19 percent Clovis and similar soils. The remaining 18 percent is comprised of components of minor extent.

Silver soils are on mesas. These soils are very deep, well drained, and slowly permeable. They formed in eolian material and slope alluvium. The surface layer is pale brown loam about 4 inches thick. The upper 16 inches of the subsoil is light brown and brown silty clay loam. The lower 19 inches is brown clay loam. The substratum is brown clay loam to a depth of 60 inches or more.

Ildefonso soils are on fan terraces. These soils are very deep, well drained, and moderately rapidly permeable. They formed in fan alluvium and colluvium derived from basalt. The surface layer is brown cobbly loam about 2 inches thick. The subsoil

is brown and pale brown very gravelly loam about 11 inches thick. The substratum is very pale brown very cobbly sandy loam and extremely cobbly sand to a depth of 60 inches or more.

Clovis soils are on plains. These soils are very deep, well drained, and moderately permeable. They formed in eolian material and slope alluvium. The surface layer is pale brown fine sandy loam about 3 inches thick. The subsoil is brown sandy clay loam about 19 inches thick. The substratum is light brown and reddish yellow sandy clay loam to a depth of 60 inches or more.

Other soils and miscellaneous areas in this unit are Sandoval, Orejas, and Prieta soils, and Rock outcrop.

This unit is used for livestock grazing. It is also used for wildlife habitat. Overgrazing is an important concern of management because of the increase in undesirable plants.

This unit consists of a mesa grassland wildlife habitat.

Characteristic wildlife includes coyote, blacktailed jackrabbit, ground squirrel, least chipmunk, prairie falcon, golden eagle, and bullsnake.

9. Royosa-Fragua

Very deep soils on dunes and fan remnants

This map unit is in the central part of the survey area. The slopes range from 1 to 8 percent. The vegetation on this unit consists mainly of pinyon and juniper with a grass understory. Elevation is 5,600 to 6,200 feet. The average annual precipitation is 13 to 16 inches; the average annual air temperature is 48 to 52 degrees F. and the average frost-free period is 110 to 130 days.

This unit makes up about 6 percent of the survey area. It is about 60 percent Royosa and similar soils and 35 percent Fragua and similar soils. The remaining 5 percent is comprised of components of minor extent.

Royosa soils are on dunes. These soils are very deep, somewhat excessively drained, and very rapidly permeable. They formed in eolian sands. The surface layer is very pale brown sand about 5 inches thick. The underlying material is brown and brownish yellow sand and loamy sand to a depth of 60 inches or more.

Fragua soils are on fan remnants. These soils are very deep, well drained, and moderately rapidly permeable. They formed in fan alluvium and eolian material derived from sandstone. The surface layer is brown loamy sand about 3 inches thick. The subsoil is brown sandy loam about 21 inches thick. The substratum is brown sandy loam to a depth of 60 inches or more.

Other soils and miscellaneous areas in this unit are San Mateo soils and Rock outcrop.

This unit is used mainly for livestock grazing. It is also used for wildlife habitat and fuel wood production. A hazard of droughtiness, soil blowing, and a sandy surface layer are the main limitations for most uses. Overgrazing is an important concern of management because it increases the risk of soil blowing and promotes an increase in undesirable plants.

This unit provides juniper grassland and pinyon-juniper woodland wildlife habitats. Habitat condition is low and provides poor winter range for elk and mule deer.

10. Blancot-Badland-Councelor

Very deep soils and Badland on valley sides and stream terraces

This map unit is in the northwestern part of the survey area. The slopes range from 1 to 8 percent. The vegetation on this unit consists mainly of grasses and shrubs with widely scattered trees. Elevation is 6,600 to 7,000 feet. The average annual precipitation is 10 to 13 inches; the average annual air temperature is 48 to 52 degrees F.; and the average frost-free period is 120 to 140 days.

This unit makes up about 5 percent of the survey area. It is about 31 percent Blancot and similar soils, 25 percent Badland, and 20 percent Councelor soils. The remaining 24 percent is comprised of components of minor extent.

Blancot soils are on valley sides. These soils are very deep, well drained, and moderately slowly permeable. They formed in fan alluvium. The surface layer is pale brown fine sandy loam about 2 inches thick. The subsoil is grayish brown and yellowish brown clay loam about 21 inches thick. The substratum is pale brown and light brownish gray sandy loam with thin strata of silty clay loam to a depth of 60 inches or more.

Badland areas are on ridges and side slopes. They are derived from shale.

Councelor soils are on stream terraces. These soils are very deep, well drained, and moderately rapidly permeable. They formed in eolian material and stream alluvium. The surface layer is pale brown fine sandy loam about 2 inches thick. The upper 35 inches of the underlying material is pale brown fine sandy loam. The next 3 inches is pale brown clay loam. The lower part is pale brown sandy loam to a depth of 60 inches or more.

Other soils in this unit are Doakum, Mespun, Tsosie, and Lybrook soils.

This unit is used mainly for livestock grazing. It is also used for wildlife habitat. A hazard of soil blowing, gullying, and water erosion are the main limitations for most uses. Overgrazing is an important concern of management because it increases the risk of soil blowing and gullying and promotes an increase of undesirable plants.

This unit provides a grassland wildlife habitat of low rating.

Characteristic wildlife includes coyote, prairie dog, pocket gopher, blacktailed jackrabbit, burrowing owl, horned lark, meadowlark, horned lizard, and western toad.

11. Sandoval-Querencia-Zia

Shallow and very deep soils on ridges, alluvial fans, and stream terraces

This map unit is in the west-central part of the survey area. The slopes range from 1 to 30 percent. The vegetation on this unit consists mainly of grasses and shrubs. Elevation is 5,100 to 7,000 feet. The average annual precipitation is 10 to 13 inches; the average annual air temperature is 52 to 54 degrees F.; and the average frost-free period is 120 to 140 days.

This unit makes up about 20 percent of the survey area. It is about 31 percent Sandoval and similar soils, 27 percent Querencia and similar soils, and 17 percent Zia and similar soils. The remaining 25 percent is comprised of components of minor extent.

Sandoval soils are on ridges. These soils are shallow, well drained, and moderately slowly permeable. They formed in slope alluvium. The surface layer is light yellowish brown fine sandy loam about 2 inches thick. The upper 4 inches of the underlying material is light gray clay loam. The lower part is light brownish gray clay loam to a depth of 15 inches. Shale is at a depth of 15 inches.

Querencia soils are on alluvial fans. These soils are very deep, well drained, and moderately permeable. They formed in fan alluvium and colluvium. The surface layer is light brownish gray sandy clay loam about 4 inches thick. The upper 8 inches of the subsoil is light yellowish brown clay loam. The lower 12 inches is pale yellow loam. The substratum is pale yellow loam to a depth of 60 inches or more.

Zia soils are on stream terraces and alluvial fan. These soils are very deep, well drained, and moderately rapidly permeable. They formed in eolian material and fan and stream alluvium. The surface layer is pale brown sandy loam about 5 inches thick. The underlying material is pale brown, light gray, very pale brown, and light yellowish brown sandy loam and sandy clay loam to a depth of 60 inches or more.

Other soils and miscellaneous areas in this unit are Saido, Camino, Winona, San Mateo, and Sparank soils, and Rock outcrop.

This unit is used mainly for livestock grazing. It is also used for wildlife habitat. The hazard of soil blowing and water erosion are the main limitations for most uses. Overgrazing is an important concern of management because it increases the hazard of soil blowing and water erosion and promotes an increase of undesirable plants.

This unit furnishes a grassland wildlife habitat with shrubs located in drainages and on eroded areas. There is a herd of pronghorn antelope located east of Cabezon Peak. Overall pronghorn antelope habitat has been rated as low. An important migration route for elk and mule deer lies between Sierra Nacimiento and La Ventana Mesa.

Characteristic wildlife includes pronghorn antelope, blacktailed jackrabbit, coyote, kangaroo rat, prairie dog, horned lark, raven, ferruginous hawk, and golden eagle.

12. Menefee-Vessilla-Orlie

Shallow and very deep soils on hillslopes, mesas, and cuestas

This map unit is in the western and northwestern parts of the survey area. The slopes range from 2 to 60 percent. The vegetation consists mainly of pinyon and juniper. Elevation is 6,500 to 8,000 feet. The average annual precipitation is 13 to 16 inches; the average annual air temperature is 48 to 52 degrees F.; and the frost-free period is 110 to 130 days.

This unit makes up about 12 percent of the survey area. It is about 26 percent Menefee and similar soils, 25 percent Vessilla and similar soils, and 25 percent Orlie and similar soils. The remaining 24 percent is comprised of components of minor extent.

Menefee soils are on hillslopes. These soils are shallow, well drained, and slowly permeable. They formed in colluvium and residuum. The surface layer is light yellowish brown clay loam about 5 inches thick. The underlying material is light olive brown and light brownish gray clay loam to a depth of 17 inches. Shale is at a depth of 17 inches.

Vessilla soils are on structural benches and mesas. These soils are shallow or very shallow, well drained, and moderately rapidly permeable. They formed in eolian material, slope alluvium and residuum. The surface layer is light yellowish brown gravelly fine sandy loam about 2 inches thick. The underlying material is light brown gravelly fine sandy loam about 9 inches thick. Sandstone is at a depth of 11 inches.

Orlie soils are on cuestas. These soils are very deep, well drained, and moderately slowly permeable. They formed in fan alluvium and eolian material. The surface layer is pale brown loam about 2 inches thick. The subsoil is brown clay loam about 20 inches thick. The substratum is pale brown and brown silty clay loam and clay loam to a depth of 60 inches or more.

Other soils and miscellaneous areas in this unit are Sparham, Teco, and Wauquie soils, Rock outcrop, and Badland.

This unit is used mainly for livestock grazing. It is also used for wildlife habitat and fuel wood production. Shallow soil depth, water erosion hazard and slope are the main limitations for most uses. Overgrazing is an important concern of management because it increases the risk of water erosion and gullying and promotes an increase in undesirable plants.

This unit occurs as widely scattered wildlife habitats dominated by pinyon-juniper woodland, but also including rocky areas. Shrubs may be an important habitat component. Sources of water may be scarce in dry years.

Characteristic wildlife includes mule deer, bobcat, porcupine, mountain cottontail, woodrat, scrub jay, junco, Cooper's hawk, brown towhee, and blacktailed rattlesnake.

13. Doakum-Betonnie
Very deep soils on hills

This map unit is in the northwestern part of the survey area. The slopes range from 0 to 8 percent. The vegetation consists mainly of grasses and shrubs with scattered trees. Elevation is 6,600 to 7,000 feet. The average annual precipitation is 10 to 13 inches; the average annual air temperature is 48 to 52 degrees F.; the average frost-free period is 110 to 130 days.

This unit makes up about 2 percent of the survey area. It is about 55 percent Doakum soils, and 35 percent Betonnie soils. The remaining 10 percent is components of minor extent.

Doakum soils are on hills. These soils are very deep, well drained and moderately permeable. They formed in eolian material and slope alluvium. The surface layer is light yellowish brown fine sandy loam about 5 inches thick. The subsoil is brown clay loam and sandy clay loam about 19 inches thick. The substratum to a depth of 60 inches or more is very pale brown loam and clay loam.

Betonnie soils are on hills. These soils are very deep, well drained, and moderately rapidly permeable. They formed in eolian material and slope alluvium. The surface layer is light yellowish brown fine sandy loam about 2 inches thick. The subsoil is brown fine sandy loam and sandy loam about 16 inches thick. The substratum to a depth of 60 inches or more is yellowish brown and pale brown sandy loam.

Other soils in this unit are Blancot, Eslendo, and Mespun soils.

This unit is used mainly for livestock grazing. It is also used for wildlife habitat. Overgrazing is an important concern of management because it increases the risk of soil blowing and gullying and promotes an increase of undesirable plants.

This unit of desert shrub and desert grassland wildlife habitat is interspersed by thin shrub thickets along drainageways. Habitats have been rated as fair for pronghorn antelope and poor for mule deer.

Characteristic wildlife include coyote, kit fox, pronghorn antelope, blacktailed jackrabbit, spotted ground squirrel, horned lark, prairie falcon, meadowlark, horned lizard, bullsnake, and prairie rattlesnake.

Moist, cold soils on mountain slopes and mountain valleys

This group consists of 2 units. It makes up about 9 percent of the survey area. The slopes range from 1 to 80 percent. The present vegetation consists of mountain grasses and trees. Elevation is 8,000 to 11,000 feet, but included areas range only to 7,500 feet. The average annual precipitation is 20 to 30 inches; the average annual air temperature is 38 to 45 degrees F.; and the average frost-free period is 45 to 90 days.

The soils formed in alluvium and colluvium derived dominantly from tuff and rhyolite.

This group is used for livestock grazing, timber production, and wildlife habitat.

14. Cosey-Jarmillo-Tranquilar
Very deep soils on mountain slopes and stream terraces

This map unit is in the northern part of the survey area. The slopes range from 1 to 20 percent. The vegetation on this unit consists mainly of grasses and shrubs. Elevation is 8,000 to 9,200 feet. The average annual precipitation is 20 to 25 inches; the average annual air temperature is 42 to 45 degrees F.; and the average frost-free period is 60 to 90 days.

This unit makes up about 2 percent of the survey area. It is about 30 percent Cosey and similar soils, 24 percent Jarmillo and similar soils, and 21 percent Tranquilar soils. The remaining 25 percent is components of minor extent.

Cosey soils are on mountain slopes. These soils are very deep, well drained and moderately slowly permeable. They formed in slope alluvium and colluvium. The

surface layer is dark grayish brown and grayish brown silt loam about 15 inches thick. The upper 13 inches of the subsoil is very pale brown gravelly loam. The lower subsoil to 60 inches or more is very pale brown very gravelly sandy clay loam over light brown extremely cobbly clay loam.

Jarmillo soils are on stream terraces. These soils are very deep, well drained, and moderately permeable. They formed in lacustrine sediments, alluvium and colluvium. The surface layer is dark grayish brown loam about 13 inches thick. The subsoil is grayish brown, light brownish gray, very pale brown, light yellowish brown and white loam, fine sandy loam, clay loam, and very fine sandy loam to a depth of 60 inches or more.

Tranquilar soils are on stream terraces. These soils are very deep, somewhat poorly drained, and very slowly permeable. They formed in clayey lacustrine deposits. The surface layer is dark grayish brown silty clay loam about 8 inches thick. The subsurface layer is gray and light gray silty clay loam about 5 inches thick. The upper 21 inches of the subsoil is very dark grayish brown and dark grayish brown clay. The lower subsoil to a depth of 60 inches or more is light yellowish brown and light gray clay.

Other soils in this unit are Cajete, Jarola, and Vastine soils.

This unit is used mainly for livestock grazing. It is also used for wildlife habitat. Short growing period and somewhat poor drainage are the main limitations to use.

This unit consists of a mountain meadow wildlife habitat. There are permanent streams which support trout. This is an important late winter range for elk. Characteristic wildlife includes northern pocket gopher, least chipmunk, meadow mole, garter snake, leopard frog, and tiger salamander.

15. Redondo-Palon-Calaveras

Very deep soils on mountain slopes

This map unit is in the northern part of the survey area. The slopes range from 5 to 80 percent. The vegetation on this unit consists mainly of trees. Elevation is 8,500 to 11,000 feet. The average annual precipitation is 25 to 30 inches; the average annual air temperature is 38 to 42 degrees F.; and the average frost-free period is 45 to 60 days.

This unit makes up about 7 percent of the survey area. It is about 33 percent Redondo and similar soils, 23 percent Palon and similar soils, and 22 percent Calaveras and similar soils. The remaining 22 percent is comprised of components of minor extent.

Redondo soils are on mountain slopes. These soils are very deep, well drained, and moderately rapidly permeable. They formed in colluvium. The surface layer is grayish brown coarse sandy loam about 2 inches thick. The subsurface layer is light brownish gray and light gray coarse sandy loam about 13 inches thick. The upper 7 inches of the subsoil is pink coarse sandy loam. The lower subsoil is light gray and light brown gravelly coarse sandy loam, very gravelly coarse sandy loam, extremely gravelly coarse sandy loam, and extremely cobbly coarse sandy loam to a depth of 60 inches or more.

Palon soils are on mountain slopes. They formed in colluvium and slope alluvium. These soils are very deep, well drained, and moderately rapidly permeable. The surface layer is dark gray and light brownish gray very cobbly sandy loam and extremely cobbly sandy loam about 8 inches thick. The subsurface layer is light gray extremely cobbly sandy loam about 22 inches thick. The subsoil is pink very cobbly sandy loam with light brown sandy clay loam lamellae to a depth of 60 inches or more.

Calaveras soils are on mountain slopes. These soils are very deep, well drained, and moderately permeable. They formed in colluvium. The surface layer is grayish brown and pale brown silt loam about 11 inches thick. The upper 19 inches of the

subsoil is pale brown gravelly silt loam and very cobbly loam. The lower part is light brown extremely cobbly coarse sandy loam and extremely cobbly loamy sand to a depth of 60 inches or more.

Other soils and miscellaneous areas in this unit are Cypher, Osha, Sedmar, Tocal, and Totavi soils, Rubble land, and Rock outcrop.

This unit is used mainly for timber production. It is also used for wildlife habitat. The slopes are the main limitation for most uses.

This unit furnishes montane conifer forest wildlife habitats. The endangered Jemez Mountain Salamander is found within drainages containing volcanic talus.

Characteristic wildlife includes elk, mule deer, black bear, tassel eared and red squirrel, sapsucker, hairy woodpecker, and Clark's nutcracker.

Detailed Soil Map Units

The map units delineated on the detailed soil maps in this survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions in this section, along with the maps, can be used to determine the suitability and potential of a unit for specific uses. They also can be used to plan the management needed for those uses.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. The contrasting components are mentioned in the map unit descriptions. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives the principal hazards and limitations to be considered in planning for specific uses.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown

on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Sparham clay loam is a phase of the Sparham series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Flugle-Waumac complex, 1 to 8 percent slopes is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Orlie-Sparham association, 0 to 5 percent slopes is an example.

This survey includes *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Riverwash is an example.

Table 4 gives the acreage and proportionate extent of each map unit. Other tables give properties of the soils and the limitations, capabilities, and potentials for many uses. The *Glossary* defines many of the terms used in describing the soils or miscellaneous areas.

1—Silver-Clovis loams, 1 to 7 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,600 to 7,300 feet (1,707 to 2,225 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Silver and similar soils: 55 percent
Clovis and similar soils: 35 percent
Minor components: 10 percent

Component Descriptions

Silver soils
Landscape: Uplands
Landform: Mesas, plateaus, hills, fan remnants
Position on landform: Toeslopes
Position on landform: Side slope
Parent material: Eolian deposits over slope alluvium derived from sandstone and shale
Slope: 1 to 7 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 11.7 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low

Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, spike muhly, needlegrass, winterfat
Land capability subclass (irrigated): 4e
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 4 inches; loam
Bt1—4 to 8 inches; silty clay loam
Bt2—8 to 20 inches; silty clay loam
Bt3—20 to 39 inches; clay loam
C—39 to 60 inches; clay loam

Clovis soils
Landscape: Uplands
Landform: Fan remnants, plains
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits over slope alluvium derived from sandstone and shale
Slope: 1 to 7 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.6 inches (high)
Shrink-swell potential: About 3.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, bottlebrush squirreltail
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; loam
Bt—3 to 20 inches; clay loam
Bk1—20 to 40 inches; sandy clay loam
Bk2—40 to 60 inches; fine sandy loam

Minor Components
Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Prieta and similar soils
Composition: About 5 percent
Slope: 1 to 7 percent

Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Malpais

2—Clovis-Prieta-Silver association, 3 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,600 to 7,300 feet (1,707 to 2,225 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Clovis and similar soils: 35 percent
Prieta and similar soils: 35 percent
Silver and similar soils: 20 percent
Minor components: 10 percent

Component Descriptions

Clovis soils
Landscape: Uplands
Landform: Fan remnants, plains
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits over slope alluvium derived from sandstone and shale
Slope: 3 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.6 inches (high)
Shrink-swell potential: About 2.6 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, bottlebrush squirreltail
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; loam
Bt—3 to 24 inches; clay loam
Bk—24 to 60 inches; fine sandy loam

Prieta soils
Landscape: Plains
Landform: Mesas, lava flows
Position on landform: Footslopes

Position on landform: Side slope
Parent material: Eolian deposits over slope alluvium derived from basalt
Slope: 3 to 15 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 1.8 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 14 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Malpais
Potential native vegetation: blue grama, alkali sacaton, hairy grama, little bluestem, sideoats grama, black grama, spike muhly, wolftail
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; very stony loam
Bt1—3 to 10 inches; very stony clay loam
Bt2—10 to 14 inches; very stony clay loam
Bk—14 to 19 inches; very stony clay loam
R—19 to 60 inches; bedrock

Silver soils
Landscape: Plains
Landform: Fan remnants, hills, mesas, plateaus
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Eolian deposits over slope alluvium derived from sandstone and shale
Slope: 3 to 8 percent
Aspect: East to west
Shape (down/across): Concave/linear
Surface fragments: About 2 percent subrounded cobbles, about 2 percent subrounded gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 11.6 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, spike muhly, bottlebrush squirreltail, needlegrass, winterfat
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 8 inches; loam
Bt—8 to 30 inches; silty clay loam
C—30 to 60 inches; silty clay loam

Minor Components
Rock outcrop
Composition: About 10 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

3—Montecito-Orejas complex, 1 to 7 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,800 to 7,600 feet (2,073 to 2,316 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Montecito and similar soils: 60 percent
Orejas and similar soils: 30 percent
Minor components: 10 percent

Component Descriptions

Montecito soils
Landscape: Uplands
Landform: Plains, mesas, hills
Position on landform: Summits
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone and shale
Slope: 1 to 7 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 11.6 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: twoneedle pinyon, oneseed juniper
Other plants: blue grama, bottlebrush squirreltail, muttongrass
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 3 inches; fine sandy loam
Bt—3 to 18 inches; clay loam
2Bk—18 to 60 inches; clay loam

Orejas soils
Landscape: Uplands
Landform: Plateaus, mesas
Position on landform: Summits
Position on landform: Side slope
Parent material: Eolian deposits over colluvium and/or slope alluvium derived from sandstone and shale
Slope: 1 to 7 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 30 percent subrounded cobbles
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 1.9 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: twoneedle pinyon, oneseed juniper
Other plants: big sagebrush, blue grama, sideoats grama, oneseed juniper, twoneedle pinyon
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 2 inches; cobbly loam
Bt1—2 to 5 inches; very cobbly clay loam
Bt2—5 to 14 inches; very cobbly clay loam
Bt3—14 to 17 inches; very cobbly clay loam
C—17 to 19 inches; very gravelly clay loam
R—19 to 60 inches; bedrock

Minor Components
Rock outcrop
Composition: About 10 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

4—Montecito complex, 3 to 30 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 7,000 feet (1,829 to 2,134 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)

Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Montecito and similar soils: 45 percent
Montecito, bouldery and similar soils: 35 percent
Minor components: 20 percent

Component Descriptions

Montecito soils
Landscape: Uplands
Landform: Hills, mesas, plains
Position on landform: Summits
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone and shale
Slope: 3 to 30 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.5 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: twoneedle pinyon, oneseed juniper
Other plants: blue grama, bottlebrush squirreltail, muttongrass
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 3 inches; fine sandy loam
Bt—3 to 22 inches; clay loam
2Bk—22 to 60 inches; loam

Montecito, bouldery soils
Landscape: Uplands
Landform: Hills, mesas, plains
Position on landform: Summits
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone and shale
Slope: 3 to 30 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.3 inches (high)
Shrink-swell potential: About 3.7 percent (moderate)
Runoff class: Medium

Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: twoneedle pinyon, oneseed juniper
Other plants: big sagebrush, Gambel oak, blue grama, bottlebrush squirreltail, broom snakeweed, muttongrass, pingue rubberweed, sideoats grama
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 5 inches; extremely bouldery loam
Bt—5 to 28 inches; clay loam
2Bk1—28 to 45 inches; loam
2Bk2—45 to 60 inches; sandy loam

Minor Components

Rock outcrop
Composition: About 10 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Vessilla and similar soils
Composition: About 5 percent
Slope: 3 to 30 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

Sandoval and similar soils
Composition: About 5 percent
Slope: 3 to 30 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

10—Trail silty clay loam, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Trail and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Trail soils
Landscape: Valleys
Landform: Channels, valley floor remnants, flood plains, alluvial fans
Position on landform: Toeslopes
Position on landform: Base slope, rise
Parent material: Eolian deposits over stream alluvium derived from sandstone
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Concave, linear/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 4.9 inches (low)
Shrink-swell potential: About 1.6 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Very low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: alkali sacaton, giant sacaton, fourwing saltbush
Land capability subclass (irrigated): 4e
Land capability subclass (nonirrigated): 7s

Typical Profile:
Ap—0 to 6 inches; silty clay loam
C1—6 to 30 inches; stratified loamy sand to sandy loam
C2—30 to 45 inches; sand
C3—45 to 60 inches; loamy fine sand

Minor Components
Aga and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

11—Trail fine sandy loam, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)

Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Trail and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Trail soils
Landscape: Valleys
Landform: Alluvial fans, channels, flood plains, valley floor remnants
Position on landform: Toeslopes
Position on landform: Rise, tread
Parent material: Eolian deposits over stream alluvium derived from sandstone
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Linear, concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 5.9 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Occasional
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Very low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: alkali sacaton, giant sacaton, fourwing saltbush
Land capability subclass (irrigated): 4e
Land capability subclass (nonirrigated): 7s

Typical Profile:
Ap—0 to 9 inches; fine sandy loam
C1—9 to 36 inches; stratified loamy sand to sandy loam
C2—36 to 60 inches; sandy loam

Minor Components
Aga and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Riverwash
Composition: About 3 percent
Landscape: Valleys
Landform: Streams, channels
Slope: 0 to 3 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Peralta and similar soils
Composition: About 2 percent
Slope: 1 to 3 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Occasional
Ecological site: Bottomland

13—Sandoval-Querencia association, 2 to 7 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,800 to 6,400 feet (1,768 to 1,951 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Sandoval and similar soils: 65 percent
Querencia and similar soils: 20 percent
Minor components: 15 percent

Component Descriptions

Sandoval soils
Landscape: Uplands
Landform: Hills, ridges
Position on landform: Summits
Position on landform: Nose slope
Parent material: Slope alluvium derived from shale
Slope: 2 to 7 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 2.9 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: About 5 percent
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Shallow

Potential native vegetation: sideoats grama, New Mexico Feathergrass, cane bluestem, little bluestem, galleta
Land capability subclass (nonirrigated): 7s

Typical Profile:
A1—0 to 2 inches; fine sandy loam
A2—2 to 6 inches; clay loam
C1—6 to 10 inches; clay loam
C2—10 to 15 inches; clay loam
Cr—15 to 60 inches; bedrock

Querencia soils
Landscape: Uplands
Landform: Valley sides, stream terraces, alluvial fans
Position on landform: Footslopes
Position on landform: Rise
Parent material: Fan alluvium over colluvium derived from sandstone and shale
Slope: 2 to 7 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.2 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, spike muhly, bottlebrush squirreltail, fourwing saltbush, needlegrass, winterfat
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 4 inches; sandy clay loam
Bw—4 to 12 inches; clay loam
Bw—12 to 24 inches; loam
Bk—24 to 60 inches; loam

Minor Components
Camino and similar soils
Composition: About 5 percent
Slope: 1 to 6 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Clayey

Badland
Composition: About 5 percent
Slope: 5 to 75 percent
Depth to restrictive feature: 0 inches to bedrock (paralithic)

San Mateo and similar soils
Composition: About 3 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

Skyvillage and similar soils
Composition: About 2 percent
Slope: 8 to 25 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

15—Camino-Sandoval complex, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,900 to 6,200 feet (1,798 to 1,890 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Camino and similar soils: 40 percent
Sandoval and similar soils: 35 percent
Minor components: 25 percent

Component Descriptions

Camino soils
Landscape: Uplands
Landform: Valley sides, plateaus
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Fan alluvium over residuum weathered from shale
Slope: 1 to 6 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Deep
Depth to restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 7.8 inches (moderate)
Shrink-swell potential: About 7.5 percent (high)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Clayey
Potential native vegetation: alkali sacaton, giant sacaton, western wheatgrass, galleta, blue grama, fourwing saltbush
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 2 inches; silty clay loam
Bw1—2 to 5 inches; clay
Bw2—5 to 20 inches; clay
Bk—20 to 51 inches; clay
Cr—51 to 60 inches; bedrock

Sandoval soils
Landscape: Uplands
Landform: Ridges, hills
Position on landform: Summits
Position on landform: Nose slope
Parent material: Slope alluvium derived from shale
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 3.3 inches (low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: About 10 percent
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 13 (moderately sodic)
Ecological site: Shallow
Potential native vegetation: sideoats grama, New Mexico Feathergrass, cane bluestem, little bluestem, galleta
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 2 inches; fine sandy loam
C—2 to 17 inches; clay loam
Cr—17 to 60 inches; bedrock

Minor Components
Querencia and similar soils
Composition: About 10 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

Badland
Composition: About 10 percent
Slope: 5 to 75 percent
Depth to restrictive feature: 0 inches to bedrock (paralithic)

Sparank and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Occasional
Ecological site: Clayey Bottomland

16—Rock outcrop-Prieta complex, 3 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,600 to 7,200 feet (1,707 to 2,195 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Rock outcrop: 50 percent
Prieta and similar soils: 30 percent
Minor components: 20 percent

Component Descriptions

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Ridges, volcanic cones
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Prieta soils
Landscape: Uplands
Landform: Lava flows, mesas
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian deposits over slope alluvium derived from basalt
Slope: 3 to 15 percent
Aspect: East to west
Shape (down/across): Convex/linear
Surface fragments: About 20 percent subrounded stones
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 2.1 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 8 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Malpais
Potential native vegetation: blue grama, alkali sacaton, hairy grama, sideoats grama, black grama, little bluestem, spike muhly, wolftail
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 5 inches; stony silt loam
Bt—5 to 15 inches; very stony clay loam
Bk—15 to 19 inches; very stony clay loam
R—19 to 60 inches; bedrock

Minor Components
Clovis and similar soils
Composition: About 10 percent
Slope: 1 to 4 percent
Drainage class: Well drained
Ecological site: Loamy

Silver and similar soils
Composition: About 5 percent
Slope: 1 to 7 percent
Drainage class: Well drained
Ecological site: Loamy

Prieta and similar soils
Composition: About 5 percent
Slope: 1 to 2 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Malpais

17—Vessilla-Menefee-Rock outcrop complex, 3 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,800 to 7,500 feet (2,073 to 2,286 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Vessilla and similar soils: 35 percent
Menefee and similar soils: 25 percent
Rock outcrop: 20 percent
Minor components: 20 percent

Component Descriptions

Vessilla soils
Landscape: Uplands
Landform: Ridges, breaks, hills, mesas
Position on landform: Shoulders
Position on landform: Nose slope
Parent material: Eolian deposits over slope alluvium derived from sandstone
Slope: 3 to 15 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow

Depth to restrictive feature: 4 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 1.3 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Indian ricegrass, blue grama, mountain big sagebrush, oak, galleta, sideoats grama
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 5 inches; sandy loam
C—5 to 11 inches; sandy loam
R—11 to 60 inches; bedrock

Menefee soils
Landscape: Uplands
Landform: Hillslopes, mesas, mountainsides
Position on landform: Shoulders
Position on landform: Nose slope
Parent material: Colluvium over residuum weathered from shale
Slope: 3 to 15 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 2.0 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, Rocky Mountain juniper, twoneedle pinyon
Other plants: blue grama, galleta, Gambel oak, big sagebrush, sideoats grama
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; clay loam
C—3 to 10 inches; clay loam
2Cr—10 to 60 inches; bedrock

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Breaks, escarpments, ledges
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Orlie and similar soils
Composition: About 10 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Sparham and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Clayey

18—Sparham clay, 0 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Sparham and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Sparham soils
Landscape: Valleys
Landform: Flood plains, valley sides, alluvial fans
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Fan alluvium derived from sandstone and shale
Slope: 0 to 3 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 11.8 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Flooding hazard: Occasional
Runoff class: Low
Calcium carbonate maximum: About 10 percent

Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Clayey
Potential native vegetation: western wheatgrass, alkali sacaton, bottlebrush squirreltail, prairie junegrass
Land capability subclass (irrigated): 3s
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 7 inches; clay
C1—7 to 20 inches; clay loam
C2—20 to 29 inches; clay loam
C3—29 to 47 inches; silty clay loam
C4—47 to 53 inches; clay loam
C5—53 to 60 inches; clay loam

Minor Components
Riverwash
Composition: About 5 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Menefee and similar soils
Composition: About 5 percent
Slope: 5 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

Vessilla and similar soils
Composition: About 5 percent
Slope: 5 to 30 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

20—Gilco clay loam, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Gilco and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Gilco soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Concave/linear
Surface fragments: About 12 percent subrounded gravel
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.2 inches (high)
Shrink-swell potential: About 1.6 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 7c

Typical Profile:
Ap—0 to 6 inches; clay loam
C—6 to 60 inches; stratified fine sandy loam to loam

Minor Components
Peralta and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

Sparham and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Occasional
Ecological site: Bottomland

Aga and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

21—Rock outcrop-Hackroy complex, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 7,200 feet (1,829 to 2,195 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Rock outcrop: 60 percent
Hackroy and similar soils: 25 percent
Minor components: 15 percent

Component Descriptions

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Ledges, escarpments, benches
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Hackroy soils
Landscape: Uplands
Landform: Mesas, plateaus
Position on landform: Summits
Position on landform: Nose slope
Parent material: Residuum weathered from tuff
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 1.7 inches (very low)
Shrink-swell potential: About 7.5 percent (high)
Runoff class: Very high
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon

Other plants: blue grama, Indian ricegrass, needle and thread, skunkbush sumac
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; sandy loam
Bt—3 to 12 inches; clay
2R—12 to 60 inches; bedrock

Minor Components
Frijoles and similar soils
Composition: About 10 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Nyjack and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

22—Aga silty clay loam, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Aga and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Aga soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 6.8 inches (moderate)
Shrink-swell potential: About 1.7 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 42 to 60 inches
Runoff class: Low

Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 2s
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 8 inches; silty clay loam
C1—8 to 24 inches; loam
2C2—24 to 60 inches; sand

Minor Components
Gilco and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Trail and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Somewhat excessively drained
Flooding hazard: Rare
Ecological site: Bottomland

23—Hickman clay loam, 1 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Hickman and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Hickman soils
Landscape: Valleys
Landform: Flood plains, valley floors
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep

Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.9 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Flooding hazard: Rare
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Swale
Potential native vegetation: western wheatgrass, alkali sacaton, big sagebrush, bottlebrush squirreltail
Land capability subclass (irrigated): 3e
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 4 inches; clay loam
C1—4 to 12 inches; sandy clay loam
C2—12 to 49 inches; clay loam
C3—49 to 60 inches; sandy clay loam

Minor Components
Royosa and similar soils
Composition: About 8 percent
Slope: 1 to 8 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

Sparham and similar soils
Composition: About 7 percent
Slope: 0 to 1 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Clayey Bottomland

24—Orlie-Sparham association, 0 to 5 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 7,000 to 7,500 feet (2,134 to 2,286 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Orlie and similar soils: 45 percent
Sparham and similar soils: 35 percent
Minor components: 20 percent

Component Descriptions

Orlie soils
Landscape: Valleys
Landform: Valley sides, mesas, cuestas, hills
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone and shale
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.0 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Loamy
Potential native vegetation: western wheatgrass, big sagebrush, galleta, Indian ricegrass, needle and thread, fourwing saltbush
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 2 inches; fine sandy loam
Bt—2 to 25 inches; clay loam
C—25 to 60 inches; stratified sandy clay loam to clay loam

Sparham soils
Landscape: Valleys
Landform: Alluvial fans, valley sides, flood plains
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Stream alluvium derived from sandstone and shale
Slope: 0 to 2 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 9.4 inches (high)
Shrink-swell potential: About 7.5 percent (high)
Flooding hazard: Occasional
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Clayey

Potential native vegetation: western wheatgrass, alkali sacaton, bottlebrush squirreltail, prairie junegrass
Land capability subclass (irrigated): 3s
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; clay
C—3 to 60 inches; silty clay

Minor Components
Menefee and similar soils
Composition: About 10 percent
Slope: 5 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

Riverwash
Composition: About 5 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Sedmar and similar soils
Composition: About 5 percent
Slope: 1 to 15 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

25—Gilco loam, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Gilco and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Gilco soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes

Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.4 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 7e

Typical Profile:
Ap—0 to 4 inches; loam
C1—4 to 34 inches; stratified silt loam to loam to fine sandy loam
C2—34 to 60 inches; stratified fine sandy loam to loam

Minor Components
Aga and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Sparham and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Occasional
Ecological site: Bottomland

26—Orlie loam, 0 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,200 to 6,800 feet (1,890 to 2,073 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Orlie and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Orlie soils
Landscape: Valleys
Landform: Cuestas, mesas, valley sides, hills
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone and shale
Slope: 0 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 11.8 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Loamy
Potential native vegetation: western wheatgrass, big sagebrush, galleta, Indian ricegrass, needle and thread, fourwing saltbush
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 2 inches; loam
Bt1—2 to 13 inches; clay loam
Bt2—13 to 22 inches; clay loam
C1—22 to 36 inches; silty clay loam
C2—36 to 50 inches; clay loam
C3—50 to 60 inches; silty clay loam

Minor Components
Menefee and similar soils
Composition: About 8 percent
Slope: 5 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

Vessilla and similar soils
Composition: About 7 percent
Slope: 1 to 3 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

27—Aga loam, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Aga and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Aga soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 5.0 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 42 to 60 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 2s
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 10 inches; loam
C1—10 to 23 inches; loam
2C2—23 to 43 inches; sand
2C3—43 to 60 inches; sand

Minor Components
Gilco and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Trail and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

29—Trail loamy sand, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Trail and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Trail soils
Landscape: Valleys
Landform: Alluvial fans, channels, flood plains, valley floor remnants



Figure 2.—Typical landscape of Trail loamy sand, 0 to 1 percent slopes, and Riverwash, along the Jemez River.

Position on landform: Toeslopes
Position on landform: Rise, base slope
Parent material: Eolian deposits derived from sandstone over stream alluvium derived from igneous and sedimentary rock
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Linear, concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 4.1 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Very low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, black grama, dropseed, sand sagebrush
Land capability subclass (irrigated): 4s
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 6 inches; loamy sand
C—6 to 60 inches; stratified loamy sand to sandy loam

Minor Components
Aga and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Peralta and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

31—Riverwash

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 54 to 56 degrees F. (12.2 to 13.3 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Riverwash: 90 percent
Minor components: 10 percent

Component Descriptions

Riverwash
Description: Riverwash consists of unstable sand and silt that is reworked by water and wind so frequently, that it supports little or no vegetation.
Landscape: Valleys
Landform: Streams
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 0 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 2.9 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Frequent
Runoff class: Very low
Calcium carbonate maximum: About 1 percent
Gypsum maximum: About 1 percent
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 1 (slightly sodic)
Land capability subclass (nonirrigated): 8w

Minor Components
Torrifluvents and similar soils
Composition: About 10 percent
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Concave/linear
Drainage class: Moderately well drained
Flooding hazard: Rare

33—Pits

Map Unit Setting

Major Land Resource Area: 36

Map Unit Composition

Pits: 100 percent

Component Descriptions

Pits
Description: Pits consist of quarries and gravel and borrow pits.
Slope: 0 to 4 percent
Aspect: East to west
Runoff class: Low
Land capability subclass (nonirrigated): 8s

34—Ildefonso-Witt association, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,200 to 5,700 feet (1,585 to 1,737 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Ildefonso and similar soils: 55 percent
Witt and similar soils: 30 percent
Minor components: 15 percent

Component Descriptions

Ildefonso soils
Landscape: Uplands
Landform: Hills, fan remnants, mesas
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Fan alluvium over colluvium derived from igneous and sedimentary rock
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 25 percent subrounded gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 5.0 inches (low)
Shrink-swell potential: About 2.2 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Limy

Potential native vegetation: thickspike wheatgrass, western wheatgrass, New Mexico Feathergrass, blue grama, hairy grama, winterfat
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; cobbly loam
Bk—3 to 17 inches; cobbly loam
C—17 to 60 inches; stratified very cobbly sandy loam to very cobbly loam

Witt soils
Landscape: Uplands
Landform: Mesas, fan remnants, bajadas
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone over fan alluvium derived from basalt
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 10.0 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, spike muhly, fourwing saltbush, galleta
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 3 inches; very fine sandy loam
Bt—3 to 27 inches; loam
Bk—27 to 60 inches; loam

Minor Components
Rock outcrop
Composition: About 10 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Prieta and similar soils
Composition: About 5 percent
Slope: 3 to 15 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Malpais

41—Dune land

Map Unit Setting

Major Land Resource Area: 36

Map Unit Composition

Dune land: 100 percent

Component Descriptions

Dune land
Description: Dune land consists of areas of loose, windblown, generally sandy material, mostly bare of vegetation. There characteristic shape is low mounds, ridges, or hills. They are capable of movement from place to place.
Landscape: Dune fields
Landform: Shrub-coppice dunes
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone
Slope: 0 to 20 percent
Aspect: East to west
Shape (down/across): Convex/convex
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 2.4 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 1 percent
Gypsum maximum: About 1 percent
Salinity maximum: About 1 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 1 (slightly sodic)
Land capability subclass (nonirrigated): 8e

47—Cascajo very gravelly sandy loam, 12 to 30 percent slopes

Map Unit Setting

Major Land Resource Area: 70
Elevation: 5,300 to 6,100 feet (1,615 to 1,859 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Cascajo and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Cascajo soils
Landscape: Uplands
Landform: Ridges, knolls, hills
Position on landform: Backslopes
Position on landform: Side slope

Parent material: Fan alluvium derived from sandstone
Slope: 12 to 30 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 59 percent subrounded gravel
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 2.2 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Gravelly
Potential native vegetation: blue grama, New Mexico Feathergrass, sideoats grama, twoneedle pinyon, black grama, oneseed juniper
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; very gravelly sandy loam
Bw—2 to 5 inches; very gravelly sandy loam
Bk1—5 to 11 inches; very gravelly sandy loam
Bk2—11 to 23 inches; very gravelly loamy sand
C1—23 to 30 inches; very gravelly loamy sand
C2—30 to 60 inches; extremely cobbly loamy sand

Minor Components
La Fonda and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Harvey and similar soils
Composition: About 5 percent
Slope: 5 to 10 percent
Drainage class: Well drained
Ecological site: Limy

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

51—Sparham clay loam, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Sparham and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Sparham soils
Landscape: Valleys
Landform: Alluvial fans, valley sides, flood plains
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Stream alluvium derived from sandstone and shale
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Somewhat poorly drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 11.0 inches (high)
Shrink-swell potential: About 5.4 percent (moderate)
Flooding hazard: Occasional
Seasonal high water table depth: About 4 to 10 inches
Runoff class: High
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Clayey Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 3e
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 6 inches; clay loam
C1—6 to 20 inches; clay loam
C2—20 to 36 inches; clay
C3—36 to 60 inches; clay loam

Minor Components
Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Clayey Bottomland

Gilco, sandy substrata and similar soils
Composition: About 5 percent
Slope: 1 to 4 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Clayey Bottomland

Riverwash
Composition: About 5 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 1 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

52—Totavi loamy sand, 0 to 5 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 7,000 to 7,500 feet (2,134 to 2,286 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Totavi and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Totavi soils
Landscape: Valleys
Landform: Closed depressions, valley floors, stream terraces
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from tuff
Slope: 0 to 5 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 4.1 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Runoff class: Very low
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa-Juniperus deppeana/Quercus gambelii
Potential native vegetation:
Common trees: oneseed juniper, Utah juniper, ponderosa pine
Other plants: needle and thread, western wheatgrass, Gambel oak, oneseed juniper, skunkbush sumac
Land capability subclass (nonirrigated): 4s

Typical Profile:
A—0 to 15 inches; loamy sand
C1—15 to 19 inches; loamy sand
C2—19 to 60 inches; loamy sand

Minor Components
Riverwash
Composition: About 5 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Hackroy and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Depth to restrictive feature: 8 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Nyjack and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

53—Witt-Harvey association, 1 to 7 percent slopes

Map Unit Setting

Major Land Resource Area: 70
Elevation: 5,600 to 6,700 feet (1,707 to 2,042 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Witt and similar soils: 55 percent
Harvey and similar soils: 30 percent
Minor components: 15 percent

Component Descriptions

Witt soils
Landscape: Uplands
Landform: Bajadas, fan remnants, mesas
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian deposits and alluvium derived from igneous and sedimentary rock

Slope: 1 to 7 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 11.7 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, galleta, sideoats grama, black grama, fourwing saltbush, obtuse panicgrass, plains lovegrass, sand dropseed, threeawn
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 3 inches; loam
BA—3 to 6 inches; silt loam
Bt1—6 to 11 inches; silty clay loam
Bt2—11 to 18 inches; silty clay loam
Btk—18 to 25 inches; silty clay loam
Bk1—25 to 39 inches; silt loam
Bk2—39 to 53 inches; silt loam
C—53 to 60 inches; silt loam

Harvey soils
Landscape: Uplands
Landform: Bajadas, plateaus, mesas
Position on landform: Shoulders
Position on landform: Nose slope
Parent material: Eolian deposits derived from sandstone over fan alluvium derived from basalt
Slope: 1 to 7 percent
Aspect: East to west
Shape (down/across): Convex/linear
Surface fragments: About 5 percent subrounded gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.5 inches (high)
Shrink-swell potential: About 3.6 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Limy
Potential native vegetation: black grama, sideoats grama, blue grama, needlegrass, winterfat, Bigelow sagebrush, fourwing saltbush, western wheatgrass
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 10 inches; loam
Bw—10 to 28 inches; clay loam
Bk—28 to 42 inches; sandy clay loam
C—42 to 60 inches; sandy loam

Minor Components
Ildefonso and similar soils
Composition: About 10 percent
Slope: 10 to 35 percent
Drainage class: Well drained
Ecological site: Limy

La Fonda and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

54—Harvey-Cascajo association, 5 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 70
Elevation: 5,300 to 6,500 feet (1,615 to 1,981 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Harvey and similar soils: 45 percent
Cascajo and similar soils: 40 percent
Minor components: 15 percent

Component Descriptions

Harvey soils
Landscape: Uplands
Landform: Bajadas, mesas, plateaus
Position on landform: Shoulders
Position on landform: Nose slope
Parent material: Eolian deposits and alluvium derived from igneous and sedimentary rock
Slope: 5 to 15 percent
Aspect: East to west
Shape (down/across): Convex/linear
Surface fragments: About 10 percent subrounded gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.3 inches (high)
Shrink-swell potential: About 4.1 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None

Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Limy
Potential native vegetation: black grama, sideoats grama, blue grama, needlegrass, winterfat, Bigelow sagebrush, fourwing saltbush, western wheatgrass
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; fine sandy loam
Bw—2 to 11 inches; fine sandy loam
Bk—11 to 23 inches; clay loam
C—23 to 60 inches; sandy clay loam

Cascajo soils
Landscape: Uplands
Landform: Hills, knolls, ridges
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from sandstone
Slope: 5 to 15 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 10 percent subrounded gravel
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 1.5 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 20 percent
Gypsum maximum: About 1 percent
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Gravelly
Potential native vegetation: New Mexico Feathergrass, black grama, blue grama, hairy grama, sideoats grama, plains lovegrass, winterfat, wolftail
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; very gravelly sandy loam
AB—3 to 9 inches; very gravelly sandy loam
Bk—9 to 28 inches; very gravelly sand
C—28 to 60 inches; very gravelly sand

Minor Components
La Fonda and similar soils
Composition: About 10 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Witt and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

55—La Fonda loam, 1 to 5 percent slopes

Map Unit Setting

Major Land Resource Area: 70
Elevation: 6,000 to 6,500 feet (1,829 to 1,981 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

La Fonda and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

La Fonda soils
Landscape: Plains
Landform: Fan remnants, fan piedmonts
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from igneous and sedimentary rock
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 10.0 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, galleta, sideoats grama, black grama, fourwing saltbush, obtuse panicgrass, plains lovegrass, sand dropseed, threeawn
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 4 inches; loam
Bw—4 to 26 inches; loam
Bk—26 to 60 inches; loam

Minor Components

Harvey and similar soils
Composition: About 5 percent
Slope: 5 to 10 percent
Drainage class: Well drained
Ecological site: Limy

Witt and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

Ildefonso and similar soils
Composition: About 5 percent
Slope: 15 to 35 percent
Drainage class: Well drained
Ecological site: Breaks

56—Ildefonso cobbly loam, 15 to 35 percent slopes

Map Unit Setting

Major Land Resource Area: 70
Elevation: 5,500 to 6,500 feet (1,676 to 1,981 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Ildefonso and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Ildefonso soils

Landscape: Plains
Landform: Mesas, fan remnants, hills
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium and colluvium derived from sandstone
Slope: 15 to 35 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 30 percent subangular gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 5.6 inches (low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)

Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Breaks
Potential native vegetation: black grama, blue grama, little bluestem, mountain muhly, sideoats grama, New Mexico Feathergrass, twoneedle pinyon, wolftail
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 3 inches; cobbly loam
Bw—3 to 9 inches; cobbly loam
Bk—9 to 15 inches; very gravelly loam
C—15 to 60 inches; very cobbly loam

Minor Components
La Fonda and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Harvey and similar soils
Composition: About 5 percent
Slope: 5 to 10 percent
Drainage class: Well drained
Ecological site: Limy

Rock outcrop
Composition: About 3 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Witt and similar soils
Composition: About 2 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

57—Badland

Map Unit Setting

Major Land Resource Area: 37

Map Unit Composition

Badland: 90 percent
Minor components: 10 percent

Component Descriptions

Badland
Description: Badland consists of areas of exposed raw shale that is essentially denuded of vegetation. These areas are highly dissected.
Landscape: Hills
Landform: Escarpments, ledges, rockfalls
Position on landform: Summits
Position on landform: Nose slope

Slope: 5 to 75 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth to restrictive feature: 0 inches to bedrock (paralithic)
Drainage class: Somewhat excessively drained
Runoff class: Very high
Land capability subclass (nonirrigated): 8

Minor Components
Eslendo and similar soils
Composition: About 5 percent
Slope: 5 to 30 percent
Depth to restrictive feature: 4 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

Doakum and similar soils
Composition: About 5 percent
Slope: 0 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

58—Deama-Elpedro association, 5 to 30 percent slopes

Map Unit Setting

Major Land Resource Area: 70
Elevation: 6,000 to 7,000 feet (1,829 to 2,134 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Deama and similar soils: 45 percent
Elpedro and similar soils: 35 percent
Minor components: 20 percent

Component Descriptions

Deama soils
Landscape: Hills
Landform: Mesas, ridges, plateaus
Position on landform: Shoulders
Position on landform: Nose slope
Parent material: Colluvium derived from limestone
Slope: 15 to 30 percent
Aspect: East to west
Shape (down/across): Convex/linear
Surface fragments: About 10 percent subrounded cobbles, about 10 percent subangular channers, about 20 percent subrounded stones
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 1.4 inches (very low)

Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 60 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: black grama, Bigelow sagebrush, little bluestem, sideoats grama
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 7 inches; very stony silt loam
Bk—7 to 14 inches; very cobbly silt loam
2R—14 to 60 inches; bedrock

Elpedro soils
Landscape: Hills
Landform: Benches, mesas, fan piedmonts, valley sides
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian deposits over colluvium derived from limestone
Slope: 5 to 12 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 11.2 inches (high)
Shrink-swell potential: About 3.7 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: juniper, twoneedle pinyon
Other plants: blue grama, galleta, bottlebrush squirreltail, oak, western wheatgrass
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 5 inches; loam
Bt1—5 to 12 inches; silty clay loam
Bt2—12 to 19 inches; silty clay loam
Bt3—19 to 25 inches; silty clay loam
Btk1—25 to 36 inches; silty clay loam
Btk2—36 to 45 inches; silt loam
Btk3—45 to 60 inches; loam

Minor Components

La Fonda and similar soils
Composition: About 10 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Rock outcrop
Composition: About 10 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

59—Harvey-Ildefonso-La Fonda association, 3 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 70
Elevation: 6,200 to 6,800 feet (1,890 to 2,073 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Harvey and similar soils: 35 percent
Ildefonso and similar soils: 35 percent
La Fonda and similar soils: 15 percent
Minor components: 15 percent

Component Descriptions

Harvey soils

Landscape: Uplands
Landform: Bajadas, mesas, plateaus
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone over fan alluvium and colluvium derived from igneous and sedimentary rock
Slope: 3 to 9 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.6 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Limy
Potential native vegetation: black grama, sideoats grama, blue grama, winterfat, Bigelow sagebrush, fourwing saltbush, needlegrass, western wheatgrass
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 4 inches; loam
Bw—4 to 10 inches; loam
Bk1—10 to 18 inches; clay loam
Bk2—18 to 41 inches; clay loam
C—41 to 60 inches; sandy clay loam

Ildefonso soils
Landscape: Uplands
Landform: Fan remnants, mesas, hills
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Fan alluvium and/or colluvium derived from igneous and sedimentary rock
Slope: 7 to 15 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 5 percent subrounded gravel, about 10 percent subrounded cobbles
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 3.0 inches (low)
Shrink-swell potential: About 2.0 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Breaks
Potential native vegetation: black grama, blue grama, little bluestem, mountain muhly, sideoats grama, New Mexico Feathergrass, twoneedle pinyon, wolftail
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 2 inches; cobbly loam
Bw1—2 to 8 inches; very gravelly loam
Bw2—8 to 13 inches; very gravelly loam
Bk1—13 to 32 inches; very cobbly sandy loam
Bk2—32 to 40 inches; very cobbly sandy loam
C—40 to 60 inches; extremely cobbly sand

La Fonda soils
Landscape: Uplands
Landform: Fan remnants, fan piedmonts
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from igneous and sedimentary rock
Slope: 3 to 7 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)

Available water capacity: About 10.3 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, galleta, sideoats grama, black grama, fourwing saltbush, obtuse panicgrass, plains lovegrass, sand dropseed, threeawn
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; loam
Bw1—3 to 7 inches; loam
Bw2—7 to 14 inches; clay loam
Bw3—14 to 26 inches; loam
Bk1—26 to 42 inches; loam
Bk2—42 to 60 inches; loam

Minor Components
Ildefonso and similar soils
Composition: About 10 percent
Slope: 15 to 35 percent
Drainage class: Well drained
Ecological site: Breaks

Witt and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

63—Placitas gravelly loam, 8 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 70
Elevation: 5,700 to 6,300 feet (1,737 to 1,920 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Placitas and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Placitas soils
Landscape: Uplands
Landform: Fan remnants
Position on landform: Toeslopes
Position on landform: Tread

Parent material: Fan alluvium derived from conglomerate
Slope: 8 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 1.8 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: High
Calcium carbonate maximum: About 25 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Gravelly
Potential native vegetation: blue grama, New Mexico Feathergrass, sideoats grama, twoneedle pinyon, black grama, oneseed juniper
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 5 inches; gravelly loam
Bw—5 to 10 inches; very gravelly sandy loam
Bk—10 to 27 inches; very gravelly sandy loam
R—27 to 60 inches; bedrock

Minor Components
Skyvillage and similar soils
Composition: About 8 percent
Slope: 5 to 40 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

Zia and similar soils
Composition: About 7 percent
Slope: 5 to 20 percent
Drainage class: Well drained
Ecological site: Sandy

64—Skyvillage-Ildefonso association, 8 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,800 to 6,400 feet (1,768 to 1,951 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Skyvillage and similar soils: 40 percent
Ildefonso and similar soils: 35 percent
Minor components: 25 percent

Component Descriptions

Skyvillage soils
Landscape: Uplands
Landform: Ridges, structural benches, mesas, hills, breaks, cuestas
Position on landform: Shoulders
Position on landform: Head slope, side slope, nose slope
Parent material: Slope alluvium derived from sandstone
Slope: 8 to 25 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 2.4 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Shallow Sandstone
Potential native vegetation: sideoats grama, blue grama, little bluestem, Indian ricegrass, galleta
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 4 inches; fine sandy loam
C1—4 to 11 inches; fine sandy loam
C2—11 to 18 inches; sandy loam
2R—18 to 60 inches; bedrock

Ildefonso soils
Landscape: Uplands
Landform: Fan remnants, mesas
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Fan alluvium and/or colluvium derived from igneous and sedimentary rock
Slope: 8 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 2 percent subrounded stones, about 8 percent subrounded cobbles, about 32 percent subrounded gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 3.6 inches (low)
Shrink-swell potential: About 1.5 percent (low)

Runoff class: Medium
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Breaks
Potential native vegetation: black grama, blue grama, little bluestem, mountain muhly, plains lovegrass, sideoats grama, New Mexico Feathergrass
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 3 inches; gravelly sandy loam
Bw—3 to 14 inches; very gravelly sandy loam
Bk—14 to 60 inches; very gravelly sandy loam

Minor Components
Riverwash
Composition: About 10 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Deama and similar soils
Composition: About 10 percent
Slope: 15 to 30 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

65—Ildefonso-Harvey association, 10 to 35 percent slopes

Map Unit Setting

Major Land Resource Area: 70
Elevation: 5,000 to 5,700 feet (1,524 to 1,737 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Ildefonso and similar soils: 50 percent
Harvey and similar soils: 30 percent
Minor components: 20 percent

Component Descriptions

Ildefonso soils
Landscape: Hills
Landform: Mesas, fan remnants
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Fan alluvium over colluvium derived from igneous and sedimentary rock
Slope: 10 to 35 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 2 percent subrounded stones, about 13 percent subrounded cobbles, about 43 percent subrounded gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 3.5 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Breaks
Potential native vegetation: black grama, blue grama, little bluestem, mountain muhly, plains lovegrass, sideoats grama, New Mexico Feathergrass
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 6 inches; very gravelly sandy loam
Bw—6 to 38 inches; very gravelly sandy loam
Bk—38 to 60 inches; very gravelly sandy loam

Harvey soils
Landscape: Uplands
Landform: Bajadas, mesas, plateaus
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian deposits over slope alluvium derived from igneous and sedimentary rock
Slope: 10 to 15 percent
Aspect: East to west
Shape (down/across): Convex/linear
Surface fragments: About 5 percent subrounded gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.9 inches (moderate)
Shrink-swell potential: About 3.2 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)

Ecological site: Limy
Potential native vegetation: black grama, sideoats grama, blue grama, needlegrass, winterfat, Bigelow sagebrush, fourwing saltbush, western wheatgrass
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 4 inches; loam
Bk1—4 to 23 inches; loam
Bk2—23 to 36 inches; loam
C—36 to 60 inches; sandy loam

Minor Components
La Fonda and similar soils
Composition: About 10 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Riverwash
Composition: About 5 percent
Landscape: Valleys
Landform: Channels, streams
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Placitas and similar soils
Composition: About 5 percent
Slope: 8 to 40 percent
Depth to restrictive feature: 20 to 40 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Gravelly

66—Zia sandy loam, 3 to 6 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,100 to 5,700 feet (1,554 to 1,737 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Zia and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Zia soils
Landscape: Valleys
Landform: Alluvial fans

Position on landform: Toeslopes
Position on landform: Rise
Parent material: Eolian deposits over fan alluvium derived from sandstone
Slope: 3 to 6 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 7.1 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: blue grama, western wheatgrass, Indian ricegrass, black grama, oneseed juniper
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 4 inches; sandy loam
C—4 to 60 inches; sandy loam

Minor Components
Riverwash
Composition: About 5 percent
Landscape: Valleys
Landform: Channels, streams
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

San Mateo and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

Cascajo and similar soils
Composition: About 5 percent
Slope: 12 to 30 percent
Drainage class: Excessively drained
Ecological site: Hills

67—Sandoval-Poley complex, 3 to 30 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 7,000 feet (1,829 to 2,134 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Sandoval and similar soils: 40 percent
Poley and similar soils: 35 percent
Minor components: 25 percent

Component Descriptions

Sandoval soils
Landscape: Hills
Landform: Ridges
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Slope alluvium derived from shale
Slope: 3 to 30 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 2.1 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: About 10 percent
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Shallow
Potential native vegetation: sideoats grama, New Mexico Feathergrass, cane bluestem, little bluestem, galleta
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 2 inches; loam
C—2 to 11 inches; clay loam
Cr—11 to 60 inches; bedrock

Poley soils
Landscape: Hills
Landform: Fan remnants
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Colluvium derived from sandstone and shale

Slope: 3 to 30 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 8.8 inches (moderate)
Shrink-swell potential: About 3.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: About 1 percent
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Foothills
Potential native vegetation: blue grama, black grama, sideoats grama, oneseed juniper, New Mexico Feathergrass, sacahuista
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 3 inches; very cobbly loam
Bt1—3 to 12 inches; clay loam
Bt2—12 to 17 inches; clay loam
Btk—17 to 21 inches; clay loam
Bk1—21 to 40 inches; clay loam
Bk2—40 to 60 inches; very gravelly sandy loam

Minor Components

Camino and similar soils
Composition: About 10 percent
Slope: 1 to 6 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Clayey

Skyvillage and similar soils
Composition: About 5 percent
Slope: 8 to 25 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

Montecito and similar soils
Composition: About 5 percent
Slope: 3 to 30 percent
Drainage class: Well drained
Ecological site: pinyon-juniper forest

San Mateo and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

68—Penistaja-Querencia complex, 2 to 7 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,700 to 6,400 feet (1,737 to 1,951 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Penistaja and similar soils: 45 percent
Querencia and similar soils: 35 percent
Minor components: 20 percent

Component Descriptions

Penistaja soils
Landscape: Uplands
Landform: Mesas, alluvial fans, bajadas, plateaus, cuestas, hills
Position on landform: Footslopes
Position on landform: Head slope, side slope, nose slope, rise
Parent material: Eolian deposits over slope alluvium derived from sandstone and shale
Slope: 2 to 7 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.3 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: sand dropseed, spike muhly, winterfat, galleta, sand bluestem, black grama, blue grama
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 2 inches; loamy fine sand
Bt—2 to 15 inches; sandy clay loam
Btk—15 to 27 inches; sandy clay loam
Bk—27 to 38 inches; clay loam
C—38 to 60 inches; sandy clay loam

Querencia soils
Landscape: Uplands
Landform: Stream terraces, valley sides, alluvial fans
Position on landform: Footslopes
Position on landform: Rise
Parent material: Fan alluvium over colluvium derived from sandstone and shale

Slope: 2 to 7 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.6 inches (moderate)
Shrink-swell potential: About 3.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, spike muhly, bottlebrush squirreltail, fourwing saltbush, needlegrass, winterfat
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 2 inches; fine sandy loam
Bw—2 to 40 inches; sandy clay loam
Bk—40 to 60 inches; fine sandy loam

Minor Components
Camino and similar soils
Composition: About 10 percent
Slope: 1 to 6 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Clayey

San Mateo and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

Sandoval and similar soils
Composition: About 5 percent
Slope: 3 to 30 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

71—Palon cobbly sandy loam, 15 to 35 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,500 to 9,500 feet (2,591 to 2,896 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Palon and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Palon soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Slope alluvium over colluvium derived from rhyolite
Slope: 15 to 35 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 2.8 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: white fir, ponderosa pine, Douglas-fir
Other plants: prairie junegrass, quaking aspen, silverweed cinquefoil, Arizona fescue, mountain muhly, nodding brome
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 6 inches; cobbly sandy loam
E—6 to 27 inches; very cobbly sandy loam
Bt—27 to 60 inches; extremely cobbly sandy loam

Minor Components
Jarmillo and similar soils
Composition: About 8 percent
Slope: 2 to 20 percent
Drainage class: Well drained
Ecological site: Mountain Loam

Rock outcrop
Composition: About 7 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

72—Palon very cobbly sandy loam, 35 to 65 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,600 to 9,300 feet (2,621 to 2,835 meters)

Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Palon and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Palon soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Slope alluvium over colluvium derived from rhyolite
Slope: 35 to 65 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 3.2 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: white fir, ponderosa pine, Douglas-fir
Other plants: prairie junegrass, quaking aspen, silverweed cinquefoil, Arizona fescue, mountain muhly, nodding brome
Land capability subclass (nonirrigated): 7c

Typical Profile:
Oi—0 to 2 inches; slightly decomposed plant material
A1—2 to 4 inches; very cobbly sandy loam
A2—4 to 10 inches; extremely cobbly sandy loam
E—10 to 32 inches; extremely cobbly sandy loam
Bt1—32 to 53 inches; very cobbly sandy loam
Bt2—53 to 60 inches; very cobbly sandy loam

Minor Components
Palon, bouldery and similar soils
Composition: About 5 percent
Slope: 15 to 35 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Rubble land
Composition: About 5 percent
Slope: 35 to 60 percent
Drainage class: Excessively drained

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

74—Origo-Pavo association, 5 to 35 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,600 to 10,000 feet (2,621 to 3,048 meters)
Mean annual precipitation: 25 to 30 inches (635 to 762 millimeters)
Mean annual air temperature: 38 to 42 degrees F. (3.3 to 5.6 degrees C.)
Frost-free period: 45 to 60 days

Map Unit Composition

Origo and similar soils: 50 percent
Pavo and similar soils: 25 percent
Minor components: 25 percent

Component Descriptions

Origo soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Slope alluvium over colluvium derived from rhyolite
Slope: 15 to 35 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 2.0 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: white fir, Douglas-fir, limber pine, quaking aspen
Other plants: common juniper, nodding brome, prairie junegrass, unknown, ponderosa pine
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 7 inches; very cobbly sandy loam
E—7 to 28 inches; extremely cobbly sandy loam
Bt—28 to 60 inches; extremely cobbly sandy loam

Pavo soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Colluvium derived from tuff
Slope: 5 to 20 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 7.6 inches (moderate)
Shrink-swell potential: About 1.8 percent (low)
Runoff class: Low
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Mountain Loam
Potential native vegetation: Arizona fescue, bluegrass, western wheatgrass, muhly, needlegrass, bottlebrush squirreltail
Land capability subclass (nonirrigated): 7c

Typical Profile:
A1—0 to 9 inches; loam
A2—9 to 12 inches; sandy loam
E—12 to 25 inches; sandy loam
E/Bt1—25 to 35 inches; sandy loam
E/Bt2—35 to 45 inches; fine sandy loam
2Bt1—45 to 50 inches; gravelly clay loam
3Bt2—50 to 60 inches; sandy loam

Minor Components
Cajete and similar soils
Composition: About 10 percent
Slope: 0 to 8 percent
Drainage class: Well drained
Ecological site: Mountain Grassland

Rock outcrop
Composition: About 10 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Rubble land
Composition: About 5 percent
Slope: 35 to 60 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)
Drainage class: Excessively drained

75—Origo very cobbly sandy loam, 35 to 65 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,600 to 10,000 feet (2,621 to 3,048 meters)
Mean annual precipitation: 25 to 30 inches (635 to 762 millimeters)
Mean annual air temperature: 38 to 42 degrees F. (3.3 to 5.6 degrees C.)
Frost-free period: 45 to 60 days

Map Unit Composition

Origo and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Origo soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Slope alluvium over colluvium derived from rhyolite
Slope: 35 to 65 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 3.8 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: Engelmann spruce, white fir, Douglas-fir
Other plants: common juniper, nodding brome, prairie junegrass, limber pine, ponderosa pine, quaking aspen
Land capability subclass (nonirrigated): 7e

Typical Profile:
Oi—0 to 1 inch; slightly decomposed plant material
A1—1 inch to 6 inches; very cobbly sandy loam
A2—6 to 12 inches; very cobbly sandy loam
E—12 to 32 inches; very cobbly sandy loam
Bt1—32 to 56 inches; very cobbly sandy loam
Bt2—56 to 60 inches; very cobbly loamy sand

Minor Components

Pavo and similar soils
Composition: About 5 percent
Slope: 5 to 20 percent
Drainage class: Well drained
Ecological site: Mountain Loam

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Rubble land
Composition: About 5 percent
Slope: 35 to 60 percent
Drainage class: Excessively drained

82—Calaveras loam, 15 to 35 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,500 to 9,000 feet (2,591 to 2,743 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Calaveras and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Calaveras soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Colluvium derived from tuff
Slope: 15 to 35 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 3.4 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)

Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: white fir, limber pine, Douglas-fir, ponderosa pine
Other plants: common juniper, nodding brome, prairie junegrass, quaking aspen
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 2 inches; loam
AE—2 to 6 inches; sandy loam
2Bt—6 to 40 inches; very cobbly sandy loam
3Bt—40 to 60 inches; extremely cobbly coarse sandy loam

Minor Components
Redondo and similar soils
Composition: About 5 percent
Slope: 35 to 80 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Cajete and similar soils
Composition: About 5 percent
Slope: 0 to 8 percent
Drainage class: Well drained
Ecological site: Mountain Grassland

Cosey and similar soils
Composition: About 5 percent
Slope: 2 to 20 percent
Drainage class: Well drained
Ecological site: Mountain Loam

83—Calaveras-Rubble land association, 35 to 60 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,500 to 9,000 feet (2,591 to 2,743 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Calaveras and similar soils: 60 percent
Rubble land: 20 percent
Minor components: 20 percent

Component Descriptions

Calaveras soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank

Parent material: Colluvium derived from tuff
Slope: 35 to 60 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 3.5 inches (low)
Shrink-swell potential: About 1.6 percent (low)
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: white fir, limber pine, Douglas-fir, ponderosa pine
Other plants: common juniper, nodding brome, prairie junegrass, quaking aspen
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 6 inches; loam
AE—6 to 12 inches; sandy loam
2Bt—12 to 24 inches; very cobbly sandy loam
3Bt—24 to 60 inches; extremely cobbly coarse sandy loam

Rubble land
Description: Rubble land consists of areas with 90 percent or more of the surface covered with cobbles, stones, and boulders.
Landscape: Mountains
Landform: Ledges, escarpments
Position on landform: Shoulders
Position on landform: Mountainflank
Slope: 35 to 60 percent
Aspect: East to west
Shape (down/across): Linear/linear
Drainage class: Excessively drained
Available water capacity: About 0.6 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 0 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Land capability subclass (nonirrigated): 8s

Minor Components
Redondo and similar soils
Composition: About 10 percent
Slope: 15 to 35 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Rock outcrop
Composition: About 10 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

85—Redondo coarse sandy loam, 15 to 35 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,700 to 10,000 feet (2,652 to 3,048 meters)
Mean annual precipitation: 25 to 30 inches (635 to 762 millimeters)
Mean annual air temperature: 38 to 42 degrees F. (3.3 to 5.6 degrees C.)
Frost-free period: 45 to 60 days

Map Unit Composition

Redondo and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Redondo soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Colluvium derived from tuff
Slope: 15 to 35 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 4.2 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: Engelmann spruce
Other plants: Arizona fescue, corkbark fir, sedge, Fendler meadowrue, common juniper, kinnikinnick, prairie junegrass, silverweed cinquefoil
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 2 inches; coarse sandy loam
E1—2 to 7 inches; coarse sandy loam
E2—7 to 15 inches; coarse sandy loam
BE—15 to 22 inches; coarse sandy loam
Bt1—22 to 29 inches; gravelly coarse sandy loam
Bt2—29 to 38 inches; very gravelly coarse sandy loam
Bt3—38 to 54 inches; extremely gravelly coarse sandy loam
Bt4—54 to 60 inches; extremely cobbly coarse sandy loam

Minor Components
Ess and similar soils
Composition: About 10 percent
Slope: 5 to 45 percent
Drainage class: Well drained
Ecological site: Subalpine Grassland

Rubble land
Composition: About 5 percent
Slope: 35 to 80 percent
Drainage class: Excessively drained

86—Redondo cobbly coarse sandy loam, 35 to 80 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,700 to 11,000 feet (2,652 to 3,353 meters)
Mean annual precipitation: 25 to 30 inches (635 to 762 millimeters)
Mean annual air temperature: 38 to 42 degrees F. (3.3 to 5.6 degrees C.)
Frost-free period: 45 to 60 days

Map Unit Composition

Redondo and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Redondo soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Colluvium derived from tuff
Slope: 35 to 80 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 2.4 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: Engelmann spruce
Other plants: Arizona fescue, Fendler meadowrue, Rocky Mountain maple, corkbark fir, kinnikinnick, limber pine, quaking aspen
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 8 inches; cobbly coarse sandy loam
E—8 to 13 inches; very cobbly coarse sandy loam
BE—13 to 34 inches; extremely cobbly coarse sandy loam
Bt—34 to 60 inches; extremely cobbly coarse sandy loam

Minor Components
Ess and similar soils
Composition: About 8 percent
Slope: 5 to 45 percent
Drainage class: Well drained
Ecological site: Subalpine Grassland

Rubble land
Composition: About 7 percent
Slope: 35 to 80 percent
Drainage class: Excessively drained

87—Redondo-Rubble land association, 35 to 80 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 9,000 to 10,500 feet (2,743 to 3,200 meters)
Mean annual precipitation: 25 to 30 inches (635 to 762 millimeters)
Mean annual air temperature: 38 to 42 degrees F. (3.3 to 5.6 degrees C.)
Frost-free period: 45 to 60 days

Map Unit Composition

Redondo and similar soils: 50 percent
Rubble land: 25 percent
Minor components: 25 percent

Component Descriptions

Redondo soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Colluvium derived from tuff
Slope: 35 to 80 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 3.4 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)

Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: Engelmann spruce
Other plants: Arizona fescue, Fendler meadowrue, Rocky Mountain maple, corkbark fir, kinnikinnick, limber pine, quaking aspen
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 6 inches; cobbly loam
E—6 to 13 inches; very cobbly coarse sandy loam
Bt—13 to 60 inches; very cobbly coarse sandy loam

Rubble land
Description: Rubble land consists of areas with 90 percent or more of the surface covered with cobbles, stones, and boulders.
Landscape: Mountains
Landform: Talus slopes
Position on landform: Backslopes
Position on landform: Mountainflank, upper third
Slope: 35 to 80 percent
Aspect: East to west
Shape (down/across): Concave/linear
Drainage class: Excessively drained
Available water capacity: About 0.6 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 0 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Land capability subclass (nonirrigated): 8s

Minor Components
Ess and similar soils
Composition: About 25 percent
Landform: Mountains
Slope: 5 to 45 percent
Drainage class: Well drained
Ecological site: Subalpine Grassland

88—Totavi-Jemez-Rock outcrop association, 0 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 7,800 to 8,800 feet (2,377 to 2,682 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Totavi and similar soils: 45 percent
Jemez and similar soils: 30 percent
Rock outcrop: 15 percent
Minor components: 10 percent

Component Descriptions

Totavi soils
Landscape: Plains
Landform: Stream terraces, valley floors, closed depressions
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Fan alluvium derived from tuff
Slope: 0 to 5 percent
Aspect: East to west
Shape (down/across): Concave/concave
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 4.7 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Runoff class: Very low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa-Juniperus deppeana/Quercus gambelii
Potential native vegetation:
Common trees: oneseed juniper, ponderosa pine
Other plants: needle and thread, skunkbush sumac, western wheatgrass, Gambel oak
Land capability subclass (nonirrigated): 6s

Typical Profile:
A—0 to 12 inches; sandy loam
C—12 to 60 inches; loamy sand

Jemez soils
Landscape: Hills
Landform: Plateaus
Position on landform: Shoulders
Position on landform: Nose slope
Parent material: Slope alluvium derived from tuff
Slope: 5 to 15 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 4.6 inches (low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High

Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: white fir, ponderosa pine, Douglas-fir
Other plants: needle and thread, skunkbush sumac, western wheatgrass, Gambel oak
Land capability subclass (nonirrigated): 7c

Typical Profile:
A1—0 to 6 inches; loam
A2—6 to 13 inches; loam
BA—13 to 19 inches; clay loam
Bt—19 to 27 inches; sandy clay loam
R—27 to 60 inches; bedrock

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landscape: Hills
Landform: Breaks, escarpments
Position on landform: Summits
Position on landform: Nose slope
Aspect: East to west
Shape (down/across): Convex/linear
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Cajete and similar soils
Composition: About 10 percent
Slope: 8 to 30 percent
Drainage class: Well drained
Ecological site: Mountain Grassland

91—Zia sandy loam, 1 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,500 to 5,700 feet (1,676 to 1,737 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Zia and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Zia soils
Landscape: Valleys
Landform: Stream terraces
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Eolian deposits over stream alluvium derived from sandstone
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 7.3 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: blue grama, western wheatgrass, Indian ricegrass, black grama, oneseed juniper
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 16 inches; sandy loam
C1—16 to 22 inches; loamy sand
C2—22 to 35 inches; sandy loam
C3—35 to 60 inches; fine sandy loam

Minor Components
El Rancho and similar soils
Composition: About 10 percent
Slope: 0 to 2 percent
Drainage class: Well drained
Ecological site: Loamy

Galisteo and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Well drained
Ecological site: Salt Flats

92—Galisteo silty clay loam, moderately saline, sodic, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,500 to 5,700 feet (1,676 to 1,737 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)

Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Galisteo, moderately saline, sodic and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Galisteo, moderately saline, sodic soils
Landscape: Valleys
Landform: Stream terraces, alluvial fans
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Stream alluvium derived from sandstone and shale
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 9.4 inches (high)
Shrink-swell potential: About 7.1 percent (high)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Salty Bottomland
Potential native vegetation: alkali sacaton, western wheatgrass, bottlebrush squirreltail, galleta, fourwing saltbush, greasewood
Land capability subclass (irrigated): 4s
Land capability subclass (nonirrigated): 6c

Typical Profile:
Ap—0 to 12 inches; silty clay loam
C—12 to 60 inches; clay

Minor Components
El Rancho and similar soils
Composition: About 10 percent
Slope: 0 to 2 percent
Drainage class: Well drained
Ecological site: Loamy

Zia and similar soils
Composition: About 5 percent
Slope: 5 to 20 percent
Drainage class: Well drained
Ecological site: Sandy

93—Zia loamy sand, 1 to 4 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,100 to 5,500 feet (1,554 to 1,676 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Zia and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Zia soils
Landscape: Valleys
Landform: Stream terraces
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Eolian deposits over stream alluvium derived from sandstone
Slope: 1 to 4 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 6.7 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: blue grama, western wheatgrass, Indian ricegrass, black grama, oneseed juniper
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 8 inches; loamy sand
C—8 to 60 inches; sandy loam

Minor Components
Gilco and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Pinavetes and similar soils
Composition: About 5 percent
Slope: 5 to 15 percent
Drainage class: Excessively drained
Ecological site: Deep Sand

95—El Rancho loam, 0 to 2 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,300 to 5,500 feet (1,615 to 1,676 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

El Rancho and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

El Rancho soils
Landscape: Valleys
Landform: Stream terraces
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from sandstone and shale
Slope: 0 to 2 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.3 inches (moderate)
Shrink-swell potential: About 3.4 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, spike muhly, western wheatgrass, bottlebrush squirreltail, fourwing saltbush, winterfat
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 6c

Typical Profile:
Ap—0 to 5 inches; loam
C1—5 to 20 inches; sandy clay loam
C2—20 to 38 inches; sandy clay loam
2C3—38 to 60 inches; sandy loam

Minor Components
Galisteo and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Well drained
Ecological site: Salt Flats

Zia and similar soils
Composition: About 5 percent
Slope: 1 to 4 percent
Drainage class: Well drained
Ecological site: Sandy

97—El Rancho clay loam, 0 to 2 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,300 to 5,500 feet (1,615 to 1,676 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

El Rancho and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

El Rancho soils
Landscape: Valleys
Landform: Stream terraces
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from sandstone and shale
Slope: 0 to 2 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.3 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, spike muhly, western wheatgrass, bottlebrush squirreltail, fourwing saltbush, winterfat
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 6c

Typical Profile:
Ap—0 to 8 inches; clay loam
C—8 to 60 inches; sandy clay loam

Minor Components
Jocity and similar soils
Composition: About 8 percent
Slope: 0 to 2 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Zia and similar soils
Composition: About 7 percent
Slope: 1 to 4 percent
Drainage class: Well drained
Ecological site: Sandy

100—Orejas-Rock outcrop complex, 15 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 7,000 to 7,500 feet (2,134 to 2,286 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Orejas and similar soils: 40 percent
Rock outcrop: 40 percent
Minor components: 20 percent

Component Descriptions

Orejas soils
Landscape: Uplands
Landform: Plateaus, mesas
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian material, alluvium and colluvium derived from basalt
Slope: 15 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 1.8 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)



Figure 3.—Typical landscape of Orejas-Rock outcrop complex, 15 to 40 percent slopes.

Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: twoneedle pinyon, oneseed juniper
Other plants: blue grama, sideoats grama, big sagebrush
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 5 inches; very stony loam
Bt—5 to 15 inches; very cobbly clay loam
C—15 to 19 inches; very cobbly clay loam
R—19 to 60 inches; bedrock

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landscape: Uplands
Landform: Breaks, escarpments
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Montecito and similar soils
Composition: About 10 percent
Slope: 3 to 30 percent

Drainage class: Well drained
Ecological site: pinyon-juniper forest

San Mateo and similar soils
Composition: About 10 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

101—Blancot-Lybrook association, 0 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 37
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Blancot and similar soils: 55 percent
Lybrook and similar soils: 25 percent
Minor components: 20 percent

Component Descriptions

Blancot soils
Landscape: Uplands
Landform: Ridges, valley sides
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from sandstone and shale
Slope: 2 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.5 inches (high)
Shrink-swell potential: About 3.0 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: Indian ricegrass, blue grama, galleta, big sagebrush, sand dropseed, western wheatgrass
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 2 inches; fine sandy loam
Bt1—2 to 5 inches; clay loam
Bt2—5 to 14 inches; clay loam
Btk—14 to 23 inches; clay loam
C1—23 to 40 inches; sandy loam
C2—40 to 49 inches; silty clay loam
C3—49 to 60 inches; sandy loam

Lybrook soils
Landscape: Valleys
Landform: Stream terraces, valley floors
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from sandstone and shale
Slope: 0 to 2 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.6 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 25 mmhos/cm (strongly saline)
Sodium adsorption ratio maximum: About 50 (strongly sodic)
Ecological site: Salt Flats
Potential native vegetation: alkali sacaton, fourwing saltbush, galleta, greasewood, shadscale saltbush, big sagebrush, inland saltgrass, western wheatgrass
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 1 inch; clay loam
C1—1 inch to 5 inches; silty clay loam
C2—5 to 21 inches; clay loam
C3—21 to 30 inches; silty clay loam
C4—30 to 60 inches; clay loam

Minor Components
Betonnie and similar soils
Composition: About 10 percent
Slope: 5 to 8 percent
Drainage class: Well drained
Ecological site: Sandy

Councelor and similar soils
Composition: About 10 percent
Slope: 1 to 3 percent
Drainage class: Well drained
Ecological site: Sandy

102—Sparham clay loam, 1 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Sparham and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Sparham soils
Landscape: Valleys
Landform: Valley sides, alluvial fans, flood plains
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Stream alluvium derived from shale
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 11.8 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Flooding hazard: Occasional
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Bottomland
Potential native vegetation: western wheatgrass, alkali sacaton, bottlebrush squirreltail, prairie junegrass
Land capability subclass (irrigated): 3s
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 7 inches; clay loam
C1—7 to 29 inches; clay loam
C2—29 to 60 inches; silty clay loam

Minor Components
Hickman and similar soils
Composition: About 5 percent
Slope: 1 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

Pinitos and similar soils
Composition: About 5 percent
Slope: 2 to 10 percent
Drainage class: Well drained
Ecological site: Loamy

Royosa and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

104—Cochiti-Montecito association, 1 to 30 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,500 to 7,000 feet (1,981 to 2,134 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Cochiti and similar soils: 50 percent
Montecito and similar soils: 30 percent
Minor components: 20 percent

Component Descriptions

Cochiti soils
Landscape: Uplands
Landform: Fan remnants
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from igneous and sedimentary rock
Slope: 3 to 30 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 15 percent subrounded gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 4.8 inches (low)
Shrink-swell potential: About 4.1 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Juniperus monosperma-Pinus edulis/Fallugia paradoxa-Chrysothamnus nauseosus/Bouteloua hirsuta-Bouteloua gracilis

Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: blue grama, sideoats grama, bottlebrush squirreltail
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 7 inches; gravelly loam
Bt1—7 to 12 inches; gravelly clay loam
Bt2—12 to 20 inches; very gravelly clay
Bt3—20 to 29 inches; very gravelly clay loam
C—29 to 60 inches; very gravelly sandy loam

Montecito soils
Landscape: Uplands
Landform: Hills, mesas, plains
Position on landform: Toeslopes
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone and shale
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 8.1 inches (moderate)
Shrink-swell potential: About 2.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: twoneedle pinyon, oneseed juniper
Other plants: blue grama, bottlebrush squirreltail, muttongrass
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 3 inches; loam
Bt1—3 to 9 inches; clay loam
Bt2—9 to 15 inches; clay loam
Bt3—15 to 22 inches; clay loam
2Bk1—22 to 37 inches; sandy loam
2Bk2—37 to 60 inches; gravelly sandy loam

Minor Components
Cajete and similar soils
Composition: About 10 percent
Slope: 0 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

Waumac and similar soils
Composition: About 10 percent
Slope: 1 to 7 percent
Drainage class: Well drained
Ecological site: Sandy

105—Badland-Menefee complex, 15 to 35 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,500 to 7,600 feet (1,981 to 2,316 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Badland: 50 percent
Menefee and similar soils: 30 percent
Minor components: 20 percent

Component Descriptions

Badland
Landform: Escarpments
Slope: 15 to 35 percent
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (paralithic)
Drainage class: Somewhat excessively drained
Runoff class: Very high
Land capability subclass (nonirrigated): 8

Menefee soils
Landscape: Hills
Landform: Mesas, mountainsides, hillslopes
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Colluvium over residuum weathered from shale
Slope: 15 to 35 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 1.9 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 5 percent
Gypsum maximum: About 1 percent
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)

Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, Rocky Mountain juniper, twoneedle pinyon
Other plants: blue grama, galleta, sideoats grama, Gambel oak, big sagebrush
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 4 inches; loam
C—4 to 10 inches; clay loam
2Cr—10 to 60 inches; bedrock

Minor Components
Pinitos and similar soils
Composition: About 10 percent
Slope: 2 to 10 percent
Drainage class: Well drained
Ecological site: Loamy

Sparham and similar soils
Composition: About 10 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Occasional
Ecological site: Clayey

106—Stumble association, 1 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,600 feet (1,524 to 1,707 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Stumble and similar soils: 50 percent
Stumble, sandy and similar soils: 30 percent
Minor components: 20 percent

Component Descriptions

Stumble soils
Landscape: Valleys
Landform: Fan aprons, inset fans, alluvial fans, fan remnants
Position on landform: Footslopes
Position on landform: Side slope, rise
Parent material: Eolian deposits derived from sandstone
Slope: 10 to 40 percent
Aspect: East to west
Shape (down/across): Linear, convex/linear
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)

Available water capacity: About 2.6 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Gravelly Sand
Potential native vegetation: black grama, bush muhly
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 4 inches; very gravelly fine sandy loam
Bw—4 to 10 inches; gravelly fine sandy loam
C1—10 to 24 inches; loamy sand
C2—24 to 60 inches; gravelly coarse sand

Stumble, sandy soils
Landscape: Valleys
Landform: Alluvial fans, fan remnants, fan aprons, inset fans
Position on landform: Footslopes
Position on landform: Rise, side slope
Parent material: Eolian deposits derived from sandstone
Slope: 1 to 10 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 2.0 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Deep Sand
Potential native vegetation: black grama, Indian ricegrass, dropseed, bush muhly, sand sagebrush
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 4 inches; gravelly loamy sand
Bw—4 to 18 inches; loamy sand
C—18 to 60 inches; gravelly coarse sand

Minor Components
Embudo and similar soils
Composition: About 10 percent
Slope: 1 to 15 percent
Drainage class: Well drained
Ecological site: Sandy

Grieta and similar soils
Composition: About 10 percent
Slope: 1 to 4 percent
Drainage class: Well drained
Ecological site: Loamy

108—Embudo gravelly sandy loam, 1 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,600 feet (1,524 to 1,707 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.7 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Embudo and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Embudo soils
Landscape: Valleys
Landform: Fan remnants
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from granite
Slope: 1 to 15 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 5.5 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: black grama, dropseed, Indian ricegrass, sand sagebrush
Land capability subclass (nonirrigated): 7c

Typical Profile:
AB—0 to 6 inches; gravelly sandy loam
Bk1—6 to 30 inches; sandy loam
2Bk2—30 to 60 inches; loamy sand

Minor Components

Cascajo and similar soils
Composition: About 5 percent
Slope: 12 to 30 percent
Drainage class: Excessively drained
Ecological site: Hills

Riverwash
Composition: About 5 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Sheppard and similar soils
Composition: About 3 percent
Slope: 10 to 40 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

Tijeras and similar soils
Composition: About 2 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Sandy

109—Embudo-Tijeras association, 1 to 9 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,100 to 5,600 feet (1,554 to 1,707 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Embudo and similar soils: 50 percent
Tijeras and similar soils: 35 percent
Minor components: 15 percent

Component Descriptions

Embudo soils
Landscape: Valleys
Landform: Fan remnants
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from granite

Slope: 3 to 9 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 3.8 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: black grama, dropseed, Indian ricegrass, sand sagebrush
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 4 inches; gravelly sandy loam
Bw—4 to 12 inches; gravelly fine sandy loam
Bk1—12 to 30 inches; gravelly coarse sandy loam
2Bk2—30 to 60 inches; gravelly loamy coarse sand

Tijeras soils
Landscape: Valleys
Landform: Fan remnants
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from granite
Slope: 1 to 6 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 4.6 inches (low)
Shrink-swell potential: About 2.4 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: black grama, dropseed, Indian ricegrass, sand sagebrush
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 4 inches; gravelly fine sandy loam
Bt—4 to 10 inches; sandy clay loam
Btk—10 to 20 inches; sandy clay loam
Bk1—20 to 26 inches; gravelly sandy loam
Bk2—26 to 60 inches; very gravelly coarse sandy loam

Minor Components
Grieta and similar soils
Composition: About 10 percent
Slope: 2 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Sheppard and similar soils
Composition: About 5 percent
Slope: 3 to 8 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

110—Rock outcrop-Saido complex, 5 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,300 to 6,000 feet (1,615 to 1,829 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Rock outcrop: 45 percent
Saido and similar soils: 40 percent
Minor components: 15 percent

Component Descriptions

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Escarpments, breaks
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Saido soils
Landscape: Hills
Landform: Mesas, cuestas, knolls, fans
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Slope alluvium derived from gypsum
Slope: 5 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 10.8 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 10 percent
Gypsum maximum: About 80 percent

Salinity maximum: About 8 mmhos/cm (slightly saline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Gyp Upland
Potential native vegetation: alkali sacaton, black grama, bush muhly, gyp dropseed, blue grama, coldenia, fourwing saltbush, galleta, gypsum grama
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 5 inches; silt loam
By1—5 to 9 inches; silt loam
By2—9 to 15 inches; silt loam
By3—15 to 25 inches; silt loam
C—25 to 60 inches; loam

Minor Components
Riverwash
Composition: About 5 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Penistaja and similar soils
Composition: About 5 percent
Slope: 2 to 7 percent
Drainage class: Well drained
Ecological site: Loamy

Hagerman and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Depth to restrictive feature: 20 to 40 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Loamy

111—Rock outcrop-Zia complex, 8 to 25 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,400 to 6,400 feet (1,646 to 1,951 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Rock outcrop: 50 percent
Zia and similar soils: 35 percent
Minor components: 15 percent



Figure 4.—Typical landscape of Rock outcrop-Zia complex, 8 to 25 percent slopes.

Component Descriptions

Rock outcrop

Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Escarpments, breaks
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Zia soils

Landscape: Valleys
Landform: Alluvial fans
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Eolian deposits over fan alluvium derived from sandstone
Slope: 8 to 25 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 8.2 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None

Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Foothills
Potential native vegetation: blue grama, hairy grama, black grama, sideoats grama, galleta, oneseed juniper, sacahuista
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 5 inches; sandy loam
C—5 to 60 inches; fine sandy loam

Minor Components
Penistaja and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Hagerman and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Depth to restrictive feature: 20 to 40 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Loamy

San Mateo and similar soils
Composition: About 3 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

Skyvillage and similar soils
Composition: About 2 percent
Slope: 3 to 20 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

112—Tijeras gravelly fine sandy loam, 1 to 5 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,100 to 5,600 feet (1,554 to 1,707 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Tijeras and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Tijeras soils
Landscape: Uplands
Landform: Fan remnants
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from granite
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 6.5 inches (moderate)
Shrink-swell potential: About 2.1 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: black grama, dropseed, Indian ricegrass, sand sagebrush
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 3 inches; gravelly fine sandy loam
Bt—3 to 14 inches; sandy clay loam
Bk—14 to 60 inches; gravelly sandy loam

Minor Components
Embudo and similar soils
Composition: About 15 percent
Landform: Fan remnants
Slope: 1 to 15 percent
Drainage class: Well drained
Ecological site: Sandy

114—Zia-San Mateo association, 0 to 9 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,500 to 6,200 feet (1,676 to 1,890 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Zia and similar soils: 40 percent
San Mateo and similar soils: 40 percent
Minor components: 20 percent

Component Descriptions

Zia soils
Landscape: Valleys
Landform: Alluvial fans
Position on landform: Footslopes
Position on landform: Rise
Parent material: Eolian deposits over fan alluvium derived from sandstone
Slope: 1 to 9 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 8.3 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: blue grama, spike muhly, western wheatgrass, bottlebrush squirreltail, fourwing saltbush, oneseed juniper, winterfat
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; fine sandy loam
C—3 to 60 inches; fine sandy loam

San Mateo soils
Landscape: Valleys
Landform: Alluvial fans, valley sides, flood plains
Position on landform: Footslopes
Position on landform: Rise
Parent material: Stream alluvium derived from sandstone and shale
Slope: 0 to 3 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.2 inches (high)
Shrink-swell potential: About 4.3 percent (moderate)
Flooding hazard: Rare
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 30 mmhos/cm (strongly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Swale
Potential native vegetation: galleta, big sagebrush, blue grama, bottlebrush squirreltail, other half shrubs, western wheatgrass
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 7 inches; sandy loam
C—7 to 60 inches; stratified sandy loam to loam to clay loam to silty clay loam

Minor Components
Sparank and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Well drained
Flooding hazard: Occasional
Ecological site: Clayey Bottomland

Querencia and similar soils
Composition: About 10 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

120—Pinavetes loamy sand, 3 to 5 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,300 to 6,000 feet (1,615 to 1,829 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Pinavetes and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Pinavetes soils
Landscape: Dune fields
Landform: Dunes, valley sides
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone
Slope: 3 to 5 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 2.9 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)



Figure 5.—Typical landscape of Pinavetes loamy sand, 3 to 5 percent slopes.

Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, blue grama, sand sagebrush
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 10 inches; loamy sand
C1—10 to 35 inches; sand
C2—35 to 60 inches; sand

Minor Components
San Mateo and similar soils
Composition: About 10 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

Zia and similar soils
Composition: About 5 percent
Slope: 1 to 3 percent
Drainage class: Well drained
Ecological site: Sandy

124—Rock outcrop

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,300 to 6,000 feet (1,615 to 1,829 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)

Map Unit Composition

Rock outcrop: 90 percent
Minor components: 10 percent

Component Descriptions

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Mesas, escarpments
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Vessilla and similar soils
Composition: About 10 percent
Slope: 5 to 40 percent
Depth to restrictive feature: 5 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

129—Menefee clay loam, 5 to 35 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,800 to 7,800 feet (2,073 to 2,377 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Menefee and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Menefee soils
Landscape: Hills
Landform: Mountainsides, hillslopes, mesas
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Colluvium over residuum weathered from shale
Slope: 5 to 35 percent
Aspect: East to west
Shape (down/across): Convex/linear

Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 3.4 inches (low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 5 percent
Gypsum maximum: About 1 percent
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: Rocky Mountain juniper, oneseed juniper, twoneedle pinyon
Other plants: blue grama, Gambel oak, galleta, big sagebrush, sideoats grama
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 5 inches; clay loam
C1—5 to 10 inches; clay loam
C2—10 to 17 inches; clay loam
2Cr—17 to 60 inches; bedrock

Minor Components
Pinitos and similar soils
Composition: About 5 percent
Slope: 2 to 10 percent
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Cochiti and similar soils
Composition: About 5 percent
Slope: 3 to 30 percent
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Badland
Composition: About 5 percent
Slope: 5 to 75 percent
Depth to restrictive feature: 0 inches to bedrock (paralithic)

130—Pinavetes-Galisteo, moderately saline, sodic, association, 0 to 5 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,500 to 6,000 feet (1,676 to 1,829 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Pinavetes and similar soils: 45 percent
Galisteo, moderately saline, sodic and similar soils: 40 percent
Minor components: 15 percent

Component Descriptions

Pinavetes soils
Landscape: Valleys
Landform: Dunes, valley sides
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone
Slope: 0 to 5 percent
Aspect: East to west
Shape (down/across): Convex/convex
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 4.1 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, blue grama, sand sagebrush
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 2 inches; loamy sand
C—2 to 60 inches; loamy sand

Galisteo, moderately saline, sodic soils
Landscape: Valleys
Landform: Alluvial fans, stream terraces
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Stream alluvium derived from sandstone and shale
Slope: 0 to 2 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 9.0 inches (moderate)
Shrink-swell potential: About 7.5 percent (high)
Flooding hazard: Rare
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Salty Bottomland

Potential native vegetation: alkali sacaton, western wheatgrass, bottlebrush squirreltail, galleta, fourwing saltbush, greasewood
Land capability subclass (nonirrigated): 6c

Typical Profile:
Ap—0 to 2 inches; clay loam
C—2 to 60 inches; clay

Minor Components
Riverwash
Composition: About 5 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

El Rancho and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Well drained
Ecological site: Loamy

San Mateo and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

142—Grieta fine sandy loam, 1 to 4 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Grieta and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Grieta soils
Landscape: Uplands
Landform: Plateaus, fan remnants, ridges, mesas
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone

Slope: 1 to 4 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 5 percent fine subrounded gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 7.9 inches (moderate)
Shrink-swell potential: About 3.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Loamy
Potential native vegetation: black grama, dropseed, Indian ricegrass, sand sagebrush
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 3 inches; fine sandy loam
Bt1—3 to 11 inches; fine sandy loam
Bt2—11 to 34 inches; sandy clay loam
Bk1—34 to 48 inches; sandy clay loam
Bk2—48 to 60 inches; loamy sand

Minor Components
Sheppard and similar soils
Composition: About 15 percent
Slope: 3 to 8 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

143—Clovis fine sandy loam, 1 to 4 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 6,600 feet (1,829 to 2,012 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Clovis and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Clovis soils
Landscape: Uplands
Landform: Fan remnants, plains, mesas
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits over slope alluvium derived from sandstone and shale

Slope: 1 to 4 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.8 inches (moderate)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 25 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 1 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, bottlebrush squirreltail
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; fine sandy loam
Bt1—3 to 7 inches; sandy clay loam
Bt2—7 to 12 inches; sandy clay loam
Bt3—12 to 22 inches; sandy clay loam
Bk1—22 to 34 inches; sandy clay loam
Bk2—34 to 60 inches; sandy clay loam

Minor Components
Harvey and similar soils
Composition: About 5 percent
Slope: 5 to 10 percent
Drainage class: Well drained
Ecological site: Limy

Zia and similar soils
Composition: About 5 percent
Slope: 3 to 6 percent
Drainage class: Well drained
Ecological site: Sandy

Pinavetes and similar soils
Composition: About 5 percent
Slope: 3 to 5 percent
Drainage class: Excessively drained
Ecological site: Deep Sand

145—Grieta-Sheppard loamy fine sands, 2 to 9 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,200 to 6,000 feet (1,585 to 1,829 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Grieta and similar soils: 55 percent
Sheppard and similar soils: 40 percent
Minor components: 5 percent

Component Descriptions

Grieta soils
Landscape: Uplands
Landform: Fan remnants, ridges, plateaus, mesas
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone
Slope: 2 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 6.5 inches (moderate)
Shrink-swell potential: About 2.2 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, bottlebrush squirreltail
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 7 inches; loamy fine sand
Bt1—7 to 14 inches; sandy clay loam
Bt2—14 to 21 inches; sandy clay loam
Bk1—21 to 38 inches; coarse sandy loam
Bk2—38 to 50 inches; coarse sandy loam
Bk3—50 to 60 inches; coarse sandy loam

Sheppard soils
Landscape: Uplands
Landform: Alluvial fans, benches, dunes, structural benches, terraces
Position on landform: Shoulders
Position on landform: Rise, side slope
Parent material: Eolian deposits derived from sandstone
Slope: 3 to 9 percent
Aspect: East to west
Shape (down/across): Linear, convex/linear
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 5.3 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None

Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, black grama, sand dropseed, sand sagebrush, spike dropseed
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 5 inches; loamy fine sand
C—5 to 27 inches; loamy fine sand
C—27 to 60 inches; loamy fine sand

Minor Components
Cascajo and similar soils
Composition: About 3 percent
Slope: 12 to 30 percent
Drainage class: Excessively drained
Ecological site: Hills

Riverwash
Composition: About 2 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

146—Sedmar loamy sand, 1 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 7,000 to 8,000 feet (2,134 to 2,438 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Sedmar and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Sedmar soils
Landscape: Uplands
Landform: Ridges, cuestas
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Slope alluvium over residuum weathered from sandstone
Slope: 1 to 15 percent
Aspect: East to west
Shape (down/across): Linear/linear

Depth class: Very shallow and shallow
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 1.8 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
Common trees: ponderosa pine, Gambel oak
Other plants: prairie junegrass, Rocky Mountain juniper, Utah juniper, true mountain mahogany
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 3 inches; loamy sand
C1—3 to 13 inches; sandy loam
C2—13 to 18 inches; loamy sand
2R—18 to 60 inches; bedrock

Minor Components
Menefee and similar soils
Composition: About 8 percent
Slope: 15 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Ponderosa Pine Forest

Rock outcrop
Composition: About 7 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

150—Doakum-Betonnie fine sandy loams, 0 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 37
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Doakum and similar soils: 55 percent
Betonnie and similar soils: 35 percent
Minor components: 10 percent

Component Descriptions

Doakum soils
Landscape: Uplands
Landform: Mesas, plateaus, hills, cuestas, bajadas
Position on landform: Footslopes
Position on landform: Head slope, side slope, nose slope
Parent material: Eolian deposits over slope alluvium derived from sandstone and shale
Slope: 0 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.0 inches (high)
Shrink-swell potential: About 4.4 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 8 mmhos/cm (slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: Indian ricegrass, blue grama, galleta, big sagebrush, bottlebrush squirreltail, sand dropseed, western wheatgrass
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 5 inches; fine sandy loam
Bt1—5 to 11 inches; clay loam
Bt2—11 to 17 inches; sandy clay loam
Bk1—17 to 24 inches; sandy clay loam
Bk2—24 to 31 inches; clay loam
Bk3—31 to 44 inches; loam
C—44 to 60 inches; loam

Betonnie soils
Landscape: Uplands
Landform: Cuestas, mesas, plateaus, hills, valley sides, fan remnants
Position on landform: Footslopes
Position on landform: Head slope, side slope, nose slope
Parent material: Eolian deposits over slope alluvium derived from sandstone
Slope: 5 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 7.3 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)

Ecological site: Sandy
Potential native vegetation: Indian ricegrass, dropseed, needle and thread, winterfat, alkali sacaton, fourwing saltbush, mormon tea, sand sagebrush, sandhill muhly
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 2 inches; fine sandy loam
BA—2 to 4 inches; fine sandy loam
Bt—4 to 12 inches; fine sandy loam
BC—12 to 18 inches; sandy loam
C1—18 to 34 inches; sandy loam
C2—34 to 60 inches; sandy loam

Minor Components
Blancot and similar soils
Composition: About 5 percent
Slope: 3 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Eslendo and similar soils
Composition: About 3 percent
Slope: 5 to 30 percent
Depth to restrictive feature: 4 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

Mespun and similar soils
Composition: About 2 percent
Slope: 5 to 30 percent
Drainage class: Excessively drained
Ecological site: Sandy

162—Hackroy-Nyjack association, 1 to 5 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 7,200 feet (1,829 to 2,195 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Hackroy and similar soils: 45 percent
Nyjack and similar soils: 40 percent
Minor components: 15 percent

Component Descriptions

Hackroy soils
Landscape: Uplands
Landform: Mesas, plateaus
Position on landform: Shoulders
Position on landform: Side slope

Parent material: Residuum weathered from tuff
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 1.9 inches (very low)
Shrink-swell potential: About 7.5 percent (high)
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Indian ricegrass, blue grama, needle and thread, skunkbush sumac
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; sandy loam
Bt—3 to 13 inches; clay
2R—13 to 60 inches; bedrock

Nyjack soils
Landscape: Uplands
Landform: Plateaus, mesas
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits over slope alluvium derived from tuff
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 6.1 inches (moderate)
Shrink-swell potential: About 3.2 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa-Juniperus deppeana/Quercus gambelii
Potential native vegetation:
Common trees: oneseed juniper, ponderosa pine, twoneedle pinyon
Other plants: blue grama, little bluestem, wavyleaf oak, western wheatgrass
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; loam
Bt1—3 to 13 inches; clay loam
Bt2—13 to 24 inches; clay loam
2C—24 to 39 inches; gravelly sandy loam
2Cr—39 to 60 inches; bedrock

Minor Components
Frijoles and similar soils
Composition: About 10 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

163—Jemez loam, 1 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 7,000 to 7,500 feet (2,134 to 2,286 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Jemez and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Jemez soils
Landscape: Uplands
Landform: Plateaus, hills
Position on landform: Summits
Position on landform: Side slope
Parent material: Slope alluvium derived from tuff
Slope: 1 to 15 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 7.0 inches (moderate)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)

Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: white fir, ponderosa pine, Douglas-fir
Other plants: needle and thread, skunkbush sumac, western wheatgrass, Gambel oak
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 3 inches; loam
BA—3 to 24 inches; clay loam
Bt—24 to 39 inches; sandy clay loam
R—39 to 60 inches; bedrock

Minor Components
Carjo and similar soils
Composition: About 5 percent
Slope: 1 to 9 percent
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Pinus ponderosa/Quercus gambelii

Alanos and similar soils
Composition: About 5 percent
Slope: 5 to 40 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Mirand and similar soils
Composition: About 3 percent
Slope: 5 to 30 percent
Drainage class: Well drained
Ecological site: Pinus ponderosa/Quercus gambelii

Rock outcrop
Composition: About 2 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

170—San Mateo loam, 0 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,800 to 6,800 feet (1,768 to 2,073 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

San Mateo and similar soils: 85 percent
Minor components: 15 percent



Figure 6.—Typical landscape of San Mateo loam, 0 to 3 percent slopes. This area is prone to flooding.

Component Descriptions

San Mateo soils

Landscape: Valleys
Landform: Alluvial fans, valley sides, flood plains
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Stream alluvium derived from sandstone and shale
Slope: 0 to 3 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.7 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Flooding hazard: Rare
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 8 mmhos/cm (slightly saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Swale
Potential native vegetation: galleta, big sagebrush, blue grama, bottlebrush squirreltail, other half shrubs, western wheatgrass

Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 2 inches; loam
C1—2 to 10 inches; clay loam
C2—10 to 23 inches; clay loam
C3—23 to 32 inches; clay loam
C4—32 to 54 inches; clay loam
C5—54 to 60 inches; clay loam

Minor Components
Camino and similar soils
Composition: About 5 percent
Slope: 1 to 6 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Clayey

Querencia and similar soils
Composition: About 3 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

Sandoval and similar soils
Composition: About 3 percent
Slope: 3 to 30 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

Skyvillage and similar soils
Composition: About 2 percent
Slope: 3 to 20 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

Sparank and similar soils
Composition: About 2 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Occasional
Ecological site: Clayey Bottomland

180—Councelor-Eslendo-Mespun complex, 5 to 30 percent slopes

Map Unit Setting

Major Land Resource Area: 37
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)

Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Councelor and similar soils: 40 percent
Eslendo and similar soils: 30 percent
Mespun and similar soils: 25 percent
Minor components: 5 percent

Component Descriptions

Councelor soils
Landscape: Uplands
Landform: Stream terraces, fan remnants, valley floors, valley sides
Position on landform: Toeslopes
Position on landform: Side slope
Parent material: Eolian deposits over stream alluvium derived from sandstone and shale
Slope: 5 to 30 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 8.1 inches (moderate)
Shrink-swell potential: About 1.7 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: Indian ricegrass, blue grama, dropseed, New Mexico Feathergrass, big sagebrush, galleta, mormon tea, needle and thread, winterfat
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 2 inches; fine sandy loam
C1—2 to 7 inches; fine sandy loam
C2—7 to 37 inches; fine sandy loam
C3—37 to 40 inches; clay loam
C4—40 to 60 inches; sandy loam

Eslendo soils
Landscape: Uplands
Landform: Ridges
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Residuum weathered from shale
Slope: 5 to 30 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 4 to 20 inches to bedrock (paralithic)
Drainage class: Well drained

Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 2.0 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Shallow
Potential native vegetation: Indian ricegrass, galleta, blue grama, big sagebrush, mormon tea, threeawn
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 3 inches; clay loam
C—3 to 10 inches; clay loam
Cr—10 to 60 inches; bedrock

Mespun soils
Landscape: Uplands
Landform: Dunes
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone
Slope: 5 to 30 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 4.8 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, blue grama, sand dropseed, sand sagebrush, spike dropseed
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 6 inches; loamy fine sand
C—6 to 60 inches; loamy sand

Minor Components
Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

183—Sheppard loamy fine sand, 8 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,200 to 5,700 feet (1,585 to 1,737 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Sheppard and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Sheppard soils
Landscape: Uplands
Landform: Structural benches, stream terraces, alluvial fans, benches, dunes
Position on landform: Shoulders
Position on landform: Rise, side slope
Parent material: Eolian deposits derived from sandstone
Slope: 8 to 15 percent
Aspect: East to west
Shape (down/across): Linear, convex/linear, convex
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 5.3 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, black grama, sand dropseed, sand sagebrush, spike dropseed
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 4 inches; loamy fine sand
C1—4 to 45 inches; loamy fine sand
C2—45 to 60 inches; loamy fine sand

Minor Components
Cascajo and similar soils
Composition: About 7 percent
Slope: 1 to 9 percent
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Hills

Sheppard and similar soils
Composition: About 7 percent
Slope: 3 to 8 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

Riverwash
Composition: About 1 percent
Landscape: Valleys
Landform: Channels, streams
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

185—Frijoles very fine sandy loam, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 7,000 feet (1,829 to 2,134 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Frijoles and similar soils: 90 percent
Minor components: 10 percent

Component Descriptions

Frijoles soils
Landscape: Uplands
Landform: Mesas
Position on landform: Summits
Position on landform: Side slope
Parent material: Eolian deposits over alluvium derived from pumice
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Depth to restrictive feature: 15 to 30 inches to abrupt textural change
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 2.1 inches (very low)
Shrink-swell potential: About 2.0 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)

Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Arizona fescue, blue grama
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 3 inches; very fine sandy loam
Bt1—3 to 8 inches; very gravelly clay loam
Bt2—8 to 13 inches; very gravelly clay loam
2C1—13 to 20 inches; extremely gravelly sandy loam
3C2—20 to 60 inches; fragmental material

Minor Components
Nyjack and similar soils
Composition: About 10 percent
Slope: 1 to 5 percent
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

190—Zia-Skyvillage-Rock outcrop complex, 5 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,800 to 6,400 feet (1,768 to 1,951 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Zia and similar soils: 35 percent
Skyvillage and similar soils: 25 percent
Rock outcrop: 15 percent
Minor components: 25 percent

Component Descriptions

Zia soils
Landscape: Uplands
Landform: Alluvial fans
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Eolian deposits over fan alluvium derived from sandstone
Slope: 5 to 20 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 7.1 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low

Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Sandy
Potential native vegetation: blue grama, hairy grama, black grama, sideoats grama, galleta, oneseed juniper, sacahuista
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 5 inches; sandy loam
C1—5 to 28 inches; sandy loam
C2—28 to 60 inches; sandy loam

Skyvillage soils
Landscape: Uplands
Landform: Breaks, cuestas, hills, mesas, ridges, structural benches
Position on landform: Backslopes
Position on landform: Side slope, nose slope, head slope
Parent material: Slope alluvium derived from sandstone
Slope: 5 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 2.3 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Shallow Sandstone
Potential native vegetation: sideoats grama, blue grama, little bluestem, Indian ricegrass, galleta
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 2 inches; fine sandy loam
C1—2 to 11 inches; fine sandy loam
C2—11 to 16 inches; fine sandy loam
2R—16 to 60 inches; bedrock

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Breaks, escarpments
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components

Penistaja and similar soils
Composition: About 10 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Badland
Composition: About 10 percent
Slope: 5 to 75 percent
Depth to restrictive feature: 0 inches to bedrock (paralithic)

Sandoval and similar soils
Composition: About 5 percent
Slope: 3 to 30 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

191—Sheppard loamy fine sand, 3 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,200 to 5,700 feet (1,585 to 1,737 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Sheppard and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Sheppard soils

Landscape: Uplands
Landform: Alluvial fans, stream terraces, dunes, benches, structural benches
Position on landform: Shoulders
Position on landform: Side slope, rise
Parent material: Eolian deposits derived from sandstone
Slope: 3 to 8 percent
Aspect: East to west
Shape (down/across): Convex, linear/convex, linear
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 5.3 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)

Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, black grama, sand dropseed, sand sagebrush, spike dropseed
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; loamy fine sand
C1—3 to 27 inches; loamy fine sand
C2—27 to 60 inches; loamy fine sand

Minor Components
Grieta and similar soils
Composition: About 12 percent
Slope: 1 to 4 percent
Drainage class: Well drained
Ecological site: Loamy

Riverwash
Composition: About 3 percent
Landscape: Valleys
Landform: Channels, streams
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

200—Sedillo very cobbly sandy loam, 5 to 25 percent slopes, stony

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,400 to 6,100 feet (1,646 to 1,859 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Sedillo and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Sedillo soils
Landscape: Uplands
Landform: Fan remnants, stream terraces, bajadas
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from igneous and sedimentary rock
Slope: 5 to 25 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep

Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 2.3 inches (very low)
Shrink-swell potential: About 2.0 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 30 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Gravelly
Potential native vegetation: blue grama, big sagebrush, black grama, hairy grama, needlegrass, New Mexico Feathergrass, oneseed juniper, sideoats grama, western wheatgrass, winterfat
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 4 inches; very cobbly sandy loam
Bt—4 to 13 inches; very gravelly sandy clay loam
Bk—13 to 60 inches; extremely gravelly coarse sandy loam

Minor Components

Pastura and similar soils
Composition: About 5 percent
Slope: 1 to 4 percent
Depth to restrictive feature: 7 to 20 inches to petrocalcic
Drainage class: Well drained
Ecological site: Limy

Clovis and similar soils
Composition: About 5 percent
Slope: 1 to 4 percent
Drainage class: Well drained
Ecological site: Loamy

Riverwash
Composition: About 3 percent
Landscape: Valleys
Landform: Channels, streams
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Sedillo and similar soils
Composition: About 2 percent
Slope: 5 to 25 percent
Drainage class: Well drained
Ecological site: Foothills

201—Rock outcrop-Sedgran association, 25 to 55 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,800 to 8,000 feet (1,768 to 2,438 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Rock outcrop: 55 percent
Sedgran and similar soils: 35 percent
Minor components: 10 percent

Component Descriptions

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Escarpments, ridges
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Sedgran soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank, lower third
Parent material: Colluvium derived from granite
Slope: 25 to 55 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 0.4 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Hills
Potential native vegetation: black grama, sideoats grama, New Mexico Feathergrass, little bluestem, New Mexico muhly, blue grama, mountain mahogany, needle and thread, oneseed juniper, skunkbush sumac, wavyleaf oak
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 4 inches; extremely gravelly loamy coarse sand
C—4 to 13 inches; very gravelly loamy coarse sand
2R—13 to 60 inches; bedrock

Minor Components
Sedillo and similar soils
Composition: About 9 percent
Slope: 5 to 25 percent
Drainage class: Well drained
Ecological site: Foothills

Riverwash
Composition: About 1 percent
Landscape: Valleys
Landform: Channels, streams
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

206—Pinitos loam, 1 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 7,000 to 7,600 feet (2,134 to 2,316 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Pinitos and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Pinitos soils
Landscape: Uplands
Landform: Hills, mesas, cuestas, fan remnants
Position on landform: Shoulders
Position on landform: Side slope, side slope
Parent material: Fan alluvium derived from sandstone and shale
Slope: 1 to 15 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 11.7 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 12 percent

Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Indian ricegrass, blue grama, New Mexico Feathergrass, bottlebrush squirreltail, mountain big sagebrush, western wheatgrass
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 4 inches; loam
Bt1—4 to 10 inches; clay loam
Bt2—10 to 27 inches; clay loam
Btk—27 to 39 inches; clay loam
C—39 to 60 inches; clay loam

Minor Components
Sparham and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Occasional
Ecological site: Clayey

Hickman and similar soils
Composition: About 5 percent
Slope: 1 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

Menefee and similar soils
Composition: About 5 percent
Slope: 5 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

207—Penistaja-Zia complex, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,400 to 6,100 feet (1,646 to 1,859 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Penistaja and similar soils: 60 percent
Zia and similar soils: 25 percent
Minor components: 15 percent

Component Descriptions

Penistaja soils
Landscape: Uplands
Landform: Plateaus, alluvial fans, bajadas, cuestas, hills, mesas
Position on landform: Footslopes
Position on landform: Head slope, rise, side slope, nose slope
Parent material: Eolian deposits over alluvium derived from sandstone and shale
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.6 inches (moderate)
Shrink-swell potential: About 2.9 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, spike muhly, western wheatgrass, bottlebrush squirreltail, galleta, winterfat
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; very fine sandy loam
Btk—3 to 29 inches; sandy clay loam
C—29 to 60 inches; fine sandy loam

Zia soils
Landscape: Uplands
Landform: Plateaus
Position on landform: Toeslopes
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 8.3 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, spike muhly, western wheatgrass, bottlebrush squirreltail, fourwing saltbush, oneseed juniper, winterfat
Land capability subclass (irrigated): 3e
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 5 inches; fine sandy loam
C—5 to 60 inches; fine sandy loam

Minor Components
Clovis and similar soils
Composition: About 10 percent
Slope: 3 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

Pinavetes and similar soils
Composition: About 5 percent
Slope: 5 to 15 percent
Drainage class: Excessively drained
Ecological site: Deep Sand

208—Sedillo very gravelly fine sandy loam, 25 to 55 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,100 to 6,500 feet (1,554 to 1,981 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Sedillo and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Sedillo soils
Landscape: Uplands
Landform: Bajadas, fan remnants, stream terraces
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from igneous and sedimentary rock
Slope: 25 to 55 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 3.6 inches (low)
Shrink-swell potential: About 1.7 percent (low)
Runoff class: High
Calcium carbonate maximum: About 25 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)

Ecological site: Gravelly
Potential native vegetation: blue grama, big sagebrush, black grama, hairy grama, needlegrass, New Mexico Feathergrass, oneseed juniper, sideoats grama, western wheatgrass, winterfat
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; very gravelly fine sandy loam
Bt—2 to 8 inches; very gravelly sandy clay loam
Bk1—8 to 12 inches; very gravelly sandy loam
Bk2—12 to 60 inches; extremely gravelly sandy loam

Minor Components
Ildefonso and similar soils
Composition: About 5 percent
Slope: 15 to 35 percent
Drainage class: Well drained
Ecological site: Limy

Pinavetes and similar soils
Composition: About 5 percent
Slope: 5 to 15 percent
Drainage class: Excessively drained
Ecological site: Deep Sand

Rock outcrop
Composition: About 3 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Zia and similar soils
Composition: About 2 percent
Slope: 3 to 6 percent
Drainage class: Well drained
Ecological site: Sandy

210—Ildefonso very stony loam, 25 to 70 percent slopes, rubbly

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,000 to 5,800 feet (1,524 to 1,768 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Ildefonso and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Ildefonso soils
Landscape: Uplands
Landform: Fan remnants, hills, mesas

Position on landform: Backslopes, side slopes
Parent material: Fan alluvium over colluvium derived from sandstone and shale
Slope: 25 to 70 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 4.7 inches (low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Limy
Potential native vegetation: blue grama, New Mexico Feathergrass, sideoats grama, twoneedle pinyon
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 3 inches; very stony loam
Bw—3 to 9 inches; very stony loam
Bk—9 to 60 inches; very stony loam

Minor Components
Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Rubble land
Composition: About 5 percent
Slope: 35 to 60 percent
Drainage class: Excessively drained

Prieta and similar soils
Composition: About 5 percent
Slope: 3 to 15 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Malpais

211—Zia-Clovis association, 2 to 10 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,500 to 6,400 feet (1,676 to 1,951 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Zia and similar soils: 45 percent
Clovis and similar soils: 30 percent
Minor components: 25 percent

Component Descriptions

Zia soils
Landscape: Uplands
Landform: Plateaus
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone over fan alluvium derived from sandstone, eolian deposits and alluvium derived from sandstone and shale
Slope: 2 to 10 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 7.5 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: blue grama, western wheatgrass, Indian ricegrass, black grama, oneseed juniper
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 5 inches; sandy loam
Bw—5 to 14 inches; sandy loam
C1—14 to 33 inches; sandy loam
C2—33 to 46 inches; sandy clay loam
C3—46 to 60 inches; sandy loam

Clovis soils
Landscape: Uplands
Landform: Fan remnants, plains
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone over fan alluvium derived from sandstone and shale, eolian deposits and alluvium derived from sandstone and shale
Slope: 2 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.8 inches (moderate)
Shrink-swell potential: About 4.4 percent (moderate)

Runoff class: Medium
Calcium carbonate maximum: About 25 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, bottlebrush squirreltail
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 5 inches; fine sandy loam
B—5 to 60 inches; sandy clay loam

Minor Components
Penistaja and similar soils
Composition: About 15 percent
Slope: 2 to 7 percent
Drainage class: Well drained
Ecological site: Loamy

Pinavetes and similar soils
Composition: About 10 percent
Slope: 5 to 15 percent
Drainage class: Excessively drained
Ecological site: Deep Sand

213—Pinavetes-Rock outcrop complex, 15 to 35 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,600 to 6,100 feet (1,707 to 1,859 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Pinavetes and similar soils: 55 percent
Rock outcrop: 30 percent
Minor components: 15 percent

Component Descriptions

Pinavetes soils
Landscape: Uplands
Landform: Valley sides, dunes
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone
Slope: 15 to 35 percent
Aspect: East to west
Shape (down/across): Convex/convex
Depth class: Very deep
Drainage class: Excessively drained

Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 2.9 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, blue grama, western wheatgrass, galleta, oneseed juniper, sand sagebrush, twoneedle pinyon
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 7 inches; sand
C—7 to 60 inches; stratified sand to loamy sand

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Escarpments, breaks
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Skyvillage and similar soils
Composition: About 10 percent
Slope: 8 to 25 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

Zia and similar soils
Composition: About 5 percent
Slope: 3 to 6 percent
Drainage class: Well drained
Ecological site: Sandy

215—Ess-Rock outcrop complex, 5 to 45 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 9,000 to 11,000 feet (2,743 to 3,353 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Ess and similar soils: 60 percent
Rock outcrop: 30 percent
Minor components: 10 percent

Component Descriptions

Ess soils
Landscape: Mountains
Landform: Mountain slopes, hills
Position on landform: Backslopes
Position on landform: Mountainflank, side slope
Parent material: Colluvium derived from rhyolite
Slope: 5 to 45 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 4.6 inches (low)
Shrink-swell potential: About 2.3 percent (low)
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 0 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Subalpine Grassland
Potential native vegetation: Arizona fescue, sedge, bottlebrush squirreltail, mountain muhly, muttongrass, prairie junegrass, western wheatgrass
Land capability subclass (nonirrigated): 7c

Typical Profile:
A1—0 to 7 inches; very cobbly sandy loam
A2—7 to 15 inches; very cobbly sandy loam
Bt—15 to 29 inches; very cobbly sandy clay loam
C—29 to 60 inches; very cobbly loam

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Mountains
Position on landform: Mountainflank, mountaintop
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Calaveras and similar soils
Composition: About 10 percent
Landform: Mountain slopes
Position on landform: Mountainflank
Slope: 35 to 60 percent
Aspect: East to west
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

217—Witt loam, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,200 to 6,000 feet (1,585 to 1,829 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Witt and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Witt soils
Landscape: Uplands
Landform: Mesas, fan remnants, bajadas
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone over fan alluvium derived from basalt, eolian deposits and alluvium derived from sandstone and shale
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 10.0 inches (high)
Shrink-swell potential: About 1.8 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, spike muhly, fourwing saltbush, galleta
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 2 inches; loam
Bt—2 to 9 inches; loam
Bk—9 to 60 inches; stratified very fine sandy loam to loam

Minor Components
Penistaja and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Harvey and similar soils
Composition: About 5 percent
Slope: 5 to 10 percent
Drainage class: Well drained
Ecological site: Limy

Ildefonso and similar soils
Composition: About 5 percent
Slope: 15 to 35 percent
Drainage class: Well drained
Ecological site: Limy

218—Ildefonso very cobbly loam, 1 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,200 to 5,800 feet (1,585 to 1,768 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Ildefonso and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Ildefonso soils
Landscape: Uplands
Landform: Hills, fan remnants, mesas
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium over colluvium derived from sandstone and shale
Slope: 1 to 15 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 3.8 inches (low)
Shrink-swell potential: About 1.7 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Limy
Potential native vegetation: thickspike wheatgrass, western wheatgrass, New Mexico Feathergrass, blue grama, hairy grama, winterfat
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 4 inches; very cobbly loam
B—4 to 8 inches; very cobbly loam
B—8 to 60 inches; very cobbly sandy loam

Minor Components
Pastura and similar soils
Composition: About 5 percent
Slope: 1 to 4 percent
Depth to restrictive feature: 7 to 20 inches to petrocalcic
Drainage class: Well drained
Ecological site: Limy

Prieta and similar soils
Composition: About 5 percent
Slope: 3 to 15 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Malpais

Rock outcrop
Composition: About 3 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Witt and similar soils
Composition: About 2 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

220—Rock outcrop-Vessilla-Menefee complex, 30 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,100 to 7,200 feet (1,859 to 2,195 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Rock outcrop: 40 percent
Vessilla and similar soils: 30 percent
Menefee and similar soils: 20 percent
Minor components: 10 percent

Component Descriptions

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.

Landform: Escarpments, breaks
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Vessilla soils
Landscape: Uplands
Landform: Mesas, hills, breaks, ridges
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium over residuum weathered from sandstone
Slope: 30 to 40 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 4 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 1.2 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Indian ricegrass, blue grama, mountain big sagebrush, oak, galleta, sideoats grama
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; sandy loam
C—2 to 10 inches; sandy loam
R—10 to 60 inches; bedrock

Menefee soils
Landscape: Uplands
Landform: Mountainsides, mesas, hillslopes
Position on landform: Shoulders
Position on landform: Nose slope
Parent material: Colluvium over residuum weathered from shale
Slope: 30 to 40 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 2.0 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high

Calcium carbonate maximum: About 5 percent
Gypsum maximum: About 1 percent
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, Rocky Mountain juniper, twoneedle pinyon
Other plants: blue grama, galleta, Gambel oak, big sagebrush, sideoats grama
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; clay loam
C—2 to 10 inches; clay loam
2Cr—10 to 60 inches; bedrock

Minor Components
Badland
Composition: About 5 percent
Slope: 5 to 75 percent
Depth to restrictive feature: 0 inches to bedrock (paralithic)

Rubble land
Composition: About 5 percent
Slope: 35 to 60 percent
Drainage class: Excessively drained

226—Galisteo loam, moderately saline, sodic, 1 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,700 to 6,200 feet (1,737 to 1,890 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Galisteo, moderately saline, sodic and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Galisteo, moderately saline, sodic soils
Landscape: Valleys
Landform: Alluvial fans, stream terraces
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Stream alluvium derived from sandstone and shale
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained

Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 11.5 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 20 (moderately sodic)
Ecological site: Salty Bottomland
Potential native vegetation: alkali sacaton, western wheatgrass, galleta, fourwing saltbush, greasewood
Land capability subclass (nonirrigated): 6c

Typical Profile:
Ap—0 to 10 inches; loam
C—10 to 60 inches; silty clay loam

Minor Components
Zia and similar soils
Composition: About 5 percent
Slope: 1 to 3 percent
Drainage class: Well drained
Ecological site: Sandy

El Rancho and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Well drained
Ecological site: Loamy

Ildefonso and similar soils
Composition: About 5 percent
Slope: 1 to 15 percent
Drainage class: Well drained
Ecological site: Limy

227—Hagerman-Bond association, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,700 to 6,000 feet (1,737 to 1,829 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Hagerman and similar soils: 65 percent
Bond and similar soils: 20 percent
Minor components: 15 percent

Component Descriptions

Hagerman soils
Landscape: Uplands
Landform: Mesas, hills, ridges
Position on landform: Shoulders
Position on landform: Crest
Parent material: Eolian deposits over slope alluvium derived from sandstone
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 5 percent subangular channers
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 6.5 inches (moderate)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, spike muhly, fourwing saltbush, galleta, sand dropseed
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 4 inches; fine sandy loam
Bt—4 to 34 inches; clay loam
2R—34 to 60 inches; bedrock

Bond soils
Landscape: Uplands
Landform: Ridges, cuestas, mesas, hills
Position on landform: Summits
Position on landform: Crest
Parent material: Eolian deposits over slope alluvium derived from sandstone
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 1.5 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)

Ecological site: Shallow Sandstone
Potential native vegetation: sideoats grama, blue grama, little bluestem, Indian ricegrass, galleta
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 4 inches; loamy fine sand
Bt—4 to 12 inches; sandy clay loam
R—12 to 60 inches; bedrock

Minor Components
Penistaja and similar soils
Composition: About 10 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

228—Winona very channery fine sandy loam, 8 to 25 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,900 to 6,300 feet (1,798 to 1,920 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Winona and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Winona soils
Landscape: Uplands
Landform: Plateaus, hills
Position on landform: Shoulders
Position on landform: Nose slope, head slope, nose slope, side slope
Parent material: Residuum weathered from travertine
Slope: 8 to 25 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 5 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 1.1 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 50 percent

Gypsum maximum: None
Salinity maximum: About 8 mmhos/cm (slightly saline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Shallow Sandstone
Potential native vegetation: sideoats grama, blue grama, little bluestem, needlegrass, juniper, muhly, winterfat
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; very channery fine sandy loam
Bk—2 to 13 inches; very channery loam
R—13 to 60 inches; bedrock

Minor Components
Rock outcrop
Composition: About 15 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

230—Skyvillage-Sandoval-Rock outcrop complex, 3 to 20 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,800 to 6,400 feet (1,768 to 1,951 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Skyvillage and similar soils: 35 percent
Sandoval and similar soils: 25 percent
Rock outcrop: 20 percent
Minor components: 20 percent

Component Descriptions

Skyvillage soils
Landscape: Uplands
Landform: Structural benches, cuestas, ridges, breaks, mesas, hills
Position on landform: Shoulders
Position on landform: Side slope, nose slope, head slope
Parent material: Slope alluvium derived from sandstone
Slope: 3 to 20 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 1.3 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: High
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None

Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Shallow Sandstone
Potential native vegetation: sideoats grama, blue grama, little bluestem, Indian ricegrass, galleta
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 6 inches; sandy loam
C—6 to 11 inches; sandy loam
2R—11 to 60 inches; bedrock

Sandoval soils
Landscape: Uplands
Landform: Hills, ridges
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Slope alluvium derived from shale
Slope: 3 to 20 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 2.0 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 10 percent
Gypsum maximum: About 10 percent
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Shallow
Potential native vegetation: sideoats grama, New Mexico Feathergrass, cane bluestem, little bluestem, galleta
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 2 inches; clay loam
C—2 to 10 inches; clay loam
Cr—10 to 60 inches; bedrock

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Escarpments, breaks
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Penistaja and similar soils
Composition: About 10 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

Querencia and similar soils
Composition: About 10 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

231—Querencia loam, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,200 to 6,900 feet (1,890 to 2,103 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Querencia and similar soils: 85 percent
Minor components: 15 percent



Figure 7.—Typical landscape of Querencia loam, 1 to 8 percent slopes.

Component Descriptions

Querencia soils
Landscape: Valleys
Landform: Valley sides, stream terraces, alluvial fans
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Fan alluvium over colluvium derived from sandstone and shale
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 10.0 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, spike muhly, bottlebrush squirreltail, fourwing saltbush, needlegrass, winterfat
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; loam
Bw—3 to 21 inches; loam
Bk—21 to 60 inches; loam

Minor Components
Sandoval and similar soils
Composition: About 5 percent
Slope: 3 to 20 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

Sparank and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Well drained
Flooding hazard: Occasional
Ecological site: Clayey Bottomland

San Mateo and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

234—Querencia-Zia complex, 2 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,800 to 6,900 feet (1,768 to 2,103 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Querencia and similar soils: 60 percent
Zia and similar soils: 20 percent
Minor components: 20 percent

Component Descriptions

Querencia soils
Landscape: Valleys
Landform: Stream terraces, valley sides, alluvial fans
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Fan alluvium over colluvium derived from sandstone and shale
Slope: 2 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 9.3 inches (high)
Shrink-swell potential: About 2.7 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, spike muhly, bottlebrush squirreltail, fourwing saltbush, needlegrass, winterfat
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; fine sandy loam
Bw—3 to 25 inches; loam
Bk—25 to 60 inches; stratified loam to fine sandy loam

Zia soils
Landscape: Valleys
Landform: Alluvial fans
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Eolian deposits over fan alluvium derived from sandstone
Slope: 2 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear

Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 7.1 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: blue grama, western wheatgrass, Indian ricegrass, black grama, oneseed juniper
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 11 inches; sandy loam
C—11 to 60 inches; sandy loam

Minor Components
Penistaja and similar soils
Composition: About 10 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Loamy

San Mateo and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

Sandoval and similar soils
Composition: About 5 percent
Slope: 3 to 20 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

235—Sandoval fine sandy loam, 3 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,800 to 6,400 feet (1,768 to 1,951 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Sandoval and similar soils: 85 percent
Minor components: 15 percent



Figure 8.—Typical landscape of Sandoval fine sandy loam, 3 to 15 percent slopes.

Component Descriptions

Sandoval soils
Landscape: Uplands
Landform: Hills, ridges
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Slope alluvium derived from shale
Slope: 3 to 15 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 3.7 inches (low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: About 10 percent
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 13 (moderately sodic)
Ecological site: Shallow
Potential native vegetation: sideoats grama, New Mexico Feathergrass, cane bluestem, little bluestem, galleta
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 2 inches; fine sandy loam
C1—2 to 16 inches; clay loam
C2—16 to 19 inches; clay loam
Cr—19 to 60 inches; bedrock

Minor Components
Querencia and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: Loamy

San Mateo and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

Badland
Composition: About 5 percent
Slope: 5 to 75 percent
Depth to restrictive feature: 0 inches to bedrock (paralithic)

236—Sparank clay loam, moderately saline, sodic, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,800 to 6,400 feet (1,768 to 1,951 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Sparank, moderately saline, sodic and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Sparank, moderately saline, sodic soils
Landscape: Valleys
Landform: Stream terraces, alluvial fans, valley sides, valley floors, flood plains
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Stream alluvium derived from sandstone and shale
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 10.2 inches (high)

Shrink-swell potential: About 6.6 percent (high)
Flooding hazard: Occasional
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Salty Bottomland
Potential native vegetation: alkali sacaton, western wheatgrass, galleta, fourwing saltbush, greasewood
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 2 inches; clay loam
C1—2 to 10 inches; silty clay
C2—10 to 24 inches; silty clay
C3—24 to 40 inches; silty clay loam
C4—40 to 44 inches; silty clay
C5—44 to 60 inches; silty clay

Minor Components
Camino and similar soils
Composition: About 10 percent
Slope: 1 to 6 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Clayey

San Mateo and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

237—Sparank silty clay loam, 0 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,500 to 6,400 feet (1,676 to 1,951 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Sparank and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Sparank soils
Landscape: Valleys
Landform: Valley sides, valley floors, alluvial fans, flood plains, stream terraces
Position on landform: Toeslopes

Position on landform: Rise
Parent material: Stream alluvium derived from sandstone and shale
Slope: 0 to 3 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 11.8 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Flooding hazard: Occasional
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 10 (slightly sodic)
Ecological site: Clayey Bottomland
Potential native vegetation: western wheatgrass, alkali sacaton, blue grama, fourwing saltbush, galleta, obtuse panicgrass
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 4 inches; silty clay loam
C—4 to 60 inches; silty clay loam

Minor Components
Camino and similar soils
Composition: About 10 percent
Slope: 1 to 6 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Clayey

San Mateo and similar soils
Composition: About 5 percent
Slope: 0 to 3 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Swale

240—Penistaja-Hagerman association, 1 to 5 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 6,400 feet (1,829 to 1,951 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Penistaja and similar soils: 45 percent
Hagerman and similar soils: 35 percent
Minor components: 20 percent

Component Descriptions

Penistaja soils
Landscape: Uplands
Landform: Plateaus, mesas, hills, cuestas, alluvial fans, bajadas
Position on landform: Footslopes
Position on landform: Rise, side slope, nose slope, head slope
Parent material: Eolian material and slope alluvium derived from sandstone and shale
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.3 inches (high)
Shrink-swell potential: About 2.8 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, spike muhly, western wheatgrass, bottlebrush squirreltail, galleta, winterfat
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 5 inches; fine sandy loam
Bt—5 to 14 inches; clay loam
Btk—14 to 29 inches; sandy clay loam
C—29 to 60 inches; stratified sandy clay loam to fine sandy loam to loam

Hagerman soils
Landscape: Uplands
Landform: Mesas, hills, ridges
Position on landform: Shoulders
Position on landform: Crest
Parent material: Eolian material and slope alluvium derived from sandstone and shale
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 4.7 inches (low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None

Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Loamy
Potential native vegetation: blue grama, western wheatgrass, spike muhly, fourwing saltbush, galleta, sand dropseed
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 2 inches; fine sandy loam
Bt—2 to 9 inches; clay loam
Btk—9 to 24 inches; clay loam
2R—24 to 60 inches; bedrock

Minor Components
Skyvillage and similar soils
Composition: About 10 percent
Slope: 8 to 25 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

Rock outcrop
Composition: About 10 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

250—Pinavetes loamy fine sand, 5 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,200 to 5,700 feet (1,585 to 1,737 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Pinavetes and similar soils: 90 percent
Minor components: 10 percent

Component Descriptions

Pinavetes soils
Landscape: Uplands
Landform: Dunes, valley sides
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone
Slope: 5 to 15 percent
Aspect: East to west
Shape (down/across): Convex/convex
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 4.2 inches (low)
Shrink-swell potential: About 1.5 percent (low)

Runoff class: Low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, blue grama, sand sagebrush
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 4 inches; loamy fine sand
C—4 to 60 inches; loamy sand

Minor Components
Zia and similar soils
Composition: About 10 percent
Slope: 8 to 25 percent
Drainage class: Well drained
Ecological site: Sandy

262—Pastura loam, 1 to 4 percent slopes

Map Unit Setting

Major Land Resource Area: 70
Elevation: 5,400 to 5,800 feet (1,646 to 1,768 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Pastura and similar soils: 90 percent
Minor components: 10 percent

Component Descriptions

Pastura soils
Landscape: Uplands
Landform: Cuestas, mesas
Position on landform: Shoulders
Position on landform: Tread
Parent material: Eolian materials and alluvium derived from sandstone and shale
Slope: 1 to 4 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 5 to 20 inches to petrocalcic
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 1.9 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: About 1 percent
Salinity maximum: About 2 mmhos/cm (nonsaline)

Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Shallow Limy Savannah
Potential native vegetation: black grama, blue grama, sideoats grama, needle and thread, winterfat, dropseed, galleta, juniper, muttongrass, bastardsage, Menodora
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; loam
Bw—3 to 10 inches; gravelly loam
Bk—10 to 14 inches; gravelly loam
Bkm—14 to 60 inches; cemented material

Minor Components
Ildefonso and similar soils
Composition: About 5 percent
Slope: 1 to 15 percent
Drainage class: Well drained
Ecological site: Limy

Harvey and similar soils
Composition: About 5 percent
Slope: 10 to 15 percent
Drainage class: Well drained
Ecological site: Limy

270—Blancot-Councelor-Tsosie association, 0 to 5 percent slopes

Map Unit Setting

Major Land Resource Area: 37
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Blancot and similar soils: 40 percent
Councelor and similar soils: 30 percent
Tsosie and similar soils: 25 percent
Minor components: 5 percent

Component Descriptions

Blancot soils
Landscape: Uplands
Landform: Ridges, valley sides
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Fan alluvium derived from sandstone and shale
Slope: 3 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained

Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 8.1 inches (moderate)
Shrink-swell potential: About 2.4 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 13 (moderately sodic)
Ecological site: Loamy
Potential native vegetation: Indian ricegrass, blue grama, galleta, big sagebrush, bottlebrush squirreltail, sand dropseed, western wheatgrass
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 2 inches; fine sandy loam
Bt1—2 to 12 inches; sandy clay loam
B2—12 to 21 inches; clay loam
C—21 to 60 inches; sandy loam

Councelor soils
Landscape: Uplands
Landform: Fan remnants, valley sides, valley floors, stream terraces
Position on landform: Footslopes
Position on landform: Tread
Parent material: Eolian deposits over stream alluvium derived from sandstone and shale
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 7.1 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: Indian ricegrass, blue grama, dropseed, New Mexico Feathergrass, big sagebrush, galleta, mormon tea, needle and thread, winterfat
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 2 inches; fine sandy loam
C—2 to 60 inches; sandy loam

Tsosie soils
Landscape: Uplands
Landform: Alluvial fans, stream terraces
Position on landform: Footslopes
Position on landform: Tread, rise
Parent material: Stream alluvium derived from sandstone and shale

Slope: 0 to 3 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.7 inches (high)
Shrink-swell potential: About 3.2 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 8 mmhos/cm (slightly saline)
Sodium adsorption ratio maximum: About 10 (slightly sodic)
Ecological site: Salt Flats
Potential native vegetation: alkali sacaton, fourwing saltbush, galleta, greasewood, shadscale saltbush, big sagebrush, inland saltgrass, western wheatgrass
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 2 inches; clay loam
C1—2 to 10 inches; loam
C2—10 to 20 inches; clay loam
C3—20 to 26 inches; clay loam
C4—26 to 36 inches; clay loam
C5—36 to 44 inches; sandy loam
C6—44 to 55 inches; sandy loam
C7—55 to 60 inches; sandy loam

Minor Components
Badland
Composition: About 5 percent
Slope: 5 to 75 percent
Depth to restrictive feature: 0 inches to bedrock (paralithic)

281—Carjo loam, 1 to 9 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 7,000 to 8,000 feet (2,134 to 2,438 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Carjo and similar soils: 90 percent
Minor components: 10 percent

Component Descriptions

Carjo soils
Landscape: Uplands
Landform: Ridges, hills, mesas
Position on landform: Shoulders
Position on landform: Side slope

Parent material: Residuum weathered from tuff
Slope: 1 to 9 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 4.2 inches (low)
Shrink-swell potential: About 4.9 percent (moderate)
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
Common trees: ponderosa pine
Other plants: Arizona fescue, blue grama, big bluestem, little bluestem, twoneedle pinyon, wavyleaf oak
Land capability subclass (nonirrigated): 5c

Typical Profile:
A—0 to 4 inches; loam
BA—4 to 12 inches; clay loam
Bt—12 to 20 inches; clay
C—20 to 25 inches; very fine sandy loam
2R—25 to 60 inches; bedrock

Minor Components

Frijoles and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: ponderosa forest

Nyjack and similar soils
Composition: About 3 percent
Slope: 1 to 5 percent
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: ponderosa forest

Tocal and similar soils
Composition: About 2 percent
Slope: 3 to 8 percent
Depth to restrictive feature: 8 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

282—Tocal very fine sandy loam, 3 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 7,000 to 8,000 feet (2,134 to 2,438 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Tocal and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Tocal soils
Landscape: Mountains
Landform: Plateaus
Position on landform: Shoulders
Position on landform: Mountaintop
Parent material: Eolian deposits derived from sandstone over residuum weathered from tuff
Slope: 3 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 2.5 inches (very low)
Shrink-swell potential: About 5.1 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 1 percent
Gypsum maximum: About 1 percent
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: ponderosa pine, white fir, Douglas-fir
Other plants: bottlebrush squirreltail, Gambel oak, little bluestem, mountain muhly, true mountain mahogany
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 5 inches; very fine sandy loam
Bt1—5 to 8 inches; clay loam
Bt2—8 to 11 inches; clay
2Bt3—11 to 14 inches; silt loam
2Cr—14 to 60 inches; bedrock

Minor Components

Alanos and similar soils
Composition: About 10 percent
Slope: 20 to 40 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Mirand and similar soils
Composition: About 5 percent
Slope: 5 to 30 percent
Drainage class: Well drained
Ecological site: Pinus ponderosa/Quercus gambelii

283—Mirand-Alanos complex, 5 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,500 to 9,500 feet (2,591 to 2,896 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Mirand and similar soils: 45 percent
Alanos and similar soils: 30 percent
Minor components: 25 percent

Component Descriptions

Mirand soils
Landscape: Mountains
Landform: Canyons, mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Colluvium derived from volcanic rock
Slope: 5 to 30 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .001 to .06 in./hr. (very slow)
Available water capacity: About 10.8 inches (high)
Shrink-swell potential: About 5.6 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
Common trees: ponderosa pine
Other plants: Arizona fescue, mountain muhly, muttongrass, California brome, Gambel oak, prairie junegrass
Land capability subclass (nonirrigated): 7c

Typical Profile:
Oi—0 to 2 inches; slightly decomposed plant material
A—2 to 6 inches; loam
Bt1—6 to 11 inches; clay loam
Bt2—11 to 17 inches; gravelly clay loam
Bt3—17 to 27 inches; clay loam
Bt4—27 to 47 inches; clay
2Bt5—47 to 60 inches; clay loam

Alanos soils
Landscape: Mountains
Landform: Mountain slopes, hillsides
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Slope alluvium over colluvium derived from volcanic rock
Slope: 5 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 4.7 inches (low)
Shrink-swell potential: About 6.1 percent (high)
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: ponderosa pine, Douglas-fir
Other plants: Arizona fescue, blue grama, California brome, pine dropseed, Gambel oak, lupine
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 6 inches; cobbly loam
E—6 to 9 inches; cobbly loam
Bt1—9 to 30 inches; extremely gravelly clay loam
Bt2—30 to 60 inches; very gravelly clay

Minor Components
Calaveras and similar soils
Composition: About 10 percent
Slope: 35 to 60 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Palon and similar soils
Composition: About 5 percent
Slope: 35 to 65 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Pavo and similar soils
Composition: About 5 percent
Slope: 5 to 20 percent
Drainage class: Well drained
Ecological site: Mountain Loam

Rubble land
Composition: About 5 percent
Slope: 35 to 60 percent
Drainage class: Excessively drained

290—Alanos-Rock outcrop complex, 20 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 7,800 to 8,500 feet (2,377 to 2,591 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Alanos and similar soils: 50 percent
Rock outcrop: 30 percent
Minor components: 20 percent

Component Descriptions

Alanos soils
Landscape: Mountains
Landform: Hillsides, mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Slope alluvium over colluvium derived from tuff
Slope: 20 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 4.3 inches (low)
Shrink-swell potential: About 6.7 percent (high)
Runoff class: Very high
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: ponderosa pine, Douglas-fir
Other plants: Arizona fescue, California brome, blue grama, pine dropseed, Gambel oak, lupine
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 4 inches; loam
E—4 to 9 inches; loam
BE—9 to 18 inches; very gravelly loam
Bt1—18 to 26 inches; extremely gravelly clay
Bt2—26 to 60 inches; extremely gravelly clay

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Ridges
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Alanos and similar soils
Composition: About 10 percent
Slope: 5 to 40 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Tocal and similar soils
Composition: About 5 percent
Slope: 3 to 8 percent
Depth to restrictive feature: 8 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Carjo and similar soils
Composition: About 5 percent
Slope: 1 to 9 percent
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Pinus ponderosa/Quercus gambelii

300—Waumac-Bamac association, 1 to 7 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,400 to 6,200 feet (1,646 to 1,890 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Waumac and similar soils: 50 percent
Bamac and similar soils: 35 percent
Minor components: 15 percent

Component Descriptions

Waumac soils
Landscape: Valleys
Landform: Valley floors
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Fan alluvium derived from igneous and sedimentary rock
Slope: 1 to 7 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 6.9 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very low
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: blue grama, western wheatgrass, Indian ricegrass, black grama, oneseed juniper, twoneedle pinyon
Land capability subclass (nonirrigated): 6s

Typical Profile:
A—0 to 3 inches; loamy sand
C1—3 to 31 inches; fine sandy loam
C2—31 to 60 inches; gravelly fine sandy loam

Bamac soils
Landscape: Valleys
Landform: Fan remnants, fan remnants, ridges, hills
Position on landform: Footslopes
Position on landform: Side slope, head slope
Parent material: Slope alluvium derived from igneous and sedimentary rock
Slope: 1 to 7 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 1.9 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Foothills
Potential native vegetation: blue grama, western wheatgrass, Indian ricegrass, black grama
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 6 inches; gravelly loamy sand
C—6 to 60 inches; stratified very gravelly coarse sand to very gravelly loamy sand

Minor Components
Riverwash
Composition: About 10 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Royosa and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

301—Vastine-Jarola silt loams, 0 to 5 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,400 to 8,600 feet (2,560 to 2,621 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Vastine and similar soils: 45 percent
Jarola and similar soils: 40 percent
Minor components: 15 percent

Component Descriptions

Vastine soils
Landscape: Valleys
Landform: Stream terraces, flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 0 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Poorly drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 5.3 inches (low)
Shrink-swell potential: About 2.6 percent (low)
Flooding hazard: Rare

Seasonal high water table depth: About 12 to 36 inches
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Mountain Loam
Potential native vegetation: tufted hairgrass, bluegrass, sedge, Canada wildrye, Rocky Mountain iris, bluejoint, clover, shrubby cinquefoil, western wheatgrass
Land capability subclass (nonirrigated): 7c

Typical Profile:
A1—0 to 4 inches; silt loam
A2—4 to 11 inches; loam
Bw—11 to 24 inches; loam
2C—24 to 60 inches; very gravelly loamy sand

Jarola soils
Landscape: Mountains
Landform: Stream terraces
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous rock
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Poorly drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 7.7 inches (moderate)
Shrink-swell potential: About 3.6 percent (moderate)
Flooding hazard: Rare
Seasonal high water table depth: About 12 to 36 inches
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Mountain Meadow
Potential native vegetation: tufted hairgrass, bluegrass, sedge, Canada wildrye, Rocky Mountain iris, clover, reedgrass, shrubby cinquefoil, western wheatgrass
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 9 inches; silt loam
E—9 to 11 inches; silt loam
Bt1—11 to 17 inches; silty clay loam
Bt2—17 to 21 inches; clay loam
2C1—21 to 42 inches; gravelly sandy clay loam
2C2—42 to 60 inches; very gravelly sandy loam

Minor Components

Organic soils and similar soils
Composition: About 10 percent
Landscape: Mountains
Landform: Marshes
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Aspect: East to west
Shape (down/across): Concave/concave
Drainage class: Poorly drained
Flooding hazard: Frequent

Tranquilar and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Somewhat poorly drained
Ecological site: Mountain Grassland

302—Tranquilar-Jarmillo complex, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,500 to 8,800 feet (2,591 to 2,682 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Tranquilar and similar soils: 50 percent
Jarmillo and similar soils: 30 percent
Minor components: 20 percent

Component Descriptions

Tranquilar soils
Landscape: Mountains
Landform: Valley floors, stream terraces
Position on landform: Toeslopes
Position on landform: Side slope
Parent material: Lacustrine deposits derived from igneous rock
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Somewhat poorly drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 9.5 inches (high)
Shrink-swell potential: About 7.0 percent (high)
Seasonal high water table depth: About 18 to 48 inches
Runoff class: Very high
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)

Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Mountain Grassland
Potential native vegetation: western wheatgrass, prairie junegrass, spike muhly, Rocky Mountain iris, sedge, shrubby cinquefoil
Land capability subclass (nonirrigated): 7c

Typical Profile:
A1—0 to 4 inches; silty clay loam
A2—4 to 8 inches; silty clay loam
E1—8 to 11 inches; silty clay loam
E2—11 to 13 inches; silty clay loam
Bt1—13 to 20 inches; clay
Bt2—20 to 34 inches; clay
Bt3—34 to 42 inches; clay
Bt4—42 to 50 inches; clay
Bt5—50 to 60 inches; clay

Jarmillo soils
Landscape: Mountains
Landform: Stream terraces
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium over colluvium over lacustrine deposits derived from igneous rock
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.1 inches (high)
Shrink-swell potential: About 2.1 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Mountain Loam
Potential native vegetation: Arizona fescue, bluegrass, western wheatgrass, muhly, needlegrass, bottlebrush squirreltail
Land capability subclass (nonirrigated): 7c

Typical Profile:
A1—0 to 4 inches; loam
A2—4 to 13 inches; loam
AB—13 to 20 inches; loam
Bw1—20 to 26 inches; loam
Bw2—26 to 36 inches; loam
Bw3—36 to 41 inches; fine sandy loam
2Bw4—41 to 51 inches; clay loam
3C—51 to 60 inches; very fine sandy loam

Minor Components

Vastine and similar soils
- *Composition:* About 5 percent
- *Landscape:* Mountains
- *Landform:* Flood plains
- *Position on landform:* Toeslopes
- *Position on landform:* Base slope
- *Slope:* 0 to 3 percent
- *Aspect:* East to west
- *Shape (down/across):* Concave/linear
- *Drainage class:* Poorly drained
- *Flooding hazard:* Rare
- *Ecological site:* Mountain Loam

Jarola and similar soils
- *Composition:* About 5 percent
- *Landscape:* Valleys
- *Landform:* Stream terraces
- *Position on landform:* Toeslopes
- *Position on landform:* Base slope
- *Slope:* 1 to 5 percent
- *Aspect:* East to west
- *Shape (down/across):* Concave/linear
- *Drainage class:* Poorly drained
- *Flooding hazard:* Rare
- *Ecological site:* Mountain Meadow

Cosey and similar soils
- *Composition:* About 5 percent
- *Slope:* 2 to 20 percent
- *Drainage class:* Well drained
- *Ecological site:* Mountain Loam

Tranquilar, stony silt loam and similar soils
- *Composition:* About 5 percent
- *Slope:* 5 to 8 percent
- *Drainage class:* Somewhat poorly drained
- *Ecological site:* Mountain Grassland

304—Cosey-Jarmillo association, 2 to 20 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,600 to 8,800 feet (2,621 to 2,682 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Cosey and similar soils: 45 percent
Jarmillo and similar soils: 40 percent
Minor components: 15 percent

Component Descriptions

Cosey soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Slope alluvium over colluvium derived from rhyolite
Slope: 2 to 20 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 6.5 inches (moderate)
Shrink-swell potential: About 3.8 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Mountain Loam
Potential native vegetation: Arizona fescue, bluegrass, western wheatgrass, needlegrass, bottlebrush squirreltail, mountain muhly
Land capability subclass (nonirrigated): 7c

Typical Profile:
A1—0 to 9 inches; silt loam
A2—9 to 15 inches; silt loam
BA—15 to 28 inches; gravelly loam
Bt1—28 to 34 inches; very gravelly sandy clay loam
Bt2—34 to 60 inches; extremely cobbly clay loam

Jarmillo soils
Landscape: Mountains
Landform: Stream terraces
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Alluvial, colluvial, and lacustrine deposits derived from igneous rock
Slope: 2 to 20 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.4 inches (moderate)
Shrink-swell potential: About 2.2 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)

Ecological site: Mountain Loam
Potential native vegetation: Arizona fescue, bluegrass, western wheatgrass, muhly, needlegrass, bottlebrush squirreltail
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 17 inches; silt loam
Bw—17 to 33 inches; sandy loam
Cw—33 to 60 inches; sandy loam

Minor Components
Jarola and similar soils
Composition: About 10 percent
Landscape: Valleys
Landform: Stream terraces
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Concave/linear
Drainage class: Poorly drained
Flooding hazard: Rare
Ecological site: Mountain Meadow

Vastine and similar soils
Composition: About 5 percent
Landscape: Mountains
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Drainage class: Poorly drained
Flooding hazard: Rare
Ecological site: Mountain Loam

307—Flugle-Waumac complex, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,600 to 6,100 feet (1,707 to 1,859 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Flugle and similar soils: 60 percent
Waumac and similar soils: 25 percent
Minor components: 15 percent



Figure 9.—Typical landscape of Flugle-Waumac complex, 1 to 8 percent slopes.

Component Descriptions

Flugle soils
Landscape: Uplands
Landform: Cuestas, hills, valley sides, fan remnants, ridges
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone and shale
Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.5 inches (moderate)
Shrink-swell potential: About 2.3 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Savannah
Potential native vegetation: blue grama, twoneedle pinyon, western wheatgrass, Indian ricegrass, juniper, needlegrass, other half shrubs
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; loam
Bt—3 to 7 inches; sandy clay loam
Btk1—7 to 12 inches; sandy clay loam
Btk2—12 to 19 inches; sandy clay loam
Bk—19 to 60 inches; fine sandy loam

Waumac soils
Landscape: Uplands
Landform: Valley floors
Position on landform: Toeslopes
Position on landform: Side slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 7.5 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: blue grama, western wheatgrass, Indian ricegrass, black grama, oneseed juniper, twoneedle pinyon
Land capability subclass (nonirrigated): 6s

Typical Profile:
A—0 to 3 inches; loamy sand
C—3 to 60 inches; stratified fine sandy loam to sandy loam

Minor Components
Fragua and similar soils
Composition: About 10 percent
Slope: 1 to 15 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Foothills

Royosa and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

308—Cajete gravelly loam, 0 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,000 to 8,500 feet (2,438 to 2,591 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Cajete and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Cajete soils
Landscape: Mountains
Landform: Mountain slopes, stream terraces, hills
Position on landform: Footslopes
Position on landform: Mountainbase
Parent material: Residuum weathered from pumice
Slope: 0 to 8 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 3.7 inches (low)
Shrink-swell potential: About 2.1 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Mountain Grassland
Potential native vegetation: Arizona fescue, needlegrass, Kentucky bluegrass, bluegrass, western wheatgrass, Thurber fescue, pine dropseed
Land capability subclass (nonirrigated): 7c

Typical Profile:
A1—0 to 7 inches; gravelly loam
A2—7 to 15 inches; gravelly loam
Bw—15 to 33 inches; very gravelly sandy loam
C1—33 to 45 inches; very gravelly sand
C2—45 to 49 inches; extremely gravelly sand
C3—49 to 60 inches; very gravelly sand

Minor Components
Calaveras and similar soils
Composition: About 10 percent
Slope: 15 to 35 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Jarmillo and similar soils
Composition: About 5 percent
Slope: 2 to 20 percent
Drainage class: Well drained
Ecological site: Mountain Loam

311—Cosey-Tranquilar-Calaveras association, 5 to 20 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,600 to 9,200 feet (2,621 to 2,804 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Cosey and similar soils: 35 percent
Tranquilar and similar soils: 30 percent
Calaveras and similar soils: 25 percent
Minor components: 10 percent

Component Descriptions

Cosey soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Toeslopes
Position on landform: Mountainbase
Parent material: Slope alluvium over colluvium derived from rhyolite
Slope: 5 to 20 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 5.7 inches (low)
Shrink-swell potential: About 3.9 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Mountain Loam
Potential native vegetation: Arizona fescue, bluegrass, western wheatgrass, needlegrass, bottlebrush squirreltail, mountain muhly
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 13 inches; silt loam
BA—13 to 24 inches; gravelly loam
Bt—24 to 60 inches; extremely cobbly clay loam

Tranquilar soils
Landscape: Mountains
Landform: Stream terraces, valley floors
Position on landform: Toeslopes
Position on landform: Mountainbase
Parent material: Lacustrine deposits derived from igneous rock
Slope: 5 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Somewhat poorly drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 9.9 inches (high)
Shrink-swell potential: About 6.6 percent (high)
Seasonal high water table depth: About 18 to 48 inches
Runoff class: Very high
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Mountain Grassland
Potential native vegetation: western wheatgrass, prairie junegrass, spike muhly, Rocky Mountain iris, sedge, shrubby cinquefoil
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 14 inches; silt loam
E—14 to 20 inches; silt loam
Bt1—20 to 42 inches; clay
Bt2—42 to 60 inches; clay

Calaveras soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Footslopes
Position on landform: Mountainbase
Parent material: Colluvium derived from tuff
Slope: 5 to 20 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 4.9 inches (low)
Shrink-swell potential: About 2.2 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)

Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia
Potential native vegetation:
Common trees: limber pine, ponderosa pine, white fir, Douglas-fir
Other plants: common juniper, nodding brome, prairie junegrass, unknown, quaking aspen
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 4 inches; silt loam
E—4 to 11 inches; silt loam
Bw—11 to 17 inches; gravelly silt loam
2Bt1—17 to 30 inches; very cobbly loam
2B2—30 to 39 inches; extremely cobbly coarse sandy loam
3Bt3—39 to 60 inches; extremely cobbly loamy sand

Minor Components
Jarmillo and similar soils
Composition: About 5 percent
Slope: 2 to 20 percent
Drainage class: Well drained
Ecological site: Mountain Loam

Cosey and similar soils
Composition: About 5 percent
Slope: 2 to 20 percent
Drainage class: Well drained
Ecological site: Mountain Loam

312—Royosa sand, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,900 to 6,200 feet (1,798 to 1,890 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Royosa and similar soils: 90 percent
Minor components: 10 percent

Component Descriptions

Royosa soils
Landscape: Dune fields
Landform: Dunes
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Convex/convex
Depth class: Very deep
Drainage class: Somewhat excessively drained

Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 3.6 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 3 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, blue grama, dropseed, needle and thread, bottlebrush squirreltail, oneseed juniper
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 5 inches; sand
C1—5 to 16 inches; sand
C2—16 to 60 inches; loamy sand

Minor Components
Waumac and similar soils
Composition: About 5 percent
Slope: 1 to 7 percent
Drainage class: Well drained
Ecological site: Sandy

Fragua and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Foothills

314—Fragua-Waumac-Royosa complex, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,600 to 6,200 feet (1,707 to 1,890 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Fragua and similar soils: 40 percent
Waumac and similar soils: 30 percent
Royosa and similar soils: 25 percent
Minor components: 5 percent

Component Descriptions

Fragua soils
Landscape: Uplands
Landform: Dipslopes, fan remnants
Position on landform: Footslopes

Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 7.0 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Foothills
Potential native vegetation: Indian ricegrass, blue grama, western wheatgrass, alkali sacaton, mesa dropseed, oneseed juniper, twoneedle pinyon
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 3 inches; loamy sand
Bt1—3 to 8 inches; sandy loam
Bt2—8 to 24 inches; sandy loam
C—24 to 60 inches; sandy loam

Waumac soils
Landscape: Uplands
Landform: Valley floors
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 8.1 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: Indian ricegrass, blue grama, western wheatgrass, alkali sacaton, mesa dropseed, oneseed juniper, twoneedle pinyon
Land capability subclass (nonirrigated): 6s

Typical Profile:
A—0 to 3 inches; loamy fine sand
C—3 to 60 inches; fine sandy loam

Royosa soils
Landscape: Uplands
Landform: Dunes
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Convex/convex
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 3.5 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 3 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, blue grama, dropseed, needleandthread, oneseed juniper, squirreltail
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 7 inches; fine sand
C—7 to 60 inches; fine sand

Minor Components
Flugle and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Savannah

317—Elpedro loam, 1 to 8 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,700 to 6,300 feet (1,737 to 1,920 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Elpedro and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Elpedro soils
Landscape: Uplands
Landform: Valley sides, benches, fan piedmonts, hills, mesas
Position on landform: Footslopes

Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone over colluvium derived from limestone
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.6 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: juniper, twoneedle pinyon
Other plants: blue grama, galleta, oak, bottlebrush squirreltail, western wheatgrass
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 2 inches; loam
Bt—2 to 22 inches; silty clay loam
Btk—22 to 60 inches; loam

Minor Components
Flugle and similar soils
Composition: About 8 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Savannah

Waumac and similar soils
Composition: About 7 percent
Slope: 1 to 7 percent
Drainage class: Well drained
Ecological site: Sandy

319—Bamac-Rock outcrop complex, 15 to 55 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,600 to 6,400 feet (1,707 to 1,951 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Bamac and similar soils: 60 percent
Rock outcrop: 25 percent
Minor components: 15 percent

Component Descriptions

Bamac soils
Landscape: Uplands
Landform: Fan remnants, fan remnants, ridges, hills
Position on landform: Footslopes
Position on landform: Head slope, side slope
Parent material: Alluvium derived from igneous and sedimentary rock
Slope: 15 to 55 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 2.0 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Foothills
Potential native vegetation: blue grama, hairy grama, black grama, sideoats grama, New Mexico Feathergrass, galleta, oneseed juniper, sacahuista
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 4 inches; very gravelly loamy sand
AC—4 to 10 inches; loamy sand
C1—10 to 21 inches; very gravelly loamy coarse sand
C2—21 to 37 inches; very gravelly loamy coarse sand
C3—37 to 60 inches; very gravelly loamy coarse sand

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Benches, ledges
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Espiritu and similar soils
Composition: About 10 percent
Slope: 15 to 40 percent
Drainage class: Well drained
Ecological site: Foothills

Waumac and similar soils
Composition: About 5 percent
Slope: 1 to 15 percent
Drainage class: Well drained
Ecological site: Sandy

320—Sparham silt loam, 0 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Sparham and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Sparham soils
Landscape: Valleys
Landform: Flood plains, valley sides, alluvial fans
Position on landform: Toeslopes
Position on landform: Rise
Parent material: Fan alluvium derived from sandstone and shale
Slope: 0 to 3 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 9.8 inches (high)
Shrink-swell potential: About 7.2 percent (high)
Flooding hazard: Occasional
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Clayey
Potential native vegetation: western wheatgrass, alkali sacaton, bottlebrush squirreltail, prairie junegrass
Land capability subclass (irrigated): 3s
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 9 inches; silt loam
C1—9 to 32 inches; silty clay
C2—32 to 60 inches; silty clay

Minor Components

Hickman and similar soils
Composition: About 10 percent
Slope: 1 to 5 percent
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Swale

Royosa and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

321—Waumac-Royosa association, 1 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,600 to 6,700 feet (1,707 to 2,042 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Waumac and similar soils: 60 percent
Royosa and similar soils: 30 percent
Minor components: 10 percent

Component Descriptions

Waumac soils
Landscape: Valleys
Landform: Valley floors
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Fan alluvium derived from igneous and sedimentary rock
Slope: 1 to 15 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 8.1 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: Indian ricegrass, blue grama, western wheatgrass, alkali sacaton, mesa dropseed, oneseed juniper, twoneedle pinyon
Land capability subclass (nonirrigated): 6s

Typical Profile:
A—0 to 3 inches; loamy fine sand
C—3 to 60 inches; fine sandy loam

Royosa soils
Landscape: Valleys
Landform: Dunes
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian deposits derived from sandstone
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Convex/convex
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 3.5 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 3 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, blue grama, dropseed, needleandthread, bottlebrush squirreltail, oneseed juniper
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 12 inches; fine sand
C—12 to 60 inches; fine sand

Minor Components
Bamac and similar soils
Composition: About 5 percent
Slope: 1 to 15 percent
Drainage class: Excessively drained
Ecological site: Foothills

Fragua and similar soils
Composition: About 3 percent
Slope: 1 to 15 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Foothills

Rock outcrop
Composition: About 2 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

322—Fragua very cobbly fine sandy loam, 15 to 70 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,600 to 7,400 feet (1,707 to 2,256 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Fragua and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Fragua soils
Landscape: Uplands
Landform: Dipslopes, fan remnants
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian deposits over fan alluvium derived from sandstone
Slope: 15 to 70 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Deep and very deep
Depth to restrictive feature: 40 to 80 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 4.6 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Foothills
Potential native vegetation: blue grama, hairy grama, black grama, sideoats grama, New Mexico Feathergrass, galleta, sacahuista
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 3 inches; very cobbly fine sandy loam
Bt1—3 to 16 inches; very fine sandy loam
Bk—16 to 45 inches; loamy fine sand
Cr—45 to 60 inches; bedrock

Minor Components
Flugle and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Savannah

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Vessilla and similar soils
Composition: About 3 percent
Slope: 5 to 30 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Waumac and similar soils
Composition: About 2 percent
Slope: 1 to 15 percent
Drainage class: Well drained
Ecological site: Sandy

324—Rock outcrop-Atarque-Menefee complex, 5 to 25 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,700 to 6,600 feet (1,737 to 2,012 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Rock outcrop: 30 percent
Atarque and similar soils: 25 percent
Menefee and similar soils: 25 percent
Minor components: 20 percent

Component Descriptions

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Ledges, escarpments
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Atarque soils
Landscape: Uplands
Landform: Cuestas, hills, dipslopes, mesas
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Slope alluvium derived from sandstone and shale
Slope: 5 to 25 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (lithic)

Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 2.0 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Shallow Sandstone
Potential native vegetation: sideoats grama, blue grama, little bluestem, Indian ricegrass, galleta, twoneedle pinyon
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; sandy loam
Bt—3 to 9 inches; sandy clay loam
Btk—9 to 14 inches; sandy clay loam
R—14 to 60 inches; bedrock

Menefee soils
Landscape: Uplands
Landform: Hillslopes, mesas, mountainsides
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Colluvium over residuum weathered from shale
Slope: 8 to 25 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 1.8 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 5 percent
Gypsum maximum: About 1 percent
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Shallow
Potential native vegetation: blue grama, New Mexico Feathergrass, sideoats grama, little bluestem, black grama, galleta
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; gravelly loam
C—2 to 9 inches; clay loam
2Cr—9 to 60 inches; bedrock

Minor Components

Waumac and similar soils
Composition: About 10 percent
Slope: 1 to 15 percent
Drainage class: Well drained
Ecological site: Sandy

Vessilla and similar soils
Composition: About 10 percent
Slope: 5 to 30 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

325—Rock outcrop-Vessilla-Espiritu complex, 25 to 65 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 6,400 feet (1,829 to 1,951 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Rock outcrop: 35 percent
Vessilla and similar soils: 25 percent
Espiritu and similar soils: 25 percent
Minor components: 15 percent

Component Descriptions

Rock outcrop

Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Ledges, escarpments
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Vessilla soils

Landscape: Mountains
Landform: Mesas, hills, breaks, ridges, structural benches
Position on landform: Footslopes
Position on landform: Mountainflank, lower third
Parent material: Eolian deposits over slope alluvium over residuum weathered from sandstone
Slope: 25 to 55 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 4 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)

Available water capacity: About 1.1 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: sideoats grama, New Mexico Feathergrass, blue grama, little bluestem, galleta
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 1 inch; very gravelly sandy loam
C—1 inch to 10 inches; gravelly loam
R—10 to 60 inches; bedrock

Espiritu soils
Landscape: Mountains
Landform: Mountain slopes, mesas
Position on landform: Toeslopes
Position on landform: Mountainflank, lower third
Parent material: Alluvium, eolian material and colluvium derived from igneous and sedimentary rock
Slope: 25 to 65 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 5.1 inches (low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Foothills
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: blue grama, wavyleaf oak, black grama, hairy grama, needle and thread, sideoats grama, true mountain mahogany
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; very gravelly fine sandy loam
Bt—2 to 20 inches; very gravelly sandy clay loam
Bk—20 to 60 inches; very gravelly loam

Minor Components

Atarque and similar soils
Composition: About 5 percent
Slope: 25 to 45 percent
Depth to restrictive feature: 8 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

Fragua and similar soils
Composition: About 5 percent
Slope: 5 to 25 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Foothills

Sedillo and similar soils
Composition: About 3 percent
Slope: 5 to 25 percent
Drainage class: Well drained
Ecological site: Foothills

Skyvillage and similar soils
Composition: About 2 percent
Slope: 8 to 25 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

342—Waumac-Vessilla-Rock outcrop complex, 5 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,200 to 6,900 feet (1,890 to 2,103 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Waumac and similar soils: 35 percent
Vessilla and similar soils: 25 percent
Rock outcrop: 20 percent
Minor components: 20 percent

Component Descriptions

Waumac soils

Landscape: Uplands
Landform: Valley floors
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Fan alluvium derived from igneous and sedimentary rock

Slope: 5 to 20 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 6.9 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Sandy
Potential native vegetation: Indian ricegrass, blue grama, western wheatgrass, alkali sacaton, mesa dropseed, oneseed juniper, twoneedle pinyon
Land capability subclass (nonirrigated): 6s

Typical Profile:
A—0 to 5 inches; loamy fine sand
C—5 to 60 inches; sandy loam

Vessilla soils
Landscape: Uplands
Landform: Hills, ridges, breaks, mesas
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian deposits over slope alluvium over residuum weathered from sandstone
Slope: 5 to 40 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 4 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 1.8 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Indian ricegrass, blue grama, mountain big sagebrush, oak, galleta, sideoats grama
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; fine sandy loam
C—3 to 13 inches; fine sandy loam
R—13 to 60 inches; bedrock

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Ledges, escarpments
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Badland
Composition: About 10 percent
Slope: 15 to 35 percent
Depth to restrictive feature: 0 inches to bedrock (paralithic)

Royosa and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

Menefee and similar soils
Composition: About 5 percent
Slope: 15 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

345—Espiritu-Bamac association, 15 to 55 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,500 to 6,600 feet (1,676 to 2,012 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Espiritu and similar soils: 50 percent
Bamac and similar soils: 35 percent
Minor components: 15 percent

Component Descriptions

Espiritu soils
Landscape: Uplands
Landform: Fan piedmonts, mesas
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Slope alluvium over colluvium derived from igneous and sedimentary rock
Slope: 15 to 55 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 10 percent subrounded cobbles

Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 4.7 inches (low)
Shrink-swell potential: About 3.3 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Foothills
Potential native vegetation: blue grama, hairy grama, black grama, sideoats grama, New Mexico Feathergrass, galleta, oneseed juniper, sacahuista
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 6 inches; very gravelly fine sandy loam
Bt1—6 to 15 inches; very gravelly sandy clay loam
Bt2—15 to 22 inches; very gravelly sandy clay loam
Bk1—22 to 29 inches; very cobbly sandy clay loam
Bk2—29 to 38 inches; very cobbly sandy clay loam
2C1—38 to 46 inches; fine sandy loam
3C2—46 to 60 inches; very gravelly sandy loam

Bamac soils
Landscape: Uplands
Landform: Fan remnants, hills, ridges, fan remnants
Position on landform: Summits
Position on landform: Side slope, head slope
Parent material: Slope alluvium derived from igneous and sedimentary rock
Slope: 15 to 55 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 1.8 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Foothills
Potential native vegetation: blue grama, hairy grama, black grama, sideoats grama, New Mexico Feathergrass, galleta, oneseed juniper, sacahuista
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 3 inches; very gravelly loamy sand
C1—3 to 30 inches; very gravelly loamy sand
C2—30 to 60 inches; stratified very gravelly loamy sand to loamy sand

Minor Components

Waumac and similar soils
Composition: About 5 percent
Slope: 1 to 7 percent
Drainage class: Well drained
Ecological site: Sandy

Cochiti and similar soils
Composition: About 5 percent
Slope: 15 to 40 percent
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

346—Espiritu, cobbly-Bamac association, 15 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,900 to 6,900 feet (1,798 to 2,103 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Espiritu, cobbly and similar soils: 70 percent
Bamac and similar soils: 20 percent
Minor components: 10 percent

Component Descriptions

Espiritu, cobbly soils

Landscape: Uplands
Landform: Fan piedmonts, mesas
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Slope alluvium over colluvium derived from igneous and sedimentary rock
Slope: 15 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 7 percent subrounded cobbles
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 3.3 inches (low)
Shrink-swell potential: About 2.6 percent (low)
Runoff class: High
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)

Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Foothills
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: black grama, blue grama, sideoats grama, hairy grama, needle and thread, true mountain mahogany, wavyleaf oak
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 2 inches; extremely cobbly sandy loam
Bt—2 to 24 inches; very gravelly sandy clay loam
Bk—24 to 36 inches; extremely gravelly sandy loam
2C—36 to 60 inches; very gravelly loamy sand

Bamac soils
Landscape: Uplands
Landform: Hills, ridges, fan remnants
Position on landform: Shoulders
Position on landform: Side slope, head slope
Parent material: Slope alluvium derived from igneous and sedimentary rock
Slope: 15 to 40 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 2.4 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Foothills
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: black grama, blue grama, sideoats grama, hairy grama, needle and thread, true mountain mahogany, wavyleaf oak
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 3 inches; very gravelly loamy sand
C1—3 to 30 inches; very gravelly loamy coarse sand
C2—30 to 45 inches; loamy sand
C3—45 to 60 inches; very gravelly loamy sand

Minor Components
Cochiti and similar soils
Composition: About 5 percent
Slope: 15 to 40 percent
Drainage class: Well drained

Rock outcrop
Composition: About 3 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Royosa and similar soils
Composition: About 2 percent
Slope: 1 to 8 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

348—Wauquie-Rock outcrop complex, 25 to 45 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 6,800 feet (1,829 to 2,073 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Wauquie and similar soils: 60 percent
Rock outcrop: 20 percent
Minor components: 20 percent

Component Descriptions

Wauquie soils
Landscape: Mountains
Landform: Mountain slopes, hills, mesas, benches, canyons
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Slope alluvium over colluvium derived from igneous and sedimentary rock
Slope: 25 to 45 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 3.7 inches (low)
Shrink-swell potential: About 2.2 percent (low)
Runoff class: High
Calcium carbonate maximum: About 3 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Juniperus monosperma-Pinus edulis/Fallugia paradoxa-Chrysothamnus nauseosus/Bouteloua hirsuta-Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Eriogonum, blue grama, skunkbush sumac, slender wheatgrass, bottlebrush squirreltail, wavyleaf oak
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 2 inches; extremely gravelly sandy clay loam
Bt1—2 to 16 inches; very gravelly clay loam
Bt2—16 to 40 inches; very gravelly sandy loam
Bk—40 to 60 inches; extremely gravelly loamy sand

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Escarpments, ledges
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Bamac and similar soils
Composition: About 5 percent
Slope: 15 to 55 percent
Drainage class: Excessively drained
Ecological site: Foothills

Waumac and similar soils
Composition: About 5 percent
Slope: 1 to 7 percent
Drainage class: Well drained
Ecological site: Sandy

Vessilla and similar soils
Composition: About 5 percent
Slope: 5 to 30 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

Royosa and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Somewhat excessively drained
Ecological site: Deep Sand

353—Cochiti-Espiritu association, 15 to 55 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,300 to 6,400 feet (1,615 to 1,951 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Cochiti and similar soils: 50 percent
Espiritu and similar soils: 45 percent
Minor components: 5 percent

Component Descriptions

Cochiti soils
Landscape: Uplands
Landform: Fan remnants
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Slope alluvium derived from igneous and sedimentary rock
Slope: 15 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 3 percent subrounded cobbles
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 3.8 inches (low)
Shrink-swell potential: About 2.5 percent (low)
Runoff class: High
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Juniperus monosperma-Pinus edulis/Fallugia paradoxa-Chrysothamnus nauseosus/Bouteloua hirsuta-Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: blue grama, bottlebrush squirreltail, sideoats grama
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 4 inches; extremely gravelly loam
Bt—4 to 22 inches; very gravelly clay loam
C—22 to 60 inches; very gravelly loamy sand

Espiritu soils
Landscape: Uplands
Landform: Fan piedmonts, mesas
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Slope alluvium over colluvium derived from igneous and sedimentary rock
Slope: 25 to 55 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 3 percent subrounded cobbles
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 2.4 inches (very low)
Shrink-swell potential: About 2.2 percent (low)
Runoff class: High
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)

Ecological site: Foothills
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: black grama, blue grama, sideoats grama, hairy grama, needle and thread, true mountain mahogany, wavyleaf oak
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 3 inches; very gravelly loam
Bt—3 to 16 inches; very gravelly sandy clay loam
Bk—16 to 60 inches; extremely gravelly loamy sand

Minor Components
Teco and similar soils
Composition: About 3 percent
Slope: 8 to 40 percent
Drainage class: Well drained
Ecological site: Clayey

Waumac and similar soils
Composition: About 2 percent
Slope: 1 to 7 percent
Drainage class: Well drained
Ecological site: Sandy

354—Waumac Variant very gravelly sandy loam, 1 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,600 to 5,900 feet (1,707 to 1,798 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Waumac Variant and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Waumac Variant soils
Landscape: Uplands
Landform: Ridges, hills
Position on landform: Summits
Position on landform: Nose slope
Parent material: Residuum weathered from tuff
Slope: 1 to 15 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)

Available water capacity: About 0.7 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Apache plume, black grama, blue grama, broom snakeweed, little bluestem, sandhill muhly
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; very gravelly sandy loam
C—3 to 12 inches; very gravelly sandy loam
Cr—12 to 60 inches; bedrock

Minor Components
Rock outcrop
Composition: About 10 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Waumac and similar soils
Composition: About 5 percent
Slope: 1 to 7 percent
Drainage class: Well drained
Ecological site: Sandy

358—Deama-Elpedro-Rock outcrop complex, 10 to 55 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,800 to 6,800 feet (1,768 to 2,073 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Deama and similar soils: 35 percent
Elpedro and similar soils: 25 percent
Rock outcrop: 25 percent
Minor components: 15 percent

Component Descriptions

Deama soils
Landscape: Uplands
Landform: Plateaus, hills, ridges, mesas
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Colluvium over residuum weathered from limestone

Slope: 10 to 55 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 1.3 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 60 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: twoneedle pinyon
Other plants: blue grama, sideoats grama, New Mexico Feathergrass
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 3 inches; very gravelly loam
Bk—3 to 19 inches; very gravelly loam
2R—19 to 60 inches; bedrock

Elpedro soils
Landscape: Uplands
Landform: Valley sides, mesas, hills, fan piedmonts, benches
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian deposits over colluvium derived from limestone
Slope: 10 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 10.8 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Juniperus monosperma-Pinus edulis/Fallugia paradoxa-Chrysothamnus nauseosus/Bouteloua hirsuta-Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: blue grama, bottlebrush squirreltail, galleta, oak, western wheatgrass
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 3 inches; very gravelly loam
Bt—3 to 37 inches; silty clay loam
Btk—37 to 60 inches; loam

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Escarpments
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Espiritu and similar soils
Composition: About 10 percent
Slope: 15 to 40 percent
Drainage class: Well drained
Ecological site: Foothills

Menefee and similar soils
Composition: About 5 percent
Slope: 5 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

396—Atarque-Menefee-Rock outcrop complex, 25 to 45 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 6,600 feet (1,829 to 2,012 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Atarque and similar soils: 30 percent
Menefee and similar soils: 30 percent
Rock outcrop: 25 percent
Minor components: 15 percent

Component Descriptions

Atarque soils
Landscape: Uplands
Landform: Dipslopes, hills, mesas, cuestas
Position on landform: Shoulders
Position on landform: Nose slope
Parent material: Slope alluvium derived from sandstone and shale
Slope: 25 to 45 percent
Aspect: East to west
Shape (down/across): Linear/linear

Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 3.1 inches (low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Shallow Sandstone
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: sideoats grama, New Mexico Feathergrass, blue grama, little bluestem
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; extremely gravelly sandy loam
Bt—2 to 16 inches; clay loam
R—16 to 60 inches; bedrock

Menefee soils
Landscape: Uplands
Landform: Hillslopes, mesas, mountainsides
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Colluvium over residuum weathered from shale
Slope: 25 to 45 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 2.7 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Bigelow sagebrush, mormon tea, Indian ricegrass, Mexican cliffrose, bluegrass, galleta, green rabbitbrush
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 2 inches; gravelly clay loam
C—2 to 14 inches; clay loam
2Cr—14 to 60 inches; bedrock

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Hills, escarpments
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Waumac and similar soils
Composition: About 5 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: Sandy

Flugle and similar soils
Composition: About 5 percent
Slope: 1 to 5 percent
Drainage class: Well drained
Ecological site: Savannah

Vessilla and similar soils
Composition: About 5 percent
Slope: 3 to 15 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

397—Rock outcrop-Cucho-Vessilla complex, 25 to 70 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 7,200 feet (1,829 to 2,195 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Rock outcrop: 30 percent
Cucho and similar soils: 25 percent
Vessilla and similar soils: 25 percent
Minor components: 20 percent

Component Descriptions

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.

Landform: Hills, escarpments
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Cucho soils
Landscape: Uplands
Landform: Cuestas, fan remnants
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Colluvium derived from shale
Slope: 25 to 70 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 45 percent subrounded gravel
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 4.4 inches (low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Juniperus monosperma-Pinus edulis/Fallugia paradoxa-Chrysothamnus nauseosus/Bouteloua hirsuta-Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Indian ricegrass, bottlebrush squirreltail, galleta, mountain mahogany, needle and thread, sideoats grama, skunkbush sumac, wavyleaf oak
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; very gravelly clay loam
C1—2 to 9 inches; clay loam
C2—9 to 37 inches; very gravelly clay loam
Cr—37 to 60 inches; bedrock

Vessilla soils
Landscape: Uplands
Landform: Structural benches, hills, ridges, breaks, mesas
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian material and alluvium derived from sandstone
Slope: 25 to 65 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 4 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)

Available water capacity: About 1.1 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: sideoats grama, New Mexico Feathergrass, blue grama, little bluestem, galleta
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; gravelly fine sandy loam
C—2 to 11 inches; gravelly fine sandy loam
R—11 to 60 inches; bedrock

Minor Components
Atarque and similar soils
Composition: About 5 percent
Slope: 25 to 45 percent
Depth to restrictive feature: 8 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

Menefee and similar soils
Composition: About 5 percent
Slope: 25 to 45 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Skyvillage and similar soils
Composition: About 5 percent
Slope: 8 to 25 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Shallow Sandstone

Waumac and similar soils
Composition: About 5 percent
Slope: 1 to 7 percent
Drainage class: Well drained
Ecological site: Sandy

398—Espiritu-Cucho association, 8 to 55 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 6,900 feet (1,829 to 2,103 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)

Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Espiritu and similar soils: 45 percent
Cucho and similar soils: 35 percent
Minor components: 20 percent

Component Descriptions

Espiritu soils
Landscape: Uplands
Landform: Mountain slopes, mesas
Position on landform: Backslopes
Position on landform: Mountainflank, lower third, side slope
Parent material: Slope alluvium and colluvium derived from igneous and sedimentary rock
Slope: 8 to 55 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 20 percent subrounded gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 3.0 inches (very low)
Shrink-swell potential: About 2.6 percent (low)
Runoff class: High
Calcium carbonate maximum: About 1 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Foothills
Potential native vegetation: blue grama, hairy grama, black grama, sideoats grama, New Mexico Feathergrass, galleta, oneseed juniper, sacahuista
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 4 inches; very gravelly fine sandy loam
Bt—4 to 24 inches; very gravelly sandy clay loam
Bk—24 to 60 inches; extremely gravelly sandy loam

Cucho soils
Landscape: Uplands
Landform: Cuestas, fan remnants
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Colluvium derived from shale
Slope: 15 to 55 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 7.2 inches (moderate)

Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Juniperus monosperma-Pinus edulis/Fallugia paradoxa-Chrysothamnus nauseosus/Bouteloua hirsuta-Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Indian ricegrass, bottlebrush squirreltail, galleta, mountain mahogany, needle and thread, sideoats grama, skunkbush sumac, wavyleaf oak
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 2 inches; very gravelly clay loam
C—2 to 37 inches; silty clay loam
Cr—37 to 60 inches; bedrock

Minor Components
Menefee and similar soils
Composition: About 10 percent
Slope: 5 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: Shallow

Waumac and similar soils
Composition: About 5 percent
Slope: 1 to 7 percent
Drainage class: Well drained
Ecological site: Sandy

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

399—Cucho-Teco complex, 8 to 40 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,900 to 7,000 feet (1,798 to 2,134 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Cucho and similar soils: 45 percent
Teco and similar soils: 35 percent
Minor components: 20 percent

Component Descriptions

Cucho soils
Landscape: Uplands
Landform: Cuestas, fan remnants
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Colluvium derived from shale
Slope: 15 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 50 percent subrounded gravel
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 7.2 inches (moderate)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Juniperus monosperma-Pinus edulis/Fallugia paradoxa-Chrysothamnus nauseosus/Bouteloua hirsuta-Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Indian ricegrass, bottlebrush squirreltail, galleta, mountain mahogany, needle and thread, sideoats grama, skunkbush sumac, wavyleaf oak
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 2 inches; very gravelly clay loam
C—2 to 37 inches; clay loam
Cr—37 to 60 inches; bedrock

Teco soils
Landscape: Uplands
Landform: Hills, cuestas
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Slope alluvium derived from sandstone and shale
Slope: 8 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 7.7 inches (moderate)
Shrink-swell potential: About 6.2 percent (high)
Runoff class: Very high
Calcium carbonate maximum: About 13 percent
Gypsum maximum: None
Salinity maximum: About 8 mmhos/cm (slightly saline)

Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Clayey
Potential native vegetation: alkali sacaton, western wheatgrass, New Mexico Feathergrass, blue grama, galleta, fourwing saltbush, winterfat
Land capability subclass (nonirrigated): 6e

Typical Profile:
A—0 to 1 inch; very cobbly fine sandy loam
Bt1—1 inch to 7 inches; sandy clay
Bt2—7 to 23 inches; clay
Btk—23 to 40 inches; clay
2C—40 to 45 inches; very gravelly fine sandy loam
3Bkb—45 to 60 inches; channery sandy clay loam

Minor Components
Espiritu and similar soils
Composition: About 10 percent
Slope: 15 to 40 percent
Drainage class: Well drained
Ecological site: Foothills

Menefee and similar soils
Composition: About 5 percent
Slope: 5 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

405—Charo complex, 1 to 5 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,100 to 8,300 feet (2,469 to 2,530 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Charo and similar soils: 50 percent
Charo, noncobbly, and similar soils: 40 percent
Minor components: 10 percent

Component Descriptions

Charo soils
Landscape: Mountains
Landform: Mesas, ridges, hills
Position on landform: Shoulders
Position on landform: Crest, mountaintop
Parent material: Eolian deposits over residuum weathered from basalt

Slope: 1 to 5 percent
Aspect: East to west
Shape (down/across): Convex/linear
Surface fragments: About 2 percent subrounded stones
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 4.0 inches (low)
Shrink-swell potential: About 7.4 percent (high)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa-Juniperus deppeana/Quercus gambelii
Potential native vegetation:
Common trees: Rocky Mountain juniper, twoneedle pinyon, ponderosa pine
Other plants: blue grama, Arizona fescue, mountain muhly, spineless horsebrush, Fendler ceanothus, prairie junegrass
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 5 inches; cobbly loam
Bt1—5 to 12 inches; clay
Bt2—12 to 15 inches; clay
Bt3—15 to 25 inches; clay
C—25 to 28 inches; clay
R—28 to 60 inches; bedrock

Charo, noncobbly soils
Landscape: Mountains
Landform: Hills, ridges, mesas
Position on landform: Shoulders
Position on landform: Crest, mountaintop
Parent material: Eolian deposits over residuum weathered from basalt
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Moderately deep
Depth to restrictive feature: 20 to 40 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 6.5 inches (moderate)
Shrink-swell potential: About 4.2 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Mountain Grassland
Potential native vegetation: Arizona fescue, mountain muhly, muttongrass, prairie junegrass
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 8 inches; loam
Bt—8 to 38 inches; clay
R—38 to 60 inches; bedrock

Minor Components
Rock outcrop
Composition: About 10 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

409—Santa Fe very gravelly sandy loam, 15 to 40 percent slopes, stony

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,800 to 7,600 feet (2,073 to 2,316 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Santa Fe and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Santa Fe soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Slope alluvium over residuum weathered from granite
Slope: 15 to 40 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 0.5 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: sideoats grama, blue grama, galleta, pinyon ricegrass
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; very gravelly sandy loam
Bt—3 to 8 inches; very gravelly sandy clay loam
2R—8 to 60 inches; bedrock

Minor Components
Rock outcrop
Composition: About 10 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)
Ecological site: pinyon-juniper forest

Vessilla and similar soils
Composition: About 3 percent
Slope: 5 to 40 percent
Depth to restrictive feature: 6 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Waumac and similar soils
Composition: About 2 percent
Slope: 5 to 20 percent
Drainage class: Well drained
Ecological site: Sandy

410—Zia loam, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Zia and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Zia soils
Landscape: Valleys
Landform: Stream terraces
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Eolian deposits over stream alluvium derived from sandstone
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.1 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low

Calcium carbonate maximum: About 15 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: blue grama, spike muhly, western wheatgrass, bottlebrush squirreltail, fourwing saltbush, oneseed juniper, winterfat
Land capability subclass (irrigated): 3e
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 10 inches; loam
C—10 to 60 inches; stratified sandy loam to fine sandy loam

Minor Components
Pinavetes and similar soils
Composition: About 10 percent
Landform: Dunes, valley sides
Slope: 1 to 3 percent
Aspect: East to west
Drainage class: Excessively drained
Ecological site: Deep Sand

El Rancho and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Well drained
Ecological site: Loamy

414—Wauquie very gravelly fine sandy loam, 8 to 25 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,400 to 6,700 feet (1,951 to 2,042 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Wauquie and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Wauquie soils
Landscape: Uplands
Landform: Mesas, canyons, fan piedmonts, benches, hills
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Slope alluvium over colluvium derived from igneous and sedimentary rock

Slope: 8 to 25 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 3.6 inches (low)
Shrink-swell potential: About 2.9 percent (low)
Runoff class: Medium
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Juniperus monosperma-Pinus edulis/Fallugia paradoxa-Chrysothamnus nauseosus/Bouteloua hirsuta-Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Eriogonum, blue grama, skunkbush sumac, slender wheatgrass, bottlebrush squirreltail, wavyleaf oak
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; very gravelly fine sandy loam
Bt—3 to 30 inches; very gravelly sandy clay loam
Bk—30 to 60 inches; stratified very gravelly sandy loam to very gravelly loamy coarse sand

Minor Components

Santa Fe and similar soils
Composition: About 5 percent
Slope: 15 to 40 percent
Depth to restrictive feature: 8 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Bamac and similar soils
Composition: About 5 percent
Slope: 15 to 55 percent
Drainage class: Excessively drained
Ecological site: Foothills

Laventana and similar soils
Composition: About 5 percent
Slope: 3 to 15 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

417—Jocity loam, 0 to 2 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,300 to 5,500 feet (1,615 to 1,676 meters)

Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Jocity and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Jocity soils
Landscape: Valleys
Landform: Alluvial fans, flood plains
Position on landform: Toeslopes
Position on landform: Rise, base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 0 to 2 percent
    Aspect: East to west
    Shape (down/across): Linear, concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.6 inches (high)
Shrink-swell potential: About 4.0 percent (moderate)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 7c

Typical Profile:
    Ap—0 to 10 inches; loam
    C1—10 to 26 inches; silty clay loam
    C2—26 to 32 inches; loam
    C3—32 to 50 inches; sandy clay loam
    C4—50 to 56 inches; sandy loam
    C5—56 to 60 inches; loamy sand

Minor Components
Zia and similar soils
    Composition: About 5 percent
    Slope: 1 to 3 percent
    Drainage class: Well drained
    Ecological site: Sandy

Aga and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Sparham and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

418—Jocity clay loam, 0 to 2 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,300 to 5,600 feet (1,615 to 1,707 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Jocity and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Jocity soils
Landscape: Valleys
Landform: Alluvial fans, flood plains
Position on landform: Toeslopes
Position on landform: Base slope, rise
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 0 to 2 percent
Aspect: East to west
Shape (down/across): Concave, linear/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 8.6 inches (moderate)
Shrink-swell potential: About 2.9 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 12 inches; clay loam
C1—12 to 30 inches; clay loam
C2—30 to 60 inches; stratified loamy sand to sandy loam

Minor Components
Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Aga and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Sparham and similar soils
Composition: About 3 percent
Slope: 0 to 1 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

Zia and similar soils
Composition: About 2 percent
Slope: 1 to 4 percent
Drainage class: Well drained
Ecological site: Sandy

419—Santa Fe-Wauquie-Rock outcrop complex, 25 to 70 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,400 to 8,400 feet (1,951 to 2,560 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Santa Fe and similar soils: 40 percent
Wauquie and similar soils: 30 percent
Rock outcrop: 20 percent
Minor components: 10 percent

Component Descriptions

Santa Fe soils
Landscape: Mountains
Landform: Mountain slopes

Position on landform: Backslopes, mountainflanks
Parent material: Slope alluvium over residuum weathered from granite
Slope: 25 to 70 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 0.8 inches (very low)
Shrink-swell potential: About 3.2 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: sideoats grama, blue grama, galleta, pinyon ricegrass
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 9 inches; extremely cobbly coarse sandy loam
Bt—9 to 16 inches; very gravelly sandy clay loam
2R—16 to 60 inches; bedrock

Wauquie soils
Landscape: Mountains
Landform: Benches, mountain slopes, canyons, hills, mesas
Position on landform: Footslopes
Position on landform: Mountainflank
Parent material: Slope alluvium over residuum weathered from granite
Slope: 25 to 55 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 1.4 inches (very low)
Shrink-swell potential: About 2.3 percent (low)
Runoff class: High
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Juniperus monosperma-Pinus edulis/Fallugia paradoxa-Chrysothamnus nauseosus/Bouteloua hirsuta-Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: skunkbush sumac, Gambel oak, bluegrass, bottlebrush squirreltail, mountain big sagebrush, mountain mahogany, mountain muhly, pine dropseed, pinyon ricegrass, prairie junegrass
Land capability subclass (nonirrigated): 7e

Typical Profile:
A—0 to 4 inches; extremely cobbly fine sandy loam
Bt1—4 to 11 inches; extremely cobbly sandy clay loam
Bt2—11 to 18 inches; extremely cobbly sandy clay loam
Bt3—18 to 29 inches; extremely cobbly sandy loam
Bk—29 to 60 inches; extremely cobbly sand

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Escarpments, hills
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Minor Components
Osha and similar soils
Composition: About 10 percent
Slope: 35 to 55 percent
Drainage class: Somewhat excessively drained
Ecological site: Pinus ponderosa/Quercus gambelii

420—Pinavetes loamy sand, 1 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 5,200 to 6,000 feet (1,585 to 1,829 meters)
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Map Unit Composition

Pinavetes and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Pinavetes soils
Landscape: Uplands
Landform: Dunes, valley sides
Position on landform: Shoulders
Position on landform: Side slope
Parent material: Eolian sands derived from sandstone
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Convex/convex
Depth class: Very deep
Drainage class: Excessively drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 2.7 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None

Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, blue grama, sand sagebrush
Land capability subclass (irrigated): 3s
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 10 inches; loamy sand
C—10 to 60 inches; sand

Minor Components
Zia and similar soils
Composition: About 5 percent
Slope: 5 to 20 percent
Drainage class: Well drained
Ecological site: Sandy

El Rancho and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Well drained
Ecological site: Loamy

Pinavetes and similar soils
Composition: About 5 percent
Slope: 5 to 15 percent
Drainage class: Excessively drained
Ecological site: Deep Sand

421—Gilco loam, moderately saline, sodic, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,100 to 5,500 feet (1,554 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Gilco, moderately saline, sodic and similar soils: 90 percent
Minor components: 10 percent

Component Descriptions

Gilco, moderately saline, sodic soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock

Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 9.0 inches (high)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Salty Bottomland
Potential native vegetation: alkali sacaton, galleta, bottlebrush squirreltail, fourwing saltbush, greasewood
Land capability subclass (irrigated): 4s
Land capability subclass (nonirrigated): 7c

Typical Profile:
Ap—0 to 7 inches; loam
C1—7 to 19 inches; very fine sandy loam
C2—19 to 60 inches; stratified fine sandy loam to loam

Minor Components

Aga and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Jocity and similar soils
Composition: About 3 percent
Slope: 0 to 2 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Peralta and similar soils
Composition: About 2 percent
Slope: 0 to 2 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

422—Vessilla-Menefee-Orlie association, 0 to 30 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,100 to 7,200 feet (1,859 to 2,195 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Vessilla and similar soils: 35 percent
Menefee and similar soils: 30 percent
Orlie and similar soils: 25 percent
Minor components: 10 percent

Component Descriptions

Vessilla soils
Landscape: Uplands
Landform: Ridges, breaks, mesas, hills
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian deposits over slope alluvium over residuum weathered from sandstone
Slope: 5 to 30 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 4 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 1.8 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis/Rhus trilobata/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: Indian ricegrass, blue grama, mountain big sagebrush, oak, galleta, sideoats grama
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 1 inch; sandy loam
C—1 inch to 15 inches; sandy loam
R—15 to 60 inches; bedrock

Menefee soils
Landscape: Uplands
Landform: Hillslopes, mesas, mountainsides

Position on landform: Backslopes
Position on landform: Side slope
Parent material: Colluvium over residuum weathered from shale
Slope: 2 to 9 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very shallow and shallow
Depth to restrictive feature: 8 to 20 inches to bedrock (paralithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 2.0 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 15 percent
Gypsum maximum: About 1 percent
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: Rocky Mountain juniper, oneseed juniper, twoneedle pinyon
Other plants: blue grama, galleta, Gambel oak, big sagebrush, sideoats grama
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 3 inches; clay loam
C—3 to 10 inches; clay loam
2Cr—10 to 60 inches; bedrock

Orlie soils
Landscape: Uplands
Landform: Mesas, valley sides, hills, cuestas
Position on landform: Footslopes
Position on landform: Side slope
Parent material: Eolian material and alluvium derived from sandstone and shale
Slope: 0 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 11.7 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 2 (slightly sodic)
Ecological site: Loamy
Potential native vegetation: western wheatgrass, big sagebrush, galleta, Indian ricegrass, needle and thread, fourwing saltbush
Land capability subclass (nonirrigated): 6c

Typical Profile:
A—0 to 4 inches; loam
Bt—4 to 14 inches; silty clay loam
C—14 to 60 inches; silty clay loam

Minor Components
Sparank and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Well drained
Flooding hazard: Occasional
Ecological site: Clayey Bottomland

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

423—Gilco loam, 1 to 4 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,300 to 5,500 feet (1,615 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Gilco and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Gilco soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 1 to 4 percent
Aspect: East to west
Shape (down/across): Concave/linear
Surface fragments: About 12 percent subrounded gravel
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 9.6 inches (high)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)

Ecological site: Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 4e
Land capability subclass (nonirrigated): 7e

Typical Profile:
Ap—0 to 8 inches; loam
C1—8 to 14 inches; loam
C2—14 to 60 inches; stratified fine sandy loam to silt loam

Minor Components
Peralta and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

Jocity and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Aga and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

426—Aga loam, moderately saline, sodic, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Aga, moderately saline, sodic and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Aga, moderately saline, sodic soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock

Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 5.0 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Bottomland
Potential native vegetation: alkali sacaton, fourwing saltbush, giant sacaton, inland saltgrass, greasewood
Land capability subclass (irrigated): 4s
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 8 inches; loam
C1—8 to 20 inches; loam
2C2—20 to 36 inches; loamy sand
2C3—36 to 60 inches; gravelly sand

Minor Components
Gilco and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Peralta and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

427—Aga loam, 1 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Aga and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Aga soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 7.6 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 42 to 60 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 8 inches; loam
C1—8 to 28 inches; loam
2C2—28 to 60 inches; loamy fine sand

Minor Components
Gilco and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Jocity and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

428—Aga loam, moderately saline, sodic, 1 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,200 to 5,500 feet (1,585 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Aga, moderately saline, sodic and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Aga, moderately saline, sodic soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 5.5 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Salty Bottomland
Potential native vegetation: alkali sacaton, fourwing saltbush, giant sacaton, inland saltgrass, greasewood
Land capability subclass (irrigated): 4s
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 4 inches; loam
C1—4 to 16 inches; very fine sandy loam
2C2—16 to 22 inches; loam
2C3—22 to 60 inches; stratified sand to loamy sand

Minor Components

Peralta and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Jocity and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

430—Trail loam, 1 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Trail and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Trail soils

Landscape: Valleys
Landform: Flood plains, valley floor remnants, channels, alluvial fans
Position on landform: Toeslopes
Position on landform: Rise, base slope
Parent material: Eolian deposits over stream alluvium derived from sandstone
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 4.4 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Runoff class: Very low
Calcium carbonate maximum: About 5 percent

Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: alkali sacaton, giant sacaton, fourwing saltbush
Land capability subclass (irrigated): 4e
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 10 inches; loam
C1—10 to 34 inches; loamy sand
C2—34 to 60 inches; stratified sand to fine sandy loam

Minor Components
Aga and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Peralta and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

431—Trail loamy sand, 1 to 4 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Trail and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Trail soils
Landscape: Valleys
Landform: Valley floor remnants, flood plains, channels, alluvial fans
Position on landform: Toeslopes

Position on landform: Base slope, rise
Parent material: Eolian deposits over stream alluvium derived from sandstone
Slope: 1 to 4 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 5.1 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Runoff class: Very low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Deep Sand
Potential native vegetation: Indian ricegrass, black grama, sand sagebrush, dropseed
Land capability subclass (irrigated): 4e
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 10 inches; loamy sand
C—10 to 60 inches; stratified loamy sand to sand to gravelly sand to fine sandy loam

Minor Components
El Rancho and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Well drained
Ecological site: Loamy

Aga and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Riverwash
Composition: About 3 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 3 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Zia and similar soils
Composition: About 2 percent
Slope: 1 to 9 percent
Drainage class: Well drained
Ecological site: Sandy

433—Peralta loam, 0 to 1 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Peralta and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Peralta soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Somewhat poorly drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.6 inches (moderate)
Shrink-swell potential: About 1.8 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 24 to 36 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 8 mmhos/cm (slightly saline)
Sodium adsorption ratio maximum: About 13 (moderately sodic)
Ecological site: Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 3e
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 10 inches; loam
C—10 to 60 inches; stratified very fine sandy loam to fine sandy loam to loamy fine sand

Minor Components

Aga and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

434—Peralta loam, 1 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,400 feet (1,524 to 1,646 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Peralta and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Peralta soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes, base slopes
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Somewhat poorly drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 7.8 inches (moderate)
Shrink-swell potential: About 2.3 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 24 to 36 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 8 mmhos/cm (slightly saline)
Sodium adsorption ratio maximum: About 13 (moderately sodic)
Ecological site: Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 3e
Land capability subclass (nonirrigated): 7c

Typical Profile:
Ap—0 to 10 inches; loam
C1—10 to 16 inches; very fine sandy loam
C2—16 to 20 inches; clay loam
C3—20 to 28 inches; fine sandy loam
C4—28 to 40 inches; loamy sand
C5—40 to 45 inches; silt loam
C6—45 to 60 inches; loamy fine sand

Minor Components
Aga and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

437—Peralta loam, moderately saline, sodic, 1 to 3 percent slopes

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,400 feet (1,524 to 1,646 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Peralta, moderately saline, sodic and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Peralta, moderately saline, sodic soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Somewhat poorly drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 8.4 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)

Flooding hazard: Rare
Seasonal high water table depth: About 24 to 36 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Salty Bottomland
Potential native vegetation: alkali sacaton, fourwing saltbush, giant sacaton, inland saltgrass, greasewood
Land capability subclass (irrigated): 4s
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 4 inches; loam
C—4 to 60 inches; stratified loam to fine sandy loam to loamy sand

Minor Components
Aga and similar soils
Composition: About 10 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

500—Rock outcrop-Osha-Rubble land complex, 40 to 70 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 7,000 to 9,000 feet (2,134 to 2,743 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Rock outcrop: 40 percent
Osha and similar soils: 30 percent
Rubble land: 20 percent
Minor components: 10 percent

Component Descriptions

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.

Landform: Ledges, escarpments, benches
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Osha soils
Landscape: Mountains
Landform: Mountain slopes, ridges
Position on landform: Backslopes
Position on landform: Mountainflank, crest
Parent material: Colluvium over residuum weathered from granite
Slope: 40 to 70 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Deep
Depth to restrictive feature: 40 to 60 inches to bedrock (lithic)
Drainage class: Somewhat excessively drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 1.4 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
Common trees: ponderosa pine
Other plants: Gambel oak, blue grama, New Mexico locust, Rocky Mountain juniper, mountain muhly, prairie junegrass, skunkbush sumac, wavyleaf oak
Land capability subclass (nonirrigated): 7c

Typical Profile:
AB—0 to 10 inches; very gravelly coarse sandy loam
Bw—10 to 20 inches; very gravelly coarse sandy loam
Ct—20 to 43 inches; extremely gravelly loamy coarse sand
R—43 to 60 inches; bedrock

Rubble land
Description: Rubble land consists of areas with 90 percent or more of the surface covered with cobbles, stones, and boulders.
Landform: Hills
Position on landform: Side slope
Slope: 40 to 70 percent
Aspect: East to west
Drainage class: Excessively drained
Available water capacity: About 0.6 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 0 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Land capability subclass (nonirrigated): 8s

Minor Components

Cypher and similar soils
Composition: About 5 percent
Slope: 15 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Pinus ponderosa/Quercus gambelii

Palon and similar soils
Composition: About 5 percent
Slope: 15 to 35 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

503—Cajete-Cypher association, 8 to 50 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 7,000 to 7,300 feet (2,134 to 2,225 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Cajete and similar soils: 65 percent
Cypher and similar soils: 25 percent
Minor components: 10 percent

Component Descriptions

Cajete soils

Landscape: Mountains
Landform: Hills, mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank, upper third, crest
Parent material: Residuum weathered from pumice
Slope: 8 to 30 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 3.3 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii

Potential native vegetation:
Common trees: ponderosa pine
Other plants: Arizona fescue, Kentucky bluegrass, Thurber fescue, bluegrass, common juniper, mountain muhly, needlegrass, pine dropseed, sedge, western wheatgrass
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 8 inches; extremely gravelly coarse sandy loam
C—8 to 60 inches; very gravelly sandy loam

Cypher soils
Landscape: Mountains
Landform: Ridges, mountain slopes
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Colluvium derived from tuff over residuum weathered from rhyolite
Slope: 30 to 50 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 2 percent subrounded cobbles
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 0.8 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
Common trees: ponderosa pine
Other plants: Arizona fescue, little bluestem, mountain muhly, California brome, big bluestem, sideoats grama
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 3 inches; very gravelly loam
BC1—3 to 11 inches; very gravelly sandy loam
BC2—11 to 15 inches; extremely gravelly sandy loam
2R—15 to 60 inches; bedrock

Minor Components
Laventana and similar soils
Composition: About 5 percent
Slope: 3 to 15 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: ponderosa forest

Mirand and similar soils
Composition: About 3 percent
Slope: 5 to 30 percent
Drainage class: Well drained
Ecological site: Pinus ponderosa/Quercus gambelii

Rock outcrop
Composition: About 2 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

504—Orejas-Guaje complex, 1 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 36
Elevation: 6,000 to 7,000 feet (1,829 to 2,134 meters)
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (8.9 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Map Unit Composition

Orejas and similar soils: 40 percent
Guaje and similar soils: 35 percent
Minor components: 25 percent

Component Descriptions

Orejas soils
Landscape: Uplands
Landform: Plateaus, mesas
Position on landform: Summits
Position on landform: Side slope
Parent material: Eolian material, slope alluvium and colluvium derived from basalt
Slope: 5 to 15 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 1.7 inches (very low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: Very high
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: twoneedle pinyon, oneseed juniper
Other plants: big sagebrush, blue grama, sideoats grama
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 2 inches; very cobbly loam
Bt—2 to 9 inches; very cobbly clay loam
C—9 to 17 inches; very gravelly clay loam
R—17 to 60 inches; bedrock

Guaje soils
Landscape: Uplands
Landform: Hills, volcanic cones
Position on landform: Backslopes
Position on landform: Side slope
Parent material: Eolian material and alluvium derived from volcanic rock
Slope: 1 to 8 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 20 percent subrounded gravel
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 3.1 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: About 20 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis
Potential native vegetation:
Common trees: oneseed juniper, twoneedle pinyon
Other plants: blue grama, galleta, sideoats grama, New Mexico Feathergrass, little bluestem, mountain muhly, pine dropseed, sand dropseed
Land capability subclass (nonirrigated): 6s

Typical Profile:
A—0 to 4 inches; gravelly sandy loam
Bw—4 to 12 inches; gravelly sandy loam
Bk1—12 to 17 inches; very gravelly sandy loam
Bk2—17 to 45 inches; extremely gravelly sandy loam
Bk3—45 to 60 inches; very gravelly sandy loam

Minor Components
Elpedro and similar soils
Composition: About 10 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Guaje, very cobbly and similar soils
Composition: About 10 percent
Slope: 1 to 8 percent
Drainage class: Well drained
Ecological site: pinyon-juniper forest

Orejas, steep and similar soils
Composition: About 5 percent
Slope: 15 to 40 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: pinyon-juniper forest

600—Rock outcrop-Cypher complex, 35 to 60 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 6,500 to 7,400 feet (1,981 to 2,256 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Rock outcrop: 50 percent
Cypher and similar soils: 35 percent
Minor components: 15 percent

Component Descriptions

Rock outcrop
Description: Rock outcrop consists of barren or nearly barren areas of bedrock as benches, ledges, and escarpments.
Landform: Mountain slopes, scarps
Aspect: East to west
Depth to restrictive feature: 0 inches to bedrock (lithic)
Land capability subclass (nonirrigated): 8s

Cypher soils
Landscape: Mountains
Landform: Mountain slopes, ridges
Position on landform: Backslopes, mountainflanks
Parent material: Colluvium and residuum weathered from tuff and/or colluvium and residuum weathered from rhyolite
Slope: 35 to 60 percent
Aspect: East to west
Shape (down/across): Linear/linear
Surface fragments: About 3 percent subrounded gravel
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 1.5 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Very high
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii

Potential native vegetation:
Common trees: ponderosa pine
Other plants: Arizona fescue, California brome, little bluestem, mountain muhly
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 4 inches; very cobbly loam
BC1—4 to 14 inches; very gravelly loam
BC2—14 to 16 inches; very gravelly loam
2R—16 to 60 inches; bedrock

Minor Components
Cypher and similar soils
Composition: About 5 percent
Slope: 15 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Pinus ponderosa/Quercus gambelii

Cajete and similar soils
Composition: About 5 percent
Slope: 8 to 30 percent
Drainage class: Well drained
Ecological site: Mountain Grassland

Laventana and similar soils
Composition: About 3 percent
Slope: 3 to 15 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Pinus ponderosa/Quercus gambelii

Rock outcrop
Composition: About 2 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

601—Laventana gravelly sandy loam, 3 to 15 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 7,400 to 7,600 feet (2,256 to 2,316 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Laventana and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Laventana soils
Landscape: Mountains
Landform: Pediments, mountain slopes
Position on landform: Footslopes
Position on landform: Mountainflank
Parent material: Colluvium derived from granite and/or colluvium derived from andesite
Slope: 3 to 15 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Deep
Depth to restrictive feature: 40 to 60 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 4.1 inches (low)
Shrink-swell potential: About 4.4 percent (moderate)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
Common trees: ponderosa pine
Other plants: Gambel oak, mountain mahogany, bottlebrush squirreltail, prairie junegrass, sedge
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 5 inches; gravelly sandy loam
E—5 to 9 inches; very gravelly loam
Bt—9 to 50 inches; very gravelly sandy clay loam
2R—50 to 60 inches; bedrock

Minor Components
Mirand and similar soils
Composition: About 10 percent
Slope: 5 to 30 percent
Drainage class: Well drained
Ecological site: Pinus ponderosa/Quercus gambelii

Rock outcrop
Composition: About 5 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

603—Laventana-Mirand very cobbly loams, 15 to 55 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 7,000 to 8,900 feet (2,134 to 2,713 meters)

Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Laventana and similar soils: 50 percent
Mirand and similar soils: 35 percent
Minor components: 15 percent

Component Descriptions

Laventana soils
Landscape: Mountains
Landform: Pediments, mountain slopes
Position on landform: Footslopes
Position on landform: Mountainflank
Parent material: Colluvium derived from granite and/or colluvium derived from andesite
Slope: 20 to 55 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Deep
Depth to restrictive feature: 40 to 60 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 4.8 inches (low)
Shrink-swell potential: About 4.5 percent (moderate)
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
Common trees: ponderosa pine
Other plants: Gambel oak, mountain mahogany, bottlebrush squirreltail, prairie junegrass, sedge
Land capability subclass (nonirrigated): 7c

Typical Profile:
Oi—0 to 1 inch; slightly decomposed plant material
A—1 inch to 5 inches; very cobbly loam
E—5 to 12 inches; gravelly silt loam
Bt1—12 to 20 inches; very cobbly loam
Bt2—20 to 31 inches; very gravelly loam
Bt3—31 to 51 inches; very gravelly loam
2R—51 to 60 inches; bedrock

Mirand soils
Landscape: Mountains
Landform: Mountain slopes
Position on landform: Toeslopes
Position on landform: Mountainflank
Parent material: Colluvium derived from rhyolite and/or colluvium derived from tuff

Slope: 15 to 25 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 8.0 inches (moderate)
Shrink-swell potential: About 7.4 percent (high)
Runoff class: Very high
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
Common trees: ponderosa pine
Other plants: Arizona fescue, mountain muhly, prairie junegrass, California brome, Gambel oak, bottlebrush squirreltail, muttongrass, pine dropseed
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 6 inches; very cobbly loam
Bt1—6 to 27 inches; cobbly clay
Bt2—27 to 60 inches; sandy clay

Minor Components

Cypher and similar soils
Composition: About 5 percent
Slope: 15 to 35 percent
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Pinus ponderosa/Quercus gambelii

Cajete and similar soils
Composition: About 5 percent
Slope: 8 to 30 percent
Drainage class: Well drained
Ecological site: Mountain Grassland

Rock outcrop
Composition: About 3 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Totavi and similar soils
Composition: About 2 percent
Slope: 0 to 5 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Pinus ponderosa-Juniperus deppeana/Quercus gambelii

604—Cypher-Mirand complex, 15 to 55 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 6,900 to 9,000 feet (2,103 to 2,743 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Cypher and similar soils: 55 percent
Mirand and similar soils: 30 percent
Minor components: 15 percent

Component Descriptions

Cypher soils
Landscape: Mountains
Landform: Mountain slopes, ridges
Position on landform: Summits
Position on landform: Mountainflank
Parent material: Colluvium derived from tuff over residuum weathered from rhyolite
Slope: 15 to 35 percent
    Aspect: East to west
    Shape (down/across): Linear/linear
Surface fragments: About 10 percent subrounded gravel
Depth class: Shallow
Depth to restrictive feature: 10 to 20 inches to bedrock (lithic)
Drainage class: Well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 1.5 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
    Common trees: ponderosa pine
    Other plants: Arizona fescue, little bluestem, mountain muhly, California brome, big bluestem, sideoats grama
Land capability subclass (nonirrigated): 7c

Typical Profile:
    Oi—0 to 1 inch; slightly decomposed plant material
    A—1 inch to 4 inches; very gravelly loam
    BCw—4 to 11 inches; very gravelly loam
    C—11 to 19 inches; extremely gravelly sandy loam
    2R—19 to 60 inches; bedrock

Mirand soils
Landscape: Mountains
Landform: Mountain slopes

Position on landform: Toeslopes
Position on landform: Mountainflank
Parent material: Colluvium derived from rhyolite and/or colluvium derived from tuff
Slope: 15 to 55 percent
Aspect: East to west
Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Well drained
Slowest permeability: .06 to 0.2 in./hr. (slow)
Available water capacity: About 6.4 inches (moderate)
Shrink-swell potential: About 7.5 percent (high)
Runoff class: High
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
Common trees: ponderosa pine
Other plants: Arizona fescue, mountain muhly, California brome, Gambel oak, bottlebrush squirreltail, muttongrass, pine dropseed, prairie junegrass
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 4 inches; very cobbly loam
Bt—4 to 60 inches; cobbly clay

Minor Components
Alanos and similar soils
Composition: About 5 percent
Slope: 20 to 40 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Laventana and similar soils
Composition: About 5 percent
Slope: 3 to 15 percent
Depth to restrictive feature: 40 to 60 inches to bedrock (lithic)
Drainage class: Well drained
Ecological site: Pinus ponderosa/Quercus gambelii

Rock outcrop
Composition: About 3 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

Totavi and similar soils
Composition: About 2 percent
Slope: 0 to 5 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Pinus ponderosa-Juniperus deppeana/Quercus gambelii

608—Osha association, 3 to 55 percent slopes

Map Unit Setting

Major Land Resource Area: 48A
Elevation: 8,500 to 9,000 feet (2,591 to 2,743 meters)
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Map Unit Composition

Osha, steep and similar soils: 60 percent
Osha and similar soils: 30 percent
Minor components: 10 percent

Component Descriptions

Osha, steep soils
Landscape: Mountains
Landform: Mountain slopes, ridges
Position on landform: Backslopes
Position on landform: Mountainflank
Parent material: Colluvium over residuum weathered from granite
Slope: 35 to 55 percent
    Aspect: East to west
    Shape (down/across): Linear/linear
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 1.8 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Medium
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
    Common trees: ponderosa pine
    Other plants: Arizona fescue, pine dropseed, prairie junegrass, Gambel oak, New Mexico locust, bluegrass, mountain muhly
Land capability subclass (nonirrigated): 7c

Typical Profile:
    A—0 to 3 inches; gravelly coarse sandy loam
    AB—3 to 8 inches; gravelly coarse sandy loam
    Bw—8 to 16 inches; gravelly coarse sandy loam
    Ct1—16 to 32 inches; extremely gravelly coarse sandy loam
    Ct2—32 to 60 inches; extremely gravelly loamy coarse sand

Osha soils
Landscape: Mountains
Landform: Ridges, mountain slopes
Position on landform: Shoulders
Position on landform: Mountainflank

Parent material: Colluvium and residuum weathered from granite
Slope: 3 to 35 percent
Aspect: East to west
Shape (down/across): Convex/linear
Depth class: Very deep
Drainage class: Somewhat excessively drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 2.2 inches (very low)
Shrink-swell potential: About 1.5 percent (low)
Runoff class: Low
Calcium carbonate maximum: None
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 0 (nonsodic)
Ecological site: Pinus ponderosa/Quercus gambelii
Potential native vegetation:
Common trees: ponderosa pine
Other plants: Arizona fescue, Gambel oak, New Mexico locust, bluegrass, grouse whortleberry, mountain muhly, pine dropseed, prairie junegrass
Land capability subclass (nonirrigated): 7c

Typical Profile:
AB—0 to 8 inches; gravelly coarse sandy loam
Bw—8 to 16 inches; gravelly coarse sandy loam
Ct1—16 to 32 inches; extremely gravelly coarse sandy loam
Ct2—32 to 60 inches; extremely gravelly loamy coarse sand

Minor Components
Palon and similar soils
Composition: About 8 percent
Slope: 15 to 35 percent
Drainage class: Well drained
Ecological site: Pseudotsuga menziesii-Pinus ponderosa/Muhlenbergia

Rock outcrop
Composition: About 2 percent
Depth to restrictive feature: 0 inches to bedrock (lithic)

823—Gilco loam, 1 to 4 percent slopes, unprotected

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Gilco, unprotected and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Gilco, unprotected soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 1 to 4 percent
Aspect: East to west
Shape (down/across): Concave/linear
Surface fragments: About 12 percent subrounded medium and coarse gravel
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 9.4 inches (high)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation:
Common trees: Rio Grande cottonwood
Other plants: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 4e
Land capability subclass (nonirrigated): 7e

Typical Profile:
Ap—0 to 8 inches; loam
C—8 to 60 inches; stratified fine sandy loam to loam to silt loam

Minor Components
Jocity and similar soils
Composition: About 6 percent
Slope: 0 to 2 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Aga and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Peralta and similar soils
Composition: About 2 percent
Slope: 1 to 3 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

Trail and similar soils
Composition: About 2 percent
Slope: 1 to 3 percent
Drainage class: Somewhat excessively drained
Flooding hazard: Rare
Ecological site: Bottomland

827—Aga loam, 1 to 3 percent slopes, unprotected

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Aga, unprotected and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Aga, unprotected soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 7.6 inches (moderate)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 42 to 60 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: giant sacaton, alkali sacaton, fourwing saltbush
Land capability subclass (irrigated): 2e
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 8 inches; loam
C1—8 to 28 inches; loam
2C2—28 to 60 inches; loamy fine sand

Minor Components
Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Jocity and similar soils
Composition: About 3 percent
Slope: 0 to 2 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Riverwash
Composition: About 3 percent
Landscape: Valleys
Landform: Channels, streams
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 1 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Peralta and similar soils
Composition: About 2 percent
Slope: 0 to 1 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

Trail and similar soils
Composition: About 2 percent
Slope: 0 to 1 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Bottomland

830—Trail loam, 1 to 3 percent slopes, unprotected

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.7 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Trail, unprotected and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Trail, unprotected soils
Landscape: Valleys
Landform: Valley floor remnants, alluvial fans, channels, flood plains
Position on landform: Toeslopes
Position on landform: Base slope, rise
Parent material: Eolian deposits over stream alluvium derived from sandstone
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Linear, concave/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 2.0 to 6.0 in./hr. (moderately rapid)
Available water capacity: About 5.4 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Very low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 4 mmhos/cm (very slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland
Potential native vegetation: alkali sacaton, giant sacaton, fourwing saltbush
Land capability subclass (irrigated): 4e
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 8 inches; loam
C—8 to 60 inches; stratified loamy sand to sand to sandy loam

Minor Components
Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Aga and similar soils
Composition: About 5 percent
Slope: 1 to 3 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Riverwash
Composition: About 3 percent
Landscape: Valleys
Landform: Channels, streams
Position on landform: Toeslopes, base slopes
Slope: 0 to 1 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Peralta and similar soils
Composition: About 2 percent
Slope: 0 to 1 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

831—Trail loamy sand, 1 to 3 percent slopes, unprotected

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Trail, unprotected and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Trail, unprotected soils
Landscape: Valleys
Landform: Alluvial fans, channels, flood plains, valley floor remnants
Position on landform: Toeslopes
Position on landform: Rise, base slope
Parent material: Eolian deposits over stream alluvium derived from sandstone
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Concave, linear/linear
Depth class: Very deep
Drainage class: Moderately well drained
Slowest permeability: 6.0 to 20 in./hr. (rapid)
Available water capacity: About 3.3 inches (low)
Shrink-swell potential: About 1.5 percent (low)
Flooding hazard: Rare
Seasonal high water table depth: About 48 to 72 inches
Runoff class: Very low
Calcium carbonate maximum: About 5 percent
Gypsum maximum: None
Salinity maximum: About 2 mmhos/cm (nonsaline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland

Potential native vegetation: alkali sacaton, giant sacaton, fourwing saltbush
Land capability subclass (irrigated): 4s
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 10 inches; loamy sand
C1—10 to 30 inches; loamy sand
C2—30 to 60 inches; stratified sand to gravelly sand to sandy loam

Minor Components
Aga and similar soils
Composition: About 5 percent
Slope: 1 to 3 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Riverwash
Composition: About 3 percent
Landscape: Valleys
Landform: Streams, channels
Position on landform: Toeslopes, base slopes
Slope: 0 to 1 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Peralta and similar soils
Composition: About 2 percent
Slope: 0 to 1 percent
Drainage class: Somewhat poorly drained
Flooding hazard: Rare
Ecological site: Bottomland

835—Peralta loam, 1 to 3 percent slopes, unprotected

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Peralta, unprotected, and similar soils: 85 percent
Minor components: 15 percent



Figure 10.—Typical landscape of Peralta loam, 1 to 3 percent slopes, unprotected.

Component Descriptions

Peralta, unprotected soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 1 to 3 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Somewhat poorly drained
Slowest permeability: 0.6 to 2.0 in./hr. (moderate)
Available water capacity: About 9.2 inches (high)
Shrink-swell potential: About 3.8 percent (moderate)
Flooding hazard: Occasional
Seasonal high water table depth: About 24 to 36 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 8 mmhos/cm (slightly saline)
Sodium adsorption ratio maximum: About 5 (slightly sodic)
Ecological site: Bottomland

Potential native vegetation:
Common trees: Rio Grande cottonwood
Other plants: giant sacaton, alkali sacaton, fourwing saltbush, willow
Land capability subclass (nonirrigated): 7c

Typical Profile:
A—0 to 6 inches; loam
C—6 to 16 inches; loam
C—16 to 60 inches; stratified sandy loam to clay loam

Minor Components
Gilco and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Aga and similar soils
Composition: About 5 percent
Slope: 1 to 3 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Riverwash
Composition: About 3 percent
Landscape: Valleys
Landform: Channels, streams
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 1 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

Trail and similar soils
Composition: About 2 percent
Slope: 0 to 1 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Bottomland

842—Peralta clay loam, moderately saline, sodic, 0 to 2 percent slopes, unprotected

Map Unit Setting

Major Land Resource Area: 42
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Map Unit Composition

Peralta, moderately saline, sodic, unprotected and similar soils: 85 percent
Minor components: 15 percent

Component Descriptions

Peralta, moderately saline, sodic, unprotected soils
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes
Position on landform: Base slope
Parent material: Stream alluvium derived from igneous and sedimentary rock
Slope: 0 to 2 percent
Aspect: East to west
Shape (down/across): Concave/linear
Depth class: Very deep
Drainage class: Somewhat poorly drained
Slowest permeability: 0.2 to 0.6 in./hr. (moderately slow)
Available water capacity: About 9.4 inches (high)
Shrink-swell potential: About 4.5 percent (moderate)
Flooding hazard: Rare
Seasonal high water table depth: About 24 to 36 inches
Runoff class: Low
Calcium carbonate maximum: About 10 percent
Gypsum maximum: None
Salinity maximum: About 16 mmhos/cm (moderately saline)
Sodium adsorption ratio maximum: About 30 (strongly sodic)
Ecological site: Salty Bottomland
Potential native vegetation: alkali sacaton, fourwing saltbush, giant sacaton, inland saltgrass, greasewood
Land capability subclass (irrigated): 4s
Land capability subclass (nonirrigated): 7s

Typical Profile:
A—0 to 10 inches; clay loam
C—10 to 60 inches; stratified sandy clay loam to sandy loam to clay loam

Minor Components
Trail and similar soils
Composition: About 5 percent
Slope: 0 to 1 percent
Drainage class: Well drained
Flooding hazard: Rare
Ecological site: Bottomland

Jocity and similar soils
Composition: About 5 percent
Slope: 0 to 2 percent
Drainage class: Moderately well drained
Flooding hazard: Rare
Ecological site: Bottomland

Riverwash
Composition: About 5 percent
Landscape: Valleys
Landform: Channels, streams
Position on landform: Toeslopes
Position on landform: Base slope
Slope: 0 to 1 percent
Shape (down/across): Concave/linear
Drainage class: Somewhat poorly drained
Flooding hazard: Frequent

850—Water

Map Unit Setting

Major Land Resource Area: 36

Map Unit Composition

Water: 95 percent
Minor components: 5 percent

Component Descriptions

Water
Aspect: East to west

Minor Components
Typic Torrifluvents and similar soils
Composition: About 5 percent
Landscape: Valleys
Landform: Flood plains
Position on landform: Toeslopes, base slopes
Slope: 0 to 1 percent
Aspect: East to west
Shape (down/across): Concave/linear
Drainage class: Moderately well drained
Flooding hazard: Frequent

DAM—Dam

Map Unit Setting

Major Land Resource Area: 36

Map Unit Composition

Dam: 100 percent

Component Descriptions

Dam

Use and Management of the Soils

This soil survey is an inventory and evaluation of the soils in the survey area. It can be used to adjust land uses to the limitations and potentials of natural resources and the environment. Also, it can help to prevent soil-related failures in land uses.

In preparing a soil survey, soil scientists, conservationists, engineers, and others collect extensive field data about the nature and behavioral characteristics of the soils. They collect data on erosion, droughtiness, flooding, and other factors that affect various soil uses and management. Field experience and collected data on soil properties and performance are used as a basis in predicting soil behavior.

Information in this section can be used to plan the use and management of soils for crops and pasture; as rangeland and forestland; as sites for buildings, sanitary facilities, highways and other transportation systems, and parks and other recreational facilities; for agricultural waste management; and as wildlife habitat. It can be used to identify the potentials and limitations of each soil for specific land uses and to help prevent construction failures caused by unfavorable soil properties.

Planners and others using soil survey information can evaluate the effect of specific land uses on productivity and on the environment in all or part of the survey area. The survey can help planners to maintain or create a land use pattern in harmony with the natural soil.

Contractors can use this survey to locate sources of sand and gravel, roadfill, and topsoil. They can use it to identify areas where bedrock, wetness, or very firm soil layers can cause difficulty in excavation.

Health officials, highway officials, engineers, and others may also find this survey useful. The survey can help them plan the safe disposal of wastes and locate sites for pavements, sidewalks, campgrounds, playgrounds, lawns, and trees and shrubs.

Interpretive Ratings

The interpretive tables in this survey rate the soils in the survey area for various uses. Many of the tables identify the limitations that affect specified uses and indicate the severity of those limitations. The ratings in these tables are both verbal and numerical.

Rating Class Terms

Rating classes are expressed in the tables in terms that indicate the extent to which the soils are limited by all of the soil features that affect a specified use or in terms that indicate the suitability of the soils for the use. Thus, the tables may show limitation classes or suitability classes. Terms for the limitation classes are *not limited, slightly limited, somewhat limited,* and *very limited*. The suitability ratings are expressed as *well suited, moderately well suited, poorly suited,* and *unsuited* or as *good, fair,* and *poor*.

Numerical Ratings

Numerical ratings in the tables indicate the relative severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.00 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact

on the use and the point at which the soil feature is not a limitation. The limitations appear in order from the most limiting to the least limiting. Thus, if more than one limitation is identified, the most severe limitation is listed first and the least severe one is listed last.

Crops and Pasture

General management needed for crops and pasture is suggested in this section. The crops or pasture plants best suited to the soils, including some not commonly grown in the survey area, are identified; the system of land capability classification used by the Natural Resources Conservation Service is explained; and the estimated yields of the main crops, hay, and pasture plants are listed for each soil.

Planners of management systems for individual fields or farms should consider the detailed information given in the description of each soil in the section *Detailed Soil Map Units*. Specific information can be obtained from the local office of the Natural Resources Conservation Service or the Cooperative Extension Service.

Cropland in the survey area comprises about 16,000 acres. The major concerns are a moderate hazard of soil blowing, moderate to low available water capacity, slow water intake rate, and seasonal high water tables.

Soil blowing is best controlled by cropping systems that keep the soil covered during the spring season. Low available water capacity can be overcome by method of irrigation, more frequent light irrigations, and crop selection. Slow water intake rates can be overcome by frequent, light applications after a deep early irrigation. High water tables can be overcome by drainage, crop selection, and irrigation water management.

Fertilization

All crops generally respond favorably to applications of nitrogen fertilizer. On sandy soils or on soils that have regularly received heavy applications of nitrogen and phosphorus, potassium may be needed. On cropland areas, soils should be tested at least every other year to determine present nutrient levels. Due to the high pH (8.0 - 8.5) of most of the soils in the area, some trace elements such as iron and zinc may become limiting. Lowering the pH by applying sulfur allows the trace elements to become available, as well as allowing for more efficient uptake of the major nutrients.

All of the soils in the area have low contents of organic matter. Use of barnyard manure, growing green manure crops that are plowed under, or returning large amounts of crop residues to the soil are beneficial practices. Care should be taken to avoid a buildup of salts when large amounts of manure are used.

Irrigation

All of the cropland in Sandoval County is irrigated. For the most part, water is supplied from the Rio Grande and the Jemez River. *Irrigation water management* is controlling the application of irrigation water in such a way that good crop growth is obtained without wasting water or causing soil erosion.

To irrigate properly, the farmer should know the amount of water the soil will hold, the depth to which plant roots penetrate, and the water requirements of the crop. Most crops should be irrigated when 40 to 50 percent of the available soil moisture has been depleted. A soil probe, auger, or even a shovel can be used to determine the moisture content of the root zone. The most visible symptoms of moisture stress are wilting leaves or leaves that take on a bluish cast. More drought-tolerant plants just exhibit a slow rate of growth. A check of the soil profile should be made about 48 hours after irrigation to determine whether the water reached the desired depth and whether it was applied uniformly. This simple check can reveal many problems of which the producer would not otherwise be aware.

The furrow and border methods are the two primary irrigation methods used in the survey area. The *border* method, which consists of surface flooding between low dikes on leveled land, is most widely used for alfalfa, pastures, and small grain. The *furrow* method, consisting of deeper, large furrows between the rows, is used for row crops.

If water is applied too rapidly on clayey soils such as the Sparham series in the survey area, it runs off or ponds at the lower end of the field. (Alfalfa is easily drowned.) If water is applied too slowly on sandy soils such as the Trail series, it penetrates below the root zone and is lost to plant use. A properly designed irrigation system matches the soil characteristics with the amount of water applied. Concrete-lined ditches and pipelines also are used to help conserve water.

Tillage

Most irrigated soils in this survey area have weak structure or poor tilth. Tillage performed when the soil is wet breaks down the soil structure and compacts the soil, resulting in restricted movement of air and water into the root zone. When farm equipment is driven over wet soil, a compacted layer (usually called a *plowpan*), commonly develops several inches below the surface due to the weight of the equipment. This one- to two-inch thick, tightly compressed layer restricts water intake and is often so dense that plant roots have difficulty penetrating it.

Tillage should be performed at varying depths, and only when the soil is dry, to prevent formation of a plowpan. The effect of such a pan can be corrected by chiseling or subsoiling and by growing deep-rooted crops such as alfalfa. Using a grass crop in a long-term rotation also helps to eliminate such restrictive layers. The practice of minimum tillage limits the number of trips over the field to only those that are essential, and this prevents soil damage. Growing “green manure crops,” which are crops that are plowed under, is also very beneficial to these soils. Both of these practices can improve soil tilth, improve the water intake rate, and improve the soil structure. Minimum tillage also lowers operating costs.

Conservation Cropping

A *conservation cropping sequence* is the growing of crops with the needed cultural and management measures to maintain or improve soil tilth. The conservation cropping sequence should also help to control erosion. Cropping systems include rotations that contain grasses and legumes, as well as rotations that provide benefits without these crops. In this survey area, a simple crop sequence usually is used. The sequence is influenced by the needs and choices of the operator.

Use of Crop Residue

To maintain good crop yields, it is essential to incorporate crop residues into the soil. Stubble from small grains and other crop residues are important sources of organic matter. When residues are incorporated into the soil, soil microorganisms decompose them. This process of decomposition improves the soil structure, which, in turn, improves water intake and increases soil aeration. The organisms also release plant nutrients from the material they are breaking down, and the nutrients again become available to the growing crop.

Alfalfa Production

Alfalfa produces well in the Rio Grande and Jemez Valleys. Alfalfa stands with a density of less than 4 to 5 plants per square foot generally are not profitable and are grassy and weedy. Such stands should be rotated out of alfalfa for 1 to 2 years before replanting to alfalfa. Alfalfa roots produce a chemical that kills alfalfa seedlings and takes at least a year to dissipate. Consequently, at least one other crop should be

grown in the field prior to replanting alfalfa to prevent this early thinning due to the toxin in the soil.

Considerations when planting alfalfa are: 1) avoid soils that have a fluctuating high water table; 2) select the best adapted varieties; 3) prepare a good seedbed; 4) incorporate phosphorus fertilizer before planting; 5) control weeds (fall seedings have fewer weed problems); 6) use correct seeding rate (rates vary depending on variety and seeding method); 7) do not use a companion crop unless needed to prevent soil blowing; and 8) control insects at the proper time.

After a good stand is established, maintain the stand by cutting at about $^{1}/_{10}$ bloom. This is a compromise that provides good quality and quantity without damaging the stand.

Yields per Acre

The average irrigated yields per acre that can be expected of the principal crops under a high level of management are shown in Table 5. In any given year, yields may be higher or lower than those indicated in the table because of variations in rainfall and other climatic factors. The land capability classification of map units in the survey area also is shown in the table.

The yields are based mainly on the experience and records of farmers, conservationists, and extension agents. Available yield data from nearby counties and results of field trials and demonstrations also are considered.

The management needed to obtain the indicated yields of the various crops depends on the kind of soil and the crop. Management can include drainage, erosion control, and protection from flooding; the proper planting and seeding rates; suitable high-yielding crop varieties; appropriate and timely tillage; control of weeds, plant diseases, and harmful insects; favorable soil reaction and optimum levels of nitrogen, phosphorus, potassium, and trace elements for each crop; effective use of crop residue, barnyard manure, and green manure crops; and harvesting that ensures the smallest possible loss.

For yields of irrigated crops, it is assumed that the irrigation system is adapted to the soils and to the crops grown, that good-quality irrigation water is uniformly applied as needed, and that tillage is kept to a minimum.

The estimated yields reflect the productive capacity of each soil for each of the principal crops. Yields are likely to increase as new production technology is developed. The productivity of a given soil compared with that of other soils, however, is not likely to change.

Crops other than those shown in Table 5 are grown in the survey area, but estimated yields are not listed because the acreage of such crops is small. The local office of the Natural Resources Conservation Service or of the Cooperative Extension Service can provide information about the management and productivity of the soils for those crops.

The *productivity index* is a relative rating of the capacity of a soil to produce a specific plant under a defined management system. The index is determined from yield data on a few benchmark soils and is used to calculate yields, the net returns from crops, land assessment values, and taxes and to perform risk analysis when land management decisions are made.

Land Capability Classification

Land capability classification shows, in a general way, the suitability of soils for most kinds of field crops. Crops that require special management are excluded. The soils are grouped according to their limitations for field crops, the risk of damage if they are used for crops, and the way they respond to management. The criteria used in grouping the soils do not include major and generally expensive land forming that would change slope, depth, or other characteristics of the soils, nor do they include

possible but unlikely major reclamation projects. Capability classification is not a substitute for interpretations designed to show suitability and limitations of groups of soils for rangeland, for forestland, or for engineering purposes.

Land capability classifications for the individual soils in this survey can be found in the section *Detailed Soil Map Units*.

In the capability system, soils are generally grouped at two levels—capability class and subclass.

Capability classes, the broadest groups, are designated by the numbers 1 through 8. The numbers indicate progressively greater limitations and narrower choices for practical use. The classes are defined as follows:

Class 1 soils have slight limitations that restrict their use.

Class 2 soils have moderate limitations that restrict the choice of plants or that require moderate conservation practices.

Class 3 soils have severe limitations that restrict the choice of plants or that require special conservation practices, or both.

Class 4 soils have very severe limitations that restrict the choice of plants or that require very careful management, or both.

Class 5 soils are subject to little or no erosion but have other limitations, impractical to remove, that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.

Class 6 soils have severe limitations that make them generally unsuitable for cultivation and that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.

Class 7 soils have very severe limitations that make them unsuitable for cultivation and that restrict their use mainly to grazing, forestland, or wildlife habitat.

Class 8 soils and miscellaneous areas have limitations that preclude commercial plant production and that restrict their use to recreational purposes, wildlife habitat, watershed, or esthetic purposes.

Capability subclasses are soil groups within one class. They are designated by adding a small letter, *e, w, s,* or *c,* to the class numeral, for example, 2e. The letter *e* shows that the main hazard is the risk of erosion unless close-growing plant cover is maintained; *w* shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); *s* shows that the soil is limited mainly because it is shallow, droughty, or stony; and *c,* used in only some parts of the United States, shows that the chief limitation is climate that is very cold or very dry.

In class 1 there are no subclasses because the soils of this class have few limitations. Class 5 contains only the subclasses indicated by *w, s,* or *c* because the soils in class 5 are subject to little or no erosion. They have other limitations that restrict their use to pasture, rangeland, forestland, wildlife habitat, or recreation.

Prime Farmland and Farmland of Statewide and Local Importance

Prime farmland is one of several kinds of important farmland defined by the U.S. Department of Agriculture. It is of major importance in meeting the Nation's short- and long-range needs for food and fiber. Because the supply of high-quality farmland is limited, the U.S. Department of Agriculture recognizes that responsible levels of government, as well as individuals, should encourage and facilitate the wise use of our Nation's prime farmland.

Prime farmland, as defined by the U.S. Department of Agriculture, is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. It could be cultivated land, pastureland, forestland, or other land, but it is not urban or built-up land or water areas. The soil qualities, growing season, and moisture supply are those needed for the soil to economically produce sustained high yields of crops

when proper management, including water management, and acceptable farming methods are applied. In general, prime farmland has an adequate and dependable supply of moisture from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, an acceptable salt and sodium content, and few or no rocks. It is permeable to water and air. It is not excessively erodible or saturated with water for long periods, and it either is not frequently flooded during the growing season or is protected from flooding. Slopes generally range from 0 to 6 percent. More detailed information about the criteria for prime farmland is available at the local office of the Natural Resources Conservation Service There is no farmland in the survey that meets the criteria for prime farmland without supplemental irrigation. Statewide important farmlands are those having an irrigated land capability class of IV or better and are irrigated with a supply of irrigation water that will meet crop needs throughout the growing season.

In some local areas there is a need for certain additional farmlands for the production of food, feed, fiber, and forage, even though these lands are not identified as having national or statewide importance. Where appropriate, these lands are to be identified by the local agency or agencies concerned. In places, additional farmlands of local importance may include tracts of land that have been designated for agriculture by local ordinance.

The map units in the survey area that are considered prime farmland when irrigated listed in Table 6. This list does not constitute a recommendation for a particular land use. On some soils included in the list, measures that overcome a hazard or limitation, such as flooding, wetness, and droughtiness, are needed. Onsite evaluation is needed to determine whether or not the hazard or limitation has been overcome by corrective measures. The location is shown on the detailed soil maps. The soil qualities that affect use and management are described in the section *Detailed Soil Map Units*.

Rangeland

By George Chavez, State Rangeland Management Specialist, Natural Resource Conservation Service

Rangeland is land on which the historic climax plant community is predominantly grasses, grasslike plants, forbs, or shrubs. In areas that have similar climate and topography, the kind and amount of vegetation produced on rangeland is closely related to the kind of soil. Effective management is based on knowledge about the relationship among the soils, vegetation, and water.

The *historic climax plant community* is the association of plants that are best adapted to a unique combination of environmental factors. Even on the same soil, the proportion of these plants varies from place to place and from year to year. The dominant plant or plants are used to characterize the plant community because of their relative stability in areas where abnormal disturbance or deterioration has not occurred. The grasses, forbs and shrubs that characterize the potential natural plant community on each major soil are listed by common name.

Once the plant community has been characterized for each soil, similar plant communities are grouped into ecological sites. An *ecological site* is a distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation.

Soil properties that have the greatest influence on the productivity of range plants are those that affect the availability of moisture and plant nutrients. Other soil properties such as soil reaction, salt content, and the presence or absence of a high water table during any period of the year, are also important factors in differentiating ecological sites.

Ecological site descriptions can be used to identify the proportions of the total annual production of each plant. Detailed information on the ecological sites in this

survey area is available in the local office of the Natural Resource Conservation Service.

About 55 percent of the survey area is rangeland that supports grasses, forbs, and shrubs suitable for grazing. Yearlong cow and calf operations are the dominant ranch enterprise, but many cattle and sheep ranches and yearling operations are in the area. The livestock produced on these ranches provide the principal agricultural income in the area.

Management of grazing to increase ground cover improves the vigor and reproduction of the more productive grasses and shrubs. Continuous yearlong grazing or grazing the same pasture during the growing season every year may result in the deterioration of the plant community, reducing its value for livestock grazing, watershed, wildlife habitat, and erosion control.

A proper degree of grazing use combined with deferred grazing or prescribed grazing that varies the season of grazing is needed to maintain a healthy, balanced plant community. This practice will also result in high quality forage throughout the year. Periodic rest during different seasons of the year benefits different plants. Rest in summer encourages the production and reproduction of warm-season grasses such as sideoats grama, black grama, galleta, and blue grama. Rest in spring or fall, or both, is beneficial to the cool-season grasses such as western wheatgrass, New Mexico feathergrass, and bottlebrush squirreltail. Rest during fall and winter months benefits shrubs such as fourwing saltbush and winterfat.

Flexibility in livestock and wildlife numbers and in the frequency and intensity of grazing is essential to the success of any grazing program. Effective livestock distribution is accomplished by the proper use of fences, livestock water developments, and salt for livestock.

The major management concern on most rangeland is to control the time and intensity of grazing so that the kinds and amounts of plants that make up the desired plant community may be maintained or reestablished. Forage production often is less than half of the potential because the natural vegetation in many parts of the county has been greatly depleted due to drought, infrequent beneficial wildfires, or continuous and excessive use. Brush, weeds, and cacti have increased or invaded on much of the rangeland, causing further depletion of the grass cover. Soil erosion generally occurs when the soils are not adequately covered.

In many areas where the landscape is broken by mesas, or where pastures are large, the distribution of grazing by livestock generally is poor. Poor distribution of livestock grazing results in areas that are underused and areas that are excessively used. This in turn results in loss of cover, invasion of undesirable plants, and accelerated erosion. Prescribed grazing that improves grazing distribution and proper grazing use is a management concern that may be facilitated by the installation of fencing and additional water. Manipulating or reducing undesirable brush species and minimizing soil erosion are other management concerns.

Table 7 shows, for each soil that supports vegetation suitable for grazing, the ecological site; the total annual production of vegetation in favorable, normal, and unfavorable years; the characteristic vegetation; and the average percentage of each species. An explanation of the column headings in Table 7 follows.

An *ecological site* is the product of all the environmental factors responsible for its development. It has characteristic soils that have developed over time throughout the soil development process; a characteristic hydrology, particularly infiltration and runoff, that has developed over time; and a characteristic plant community (kind and amount of vegetation). The hydrology of the site is influenced by development of the soil and plant community. The vegetation, soils, and hydrology are all interrelated. Each is influenced by the others and influences the development of the others. The plant community on an ecological site is typified by an association of species that differs from that of other ecological sites in the kind and/or proportion of species or in

total production. Descriptions of ecological sites are provided in the Field Office Technical Guide, which is available in local offices of the Natural Resources Conservation Service.

Total dry-weight production is the amount of vegetation that can be expected to grow annually in a well managed area that is supporting the potential natural plant community. It includes all vegetation, whether or not it is palatable to grazing animals. It includes the current year's growth of leaves, twigs, and fruits of woody plants. It does not include the increase in stem diameter of trees and shrubs. It is expressed in pounds per acre of air-dry vegetation for favorable, normal, and unfavorable years. In a favorable year, the amount and distribution of precipitation and the temperatures make growing conditions substantially better than average. In a normal year, growing conditions are about average. In an unfavorable year, growing conditions are well below average, generally because of low available soil moisture. Yields are adjusted to a common percent of air-dry moisture content.

Characteristic vegetation—the grasses, forbs, and shrubs that make up most of the potential natural plant community on each soil—is listed by common name. Under *rangeland composition*, the expected percentage of the total annual production is given for each species making up the characteristic vegetation. The amount that can be used as forage depends on the kinds of grazing animals and on the grazing season.

Range management requires a knowledge of the kinds of soil and of the potential natural plant community. It also requires an evaluation of the present range similarity index and rangeland trend. Range similarity index is determined by comparing the present plant community with the potential natural plant community on a particular rangeland ecological site. The more closely the existing community resembles the potential community, the higher the range similarity index. Rangeland trend is defined as the direction of change in an existing plant community relative to the potential natural plant community. Further information about the range similarity index and rangeland trend is available in the "National Range and Pasture Handbook," which is available in local offices of the Natural Resources Conservation Service.

The objective in range management is to control grazing so that the plants growing on a site are about the same in kind and amount as the potential natural plant community for that site. Such management generally results in the optimum production of vegetation, control of undesirable brush species, conservation of water, and control of erosion. Sometimes, however, an area with a range similarity index somewhat below the potential meets grazing needs, provides wildlife habitat, and protects soil and water resources.

Forest Productivity

The tables in this section can help forest owners or managers plan the use of soils for wood crops. They show the potential productivity of the soils for wood crops and rate the soils according to the limitations that affect various aspects of forest management.

Forest Productivity

In Table 8, the *potential productivity* of merchantable or *common trees* on a soil is expressed as a site index and as a volume number. The *site index* is the average height, in feet, that dominant and codominant trees of a given species attain in a specified number of years. The site index applies to fully stocked, even-aged, unmanaged stands. *Commonly grown trees* are those that forest managers generally favor in intermediate or improvement cuttings. They are selected on the basis of growth rate, quality, value, and marketability. More detailed information regarding site

index is available in the “National Forestry Manual,” which is available in local offices of the Natural Resources Conservation Service or on the Internet.

The *volume of wood fiber*, a number, is the yield likely to be produced by the most important tree species. This number, expressed as cubic feet per acre per year and calculated at the age of culmination of the mean annual increment (CMAI), indicates the amount of fiber produced in a fully stocked, even-aged, unmanaged stand.

Trees to manage are those that are preferred for planting, seeding, or natural regeneration and those that remain in the stand after thinning or partial harvest.

Recreation

The soils of the survey area are rated in Tables 9A and 9B according to limitations that affect their suitability for recreation. The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect the recreational uses. *Not limited* indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. *Slightly limited* indicates that the soil has features that are favorable for the specified use. The limitations are minor and can be easily overcome. Good performance and low maintenance can be expected. *Somewhat limited* indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. *Very limited* indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings in the tables indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.00 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

The ratings in the tables are based on restrictive soil features, such as wetness, slope, and texture of the surface layer. Susceptibility to flooding is considered. Not considered in the ratings, but important in evaluating a site, are the location and accessibility of the area, the size and shape of the area and its scenic quality, vegetation, access to water, potential water impoundment sites, and access to public sewer lines. The capacity of the soil to absorb septic tank effluent and the ability of the soil to support vegetation also are important. Soils that are subject to flooding are limited for recreational uses by the duration and intensity of flooding and the season when flooding occurs. In planning recreational facilities, onsite assessment of the height, duration, intensity, and frequency of flooding is essential.

The information in Tables 9A and 9B can be supplemented by other information in this survey, for example, interpretations for building site development, construction materials, sanitary facilities, and water management.

Camp areas require site preparation, such as shaping and leveling the tent and parking areas, stabilizing roads and intensively used areas, and installing sanitary facilities and utility lines. Camp areas are subject to heavy foot traffic and some vehicular traffic. The ratings are based on the soil properties that affect the ease of developing camp areas and the performance of the areas after development. Slope, stoniness, and depth to bedrock or a cemented pan are the main concerns affecting the development of camp areas.

The soil properties that affect the performance of the areas after development are those that influence trafficability and promote the growth of vegetation, especially in heavily used areas. For good trafficability, the surface of camp areas should absorb rainfall readily, remain firm under heavy foot traffic, and not be dusty when dry. The

soil properties that influence trafficability are texture of the surface layer, depth to a water table, ponding, flooding, permeability, and large stones. The soil properties that affect the growth of plants are depth to bedrock or a cemented pan, permeability, and toxic substances in the soil.

Picnic areas are subject to heavy foot traffic. Most vehicular traffic is confined to access roads and parking areas. The ratings are based on the soil properties that affect the ease of developing picnic areas and that influence trafficability and the growth of vegetation after development. Slope and stoniness are the main concerns affecting the development of picnic areas. For good trafficability, the surface of picnic areas should absorb rainfall readily, remain firm under heavy foot traffic, and not be dusty when dry. The soil properties that influence trafficability are texture of the surface layer, depth to a water table, ponding, flooding, permeability, and large stones. The soil properties that affect the growth of plants are depth to bedrock or a cemented pan, permeability, and toxic substances in the soil.

Playgrounds require soils that are nearly level, are free of stones, and can withstand intensive foot traffic. The ratings are based on the soil properties that affect the ease of developing playgrounds and that influence trafficability and the growth of vegetation after development. Slope and stoniness are the main concerns affecting the development of playgrounds. For good trafficability, the surface of the playgrounds should absorb rainfall readily, remain firm under heavy foot traffic, and not be dusty when dry. The soil properties that influence trafficability are texture of the surface layer, depth to a water table, ponding, flooding, permeability, and large stones. The soil properties that affect the growth of plants are depth to bedrock or a cemented pan, permeability, and toxic substances in the soil.

Paths and trails for hiking and horseback riding should require little or no slope modification through cutting and filling. The ratings are based on the soil properties that affect trafficability and erodibility. These properties are stoniness, depth to a water table, ponding, flooding, slope, and texture of the surface layer.

Off-road motorcycle trails require little or no site preparation. They are not covered with surfacing material or vegetation. Considerable compaction of the soil material is likely. The ratings are based on the soil properties that influence erodibility, trafficability, dustiness, and the ease of revegetation. These properties are stoniness, slope, depth to a water table, ponding, flooding, and texture of the surface layer.

Golf fairways are subject to heavy foot traffic and some light vehicular traffic. Cutting or filling may be required. Irrigation is not considered in the ratings. The ratings are based on the soil properties that affect plant growth and trafficability after vegetation is established. The properties that affect plant growth are reaction; depth to a water table; ponding; depth to bedrock or a cemented pan; the available water capacity in the upper 40 inches; the content of salts, sodium, or calcium carbonate; and sulfidic materials. The properties that affect trafficability are flooding, depth to a water table, ponding, slope, stoniness, and the amount of sand, clay, or organic matter in the surface layer. The suitability of the soil for traps, tees, roughs, and greens is not considered in the ratings.

Wildlife Habitat

The six general areas containing wildlife habitat in the Sandoval County Area are discussed in the following paragraphs.

Plateaus, mesas, and *terraces* contain soils that have grasslands and pinyon-juniper forests on the gently undulating to steep slopes. Grasses and shrubs grow on soils ranging from very shallow to very deep.

The summits of plateaus and mesas support pinyon-juniper forests. Elevations range from 6,800 to 7,800 feet. A variety of wildlife utilizes these areas, some of which include gray squirrels, cottontail rabbits, prairie rattlesnakes, and pinyon jays.

Fan remnants and stream terraces form near valleys and mountains. These upland sites are home to badger, stripped skunk, prairie dogs, prairie rattlesnakes, black-tailed jackrabbit, and hawks. Antelope could be reintroduced in the northern half of the survey if given protection until established. Badgers and other burrowing animals make extensive use of areas of coarse and moderately coarse textured soils.

Mountains occur in the northeastern portion of the survey area north of Bernalillo. The Jemez Mountains contain some of the most important wildlife habitat in the survey area. Woodlands of ponderosa pine, Douglas-fir, pinyon, juniper, and Gambel oak, provide habitat for turkey, mule deer, Elk, black bear, porcupine, cottontail rabbits, gray squirrel, band-tailed pigeons, owls, hawks, prairie rattlesnakes, and songbirds.

Open grassy valleys are home to prairie dogs. The Long tailed weasel also occurs in these areas. Local wetlands are important for many birds, waterfowl, and local mammals. Steep slopes and variable topography also play important roles in wildlife habitat.

River and stream valleys occur along such streams as the Rio Grande, Rio Puerco, and Jemez River. They contain riparian vegetation and water for wildlife use. These areas are used by all local wildlife for some part of their needs.

Songbirds nest in cottonwood and willow trees in large numbers. Cavity nesting birds find many nest sites in holes within large cottonwood trees. Quail use the thick vegetation for cover and seed sources. The abundant prey species attract many predators such as coyote, hawks, prairie rattlesnakes, and bobcat. Mule deer may spend their whole lives in these river bottoms.

The potential for competition between livestock and wildlife is high. The plant communities in these riparian areas must be maintained in good condition to provide wildlife habitat, flood protection, water quality, and soil erosion control.

Wetlands are areas containing hydrophytic vegetation, hydric soils, and wetland hydrology. Marshes are wetlands dominated by grasses and grass-like plants, and they occur in few areas of the survey area. Some are in channels of the Rio Grande, Rio Puerco, and Jemez River valleys and are produced by ground water. Other small marshes are man-induced and formed by irrigation impoundments.

All of these wetlands are used extensively by a large variety of wildlife species. Predators and prey species alike gather at these oases in an otherwise dry landscape.

Wetlands provide natural protection from flooding, enhance water quality, furnish habitat for wildlife, and conserve water. Wetlands need protection from excessive grazing, drainage projects, and poorly planned urban development.

Breaks are the steep, broken lands on the escarpments of mesas and plateaus. Breaks are very eroded and dissected, with many small ridges and gullies. Vegetation grows on the soils occurring in breaks, but not in large amounts. Although annual production of air-dry vegetation is generally low, plant diversity is high. This botanic diversity along with the physical cover provided by the terrain provides an attractive habitat for wildlife. Mule deer hide in breaks and feed on browse plants such as true mountainmahogany. Coyote and red fox find cover in the intricate, rocky landscapes. Trees growing on breaks of higher elevation provide nest sites and hunting perches for raptors such as the red-tailed hawk.

Rock outcrops furnish wildlife habitat when they occur as cliffs below rims of plateaus, mesas, and canyons. Although little or no vegetation grows on rock outcrops, they are still important to many species. Eagles, hawks, turkey vultures, owls, diamondback rattlers, and swallows utilize cliffs and ledges. Migratory bats seasonally roost in cracks and caves. Foxes, bobcats, bear, and cougars have dens in alcoves and caves.

Engineering

This section provides information for planning land uses related to urban development and to water management. Soils are rated for various uses, and the most limiting features are identified. Ratings are given for building site development, sanitary facilities, construction materials, and water management. The ratings are based on observed performance of the soils and on the estimated data and test data in the *Soil Properties* section.

Information in this section is intended for land use planning, for evaluating land use alternatives, and for planning site investigations prior to design and construction. The information, however, has limitations. For example, estimates and other data generally apply only to that part of the soil between the surface and a depth of 5 to 7 feet. Because of the map scale, small areas of different soils may be included within the mapped areas of a specific soil.

The information is not site specific and does not eliminate the need for onsite investigation of the soils or for testing and analysis by personnel experienced in the design and construction of engineering works.

Government ordinances and regulations that restrict certain land uses or impose specific design criteria were not considered in preparing the information in this section. Local ordinances and regulations should be considered in planning, in site selection, and in design.

Soil properties, site features, and observed performance were considered in determining the ratings in this section. During the fieldwork for this soil survey, determinations were made about particle-size distribution, liquid limit, plasticity index, soil reaction, depth to bedrock, hardness of bedrock within 5 to 7 feet of the surface, soil wetness, depth to a water table, ponding, slope, likelihood of flooding, natural soil structure aggregation, and soil density. Data were collected about kinds of clay minerals, mineralogy of the sand and silt fractions, and the kinds of adsorbed cations. Estimates were made for erodibility, permeability, corrosivity, shrink-swell potential, available water capacity, and other behavioral characteristics affecting engineering uses.

This information can be used to evaluate the potential of areas for residential, commercial, industrial, and recreational uses; make preliminary estimates of construction conditions; evaluate alternative routes for roads, streets, highways, pipelines, and underground cables; evaluate alternative sites for sanitary landfills, septic tank absorption fields, and sewage lagoons; plan detailed onsite investigations of soils and geology; locate potential sources of gravel, sand, earthfill, and topsoil; plan drainage systems, irrigation systems, ponds, terraces, and other structures for soil and water conservation; and predict performance of proposed small structures and pavements by comparing the performance of existing similar structures on the same or similar soils.

The information in the tables, along with the soil maps, the soil descriptions, and other data provided in this survey, can be used to make additional interpretations.

Some of the terms used in this soil survey have a special meaning in soil science and are defined in the *Glossary*.

Building Site Development

Soil properties influence the development of building sites, including the selection of the site, the design of the structure, construction, performance after construction, and maintenance. Tables 10A and 10B show the degree and kind of soil limitations that affect dwellings with and without basements, small commercial buildings, local roads and streets, shallow excavations, and lawns and landscaping.

The ratings in the tables are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect building

site development. *Not limited* indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. *Slightly limited* indicates that the soil has features that are favorable for the specified use. The limitations are minor and can be easily overcome. Good performance and low maintenance can be expected. *Somewhat limited* indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. *Very limited* indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings in the tables indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.00 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

Dwellings are single-family houses of three stories or less. For dwellings without basements, the foundation is assumed to consist of spread footings of reinforced concrete built on undisturbed soil at a depth of 2 feet or at the depth of maximum frost penetration, whichever is deeper. For dwellings with basements, the foundation is assumed to consist of spread footings of reinforced concrete built on undisturbed soil at a depth of about 7 feet. The ratings for dwellings are based on the soil properties that affect the capacity of the soil to support a load without movement and on the properties that affect excavation and construction costs. The properties that affect the load-supporting capacity include depth to a water table, ponding, flooding, subsidence, linear extensibility (shrink-swell potential), and compressibility. Compressibility is inferred from the Unified classification. The properties that affect the ease and amount of excavation include depth to a water table, ponding, flooding, slope, depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, and the amount and size of rock fragments.

Small commercial buildings are structures that are less than three stories high and do not have basements. The foundation is assumed to consist of spread footings of reinforced concrete built on undisturbed soil at a depth of 2 feet or at the depth of maximum frost penetration, whichever is deeper. The ratings are based on the soil properties that affect the capacity of the soil to support a load without movement and on the properties that affect excavation and construction costs. The properties that affect the load-supporting capacity include depth to a water table, ponding, flooding, subsidence, linear extensibility (shrink-swell potential), and compressibility (which is inferred from the Unified classification). The properties that affect the ease and amount of excavation include flooding, depth to a water table, ponding, slope, depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, and the amount and size of rock fragments.

Local roads and streets have an all-weather surface and carry automobile and light truck traffic all year. They have a subgrade of cut or fill soil material; a base of gravel, crushed rock, or soil material stabilized by lime or cement; and a surface of flexible material (asphalt), rigid material (concrete), or gravel with a binder. The ratings are based on the soil properties that affect the ease of excavation and grading and the traffic-supporting capacity. The properties that affect the ease of excavation and grading are depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, depth to a water table, ponding, flooding, the amount of large stones, and slope. The properties that affect the traffic-supporting capacity are soil strength (as inferred from the AASHTO group index number), subsidence, linear extensibility (shrink-swell potential), the potential for frost action, depth to a water table, and ponding.

Shallow excavations are trenches or holes dug to a maximum depth of 5 or 6 feet for graves, utility lines, open ditches, or other purposes. The ratings are based on the soil properties that influence the ease of digging and the resistance to sloughing. Depth to bedrock or a cemented pan, hardness of bedrock or a cemented pan, the amount of large stones, and dense layers influence the ease of digging, filling, and compacting. Depth to the seasonal high water table, flooding, and ponding may restrict the period when excavations can be made. Slope influences the ease of using machinery. Soil texture, depth to the water table, and linear extensibility (shrink-swell potential) influence the resistance to sloughing.

Lawns and landscaping require soils on which turf and ornamental trees and shrubs can be established and maintained. Irrigation is not considered in the ratings. The ratings are based on the soil properties that affect plant growth and trafficability after vegetation is established. The properties that affect plant growth are reaction; depth to a water table; ponding; depth to bedrock or a cemented pan; the available water capacity in the upper 40 inches; the content of salts, sodium, or calcium carbonate; and sulfidic materials. The properties that affect trafficability are flooding, depth to a water table, ponding, slope, stoniness, and the amount of sand, clay, or organic matter in the surface layer.

Sanitary Facilities

Tables 11A and 11B show the degree and kind of soil limitations that affect septic tank absorption fields, sewage lagoons, sanitary landfills, and daily cover for landfill. The ratings are both verbal and numerical. Rating class terms indicate the extent to which the soils are limited by all of the soil features that affect these uses. *Not limited* indicates that the soil has features that are very favorable for the specified use. Good performance and very low maintenance can be expected. *Slightly limited* indicates that the soil has features that are favorable for the specified use. The limitations are minor and can be easily overcome. Good performance and low maintenance can be expected. *Somewhat limited* indicates that the soil has features that are moderately favorable for the specified use. The limitations can be overcome or minimized by special planning, design, or installation. Fair performance and moderate maintenance can be expected. *Very limited* indicates that the soil has one or more features that are unfavorable for the specified use. The limitations generally cannot be overcome without major soil reclamation, special design, or expensive installation procedures. Poor performance and high maintenance can be expected.

Numerical ratings in the tables indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.00 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the use (1.00) and the point at which the soil feature is not a limitation (0.00).

Septic tank absorption fields are areas in which effluent from a septic tank is distributed into the soil through subsurface tiles or perforated pipe. Only that part of the soil between depths of 24 and 60 inches is evaluated. The ratings are based on the soil properties that affect absorption of the effluent, construction and maintenance of the system, and public health. Permeability, depth to a water table, ponding, depth to bedrock or a cemented pan, and flooding affect absorption of the effluent. Stones and boulders, ice, and bedrock or a cemented pan interfere with installation. Subsidence interferes with installation and maintenance. Excessive slope may cause lateral seepage and surfacing of the effluent in downslope areas.

Some soils are underlain by loose sand and gravel or fractured bedrock at a depth of less than 4 feet below the distribution lines. In these soils the absorption field may not adequately filter the effluent, particularly when the system is new. As a result, the ground water may become contaminated.

Sewage lagoons are shallow ponds constructed to hold sewage while aerobic bacteria decompose the solid and liquid wastes. Lagoons should have a nearly level

floor surrounded by cut slopes or embankments of compacted soil. Nearly impervious soil material for the lagoon floor and sides is required to minimize seepage and contamination of ground water. Considered in the ratings are slope, permeability, depth to a water table, ponding, depth to bedrock or a cemented pan, flooding, large stones, and content of organic matter.

Soil permeability is a critical property affecting the suitability for sewage lagoons. Most porous soils eventually become sealed when they are used as sites for sewage lagoons. Until sealing occurs, however, the hazard of pollution is severe. Soils that have a permeability rate of more than 2 inches per hour are too porous for the proper functioning of sewage lagoons. In these soils, seepage of the effluent can result in contamination of the ground water. Ground-water contamination is also a hazard if fractured bedrock is within a depth of 40 inches, if the water table is high enough to raise the level of sewage in the lagoon, or if floodwater overtops the lagoon.

A high content of organic matter is detrimental to proper functioning of the lagoon because it inhibits aerobic activity. Slope, bedrock, and cemented pans can cause construction problems, and large stones can hinder compaction of the lagoon floor. If the lagoon is to be uniformly deep throughout, the slope must be gentle enough and the soil material must be thick enough over bedrock or a cemented pan to make land smoothing practical.

A *trench sanitary landfill* is an area where solid waste is placed in successive layers in an excavated trench. The waste is spread, compacted, and covered daily with a thin layer of soil excavated at the site. When the trench is full, a final cover of soil material at least 2 feet thick is placed over the landfill. The ratings in the table are based on the soil properties that affect the risk of pollution, the ease of excavation, trafficability, and revegetation. These properties include permeability, depth to bedrock or a cemented pan, depth to a water table, ponding, slope, flooding, texture, stones and boulders, highly organic layers, soil reaction, and content of salts and sodium. Unless otherwise stated, the ratings apply only to that part of the soil within a depth of about 6 feet. For deeper trenches, onsite investigation may be needed.

Hard, nonrippable bedrock, creviced bedrock, or highly permeable strata in or directly below the proposed trench bottom can affect the ease of excavation and the hazard of ground-water pollution. Slope affects construction of the trenches and the movement of surface water around the landfill. It also affects the construction and performance of roads in areas of the landfill.

Soil texture and consistence affect the ease with which the trench is dug and the ease with which the soil can be used as daily or final cover. They determine the workability of the soil when dry and when wet. Soils that are plastic and sticky when wet are difficult to excavate, grade, or compact and are difficult to place as a uniformly thick cover over a layer of refuse.

The soil material used as the final cover for a trench landfill should be suitable for plants. It should not have excess sodium or salts and should not be too acid. The surface layer generally has the best workability, the highest content of organic matter, and the best potential for plants. Material from the surface layer should be stockpiled for use as the final cover.

In an *area sanitary landfill*, solid waste is placed in successive layers on the surface of the soil. The waste is spread, compacted, and covered daily with a thin layer of soil from a source away from the site. A final cover of soil material at least 2 feet thick is placed over the completed landfill. The ratings in the table are based on the soil properties that affect trafficability and the risk of pollution. These properties include flooding, permeability, depth to a water table, ponding, slope, and depth to bedrock or a cemented pan.

Flooding is a serious problem because it can result in pollution in areas downstream from the landfill. If permeability is too rapid or if fractured bedrock, a fractured cemented pan, or the water table is close to the surface, the leachate can

contaminate the water supply. Slope is a consideration because of the extra grading required to maintain roads in the steeper areas of the landfill. Also, leachate may flow along the surface of the soils in the steeper areas and cause difficult seepage problems.

Daily cover for landfill is the soil material that is used to cover compacted solid waste in an area sanitary landfill. The soil material is obtained offsite, transported to the landfill, and spread over the waste. The ratings in the table also apply to the final cover for a landfill. They are based on the soil properties that affect workability, the ease of digging, and the ease of moving and spreading the material over the refuse daily during wet and dry periods. These properties include soil texture, depth to a water table, ponding, rock fragments, slope, depth to bedrock or a cemented pan, reaction, and content of salts, sodium, or lime.

Loamy or silty soils that are free of large stones and excess gravel are the best cover for a landfill. Clayey soils may be sticky and difficult to spread; sandy soils are subject to wind erosion.

Slope affects the ease of excavation and of moving the cover material. Also, it can influence runoff, erosion, and reclamation of the borrow area.

After soil material has been removed, the soil material remaining in the borrow area must be thick enough over bedrock, a cemented pan, or the water table to permit revegetation. The soil material used as the final cover for a landfill should be suitable for plants. It should not have excess sodium, salts, or lime and should not be too acid.

Construction Materials

Tables 12A and 12B give information about the soils as potential sources of gravel, sand, topsoil, reclamation material, and roadfill. Normal compaction, minor processing, and other standard construction practices are assumed.

The soils are rated *good, fair,* or *poor* as potential sources of topsoil, reclamation material, and roadfill. The features that limit the soils as sources of these materials are specified in the tables. The numerical ratings given after the specified features indicate the degree to which the features limit the soils as sources of topsoil, reclamation material, or roadfill. The lower the number, the greater the limitation.

The soils are rated as a *probable* or *improbable* source of sand and gravel. A rating of *probable* means that the source material is likely to be in or below the soil. The numerical ratings in these columns indicate the degree of probability. The number 0.00 indicates that the soil is an improbable source. A number between 0.00 and 1.00 indicates the degree to which the soil is a probable source of sand or gravel.

Sand and *gravel* are natural aggregates suitable for commercial use with a minimum of processing. They are used in many kinds of construction. Specifications for each use vary widely. In Table 12A, only the probability of finding material in suitable quantity is evaluated. The suitability of the material for specific purposes is not evaluated, nor are factors that affect excavation of the material. The properties used to evaluate the soil as a source of sand or gravel are gradation of grain sizes (as indicated by the Unified classification of the soil), the thickness of suitable material, and the content of rock fragments. If the lowest layer of the soil contains sand or gravel, the soil is rated as a probable source regardless of thickness. The assumption is that the sand or gravel layer below the depth of observation exceeds the minimum thickness.

Topsoil is used to cover an area so that vegetation can be established and maintained. The upper 40 inches of a soil is evaluated for use as topsoil. Also evaluated is the reclamation potential of the borrow area. The ratings are based on the soil properties that affect plant growth; the ease of excavating, loading, and spreading the material; and reclamation of the borrow area. Toxic substances, soil reaction, and the properties that are inferred from soil texture, such as available water

capacity and fertility, affect plant growth. The ease of excavating, loading, and spreading is affected by rock fragments, slope, depth to a water table, soil texture, and thickness of suitable material. Reclamation of the borrow area is affected by slope, depth to a water table, rock fragments, depth to bedrock or a cemented pan, and toxic material.

The surface layer of most soils is generally preferred for topsoil because of its organic matter content. Organic matter greatly increases the absorption and retention of moisture and nutrients for plant growth.

Reclamation material is used in areas that have been drastically disturbed by surface mining or similar activities. When these areas are reclaimed, layers of soil material or unconsolidated geological material, or both, are replaced in a vertical sequence. The reconstructed soil favors plant growth. The ratings in the table do not apply to quarries and other mined areas that require an offsite source of reconstruction material. The ratings are based on the soil properties that affect erosion and stability of the surface and the productive potential of the reconstructed soil. These properties include the content of sodium, salts, and calcium carbonate; reaction; available water capacity; erodibility; texture; content of rock fragments; and content of organic matter and other features that affect fertility.

Roadfill is soil material that is excavated in one place and used in road embankments in another place. In the table, the soils are rated as a source of roadfill for low embankments, generally less than 6 feet high and less exacting in design than higher embankments.

The ratings are for the whole soil, from the surface to a depth of about 5 feet. It is assumed that soil layers will be mixed when the soil material is excavated and spread.

The ratings are based on the amount of suitable material and on soil properties that affect the ease of excavation and the performance of the material after it is in place. The thickness of the suitable material is a major consideration. The ease of excavation is affected by large stones, depth to a water table, and slope. How well the soil performs in place after it has been compacted and drained is determined by its strength (as inferred from the AASHTO classification of the soil) and linear extensibility (shrink-swell potential).

Water Management

Table 13 gives information on the soil properties and site features that affect water management. The degree and kind of soil limitations are given for pond reservoir areas; embankments, dikes, and levees; and aquifer-fed excavated ponds. The limitations are considered *slight* if soil properties and site features are generally favorable for the indicated use and limitations are minor and are easily overcome; *moderate* if soil properties or site features are not favorable for the indicated use and special planning, design, or maintenance is needed to overcome or minimize the limitations; and *severe* if soil properties or site features are so unfavorable or so difficult to overcome that special design, significant increase in construction costs, and possibly increased maintenance are required.

Table 13 also gives, for each soil, the restrictive features that affect drainage, irrigation, terraces and diversions, and grassed waterways.

Pond reservoir areas hold water behind a dam or embankment. Soils best suited to this use have low seepage potential in the upper 60 inches. The seepage potential is determined by the permeability of the soil and the depth to fractured bedrock or other permeable material. Excessive slope can affect the storage capacity of the reservoir area.

Embankments, dikes, and levees are raised structures of soil material, generally less than 20 feet high, constructed to impound water or to protect land against overflow. In this table, the soils are rated as a source of material for embankment fill.

The ratings apply to the soil material below the surface layer to a depth of about 5 feet. It is assumed that soil layers will be uniformly mixed and compacted during construction.

The ratings do not indicate the ability of the natural soil to support an embankment. Soil properties to a depth even greater than the height of the embankment can affect performance and safety of the embankment. Generally, deeper onsite investigation is needed to determine these properties.

Soil material in embankments must be resistant to seepage, piping, and erosion and have favorable compaction characteristics. Unfavorable features include less than 5 feet of suitable material and a high content of stones or boulders, organic matter, or salts or sodium. A high water table affects the amount of usable material. It also affects trafficability.

Aquifer-fed excavated ponds are pits or dugouts that extend to a ground-water aquifer or to a depth below a permanent water table. Excluded are ponds that are fed only by surface runoff and embankment ponds that impound water 3 feet or more above the original surface. Excavated ponds are affected by depth to a permanent water table, permeability of the aquifer, and quality of the water as inferred from the salinity of the soil. Depth to bedrock and the content of large stones affect the ease of excavation.

Drainage is the removal of excess surface and subsurface water from the soil. How easily and effectively the soil is drained depends on the depth to bedrock, a cemented pan, or other layers that affect the rate of water movement; permeability; depth to a high water table or depth of standing water if the soil is subject to ponding; slope; susceptibility to flooding; subsidence of organic layers; and the potential for frost action. Excavating and grading and the stability of ditchbanks are affected by depth to bedrock or a cemented pan, large stones, slope, and the hazard of cutbanks caving. The productivity of the soil after drainage is adversely affected by extreme acidity or by toxic substances in the root zone, such as salts, sodium, and sulfur. Availability of drainage outlets is not considered in the ratings.

Irrigation is the controlled application of water to supplement rainfall and support plant growth. The design and management of an irrigation system are affected by depth to the water table, the need for drainage, flooding, available water capacity, intake rate, permeability, erosion hazard, and slope. The construction of a system is affected by large stones and depth to bedrock or a cemented pan. The performance of a system is affected by the depth of the root zone, the amount of salts or sodium, and soil reaction.

Terraces and diversions are embankments or a combination of channels and ridges constructed across a slope to control erosion and conserve moisture by intercepting runoff. Slope, wetness, large stones, and depth to bedrock or a cemented pan affect the construction of terraces and diversions. A restricted rooting depth, a severe hazard of wind erosion or water erosion, an excessively coarse texture, and restricted permeability adversely affect maintenance.

Grassed waterways are natural or constructed channels, generally broad and shallow, that conduct surface water to outlets at a nonerosive velocity. Large stones, wetness, slope, and depth to bedrock or a cemented pan affect the construction of grassed waterways. A hazard of wind erosion, low available water capacity, restricted rooting depth, toxic substances such as salts and sodium, and restricted permeability adversely affect the growth and maintenance of the grass after construction.

Soil Properties

Data relating to soil properties are collected during the course of the soil survey.

Soil properties are ascertained by field examination of the soils and by laboratory index testing of some benchmark soils. Established standard procedures are followed. During the survey, many shallow borings are made and examined to identify and classify the soils and to delineate them on the soil maps. Samples are taken from some typical profiles and tested in the laboratory to determine particle-size distribution, plasticity, and compaction characteristics.

Estimates of soil properties are based on field examinations, on laboratory tests of samples from the survey area, and on laboratory tests of samples of similar soils in nearby areas. Tests verify field observations, verify properties that cannot be estimated accurately by field observation, and help to characterize key soils.

The estimates of soil properties are shown in tables. They include engineering index properties, physical and chemical properties, and pertinent soil and water features.

Engineering Index Properties

Table 14 gives the engineering classifications and the range of index properties for the layers of each soil in the survey area.

Depth to the upper and lower boundaries of each layer is indicated.

Texture is given in the standard terms used by the U.S. Department of Agriculture. These terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. “Loam,” for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is 15 percent or more, an appropriate modifier is added, for example, “gravelly.” Textural terms are defined in the *Glossary*.

Classification of the soils is determined according to the Unified soil classification system (ASTM, 1998) and the system adopted by the American Association of State Highway and Transportation Officials (AASHTO, 1998).

The Unified system classifies soils according to properties that affect their use as construction material. Soils are classified according to particle-size distribution of the fraction less than 3 inches in diameter and according to plasticity index, liquid limit, and organic matter content. Sandy and gravelly soils are identified as GW, GP, GM, GC, SW, SP, SM, and SC; silty and clayey soils as ML, CL, OL, MH, CH, and OH; and highly organic soils as PT. Soils exhibiting engineering properties of two groups can have a dual classification, for example, CL-ML.

The AASHTO system classifies soils according to those properties that affect roadway construction and maintenance. In this system, the fraction of a mineral soil that is less than 3 inches in diameter is classified in one of seven groups from A-1 through A-7 on the basis of particle-size distribution, liquid limit, and plasticity index. Soils in group A-1 are coarse grained and low in content of fines (silt and clay). At the other extreme, soils in group A-7 are fine grained. Highly organic soils are classified in group A-8 on the basis of visual inspection.

Rock fragments larger than 10 inches in diameter and 3 to 10 inches in diameter are indicated as a percentage of the total soil on a dry-weight basis. The percentages

are estimates determined mainly by converting volume percentage in the field to weight percentage.

Percentage (of soil particles) passing designated sieves is the percentage of the soil fraction less than 3 inches in diameter based on an ovendry weight. The sieves, numbers 4, 10, 40, and 200 (USA Standard Series), have openings of 4.76, 2.00, 0.420, and 0.074 millimeters, respectively. Estimates are based on laboratory tests of soils sampled in the survey area and in nearby areas and on estimates made in the field.

Liquid limit and *plasticity index* (Atterberg limits) indicate the plasticity characteristics of a soil. The estimates are based on test data from the survey area or from nearby areas and on field examination.

The estimates of particle-size distribution, liquid limit, and plasticity index are generally rounded to the nearest 5 percent. Thus, if the ranges of gradation and Atterberg limits extend a marginal amount (1 or 2 percentage points) across classification boundaries, the classification in the marginal zone is generally omitted in the table.

Physical Properties

Table 15 shows estimates of some physical characteristics and features that affect soil behavior. These estimates are given for the layers of each soil in the survey area. The estimates are based on field observations and on test data for these and similar soils.

Depth to the upper and lower boundaries of each layer is indicated.

Particle size is the effective diameter of a soil particle as measured by sedimentation, sieving, or micrometric methods. Particle sizes are expressed as classes with specific effective diameter class limits. The broad classes are sand, silt, and clay, ranging from the larger to the smaller.

Sand as a soil separate consists of mineral soil particles that are 0.05 millimeter to 2 millimeters in diameter. In Table 15, the estimated sand content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

Silt as a soil separate consists of mineral soil particles that are 0.002 to 0.05 millimeter in diameter. In Table 15, the estimated silt content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

Clay as a soil separate consists of mineral soil particles that are less than 0.002 millimeter in diameter. In Table 15, the estimated clay content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

The content of sand, silt, and clay affects the physical behavior of a soil. Particle size is important for engineering and agronomic interpretations, for determination of soil hydrologic qualities, and for soil classification.

The amount and kind of clay affect the fertility and physical condition of the soil and the ability of the soil to adsorb cations and to retain moisture. They influence shrink-swell potential, permeability, plasticity, the ease of soil dispersion, and other soil properties. The amount and kind of clay in a soil also affect tillage and earthmoving operations.

Moist bulk density is the weight of soil (ovendry) per unit volume. Volume is measured when the soil is at field moisture capacity, that is, the moisture content at $^1/_3$- or $^1/_{10}$-bar (33kPa or 10kPa) moisture tension. Weight is determined after the soil is dried at 105 degrees C. In the table, the estimated moist bulk density of each soil horizon is expressed in grams per cubic centimeter of soil material that is less than 2 millimeters in diameter. Bulk density data are used to compute shrink-swell potential,

available water capacity, total pore space, and other soil properties. The moist bulk density of a soil indicates the pore space available for water and roots. Depending on soil texture, a bulk density of more than 1.4 can restrict water storage and root penetration. Moist bulk density is influenced by texture, kind of clay, content of organic matter, and soil structure.

Permeability (K_{sat}) refers to the ability of a soil to transmit water or air. The term "permeability," as used in soil surveys, indicates saturated hydraulic conductivity (K_{sat}). The estimates in the table indicate the rate of water movement, in inches per hour, when the soil is saturated. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Permeability is considered in the design of soil drainage systems and septic tank absorption fields.

Available water capacity refers to the quantity of water that the soil is capable of storing for use by plants. The capacity for water storage is given in inches of water per inch of soil for each soil layer. The capacity varies, depending on soil properties that affect retention of water. The most important properties are the content of organic matter, soil texture, bulk density, and soil structure. Available water capacity is an important factor in the choice of plants or crops to be grown and in the design and management of irrigation systems. Available water capacity is not an estimate of the quantity of water actually available to plants at any given time.

Linear extensibility refers to the change in length of an unconfined clod as moisture content is decreased from a moist to a dry state. It is an expression of the volume change between the water content of the clod at $^1/_3$- or $^1/_{10}$-bar tension (33kPa or 10kPa tension) and oven dryness. The volume change is reported in the table as percent change for the whole soil. Volume change is influenced by the amount and type of clay minerals in the soil.

Linear extensibility is used to determine the shrink-swell potential of soils. The shrink-swell potential is low if the soil has a linear extensibility of less than 3 percent; moderate if 3 to 6 percent; high if 6 to 9 percent; and very high if more than 9 percent. If the linear extensibility is more than 3, shrinking and swelling can cause damage to buildings, roads, and other structures and to plant roots. Special design commonly is needed.

Organic matter is the plant and animal residue in the soil at various stages of decomposition. In Table 15, the estimated content of organic matter is expressed as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

The content of organic matter in a soil can be maintained by returning crop residue to the soil. Organic matter has a positive effect on available water capacity, water infiltration, soil organism activity, and tilth. It is a source of nitrogen and other nutrients for crops and soil organisms.

Erosion factors are shown in Table 15 as the K factor (Kw and Kf) and the T factor. Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of several factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and permeability. Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

Erosion factor Kw indicates the erodibility of the whole soil. The estimates are modified by the presence of rock fragments.

Erosion factor Kf indicates the erodibility of the fine-earth fraction, or the material less than 2 millimeters in size.

Erosion factor T is an estimate of the maximum average annual rate of soil erosion by wind or water that can occur without affecting crop productivity over a sustained period. The rate is in tons per acre per year.

Wind erodibility groups are made up of soils that have similar properties affecting their susceptibility to wind erosion in cultivated areas. The soils assigned to group 1 are the most susceptible to wind erosion, and those assigned to group 8 are the least susceptible. The groups are as follows:

1. Coarse sands, sands, fine sands, and very fine sands.
2. Loamy coarse sands, loamy sands, loamy fine sands, loamy very fine sands, ash material, and sapric soil material.
3. Coarse sandy loams, sandy loams, fine sandy loams, and very fine sandy loams.

4L. Calcareous loams, silt loams, clay loams, and silty clay loams.

4. Clays, silty clays, noncalcareous clay loams, and silty clay loams that are more than 35 percent clay.
5. Noncalcareous loams and silt loams that are less than 20 percent clay and sandy clay loams, sandy clays, and hemic soil material.
6. Noncalcareous loams and silt loams that are more than 20 percent clay and noncalcareous clay loams that are less than 35 percent clay.
7. Silts, noncalcareous silty clay loams that are less than 35 percent clay, and fibric soil material.
8. Soils that are not subject to wind erosion because of coarse fragments on the surface or because of surface wetness.

Wind erodibility index is a numerical value indicating the susceptibility of soil to wind erosion, or the tons per acre per year that can be expected to be lost to wind erosion. There is a close correlation between wind erosion and the texture of the surface layer, the size and durability of surface clods, rock fragments, organic matter, and a calcareous reaction. Soil moisture and frozen soil layers also influence wind erosion.

Chemical Properties

Table 16 shows estimates of some chemical characteristics and features that affect soil behavior. These estimates are given for the layers of each soil in the survey area. The estimates are based on field observations and on test data for these and similar soils.

Depth to the upper and lower boundaries of each layer is indicated.

Cation-exchange capacity is the total amount of extractable bases that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value. Soils having a low cation-exchange capacity hold fewer cations and may require more frequent applications of fertilizer than soils having a high cation-exchange capacity. The ability to retain cations reduces the hazard of ground-water pollution.

Soil reaction is a measure of acidity or alkalinity. The pH of each soil horizon is based on many field tests. For many soils, values have been verified by laboratory analyses. Soil reaction is important in selecting crops and other plants, in evaluating soil amendments for fertility and stabilization, and in determining the risk of corrosion.

Calcium carbonate equivalent is the percent of carbonates, by weight, in the fraction of the soil less than 2 millimeters in size. The availability of plant nutrients is influenced by the amount of carbonates in the soil. Incorporating nitrogen fertilizer into calcareous soils helps to prevent nitrite accumulation and ammonium-N volatilization.

Gypsum is expressed as a percent, by weight, of hydrated calcium sulfates in the fraction of the soil less than 20 millimeters in size. Gypsum is partially soluble in water. Soils that have a high content of gypsum may collapse if the gypsum is removed by percolating water.

Salinity is a measure of soluble salts in the soil at saturation. It is expressed as the electrical conductivity of the saturation extract, in millimhos per centimeter at 25 degrees C. Estimates are based on field and laboratory measurements at representative sites of nonirrigated soils. The salinity of irrigated soils is affected by the quality of the irrigation water and by the frequency of water application. Hence, the salinity of soils in individual fields can differ greatly from the value given in the table. Salinity affects the suitability of a soil for crop production, the stability of soil if used as construction material, and the potential of the soil to corrode metal and concrete.

Sodium adsorption ratio (SAR) is a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration. Soils that have SAR values of 13 or more may be characterized by an increased dispersion of organic matter and clay particles, reduced permeability and aeration, and a general degradation of soil structure.

Soil Features

Table 17 gives estimates of various soil features. The estimates are used in land use planning that involves engineering considerations.

A *restrictive layer* is a nearly continuous layer that has one or more physical, chemical, or thermal properties that significantly impede the movement of water and air through the soil or that restrict roots or otherwise provide an unfavorable root environment. Examples are bedrock, cemented layers, dense layers, and frozen layers.

Potential for frost action is the likelihood of upward or lateral expansion of the soil caused by the formation of segregated ice lenses (frost heave) and the subsequent collapse of the soil and loss of strength on thawing. Frost action occurs when moisture moves into the freezing zone of the soil. Temperature, texture, density, permeability, content of organic matter, and depth to the water table are the most important factors considered in evaluating the potential for frost action. It is assumed that the soil is not insulated by vegetation or snow and is not artificially drained. Silty and highly structured, clayey soils that have a high water table in winter are the most susceptible to frost action. Well drained, very gravelly, or very sandy soils are the least susceptible. Frost heave and low soil strength during thawing cause damage to pavements and other rigid structures.

Risk of corrosion pertains to potential soil-induced electrochemical or chemical action that corrodes or weakens uncoated steel or concrete. The rate of corrosion of uncoated steel is related to such factors as soil moisture, particle-size distribution, acidity, and electrical conductivity of the soil. The rate of corrosion of concrete is based mainly on the sulfate and sodium content, texture, moisture content, and acidity of the soil. Special site examination and design may be needed if the combination of factors results in a severe hazard of corrosion. The steel or concrete in installations that intersect soil boundaries or soil layers is more susceptible to corrosion than the steel or concrete in installations that are entirely within one kind of soil or within one soil layer.

For uncoated steel, the risk of corrosion, expressed as *low, moderate,* or *high,* is based on soil drainage class, total acidity, electrical resistivity near field capacity, and electrical conductivity of the saturation extract.

For concrete, the risk of corrosion also is expressed as *low, moderate,* or *high*. It is based on soil texture, acidity, and amount of sulfates in the saturation extract.

Water Features

Table 18 gives estimates of various water features. The estimates are used in land use planning that involves engineering considerations.

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The four hydrologic soil groups are:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas.

The *months* in the table indicate the portion of the year in which the feature is most likely to be a concern.

Water table refers to a saturated zone in the soil. Table 18 indicates, by month, depth to the top (*upper limit*) and base (*lower limit*) of the saturated zone in most years. Estimates of the upper and lower limits are based mainly on observations of the water table at selected sites and on evidence of a saturated zone, namely grayish colors or mottles (redoximorphic features) in the soil. A saturated zone that lasts for less than a month is not considered a water table.

Ponding is standing water in a closed depression. Unless a drainage system is installed, the water is removed only by percolation, transpiration, or evaporation. Table 18 indicates *surface water depth* and the *duration* and *frequency* of ponding. Duration is expressed as *very brief* if less than 2 days, *brief* if 2 to 7 days, *long* if 7 to 30 days, and *very long* if more than 30 days. Frequency is expressed as none, rare, occasional, and frequent. *None* means that ponding is not probable; *rare* that it is unlikely but possible under unusual weather conditions (the chance of ponding is nearly 0 percent to 5 percent in any year); *occasional* that it occurs, on the average, once or less in 2 years (the chance of ponding is 5 to 50 percent in any year); and *frequent* that it occurs, on the average, more than once in 2 years (the chance of ponding is more than 50 percent in any year).

Flooding is the temporary inundation of an area caused by overflowing streams, by runoff from adjacent slopes, or by tides. Water standing for short periods after rainfall or snowmelt is not considered flooding, and water standing in swamps and marshes is considered ponding rather than flooding.

Duration and *frequency* are estimated. Duration is expressed as *extremely brief* if 0.1 hour to 4 hours, *very brief* if 4 hours to 2 days, *brief* if 2 to 7 days, *long* if 7 to 30 days, and *very long* if more than 30 days. Frequency is expressed as none, very rare,

rare, occasional, frequent, and very frequent. *None* means that flooding is not probable; *very rare* that it is very unlikely but possible under extremely unusual weather conditions (the chance of flooding is less than 1 percent in any year); *rare* that it is unlikely but possible under unusual weather conditions (the chance of flooding is 1 to 5 percent in any year); *occasional* that it occurs infrequently under normal weather conditions (the chance of flooding is 5 to 50 percent in any year); *frequent* that it is likely to occur often under normal weather conditions (the chance of flooding is more than 50 percent in any year but is less than 50 percent in all months in any year); and *very frequent* that it is likely to occur very often under normal weather conditions (the chance of flooding is more than 50 percent in all months of any year).

The information is based on evidence in the soil profile, namely thin strata of gravel, sand, silt, or clay deposited by floodwater; irregular decrease in organic matter content with increasing depth; and little or no horizon development.

Also considered are local information about the extent and levels of flooding and the relation of each soil on the landscape to historic floods. Information on the extent of flooding based on soil data is less specific than that provided by detailed engineering surveys that delineate flood-prone areas at specific flood frequency levels.

Classification of the Soils

Soils are classified so that we can more easily remember significant characteristics. Classification enables us to assemble knowledge about the soils, to see their relationship to one another and to the whole environment, and to develop principles that help us to understand their behavior and their responses to manipulation. Through classification and then the use of soil maps, we can apply our knowledge of soils to specific areas.

The system of soil classification used by the National Cooperative Soil Survey has six categories (USDA, 1998 and 1999). Beginning with the broadest, these categories are the order, suborder, great group, subgroup, family, and series. Classification is based on soil properties observed in the field or inferred from those observations or from laboratory measurements. Table 19 shows the classification of the soils in the survey area. The categories are defined in the following paragraphs.

ORDER. Twelve soil orders are recognized. The differences among orders reflect the dominant soil-forming processes and the degree of soil formation. Each order is identified by a word ending in *sol*. An example is Aridisol.

SUBORDER. Each order is divided into suborders primarily on the basis of properties that influence soil genesis and are important to plant growth or properties that reflect the most important variables within the orders. The last syllable in the name of a suborder indicates the order. An example is Argid (*Arg*, meaning presence of argillic horizon, plus *id*, from Aridisol).

GREAT GROUP. Each suborder is divided into great groups on the basis of close similarities in kind, arrangement, and degree of development of pedogenic horizons; soil moisture and temperature regimes; type of saturation; and base status. Each great group is identified by the name of a suborder and by a prefix that indicates a property of the soil. An example is Haplargids (*Hapl*, meaning minimal horizonation, plus *argid*, the suborder of the Aridisols that has a argillic horizon).

SUBGROUP. Each great group has a typic subgroup. Other subgroups are intergrades or extragrades. The typic subgroup is the central concept of the great group; it is not necessarily the most extensive. Intergrades are transitions to other orders, suborders, or great groups. Extragrades have some properties that are not representative of the great group but do not indicate transitions to any other taxonomic class. Each subgroup is identified by one or more adjectives preceding the name of the great group. The adjective *Typic* identifies the subgroup that typifies the great group. An example is Typic Haplargids.

FAMILY. Families are established within a subgroup on the basis of physical and chemical properties and other characteristics that affect management. Generally, the properties are those of horizons below plow depth where there is much biological activity. Among the properties and characteristics considered are particle size, mineral content, soil temperature regime, soil depth, and reaction. A family name consists of the name of a subgroup preceded by terms that indicate soil properties. An example is fine-loamy, mixed, , mesic Typic Haplargids.

SERIES. The series consists of soils within a family that have horizons similar in color, texture, structure, reaction, consistence, mineral and chemical composition, and arrangement in the profile. The Grieta series is an example of a fine-loamy, mixed, mesic Typic Haplargid.

Soil Series and Their Morphology

In this section, each soil series recognized in the survey area is described. Characteristics of the soil and the material in which it formed are identified for each series. A pedon, a small three-dimensional area of soil, that is typical of the series in the survey area is described. The detailed description of each soil horizon follows standards in the “Soil Survey Manual” (USDA, 1993). Many of the technical terms used in the descriptions are defined in “Soil Taxonomy” (USDA, 1975,). Unless otherwise indicated, colors in the descriptions are for moist soil. Following the pedon description is the range of important characteristics of the soils in the series.

The classifications given in Table 19 are those of the classifications at the time of correlation of this survey (1987).

Aga Series

Map units: 22, 27, 426, 427, 428, 827
Depth class: very deep
Drainage class: moderately well drained
Landform: flood plains
Parent material: stream alluvium derived from mixed sources
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Slope: 0 to 3 percent
Climatic data:
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Taxonomic class: Coarse-loamy over sandy or sandy-skeletal, mixed, calcareous, mesic Typic Torrifluvents

Typical Pedon

Aga loam, in an area of mapping unit 27, Aga loam, 0 to 1 percent slopes; Sandoval County; Santo Domingo Pueblo Quadrangle, unsectionized state plane coordinates N. 1,659,900 feet and E. 471,850 feet. NAD 83, UTM 13—03 78 346 E—39 35 898 N.

A—0 to 10 inches; brown (10YR 5/3) loam, dark brown (10YR 4/3) moist; massive; hard, firm, sticky and plastic; many fine and very fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.

C1—10 to 23 inches; brown (10YR 5/3) loam, dark brown (10YR 4/3) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; common fine and very fine roots; slightly effervescent; moderately alkaline; abrupt smooth boundary.

2C2—23 to 43 inches; light yellowish brown (10YR 6/4) sand, yellowish brown (10YR 5/4) moist; single grain; loose, nonsticky and nonplastic; few fine and very fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.

2C3—43 to 60 inches; very pale brown (10YR 7/4) sand, light yellowish brown (10YR 6/4) moist; single grain; loose, nonsticky and nonplastic; 10 percent gravel; slightly effervescent; moderately alkaline.

Range in Characteristics

A horizon
Texture: loam or silty clay loam

C horizon
Texture: very fine sandy loam

2C horizon
Hue: 10YR or 7.5YR
Value: 5 to 7 when dry, and 4 to 6 when moist
Chroma: 3 or 4
Texture: sand, loamy sand, gravelly sand, or loamy fine sand
Salinity: from less than 2 to 16 mmhos/cm.

Note: The water table ranges from 4 to 6 feet.

Alanos Series

Map units: 283, 290
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes and hillsides
Parent material: slope alluvium and colluvium derived from tuff and rhyolite
Elevation: 7,800 to 9,500 feet (2,377 to 2,896 meters)
Slope: 5 to 40 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Clayey-skeletal, mixed Typic Eutroboralfs

Typical Pedon

Alanos loam, in an area of mapping unit 290, Alanos-Rock outcrop complex, 20 to 40 percent slopes; Los Alamos County; Frijoles Quadrangle. NAD 83, UTM 13—03 78 360 E—39 67 869 N.

A—0 to 4 inches; grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; weak fine granular structure; soft, very friable, slightly sticky and nonplastic; many fine and medium roots; 10 percent gravel; neutral; abrupt smooth boundary.
E—4 to 9 inches; light gray (10YR 7/2) loam, grayish brown (10YR 5/2) moist; weak fine granular structure; slightly hard, very friable, nonsticky and nonplastic; common fine roots; few fine vesicular pores; 10 percent gravel; neutral; abrupt smooth boundary.
BE—9 to 18 inches; pinkish gray (7.5YR 7/2) and reddish brown (5YR 5/4) very gravelly loam, brown (7.5YR 5/2) and reddish brown (5YR 4/4) moist; weak fine subangular blocky structure; hard, very friable, slightly sticky and slightly plastic; common very fine roots; common fine black (5YR 2/1) iron and manganese concretions; 55 percent gravel; medium acid; clear smooth boundary.
Bt1—18 to 26 inches; reddish brown (5YR 5/4) extremely gravelly clay, reddish brown (5YR 4/4) moist; weak fine subangular blocky structure; hard, firm, sticky and plastic; few fine roots; few fine tubular pores; common fine black (5YR 2/1) iron and manganese concretions; common thin clay films in pores and on gravel; 20 percent cobbles and 55 percent gravel; medium acid; clear smooth boundary.
Bt2—26 to 60 inches; brown (7.5YR 5/4) extremely gravelly clay, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; few fine roots; few fine tubular pores; few thin clay films in pores and on gravel; 20 percent cobbles and 55 percent gravel; medium acid.

Range in Characteristics

Particle-size control section: 35 to 55 percent clay
Other features: Some pedons are slightly alkaline in the lower subhorizons.

A horizon
Hue: 7.5YR or 10YR
Value: 5 or 6 dry, 3 to 5 moist
Chroma: 2 or 3
Texture: loam or cobbly loam

E horizon
Hue: 7.5YR or 10YR
Value: 6 or 7 dry, 4 or 5 moist
Chroma: 2 to 4
Texture: loam, gravelly loam, or cobbly loam

Bt horizon
Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 3 to 6 moist
Chroma: 2 to 6
Texture: extremely gravelly clay loam, extremely gravelly clay, or very gravelly clay
Concretions: fine or medium iron and manganese concretions are in the upper part of the Bt horizon.

Note: C horizons are below 38 inches in some pedons.

Atarque Series

Map units: 324, 396
Depth class: very shallow to shallow
Drainage class: well drained
Landform: breaks; dipslopes of cuestas, hills, mesas, and ridges
Parent material: slope alluvium derived from sandstone and shale
Elevation: 5,700 to 6,600 feet (1,737 to 2,012 meters)
Slope: 5 to 45 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Loamy, mixed, mesic Lithic Haplustalfs

Typical Pedon

Atarque sandy loam, in an area of mapping unit 324, Rock outcrop-Atarque-Menefee complex, 5 to 25 percent slopes; Sandoval County; Ponderosa Quadrangle; about 2 miles northeast of the Jemez Pueblo; 200 feet south and 1,400 feet east of the northwest corner of sec. 11, T 16 N, R 2 E. NAD 27; UTM 13—03 45 805 E—39 44 974 N.

A—0 to 3 inches; light brown (7.5YR 6/4) sandy loam, dark brown (7.5YR 4/4) moist; moderate very thin platy structure; soft, very friable, nonsticky and nonplastic; many very fine roots; neutral; clear smooth boundary.
Bt—3 to 9 inches; reddish brown (5YR 5/4) sandy clay loam, reddish brown (5YR 4/4) moist; moderate fine and medium subangular blocky structure; hard, firm, sticky and plastic; common very fine roots; many very fine tubular pores; many thin clay films on faces of peds and lining pores; neutral; clear smooth boundary.

Btk—9 to 14 inches; strong brown (7.5YR 5/6) sandy clay loam, strong brown (7.5YR 4/6) moist; weak moderate subangular blocky structure; hard, firm, sticky and plastic; few very fine roots; many very fine tubular pores; common thin clay films on faces of peds and lining pores; violently effervescent; common fine irregular shaped soft masses of calcium carbonate; slightly alkaline.
R—14 inches; sandstone bedrock.

Range in Characteristics

A horizon
Hue: 10YR to 5YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 2 to 6
Texture: sandy loam or extremely gravelly sandy loam

B horizons
Hue: 10YR to 5YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 to 6
Texture: sandy clay loam or clay loam

Note: Depth to bedrock: 6 to 20 inches

Bamac Series

Map units: 300, 319, 345, 346
Depth class: very deep
Drainage class: excessively drained
Landform: alluvial fans, fan remnants, fan terraces, hills, and ridges
Parent material: slope and fan alluvium derived from mixed sources
Elevation: 5,400 to 6,900 feet (1,646 to 2,103 meters)
Slope: 1 to 55 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Sandy-skeletal, mixed, mesic Typic Ustorthents

Typical Pedon

Bamac very gravelly loamy sand, in an area of mapping unit 319, Bamac-Rock outcrop complex, 15 to 55 percent slopes; Sandoval County; Santo Domingo Pueblo SW Quadrangle; about 2.5 miles southwest of the Cochiti Pueblo; 2,550 feet east and 100 feet south of the northwest corner of sec. 26, T. 16 N., R. 5 E. NAD 83, UTM 13—03 74 829 E—39 39 774 N.

A—0 to 4 inches; light yellowish brown (10YR 6/4) very gravelly loamy sand, dark yellowish brown (10YR 4/4) moist; weak very fine granular structure; soft, very friable, nonsticky and nonplastic; common fine and medium roots; 55 percent gravel; slightly effervescent; moderately alkaline; clear smooth boundary.
AC—4 to 10 inches; light yellowish brown (10YR 6/4) loamy sand, brown (10YR 4/3) moist; weak medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common medium roots; 10 percent gravel; slightly effervescent; moderately alkaline; clear wavy boundary.
C1—10 to 21 inches; very pale brown (10YR 7/3) very gravelly loamy coarse sand, brown (10YR 5/3) moist; massive; soft, very friable, nonsticky and nonplastic; few

fine roots; 45 percent gravel; slightly effervescent; moderately alkaline; gradual wavy boundary

C2—21 to 37 inches; pale brown (10YR 6/3) very gravelly loamy coarse sand, brown (10YR 4/3) moist; massive; soft, very friable, nonsticky and nonplastic; 55 percent gravel; slightly effervescent; moderately alkaline; gradual wavy boundary.

C3—37 to 60 inches; pink (7.5YR 7/4) very gravelly loamy coarse sand, yellowish brown (10YR 5/4) moist; massive; soft, very friable, nonsticky and nonplastic; 50 percent gravel; slightly effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 0 to 5 percent clay

A horizon

Value: 5 or 6 dry, 4 or 5 moist
Chroma: 3 or 4
Texture: Gravelly or very gravelly loamy sand or sandy loam or extremely gravelly coarse sandy loam

C horizon

Hue: 7.5YR or 10YR
Value: 3 to 7 dry, 4 to 6 moist
Chroma: 3 to 6 moist or dry
Texture: very gravelly coarse sand, very gravelly loamy sand, or very gravelly loamy coarse sand. Some pedons have thin strata of loamy sand or coarse sand.

Note: Some pedons have Ck horizons.

Betonnie Series

Map unit: 150
Depth class: very deep
Drainage class: well drained
Landform: dipslopes on cuestas, fan terraces, hills, valley sides, summits of plateaus and mesas
Parent material: eolian material and slope alluvium derived from sandstone
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)
Slope: 5 to 8 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Coarse-loamy, mixed, mesic Ustalfic Haplargids

Typical Pedon

Betonnie fine sandy loam, in an area of mapping unit 150, Doakum-Betonnie fine sandy loams, 0 to 8 percent slopes; Sandoval County; Mule Dam Quadrangle; about 15 miles south of Councelor and 500 feet south and 2,400 feet west of the northeast corner of sec. 29, T. 22 N., R. 6 W. NAD 83, UTM 13—02 75 951 E—39 99 372 N.

A—0 to 2 inches; light yellowish brown (10YR 6/4) fine sandy loam, yellowish brown (10YR 5/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; few very fine roots; few very fine and fine continuous pores; moderately alkaline; clear smooth boundary.

BA—2 to 4 inches; brown (7.5YR 5/4) fine sandy loam, brown (7.5YR 4/4) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and fine roots; common very fine and fine continuous pores; moderately alkaline; clear smooth boundary.

Bt—4 to 12 inches; brown (7.5YR 5/4) fine sandy loam, dark brown (7.5YR 4/4) moist; moderate fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common fine and medium roots; common fine continuous pores; clay bridging sand grains and few thin clay films on faces of peds; moderately alkaline; clear smooth boundary.

BC—12 to 18 inches; brown (7.5YR 5/4) sandy loam, brown (7.5YR 4/4) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; few very fine roots; few very fine continuous pores; moderately alkaline; clear smooth boundary.

C1—18 to 34 inches; yellowish brown (10YR 5/4) sandy loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard, friable, slightly sticky and nonplastic; few very fine roots; strongly effervescent; strongly alkaline; clear gradual boundary.

C2—34 to 60 inches; pale brown (10YR 6/3) sandy loam, brown (10YR 5/3) moist; massive; slightly hard, firm, slightly sticky and nonplastic; strongly effervescent; moderately alkaline.

Range in Characteristics

A horizon

Hue: 7.5YR or 10YR
Value: 5 to 6 dry, 3 or 5 moist
Chroma: 3 or 4
Texture: loamy fine sand, fine sandy loam, or sandy loam

Bt horizon

Hue: 5YR or 7.5YR
Value: 4 to 6 dry and moist
Chroma: 3 to 6
Texture: fine sandy loam or sandy loam

C horizon

Hue: 7.5YR or 10YR
Value: 4 to 7 dry, 4 to 6 moist
Chroma: 3 to 6
Texture: fine sandy loam, loamy sand, and sandy loam

Note: Some pedons have Bk horizons; some contain thin strata of loamy sand.

Blancot Series

Map units: 101, 270
Depth class: very deep
Drainage class: well drained
Landform: valley sides and ridges
Parent material: fan alluvium derived from sandstone and shale
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)
Slope: 2 to 8 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine-loamy, mixed, mesic Ustalfic Haplargids

Typical Pedon

Blancot fine sandy loam, in an area of mapping unit 101, Blancot-Lybrook association, 0 to 8 percent slopes; Sandoval County; Galisteo Quadrangle; about 2,580 feet north and 1,450 feet east of the southwest corner of sec. 15, T. 22 N., R. 7 W. NAD 83, UTM 13—02 69 104 E—40 02 257 N.

A—0 to 2 inches; pale brown (10YR 6/3) fine sandy loam, brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; few very fine and fine roots; few very fine and fine continuous pores; moderately alkaline; clear smooth boundary.

Bt1—2 to 5 inches; grayish brown (10YR 5/2) clay loam, brown (10YR 4/3) moist; moderate fine subangular blocky structure; slightly hard, friable, sticky and plastic; common fine and medium roots; common very fine and fine continuous pores; few thin clay films on faces of peds; moderately alkaline; clear smooth boundary.

Bt2—5 to 14 inches; yellowish brown (10YR 5/4) clay loam, dark yellowish brown (10YR 4/4) moist; moderate fine subangular blocky structure; slightly hard, firm, slightly sticky and slightly plastic; common very fine and fine continuous pores; few thin clay films on faces of peds; moderately alkaline; clear smooth boundary.

Btk—14 to 23 inches; yellowish brown (10YR 5/4) clay loam, yellowish brown (10YR 5/4) moist; weak fine subangular blocky structure; hard, firm, slightly sticky and slightly plastic; few very fine and fine roots; few very fine and fine continuous pores; few thin clay films on faces of peds; strongly effervescent; moderately alkaline; clear smooth boundary.

C1—23 to 40 inches; pale brown (10YR 6/3) sandy loam, brown (10YR 5/3) moist; massive; hard, friable, nonsticky and nonplastic; few very fine and fine roots; slightly effervescent; moderately alkaline; clear gradual boundary.

C2—40 to 49 inches; light brownish gray (10YR 6/2) silty clay loam, grayish brown (10YR 5/2) moist; massive; slightly hard, friable, sticky and plastic; strongly effervescent; moderately alkaline; clear gradual boundary.

C2—49 to 60 inches; pale brown (10YR 6/3) sandy loam, brown (10YR 5/3) moist; massive; slightly hard, friable, nonsticky and nonplastic; strongly effervescent; strongly alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay

A horizon
- *Hue:* 10YR or 2.5Y
- *Value:* 5 to 7 dry, 3 to 5 moist
- *Chroma:* 2 to 4
- *Texture:* fine sandy loam, loam, or silt loam

Bt horizon
- *Hue:* 10YR or 2.5Y
- *Value:* 4 to 6 dry, 3 to 5 moist
- *Chroma:* 2 to 6 dry and moist
- *Texture:* loam, sandy clay loam, or clay loam

Btk, Bk, and C horizons (when present)
- *Hue:* 10YR or 2.5Y
- *Value:* 5 or 6 dry, 3 to 5 moist
- *Chroma:* 2 to 6 dry and moist
- *Texture:* sandy loam, loam, sandy clay loam, clay loam, fine sandy loam, or silty clay loam

Note: Some pedons have accumulations of secondary calcium carbonate.

Bond Series

Map unit: 227
Depth class: very shallow to shallow
Drainage class: well drained
Landform: cuestas, hills, mesas, and ridges
Parent material: eolian material and slope alluvium derived from sandstone
Elevation: 5,700 to 6,000 feet (1,737 to 1,829 meters)
Slope: 1 to 8 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Loamy, mixed, mesic Lithic Ustollic Haplargids

Typical Pedon

Bond loamy fine sand, in an area of mapping unit 227, Hagerman-Bond association, 1 to 8 percent slopes; Sandoval County; Ojito Spring Quadrangle; about 3/4 mile north and 1/2 mile east of the Ojito Spring (along the Ojito Arroyo) on the Zia Pueblo portion of the Ojo Del Espiritu Santo Grant. NAD 83, UTM 13—03 23 191 E—39 39 809 N.

A—0 to 4 inches; light yellowish brown (10YR 6/4) loamy fine sand, yellowish brown (10YR 5/4) moist; weak fine granular structure; slightly hard, very friable, nonsticky and nonplastic; many fine and few medium roots; slightly alkaline; clear smooth boundary.
Bt—4 to 12 inches; brown (7.5YR 5/4) sandy clay loam, dark brown (7.5YR 4/4) moist; weak medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common fine roots; few fine tubular pores; common thin clay films on faces of peds; neutral; abrupt smooth boundary.
R—12 inches; sandstone bedrock.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay
Depth to lithic contact: 6 to 20 inches

A horizon
Hue: 5YR, 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 4
Texture: loamy fine sand, sandy loam, or fine sandy loam

Bt horizon
Hue: 5YR or 7.5YR
Value: 4 or 6 dry, 3 to 6 moist
Chroma: 3 to 6
Texture: sandy clay loam, loam, sandy loam, or clay loam

C horizon (when present)
Hue: 5YR or 7.5YR
Value: 5 to 8 dry, 5 or 6 moist
Chroma: 4 to 6 dry and moist
Texture: sandy clay loam, loam, sandy loam, or clay loam

Note: Some pedons have Btk horizons.

Cajete Series

Map units: 308, 503
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes, hills, and stream terraces
Parent material: residuum derived from pumice
Elevation: 7,000 to 8,500 feet (2,134 to 2,591 meters)
Slope: 0 to 30 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Ashy-skeletal, frigid Mollic Vitrandepts

Typical Pedon

Cajete gravelly loam, in an area of mapping unit 308, Cajete gravelly loam, 0 to 8 percent slopes; Sandoval County; Redondo Peak Quadrangle; about 100 yards south of dirt tank and 10 yards north of ridge crest, Baca location No. 1. NAD 83, UTM 13—03 58 759 E—39 66 454 N.

A1—0 to 7 inches; very dark grayish brown (10YR 3/2) gravelly loam, very dark brown (10YR 2/2) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; many fine and medium roots; 20 percent pumice gravel; neutral; clear smooth boundary.

A2—7 to 15 inches; dark grayish brown (10YR 4/2) gravelly loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky structure; soft, very friable, slightly sticky and slightly plastic; many fine and medium roots; 20 percent pumice gravel; neutral; gradual wavy boundary.

Bw—15 to 33 inches; pale brown (10YR 6/3) very gravelly sandy loam, yellowish brown (10YR 5/4) moist; weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; many fine and medium roots; 40 percent pumice gravel; neutral; abrupt wavy boundary.

C1—33 to 45 inches; matrix: light gray (10YR 7/2) very gravelly sand, pale brown (10YR 6/3) moist; single grain; loose, nonsticky and nonplastic; many fine and medium roots concentrated near lamella; wavy lamella 0.5 to 1 inch thick, strong brown (7.5YR 5/6) extremely gravelly sandy loam, yellowish brown (10YR 5/6) moist, 75 percent pumice gravel; matrix has 50 percent pumice gravel; neutral; abrupt wavy boundary.

C2—45 to 49 inches; very pale brown (10YR 7/3) extremely gravelly sand, light yellowish brown (10YR 6/4) moist; single grain; loose, nonsticky and nonplastic; 60 percent pumice gravel; slightly alkaline; abrupt wavy boundary.

C3—49 to 60 inches; matrix; light gray (10YR 7/2) very gravelly sand, pale brown (10YR 6/3) and light yellowish brown (10YR 6/4) moist; single grain; loose, nonsticky and nonplastic; lamella 0.25-0.5 inch thick with colors similar to those described in the C1; 50 percent fine pumice gravel; slightly alkaline.

Range in Characteristics

Depth to the base of the cambic horizon: 20 to 35 inches

A horizons
Value: 3 to 5 dry, 2 or 3 moist
Chroma: 1 to 3
Texture: extremely gravelly coarse sandy loam or gravelly loam
Content of rock fragments: 15 to 80 percent pumice

Bw horizon
Hue: 7.5YR or 10YR
Value: 6 to 8 dry, 5 or 6 moist
Chroma: 2 to 4
Content of rock fragments: 35 to 60 percent pumice gravel

C horizons
Hue: 7.5YR or 10YR
Value: 6 to 8 dry, 5 to 6 moist
Chroma: 2 to 4
Texture: very gravelly sand or very gravelly sandy loam
Content of rock fragments: 35 to 60 percent pumice

Calaveras Series

Map units: 82, 83, 311
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes
Parent material: colluvium derived from tuff
Elevation: 8,500 to 9,200 feet (2,591 to 2,804 meters)
Slope: 5 to 60 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Loamy-skeletal, mixed, frigid Dystric Eutrochrepts

Typical Pedon

Calaveras silt loam, in an area of mapping unit 311, Cosey-Tranquilar-Calaveras association, 5 to 20 percent slopes; Sandoval County, Valle San Antonio Quadrangle; about .1 mile south of movie set on the main ranch road, Baca Location No. 1; NAD 83, UTM 13—03 63 714 E—39 71 088 N.

A—0 to 4 inches; grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and slightly plastic; many very fine and fine roots; 5 percent gravel; slightly acid; clear smooth boundary.

E—4 to 11 inches; pale brown (10YR 6/3) silt loam, dark yellowish brown (10YR 3/4) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; many fine and medium roots; 10 percent gravel; slightly acid; clear smooth boundary.

Bw—11 to 17 inches; pale brown (10YR 6/3) gravelly silt loam, dark brown (10YR 4/3) moist; weak coarse subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common coarse roots; 5 percent stones and 20 percent gravel; slightly acid; clear wavy boundary.

2Bt1—17 to 30 inches; pale brown (10YR 6/3) very cobbly loam, dark brown (10YR 4/3) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common coarse roots; few thin patchy clay films on rock fragments; 5 percent stones, 20 percent cobbles, and 20 percent gravel; medium acid; gradual wavy boundary.

2Bt2—30 to 39 inches; light brown (7.5YR 6/4) extremely cobbly coarse sandy loam, brown (7.5YR 5/4) moist; weak fine and medium subangular blocky structure; hard, firm, slightly sticky and slightly plastic; few coarse roots; many clay films bridging sand grains and many thick clay films occur on tops of rock fragments; 5 percent stones, 30 percent cobbles, and 30 percent gravel; neutral; gradual wavy boundary.

3Bt3—39 to 60 inches; light brown (7.5YR 6/4) extremely cobbly loamy sand, brown (7.5YR 5/4) moist; weak fine subangular blocky structure; hard, firm, slightly sticky and slightly plastic; few coarse roots; clay bridging sand grains; 10 percent stones, 30 percent cobbles, and 20 percent gravel; neutral.

Range in Characteristics

Particle-size control section: 5 to 20 percent clay
Content of rock fragments: 10 to 85 percent total; 0 to 50 percent stones or cobbles, and 15 to 50 percent gravel

A horizon
Hue: 10YR or 7.5YR
Value: 3 to 7 dry, 2 to 5 moist
Chroma: 1 to 4
Texture: silt loam, loam, or very gravelly sandy loam

E horizon
Hue: 7.5YR or 10YR
Value: 6 or 7 dry, 3 or 4 moist
Chroma: 2 to 4
Texture: silt loam and sandy clay loam

2B horizons
Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 2 to 4
Texture: extremely cobbly coarse sandy loam, very cobbly sandy loam, or very cobbly loam. In some pedons, extremely cobbly loamy coarse sand or extremely cobbly loamy sand occurs below 35 inches.

Note: Some pedons may have an AE horizon of sandy loam texture.

Camino Series

Map unit: 15
Depth class: deep
Drainage class: well drained
Landform: valley sides and plateaus
Parent material: fan alluvium and residuum derived from shale
Elevation: 5,900 to 6,200 feet (1,798 to 1,890 meters)
Slope: 1 to 6 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine, mixed, mesic Ustollic Camborthids

Typical Pedon

Camino silty clay loam, in an area of mapping unit 15, Camino-Sandoval complex, 1 to 8 percent slopes; Sandoval County; Sky Village NW Quadrangle; on Alamo Ranch 800 feet south and 400 feet east of the northwest corner of sec. 14, T. 14 N., R. 1 W. NAD 83, UTM 13—03 25 862 E—39 24 200 N.

A—0 to 2 inches; pale olive (5Y 6/3) silty clay loam, olive (5Y 5/3) moist; weak fine subangular blocky structure; soft, friable, sticky and plastic; few very fine roots; strongly effervescent; slightly alkaline; abrupt smooth boundary.

Bw1—2 to 5 inches; pale olive (5Y 6/3) clay, olive (5Y 5/3) moist; weak medium subangular blocky structure; very hard, very firm, very sticky and very plastic; few fine and very fine roots; strongly effervescent; moderately alkaline; clear smooth boundary.

Bw2—5 to 20 inches; pale olive (5Y 6/3) clay, olive (5Y 5/3) moist; weak medium subangular blocky structure; very hard, very firm, very sticky and very plastic; few fine and very fine roots; strongly effervescent; few fine irregular soft masses of calcium carbonate; moderately alkaline; gradual smooth boundary.

Bk—20 to 51 inches; pale olive (5Y 6/3) clay, olive (5Y 5/3) moist; massive; very hard, very firm, very sticky and very plastic; 5 percent shale fragments; strongly effervescent; common fine irregular soft masses of calcium carbonate; moderately alkaline; clear wavy boundary.

Cr—51 inches; soft olive shale.

Range in Characteristics

Particle-size control section: 40 to 50 percent clay
Salinity: EC of 2 to 4
Depth to bedrock: 40 to more than 60 inches

A horizon
- *Hue:* 2.5Y or 5Y
- *Value:* 5 or 6 dry, 4 or 5 moist
- *Chroma:* 3 or 4

Bw and Bk horizons
- *Hue:* 2.5Y or 5Y
- *Value:* 5 to 7 dry, 4 to 6 moist
- *Chroma:* 3 or 4

Carjo Series

Map unit: 281
Depth class: moderately deep
Drainage class: well drained
Landform: hills, mesas, and summits of ridges
Parent material: residuum derived from tuff
Elevation: 7,000 to 8,000 feet (2,134 to 2,438 meters)
Slope: 1 to 9 percent
Climatic data:
- *Mean annual precipitation:* 20 to 25 inches (508 to 635 millimeters)
- *Mean annual air temperature:* 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
- *Frost-free period:* 60 to 90 days

Taxonomic class: Fine, mixed Mollic Eutroboralfs

Typical Pedon

Carjo loam, in an area of mapping unit 281, Carjo loam, 1 to 9 percent slopes; Los Alamos County; Frijoles Quadrangle; at the east end of 2-mile mesa; 1,100 feet south and 1,500 feet west of the northeast corner of sec. 20, T. 19 N., R. 6 E. NAD 83, UTM 13—03 80 426 E—39 70 016 N.

A—0 to 4 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine roots; many very fine interstitial pores; neutral; clear smooth boundary.

BA—4 to 12 inches; brown (7.5YR 4/4) clay loam, dark brown (7.5YR 3/4) moist; weak fine subangular blocky structure; slightly hard, very friable, sticky and plastic; many fine roots; many very fine interstitial pores; neutral; clear smooth boundary.

Bt—12 to 20 inches; reddish brown (5YR 4/4) clay, dark reddish brown (5YR 3/4) moist; moderate fine angular blocky structure; hard, firm, sticky and plastic; many fine and medium roots; common fine tubular pores; thin discontinuous clay films on faces of peds; neutral; clear smooth boundary.

C—20 to 25 inches; light brown (7.5YR 6/4) very fine sandy loam, brown (7.5YR 4/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; few fine roots; common fine tubular pores; slightly alkaline; abrupt smooth boundary.

2R—25 inches; tuff bedrock.

Range in Characteristics

Depth to bedrock: 20 to 40 inches

A horizon
- *Hue:* 7.5YR or 10YR
- *Value:* 3 to 5 dry, 2 or 3 moist
- *Chroma:* 1 to 5
- *Texture:* fine sandy loam or loam
- *Content of rock fragments:* 0 to 35 percent cobbles or flagstones, 0 to 15 percent gravel or channers

B horizon
- *Hue:* 10YR, 7.5YR or 5YR
- *Value:* 3 to 6 dry, 2 to 5 moist
- *Chroma:* 2 to 6
- *Texture:* clay or clay loam
- *Content of rock fragments:* 0 to 15 percent

C or BC horizon
- *Hue:* 7.5YR or 5YR
- *Value:* 5 or 6 dry, 4 or 5 moist
- *Chroma:* 3 or 4
- *Texture:* sandy loam, very fine sandy loam, or clay loam

Note: B/E or E horizons occur in some pedons.

Cascajo Series

Map units: 47, 54
Depth class: very deep
Drainage class: excessively drained
Landform: hills, knolls, ridges, and structural benches
Parent material: fan alluvium derived from sandstone
Elevation: 5,300 to 6,500 feet (1,615 to 1,981 meters)

Slope: 5 to 30 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Sandy-skeletal, mixed, mesic Ustollic Calciorthids

Typical Pedon

Cascajo very gravelly sandy loam, in an area of mapping unit 47, Cascajo very gravelly sandy loam, 12 to 30 percent slopes; Sandoval County; San Felipe Pueblo Quadrangle; about 7 miles northeast of Ball Ranch Headquarters; 600 feet west and 700 feet south of the northeast corner of sec. 27, T. 14 N., R. 6 E. NAD 27; UTM 13—03 83 258 E—39 20 070 N.

A—0 to 2 inches; pale brown (10YR 6/3) very gravelly sandy loam, brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine and medium roots; 19 percent cobbles and 40 percent gravel; violently effervescent; slightly alkaline; abrupt smooth boundary.
Bw—2 to 5 inches; very pale brown (10YR 7/3) very gravelly sandy loam, pale brown (10YR 6/3) moist; weak fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; many fine and medium roots; 18 percent cobbles and 40 percent gravel; violently effervescent; moderately alkaline; clear smooth boundary.
Bk1—5 to 11 inches; very pale brown (10YR 8/3) very gravelly sandy loam, very pale brown (10YR 7/3) moist; weak fine subangular structure; slightly hard, friable, slightly sticky and slightly plastic; common fine and medium roots; 5 percent cobbles and 40 percent gravel; violently effervescent; many fine filaments and threads of calcium carbonate; moderately alkaline; clear smooth boundary.
Bk2—11 to 23 inches; pale brown (10YR 6/3) very gravelly loamy sand, brown (10YR 5/3) moist; weak medium and coarse subangular blocky structure; soft, very friable, nonsticky and nonplastic; few medium roots; 5 percent cobbles and 50 percent gravel; violently effervescent; common fine filaments and threads of calcium carbonate; moderately alkaline; clear smooth boundary.
C1—23 to 30 inches; light brown (7.5YR 6/4) very gravelly loamy sand, yellowish brown (10YR 5/3) moist; massive; soft, friable, nonsticky and nonplastic; few medium roots; 10 percent cobbles and 45 percent gravel; strongly effervescent; moderately alkaline; clear smooth boundary.
C2—30 to 60 inches; light brown (7.5YR 6/4) extremely cobbly loamy sand, brown (7.5YR 5/4) moist; massive; soft, very friable; nonsticky and nonplastic; few medium roots; 50 percent cobbles and 30 percent gravel; strongly effervescent; moderately alkaline.

Range in Characteristics

A horizon
Hue: 10YR
Value: 6 dry and 4 moist
Chroma: 3 dry and moist

B and C horizons
Hue: 10YR or 7.5YR
Value: 4 to 8 dry and 5 to 7 moist
Texture: very gravelly sand, extremely cobbly loamy sand, or very gravelly loamy sand. Some pedons may have horizons of very gravelly sandy loam above the C horizons.

Charo Series

Map unit: 405
Depth class: moderately deep
Drainage class: well drained
Landform: hills, mesas, and ridges
Parent material: eolian material and residuum derived from basalt
Elevation: 8,100 to 8,300 feet (2,469 to 2,530 meters)
Slope: 1 to 5 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Fine, mixed Typic Argiborolls

Typical Pedon

Charo very cobbly loam, in an area of mapping unit 405, Charo complex, 1 to 5 percent slopes; Sandoval County; Laguna Seca Quadrangle; about one mile west of Laguna Seca; unsectionized; NAD 27; UTM 13—02 91 297 E—39 20 794 N.

A—0 to 5 inches; very dark grayish brown (10YR 3/2) cobbly loam, very dark brown (10YR 2/2) moist; moderate medium granular structure; slightly hard, friable, slightly sticky and slightly plastic; many fine and many medium roots; 2 percent stones, 15 percent cobbles and 15 percent gravel; neutral; clear smooth boundary.
Bt1—5 to 12 inches; reddish brown (5YR 4/3) clay, dark reddish brown (5YR 3/3) moist; weak medium angular blocky structure; hard, firm, sticky and plastic; many fine roots and common very fine roots; few fine tubular pores; few thin dark reddish gray (5YR 4/2) clay films on faces of peds and in pores; neutral; clear smooth boundary.
Bt2—12 to 15 inches; reddish brown (5YR 4/3) clay, dark reddish brown (5YR 3/3) moist; moderate medium and coarse angular blocky structure; hard, firm, sticky and plastic; many very fine roots; common, moderately thick, dark reddish gray (10YR 4/2), clay films on faces of peds; neutral; gradual wavy boundary.
Bt3—15 to 25 inches; reddish brown (5YR 4/4) clay, dark reddish brown (5YR 3/4) moist; weak coarse angular blocky structure; very hard, very firm, very sticky and very plastic; few very fine roots; few fine and few medium pores; few thin clay films on faces of peds, in pores, and on coarse fragments; 5 percent cobbles and 5 percent gravel; slightly alkaline; gradual wavy boundary.
C—25 to 28 inches; reddish brown (5YR 4/4) and dark reddish gray (5YR 4/2) clay, dark reddish brown (5YR 3/4) and (5YR 3/2) moist; massive; very hard, very firm, very sticky and very plastic; few very fine and fine pores; 10 percent cobbles and 10 percent gravel; slightly alkaline; abrupt wavy boundary.
R—28 inches; hard basalt.

Range in Characteristics

Particle-size control section: 35 to 60 percent clay
Depth to bedrock: 20 to 40 inches

A horizon
Hue: 7.5YR or 10YR
Chroma: 2 or 3
Texture: loam, cobbly loam or very cobbly loam

Bt horizon
Value: 4 or 5 dry, 3 or 4 moist
Chroma: 3 to 6
Texture: clay loam or clay

Note: C horizons occur in some pedons.

Clovis Series

Map units: 1, 2, 143 ,211
Depth class: very deep
Drainage class: well drained
Landform: fan terraces, mesas, and plains
Parent material: eolian material and slope alluvium derived from sandstone and shale
Elevation: 5,500 to 7,300 feet (1,676 to 2,225 meters)
Slope: 1 to 8 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine-loamy, mixed, mesic Ustollic Haplargids

Typical Pedon

Clovis fine sandy loam, in an area of mapping unit 143, Clovis fine sandy loam, 1 to 4 percent slopes; Sandoval County; Arroyo de las Calabacillas Quadrangle; about 24 miles northwest of Rio Rancho at the far northwest corner of the west mesa; 1,600 feet west and 2,000 feet north of the southeast corner of sec. 17, T. 13 N., R. 1 E. NAD 83, UTM 13—03 31 377 E—39 13 673 N.

A—0 to 3 inches; pale brown (10YR 6/3) fine sandy loam, brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; common fine and few medium roots; slightly alkaline; abrupt wavy boundary.
Bt1—3 to 7 inches; brown (7.5YR 5/4) sandy clay loam, dark brown (7.5YR 4/4) moist; medium and coarse subangular blocky structure; hard, friable, sticky and plastic; common fine and few medium roots; many thin clay films on sand grains; moderately alkaline; clear smooth boundary.
Bt2—7 to 12 inches; brown (7.5YR 5/4) sandy clay loam, dark brown (7.5YR 4/4) moist; weak coarse subangular blocky structure; hard, friable, sticky and plastic; few fine roots; many thin clay films on sand grains; moderate alkaline; gradual wavy boundary.
Bt3—12 to 22 inches; brown (7.5YR 5/4) sandy clay loam, dark brown (7.5YR 4/4) moist; weak medium subangular blocky structure; hard, friable, sticky and plastic; few fine roots; many thin clay films on sand grains; moderately alkaline; clear wavy boundary.
Bk1—22 to 34 inches; light brown (7.5YR 6/4) sandy clay loam, brown (7.5YR 5/4) moist; weak coarse prismatic structure; very hard, firm, sticky and plastic; violently effervescent; common fine filaments and threads of calcium carbonate; moderately alkaline; diffuse wavy boundary.
Bk2—34 to 60 inches; reddish yellow (7.5YR 6/6) sandy clay loam, brown (7.5YR 5/4) moist; weak coarse prismatic structure; very hard, firm, sticky and plastic; violently effervescent; common medium irregular soft masses of calcium carbonate; moderately alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent
Content of rock fragments: 0 to 15 percent stones, cobbles, or gravel

A horizon
Hue: 5YR, 7.5YR, or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 6 dry, 2 to 4 moist
Texture: fine sandy loam or loam

BA, Bt, Btk horizons
Hue: 2.5YR, 5YR, or 7.5YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 4 or 6
Texture: sandy clay loam or clay loam

Bk horizon
Hue: 7.5YR or 10YR
Value: 6 to 8 dry, 5 to 7 moist
Chroma: 2 to 6
Texture: fine sandy loam or sandy clay loam

Cochiti Series

Map units: 104, 353
Depth class: very deep
Drainage class: well drained
Landform: fan terrace, hills, mesas, plains, and stream terraces
Parent material: gravelly alluvium
Elevation: 5,300 to 7,000 feet (1,615 to 2,134 meters)
Slope: 3 to 40 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Clayey-skeletal, mixed, mesic Aridic Haplustalfs

Typical Pedon

Cochiti gravelly loam, in an area of mapping unit 104, Cochiti-Montecito association, 1 to 30 percent slopes; Sandoval County; Canada Quadrangle; about 10 miles west of Cochiti Pueblo; 1,500 feet east and 300 feet north of the center of sec. 11, T. 16 N., R. 4 E. NAD 83, UTM 13—03 65 807 E—39 44 031 N.

A—0 to 7 inches; dark yellowish brown (10YR 4/4) gravelly loam, dark brown (10YR 3/3) moist; weak fine granular structure; slightly hard, firm, sticky and plastic; many fine and medium roots; 5 percent cobbles and 15 percent gravel; neutral; clear smooth boundary.

Bt1—7 to 12 inches; reddish brown (5YR 4/3) gravelly clay loam, reddish brown (5YR 4/3) moist; strong medium subangular blocky structure; very hard, firm, very sticky and very plastic; common fine and coarse roots; thick continuous clay films on faces of peds; 5 percent cobbles and 25 percent gravel; slightly acid; clear smooth boundary.

Bt2—12 to 20 inches; reddish brown (5YR 4/4) very gravelly clay, reddish brown (5YR 4/4) moist; strong medium and coarse subangular blocky structure; very hard, firm, very sticky and very plastic; few fine and coarse roots; thick continuous clay

films on faces of peds; 5 percent cobbles and 40 percent gravel; neutral; clear smooth boundary.

Bt3—20 to 29 inches; light reddish brown (5YR 6/4) very gravelly clay loam, reddish brown (5YR 5/4) moist; weak medium subangular blocky structure; hard, firm, sticky and plastic; few fine and coarse roots; thin and continuous clay films on faces of peds; 5 percent cobbles and 40 percent gravel; neutral; clear smooth boundary.

C—29 to 60 inches; light reddish brown (5YR 6/4) very gravelly sandy loam, reddish brown (5YR 5/4) moist; massive; loose, nonsticky and nonplastic; few fine and coarse roots; 5 percent cobbles and 50 percent gravel; neutral.

Range in Characteristics

Particle-size control section: 35 to 45 percent clay
Content of rock fragments: 35 to 50 percent by volume with 5 to 10 percent cobbles and 30 to 40 percent gravel

A horizon
Hue: 7.5YR or 10YR
Value: 4 or 5 dry, 3 or 4 moist
Chroma: 3 or 4
Texture: gravelly loam or extremely gravelly loam

B horizon
Hue: 7.5YR or 5YR
Value: 4 to 6 dry, 4 or 5 moist
Chroma: 3 or 4
Texture: very gravelly clay or very gravelly clay loam

2C horizon
Hue: 7.5YR or 5YR
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 3 to 6
Texture: very gravelly loamy sand or very gravelly sandy loam

Cosey Series

Map units: 304, 311
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes
Parent material: slope alluvium and colluvium derived from rhyolite
Elevation: 8,600 to 9,200 feet (2,621 to 2,804 meters)
Slope: 2 to 20 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Loamy-skeletal, mixed Typic Paleborolls

Typical Pedon

Cosey silt loam, in an area of mapping unit 304, Cosey-Jarmillo association, 2 to 20 percent slopes; Sandoval County; Valle Toledo Quadrangle; about 13 miles northeast of La Cueva, 300 feet south of the pipeline, and 2 miles southeast of road junction at west end of Toledo Valley, Baca Location No. 1; unsectionized; NAD 83, UTM 13—03 67 849 E—39 78 865 N.

A1—0 to 9 inches; dark grayish brown (10YR 4/2) silt loam, black (10YR 2/1) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; many fine and very fine roots; slightly acid; clear smooth boundary.
A2—9 to 15 inches; grayish brown (10YR 5/2) silt loam, very dark brown (10YR 2/2) moist; moderate coarse granular structure; soft, very friable, slightly sticky and slightly plastic; common fine and very fine roots; slightly acid; clear smooth boundary.
BA—15 to 28 inches; very pale brown (10YR 7/3) gravelly loam, brown (10YR 4/3) moist; weak medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; 10 percent cobbles and 20 percent gravel; slightly acid; gradual smooth boundary.
Bt1—28 to 34 inches; very pale brown (10YR 7/3) very gravelly sandy clay loam, brown (10YR 4/3) moist; weak medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; common moderately thick clay films on faces of peds; 10 percent cobbles and 50 percent gravel; slightly acid; gradual smooth boundary.
Bt2—34 to 60 inches; light brown (7.5YR 6/4) crushed, extremely cobbly clay loam, dark brown (7.5YR 4/4) moist; strata of very pale brown (10YR 7/3) silty clay loam and brownish yellow (10YR 6/6) sandy loam; weak medium subangular blocky structure; hard, firm, sticky and plastic; continuous thick clay films on faces of peds; 40 percent cobbles and 30 percent gravel; slightly acid.

Range in Characteristics

Particle-size control section: 27 to 35 percent clay
Depth to argillic horizon: 22 to 35 inches

A horizon
Value: 3, 4 or 5 dry, 2 or 3 moist
Chroma: 1 to 3
Texture: loam, silt loam

BA horizon
Value: 6 to 8 dry, 4 to 6 moist
Chroma: 2 or 3
Texture: gravelly sandy loam, gravelly fine sandy loam, and gravelly loam

Bt horizon
Hue: 7.5YR or 10YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 3 or 4
Texture: very gravelly sandy clay loam or extremely cobbly clay loam

Councelor Series

Map units: 180, 270
Depth class: very deep
Drainage class: well drained
Landform: stream terraces, fan terraces, valley floors, and valley sides
Parent material: eolian material and stream alluvium derived from sandstone and shale
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)
Slope: 1 to 30 percent

Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Coarse-loamy, mixed, calcareous, mesic Ustic Torriorthents

Typical Pedon

Councelor fine sandy loam, in an area of mapping unit 180, Councelor-Eslendo-Mespun complex, 5 to 30 percent slopes; Sandoval County; Galisteo SE Quadrangle; about 15 miles southwest of Councelor; 1,500 feet north and 1,500 feet east of the southwest corner of sec. 6, T. 21 N., R. 6 W. NAD 83, UTM 13—02 73 616 E—39 95 265 N.

A—0 to 2 inches; pale brown (10YR 6/3) fine sandy loam, brown (10YR 5/3) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; few very fine and fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.
C1—2 to 7 inches; pale brown (10YR 6/3) fine sandy loam, dark brown (10YR 5/3) moist; massive; soft, very friable, slightly sticky and slightly plastic; few very fine and fine roots; strongly effervescent; moderately alkaline; clear smooth boundary.
C2—7 to 37 inches; pale brown (10YR 6/3) fine sandy loam, yellowish brown (10YR 5/3) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few very fine and fine roots; slightly effervescent; moderately alkaline; gradual smooth boundary.
C3—37 to 40 inches; pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; massive; hard, firm, sticky and plastic; few fine and very fine roots; strongly effervescent; very few fine irregular soft masses of calcium carbonate; moderately alkaline; clear smooth boundary.
C4—40 to 60 inches; pale brown (10YR 6/3) sandy loam, brown (10YR 5/3) moist; massive; soft, friable, slightly sticky and slightly plastic; strongly effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 8 to 18 percent clay

A horizon
Hue: 7.5YR or 10YR
Value: 5 or 6 dry, 3 to 5 moist
Chroma: 2 to 4

C horizon
Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 2 to 4 dry, 2 to 6 moist
Texture: fine sandy loam, sandy loam, or clay loam

Note: The C horizon contains thin strata of loamy sand, loamy fine sand, and sandy clay loam in some pedons.

Cucho Series

Map units: 397, 398, 399
Depth class: moderately deep
Drainage class: well drained
Landform: cuestas and fan terraces

Parent material: colluvium derived from shale
Elevation: 5,900 to 7,200 feet (1,798 to 2,195 meters)
Slope: 15 to 70 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine-silty, mixed, calcareous, mesic Typic Ustorthents

Typical Pedon

Cucho very gravelly clay loam in an area of mapping unit 397, Rock outcrop-Cucho-Vessilla complex, 25 to 70 percent slopes; Sandoval County; Holy Ghost Spring Quadrangle; 1.5 miles east of state highway 44 and 0.5 miles south of the Jemez-Zia Indian Reservations boundary. unsectionized; NAD 83, UTM 13—03 27 007 E—39 52 487 N.

A—0 to 2 inches; pale yellow (2.5Y 7/4) and very pale brown (10YR 7/4) very gravelly clay loam, light olive brown (2.5Y 5/4) and yellowish brown (10YR 5/4) moist; moderate fine granular structure; slightly hard, friable, sticky and slightly plastic; common fine and few medium roots; 45 percent gravel; slightly effervescent; slightly alkaline; abrupt smooth boundary.
C1—2 to 9 inches; light gray (5Y 7/2) clay loam, light olive gray (5Y 6/2) moist; massive; hard, firm, sticky and plastic; few medium roots; slightly effervescent; neutral; gradual wavy boundary.
C2—9 to 37 inches; pale olive (5Y 6/3) clay loam, olive (5Y 5/3) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few medium roots in upper part; 50 percent soft weathered shale fragments at upper boundary grading to 90 percent at lower boundary; matrix slightly effervescent; few medium strongly effervescent irregular soft masses of calcium carbonate; slightly alkaline; gradual wavy boundary.
Cr—37 to 60 inches; fractured shale.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay, less than 15 percent fine sand or coarser
Calcium carbonate equivalent: 1 to 10 percent
Depth to a Cr horizon: 20 to 40 inches

A horizon
Hue: 2.5Y or 10YR
Value: 6 or 7 dry

C horizon
Hue: 5Y or 2.5Y
Value: 6 or 7 dry, 5 or 6 moist
Chroma: 2 to 4
Texture: clay loam or silty clay loam

Cypher Series

Map units: 503, 600, 604
Depth class: shallow
Drainage class: well drained
Landform: mountain slopes and ridges
Parent material: colluvium and residuum derived from rhyolite and tuff

Elevation: 6,500 to 9,000 feet (1,981 to 2,743 meters)
Slope: 15 to 60 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Loamy-skeletal, mixed, frigid Lithic Ustochrepts

Typical Pedon

Cypher very gravelly loam, in an area of mapping unit 604, Cypher-Mirand complex, 15 to 55 percent slopes; Sandoval County; Bear Springs Peak Quadrangle; about 3/4 mile north of the Bear Springs Guard Station in the Canada de Cochiti; unsectionized; NAD 83, UTM 13—03 59 321 E—39 49 884 N.

Oi—0 to 1 inch; slightly decomposed forest litter.
A—1 inch to 5 inches; brown (10YR 5/3) very gravelly loam, very dark grayish brown (10YR 3/2) moist; weak platy structure parting to weak very fine granular; soft, very friable, slightly sticky and nonplastic; many very fine roots; few very fine tubular pores; 10 percent cobbles and 45 percent gravel; slightly acid; clear smooth boundary.
Bw—5 to 12 inches; pale brown (10YR 6/3) very gravelly loam, brown (10YR 4/3) moist; weak medium angular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; many very fine, few fine, and few coarse roots; common very fine tubular pores; 10 percent cobbles and 40 percent gravel; medium acid; clear smooth boundary.
C—12 to 20 inches; light brown (7.5YR 6/4) extremely gravelly sandy loam, brown (7.5YR 4/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; few very fine, few fine, and few coarse roots; common thin clay films on coarse fragments; 10 percent cobbles and 75 percent gravel; slightly acid; abrupt wavy boundary.
2R—20 inches; rhyolite bedrock.

Range in Characteristics

Particle-size control section: 10 to 25 percent clay
Calcium carbonate equivalent: 0 to 5 percent
Depth to bedrock from mineral surface: 10 to 20 inches

A horizon
Hue: 7.5YR or 10YR
Value: 2 to 5 dry, 2 to 4 moist
Chroma: 2 to 4
Texture: very gravelly loam or very cobbly loam

Bw horizon
Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 4 to 6 moist
Chroma: 2 to 4
Texture: very gravelly sandy loam or very gravelly loam

C horizon
Hue: 5YR, 7.5YR or 10YR
Value: 6 or 7 dry, 4 or 5 moist
Chroma: 2 to 4
Texture: extremely gravelly sandy loam or very gravelly loam

Deama Series

Map units: 58, 358
Depth class: very shallow and shallow
Drainage class: well drained
Landform: hills, plateaus, and mesas
Parent material: colluvium derived from limestone
Elevation: 5,800 to 7,000 feet (1,768 to 2,134 meters)
Slope: 10 to 55 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Loamy-skeletal, carbonatic, mesic Lithic Calciustolls

Typical Pedon

Deama very stony silt loam, in an area of mapping unit 58, Deama-El Pedro association, 5 to 30 percent slopes; Sandoval County; Sandia Crest Quadrangle; about .75 mile northwest of La Madera; 1,300 feet west and 1,800 feet south of the northeast corner of sec. 35, T. 12 N., R. 5 E. NAD 83, UTM 13—03 74 645 E—38 98 880 N.

A—0 to 7 inches; dark brown (7.5YR 3/2) very stony silt loam, very dark brown (7.5YR 2/2) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; many medium and coarse roots; 20 percent stones, 10 percent cobbles, and 10 percent gravel; strongly effervescent; slightly alkaline; clear smooth boundary.
Bk—7 to 14 inches; pinkish gray (7.5YR 7/2) very cobbly silt loam, dark brown (7.5YR 3/2) moist; weak fine subangular blocky structure; slightly hard, very friable, sticky and plastic; many coarse roots; 7 percent stones, 15 percent cobbles, and 20 percent gravel; violently effervescent; many thin filaments of calcium carbonate; moderately alkaline; abrupt smooth boundary.
2R—14 inches; limestone.

Range in Characteristics

Particle-size control section: 18 to 27 percent clay
Calcium carbonate equivalent: 40 to 60 percent in the particle-size control section
Depth to bedrock: 7 to 20 inches

A horizon
Hue: 5YR to 10YR
Value: 3 to 6 dry, 2 to 4 moist
Chroma: 2 or 3, dry or moist
Texture: very gravelly loam or very stony silt loam

Bk horizon
Hue: 5YR to 10YR
Value: 4 to 8 dry, 3 to 7 moist
Chroma: 2 to 4, dry or moist
Texture: very gravelly loam or very cobbly silt loam

Doakum Series

Map unit: 150
Depth class: very deep
Drainage class: well drained
Landform: bajadas, dipslopes on cuestas, plateaus, drainageways, and hills
Parent material: eolian material and slope alluvium derived from sandstone and shale
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)
Slope: 0 to 5 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine-loamy, mixed, mesic Ustalfic Haplargids

Typical Pedon

Doakum fine sandy loam, in an area of mapping unit 150, Doakum-Betonnie fine sandy loams, 0 to 8 percent slopes; Sandoval County; Mule Dam Quadrangle; about 8 miles southwest of Councelor, 800 feet south and 1,400 feet west of the northeast corner of sec. 29, T. 22 N., R. 6 W. NAD 83, UTM 13—02 76 101 E—39 99 272 N.

A—0 to 5 inches; light yellowish brown (10YR 6/4) fine sandy loam, yellowish brown (10YR 5/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; few very fine roots; few very fine continuous pores; moderately alkaline; clear smooth boundary.

Bt1—5 to 11 inches; brown (7.5YR 5/4) clay loam, dark brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; common fine and medium roots; common very fine and fine continuous pores; few thin clay films on faces of peds; moderately alkaline; clear smooth boundary.

Bt2—11 to 17 inches; brown (7.5YR 5/4) sandy clay loam, dark brown (7.5YR 4/4) moist; moderate fine subangular blocky structure; very hard, firm, slightly sticky and slight plastic; common fine and medium roots; common very fine and fine continuous pores; few thin clay films on faces of peds; moderately alkaline; clear smooth boundary.

Bk1—17 to 24 inches; brown (7.5YR 5/4) sandy clay loam, dark brown (7.5YR 4/4) moist; weak fine subangular blocky structure; hard, firm, slightly sticky and plastic; common very fine roots; few very fine and fine continuous pores; strongly effervescent; few medium irregular soft masses of calcium carbonate; strongly alkaline; clear smooth boundary.

Bk2—24 to 31 inches; very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; massive; hard, firm, sticky and plastic; few very fine roots; violently effervescent; few medium irregular soft masses of calcium carbonate; strongly alkaline; clear smooth boundary.

Bk3—31 to 44 inches; very pale brown (10YR 7/3) loam, pale brown (10YR 6/3) moist; massive; very hard, firm, slightly sticky and slightly plastic; few very fine roots; violently effervescent; few medium soft masses and seams of calcium carbonate; strongly alkaline; clear gradual boundary.

C—44 to 60 inches; very pale brown (10YR 7/4) loam, light yellowish brown (10YR 6/4) moist; massive; soft, very friable, slightly sticky and slightly plastic; violently effervescent; strongly alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay
Salinity: EC of 2 to 8

A horizon
Hue: 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 4

Bt or Btk horizons
Hue: 5YR or 7.5YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 6 dry and moist
Texture: loam, sandy clay loam, or clay loam

Bk horizon
Hue: 5YR, 7.5YR or 10YR
Value: 4 to 8 dry, 4 to 7 moist
Chroma: 2 to 6
Texture: loam, fine sandy loam, sandy clay loam, or clay loam
Calcium carbonate equivalent: less than 15 percent

C horizon
Hue: 10YR or 7.5YR
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 3 or 4
Texture: loam, very fine sandy loam, fine sandy loam, or loamy fine sand

El Rancho Series

Map units: 95, 97
Depth class: very deep
Drainage class: well drained
Landform: stream terraces
Parent material: stream alluvium derived from mixed sources
Elevation: 5,300 to 5,500 feet (1,615 to 1,676 meters)
Slope: 0 to 2 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine-loamy, mixed, calcareous, mesic Ustic Torriorthents

Typical Pedon

El Rancho loam, in an area of mapping unit 95, El Rancho loam, 0 to 2 percent slopes; Sandoval County; San Ysidro Quadrangle; the north edge of San Ysidro; unsectionized; NAD 83, UTM 13—03 39 479 E—39 36 553 N.

Ap—0 to 5 inches; reddish brown (5YR 5/3) loam, dark reddish brown (5YR 3/4) moist; weak fine granular structure; hard, friable, slightly sticky and slightly plastic; common fine and medium roots; violently effervescent; moderately alkaline; abrupt smooth boundary.
C1—5 to 20 inches; reddish brown (5YR 5/4) sandy clay loam, reddish brown (5YR 4/4) moist; weak fine subangular blocky structure; hard, firm, sticky and plastic; common fine and very fine roots; violently effervescent; moderately alkaline; clear smooth boundary.
C2—20 to 38 inches; reddish brown (5YR 5/4) sandy clay loam, reddish brown (5YR 4/4) moist; massive; hard, firm, sticky and plastic; few fine and very fine roots; violently effervescent; moderately alkaline; clear smooth boundary.

2C3—38 to 60 inches; light brown (7.5YR 6/4) sandy loam, brown (7.5YR 4/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; violently effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 10 to 27 percent clay and greater than 50 percent sand

A horizon
Hue: 5YR or 7.5YR
Value: 5 or 6 dry, 3 or 4 moist
Chroma: 3 or 4
Texture: loam or clay loam

C horizon
Hue: 5YR or 7.5YR
Value: 5 to 7 dry, 3 to 5 moist
Chroma: 3 to 6
Texture: sandy loam or sandy clay loam

Elpedro Series

Map units: 58, 317, 358
Depth class: very deep
Drainage class: well drained
Landform: benches, fan piedmonts, hills, mesas, and valley sides
Parent material: eolian material and colluvium derived from limestone
Elevation: 5,700 to 7,000 feet (1,737 to 2,134 meters)
Slope: 1 to 40 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine-silty, mixed, mesic Aridic Haplustalfs

Typical Pedon

Elpedro loam, in an area of mapping unit 58, Deama-Elpedro association, 5 to 30 percent slopes; Sandoval County; Sandia Park Quadrangle; about 2 miles northeast of La Madera; unsectionized; NAD 83, UTM 13—03 76 147 E—39 00 367 N.

A—0 to 5 inches; brown (7.5YR 4/4) loam, dark brown (7.5YR 3/3) moist; weak fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; many fine and medium roots; slightly alkaline; abrupt smooth boundary.
Bt1—5 to 12 inches; dark brown (7.5YR 3/4) silty clay loam, dark brown (7.5YR 3/4) moist; weak medium subangular blocky structure; hard, friable, sticky and plastic; many fine and coarse roots; few thin discontinuous clay films on faces of peds; slightly alkaline; clear smooth boundary.
Bt2—12 to 19 inches; brown (7.5YR 5/4) silty clay loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, friable, sticky and plastic; few very fine and coarse roots; thin discontinuous clay films on faces of peds; slightly effervescent; moderately alkaline; clear smooth boundary.
Bt3—19 to 25 inches; brown (7.5YR 5/4) silty clay loam, brown (7.5YR 4/4) moist; moderate fine and medium prismatic structure parting to moderate fine subangular blocky; hard, friable, sticky and plastic; few very fine roots; thick continuous clay films on faces of peds; slightly effervescent; few seams and filaments of calcium carbonate; moderately alkaline; clear smooth boundary.

Btk1—25 to 36 inches; brown (7.5YR 5/4) silty clay loam, brown (7.5R 4/4) moist; strong fine prismatic structure parting to strong fine and medium subangular blocky; hard, friable, sticky and plastic; few very fine roots; thick continuous clay films on faces of peds; strongly effervescent; thin filaments of calcium carbonates on peds; slightly alkaline; clear smooth boundary.
Btk2—36 to 45 inches; brown (7.5YR 5/4) silt loam, brown (7.5YR 4/4) moist; weak medium prismatic structure; hard, friable, sticky and plastic; few very fine roots; thin continuous clay films on faces of peds; strongly effervescent; seams and filaments of calcium carbonate on faces of peds; slightly alkaline; clear smooth boundary.
Btk3—45 to 60 inches; brown (7.5YR 5/4) loam, brown (7.5YR 4/4) moist; weak coarse prismatic structure; hard, friable, sticky and plastic; few very fine roots; thin discontinuous clay films on faces of peds; strongly effervescent; few calcium carbonate accumulations; slightly alkaline.

Range in Characteristics

Particle-size control section: 27 to 35 percent clay
Calcium carbonate equivalent: 0 to 15 percent
Reaction: slightly to moderately alkaline

A horizon
Hue: 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 4
Texture: loam or very gravelly loam

Bt and Btk horizons
Hue: 10YR to 5YR
Value: 3 to 6 dry, 4 to 5 moist
Chroma: 3 to 5
Texture: silty clay loam, loam, and silt loam

Bk horizon (when present)
Hue: 7.5YR or 10YR
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 3 or 4
Texture: loam, silt loam, or silty clay loam

Embudo Series

Map units: 108, 109
Depth class: very deep
Drainage class: well drained
Landform: fan remnants and fan terraces
Parent material: fan alluvium derived from granite
Elevation: 5,000 to 5,600 feet (1,524 to 1,707 meters)
Slope: 1 to 15 percent
Climatic data:
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Taxonomic class: Coarse-loamy, mixed, mesic Typic Camborthids

Typical Pedon

Embudo gravelly sandy loam, in an area of mapping unit 109, Embudo-Tijeras association, 1 to 9 percent slopes; Sandoval County; Alameda Quadrangle; about 1.5 miles east of Interstate Highway 25 and about 1 mile north of the Bernalillo-Sandoval County line; 950 feet east and 2,050 feet south of the northwest corner of sec. 32, T. 12 N., R. 4 E. NAD 83, UTM 13—03 59 192 E—38 99 070 N.

A—0 to 4 inches; brown (10YR 5/3) gravelly sandy loam, dark brown (10YR 4/3) moist; weak fine granular structure; slightly hard, friable, nonsticky and nonplastic; many very fine roots; 20 percent gravel; slightly alkaline; clear wavy boundary.

Bw—4 to 12 inches; pale brown (10YR 6/3) gravelly fine sandy loam; dark yellowish brown (10YR 4/3) moist; weak fine granular structure; slightly hard, friable, nonsticky and nonplastic; common fine roots; 15 percent gravel; slightly alkaline; gradual wavy boundary.

Bk1—12 to 30 inches; pale brown (10YR 6/4) gravelly coarse sandy loam, yellowish brown (10YR 5/4) moist; massive; hard, friable, nonsticky and nonplastic; few fine roots; 20 percent gravel; slightly effervescent with few medium rounded soft masses of calcium carbonate; moderately alkaline; gradual wavy boundary.

2Bk2—30 to 60 inches; pale brown (10YR 6/4) gravelly loamy coarse sand, yellowish brown (10YR 5/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; 30 percent gravel; slightly effervescent; few fine rounded soft masses of calcium carbonate; moderately alkaline.

Range in Characteristics

Particle-size control section: 5 to 15 percent clay

A and Bw horizons
- *Value:* 4 to 6 dry, 3 to 5 moist
- *Chroma:* 2 to 4

Bk horizon
- *Value:* 4 to 6 dry, 3 to 5 moist
- *Chroma:* 2 to 6
- *Texture:* gravelly coarse sandy loam and sandy loam

2Bk horizon
- *Value:* 4 to 6 dry, 3 to 5 moist
- *Chroma:* 2 to 6
- *Content of rock fragments:* 10 to 70 percent gravel
- *Texture:* gravelly loamy coarse sand or loamy sand
- *Depth to sandy layer:* 18 to 30 inches

Eslendo Series

Map unit: 180
Depth class: very shallow to shallow
Drainage class: well drained
Landform: ridges
Parent material: residuum derived from shale
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)
Slope: 5 to 30 percent
Climatic data:
- *Mean annual precipitation:* 10 to 13 inches (254 to 330 millimeters)
- *Mean annual air temperature:* 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
- *Frost-free period:* 110 to 130 days

Taxonomic class: Loamy, mixed, calcareous, mesic, shallow Ustic Torriorthents

Typical Pedon

Eslendo clay loam, in an area of mapping unit 180, Councelor-Eslendo-Mespun complex, 5 to 30 percent slopes; Galisteo SE Quadrangle; about 16 miles south of Galisteo; 1,760 feet south and 2,400 feet west of the northeast corner of sec. 29, T. 21 N., R. 7 W. NAD 83, UTM 13—02 65 871 E—39 89 619 N.

A—0 to 3 inches; light brownish gray (2.5Y 6/2) clay loam, grayish brown (2.5Y 5/2) moist; weak fine granular structure; hard, firm, sticky and plastic; few very fine and fine roots; slightly effervescent; moderately alkaline; abrupt smooth boundary.
C—3 to 10 inches; light yellowish brown (2.5Y 6/4) clay loam, light olive brown (2.5Y 5/4) moist; massive; hard, firm, sticky and plastic; few fine roots; few fine pores; slightly effervescent; disseminated calcium carbonate; moderately alkaline; abrupt smooth boundary.
Cr—10 inches; soft shale.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay
Soil depth: 4 to 20 inches to soft shale

Espiritu Series

Map units: 325, 345, 346, 353, 398
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes and mesas
Parent material: slope alluvium and colluvium derived from mixed sources
Elevation: 5,300 to 6,900 feet (1,615 to 2,103 meters)
Slope: 8 to 65 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Loamy-skeletal, mixed, mesic Aridic Haplustalfs

Typical Pedon

Espiritu very gravelly fine sandy loam, in an area of mapping unit 345, Espiritu-Bamac association, 15 to 55 percent slopes; Sandoval County; Loma Creston Quadrangle; 11 miles northeast of the Zia Pueblo; unsectionized; NAD 83, UTM 13—03 60 501 E—39 35 768 N.

A—0 to 6 inches; brown (10YR 5/3) very gravelly fine sandy loam, dark brown (10YR 4/3) moist; weak very fine granular structure; soft, very friable, nonsticky and slightly plastic; many fine and common medium roots; 10 percent cobbles and 30 percent gravel; slightly alkaline; clear smooth boundary.
Bt1—6 to 15 inches; brown (7.5YR 5/4) very gravelly sandy clay loam, dark brown (7.5YR 3/4) moist; moderate fine and medium subangular blocky structure; hard, firm, sticky and plastic; common fine roots; few fine tubular pores; common thin clay films on faces of peds; 10 percent cobbles and 30 percent gravel; slightly alkaline; clear wavy boundary.
Bt2—15 to 22 inches; light brown (7.5YR 6/4) very gravelly sandy clay loam, brown (7.5YR 4/4) moist; moderate fine subangular blocky structure; hard, friable, slightly sticky and slightly plastic; few fine roots; few fine tubular pores; few thin

clay films of faces of peds; 10 percent cobbles and 35 percent gravel; slightly alkaline; gradual wavy boundary.

Bk1—22 to 29 inches; pale brown (10YR 6/3) very cobbly sandy clay loam, brown (10YR 4/3) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine tubular pores; 25 percent cobbles and 25 percent gravel; strongly effervescent; few medium irregular soft masses of calcium carbonate; slightly alkaline; gradual wavy boundary.

Bk2—29 to 38 inches; pale brown (10YR 6/3) very cobbly sandy clay loam, brown (10YR 4/3) moist; massive; slightly hard, friable, slightly sticky, and slightly plastic; 25 percent cobbles and 25 percent gravel; strongly effervescent; few medium irregular soft masses of calcium carbonate; slightly alkaline; clear wavy boundary.

2C1—38 to 46 inches; strong brown (7.5YR 5/6) fine sandy loam, brown (7.5YR 4/4) moist; massive; hard, friable, slightly sticky and slightly plastic; strongly effervescent; slightly alkaline; gradual wavy boundary.

3C2—46 to 60 inches; reddish yellow (7.5YR 6/6) very gravelly sandy loam, strong brown (7.5YR 4/6) moist; massive; hard, friable, nonsticky and nonplastic; 3 percent cobbles and 35 percent gravel; strongly effervescent; slightly alkaline.

Range in Characteristics

Particle-size control section: 15 to 35 percent clay

A horizon
- *Hue:* 7.5YR or 10YR
- *Value:* 4 or 5 dry, 3 or 4 moist
- *Chroma:* 2 to 4
- *Texture:* extremely cobbly sandy loam, very gravelly loam, and very gravelly fine sandy loam

Bt horizon
- *Hue:* 5YR, 7.5YR or 10YR
- *Value:* 4 to 6 dry, 3 to 5 moist
- *Chroma:* 3 to 6

Bk horizon
- *Hue:* 5YR, 7.5YR or 10YR
- *Value:* 5 or 6 dry, 4 or 5 moist
- *Chroma:* 3 to 6
- *Texture:* extremely gravelly loamy sand, extremely gravelly sandy loam, very gravelly loam, and very cobbly sandy clay loam

C horizons (when present)
- *Hue:* 5YR, 7.5YR or 10YR
- *Value:* 5 or 6 dry, 4 or 5 moist
- *Chroma:* 3 to 6
- *Texture:* very gravelly sandy loam, extremely gravelly sandy loam, fine sandy loam, or very gravelly loam

Note: In some pedons, the lower C horizons are sand, very gravelly loamy sand, or extremely gravelly loamy sand.

Ess Series

Map unit: 215
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes

Parent material: colluvium derived from rhyolite
Elevation: 9,000 to 11,000 feet (2,743 to 3,353 meters)
Slope: 5 to 45 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Loamy-skeletal, mixed Argic Cryoborolls

Typical Pedon

Ess very cobbly sandy loam, in an area of mapping unit 215, Ess-Rock outcrop complex, 5 to 45 percent slopes; Sandoval County; Valle Toledo Quadrangle; about 100 yards west of ski lift near Baca Location No. 1; unsectionized; NAD 83, UTM 13—03 73 642 E—39 71 846 N.

A1—0 to 7 inches; very dark gray (10YR 3/1) very cobbly sandy loam, very dark brown (10YR 2/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine and medium roots; 5 percent stones, 35 percent cobbles and 10 percent gravel; neutral; clear smooth boundary.
A2—7 to 15 inches; very dark gray (10YR 3/1) very cobbly sandy loam, very dark brown (10YR 2/2) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common fine roots; 5 percent stones, 30 percent cobbles and 10 percent gravel; neutral; clear smooth boundary.
Bt—15 to 29 inches; strong brown (7.5YR 5/6) very cobbly sandy clay loam, dark brown (7.5YR 3/4) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and slightly plastic; few very fine roots; few thin discontinuous clay films on rock fragments; 10 percent stones, 30 percent cobbles and 10 percent gravel; neutral; gradual wavy boundary.
C—29 to 60 inches; very pale brown (10YR 7/3) very cobbly loam, brown (10YR 4/3) moist; massive; soft, very friable, nonsticky and nonplastic; few very fine roots; 5 percent stones, 20 percent cobbles, and 30 percent gravel; neutral.

Range in Characteristics

Particle-size control section: 20 to 30 percent clay

A horizon
Hue: 7.5YR, 10YR
Value: 3 to 5 dry, and 2 or 3 moist
Chroma: 1 to 3

B horizon
Hue: 5YR, 7.5YR, 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 to 6

Flugle Series

Map unit: 307
Depth class: very deep
Drainage class: well drained
Landform: cuestas, fan terraces, hills, ridges, and valley sides
Parent material: eolian material and fan alluvium derived from sandstone and shale
Elevation: 5,600 to 6,100 feet (1,707 to 1,859 meters)
Slope: 1 to 5 percent

Climatic data:

Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine-loamy, mixed, mesic Aridic Haplustalfs

Typical Pedon

Flugle loam, in an area of mapping unit 307, Flugle-Waumac complex, 1 to 8 percent slopes; Sandoval County; Jemez Pueblo Quadrangle; about 3 miles northeast of Zia Pueblo; 630 feet west and 750 feet south of the northeast corner of sec. 13, T. 15 N., R. 2 E. NAD 83, UTM 13—03 48 170 E—39 33 463 N.

A—0 to 3 inches; yellowish brown (10YR 5/4) loam, dark brown (10YR 4/3) moist; weak thin platy structure; soft, very friable, nonsticky and nonplastic; many very fine roots; neutral; abrupt smooth boundary.

Bt—3 to 7 inches; brown (7.5YR 5/4) sandy clay loam, dark brown (7.5YR 4/4) moist; moderate fine and medium subangular blocky structure; slightly hard, friable, sticky and plastic; many very fine roots; many very fine tubular pores; common moderately thick clay films on faces of peds; neutral; clear smooth boundary.

Btk1—7 to 12 inches; light brown (7.5YR 6/4) sandy clay loam, brown (7.5YR 5/4) moist; moderate fine and medium subangular blocky structure; slightly hard, friable, sticky and plastic; common very fine roots; many very fine tubular pores; many moderately thick clay films on faces of peds; strongly effervescent; common fine irregular filaments of calcium carbonate; slightly alkaline; clear smooth boundary.

Btk2—12 to 19 inches; light brown (7.5YR 6/4) sandy clay loam, brown (7.5YR 5/4) moist; weak medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few very fine roots; many very fine tubular pores; few thin clay films on faces of peds; strongly effervescent; few fine calcium carbonate accumulations; slightly alkaline; clear smooth boundary.

Bk—19 to 60 inches; pink (7.5YR 7/4) fine sandy loam, light brown (7.5YR 6/4) moist; massive; slightly hard, very friable, nonsticky and nonplastic; few fine roots; common very fine pores; strongly effervescent; few coarse calcium carbonate accumulations; slightly alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay and greater than 35 percent sand

A horizon

Hue: 5YR, 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 4

B horizon

Hue: 5YR, 7.5YR or 10YR
Value: 3 to 6 dry, 3 to 5 moist
Chroma: 2 to 6

C or Bk horizon

Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 4 to 6 moist
Chroma: 3 to 6

Fragua Series

Map units: 314, 322
Depth class: deep and very deep
Drainage class: well drained
Landform: fan remnants and dipslopes
Parent material: eolian material and fan alluvium derived from sandstone
Elevation: 5,600 to 7,400 feet (1,707 to 2,256 meters)
Slope: 1 to 70 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Coarse-loamy, mixed, mesic Aridic Haplustalfs

Typical Pedon

Fragua loamy sand, in an area of mapping unit 314, Fragua-Waumac-Royosa complex, 1 to 8 percent slopes; Sandoval County; Jemez Pueblo Quadrangle; 4 miles northeast of Zia Pueblo; 1,310 feet west and 760 feet north of the southeast corner of sec. 7, T. 15 N., R. 3 E. NAD 83, UTM 13—03 49 686 E—39 33 977 N.

A—0 to 3 inches; brown (10YR 5/3) loamy sand, dark brown (10YR 4/3) moist; moderate fine granular structure; soft, very friable, nonsticky and nonplastic; common fine roots; slightly alkaline; clear smooth boundary.
Bt1—3 to 8 inches; brown (7.5YR 5/4) sandy loam, dark brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common fine and few very fine roots; common thin clay films on faces of peds; slightly alkaline; gradual wavy boundary.
Bt2—8 to 24 inches; brown (7.5YR 5/6) sandy loam, strong brown (7.5YR 4/6) moist; moderate medium subangular blocky structure; hard, friable, nonsticky and nonplastic; few fine roots; few thin clay films on faces of peds; slightly alkaline; clear wavy boundary.
C—24 to 60 inches; brown (7.5YR 5/4) sandy loam, brown (7.5YR 4/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; few fine roots; slightly alkaline.

Range in Characteristics

Particle-size control section: 10 to 18 percent clay
Depth to bedrock: 40 to more than 60 inches

A horizon
Hue: 7.5YR or 10YR
Value: 5 or 6 dry, 3 or 5 moist
Chroma: 3 or 4 dry, 2 to 4 moist
Texture: loamy sand or very cobbly fine sandy loam

Bt horizon
Hue: 5YR to 10YR
Value: 4 or 6 dry, 3 to 5 moist
Chroma: 4 to 6
Texture: sandy loam, fine sandy loam, or very fine sandy loam

Bk or C horizon
Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 3 to 6 moist
Chroma: 4 to 8 dry, 4 or 6 moist
Texture: loamy fine sand, fine sandy loam, or sandy loam

Frijoles Series

Map unit: 185
Depth class: very deep
Drainage class: well drained
Landform: summits of mesas
Parent material: eolian material and alluvium derived from pumice
Elevation: 6,000 to 7,000 feet (1,829 to 2,134 meters)
Slope: 1 to 8 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Loamy-skeletal over fragmental, mixed, mesic Aridic Haplustalfs

Typical Pedon

Frijoles very fine sandy loam, in an area of mapping unit 185, Frijoles very fine sandy loam, 1 to 8 percent slopes; Los Alamos County; Frijoles Quadrangle; unsectionized; NAD 83, UTM 13—03 83 492 E—39 62 785 N.

A—0 to 3 inches; brown (10YR 5/3) very fine sandy loam, dark brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine roots; many fine vesicular pores; neutral; abrupt smooth boundary.
Bt1—3 to 8 inches; brown (7.5YR 4/4) very gravelly clay loam, dark brown (7.5YR 3/4) moist; moderate fine subangular blocky structure; hard, firm, sticky and plastic; many fine roots; many fine vesicular pores; thin discontinuous clay films on faces of peds; 35 percent fine pumice gravel; neutral; clear smooth boundary.
Bt2—8 to 13 inches; brown (7.5YR 5/4) very gravelly clay loam, dark brown (7.5YR 4/4) moist; moderate fine subangular blocky structure; hard, friable, sticky and plastic; many fine roots; many fine vesicular pores; thin discontinuous clay films on faces of peds; 45 percent fine pumice gravel; neutral clear smooth boundary.
2C1—13 to 20 inches; pinkish gray (7.5YR 7/2) extremely gravelly sandy loam, pinkish gray (7.5YR 6/2) moist; weak fine subangular blocky structure; slightly hard, friable, nonsticky and nonplastic; few fine roots; 70 percent pumice gravel; neutral; clear wavy boundary.
3C2—20 to 60 inches; pinkish white (7.5YR 8/2) pumice gravel, pinkish gray (7.5YR 7/2) moist; few fine roots; strong brown (7.5YR 5/6) lamella; few fine thin discontinuous clay films within the lamella.

Range in Characteristics

Particle-size control section: 27 to 35 percent clay
Depth to contrasting particle-size: 15 to 30 inches

A horizon
Value: 4 or 5 dry, 3 or 4 moist
Chroma: 2 or 3

Bt horizon
Value: 4 to 6 dry, 3 or 4 moist
Chroma: 4 or 6

Galisteo Series

Map units: 92, 130, 226
Depth class: very deep
Drainage class: well drained
Landform: stream terraces and alluvial fans
Parent material: stream alluvium derived from mixed sources
Elevation: 5,500 to 7,000 feet (1,676 to 2,134 meters)
Slope: 0 to 3 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 50 to 54 degrees F. (10.0 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine, mixed, calcareous, mesic Ustic Torriorthents

Typical Pedon

Galisteo silty clay loam, in an area of mapping unit 92, Galisteo silty clay loam, moderately saline, sodic, 0 to 1 percent slopes; Sandoval County; San Ysidro Quadrangle; on the west edge of San Ysidro between old and new highway; unsectionized; NAD 83, UTM 13—03 38 222 E—39 35 960 N.

Ap—O to 12 inches; reddish brown (2.5YR 4/4) silty clay loam, dark reddish brown (2.5YR 3/4) moist; massive; hard, firm, very sticky and very plastic; common fine and medium roots; strongly effervescent; strongly alkaline; clear smooth boundary.
C—12 to 60 inches; reddish brown (2.5YR 4/4) clay, dark reddish brown (2.5YR 3/4) moist; massive; very hard, extremely firm, very sticky and very plastic; few fine and very fine roots; strongly effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 35 to 59 percent clay
Salinity: EC of 8 to 16
Sodicity: SAR of 5 to 30

A horizon
Hue: 2.5YR to 7.5YR
Value: 4 to 6 dry and 3 to 5 moist
Chroma: 2 to 4 dry and moist
Texture: loam, clay loam, and silty clay loam

C horizon
Hue: 2.5YR to 7.5YR
Value: 4 to 6 dry and 3 to 5 moist
Chroma: 2 to 4 dry and moist
Texture: silty clay loam and clay

Gilco Series

Map units: 20, 25, 421, 423, 823
Depth class: very deep
Drainage class: moderately well drained
Landform: flood plains
Parent material: stream alluvium derived from mixed sources
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Slope: 0 to 4 percent
Climatic data:
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Taxonomic class: Coarse-loamy, mixed, calcareous, mesic Typic Torrifluvents

Typical Pedon

Gilco loam, in an area of mapping unit 25, Gilco loam, 0 to 1 percent slope; Sandoval County; Santo Domingo Pueblo Quadrangle; in Pena Blanca area; unsectionized; NAD 83, UTM 13—03 78 027 E—39 35 759 N.

Ap—0 to 4 inches; brown (10YR 5/3) loam, dark brown (10YR 4/3) moist; weak fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; many fine and very fine roots; strongly effervescent; moderately alkaline; clear smooth boundary.
C1—4 to 34 inches; light yellowish brown (10YR 6/4) stratified silt loam, loam, and fine sandy loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; common fine and very fine roots; strongly effervescent; moderately alkaline; clear smooth boundary.
C2—34 to 60 inches; light yellowish brown (10YR 6/4) stratified loam and fine sandy loam, dark yellowish brown (1OYR 4/4) moist; massive; hard, firm, slightly sticky and slightly plastic; few fine roots; strongly effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 10 to 18 percent clay
Salinity: EC of 0 to 16
Sodium: SAR less than 13

A Horizon
Hue: 10YR or 7.5YR
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 2 to 4
Texture: loam or clay loam

C Horizon
Hue: 10YR or 7.5YR
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 2 to 4
Texture: very fine sandy loam, fine sandy loam, silt loam, or loam

Note: The Gilco soil in mapping unit 421 Gilco loam, moderately saline, sodic, 0 to 1 percent slopes, has higher sodium absorption ratios than is typical for the Gilco Series and is considered a taxadjunct to the series.

Grieta Series

Map units: 142, 145
Depth class: very deep
Drainage class: well drained
Landform: fan remnants, mesas, plateaus, and ridges
Parent material: eolian material and fan alluvium derived from mixed sources
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Slope: 1 to 5 percent
Climatic data:
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Taxonomic class: Fine-loamy, mixed, mesic Typic Haplargids

Typical Pedon

Grieta loamy fine sand, in an area of mapping unit 145, Grieta-Sheppard loamy fine sands, 2 to 9 percent slopes; Sandoval County; Arroyo de las Calabacillas Quadrangle; about 6 miles northwest of Rio Rancho and 450 feet north and 720 feet east of the southwest corner of sec. 20, T. 13 N., R. 2 E. NAD 83, UTM 13—03 40 104 E—39 11 426 N.

A—0 to 7 inches; brown (10YR 5/3) loamy fine sand, dark brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; few fine and few very fine roots; slightly alkaline; clear smooth boundary.

Bt1—7 to 14 inches; yellowish brown (7.5YR 5/4) sandy clay loam, dark yellowish brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, friable, sticky and plastic; common fine and common very fine roots; common thin clay films on faces of peds; moderately alkaline; clear smooth boundary.

Bt2—14 to 21 inches; pale brown (10YR 6/3) sandy clay loam, brown (10YR 4/3) moist; weak medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common fine very fine roots; 5 percent gravel; slightly effervescent; moderately alkaline; clear smooth boundary.

Bk1—21 to 38 inches; light yellowish brown (10YR 6/4) coarse sandy loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard, friable, slightly sticky and nonplastic; 10 percent gravel; strongly effervescent; few fine irregularly shaped masses and thin coatings of calcium carbonate on undersides of coarse fragments; moderately alkaline; clear smooth boundary.

Bk2—38 to 50 inches; white (10YR 8/2) coarse sandy loam, yellowish brown (10YR 5/4) moist; massive; hard, friable, slightly sticky and nonplastic; 2 percent gravel; violently effervescent; calcium carbonate as coatings on sand grains and as common fine irregularly shaped masses; moderately alkaline; gradual smooth boundary.

Bk3—50 to 60 inches; very pale brown (10YR 7/4) coarse sandy loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; 3 percent gravel; strongly effervescent; calcium carbonate as few fine irregularly shaped masses; moderately alkaline.

Range in Characteristics

Particle-size control section: 18 t0 35 percent clay and greater than 35 percent sand
Depth to calcic horizon: 20 to 40 inches

A horizon
Hue: 5YR, 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 to 6
Texture: loamy fine sand or fine sandy loam

Bt horizon
Hue: 5YR, 7.5YR or 10YR
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 3 to 6
Texture: fine sandy loam or sandy clay loam

Bk horizon
Hue: 7.5YR or 10YR
Value: 5 to 8 dry, 4 to 6 moist
Chroma: 2 to 6
Texture: coarse sandy loam, sandy clay loam or loamy sand

Guaje Series

Map unit: 504
Depth class: very deep
Drainage class: well drained
Landform: basalt-capped mesas, hills, and volcanic cones
Parent material: basalt, volcanic ash, and pumice
Elevation: 6,000 to 7,000 feet (1,829 to 2,134 meters)
Slope: 1 to 8 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Medial-skeletal, mesic Aridic Ustochrepts

Typical Pedon

Guaje gravelly sandy loam, in an area of mapping unit 504, Orejas-Guaje complex, 1 to 15 percent slopes; Sandoval County; Cochiti Dam Quadrangle; about 2 miles east of the Witt Peak recreation area boat dock; unsectionized; NAD 83, UTM 13—03 85 099 E—39 44 994 N.

A—0 to 4 inches; brown (10YR 5/3) gravelly sandy loam, dark brown (10YR 4/3) moist; weak medium granular structure; soft, very friable, slightly sticky and nonplastic; many fine and very fine medium roots; common fine interstitial pores; 20 percent fine pumice gravel; slightly effervescent; slightly alkaline; clear smooth boundary.

Bw—4 to 12 inches; yellowish brown (10YR 5/4) gravelly sandy loam, dark yellowish brown (10YR 5/4) moist; moderate fine and medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common fine and common very fine roots; few fine interstitial pores; 10 percent cobbles and 20 percent gravel; slightly effervescent; slightly alkaline; clear wavy boundary.

Bk1—12 to 17 inches; very pale brown (10YR 7/4) very gravelly sandy loam, light yellowish brown (10YR 6/4) moist; weak fine and medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; common fine roots; 5 percent cobbles and 55 percent gravel; slightly effervescent; calcium carbonate as common fine soft masses and as coatings on coarse fragments; moderately alkaline; clear wavy boundary.

Bk2—17 to 45 inches; white (N 8/0) and very pale brown (10YR 8/3) extremely gravelly sandy loam, light gray (10YR 7/2) and very pale brown (10YR 7/3) moist; massive; hard, firm, nonsticky and nonplastic; weakly cemented; few fine roots; few fine tubular pores; strongly effervescent; calcium carbonate and siliceous material dominant throughout entire horizon causing 90 percent weak cementation, interrupted only by fractures less than 3 mm wide and less than 4 inches apart; 5 percent cobbles and 60 percent gravel; moderately alkaline; diffuse irregularly boundary.

Bk3—45 to 60 inches; very pale brown (10YR 7/3) very gravelly sandy loam, pale brown (10YR 6/3) moist; massive; soft, very friable, nonsticky and nonplastic; few fine roots; 5 percent cobbles and 50 percent gravel; strongly effervescent; calcium carbonate disseminated throughout and engulfing coarse fragments; moderately alkaline.

Range in Characteristics

Particle-size control section: 5 to 15 percent clay
Depth to the weakly cemented horizon: 12 to 26 inches

A horizon
Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 3 to 5 moist
Chroma: 2 to 4

B horizons
Hue: 7.5YR or 10YR
Value: 5 to 8 dry, 4 to 7 moist
Chroma: 0 to 4
Texture: gravelly, very gravelly, and extremely gravelly sandy loams

Hackroy Series

Map units: 21, 162
Depth class: very shallow to shallow
Drainage class: well drained
Landform: summits of mesas and plateaus
Parent material: residuum from tuff
Elevation: 6,000 to 7,200 feet (1,829 to 2,195 meters)
Slope: 1 to 8 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Clayey, mixed, mesic Lithic Haplustalfs

Typical Pedon

Hackroy sandy loam, in an area of mapping unit 162, Hackroy-Nyjack association, 1 to 5 percent slopes; Los Alamos County; White Rock Quadrangle; on the east end of Ancho Canyon Trail; unsectionized; NAD 83, UTM 13—03 87 647 E—39 61 208 N.

A—0 to 3 inches; brown (10YR 5/3) sandy loam, brown (10YR 4/3) moist; weak fine subangular blocky structure; hard, friable, nonsticky and nonplastic; many fine roots; common fine tubular pores; slightly alkaline; abrupt smooth boundary.

Bt—3 to 13 inches; reddish brown (5YR 4/4) clay, dark reddish brown (5YR 3/4) moist; moderate fine prismatic structure; hard, firm, sticky and plastic; many fine roots; few very fine tubular pores; 3 percent gravel; continuous clay films on faces of peds; slightly alkaline; abrupt smooth boundary.
2R—13 inches; tuff.

Range in Characteristics

Particle-size control section: 35 to 50 percent clay
Depth to lithic contact: 8 to 20 inches

A horizon
Hue: 7.5YR or 10YR
Value: 4 or 6 dry, 2 to 4 moist
Chroma: 2 to 4

Bt1 horizon
Hue: 7.5YR or 5YR
Value: 3 to 6 dry, 3 or 4 moist
Chroma: 4 or 6, dry or moist

Hagerman Series

Map units: 227, 240
Depth class: moderately deep
Drainage class: well drained
Landform: hills, mesas and ridges
Parent material: eolian material and alluvium derived from sandstone
Elevation: 5,700 to 6,400 feet (1,737 to 1,951 meters)
Slope: 1 to 5 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine-loamy, mixed, mesic Ustollic Haplargids

Typical Pedon

Hagerman fine sandy loam, in an area of mapping unit 240, Penistaja-Hagerman association, 1 to 5 percent slopes; Sandoval County; Cabezon Peak Quadrangle; about 1.5 miles southeast of the Rio Puerco along the Gas Company of New Mexico pipeline; unsectionized; NAD 83, UTM 13—03 13 428 E—39 43 499 N.

A—0 to 2 inches; brown (7.5YR 5/4) fine sandy loam, dark brown (7.5YR 4/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; common medium and many fine roots; moderately alkaline; clear smooth boundary.
Bt—2 to 9 inches; brown (7.5YR 4/4) clay loam, dark brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, firm, sticky and plastic; common medium and many fine roots; thin continuous clay films on faces of peds; moderately alkaline; clear smooth boundary.
Btk—9 to 24 inches; light brown (7.5YR 6/4) clay loam, brown (7.5YR 5/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; few medium and many fine roots; few thin clay films on faces of peds; strongly effervescent; few fine accumulations of calcium carbonate; moderately alkaline; clear smooth boundary.
2R—24 inches; sandstone.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay
Depth to bedrock: 20 to 40 inches

A horizon
Hue: 5YR to 10YR
Value: 4 to 6 dry, 3 or 4 moist
Chroma: 2 to 6

Bt horizon
Hue: 7.5YR to 2.5YR
Value: 4 to 7 dry or moist
Chroma: 3 to 6

Btk horizon (when present)
Hue: 7.5YR to 2.5YR
Value: 6 to 8 dry, 5 to 8 moist
Chroma: 3 or 4

Harvey Series

Map units: 53, 54, 59, 65
Depth class: very deep
Drainage class: well drained
Landform: ridges, bajadas, mesas, and plateaus
Parent material: eolian material and fan alluvium derived from mixed sources
Elevation: 5,000 to 6,800 feet (1,524 to 2,073 meters)
Slope: 1 to 15 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine-loamy, mixed, mesic Ustollic Calciorthids

Typical Pedon

Harvey loam, in an area of mapping unit 59, Harvey-Ildefonso-La Fonda association, 3 to 15 percent slopes; Sandoval County; Sandia Park Quadrangle; about 1.8 miles west and 50 feet south along pipeline from Highway 14; unsectionized; NAD 83, UTM 13—03 83 907 E—39 00 604 N.

A—0 to 4 inches; pinkish gray (7.5YR 6/2) loam, brown (7.5YR 5/2) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; many fine and very fine roots; violently effervescent; moderately alkaline; abrupt smooth boundary.

Bw—4 to 10 inches; pinkish gray (7.5YR 6/2) loam, brown (7.5YR 5/2) moist, weak fine subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common fine roots; violently effervescent; moderately alkaline; clear smooth boundary.

Bk1—10 to 18 inches; pinkish gray (7.5YR 7/2) clay loam, pink (7.5YR 7/4) moist; weak fine subangular blocky structure; hard, firm, sticky and plastic; few fine roots; violently effervescent; many filaments and threads of calcium carbonate; moderately alkaline; clear smooth boundary.

Bk2—18 to 41 inches; pink (7.5YR 7/4) clay loam, pink (7.5YR 7/4) moist; weak medium angular blocky structure; hard, firm, sticky and plastic; few fine roots; violently effervescent; common filaments and threads of calcium carbonate; moderately alkaline; gradual smooth boundary.
C—41 to 60 inches; reddish yellow (7.5YR 6/6) sandy clay loam, brown (7.5YR 5/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; violently effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay

A horizon
Hue: 2.5YR to 10YR
Value: 5 to 7 dry, 3 to 6 moist
Chroma: 2 to 6
Texture: fine sandy loam or loam

Bw horizon (when present)
Hue: 5YR, 7.5YR, or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 4
Texture: fine sandy loam, loam, or clay loam

Bk horizon
Hue: 2.5YR to 10YR
Value: 5 to 8 dry, 4 to 7 moist
Chroma: 0 to 6
Texture: sandy loam, loam, sandy clay loam, or clay loam

Hickman Series

Map unit: 23
Depth class: very deep
Drainage class: well drained
Landform: flood plains and valley floors
Parent material: stream alluvium derived from mixed sources
Elevation: 6,500 to 7,500 feet (1,981 to 2,286 meters)
Slope: 1 to 3 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine-loamy, mixed, calcareous, mesic Typic Ustifluvents

Typical Pedon

Hickman clay loam, 1 to 3 percent slopes, map unit 23; Sandoval County; Cuba Quadrangle; about 1/2 mile east of La Jara; about 2,100 feet west and 300 feet south of the northeast corner of sec. 33, T. 22 N., R. 1 W. NAD 83, UTM 13—03 24 826 E—39 96 568 N.

A—0 to 4 inches; brown (10YR 5/3) clay loam, dark grayish brown (10YR 4/3) moist; weak medium subangular blocky structure; hard, firm, sticky and plastic; many very fine and fine roots; slightly effervescent; moderately alkaline; abrupt smooth boundary.

C1—4 to 12 inches; pale brown (10YR 6/3) sandy clay loam, brown (10YR 4/3) moist; massive; hard, firm, sticky and plastic; many very fine and few fine roots; strongly effervescent; slightly alkaline; clear smooth boundary.
C2—12 to 49 inches; pale brown (10YR 6/3) clay loam, brown (10YR 4/3) moist; massive; hard, firm, sticky and plastic; few fine and few very fine roots; strongly effervescent; slightly alkaline; clear smooth boundary.
C3—49 to 60 inches; brown (10YR 5/3) sandy clay loam, brown (10YR 4/3) moist; massive; hard, firm, slightly sticky and slightly plastic; few fine and few very fine roots; strongly effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay

A horizon
Hue: 2.5Y, 10YR or 7.5YR
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 3 or 4

C horizon
Hue: 2.5Y, 10YR or 7.5YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 to 6

Ildefonso Series

Map units: 34, 56, 59, 64, 65, 210, 218
Depth class: very deep
Drainage class: well drained
Landform: hills, mesas, and fan terraces
Parent material: fan alluvium and colluvium derived from mixed sources
Elevation: 5,000 to 6,800 feet (1,524 to 2,073 meters)
Slope: 1 to 70 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Loamy-skeletal, mixed, mesic Ustollic Calciorthids

Typical Pedon

Ildefonso cobbly loam, in an area of mapping unit 59, Harvey-Ildefonso-La Fonda association, 3 to 15 percent slopes; Sandoval County; Sandia Park Quadrangle; about 1 mile west along pipeline from Highway 14 and the 0.5 mile north in the San Pedro Land Grant; unsectionized, NAD 83, UTM 13—03 85 342 E—38 99 611 N.

A—0 to 2 inches; brown (7.5YR 5/2) cobbly loam, dark brown (7.5YR 4/2) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; many fine and very fine roots; 10 percent cobbles and 5 percent gravel; slightly effervescent; moderately alkaline; abrupt smooth boundary.
Bw1—2 to 8 inches; brown (7.5YR 5/2) very gravelly loam, dark brown (7.5YR 4/2) moist; weak fine subangular blocky structure; soft, very friable, sticky and plastic; many fine and very fine roots; 10 percent cobbles and 40 percent gravel; violently effervescent; moderately alkaline; clear smooth boundary.

Bw2—8 to 13 inches; pale brown (10YR 6/3) very gravelly loam, dark yellowish brown (10YR 4/4) moist; weak fine subangular blocky structure; soft, friable, sticky and plastic; common very fine and medium roots; 15 percent cobbles and 40 percent gravel; violently effervescent; moderately alkaline; clear wavy boundary.
Bk1—13 to 32 inches; very pale brown (10YR 7/3) very cobbly sandy loam, light brown (7.5YR 6/4) moist; massive; hard, firm, sticky and plastic; few medium roots; 35 percent cobbles and 20 percent gravel; violently effervescent; many filaments and seams of calcium carbonate, and thick coatings of calcium carbonate on coarse fragments; moderately alkaline; clear wavy boundary.
Bk2—32 to 40 inches; very pale brown (10YR 7/3) very cobbly sandy loam, pink (7.5YR 7/4) moist; massive; hard, firm, sticky and plastic; few coarse roots; 35 percent cobbles and 20 percent gravel; violently effervescent; common filaments and seams of calcium carbonate, and thick coatings of calcium carbonate on coarse fragments; moderately alkaline; clear wavy boundary.
C—40 to 60 inches; very pale brown (10YR 7/3) extremely cobbly sand, light brown (7.5YR 6/4) moist; single grain; loose, nonsticky and nonplastic; 60 percent cobbles and 20 percent gravel; strongly effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 8 to 25 percent clay

A and Bw horizons
Hue: 5YR, 7.5YR, 10YR
Value: 4 to 6 dry, 3 or 4 moist
Chroma: 2 to 6
Texture: very stony loam, very cobbly loam, cobbly loam, gravelly sandy loam, and very gravelly sandy loam

Bk horizon
Hue: 5YR, 7.5YR, 10YR
Value: 5 to 8 dry, 4 to 7 moist
Chroma: 1 to 4
Texture: very cobbly loam, very cobbly sandy loam, very gravelly sandy loam, very stony loam, and extremely cobbly sand
Note: This horizon is weakly cemented in some pedons.

Jarmillo Series

Map units: 302, 304
Depth class: very deep
Drainage class: well drained
Landform: stream terraces
Parent material: alluvium, colluvium, and lacustrine sediments derived from rhyolite and tuff
Elevation: 8,500 to 8,800 feet (2,591 to 2,682 meters)
Slope: 1 to 20 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Coarse-loamy, mixed Pachic Haploborolls

Typical Pedon

Jarmillo loam, in an area of mapping unit 302, Tranquilar-Jarmillo complex, 1 to 8 percent slopes; Sandoval County; Valle San Antonio Quadrangle; about 6 miles northeast of La Cueva on the south side of the east-west fence in San Antonio Valley, and 450 feet west of the point where the fence intersects the road between San Antonio Valley and Sulphur Springs, Baca Location No. 1; unsectionized; NAD 83, UTM 13—03 55 699 E—39 81 078 N.

A1—0 to 4 inches; dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; weak fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; many fine, common very fine, and few medium roots; slightly acid; clear smooth boundary.

A2—4 to 13 inches; dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; weak medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common fine and few medium roots; slightly acid; clear smooth boundary.

AB—13 to 20 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common fine roots; slightly acid; clear wavy boundary.

Bw1—20 to 26 inches; light brownish gray (10YR 6/2) loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine roots; neutral; gradual wavy boundary.

Bw2—26 to 36 inches; matrix of very pale brown (10YR 7/3) loam, brown (10YR 4/3) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; lamellae (12) are 1/32 to 5/32 inch thick, brown (10YR 5/3) dry and dark brown (10YR 4/3) moist; few fine and medium roots; neutral; gradual wavy boundary.

Bw3—36 to 41 inches; matrix of light yellowish brown (10YR 6/4) fine sandy loam, yellowish brown (10YR 5/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; lamellae (5) are 1/16 to 1/4 inch thick, grayish brown (10YR 5/2) dry and dark grayish brown (10YR 4/2) moist; few very fine and medium roots; neutral; abrupt wavy boundary.

2Bw4—41 to 51 inches; white (2.5Y 8/2) clay loam, light yellowish brown (2.5Y 6/4) moist; moderate coarse prismatic structure; hard, firm, slightly sticky and plastic; organic stains on prism faces; neutral; abrupt wavy boundary.

3C—51 to 60 inches; white (2.5Y 8/2) very fine sandy loam, light yellowish brown (2.5Y 6/4) moist; massive; hard, firm, slightly sticky and slightly plastic; lamellae (1) 1/8 inch thick, grayish brown (10YR 5/2) dry and very dark grayish brown (10YR 3/2) moist; neutral; clear wavy boundary.

Range in Characteristics

Particle-size control section: 8 to 18 percent clay

A horizon
- *Hue:* 2.5Y or 10YR
- *Value:* 4 or 5 dry, 2 or 3 moist
- *Chroma:* 2 or 3
- *Texture:* silt loam or loam

B horizon
- *Hue:* 2.5Y or 10YR
- *Value:* 6 to 8 dry, 3 to 6 moist
- *Chroma:* 2 to 4
- *Texture:* fine sandy loam, loam, and clay loam

C horizon
Hue: 2.5Y or 10YR
Value: 6 to 8 dry, 5 to 7 moist
Chroma: 2 to 4
Texture: loam, very fine sandy loam, and sandy loam

Jarola Series

Map unit: 301
Depth class: very deep
Drainage class: poorly drained
Landform: stream terraces and valley floors
Parent material: stream alluvium derived from rhyolite, tuff, and pumice
Elevation: 8,400 to 8,600 feet (2,560 to 2,621 meters)
Slope: 1 to 5 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Fine-loamy, mixed, frigid Typic Argialbolls

Typical Pedon

Jarola silt loam, in an area of mapping unit 301, Vastine-Jarola silt loams, 0 to 5 percent slopes; Sandoval County; Bland Quadrangle; about 100 feet east of main road to headquarters and about 250 feet south of the Jemez River, Baca Location No. 1; unsectionized; NAD 83, UTM 13—03 65 529 E—39 67 968 N.

A—0 to 9 inches; grayish brown (10YR 5/2) silt loam, very dark brown (10YR 2/2) moist; weak medium subangular blocky structure; slightly hard, friable, sticky and plastic; many fine and very fine roots; slightly acid; abrupt smooth boundary.
E—9 to 11 inches; light gray (10YR 6/1) silt loam, very dark gray (10YR 3/1) moist; weak thin platy structure; slightly hard, friable, slightly sticky and slightly plastic; common fine and very fine roots; neutral; abrupt smooth boundary.
Bt1—11 to 17 inches; dark gray (10YR 4/1) silty clay loam, very dark gray (10YR 3/1) moist; moderate medium prismatic structure parting to moderate medium subangular blocky; very hard, very firm, very sticky and very plastic; many fine roots; many thick clay and organic coatings on faces of peds; neutral; clear smooth boundary.
Bt2—17 to 21 inches; gray (10YR 5/1) clay loam, dark gray (10YR 4/1) moist; moderate medium subangular blocky structure; very hard, very firm, sticky and plastic; few fine roots; common moderately thick organic and clay coatings on faces of peds; neutral; clear smooth boundary.
2C1—21 to 42 inches; grayish brown (10YR 5/2) gravelly sandy clay loam, dark grayish brown (10YR 4/2) moist; massive; hard, firm, sticky and plastic; few fine roots; 15 percent gravel; neutral; gradual smooth boundary.
2C2—42 to 60 inches; grayish brown (2.5Y 5/2) very gravelly sandy loam, dark grayish brown (2.5Y 4/2) moist; single grain; loose, nonsticky and nonplastic; 40 percent gravel; neutral.

Range in Characteristics

Particle-size control section: 25 to 40 percent clay

A horizon
Value: 4 or 5 dry, 2 or 3 moist
Chroma: 1 or 2

E horizon
Value: 5 to 7 dry, 3 to 5 moist
Chroma: 1 or 2

B horizon
Hue: 10YR or 2.5Y
Chroma: 1 to 3
Texture: silty clay loam or clay loam

C horizon
Hue: 10YR or 2.5Y
Value: 5 to 7 dry, 4 to 6 moist
Chroma: 1 to 4

Jemez Series

Map units: 88, 163
Depth class: moderately deep
Drainage class: well drained
Landform: hills and interfluves of plateaus
Parent material: slope alluvium derived from tuff
Elevation: 7,000 to 8,800 feet (2,134 to 2,682 meters)
Slope: 1 to 15 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Fine-loamy, mixed Mollic Eutroboralfs

Typical Pedon

Jemez loam, in an area of mapping unit 88, Totavi-Jemez-Rock outcrop association, 0 to 15 percent slopes; Sandoval County; Redondo Peak Quadrangle; about 2 miles east of Redondo Campground, Baca Location No. 1; unsectionized; NAD 83, UTM 13—03 54 807 E—39 67 297 N.

A1—0 to 6 inches; dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; many fine roots; slightly alkaline; clear smooth boundary.
A2—6 to 13 inches; pale brown (10YR 6/3) loam, brown (10YR 4/3) moist; weak medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; common medium roots; slightly alkaline; clear smooth boundary.
E—13 to 19 inches; light yellowish brown (10YR 6/4) clay loam, dark yellowish brown (10YR 4/4) moist; weak medium subangular blocky structure; hard, friable, sticky and plastic; common medium roots; slightly alkaline; clear smooth boundary.
Bt—19 to 27 inches; pink (7.5YR 7/4) sandy clay loam, brown (7.5YR 5/4) moist; moderate fine and medium subangular blocky structure; hard, firm, sticky and plastic; few fine and medium roots; common thin discontinuous clay films on faces of peds; slightly alkaline; abrupt wavy boundary.
R—27 inches; tuff.

Range in Characteristics

Particle-size control section: 20 to 35 percent clay
Depth to lithic contact: 20 to 40 inches

A horizon
Hue: 10YR or 7.5YR
Value: 2 to 5 dry, 2 to 4 moist
Chroma: 1 to 4

E horizon (a lower A horizon in some pedons)
Hue: 10YR or 7.5YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 4

Bt horizon
Hue: 5YR to 10YR
Value: 4 to 7 dry, 4 or 5 moist
Chroma: 2 to 6
Texture: clay loam or sandy clay loam
Note: 10YR colors occur in the upper part of the Bt horizon or as coatings on faces of peds.

Jocity Series

Map units: 417, 418
Depth class: very deep
Drainage class: moderately well drained
Landform: flood plains and alluvial fans
Parent material: stream alluvium derived from mixed sources
Elevation: 5,300 to 5,600 feet (1,615 to 1,707 meters)
Slope: 0 to 2 percent
Climatic data:
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Taxonomic class: Fine-loamy, mixed, calcareous, mesic Typic Torrifluvents

Typical Pedon

Jocity loam, 0 to 2 percent slope, map unit 417; on the Sandia Pueblo, Sandoval County; Bernalillo Quadrangle; 400 feet south and 450 feet east of the center of sec. 24, of T. 12 N., R. 3 E. NAD 83, UTM 13—03 56 572 E—39 02 182 N.

Ap—0 to 10 inches; brown (10YR 4/3) loam, dark yellowish brown (10YR 3/4) moist; massive; hard, friable, sticky, plastic; common very fine roots; strongly effervescent; moderately alkaline; abrupt smooth boundary.
C1—10 to 26 inches; brown (10YR 4/3) silty clay loam, dark yellowish brown (10YR 3/4) moist; massive; very hard, firm, very sticky and plastic; common very fine roots; strongly effervescent; moderately alkaline; abrupt smooth boundary.
C2—26 to 32 inches; yellowish brown (10YR 5/3) loam, dark brown (10YR 3/3) moist; massive; very hard, friable, very sticky and plastic; few very fine roots; strongly effervescent; moderately alkaline; abrupt smooth boundary.
C3—32 to 50 inches; yellowish brown (10YR 5/4) sandy clay loam, dark yellowish brown (10YR 4/4) moist; massive; very hard, friable, sticky and plastic; few very fine roots; violently effervescent; moderately alkaline; gradual smooth boundary.

C4—50 to 56 inches; pale brown (10YR 6/3) sandy loam, brown (10YR 4/3) moist; massive; slightly hard, very friable, nonsticky and nonplastic; few very fine roots; violently effervescent; strongly alkaline; abrupt smooth boundary.
C5—56 to 60 inches; light yellowish brown (10YR 6/4) loamy sand, yellowish brown (10YR 5/4) moist; loose, nonsticky and nonplastic; violently effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay

A horizon
Hue: 5YR, 7.5YR, 10YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 1 to 5, dry or moist
Texture: loam or clay loam

C horizon
Hue: 5YR, 7.5YR, 10YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 1 to 6, dry or moist
Texture: stratified, loamy sand, sandy loam, fine sandy loam, loam, silt loam, sandy clay loam, or clay loam

La Fonda Series

Map units: 55, 59
Depth class: very deep
Drainage class: well drained
Landform: fan terraces and fan piedmonts
Parent material: fan alluvium derived from mixed sources
Elevation: 6,000 to 6,800 feet (1,829 to 2,073 meters)
Slope: 1 to 7 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine-loamy, mixed, mesic Ustollic Camborthids

Typical Pedon

La Fonda loam, in an area of mapping unit 59, Harvey-Ildefonso-La Fonda association, 3 to 15 percent slopes; Sandoval County; Sandia Park Quadrangle; about 1.8 miles west along pipeline from Highway 14 and 700 feet north; unsectionized; NAD 83, UTM 13—03 85 343 E—38 99 641 N.

A—0 to 3 inches; brown (7.5YR 5/4) loam, brown (7.5YR 4/4) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; many fine and medium roots; common very fine irregular pores; violently effervescent; moderately alkaline; abrupt smooth boundary.
Bw1—3 to 7 inches; brown (7.5YR 5/4) loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, very friable, sticky and plastic; many fine and very fine roots; common very fine irregular pores; violently effervescent; few fine calcium carbonate accumulations; moderately alkaline; clear smooth boundary.

Bw2—7 to 14 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, friable, sticky and plastic; common very fine roots; common very fine irregular pores; violently effervescent; few fine calcium carbonate masses; moderately alkaline; clear smooth boundary.

Bw3—14 to 26 inches; brown (7.5YR 5/4) loam, brown (7.5YR 4/4) moist; weak fine subangular blocky structure; hard, friable, sticky and plastic; common very fine roots; common very fine irregular pores; violently effervescent; few fine calcium carbonate masses; moderately alkaline; clear smooth boundary.

Bk1—26 to 42 inches; light brown (7.5YR 6/4) loam, brown (7.5YR 5/4) moist; weak fine subangular blocky structure; hard, friable, slightly sticky and slightly plastic; few very fine roots; common very fine irregular pores; violently effervescent; common fine soft calcium carbonate accumulations; moderately alkaline; clear smooth boundary.

Bk2—42 to 60 inches; light brown (7.5YR 6/4) loam, brown (7.5YR 5/4) moist; weak medium subangular blocky structure; hard, friable, slightly sticky and slightly plastic; few very fine roots; common very fine irregular pores; violently effervescent; common fine soft calcium carbonate masses; moderately alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay

A horizon
- *Hue:* 2.5YR to 7.5YR
- *Value:* 4 to 6 dry, 3 or 4 moist
- *Chroma:* 3 or 4

Bw horizon
- *Hue:* 2.5YR to 7.5YR
- *Value:* 4 to 7 dry, 3 to 5 moist
- *Chroma:* 3 to 6

Bk and C horizons
- *Hue:* 5YR or 7.5YR
- *Chroma:* 3 or 4

Laventana Series

Map units: 601, 603
Depth class: deep
Drainage class: well drained
Landform: mountain slopes and pediments
Parent material: colluvium derived from andesite and granite
Elevation: 7,000 to 8,900 feet (2,134 to 2,713 meters)
Slope: 3 to 55 percent
Climatic data:
- *Mean annual precipitation:* 20 to 25 inches (508 to 635 millimeters)
- *Mean annual air temperature:* 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
- *Frost-free period:* 60 to 90 days

Taxonomic class: Loamy-skeletal, mixed, Mollic Eutroboralfs

Typical Pedon

Laventana very cobbly loam in an area of mapping unit 603, Laventana-Mirand very cobbly loams, 15 to 55 percent slopes; Sandoval County; Bear Springs Peak

Quadrangle; about 2 miles northwest of Bear Springs Peak; NAD 83, UTM 13—03 56 588 E—39 51 074 N.

O—0 to 1 inch; forest litter.
A—1 inch to 4 inches; brown (10YR 4/3) very cobbly loam, dark brown (10YR 3/3) moist; moderate very thin platy structure; soft, very friable, nonsticky and nonplastic; many very fine and few fine roots; many very fine tubular pores; 2 percent stones, 35 percent cobbles, and 15 percent gravel; slightly acid; clear smooth boundary.
E—4 to 11 inches; light yellowish gray (10YR 6/2) gravelly silt loam, dark grayish brown (10YR 4/2) moist; weak medium subangular blocky structure; slightly hard, friable, nonsticky and nonplastic; many very fine and a few fine, medium and coarse roots; common very fine and a few fine tubular pores; 5 percent cobbles and 20 percent gravel; slightly acid; clear smooth boundary.
Bt1—11 to 19 inches; brown (10YR 5/3) very cobbly loam, dark brown (10YR 4/3) moist; strong medium subangular blocky structure parting to strong fine angular blocky; hard, firm, sticky and plastic; common very fine roots; many very fine tubular pores; common thin clay films on faces of peds and in pores; 25 percent cobbles and 15 percent gravel; slightly acid; gradual smooth boundary.
Bt2—19 to 30 inches; brown (10YR 5/3) very gravelly loam, dark brown (10YR 4/3) moist; strong very fine and medium angular blocky structure; hard, firm, sticky and plastic; common very fine roots; many very fine tubular pores; common thin clay films on faces of peds and in pores; 10 percent cobbles and 40 percent gravel, slightly acid; gradual smooth boundary.
Bt3—30 to 50 inches; pale brown (10YR 6/3) very gravelly loam, dark brown (10YR 4/3) moist; moderate medium angular blocky structure; hard, firm, slightly sticky and slightly plastic; few very fine roots; common very fine tubular pores; common moderately thick clay films on faces of peds and in pores; 10 percent cobbles and 40 percent gravel; neutral; abrupt wavy boundary.
2R—50 inches; fractured andesite.

Range in Characteristics

Particle-size control section: 20 to 35 percent clay
Depth to bedrock: between 40 and 60 inches

A horizon
Value: 3 to 6 dry, 2 or 3 moist (when mixed to 7 inches the values are 5 or less dry)
Chroma: 2 or 3
Texture: gravelly sandy loam or very cobbly

E horizon
Value: 5 to 7 dry
Chroma: 2 or 3
Texture: very gravelly loam or gravelly silt loam

Bt horizons
Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 3 to 6
Texture: very gravelly loam, very cobbly loam, or very gravelly sandy clay loam
Depth to the base of the Bt horizons: 40 inches or more

Lybrook Series

Map unit: 101
Depth class: very deep
Drainage class: well drained
Landform: stream terraces and valley floors
Parent material: stream alluvium derived from mixed sources
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)
Slope: 0 to 2 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine, mixed, calcareous, mesic Ustic Torriorthents

Typical Pedon

Lybrook clay loam in an area of map unit 101, Blancot-Lybrook association, 0 to 8 percent slopes; Sandoval County; Lybrook SE Quadrangle; about 15 miles south of Lybrook; 2,640 feet north and 2,640 feet east of the southwest corner of sec. 3, T. 21 N., R. 7 W. NAD 83, UTM 13—02 69 155 E—39 95 751 N.

A—0 to 1 inch; pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; few very fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.
C1—1 inch to 5 inches; brown (10YR 5/3) silty clay loam, brown (10YR 4/3) moist; moderate fine granular structure; soft, very friable, slightly sticky and slightly plastic; few very fine and fine roots; moderately alkaline; clear smooth boundary.
C2—5 to 21 inches; brown (10YR 5/3) clay loam, brown (10YR 4/3) moist; massive; very hard, very firm, sticky and plastic; few very fine roots; moderately alkaline; clear gradual boundary.
C3—21 to 30 inches; pale brown (10YR 6/3) silty clay loam, brown (10YR 4/3) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few very fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.
C4—30 to 60 inches; brown (10YR 5/3) clay loam, brown (10YR 4/3) moist; massive; hard, firm, sticky and plastic; few fine roots; strongly effervescent; very strongly alkaline.

Range in Characteristics

Particle-size control section: 35 to 45 percent clay
Salinity: EC of 2 to 4
Sodicity: SAR of 13 to 30

A horizon
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 2 or 3

C horizon
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 2 through 4
Texture: clay loam or silty clay loam

Menefee Series

Map units: 17, 105, 129, 220, 324, 396, 422
Depth class: very shallow and shallow
Drainage class: well drained
Landform: hillslopes, mesas, and mountainsides
Parent material: colluvium and residuum derived from shale
Elevation: 5,700 to 7,800 feet (1,737 to 2,377 meters)
Slope: 2 to 45 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Loamy, mixed, calcareous, mesic, shallow Typic Ustorthents

Typical Pedon

Menefee clay loam, in an area of mapping unit 129, Menefee clay loam, 5 to 35 percent slopes; Sandoval County; Regina Quadrangle; about 1.5 miles north and 1.5 miles east of Regina; 50 feet east and 50 feet north of the center of sec. 22, T. 23 N., R. 1 W. NAD 83, UTM 13—03 26 573 E—40 08 671 N.

A—0 to 5 inches; light yellowish brown (2.5Y 6/4) clay loam, olive brown (2.5Y 4/4) moist; weak fine and medium subangular blocky structure; slightly hard, friable, sticky and plastic; common very fine and few fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.
C1—5 to 10 inches; light olive brown (2.5Y 5/4) clay loam, olive brown (2.5Y 4/4) moist; massive; hard, firm, sticky and plastic; few fine and medium roots; slightly effervescent; moderately alkaline; clear smooth boundary.
C2—10 to 17 inches; light brownish gray (2.5Y 6/3) clay loam, grayish brown (2.5Y 5/3) moist; massive; hard, firm, sticky and plastic; few very fine and medium roots; strongly effervescent; very strongly alkaline; gradual irregular boundary.
2Cr—17 inches; soft calcareous shale.

Range in Characteristics

Depth to paralithic contact: 8 to 20 inches

A horizon
Hue: 10YR or 2.5Y
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 2 to 4
Texture: loam, clay loam, gravelly loam, or gravelly clay loam

C horizons
Hue: 10YR or 2.5Y
Value: 5 to 7, 4 to 6 moist
Chroma: 2 to 5

Mespun Series

Map unit: 180
Depth class: very deep
Drainage class: excessively drained
Landform: dunes
Parent material: eolian sands derived mainly from sandstone
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)

Slope: 5 to 30 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Mixed, mesic Ustic Torripsamments

Typical Pedon

Mespun loamy fine sand, in an area of mapping unit 180, Councelor-Eslendo-Mespun complex, 5 to 30 percent slopes; Sandoval County; Galisteo SE Quadrangle; about 17 miles south of Galisteo; 1,560 feet south and 2,400 feet east of the NW corner of sec. 29, T. 21 N., R. 7 W. NAD 27; UTM 13—02 65 728 E—39 89 688 N.

A—0 to 6 inches; light yellowish brown (10YR 6/4) loamy fine sand, yellowish brown (10YR 5/4) moist; weak fine granular structure; loose, nonsticky and nonplastic; few very fine roots; moderately alkaline; clear smooth boundary.
C—6 to 60 inches; brown (7.5YR 5/4) loamy sand, brown (7.5YR 4/4) moist; single grain, loose, nonsticky and nonplastic; few very fine roots; moderately alkaline.

Range in Characteristics

Particle-size control section: 3 to 8 percent clay

A horizon
Hue: 7.5YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 to 6

C horizon
Hue: 7.5YR
Value: 4 to 7 dry, 3 to 6 moist
Chroma: 3 to 8

Mirand Series

Map units: 283, 603, 604
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes and canyons
Parent material: colluvium derived from rhyolite and tuff
Elevation: 6,900 to 9,500 feet (2,103 to 2,896 meters)
Slope: 5 to 55 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Fine, mixed Mollic Eutroboralfs

Typical Pedon

Mirand loam, in an area of mapping unit 283, Mirand-Alanos complex, 5 to 40 percent slopes; Sandoval County; Valle San Antonio Quadrangle; in the upper end of Redondo Canyon, 20 feet south of gate leading from hot well area into Baca Location No. 1; unsectionized; NAD 83, UTM 13—03 58 447 E—39 73 092 N.

O—0 to 2 inches; decomposed organic matter from grasses and needles.

A—2 to 4 inches; very dark grayish brown (10YR 3/2) loam, very dark brown (10YR 2/2) moist; weak fine granular structure; hard, very friable, sticky and plastic; few fine roots; 5 percent gravel; neutral; abrupt smooth boundary.
Bt1—4 to 9 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; weak fine subangular blocky structure; slightly hard, friable, sticky and plastic; common fine roots; common thin clay films on faces of peds; 10 percent gravel; slightly acid; clear smooth boundary.
Bt2—9 to 15 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; very hard, firm, sticky and plastic; common fine and medium roots; many thick clay films on faces of peds; 15 percent gravel; neutral; clear smooth boundary.
Bt3—15 to 24 inches; yellowish red (5YR 5/6) clay loam, yellowish red (5YR 4/6) moist; moderate medium prismatic structure parting to moderate medium subangular blocky; very hard, firm, very sticky and very plastic; few fine roots; many thick clay films on faces of peds; 10 percent gravel; neutral; clear smooth boundary.
Bt4—24 to 45 inches; reddish brown (5YR 5/4) clay, reddish brown (5YR 4/4) moist; moderate medium and coarse prismatic structure parting to moderate medium subangular blocky; extremely hard, firm, very sticky and very plastic; few very fine roots; many thick clay films on faces of peds; 10 percent gravel; slightly acid; abrupt wavy boundary.
2Bt5—45 to 60 inches; pink (7.5YR 7/4) clay loam, light brown (7.5YR 6/4) moist; common fine distinct strong brown (7.5YR 5/6) mottles; massive; very hard, firm, sticky and plastic; few medium roots; common thick clay film line pores; 10 percent gravel; very strongly acid.

Range in Characteristics

Particle-size control section: 35 to 55 percent clay

A horizon
Value: 3 to 5 dry, 2 or 3 moist
Chroma: 1 or 2
Texture: loam or very cobbly loam

Bt horizon
Hue: 5YR to 10YR
Value: 5 to 7 dry, 4 to 6 moist
Chroma: 3 to 6
Texture: clay loam, gravelly clay loam, sandy clay, clay, or cobbly clay

Montecito Series

Map units: 3, 4, 104
Depth class: very deep
Drainage class: well drained
Landform: hills, summits of mesas and plains
Parent material: eolian material and fan alluvium derived from sandstone and shale
Elevation: 6,000 to 7,600 feet (1,829 to 2,316 meters)
Slope: 1 to 30 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine, mixed, mesic Aridic Haplustalfs

Typical Pedon

Montecito loam, in an area of mapping unit 104, Cochiti-Montecito association, 1 to 30 percent slopes; Sandoval County; Canada Quadrangle; 10 miles northwest of Cochiti Pueblo; 2,400 feet north and 300 feet east of the center of sec. 2, T. 16 N., R. 4 E. NAD 83, UTM 13—03 65 540 E—39 46 249 N.

A—0 to 3 inches; brown (10YR 5/3) loam, brown (10YR 4/3) moist; weak fine granular structure; slightly hard, friable, sticky and plastic; common medium roots; neutral; abrupt smooth boundary.

Bt1—3 to 9 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; weak coarse prismatic structure parting to moderate medium subangular blocky; hard, firm, very sticky and very plastic; few fine and very fine roots; many thick clay films on faces of peds; neutral; clear smooth boundary.

Bt2—9 to 15 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; weak coarse prismatic structure parting to moderate medium subangular blocky; hard, firm, very sticky and very plastic; few very fine roots; many thick clay films on faces of peds; slightly alkaline; clear smooth boundary.

Bt3—15 to 22 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; few very fine roots; many thick clay films on faces of peds; moderately alkaline; abrupt wavy boundary.

2Bk1—22 to 37 inches; pinkish white (7.5YR 8/2) sandy loam, pink (7.5YR 7/4) moist; massive; soft, friable, slightly sticky and slightly plastic; few very fine roots; 10 percent gravel; violently effervescent; common weakly cemented calcium carbonate masses; moderately alkaline; gradual wavy boundary.

2Bk2—37 to 60 inches; pinkish white (7.5YR 8/2) gravelly sandy loam, pink (7.5YR 7/4) moist; massive; soft, friable, slightly sticky and slightly plastic; 25 percent gravel; violently effervescent; common weakly cemented calcium carbonate masses; moderately alkaline.

Range in Characteristics

Particle-size control section: 35 to 50 percent clay
Depth to the calcic horizon: 10 to 35 inches

A Horizon
- *Hue:* 7.5YR or 10YR
- *Value:* 4 to 6 dry, 3 to 5 moist
- *Chroma:* 3 to 6
- *Texture:* fine sandy loam, loam, or extremely bouldery loam

Bt Horizon
- *Hue:* 7.5YR or 10YR
- *Value:* 4 to 6 dry, 3 to 5 moist.
- *Chroma:* 3 to 6

Bk Horizon
- *Hue:* 7.5YR or 10YR
- *Value:* 6 to 8 dry, 5 to 8 moist
- *Chroma:* 1 to 4
- *Texture:* sandy loam, gravelly sandy loam, loam, or clay loam

Nyjack Series

Map unit: 162
Depth class: moderately deep
Drainage class: well drained
Landform: summits of mesas and plateaus
Parent material: eolian material and slope alluvium derived from tuff
Elevation: 6,000 to 7,000 feet (1,829 to 2,134 meters)
Slope: 1 to 5 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine-loamy, mixed, mesic Aridic Haplustalfs

Typical Pedon

Nyjack loam, in an area of mapping unit 162, Hackroy-Nyjack association, 1 to 5 percent slopes; Los Alamos County; Frijoles Quadrangle; about .5 mile east of LASL Administration Building, 2,000 feet west, 660 feet west, 660 feet south of the southwest corner of sec. 21, T. 19 N., R. 6 E. NAD 83, UTM 13—03 81 468 E—39 68 841 N.

A—0 to 3 inches; brown (10YR 5/3) loam, dark brown (7.5YR 3/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine roots; many vesicular pores; slightly acid; abrupt smooth boundary.
Bt1—3 to 13 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; many fine medium roots; many vesicular pores; few thin clay films on faces of peds; neutral; clear smooth boundary.
Bt2—13 to 24 inches; brown (7.5YR 4/4) clay loam, dark brown (7.5YR 3/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; few fine roots; many fine tubular pores; thin discontinuous clay films on faces of peds; neutral; abrupt smooth boundary.
2C—24 to 39 inches; light brown (7.5YR 6/4) gravelly sandy loam, brown (7.5YR 4/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; few fine roots; 25 percent pumice gravel; neutral; abrupt smooth boundary.
Cr—39 inches; tuff bedrock.

Range in Characteristics

Particle-size control section: 27 to 35 percent clay
Depth to paralithic contact: 20 to 40 inches

A horizon
Hue: 7.5YR or 10YR
Value: 4 or 5 dry, 3 or 4 moist
Chroma: 2 to 4, dry or moist

Bt horizons
Hue: 5YR to 10YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 3 to 6, dry or moist

Bt3 horizon (when present)
Hue: 5YR to 10YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 3 to 6, dry or moist

2C horizon
Hue: 5YR to 10YR
Value: 4 to 6 dry, 4 or 5 moist
Chroma: 3 or 4 dry

Orejas Series

Map units: 3, 100, 504
Depth class: shallow
Drainage class: well drained
Landform: mesas and plateaus
Parent material: eolian material, slope alluvium, and colluvium derived from basalt
Elevation: 6,000 to 7,600 feet (1,829 to 2,316 meters)
Slope: 1 to 40 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Clayey-skeletal, mixed, mesic Lithic Haplustalfs

Typical Pedon

Orejas cobbly loam, in an area of mapping unit 3, Montecito-Orejas complex, 1 to 7 percent slopes; Sandoval County; Cabezon Peak Quadrangle; on Mesa Prieta; 2,000 feet north and 350 feet east of the southwest corner of sec. 10, T. 15 N., R. 2 W. NAD 83, UTM 13—03 14 762 E—39 34 960 N.

A—0 to 2 inches; yellowish brown (10YR 5/4) cobbly loam, dark yellowish brown (10YR 3/4) moist; weak fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; 30 percent cobbles; slightly alkaline; abrupt smooth boundary.
Bt1—2 to 5 inches; brown (10YR 4/3) very cobbly clay loam, dark brown(10YR 3/3) moist; weak fine subangular blocky structure; hard, friable, sticky and plastic; common moderately thick clay films on faces of peds; 45 percent cobbles; neutral; clear smooth boundary.
Bt2—5 to 14 inches; dark yellowish brown (10YR 4/4) very cobbly clay loam, dark yellowish brown (10YR 3/4); moderate fine and medium subangular blocky structure; hard, firm, very sticky and very plastic; many thick clay films on faces of peds; 45 percent cobbles; moderately alkaline; clear smooth boundary.
Bt3—14 to 17 inches; brown (10YR 5/3) very cobbly clay loam, brown (10YR 4/3) moist; moderate medium and coarse subangular blocky structure; hard, firm, sticky and plastic; few moderately thick clay films on faces of peds; 45 percent cobbles; slightly effervescent; moderately alkaline; clear smooth boundary.
C—17 to 19 inches; pale brown (10YR 6/3) very gravelly clay loam, brown (10YR 4/3) moist; massive; hard, firm, sticky and plastic; 10 percent cobbles and 30 percent gravel; violently effervescent; moderately alkaline; abrupt smooth boundary.
R—19 inches; basalt.

Range in Characteristics

Particle-size control section: 35 to 50 percent clay
Depth to bedrock: 10 to 20 inches

A horizon
Hue: 7.5YR or 10YR
Value: 5 or 6 dry, 3 or 4 moist
Chroma: 2 to 4
Texture: cobbly loam, very cobbly loamy, or very stony loam

Bt horizon
Hue: 7.5YR or 10YR
Value: 4 to 6 dry, 3 or 4 moist
Chroma: 2 to 4

C horizons
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 2 or 3
Texture: very gravelly clay loam or very cobbly clay loam

Origo Series

Map units: 74, 75
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes
Parent material: slope alluvium and colluvium derived from rhyolite and tuff
Elevation: 8,600 to 10,000 feet (2,621 to 3,048 meters)
Slope: 15 to 65 percent
Climatic data:
Mean annual precipitation: 25 to 30 inches (635 to 762 millimeters)
Mean annual air temperature: 38 to 42 degrees F. (3.3 to 5.6 degrees C.)
Frost-free period: 45 to 60 days

Taxonomic class: Loamy-skeletal, mixed Psammentic Cryoboralfs

Typical Pedon

Origo very cobbly sandy loam, in an area of mapping unit 75, Origo very cobbly sandy loam, 35 to 65 percent slopes; Sandoval County; Valle San Antonio Quadrangle; about 7 miles north of La Cueva on the north side of Cerro Seco, Baca Location No. 1; NAD 83, UTM 13—03 58 587 E—39 80 079 N.

0—0 to 1 inch; leaves, needles, twigs, and bark.
A1—1 inch to 5 inches; gray (10YR 5/1) very cobbly sandy loam, very dark gray (10YR 3/1) moist; moderate fine and medium granular structure; soft, very friable, slightly sticky and slightly plastic; few coarse and many fine roots; 10 percent stones, 40 percent cobbles, and 5 percent gravel; slightly acid; clear smooth boundary.
A2—5 to 11 inches; light brownish gray (10YR 6/2) very cobbly sandy loam, dark grayish brown (10YR 4/2) moist; moderate fine and medium granular structure; soft, very friable, slightly sticky and slightly plastic; many fine, medium roots and common coarse roots; 10 percent stones, 40 percent cobbles, and 5 percent gravel; neutral; gradual smooth boundary.
E—11 to 31 inches; very pale brown (10YR 7/3) very cobbly sandy loam, brown (10YR 5/3) moist; weak fine subangular blocky structure parting to moderate fine granular; slightly hard, friable, slightly sticky and nonplastic; many fine and common medium roots; 10 percent stones, 40 percent cobbles, and 5 percent gravel; neutral; gradual wavy boundary.
Bt1—31 to 55 inches; very pale brown (10YR 7/3) very cobbly sandy loam, brown (10YR 5/3) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; (lamellae are 1/4 to 1 inch thick and comprise about 7 inches of the horizon; light brown (7.5YR 6/4) sandy loam, brown (7.5YR 5/4) moist;) massive; slightly hard, friable, slightly sticky and slightly plastic; few coarse medium roots;) clay films on sand grains and clay bridging sand grains in

lamellae; 10 percent stones and 40 percent cobbles; very strongly acid; gradual wavy boundary.

Bt2—55 to 60 inches; white (10YR 8/2) very cobbly loamy sand, very pale brown (10YR 7/3) moist; massive; slightly hard, firm, nonsticky and nonplastic; (lamellae are 1/4 to 1 inch thick; light brown (7.5YR 6/4) sandy loam, brown (7.5YR 4/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; clay films on sand grains and clay bridging sand grains;) few coarse and medium roots; 10 percent stones and 40 percent cobbles; very strongly acid.

Range in Characteristics

Particle-size control section: 5 to 20 percent clay

A horizon
Value: 5 or 6 dry, 3 to 5 moist
Chroma: 1 to 3

E horizon
Hue: 7.5YR or 10YR
Value: 7 or 8 dry, 5 to 7 moist
Chroma: 1 to 4
Texture: extremely cobbly sandy loam and very cobbly sandy loam

Bt horizon
Hue: 10YR or 7.5YR
Value: 5 to 8 dry, 5 to 7 moist
Chroma: 2 to 4
Texture: very cobbly loamy sand, very cobbly sandy loam, and extremely cobbly sandy loam
Depth to the Bt horizon: 18 to 34 inches

Bt lamellae
Hue: 7.5YR or 10YR
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 3 or 4
Texture: sandy loam and sandy clay loam

Orlie Series

Map units: 24, 26, 422
Depth class: very deep
Drainage class: well drained
Landform: dipslopes of cuestas, mesas, hills, and valley sides
Parent material: eolian material and fan alluvium derived from sandstone and shale
Elevation: 6,100 to 7,500 feet (1,859 to 2,286 meters)
Slope: 0 to 8 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine-loamy, mixed, mesic Aridic Haplustalfs

Typical Pedon

Orlie loam, in an area of mapping unit 26, Orlie loam, 0 to 8 percent slopes; Sandoval County; Jarosa Quadrangle; 6 miles west of the continental divide along the boundary

of the Jicarilla Indian Reservation; 1,075 feet south and 700 feet west of the northeast corner of sec. 6, T. 21 N., R. 3 E. NAD 83, UTM 13—03 51 252 E—39 94 408 N.

A—0 to 2 inches; pale brown (10YR 6/3) loam, dark brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; few coarse and common fine roots; moderately alkaline; clear smooth boundary.
Bt1—2 to 13 inches; brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; common fine and very fine roots; few thin clay films on faces of peds; moderately alkaline; clear smooth boundary.
Bt2—13 to 22 inches; brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; weak medium subangular blocky structure; hard, firm, sticky and plastic; few fine and medium roots; few thin clay films on faces of peds; slightly effervescent; moderately alkaline; clear smooth boundary.
C1—22 to 36 inches; pale brown (10YR 6/3) silty clay loam, brown (10YR 5/3) moist; massive; hard, firm, sticky and plastic; few very fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.
C2—36 to 50 inches; brown (7.5YR 5/4) clay loam, brown (10YR 5/3) moist; massive; hard, firm, sticky and plastic; few very fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.
C3—50 to 60 inches; pale brown (10YR 6/3) silty clay loam, dark brown (10YR 4/3) moist; massive; hard, firm, sticky and plastic; few fine roots; slightly effervescent; moderate alkaline.

Range in Characteristics

Particle-size control section: 27 to 35 percent clay

A horizon
Hue: 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 4
Texture: fine sandy loam or loam

Bt horizon
Hue: 5YR, 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 to 6
Texture: clay loam or silty clay loam

C or Bk horizons (when present)
Hue: 7.5YR or 10YR
Value: 4 or 6 dry, 3 or 5 moist
Chroma: 3 or 4 dry, 3 to 6 moist
Texture: sandy clay loam, clay loam, or silty clay loam

Osha Series

Map units: 500, 608
Depth class: deep
Drainage class: somewhat excessively drained
Landform: mountain slopes and ridges
Parent material: colluvium and residuum derived from granite
Elevation: 7,000 to 9,000 feet (2,134 to 2,743 meters)
Slope: 3 to 70 percent

Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Loamy-skeletal, mixed Typic Haploborolls

Typical Pedon

Osha gravelly coarse sandy loam, in an area of mapping unit 608, Osha association, 3 to 55 percent slopes; Sandoval County; San Miquel Mountain Quadrangle; about 6 miles east and 2 miles south of Laventana; NAD 83, UTM 13—03 31 585 E—39 62 960 N.

A—0 to 3 inches; very dark gray (10YR 3/1) gravelly coarse sandy loam, (10YR 2/1) moist; moderate very fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine, fine, and medium roots; common very fine tubular pores; 20 percent gravel; neutral; clear smooth boundary.
AB—3 to 8 inches; grayish brown (10YR 5/2) gravelly coarse sandy loam, very dark grayish brown (10YR 3/2) moist; moderate medium and fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; common very fine and medium and few coarse roots; many very fine tubular pores; 20 percent gravel; slightly acid; clear smooth boundary.
Bw—8 to 16 inches; light brown (7.5YR 6/4) gravelly coarse sandy loam, dark yellowish brown (10YR 3/4) moist; moderate medium and fine subangular blocky structure; slightly hard, friable, nonsticky and nonplastic; common very fine and common medium roots; many very fine tubular pores; 20 percent gravel; neutral; clear smooth boundary.
Ct1—16 to 32 inches; strong brown (7.5YR 5/6) extremely gravelly coarse sandy loam, strong brown (7.5YR 4/6) moist; massive; weathered granite has retained the original shape and relative position of the altered minerals; fractures between mineral grains that are less than 1 inch apart; hard, firm, nonsticky and nonplastic; many very fine roots; common moderately thick clay films on mineral grains; 75 percent gravel; neutral; diffuse wavy boundary.
Ct2—32 to 60 inches; reddish yellow (7.5YR 6/6) extremely gravelly loamy coarse sand, strong brown (7.5YR 5/6) moist; massive; consolidated rock structure; weathered granite has retained the original shape and relative position of the altered minerals; fractures between mineral grains are 0.5 to 2.5 inches apart; hard, friable, nonsticky and nonplastic; common very fine roots; few moderately thick clay films on mineral grains; 80 percent gravel; neutral.

Range in Characteristics

Particle-size control section: 6 to 12 percent clay
Depth to granite (lithic) contact: 40 to 60 inches, and deeper in some pedons

A horizon
Hue: 7.5YR or 10YR
Value: 3 to 5 dry, 2 or 3 moist
Chroma: 1 to 3
Texture: gravelly coarse sandy loam and very gravelly coarse sandy loam

B or C horizon
Hue: 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 to 6
Texture: gravelly coarse sandy loam, very gravelly coarse sandy loam, extremely gravelly coarse sandy loam, or extremely gravelly loamy coarse sand

Palon Series

Map units: 71, 72
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes
Parent material: slope alluvium and colluvium derived mainly of rhyolite
Elevation: 8,500 to 9,500 feet (2,591 to 2,896 meters)
Slope: 15 to 65 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Loamy-skeletal, mixed Psammentic Eutroboralfs

Typical Pedon

Palon very cobbly sandy loam; 35 to 65 percent slopes, map unit 72; Sandoval County; Valle San Antonio Quadrangle; about 5 miles north of La Cueva on the south side of Cerro Seco, Baca Location No. 1; NAD 83, UTM 13—03 58 417 E—39 78 037 N.

Oi—0 to 2 inches; leaves, needles, twigs, and bark.
A1—2 to 4 inches; dark gray (10YR 4/3) very cobbly sandy loam, very dark gray (10YR 3/1) moist; moderate fine and medium granular structure; soft, very friable, slightly sticky and nonplastic; many fine and very fine roots and common medium roots; 10 percent stones, 30 percent cobbles, and 5 percent gravel; neutral; abrupt smooth boundary.
A2—4 to 10 inches; light brownish gray (10YR 6/2) extremely cobbly sandy loam, dark grayish brown (10YR 4/2) moist; moderate fine and medium granular structure; soft, very friable, slightly sticky and nonplastic; many fine and very fine roots and common medium roots; 20 percent stones, 40 percent cobbles, and 10 percent gravel; neutral; clear wavy boundary.
E—10 to 32 inches; light gray (10YR 7/2) extremely cobbly sandy loam, brown (10YR 5/3) moist; weak fine granular structure; soft, very friable, slightly sticky and nonplastic; many medium, common fine, and few coarse roots; 20 percent stones, 45 percent cobbles, and 5 percent gravel; neutral; abrupt wavy boundary.
Bt1—32 to 53 inches; pink (7.5YR 7/4) very cobbly sandy loam, brown (7.5YR 5/4) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; (lamellae are 1/4 to 1 inch thick; total thickness of lamellae is 6 inches or more; light brown (7.5YR 6/4) sandy loam, brown (7.5YR 4/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; clay bridging sand grains;) few fine and medium roots; 15 percent stones, 35 percent cobbles, and 5 percent gravel; neutral; gradual wavy boundary.
Bt2—53 to 60 inches; pink (7.5YR 7/4) very cobbly sandy loam, brown (7.5YR 5/4) moist; weak medium subangular blocky structure; soft, very friable, slightly sticky and nonplastic; (lamellae are 1/4 to 1 inch thick; total thickness is 6 inches or more; light brown (7.5YR 6/4) sandy clay loam, brown (7.5YR 4/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; clay bridging sand grains;) few fine roots; 10 percent stones, 30 percent cobbles, and 5 percent gravel; neutral.

Range in Characteristics

Particle-size control section: 10 to 25 percent clay

A horizon
Value: 4 to 6 dry, 2 to 4 moist
Chroma: 1 to 3
Texture: cobbly sandy loam, very cobbly sandy loam, or extremely cobbly sandy loam

E horizon
Hue: 7.5YR or 10YR
Value: 6 to 8 dry, 4 to 7 moist
Chroma: 2 to 6
Texture: very cobbly sandy loam or extremely cobbly sandy loam

Bt horizon
Hue: 7.5YR or 10YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 2 to 6
Texture: very cobbly sandy loam or extremely cobbly sandy loam

Pastura Series

Map unit: 262
Depth class: very shallow to shallow
Drainage class: well drained
Landform: sideslopes of hills and mesas
Parent material: residuum derived from limestone
Elevation: 5,400 to 5,800 feet (1,646 to 1,768 meters)
Slope: 1 to 4 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 140 to 150 days

Taxonomic class: Loamy, mixed, mesic, shallow Ustollic Paleorthids

Typical Pedon

Pastura loam, in an area of mapping unit 262, Pastura loam, 1 to 4 percent slopes; Sandoval County; San Felipe Mesa Quadrangle; about 4 miles northwest of Placitas and 100 feet east and 2,640 feet south of the northwest corner of sec. 20, T. 13 N., R. 1 W. NAD 83, UTM 13—03 20 663 E—39 12 515 N.

A—0 to 3 inches; light yellowish brown (10YR 6/4) loam, brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; common fine and very fine roots; moderately alkaline; abrupt smooth boundary.
Bw—3 to 10 inches; light yellowish brown (10YR 6/4) gravelly loam, dark yellowish brown (10YR 4/4) moist; weak medium subangular blocky structure; slightly hard, friable, sticky and plastic; common fine and very fine roots; 15 percent gravel; moderately alkaline; clear smooth boundary.
Bk—10 to 14 inches; very pale brown (10YR 7/4) gravelly loam, yellowish brown (10YR 5/4) moist; weak fine subangular blocky structure; slightly hard, friable, sticky and plastic; few fine and very fine roots; 15 percent gravel; moderately alkaline; abrupt wavy boundary.
Bkm—14 inches; indurated petrocalcic broken into plates 3 to 12 inches horizontally and 2 to 4 inches vertically.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay
Depth to petrocalcic horizon: 5 to 20 inches

A horizon
Hue: 5YR to 10YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 2 to 6

Bw horizon (or Bk horizon where present)
Hue: 5YR to 10YR
Value: 4 to 7 dry, 4 to 6 moist
Chroma: 2 to 6

Note: A Bkm horizon, which consists of a series of strongly cemented to indurated petrocalcic horizons, may be present beneath the uppermost-indurated horizon. These layers range in thickness from 6 to 36 inches separated by gravelly and cobbly soil material.

Pavo Series

Map unit: 74
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes
Parent material: colluvium derived mainly from tuff and pumice
Elevation: 8,600 to 10,000 feet (2,621 to 3,048 meters)
Slope: 5 to 20 percent
Climatic data:
Mean annual precipitation: 25 to 30 inches (635 to 762 millimeters)
Mean annual air temperature: 38 to 42 degrees F. (3.3 to 5.6 degrees C.)
Frost-free period: 45 to 60 days

Taxonomic class: Fine-loamy, mixed Cryic Paleborolls

Typical Pedon

Pavo loam, in an area of mapping unit 74, Origo-Pavo association, 5 to 35 percent slopes; Sandoval County; Valle San Antonio Quadrangle; about 1 mile south of hot springs in the San Antonio Valley, Baca Location No. 1; unsectionized; NAD 83, UTM 13—03 58 992 E—39 80 935 N.

A1—0 to 9 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; weak medium granular structure; soft, very friable, slightly sticky and slightly plastic; common fine and very fine roots; slightly acid; clear wavy boundary.

A2—9 to 12 inches; grayish brown (10YR 5/2) sandy loam, very dark grayish brown (10YR 3/2) moist; weak coarse subangular blocky structure; soft, very friable, slightly sticky and slightly plastic; many very fine roots; 5 percent cobbles and 5 percent gravel; neutral; clear wavy boundary.

E—12 to 25 inches; very pale brown (10YR 7/3) sandy loam, brown (10YR 5/3) moist; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; few fine roots; 10 percent gravel; neutral; clear wavy boundary.

E/Bt1—25 to 35 inches; very pale brown (10YR 7/3) sandy loam, brown (10YR 5/3) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; (lamellae are .4 to .7 inch thick and total 1.5 inches; brown (7.5YR 5/4) sandy clay loam, dark brown (7.5YR 4/4) moist; slightly hard, friable, slightly

sticky and slightly plastic; clay films on sand grains and clay bridges between grains in lamellae;) 5 percent gravel; neutral; clear wavy boundary.

E/Bt2—35 to 45 inches; very pale brown (10YR 7/3) fine sandy loam, brown (10YR 5/3) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and nonplastic; (lamellae are about .5 inch thick and total about 5 inches yellowish brown (10YR 5/4) sandy clay loam, brown (10YR 4/3) moist; hard, friable, slightly sticky and slightly plastic; clay films on sand grains and clay bridges between grains in lamellae;) 5 percent gravel; neutral; clear smooth boundary.

2Bt1—45 to 50 inches; brown (7.5YR 5/4) gravelly clay loam, dark brown (7.5YR 4/4) moist; weak fine subangular blocky structure; hard, friable, sticky and plastic; thick continuous clay films on coarse fragments; 30 percent gravel; slightly acid; clear smooth boundary.

3Bt2—50 to 60 inches; very pale brown (10YR 7/4) sandy loam, dark yellowish brown (10YR 4/4) moist; weak coarse subangular blocky structure; hard, friable, slightly sticky and slightly plastic; clay films on sand grains and clay bridges between grains; 9 percent cobbles and 5 percent gravel; neutral.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay
Argillic horizon: greater than 24 inches deep and composed mainly of lamellae thicker than 1 cm

A horizon
Value: 4 or 5 dry, 2 or 3 moist
Chroma: 2 or 3
Texture: loam or sandy loam

E horizon
Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 3 or 4
Texture: sandy loam or fine sandy loam

Bt horizon
Hue: 5YR to 10YR
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 3 or 4
Texture: sandy loam, fine sandy loam, or sandy clay loam

2 and 3Bt horizons
Hue: 5YR to 10YR
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 3 or 4
Texture: gravelly clay loam or sandy loam

Penistaja Series

Map units: 68, 207, 240
Depth class: very deep
Drainage class: well drained
Landform: alluvial fans, bajadas, cuestas, hills, mesas, and plateaus
Parent material: eolian material and fan alluvium derived from sandstone and shale
Elevation: 5,400 to 6,400 feet (1,646 to 1,951 meters)
Slope: 1 to 7 percent

Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine-loamy, mixed, mesic Ustollic Haplargids

Typical Pedon

Penistaja loamy fine sand, in an area of mapping unit 68, Penistaja-Querencia complex, 2 to 7 percent slopes; Sandoval County; about 4 miles east of Marquez; 700 feet north and 2,100 feet west of the southeast corner of sec. 24, T. 12 N., R. 2 W.

A—0 to 2 inches; light yellowish brown (10YR 6/4) loamy fine sand, yellowish brown (10YR 5/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; few very fine roots; slightly alkaline; abrupt smooth boundary.
Bt—2 to 15 inches; strong brown (7.5YR 5/6) sandy clay loam, strong brown (7.5YR 4/6) moist; moderate fine and medium subangular blocky structure; slightly hard, friable, sticky and plastic; few very fine and fine roots; common moderately thick clay films on faces of peds; slightly alkaline; clear smooth boundary.
Btk—15 to 27 inches; brown (7.5YR 5/4) sandy clay loam, dark brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; few very fine and fine roots; few thin clay films on faces of peds; slightly effervescent; slightly alkaline; clear smooth boundary.
Bk—27 to 38 inches; pale brown (10YR 6/3) clay loam, brown (10YR 4/3) moist; massive; hard, firm, sticky and plastic; few fine roots; slightly effervescent; few fine calcium carbonate accumulations; moderately alkaline; gradual smooth boundary.
C—38 to 60 inches; light yellowish brown (10YR 6/4) sandy clay loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard, friable, sticky and plastic; slightly effervescent; slightly alkaline.

Range in Characteristics

Particle-size control section: 20 to 35 percent clay

A horizon
Hue: 5YR to 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 6
Texture: loamy fine sand, fine sandy loam, and very fine sandy loam

Bt horizon
Hue: 5YR or 7.5YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 to 6
Texture: sandy clay loam or clay loam

Bk and C horizons
Hue: 5YR to 10YR
Value: 4 to 8 dry, 3 to 7 moist
Chroma: 3 to 6
Texture: loam, fine sandy loam, loam, or sandy clay loam

Peralta Series

Map units: 433, 434, 437, 835, 842
Depth class: very deep
Drainage class: somewhat poorly drained

Landform: flood plains
Parent material: stream alluvium derived from mixed sources
Elevation: 5,000 to 5,500 feet (1,524 to 1,676 meters)
Slope: 0 to 3 percent
Climatic data:
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Taxonomic class: Coarse-loamy, mixed, calcareous, mesic Typic Ustifluvents

Typical Pedon

Peralta loam, in an area of mapping unit 434, Peralta loam, 1 to 3 percent slopes; Sandoval County; Bernalillo Quadrangle; about 1.5 miles northwest of the Sandia Pueblo; 300 feet south and 1,980 feet east of the northwest corner of sec. 13, T. 12 N., R. 3 E. NAD 83, UTM 13—03 56 360 E—39 04 486 N.

Ap—0 to 10 inches; brown (10YR 5/3) loam, dark brown (10YR 4/3) moist; massive; hard, firm, sticky and slightly plastic; many fine and very fine roots; strongly effervescent; slightly alkaline; abrupt smooth boundary.
C1—10 to 16 inches; brown (7.5YR 5/4) very fine sandy loam, dark brown (7.5YR 3/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; common fine roots; strongly effervescent; moderately alkaline; abrupt smooth boundary.
C2—16 to 20 inches; brown (7.5YR 4/4) clay loam, dark brown (7.5YR 3/4) moist; few fine faint brown (10YR 5/3) and few fine distinct brown (7.5YR 4/6) mottles; massive; very hard, firm, sticky and plastic; very fine roots; violently effervescent; moderately alkaline, abrupt smooth boundary.
C3—20 to 28 inches; light yellowish brown (10YR 6/4) fine sandy loam, dark yellowish brown (10YR 4/4) moist; few fine and prominent strong brown (7.5YR 5/6) mottles; massive; soft, very friable, nonsticky and nonplastic; few very fine roots; strongly effervescent, moderately alkaline; clear smooth boundary.
C4—28 to 40 inches; pale brown (10YR 6/3) loamy sand, dark yellowish brown (10YR 4/4) moist; massive; loose, nonsticky and nonplastic; few very fine roots; strongly effervescent; moderately alkaline; abrupt smooth boundary.
C5—40 to 45 inches; brown (7.5YR 5/2) silt loam, dark brown (7.5YR 3/2) moist; common fine distinct yellowish red (5YR 4/6) mottles; massive; hard, firm, sticky and slightly plastic; violently effervescent; moderately alkaline; abrupt smooth boundary.
C6—45 to 60 inches; yellowish brown (10YR 5/4) loamy fine sand, dark yellowish brown (10YR 3/4) moist; single grain; loose, nonsticky and nonplastic; strongly effervescent; slightly alkaline.

Range in Characteristics

Particle-size control section: less than 18 percent clay
Depth to redoximorphic features: 12 to 30 inches

A horizon
Value: 5 or 6 dry, 3 to 5 moist
Chroma: 3 or 4
Texture: loam or clay loam

C horizon
Hue: 7.5YR or 10YR
Value: 3 to 7 dry, 3 to 5 moist
Chroma: 2 to 4
Texture: stratified silt loam, clay loam, very fine sandy loam, coarse sand, loam, sandy clay loam, fine sandy loam, sandy loam, loamy fine sand, and loamy sand
Salinity: EC of 4 to 16

Pinavetes Series

Map units: 120, 130, 213, 250, 420
Depth class: very deep
Drainage class: excessively drained
Landform: dunes and valley sides
Parent material: eolian sands derived from sandstone
Elevation: 5,200 to 6,100 feet (1,585 to 1,859 meters)
Slope: 0 to 35 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Mixed, mesic Ustic Torripsamments

Typical Pedon

Pinavetes loamy sand, in an area of mapping unit 120, Pinavetes loamy sand, 3 to 5 percent slopes; Sandoval County; Bernalillo NM Quadrangle; about 5 miles southeast of Zia Pueblo; 1,100 feet south and 1,525 feet east of the northwest corner of section 24, T. 14 N., R. 2 E. NAD 83, UTM 13—03 47 076 E—39 22 110 N.

A—0 to 10 inches; light yellowish brown (10YR 6/4) loamy sand, yellowish brown (10YR 5/4) moist; single grain; loose, nonsticky and nonplastic; many very fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.
C1—10 to 35 inches; light yellowish brown (10YR 6/4) sand, yellowish brown (10YR 5/4) moist; single grain; loose, nonsticky and nonplastic; few very fine roots; strongly effervescent; strongly alkaline; clear smooth boundary.
C2—35 to 60 inches; light yellowish brown (10YR 6/4) sand, yellowish brown (10YR 5/4) moist; single grain; loose, nonsticky and nonplastic; few very fine roots; 10 percent gravel; strongly effervescent; moderately alkaline.

Range in Characteristics

A horizon
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 or 4
Texture: sand, loamy sand, or loamy fine sand

C horizon
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 3 to 6
Texture: sand, fine sand, or loamy sand

Pinitos Series

Map unit: 206
Depth class: very deep
Drainage class: well drained
Landform: dipslopes of cuestas, hills, mesas, and fan terraces
Parent material: fan alluvium derived from sandstone and shale
Elevation: 7,000 to 7,600 feet (2,134 to 2,316 meters)
Slope: 1 to 15 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 49 to 51 degrees F. (9.5 to 10.5 degrees C.)
Frost-free period: 100 to 120 days

Taxonomic class: Fine-loamy, mixed, mesic Aridic Haplustalfs

Typical Pedon

Pinitos loam, in an area of mapping unit 206, Pinitos loam, 1 to 15 percent slopes; Sandoval County; Regina Quadrangle; 1,500 feet south and 1,300 feet east of the northwest corner of sec. 33, T. 23 N., R. 1 W. NAD 83, UTM 13—03 24 475 E—40 05 845 N.

A—0 to 4 inches; yellowish brown (10YR 5/4) loam, dark brown (10YR 4/3) moist; weak medium subangular blocky structure; slightly hard, friable, sticky and plastic; many very fine and common fine roots; many very fine and fine pores; neutral; clear smooth boundary.

Bt1—4 to 10 inches; brown (7.5YR 4/4) clay loam, dark brown (10YR 3/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; common very fine and fine roots; few medium pores; many thick clay films on faces of peds; neutral; clear smooth boundary.

Bt2—10 to 27 inches; strong brown (7.5YR 5/6) clay loam, dark brown (7.5YR 4/4) moist; moderate medium and coarse subangular blocky structure; hard, firm, sticky and plastic; few very fine and fine roots; common and medium moderately thick clay films on faces of peds; neutral; clear smooth boundary.

Btk—27 to 39 inches; strong brown (7.5YR 5/6) clay loam, dark brown (7.5YR 4/4) moist; moderate coarse subangular blocky structure; hard, firm, sticky and plastic; few fine and medium roots; many very fine and fine pores; few fine clay films on faces of peds; slightly effervescent; few fine accumulations of calcium carbonate; slightly alkaline; gradual smooth boundary.

C—39 to 60 inches; strong brown (7.5YR 5/6) clay loam, dark brown (7.5YR 4/4) moist; massive; hard, firm, sticky and plastic; few fine and medium roots; slightly effervescent; slightly alkaline.

Range in Characteristics

Particle-size control section: 20 to 35 percent clay

A Horizon
Hue: 7.5YR or 10YR
Value: 5 or 6 dry, 3 or 4 moist
Chroma: 3 or 4 moist

Bt Horizon
Hue: 7.5YR or 10YR
Value: 4 or 5 dry, 3 or 4 moist
Chroma: 4 to 6 dry

Bk or C Horizons
Hue: 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 4 to 6

Placitas Series

Map unit: 63
Depth class: moderately deep
Drainage class: well drained
Landform: fan terraces
Parent material: fan alluvium from conglomerate
Elevation: 5,700 to 6,300 feet (1,737 to 1,920 meters)
Slope: 8 to 40 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Loamy-skeletal, mixed, mesic Ustollic Calciorthids

Typical Pedon

Placitas gravelly loam, in an area of mapping unit 63, Placitas gravelly loam, 8 to 40 percent slopes; Sandoval County; Placitas Quadrangle; about 2 miles northeast of Placitas; 400 feet north and 200 feet west of the southeast corner of sec. 21, T. 13 N., R. 5 E. NAD 83, UTM 13—03 71 988 E—39 10 875N.

A—0 to 5 inches; pale brown (10YR 6/3) gravelly loam, brown (10YR 4/3) moist; weak fine and medium granular structure; soft, very friable, slightly sticky and slightly plastic; many fine and few very fine roots; 30 percent gravel; strongly effervescent; moderately alkaline; clear smooth boundary.
Bw—5 to 10 inches; very pale brown (10YR 7/4) very gravelly sandy loam, yellowish brown (10YR 5/4) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and slightly plastic; few fine and very fine roots; 40 percent gravel; violently effervescent; moderately alkaline; clear smooth boundary.
Bk—10 to 27 inches; very pale brown (10YR 7/3) very gravelly sandy loam, brown (10YR 5/3) moist; massive; soft, very friable, slightly sticky and slightly plastic; few fine and very fine roots; 55 percent gravel; violently effervescent; many seams and filaments of calcium carbonate; moderately alkaline; clear smooth boundary.
R—27 inches; conglomerate.

Range in Characteristics

Particle-size control section: 10 to 18 percent clay
Depth to lithic contact: 20 to 40 inches

A horizon
Hue: 10YR to 5YR
Value: 4 or 5 moist
Chroma: 2 to 4

B horizon
Hue: 7.5YR or 10YR
Value: 6 or 7 dry, 4 or 5 moist
Chroma: 3 or 4

Poley Series

Map units: 67
Depth class: very deep
Drainage class: well drained
Landform: sideslopes of fan terraces
Parent material: colluvium derived from shale and sandstone
Elevation: 6,000 to 7,000 feet (1,829 to 2,134 meters)
Slope: 3 to 30 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine, mixed, mesic Ustollic Haplargids

Typical Pedon

Poley very cobbly loam in an area of mapping unit 67, Sandoval-Poley complex, 3 to 30 percent slopes; Sandoval County; Cerro Tinaja Quadrangle; about 1 mile northeast of Cerro de Nuestra Senora; NAD 83, UTM 13—03 03 752 E—39 19 661 N.

A—0 to 3 inches; brown (7.5YR 5/4) very cobbly loam, dark brown (7.5YR 4/4) moist; weak thin platy structure; soft, very friable, slightly sticky and slightly plastic; many very fine roots; 25 percent cobbles and 30 percent gravel; slightly effervescent; slightly alkaline; clear smooth boundary.

Bt1—3 to 12 inches; brown (7.5YR 5/4) clay loam, dark brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; slightly hard friable, sticky and plastic; many very fine roots; few very fine tubular pores; few fine clay films on faces of peds; 10 percent gravel; slightly effervescent; slightly alkaline; clear smooth boundary.

Bt2—12 to 17 inches; light brown (7.5YR 6/4) clay loam, brown (7.5YR 5/4) moist; moderate medium subangular blocky structure; slightly hard, friable, sticky and plastic; common very fine roots; few very fine tubular pores; common thin, faint clay skins on faces of peds; slightly effervescent; slightly alkaline; clear smooth boundary.

Btk—17 to 21 inches; light brown (7.5YR 6/4) clay loam, brown (7.5YR 5/4) moist; moderate medium subangular blocky structure; slightly hard, very friable, sticky and plastic; few very fine roots; few very fine tubular pores; few thin faint clay skins on faces of peds; 10 percent gravel; violently effervescent; with common medium irregularly shaped seams and filaments of segregated calcium carbonate; moderately alkaline; gradual smooth boundary.

Bk1—21 to 40 inches; pink (7.5YR 7/4) clay loam, light brown (7.5YR 6/4) moist; weak fine subangular blocky structure; slightly hard, very friable, sticky and plastic; few very fine roots; few very fine tubular pores; 2 percent cobbles and 10 percent gravel; violently effervescent; many fine irregularly shaped filaments of segregated calcium carbonate; moderately alkaline; gradual smooth boundary.

Bk2—40 to 60 inches; pale brown (10YR 6/3) very gravelly sandy loam, yellowish brown (10YR 5/4) moist; massive; loose, nonsticky and nonplastic; few very fine roots; 40 percent gravel; violently effervescent; many fine irregularly shaped filaments of segregated calcium carbonate; slightly alkaline.

Range in Characteristics

Particle-size control section: 30 to 55 percent clay
Depth to calcic horizon: 20 to 40 inches

A horizon
Hue: 5YR, 7.5YR
Value: 3 to 6 dry, 3 to 5 moist
Chroma: 4 to 6 dry, 3 to 5 moist

Bt horizon
Hue: 2.5YR, 5YR, 7.5YR
Value: 4, 5 or 6 dry, 3, 4 or 5 moist
Chroma: 3 to 8, dry or moist

Bk horizon
Hue: 5YR, 7.5YR, 10YR
Value: 5 to 8 dry, 4 to 8 moist
Chroma: 1 to 6, dry or moist

Prieta Series

Map units: 2, 16
Depth class: shallow
Drainage class: well drained
Landform: lava flows and mesas
Parent material: eolian material and slope alluvium derived from basalt
Elevation: 5,600 to 7,300 feet (1,707 to 2,225 meters)
Slope: 3 to 15 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Clayey-skeletal, mixed, mesic Lithic Ustollic Haplargids

Typical Pedon

Prieta very stony loam, in an area of mapping unit 2, Clovis-Prieta-Silver association, 3 to 15 percent slopes; Sandoval County; Casa Salazar Quadrangle; on Prieta Mesa, 580 feet east and 2,600 feet north of the southwest corner of sec. 15, T. 14 N., R. 2 W. NAD 83, UTM 13—03 14 613 E—39 23 855 N.

A—0 to 3 inches; brown (10YR 5/3) very stony loam, dark brown (10YR 3/3) moist; weak fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; many fine and very fine roots; 40 percent stones and 10 percent gravel; neutral; clear smooth boundary.
Bt1—3 to 10 inches; brown (7.5YR 5/4) very stony clay loam, dark brown (7.5YR 4/4) moist; moderate fine subangular blocky structure; hard, firm, very sticky and very plastic; common fine and very fine roots; thin continuous clay films on faces of peds; 40 percent stones and 10 percent gravel; slightly alkaline; gradual smooth boundary.
Bt2—10 to 14 inches; brown (7.5YR 5/4) very stony clay loam, dark brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; common fine and very fine roots; thin continuous clay films on faces of peds; 25 percent stones and 10 percent gravel; moderately alkaline; clear smooth boundary.
Bk—14 to 19 inches; very pale brown (10YR 7/3) very stony clay loam, brown (10YR 5/3) moist; massive; slightly hard, friable, sticky and plastic; few fine roots; 40 percent stones and 10 percent gravel; common fine filaments of calcium carbonate; moderately alkaline; abrupt smooth boundary.
R—19 inches; basalt.

Range in Characteristics

Particle-size control section: 35 to 50 percent clay
Depth to basalt: 10 to 20 inches

A horizon
Hue: 10YR or 7.5YR
Value: 4 to 6 dry, 3 or 4 moist
Chroma: 2 to 4
Texture: very stony loam or stony silt loam

Bt horizon
Hue: 10YR or 7.5YR
Value: 4 or 6 dry, 3 or 5 moist
Chroma: 2 to 4

Bk horizon
Hue: 10YR or 7.5YR
Value: 4 to 7 dry, 3 or 6 moist
Chroma: 2 to 4

Querencia Series

Map units: 13, 68, 231, 234
Depth class: very deep
Drainage class: well drained
Landform: alluvial fans, stream terraces, and valley sides
Parent material: fan alluvium and colluvium derived from sandstone and shale
Elevation: 5,700 to 6,900 feet (1,737 to 2,103 meters)
Slope: 1 to 8 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine-loamy, mixed, mesic Ustollic Camborthids

Typical Pedon

Querencia sandy clay loam, in an area of mapping unit 13, Sandoval-Querencia association, 2 to 7 percent slopes; Sandoval County; Sky Village NW Quadrangle; about 3/4 mile southeast of Trujillo Tank, Alamo Ranch; 1,100 feet south and 1,500 feet west of the northeast corner of sec. 4, T. 13 N., R. 1 W. NAD 83, UTM 13—03 23 504 E—39 17 713 N.

A—0 to 4 inches; light brownish gray (2.5Y 6/2) sandy clay loam, dark grayish brown (2.5Y 4/2) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; common coarse, many fine and very fine roots; slightly effervescent; moderately alkaline; abrupt smooth boundary.

Bw1—4 to 12 inches; light yellowish brown (2.5Y 6/4) clay loam, olive brown (2.5Y 4/4) moist; weak fine subangular blocky structure; hard, firm, slightly sticky and slightly plastic; many fine and very fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.

Bw2—12 to 24 inches; pale yellow (2.5Y 7/4) loam, light olive brown (2.5Y 5/4) moist; weak medium subangular blocky structure; hard, firm, slightly sticky and slightly plastic; many fine and very fine roots; slightly effervescent; moderately alkaline; gradual smooth boundary.

Bk—24 to 60 inches; pale yellow (2.5Y 7/4) loam, light olive brown (2.5Y 5/4) moist; massive; hard, firm, slightly sticky and slightly plastic; few fine and very fine roots; slightly effervescent; calcium carbonate as few fine irregular masses; moderately alkaline; gradual smooth boundary.

Range in Characteristics

Calcium carbonate equivalent: less than 15 percent, calcareous in all parts
Content of rock fragments: 0 to 10 percent gravel
Reaction: slightly alkaline to moderately alkaline

A horizon
Hue: 2.5Y or 10YR;
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 2 to 4
Texture: fine sandy loam, loam, or sandy clay loam

Bw horizon
Hue: 2.5Y or 10YR;
Value: 4 to 7 dry, 4 or 5 moist
Chroma: 2 to 6
Texture: loam, sandy clay loam, or clay

Bk horizon
Hue: 2.5Y or 10YR
Value: 4 to 7 dry, 4 or 5 moist
Chroma: 2 to 6
Texture: fine sandy loam and loam

Redondo Series

Map units: 85, 86, 87
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes
Parent material: colluvium derived from tuff
Elevation: 8,700 to 11,000 feet (2,652 to 3,353 meters)
Slope: 15 to 80 percent
Climatic data:
Mean annual precipitation: 25 to 30 inches (635 to 762 millimeters)
Mean annual air temperature: 38 to 42 degrees F. (3.3 to 5.6 degrees C.)
Frost-free period: 45 to 60 days

Taxonomic class: Loamy-skeletal, mixed Typic Cryoboralfs

Typical Pedon

Redondo coarse sandy loam, in an area of mapping unit 85, Redondo coarse sandy loam; 15 to 35 percent slopes; Sandoval County; Valle San Antonio Quadrangle; about 3 miles northwest of Baca Location No. 1 Headquarters; unsectionized; NAD 83, UTM 13—03 63 260 E—39 72 828 N.

A—0 to 2 inches; grayish brown (10YR 5/2) coarse sandy loam, very dark grayish brown (10YR 3/2) moist; weak medium granular structure; soft, very friable, slightly sticky and slightly plastic; many very fine and few medium roots; slightly acid; clear smooth boundary.

E1—2 to 7 inches; light brownish gray (10YR 6/2) coarse sandy loam, dark grayish brown (10YR 4/2) moist; moderate medium platy and weak fine subangular blocky structure; slightly hard, friable, slightly sticky and plastic; common very fine and few medium roots; few thin silt coatings on faces of peds; slightly acid; clear smooth boundary.

E2—7 to 15 inches; light gray (10YR 7/2) coarse sandy loam, brown (10YR 5/3) moist; weak medium platy and weak fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common very fine and few medium roots; very few very thin silt coating on faces of peds; 1 percent cobbles and 2 percent gravel; medium acid; clear wavy boundary.

BE—15 to 22 inches; pink (7.5YR 7/4) coarse sandy loam, brown (7.5YR 5/4) moist; weak fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; few thin silt coatings on faces of peds; 3 percent gravel; medium acid; clear wavy boundary.

Bt1—22 to 29 inches; light gray (10YR 7/2) gravelly coarse sandy loam, brown (10YR 5/3) moist; moderate fine and medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few very fine roots; common moderately thick clay films on faces of peds; 25 percent gravel; medium acid; gradual wavy boundary.

Bt2—29 to 38 inches; light brown (7.5YR 6/4) very gravelly coarse sandy loam, brown (7.5YR 4/4) moist; weak medium and coarse subangular blocky structure; slightly hard, friable, nonsticky and nonplastic; few fine medium and coarse roots; common moderately thick clay films on rock fragments and bridging sand grains; 5 percent stones, 10 percent cobbles and 30 percent gravel; medium acid; diffuse wavy boundary.

Bt3—38 to 54 inches; light brown (7.5YR 6/4) extremely gravelly coarse sandy loam, brown (7.5YR 4/4) moist; weak medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine and medium roots; common moderately thick clay films on rock fragments and bridging sand grains; 10 percent stones, 10 percent cobbles, and 60 percent gravel; medium acid; diffuse wavy boundary.

Bt4—54 to 60 inches; light brown (7.5YR 6/4) extremely cobbly coarse sandy loam, brown (7.5YR 4/4) moist; massive; hard, firm, slightly sticky and slightly plastic; few medium roots; few moderately thick clay films on rock fragments and bridging sand grains; 15 percent stones, 25 percent cobbles, and 50 percent gravel; medium acid; diffuse wavy boundary.

Range in Characteristics

Particle-size control section: 10 to 18 percent clay

A horizon

Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 3 to 5 moist
Chroma: 2 or 3, dry or moist
Texture: cobbly coarse sandy loam, coarse sandy loam, and cobbly loam

E horizon

Hue: 7.5YR or 10YR
Value: 6 to 8 dry, 4 to 6 moist
Chroma: 1 to 4, dry or moist
Texture: coarse sandy loam, very cobbly coarse sandy loam, or extremely cobbly coarse sandy loam

B horizon
Hue: 7.5YR or 10YR
Value: 4 to 8 dry, 4 or 5 moist
Chroma: 2 to 4, dry or moist
Texture: gravelly coarse sandy loam, very gravelly coarse sandy loam, very cobbly coarse sandy loam, or extremely cobbly coarse sandy loam

Royosa Series

Map units: 312, 314, 321
Depth class: very deep
Drainage class: somewhat excessively drained and excessively drained
Landform: dunes
Parent material: eolian sands derived from sandstone
Elevation: 5,600 to 6,700 feet (1,707 to 2,042 meters)
Slope: 1 to 8 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Mixed, mesic Typic Ustipsamments

Typical Pedon

Royosa sand, in an area of mapping unit 312, Royosa sand, 1 to 8 percent slopes; Sandoval County; Jemez Pueblo Quadrangle; about 4 miles north of the Zia Pueblo; 2,550 feet east and 2,000 feet north of the southwest corner of sec. 32, T. 16 N., R. 3 E. NAD 83, UTM 13—03 50 811 E—39 37 468 N.

A—0 to 5 inches; very pale brown (10YR 7/3) sand, brown (10YR 5/3) moist; single grain; loose, nonsticky and nonplastic; slightly alkaline; clear smooth boundary.
C1—5 to 16 inches; brown (7.5YR 5/4) sand, brown (7.5YR 4/4) moist; single grain; loose, nonsticky and nonplastic; common medium and coarse roots; slightly alkaline; gradual smooth boundary.
C2—16 to 60 inches; brownish yellow (10YR 6/6) loamy sand, yellowish brown (10YR 5/6) moist; single grain; loose, nonsticky and nonplastic; slightly alkaline.

Range in Characteristics

Reaction: neutral to moderately alkaline

A horizon
Hue: 10YR to 5YR
Value: 5 to 7 dry, 3 to 5 moist
Chroma: 3 to 6
Texture: sand or fine sand

C horizon
Hue: 10YR to 5YR
Value: 4 to 7 dry, 3 to 6 moist
Chroma: 3 to 6
Texture: sand, fine sand, or loamy sand

Saido Series

Map unit: 110
Depth class: very deep
Drainage class: well drained
Landform: cuestas, fans, mesas, and knolls
Parent material: slope alluvium derived from silty gypsiferous material
Elevation: 5,300 to 6,000 feet (1,615 to 1,829 meters)
Slope: 5 to 40 percent
Climatic data:
Mean annual precipitation: 10 to 12 inches (254 to 305 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Coarse-silty, gypsic, mesic Typic Gypsiorthids

Typical Pedon

Saido silt loam, in an area of mapping unit 110, Rock outcrop-Saido complex, 5 to 40 percent slopes; Sandoval County; San Ysidro Quadrangle; on the gypsum mine haul road about 2 miles south of San Ysidro; 1,500 feet north and 1,800 feet east of the southwest corner of sec. 13, T. 15 N., R. 1 E. NAD 83, UTM 13—03 37 730 E—39 32 751 N.

A—0 to 5 inches; very pale brown (10YR 8/3) silt loam, pink (7.5YR 7/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; few fine and coarse roots; common fine interstitial pores; strongly effervescent; moderately alkaline; clear smooth boundary.

By1—5 to 9 inches; white (10YR 8/2) silt loam, very pale brown (10YR 7/3) moist; weak medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; few fine and coarse roots; common fine tubular pores; many medium masses of gypsum crystals; violently effervescent; moderately alkaline; clear smooth boundary.

By2—9 to 15 inches; white (10YR 8/2) silt loam, white (10YR 8/2) moist; massive; soft, very friable, nonsticky and nonplastic; many medium masses of gypsum crystals; violently effervescent; moderately alkaline; clear smooth boundary.

By3—15 to 25 inches; white (10YR 8/2) silt loam, white (10YR 8/2) moist; massive; slightly hard, very friable, nonsticky and nonplastic; many medium masses of gypsum crystals; violently effervescent; moderately alkaline; clear smooth boundary.

C—25 to 60 inches; pink (7.5YR 8/4) loam, pink (7.5YR 7/4) moist; massive; soft, very friable, nonsticky and nonplastic; few medium masses of gypsum crystals; violently effervescent; moderately alkaline.

Range in Characteristics

Depth to gypsic horizon: 2 to 5 inches

A horizon
Hue: 5YR, 7.5YR, or 10YR
Value: 5 to 8 dry, 4 to 7 moist
Chroma: 3 or 4

B and C horizons
Hue: 7.5YR or 10YR
Value: 6 to 8 dry, 5 to 7 moist
Chroma: 1 to 4

San Mateo Series

Map units: 114, 170
Depth class: very deep
Drainage class: well drained
Landform: flood plains, alluvial fans, and valley sides
Parent material: stream alluvium from mixed sources
Elevation: 5,500 to 6,800 feet (1,676 to 2,073 meters)
Slope: 0 to 3 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine-loamy, mixed, calcareous, mesic Ustic Torrifluvents

Typical Pedon

San Mateo loam, in an area of mapping unit 170, San Mateo loam, 0 to 3 percent slopes; Sandoval County; San Ysidro Quadrangle; about 5 miles southwest of San Ysidro; 200 feet south and 1,500 feet east of the center of sec. 27, T. 15 N., R. 1 E. NAD 83, UTM 13—03 35 171 E—39 29 854 N.

A—0 to 2 inches; pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; weak fine granular structure; soft, very friable, nonsticky and slightly plastic; common medium and fine roots; strongly effervescent; moderately alkaline; clear smooth boundary.
C1—2 to 10 inches; dark yellowish brown (10YR 4/4) clay loam, dark yellowish brown (10YR 3/4) moist; massive; soft, friable, slightly sticky and slightly plastic; common medium, fine and very fine roots; strongly effervescent; strongly alkaline; clear smooth boundary.
C2—10 to 23 inches; light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive; slightly hard, firm, sticky and plastic; common fine and very fine roots; few medium roots; strongly effervescent; strongly alkaline; clear smooth boundary.
C3—23 to 32 inches; light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; massive; slightly hard, firm, sticky and plastic; few fine and very fine roots; strongly effervescent; moderately alkaline; clear smooth boundary.
C4—32 to 54 inches; yellowish brown (10YR 5/4) clay loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard, firm, sticky and plastic; few very fine roots; strongly effervescent; moderately alkaline; clear smooth boundary.
C5—54 to 60 inches; pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; massive; slightly hard, firm, sticky and plastic; strongly effervescent; strongly alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay

A horizon
Hue: 10YR or 2.5Y
Value: 5 or 6 dry, 3 to 5 moist
Chroma: 2 to 6 dry and moist
Texture: sandy loam and loam

C horizon
Hue: 10YR or 2.5Y
Value: 5 or 6 dry; 3 to 5, moist
Chroma: 2 to 6
Texture: stratified sandy loam, loam, silty clay loam, and clay loam
Sodicity: SAR of 5 to 30

Sandoval Series

Map units: 13, 15, 67, 230, 235
Depth class: shallow
Drainage class: well drained
Landform: hills and ridges
Parent material: slope alluvium derived from shale
Elevation: 5,800 to 7,000 feet (1,768 to 2,134 meters)
Slope: 1 to 30 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Loamy, mixed, calcareous, mesic, shallow Ustic Torriorthents

Typical Pedon

Sandoval fine sandy loam, in an area of mapping unit 13, Sandoval-Querencia association, 2 to 7 percent slopes; Sandoval County; Sky Village NW Quadrangle; about 5 miles south of the Alamo Ranch headquarters; 1,100 feet south and 2,700 feet east of the northwest corner of sec. 4, T. 13 N., R. 1 W. NAD 83, UTM 13—03 23 157 E—39 17 735 N.

A1—0 to 2 inches; light yellowish brown (10YR 6/4) fine sandy loam, dark yellowish brown (10YR 4/4) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; common fine and very fine roots; slightly effervescent; strongly alkaline; abrupt smooth boundary.
A2—2 to 6 inches; light gray (2.5YR 7/2) clay loam, light olive brown (2.5YR 5/4) moist; weak fine subangular blocky structure; slightly hard, friable, sticky and plastic; common fine and very fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.
C1—6 to 10 inches; light brownish gray (2.5YR 6/2) clay loam, grayish brown (2.5YR 5/2) moist; massive; hard, firm, sticky and plastic; common fine and very fine and few medium roots; slightly effervescent; moderately alkaline; clear smooth boundary.
C2—10 to 15 inches; light brownish gray (2.5YR 6/2) clay loam, dark grayish brown (2.5YR 4/2) moist; massive; hard, firm, sticky and plastic; few fine roots; slightly effervescent; moderately alkaline; clear smooth boundary.
Cr—15 inches; soft calcareous shale.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay
Content of gypsum: 5 to 10 percent
Salinity: EC of 2 to 4
Sodicity: SAR of 8 to 13
Depth to paralithic contact: 10 to 20 inches

A horizon
Hue: 10YR or 2.5Y
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 2 to 6
Texture: loam, clay loam, and fine sandy loam

C horizon
Hue: 2.5Y or 5Y
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 2 to 4

Santa Fe Series

Map units: 409, 419
Depth class: very shallow to shallow
Drainage class: well drained
Landform: mountain slopes
Parent material: slope alluvium and residuum derived from granite
Elevation: 6,400 to 8,400 feet (1,951 to 2,560 meters)
Slope: 15 to 70 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Loamy-skeletal, mixed, mesic Lithic Argiustolls

Typical Pedon

Santa Fe very gravelly sandy loam, in an area of mapping unit 409, Santa Fe very gravelly sandy loam, 15 to 40 percent slopes; Sandoval County; Gilman Quadrangle; about 8 miles west of the Jemez Pueblo; 1,300 feet north and 350 feet west of the SE corner of sec. 8, T. 16 N., R. 1 E. NAD 83, UTM 13—03 32 465 E—39 44 119 N

A—0 to 3 inches; dark reddish gray (5YR 4/2) very gravelly sandy loam, dark reddish brown (5YR 3/2) moist; moderate fine granular structure; soft, friable, nonsticky and nonplastic; many very fine roots; common very fine tubular pores; 2 percent stones, 3 percent cobbles and 40 percent gravel; neutral; clear smooth boundary.
Bt—3 to 8 inches; weak red (2.5YR 4/2) very gravelly sandy clay loam, dusky red (2.5YR 3/2) moist; strong fine angular block structure; slightly hard, firm, sticky and plastic, common very fine roots, many very fine tubular pores, 10 percent cobbles and 35 percent gravel; many thin clay films on faces of peds; neutral, clear smooth boundary.
2R—8 inches; granite.

Range in Characteristics

Particle-size control section: 20 to 35 percent clay
Depth to bedrock: 8 to 20 inches

A horizon
Hue: 5YR to 10YR
Value: 3 to 5 dry, 2 or 3 moist
Chroma: 2 or 3
Texture: gravelly sandy loam or extremely cobbly coarse sandy loam

Bt horizon
Hue: 2.5YR to 7.5YR
Value: 3 to 5 dry, 2 or 3 moist
Chroma: 2 or 3

Sedgran Series

Map unit: 201
Depth class: very shallow to shallow
Drainage class: excessively drained
Landform: mountain slopes
Parent material: colluvium derived from granite and sandstone
Elevation: 5,800 to 8,000 feet (1,768 to 2,438 meters)
Slope: 25 to 55 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Sandy-skeletal, mixed, mesic Lithic Ustic Torriorthents

Typical Pedon

Sedgran extremely gravelly loamy coarse sand, in an area of mapping unit 201, Rock outcrop-Sedgran association, 25 to 55 percent slopes; Sandoval County; Alameda Quadrangle; about 3 1/4 miles east of Interstate Highway 25 and 1/8 miles north of the Sandoval-Bernalillo county line on the Sandia Pueblo Indian Reservation; 1,300 feet east and 450 of north of the southwest corner of sec. 34, T. 12 N., R. 4 E. NAD 83, UTM 13—03 62 490 E—38 98 152 N.

A—0 to 4 inches; yellowish brown (10YR 5/4) extremely gravelly loamy coarse sand, dark yellowish brown (10YR 3/4) moist; moderate medium granular structure; loose, very friable, nonsticky and nonplastic; many fine roots; 20 percent cobbles and 45 percent gravel; neutral; clear wavy boundary.
C—4 to 13 inches; reddish yellow (7.5YR 6/6) and yellowish brown (7.5YR 5/4) very gravelly loamy coarse sand, brownish yellow (7.5YR 5/6) and dark yellowish brown (7.5YR 4/4) moist; massive; slightly hard, very friable, nonsticky and nonplastic; few fine roots; 5 percent cobbles and 40 percent gravel; slightly alkaline; diffuse wavy boundary.
2R—13 inches; granite bedrock.

Range in Characteristics

Particle-size control section: 5 to 10 percent clay
Depth to lithic contact: 6 to 20 inches

A horizon
Hue: 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 to 6

C horizon
Hue: 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 4 to 6

Sedillo Series

Map units: 200, 208
Depth class: very deep
Drainage class: well drained
Landform: bajadas, fan terraces, and stream terraces
Parent material: gravelly fan alluvium derived from mixed sources
Elevation: 5,100 to 6,500 feet (1,554 to 1,981 meters)
Slope: 5 to 55 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Loamy-skeletal, mixed, mesic Ustollic Haplargids

Typical Pedon

Sedillo very gravelly fine sandy loam, in an area of mapping unit 208, Sedillo very gravelly fine sandy loam, 25 to 55 percent slopes; Sandoval County; San Felipe Pueblo Quadrangle; about one mile southeast of the San Felipe Pueblo, about 2000 feet south and 300 feet west of NE corner of sec. 29, T. 14 N., R. 5 E. NAD 83, UTM 13—03 70 512 E—39 19 951 N.

A—0 to 2 inches; brown (10YR 4/3) very gravelly fine sandy loam, dark brown (10YR 3/3) moist; weak thin platy structure; soft, very friable, nonsticky and nonplastic; many very fine roots, 55 percent gravel; slightly effervescent; slightly alkaline; clear smooth boundary.

Bt—2 to 8 inches; brown (10YR 4/3) very gravelly sandy clay loam, dark yellowish brown (10YR 3/4) moist; moderate medium and fine subangular blocky structure; soft, friable, slightly sticky and slightly plastic; many very fine roots; common very fine tubular pores; few thin clay films on faces of peds; 50 percent gravel; slightly effervescent; slightly alkaline; clear smooth boundary.

Bk1—8 to 12 inches; yellowish brown (10YR 5/4) very gravelly sandy loam, dark yellowish brown (10YR 4/4) moist; medium and fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common very fine roots; many very fine tubular pores; 50 percent gravel; slightly effervescent; few coatings on undersides of rock fragments of calcium carbonate; slightly alkaline; gradual smooth boundary.

Bk2—12 to 60 inches; very pale brown (10YR 8/3) extremely gravelly sandy loam, light yellowish brown (10YR 6/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; few very fine roots; many very fine tubular pores; 60 percent gravel; violently effervescent; undersides of rock fragments coated with calcium carbonate; slightly alkaline.

Range in Characteristics

Particle-size control section: 20 to 35 percent clay

A horizon
Hue: 5YR to 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 or 4
Texture: very cobbly sandy loam and very gravelly fine sandy loam

Bt horizon
Hue: 10YR to 5YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 3 to 6

Bk horizon
Hue: 5YR to 10YR
Value: 5 to 8 dry, 3 to 7 moist
Chroma: 2 to 6
Texture: extremely gravelly coarse sandy loam, very gravelly sandy loam, and extremely gravelly sandy loam

Sedmar Series

Map unit: 146
Depth class: very shallow to shallow
Drainage class: excessively drained
Landform: dipslopes of cuestas and ridges
Parent material: slope alluvium and residuum derived from sandstone
Elevation: 7,000 to 8,000 feet (2,134 to 2,438 meters)
Slope: 1 to 15 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Sandy, mixed, frigid Lithic Ustorthents

Typical Pedon

Sedmar loamy sand, in an area of mapping unit 146, Sedmar loamy sand, 1 to 15 percent slopes; Sandoval County; Cuba Quadrangle; about 1 mile north of Cuba; 2,600 feet south and 200 feet west of the northeast corner of sec. 17, T. 21 N., R. 1 W. NAD 83, UTM 13—03 23 734 E—39 91 047 N.

A—0 to 3 inches; light yellowish brown (10YR 6/4) loamy sand, brown (10YR 4/3) moist; single grain; loose, nonsticky and nonplastic; neutral; abrupt smooth boundary.
C1—3 to 13 inches; brownish yellow (10YR 6/6) and brown (10YR 5/3) sandy loam, brown (10YR 4/3) and yellowish brown (10YR 5/6) moist; weak fine subangular blocky structure; slightly hard, friable, nonsticky and nonplastic; few common distinct yellowish brown (10YR 5/8) iron stains; neutral; clear smooth boundary.
C2—13 to 18 inches; brownish yellow (10YR 6/6) loamy sand, brownish yellow (10YR 6/6) moist; single grain; loose, nonsticky and nonplastic; neutral; abrupt smooth boundary.
2R—18 inches; sandstone.

Range in Characteristics

Particle-size control section: 5 to 15 percent clay
Depth to lithic contact: 6 to 20 inches

A and C horizons
Value: 5 to 7 dry, 4 to 6 moist
Chroma: 3 to 6
Texture: loamy sand stratified with layers of sandy loam

Sheppard Series

Map units: 145, 183, 191
Depth class: very deep
Drainage class: somewhat excessively drained
Landform: dunes, alluvial fans, benches, structural benches, terraces, and stream terraces
Parent material: eolian sands derived from sandstone
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Slope: 1 to 40 percent
Climatic data:
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Taxonomic class: Mixed, mesic Typic Torripsamments

Typical Pedon

Sheppard loamy fine sand, in an area of mapping unit 191, Sheppard loamy fine sand, 3 to 8 percent slopes; Sandoval County; Bernalillo Quadrangle; unsectionized; NAD 83, UTM 13—03 55 559 E—39 06 478 N.

A—0 to 3 inches; light brown (7.5YR 6/4) loamy fine sand, brown (7.5YR 4/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; common fine and very fine roots; slightly effervescent; moderately alkaline; abrupt smooth boundary.
C1—3 to 27 inches; strong brown (7.5YR 5/6) loamy fine sand, brown (7.5YR 4/4) moist; single grain; loose, nonsticky and nonplastic; few fine and medium roots; slightly effervescent; moderately alkaline; clear smooth boundary.
C2—27 to 60 inches; pink (7.5YR 7/4) loamy fine sand, brown (7.5YR 5/4) moist; single grain; loose, nonsticky and nonplastic; strongly effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 3 to 10 percent clay

A horizon
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 3 or 4

C horizon
Hue: 2.5YR to 7.5YR
Value: 5 to 7 (4 to 6 moist)
Chroma: 3 to 6
Texture: loamy fine sand, sand, or loamy sand

Silver Series

Map units: 1, 2
Depth class: very deep
Drainage class: well drained
Landform: mesas, fan terraces, hills, and plateaus
Parent material: eolian material and slope alluvium derived from shale and sandstone
Elevation: 5,600 to 7,300 feet (1,707 to 2,225 meters)
Slope: 1 to 8 percent

Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine, mixed, mesic Ustollic Haplargids

Typical Pedon

Silver loam, in an area of mapping unit 1, Silver-Clovis loams, 1 to 7 percent slopes; Sandoval County; Casa Salazar Quadrangle; on Mesa Prieta; 1,300 feet north and 150 feet east of the center of sec. 9, T. 14 N., R. 2 W. NAD 83, UTM 13—03 13 700 E—39 25 879 N.

A—0 to 4 inches; pale brown (10YR 6/3) loam, brown (10YR 4/3) moist; weak thick platy structure parting to moderate medium granular; slightly hard, friable, sticky and plastic; common fine and very fine roots; neutral; clear smooth boundary.
Bt1—4 to 8 inches; light brown (7.5YR 6/4) silty clay loam, brown (7.5YR 4/4) moist; moderate fine subangular blocky structure; slightly hard, friable, sticky and plastic; common fine and very fine roots; few thin clay films on faces of peds; slightly alkaline; clear smooth boundary.
Bt2—8 to 20 inches; brown (7.5YR 5/2) silty clay loam, brown (7.5YR 4/2) moist; moderate fine and medium subangular blocky structure; hard, firm, very sticky and very plastic; common fine and very fine roots; continuous thick clay films on faces of peds; slightly alkaline; gradual smooth boundary.
Bt3—20 to 39 inches; brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; moderate medium subangular blocky structure; hard, firm, very sticky and very plastic; few fine and very fine roots; many thick clay films on faces of peds; slightly alkaline; clear smooth boundary.
C—39 to 60 inches; brown (7.5YR 5/4) clay loam, dark brown (7.5YR 4/4) moist; massive; hard, firm, very sticky and very plastic; slightly alkaline.

Range in Characteristics

Particle-size control section: 35 to 50 percent clay

A horizon
Hue: 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 4

Bt and Btk horizons
Hue: 7.5YR or 10YR
Value: 4 to 7 dry, 3 to 6 moist
Chroma: 2 to 4
Texture: clay loam or silty clay loam

Bk and C horizons (where present)
Hue: 7.5YR or 10YR
Value: 6 to 8 dry, 5 to 7 moist
Chroma: 2 to 4
Texture: clay loam and silty clay loam

Skyvillage Series

Map units: 64, 190, 230
Depth class: very shallow to shallow
Drainage class: well drained

Landform: breaks, structural benches, dipslopes of cuestas, summits of mesas and hills, and ridges
Parent material: slope alluvium derived from sandstone
Elevation: 5,800 to 6,400 feet (1,768 to 1,951 meters)
Slope: 3 to 40 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Loamy, mixed, calcareous, mesic Lithic Ustic Torriorthents

Typical Pedon

Skyvillage fine sandy loam, in an area of mapping unit 190, Zia-Skyvillage-Rock outcrop complex, 5 to 40 percent slopes; Sandoval County; Sky Village NW Quadrangle; about 6 miles northeast of the Alamo Ranch headquarters; 700 feet north and 600 feet east of the center of sec. 22, T. 14 N., R. 1 W. NAD 83, UTM 13—03 25 078 E—39 22 260 N.

A—0 to 2 inches; pale yellow (2.5Y 7/4) fine sandy loam, light olive brown (2.5Y 5/4) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; few fine roots; slightly effervescent; moderately alkaline; abrupt smooth boundary.
C1—2 to 11 inches; light gray (2.5Y 7/2) fine sandy loam, light olive brown (2.5Y 5/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; common fine and very fine roots; slightly effervescent; moderately alkaline; clear wavy boundary.
C2—11 to 16 inches; light gray (2.5Y 7/2) fine sandy loam, light olive brown (2.5Y 5/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; 10 percent gravel; slightly effervescent; slightly alkaline.
2R—16 inches; sandstone.

Range in Characteristics

Particle-size control section: 10 to 27 percent clay
Depth to bedrock: 6 to 20 inches

A and C horizons
Hue: 2.5Y to 7.5YR
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 2 to 6
Texture: sandy loam or fine sandy loam

Sparank Series

Map units: 236, 237
Depth class: very deep
Drainage class: well drained
Landform: stream terraces, alluvial fans, valley sides, and flood plains
Parent material: stream alluvium derived from sandstone and shale
Elevation: 5,500 to 6,400 feet (1,676 to 1,951 meters)
Slope: 0 to 3 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine, mixed, calcareous, mesic Ustic Torrifluvents

Typical Pedon

Sparank clay loam, in an area of mapping unit 236, Sparank clay loam, moderately saline, sodic, 0 to 1 percent slopes; Sandoval County; Holy Ghost Spring Quadrangle; about 3 miles northeast of San Luis; unsectionized; NAD 83, UTM 13—03 19 302 E—39 55 938 N.

A—0 to 2 inches; brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; moderate fine granular structure; slightly hard, friable, sticky and plastic; few fine roots; slightly effervescent; strongly alkaline; clear smooth boundary.
C1—2 to 10 inches; brown (10YR 5/3) silty clay, brown (10YR 4/3) moist; massive; hard, firm, sticky and plastic; common fine roots; slightly effervescent; strongly alkaline; gradual smooth boundary.
C2—10 to 24 inches; brown (10YR 4/3) silty clay, brown (10YR 4/3) moist; massive; hard, firm, sticky and plastic; common medium roots; slightly effervescent; moderately alkaline; abrupt smooth boundary.
C3—24 to 40 inches; pale brown (10YR 6/3) silty clay loam with thin strata of silt loam, brown (10YR 5/3) moist; massive; hard, firm, slightly sticky and slightly plastic; strongly effervescent; moderately alkaline; abrupt smooth boundary.
C4—40 to 44 inches; dark grayish brown (10YR 4/2) silty clay, dark grayish brown (10YR 4/2) moist; massive; hard, firm, sticky and plastic; slightly effervescent; moderately alkaline; abrupt smooth boundary.
C5—44 to 60 inches; pale brown (10YR 6/3) silty clay, brown (10YR 5/3) moist; massive; hard, firm, sticky and plastic; slightly effervescent; strongly alkaline.

Range in Characteristics

Sodicity: SAR less than 13, typically
Salinity: EC of 4 to 8, typically

A horizon
Hue: 10YR to 5Y
Value: 4 to 6 moist, 3 to 6 dry
Chroma: 1 to 4
Texture: sandy clay loam, silt loam, clay loam, silty clay loam, silty clay, or clay
Reaction: moderately alkaline or strongly alkaline

C horizon
Hue: 10YR to 5Y
Value: 3 to 7 dry or moist
Chroma: 1 to 4
Texture: clay, silty clay, silty clay loam, or clay loam. Usually contains thin strata of silt loam or loamy sand.
Reaction: moderately alkaline to very strongly alkaline

Note: Some pedons have few to many fine prominent relict mottles of 5Y or 2.5Y 4/6 to 4/8 below 20 inches.

Sparham Series

Map units: 18, 24, 51, 102, 320
Depth class: very deep
Drainage class: well drained, somewhat poorly drained
Landform: alluvial fans, flood plains, and valley sides
Parent material: fan and stream alluvium derived from sandstone and shale
Elevation: 5,000 to 7,500 feet (1,524 to 2,286 meters)

Slope: 0 to 3 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 50 to 55 degrees F. (10.0 to 12.8 degrees C.)
Frost-free period: 110 to 160 days

Taxonomic class: Fine, mixed, calcareous, mesic Typic Ustifluvents

Typical Pedon

Sparham clay, in an area of mapping unit 102, Sparham clay loam, 1 to 3 percent slopes; Sandoval County; Cuba Quadrangle; about 1 mile northwest of Cuba; 1,500 feet south and 1,100 feet east of the northwest corner of sec. 20, T. 21 N., R. 1 W. NAD 83, UTM 13—03 22 490 E—39 89 805 N.

A—0 to 7 inches; grayish brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; many very fine and common fine roots; neutral; clear smooth boundary.
C1—7 to 20 inches; light brownish gray (10YR 6/2) clay loam, dark gray (10YR 4/1) moist; common medium prominent strong brown (7.5YR 5/8) mottles; massive; very hard, very firm, very sticky and very plastic; common very fine roots; slightly effervescent; slightly alkaline; clear smooth boundary.
C2—20 to 29 inches; pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; common fine prominent strong brown (7.5YR 5/8) mottles; massive; very hard, very firm, very sticky and very plastic; few very fine roots; slightly effervescent; moderately alkaline; gradual smooth boundary.
C3—29 to 47 inches; very pale brown (10YR 7/4) silty clay loam, yellowish brown (10YR 5/4) moist; few fine prominent strong brown (7.5YR 5/8) mottles; massive; very hard, very firm, very sticky and very plastic; few very fine roots; slightly effervescent; slightly alkaline; clear smooth boundary.
C4—47 to 53 inches; very pale brown (10YR 7/4) clay loam, yellowish brown (10YR 5/4) moist; common medium prominent strong brown (7.5YR 5/8) mottles; massive; very hard, very firm, very sticky and very plastic; slightly effervescent; moderately alkaline; abrupt smooth boundary.
C5—53 to 60 inches; dark gray (10YR 4/1) clay loam, very dark gray (10YR 3/1) moist; massive; very hard, very firm, very sticky and very plastic; 10 percent fine gravel; moderately alkaline.

Range in Characteristics

Particle-size control section: 35 to 59 percent clay
Redoximorphic features: concentrations and depletions close to the surface are relict features
Depth to salts: 20 to 35 inches, when present
Depth to water table: typically 6 feet or greater (4 to 5 feet in some pedons)

A horizon
Hue: 10YR, 2.5Y or 5Y
Value: 4 to 6 dry, 3 to 6 moist. When crushed, moist value is less than 3.5, thickness is less than 7 inches.
Chroma: 1 to 4 dry
Texture: clay loam, silty clay loam, silt loam, or clay

C horizon
Hue: 10YR, 2.5Y or 5Y
Value: 3 to 7 dry, 3 to 6 moist
Chroma: 1 to 4 dry and 1 to 6 moist

Texture: stratified clay loam, silty clay loam, silty clay, or clay (there are strata of textures as coarse as loamy sand)
Reaction: slightly alkaline to strongly alkaline
Sodicity: SAR of 5 to 30
Salinity: EC of 2 to 16, typically

Note: The Sparham component in map unit 51 is somewhat poorly drained and outside the range in characteristics of the series. The component is a taxadjunct to the series.

Stumble Series

Map unit: 106
Depth class: very deep
Drainage class: somewhat excessively drained
Landform: alluvial fans, fan aprons, fan remnants, and inset fans
Parent material: eolian sands derived from sandstone
Elevation: 5,000 to 5,600 feet (1,524 to 1,707 meters)
Slope: 1 to 40 percent
Climatic data:
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Taxonomic class: Mixed, mesic Typic Torripsamments

Typical Pedon

Stumble very gravelly fine sandy loam in an area of map unit 106, Stumble association, 1 to 40 percent slopes; Sandoval County; Bernalillo Quadrangle; about 1.5 miles northeast of the Sandia Indian Pueblo; 1,400 feet east and 401 feet north of the southwest corner of sec. 17, T. 12 N., R. 4 E. NAD 83, UTM 13—03 59 375 E—39 03 017 N.

A—0 to 4 inches; pale brown (10YR 6/3) very gravelly fine sandy loam, brown (10YR 4/3) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine and few medium roots; 45 percent pebbles; slightly effervescent; moderately alkaline; clear smooth boundary.
Bw—4 to 10 inches; brown (7.5YR 5/4) gravelly fine sandy loam, dark brown (7.5YR 4/4) moist; weak medium subangular blocky structure; slightly hard, friable, nonsticky and nonplastic; common fine roots; 25 percent pebbles; slightly effervescent; mildly alkaline; gradual wavy boundary.
C1—10 to 24 inches; very pale brown (10YR 7/4) loamy sand, yellowish brown (10YR 5/4) moist; massive; slightly hard, very friable, nonsticky and nonplastic; common fine roots; 10 percent pebbles; slightly effervescent; moderately alkaline; gradual wavy boundary.
C2—24 to 60 inches; very pale brown (10YR 7/3) gravelly coarse sand, brown (10YR 4/3) moist; single grain; loose, nonsticky and nonplastic; few fine roots; 20 percent pebbles; slightly effervescent; moderately alkaline.

Range in Characteristics

A horizon
Value: 6 or 7 dry, 4 or 5 moist
Chroma: 2 or 3, dry or moist
Reaction: neutral to moderately alkaline
Texture: gravelly loamy sand or very gravelly fine sandy loam

Bw horizon (when present)
Texture: gravelly fine sandy loam or loamy sand

C horizons
Hue: 10YR or 2.5Y
Value: 6 or 7 dry, 4 or 5 moist
Chroma: 2 or 3, dry or moist
Texture: loamy sand or gravelly coarse sand, with strata of fine sand and sand

Teco Series

Map unit: 399
Depth class: very deep
Drainage class: well drained
Landform: cuestas and hills
Parent material: slope alluvium derived from sandstone and shale
Elevation: 5,900 to 7,000 feet (1,798 to 2,134 meters)
Slope: 8 to 40 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine, mixed, mesic Aridic Haplustalfs

Typical Pedon

Teco very cobbly fine sandy loam, in an area of mapping unit 399; Cucho-Teco complex, 8 to 40 percent slopes; Sandoval County; Holy Ghost Spring Quadrangle; about 3 miles south of the Jemez-Zia Pueblo boundary along State Highway 44 then east .25 mile; unsectionized; NAD 83, UTM 13—03 27 701 E—39 48 805 N.

A—0 to 1 inch; yellowish brown (10YR 5/4) very cobbly fine sandy loam, dark brown (10YR 4/3) moist; weak fine granular structure; loose, very friable, nonsticky and nonplastic; many fine and few medium roots; 20 percent cobbles, 15 percent gravels; slightly alkaline; abrupt smooth boundary.

Bt1—1 inch to 7 inches; reddish brown (5YR 5/4) sandy clay, reddish brown (5YR 4/4) moist; moderate medium subangular blocky structure parting to moderate fine granular; hard, firm, sticky and plastic; common fine roots; few fine tubular pores; few fine clay films lining pores; slightly alkaline; clear smooth boundary.

Bt2—7 to 23 inches; reddish yellow (7.5YR 6/6) clay, strong brown (7.5YR 5/6) moist; moderate fine subangular and angular blocky structure; hard, firm, very sticky and very plastic; common fine roots; common fine tubular pores; few thin faint dark brown (7.5YR 4/4) clay skins on vertical faces of peds; slightly effervescent; slightly alkaline; gradual wavy boundary.

Btk—23 to 40 inches; pink (7.5YR 7/4) clay, light brown (7.5YR 6/4) moist; massive; hard, firm, sticky and plastic; few fine roots; strongly effervescent; few fine clay films on faces of peds; common medium irregularly shaped segregated soft masses of calcium carbonate; slightly alkaline; clear wavy boundary.

2C—40 to 45 inches; light yellowish brown (10YR 6/4) very gravelly fine sandy loam, yellowish brown (10YR 5/4) moist; massive; loose, nonsticky and nonplastic; strongly effervescent; 30 percent gravel, 10 percent cobbles; slightly alkaline; gradual wavy boundary.

3Bkb—45 to 60 inches; pale yellow (5Y 8/3) channery sandy clay loam, pale yellow (5Y 7/3) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; 25 percent soft shale fragments; strongly effervescent; many large, white (5YR 8/2) soft masses of calcium carbonate in rounded pockets and vertical seams; slightly alkaline.

Range in Characteristics

Particle-size control section: 35 to 45 percent clay
Depth to calcic horizon: 20 to 40 inches

A horizon
Hue: 10YR to 5YR
Value: 5 to 7 dry, 3 to 6 moist
Chroma: 3 or 4

Bt horizon
Hue: 7.5YR to 2.5YR
Value: 4 to 7 dry, 3 to 7 moist
Chroma: 2 to 6

Bk horizon
Hue: 7.5YR to 2.5YR
Value: 5 to 7 dry, 3 to 7 moist
Chroma: 4 to 8

Tijeras Series

Map units: 109, 112
Depth class: very deep
Drainage class: well drained
Landform: fan remnants and ridges
Parent material: fan alluvium derived from granite
Elevation: 5,100 to 5,600 feet (1,554 to 1,707 meters)
Slope: 1 to 6 percent
Climatic data:
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Taxonomic class: Fine-loamy, mixed, mesic Typic Haplargids

Typical Pedon

Tijeras gravelly fine sandy loam, in an area of mapping unit 109; Embudo-Tijeras association, 1 to 9 percent slopes; Sandoval County; Alameda Quadrangle; located about 2 miles east of interstate highway 25 and .75 mile north of the Bernalillo-Sandoval County line; 2,500 feet east and 2,000 feet south of the northwest corner of sec. 32, T. 12 N., R. 4 E. NAD 83, UTM 13—03 59 674 E—38 99 074 N.

A—0 to 4 inches; pale brown (10YR 6/3) gravelly fine sandy loam; brown (10YR 4/3) moist; moderate fine granular structure; slightly hard, friable, slightly sticky and nonplastic; many fine roots; 20 percent gravel; moderately alkaline; clear smooth boundary.
Bt—4 to 10 inches; brown (7.5YR 5/4) sandy clay loam, dark brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; slightly hard, friable, sticky and slightly plastic; common fine roots; common fine tubular pores; common thin clay films on faces of peds; moderately alkaline; clear wavy boundary.

Btk—10 to 20 inches; light brown (7.5YR 6/4) sandy clay loam, brown (7.5YR 5/4) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine roots; common fine tubular pores; few thin clay films on faces of peds; slightly effervescent; few fine rounded calcium carbonate masses; moderately alkaline; clear wavy boundary.

Bk1—20 to 26 inches; pink (7.5YR 7/4) gravelly sandy loam, light brown (10YR 6/4) moist; massive; hard, friable, slightly sticky and slightly plastic; few fine tubular pores; 20 percent gravel; strongly effervescent; few, medium rounded calcium carbonate masses; moderately alkaline; gradual wavy boundary.

Bk2—26 to 60 inches; pink (7.5YR 7/4) very gravelly coarse sandy loam, brown (7.5YR 5/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; 50 percent gravel; slightly effervescent; few fine rounded pink calcium carbonate masses; moderately alkaline.

Range in Characteristics

Particle-size control section: 18 to 30 percent clay

A horizon
Hue: 7.5YR or 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 4

Bt horizon
Hue: 5YR to 10YR
Value: 4 to 6 dry, 3 to 5 moist
Chroma: 2 to 5

Bk horizon
Hue: 7.5YR or 10YR
Value: 5 to 7 dry, 4 to 6 moist
Content of rock fragments: 35 to 70 percent granite gravel

Tocal Series

Map unit: 282
Depth class: very shallow to shallow
Drainage class: well drained
Landform: interfluves on plateaus
Parent material: eolian material over residuum derived from tuff
Elevation: 7,000 to 8,000 feet (2,134 to 2,438 meters)
Slope: 3 to 8 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90days

Taxonomic class: Clayey, mixed Lithic Eutroboralfs

Typical Pedon

Tocal very fine sandy loam, in an area of mapping unit 282, Tocal very fine sandy loam, 3 to 8 percent slopes; Los Alamos County; Guaje Mountain Quadrangle; about .5 mile northwest of LASL administration building; 750 feet west and 700 feet south of the center of sec. 17, T. 19 N., R. 6 E. NAD 83, UTM 13—03 79 860 E—39 70 969 N.

A—0 to 5 inches; grayish brown (10YR 5/2) very fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine roots; many interstitial pores; neutral; abrupt smooth boundary.
Bt1—5 to 8 inches; reddish brown (5YR 5/3) clay loam, reddish brown (5YR 4/3) moist; moderate fine subangular blocky structure; hard, friable, sticky and plastic; many fine roots; few very fine interstitial pores; thin continuous clay films on faces of peds; neutral; abrupt smooth boundary.
Bt2—8 to 11 inches; reddish brown (5YR 5/3) clay, reddish brown (5YR 4/3) moist; moderate coarse prismatic structure parting to moderate medium subangular blocky; hard, friable, sticky and plastic; many medium roots; few very fine tubular pores; thick continuous clay films on faces of peds; neutral; clear smooth boundary.
2Bt3—11 to 14 inches; light brown (7.5YR 6/4) silt loam, dark brown (7.5YR 4/4) moist; massive; hard, friable, sticky and plastic; many medium roots; few very fine tubular pores; few reddish brown (5YR 4/4) clay filling in pores; neutral; abrupt smooth boundary.
2Cr—14 inches; tuff.

Range in Characteristics

Particle-size control section: 15 to 45 percent clay
Depth to tuff bedrock: 8 to 20 inches

A horizon
Hue: 7.5YR or 10YR
Value: 4 to 6 dry, 2 to 4 moist
Chroma: 2 or 3

B horizon
Hue: 7.5YR or 5YR
Value: 4 to 6 dry, 3 or 4 moist
Chroma: 3 to 6

Totavi Series

Map units: 52, 88
Depth class: very deep
Drainage class: somewhat excessively drained
Landform: stream terraces, closed depressions, and valley floors
Parent material: stream alluvium derived from tuff and pumice
Elevation: 7,000 to 8,800 feet (2,134 to 2,682 meters)
Slope: 0 to 5 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Ashy, frigid Mollic Vitrandepts

Typical Pedon

Totavi loamy sand, in an area of mapping unit 52, Totavi loamy sand, 0 to 5 percent slopes; Los Alamos County; Frijoles Quadrangle; about 1.4 miles east of Meson Lab entrance; 100 feet south and 150 feet east of the center of sec. 24, T. 19 N., R. 6 E. NAD 83, UTM 13—03 86 516 E—39 69 460 N.

A—0 to 15 inches; grayish brown (10YR 5/2) loamy sand, very dark brown (10YR 2/2) moist; weak medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; many very fine and fine roots; 10 percent pebble-sized tuff and pumice fragments; neutral; abrupt wavy boundary.
C1—15 to 19 inches; grayish brown (10YR 5/2) loamy sand, very dark grayish brown (10YR 3/2) moist; single grain; loose, very friable, nonsticky and nonplastic; common very fine and fine roots; about 50 percent of the fine earth fraction is medium or coarser sand; 10 percent pebble-sized tuff and pumice fragments; neutral; abrupt boundary.
C2—19 to 60 inches; grayish brown (10YR 5/2) loamy sand, very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky structure; soft, very friable, nonsticky and plastic; few very fine roots; about 35 percent of the fine earth fraction is medium or coarser sand; 10 percent pebble-sized tuff and pumice fragments; neutral.

Range in Characteristics

Particle-size control section: 5 to 15 percent clay
Content of rock fragments: tuff, pumice, latite, dacite

A horizon
Hue: 7.5YR or 10YR
Value: 4 or 5 dry, 2 or 3 moist
Chroma: 2 or 3, dry or moist
Texture: loamy sand or sandy loam

C or Bw horizon
Hue: 7.5YR or 10YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 2 to 4

Trail Series

Map units: 10, 11, 29, 430, 431, 830, 831
Depth class: very deep
Drainage class: moderately well drained, somewhat excessively drained
Landform: flood plains, alluvial fans, channels, and valley floor remnants
Parent material: eolian material and stream alluvium derived from sandstone
Elevation: 5,000 to 6,000 feet (1,524 to 1,829 meters)
Slope: 0 to 4 percent
Climatic data:
Mean annual precipitation: 8 to 10 inches (203 to 254 millimeters)
Mean annual air temperature: 53 to 55 degrees F. (11.7 to 12.8 degrees C.)
Frost-free period: 140 to 160 days

Taxonomic class: Sandy, mixed, mesic Typic Torrifluvents

Typical Pedon

Trail fine sandy loam, in an area of mapping unit 11, Trail fine sandy loam, 0 to 1 percent slopes; Sandoval County; Jemez Pueblo Quadrangle; Pena Blanca Area, unsectionized; NAD 83, UTM 13—03 47 611 E—39 36 023 N.

Ap—0 to 9 inches; light yellowish brown (10YR 6/4) fine sandy loam, brown (10YR 4/3) moist; massive; soft, very friable, slightly sticky and slightly plastic; common fine roots; strongly effervescent; moderately alkaline; clear smooth boundary.

C1—9 to 36 inches; very pale brown (10YR 7/4) loamy sand with stratum of sandy loam, brown (10YR 4/3) moist; massive; soft, very friable, nonsticky and nonplastic; few fine roots; strongly effervescent; strongly alkaline; clear smooth boundary.
C2—36 to 60 inches; very pale brown (10YR 7/4) sandy loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; strongly effervescent; strongly alkaline.

Range in Characteristics

A horizon
Hue: 2.5YR to 10YR
Value: 5 to 7 dry, 4 to 6 moist
Chroma: 2 to 6 dry, 2, 3 or 4 moist
Texture: loamy sand, fine sandy loam, loam, or silty clay loam

C horizon
Hue: 2.5YR to 10YR
Value: 5 to 7 dry, 4 to 6 moist
Chroma: 2 to 6 dry, 2, 3 or 4 moist
Texture: loamy sand, loamy fine sand, fine sand, sand with thin strata of sandy loam, fine sandy loam, very fine sandy loam, loam, silt loam

Tranquilar Series

Map units: 302, 311
Depth class: very deep
Drainage class: somewhat poorly drained
Landform: stream terraces and valley floors
Parent material: lacustrine deposits from rhyolite and tuff
Elevation: 8,500 to 9,200 feet (2,591 to 2,804 meters)
Slope: 1 to 8 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Very-fine, montmorillonitic, frigid Typic Argialbolls

Typical Pedon

Tranquilar silty clay loam, in an area of mapping unit 302, Tranquilar-Jarmillo complex, 1 to 8 percent slopes; Sandoval County; Valle San Antonio Quadrangle; about 2.5 miles southeast from the northwest corner of Baca Location No. 1; unsectionized; NAD 83, UTM 13—03 56 228 E—39 83 041 N.

A1—0 to 4 inches; dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure; soft, very friable, sticky and plastic; many fine and very fine roots; slightly acid; clear smooth boundary.
A2—4 to 8 inches; dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure; slightly hard, friable, sticky and plastic; common very fine and few medium roots; slightly acid; clear smooth boundary.
E1—8 to 11 inches; gray (10YR 6/1) silty clay loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure; slightly hard, friable, sticky and plastic; few very fine roots; slightly acid; abrupt smooth boundary.

E2—11 to 13 inches; light gray (10YR 7/2) ped exteriors silty clay loam, dark grayish brown (10YR 4/2) moist; ped interiors, light brownish gray (10YR 6/2), very dark grayish brown (10YR 3/2) moist; few fine faint reddish yellow (7.5YR 6/6) mottles inside peds; weak thin platy structure; slightly hard, friable, sticky and plastic; few very fine roots; medium acid; abrupt smooth boundary.

Bt1—13 to 20 inches; very dark grayish brown (10YR 3/2) ped exteriors clay, very dark brown (10YR 2/2) moist; ped interiors brown (10YR 5/3), dark brown (10YR 3/3) moist; few fine faint reddish yellow (7.5YR 6/6) mottles inside peds; strong medium prismatic structure parting to strong medium angular blocky; very hard, very firm, very sticky and very plastic; few very fine and few medium roots; thin organic films; thin clay films on faces of peds; pressure faces on a few peds; strongly acid; gradual wavy boundary.

Bt2—20 to 34 inches; dark grayish brown (10YR 4/2) ped exteriors clay, very dark grayish brown (10YR 3/2) moist; clay interiors very pale brown (10YR 7/3), brown (10YR 4/3) moist; few fine faint reddish yellow (7.5YR 6/6) mottles inside peds; strong medium angular blocky structure; very hard, very firm, very sticky and very plastic; few very fine roots; continuous moderately thick clay films and organic stains on faces of peds; pressure faces on a few peds; very strongly acid; gradual wavy boundary.

Bt3—34 to 42 inches; light yellowish brown (10YR 6/4) clay, dark yellowish brown (10YR 4/4) moist; common fine prominent yellowish red (5YR 5/6) mottles; moderate coarse prismatic structure parting to moderate fine and medium angular blocky; very hard, very firm, very sticky and very plastic; few very fine and medium roots; continuous moderately thick clay films on faces of peds with discontinuous patchy organic films; pressure faces on a few peds; very strongly acid; gradual wavy boundary.

Bt4—42 to 50 inches; light gray (2.5Y 7/2) clay, light brownish gray (2.5Y 6/2) moist; common, fine, prominent reddish yellow (7.5YR 6/6) mottles; weak coarse prismatic structure parting to moderate fine and medium angular blocky; very hard, very firm, very sticky and very plastic; few very fine and medium roots; continuous moderately thick clay films on faces of peds; pressure faces on a few peds; extremely acid; gradual wavy boundary.

Bt5—50 to 60 inches; light gray (2.5Y 7/2) clay, light brownish gray (2.5Y 6/2) moist; common fine prominent reddish yellow (7.5YR 6/8) mottles; very dark grayish brown (2.5Y 3/2) moist; moderate coarse prismatic structure parting to moderate fine and medium subangular blocky; hard, firm, sticky and plastic; few very fine and medium roots; continuous moderately thick clay films on faces of peds; very strongly acid; gradual wavy boundary.

Range in Characteristics

Particle-size control section: 60 to 75 percent clay
Depth to a seasonal water table: 20 to 48 inches from March to July

A horizon
Value: 3 to 5 dry, 2 or 3 moist
Chroma: 1 or 2 dry or moist
Texture: silt loam, silty clay loam

E horizon
Value: 5 to 7 dry, 3 to 6 moist
Chroma: 1 or 2 dry or moist
Texture: silt loam or silty clay loam

Bt horizon
Hue: 7.5YR or 10YR
Value: 3 to 7 dry, 2 to 7 moist
Chroma: 3 to 8

Tsosie Series

Map unit: 270
Depth class: very deep
Drainage class: well drained
Landform: stream terraces and alluvial fans
Parent material: stream alluvium derived from shale and sandstone
Elevation: 6,600 to 7,000 feet (2,012 to 2,134 meters)
Slope: 0 to 3 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Fine-loamy, mixed, calcareous, mesic Ustic Torriorthents

Typical Pedon

Tsosie clay loam, in an area of mapping unit 270, Blancot-Councelor-Tsosie association, 0 to 5 percent slopes; Sandoval County; Galisteo SE Quadrangle; about 8 miles south of Galisteo, 1,100 feet north and 2,200 feet west of the southeast corner of sec. 6, T. 21 N., R. 6 W. NAD 83, UTM 13—02 74 088 E—39 95 089 N.

A—0 to 2 inches; pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; few very fine and fine roots; few very fine and fine continuous pores; slightly effervescent; moderately alkaline; clear smooth boundary.
C1—2 to 10 inches; brown (10YR 5/3) loam, dark brown (10YR 4/3) moist; massive; hard, firm, slightly sticky and slightly plastic; common very fine roots; slightly effervescent; strongly alkaline; clear gradual boundary.
C2—10 to 20 inches; brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; massive; very hard, very firm, sticky and plastic; few very fine roots; strongly effervescent; strongly alkaline; clear smooth boundary.
C3—20 to 26 inches; pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; massive; hard, firm, slightly sticky and slightly plastic; few very fine roots; slightly effervescent; strongly alkaline; clear smooth boundary.
C4—26 to 36 inches; yellowish brown (10YR 5/4) clay loam, dark yellowish brown (10YR 4/4) moist; massive; hard, friable, slightly sticky and slightly plastic; few very fine roots; few very fine continuous pores; strongly alkaline; clear smooth boundary.
C5—36 to 44 inches; yellowish brown (10YR 5/4) sandy loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; few very fine roots; moderately alkaline; clear smooth boundary.
C6—44 to 55 inches; pale brown (10YR 6/3) sandy loam, brown (10YR 5/3) moist; massive; soft, very friable, nonsticky and nonplastic; strongly alkaline; clear smooth boundary.
C7—55 to 60 inches; pale brown (10YR 6/3) sandy loam, brown (10YR 5/3) moist; massive; slightly hard, friable, nonsticky and nonplastic; strongly effervescent; strongly alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay

A horizon
Hue: 2.5Y or 10YR
Value: 5 to 7 dry, 4 or 5 moist
Chroma: 2 to 4

C horizon
Hue: 2.5Y or 10YR
Value: 5 to 7 dry, 3 to 5 moist
Chroma: 2 to 4
Texture: clay loam, sandy clay loam, or loam in upper part of the subsoil; stratified sandy loam to silty clay loam in the lower part.

Note: In some pedons, fine sandy loam, sandy loam, and silt loam textures occur below the control section or as thin lenses within it.

Vastine Series

Map unit: 301
Depth class: very deep
Drainage class: poorly drained
Landform: flood plains, stream terraces, and valley floors
Parent material: mixed stream alluvium
Elevation: 8,400 to 8,600 feet (2,560 to 2,621 meters)
Slope: 0 to 3 percent
Climatic data:
Mean annual precipitation: 20 to 25 inches (508 to 635 millimeters)
Mean annual air temperature: 42 to 45 degrees F. (5.6 to 7.2 degrees C.)
Frost-free period: 60 to 90 days

Taxonomic class: Fine-loamy over sandy or sandy-skeletal, mixed, frigid Typic Haplaquolls

Typical Pedon

Vastine silt loam, in an area of mapping unit 301, Vastine-Jarola silt loams, 0 to 5 percent slopes; Sandoval County; Valle San Antonio Quadrangle; about .1 mile southwest of hot springs in San Antonio Valley, Baca Location No. 1; unsectionized; NAD 83, UTM 13—03 59 079 E—39 81 660 N.

A1—0 to 4 inches; dark gray (10YR 4/1) silt loam, black (10YR 2/1) moist; moderate medium granular structure; slightly hard, firm, sticky and plastic; many fine and very fine roots; neutral; clear smooth boundary.
A2—4 to 11 inches; gray (10YR 5/1) loam, very dark gray (10YR 3/1) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; common fine and few very fine roots; neutral; gradual smooth boundary.
Bw—11 to 24 inches; light gray (10YR 6/1) loam, gray (10YR 5/1) moist; common fine distinct pale yellow (2.5Y 7/4) mottles; moderate medium blocky structure; hard, firm, sticky and plastic; few fine roots; 10 percent gravel; neutral; clear smooth boundary.
2C—24 to 60 inches; gray (10YR 5/1) very gravelly loamy sand, dark gray (10YR 4/1) moist; massive; loose, nonsticky and nonplastic; 55 percent gravel; slightly alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay in the upper part of the subsoil
Depth to a seasonal high water table: 12 to 36 inches
Depth to the gravelly substratum: 24 to 33 inches

A horizon
Hue: 5Y to 7.5YR
Value: 4 or 5 dry, 2 or 3 moist
Chroma: 1 or 2

B horizon
Hue: 5Y to 7.5YR
Value: 4 to 6 dry, 2 to 5 moist
Chroma: 0 to 8.
Other features: colors in this horizon are variegated in some pedons

2C horizon
Hue: 5Y to 7.5YR
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 1 to 3
Content of rock fragments: 35 to 60 percent gravel is common below 24 inches
Other features: colors in this horizon are variegated in some pedons

Vessilla Series

Map units: 17, 220, 325, 342, 397, 422
Depth class: very shallow to shallow
Drainage class: well drained
Landform: structural benches on escarpments and breaks; sideslopes of hills, mesas, and ridges
Parent material: eolian material, slope alluvium, and residuum derived from sandstone
Elevation: 6,000 to 7,500 feet (1,829 to 2,286 meters)
Slope: 3 to 65 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Loamy, mixed, calcareous, mesic Lithic Ustorthents

Typical Pedon

Vessilla gravelly fine sandy loam, in an area of mapping unit 397, Rock outcrop-Cucho-Vessilla complex, 25 to 70 percent slopes; Sandoval County; Holy Ghost Spring Quadrangle; 15 miles northwest of San Ysidro; NAD 83, UTM 13—03 28 014 E—39 50 605 N.

A—0 to 2 inches; light yellowish brown (10YR 6/4) gravelly fine sandy loam, yellowish brown (10YR 5/4) moist; weak fine granular structure; soft, very friable, slightly sticky and nonplastic; common fine and medium fine roots; 25 percent gravel; strongly effervescent; moderately alkaline; clear smooth boundary.
C—2 to 11 inches; light brown (7.5YR 6/4) gravelly fine sandy loam, brown (7.5YR 5/4) moist; massive; loose, nonsticky and nonplastic; common fine roots; 20 percent gravel; strongly effervescent; moderately alkaline; abrupt smooth boundary.
R—11 inches; sandstone.

Range in Characteristics

Particle-size control section: 12 to 20 percent clay
Depth to sandstone: 4 to 20 inches

A and C horizons
Hue: 7.5YR or 10YR
Value: 4 to 7 dry, 4 to 6 moist
Chroma: 3 to 6 dry or moist
Texture: sandy loam, fine sandy loam, loamy sand, loam, gravelly fine sandy loam, gravelly loamy sand, gravelly sandy loam, very gravelly sandy loam, gravelly loam, and channery loam

Waumac Series

Map units: 300, 307, 314, 321, 342
Depth class: very deep
Drainage class: well drained
Landform: alluvial fans, valley floors, and stream terraces
Parent material: fan and stream alluvium derived from sandstone and igneous rocks
Elevation: 5,400 to 6,900 feet (1,646 to 2,103 meters)
Slope: 1 to 20 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Coarse-loamy, mixed, calcareous, mesic Typic Ustorthents

Typical Pedon

Waumac loamy sand, in an area of mapping unit 300, Waumac-Bamac association, 1 to 7 percent slopes; Sandoval County; Santo Domingo Pueblo Quadrangle; one-half mile south of the Cochiti Indian Pueblo, 100 yards east of the Highway 85; 100 feet west and 1,070 feet north of the southeast corner of sec. 24, T. 16 N., R. 5 E. NAD 83, UTM 13—03 77 273 E—39 40 079 N.

A—0 to 3 inches; pale brown (10YR 6/3) loamy sand, dark grayish brown (10YR 4/2) moist; weak thin platy structure; soft, very friable, nonsticky and nonplastic; many very fine and common fine roots; few fine tubular pores; moderately alkaline; clear smooth boundary.
C1—3 to 31 inches; pale brown (10YR 6/3) fine sandy loam, dark yellowish brown (10YR 4/4) moist; massive; loose, nonsticky and nonplastic; few very fine roots; slightly effervescent; moderately alkaline; gradual wavy boundary.
C2—31 to 60 inches; pale brown (10YR 6/3) gravelly fine sandy loam; dark yellowish brown (10YR 4/4) moist; massive; slightly hard, friable, nonsticky and nonplastic; 20 percent gravel; slightly effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 10 to 18 percent clay

A horizon
Hue: 7.5YR, 10YR or 2.5Y
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 2 to 4
Texture: loamy sand or loamy fine sand

C horizon
Hue: 5YR, 7.5YR or 10YR
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 3 or 4
Texture: sandy loam, fine sandy loam, and gravelly fine sandy loam
Note: Thin strata of loamy sand and coarse sandy loam occur in some pedons. This horizon can be noncalcareous to depths of 18 inches in some pedons.

Waumac Variant Series

Map unit: 354
Depth class: shallow
Drainage class: well drained
Landform: hills
Parent material: coarse textured material derived from tuff
Elevation: 5,600 to 5,900 feet (1,707 to 1,798 meters)
Slope: 1 to 15 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (305 to 356 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10.0 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Ashy-skeletal, mesic, shallow Typic Ustorthents

Typical Pedon

Waumac Variant very gravelly sandy loam, in an area of mapping unit 354, Waumac variant very gravelly sandy loam, 1 to 15 percent slopes; Sandoval County; Cochiti Dam Quadrangle; 0.5 mile south of the old sawmill, 2,200 feet north and 1,000 feet east of the southwest corner of sec. 31, T. 17 N., R. 6 E. NAD 83, UTM 13—03 77 535 E—39 46 752 N.

A—0 to 3 inches; light brownish gray (10YR 6/2) very gravelly sandy loam, dark yellowish brown (10YR 3/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; common very fine roots; common interstitial pores; 55 percent gravel; slightly alkaline; clear smooth boundary.
C—3 to 12 inches; light brownish gray (10YR 6/2) very gravelly sandy loam, dark yellowish brown (10YR 3/4) moist; massive; slightly hard, very friable, nonsticky and nonplastic; common very fine roots; common interstitial pores; 55 percent gravel; slightly alkaline.
Cr—12 inches; tuff.

Range in Characteristics

Particle-size control section: 10 to 18 percent clay
Depth to paralithic contact: 10 to 20 inches

A horizon:
Hue: 10YR
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 2 to 4

C horizon
Hue: 10YR
Value: 5 or 6 dry, 4 or 5 moist
Chroma: 3 or 4

Wauquie Series

Map units: 348, 414, 419
Depth class: very deep
Drainage class: well drained
Landform: mountain slopes, benches, canyons, hills, and mesas
Parent material: slope alluvium and colluvium derived from granite and shale
Elevation: 6,000 to 8,400 feet (1,829 to 2,560 meters)
Slope: 8 to 55 percent
Climatic data:
Mean annual precipitation: 13 to 16 inches (330 to 406 millimeters)
Mean annual air temperature: 48 to 52 degrees F. (10 to 11.1 degrees C.)
Frost-free period: 110 to 130 days

Taxonomic class: Loamy-skeletal, mixed, mesic Aridic Haplustalfs

Typical Pedon

Wauquie extremely cobbly fine sandy loam, in an area of mapping unit 419; Santa Fe-Wauquie-Rock outcrop, 25 to 70 percent slopes; Sandoval County; La Ventana Quadrangle; about 5 miles east of La Ventana; unsectionized; NAD 83, UTM 13—03 28 986 E—39 62 292 N.

A—0 to 4 inches; reddish brown (5YR 5/4) extremely cobbly fine sandy loam, dark reddish brown (5YR 3/4) moist; moderate fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine and common medium roots; many very fine vesicular pores; 5 percent stones; 25 percent cobbles, and 45 percent gravel; neutral; clear smooth boundary.

Bt1—4 to 11 inches; reddish brown (2.5YR 4/4) extremely cobbly sandy clay loam, dark reddish brown (2.5YR 3/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; many very fine and common medium roots; common very fine tubular pores; common distinct clay films on faces of peds and in pores; 5 percent stones, 25 percent cobbles and 45 percent gravel; neutral; gradual smooth boundary.

Bt2—11 to 18 inches; reddish brown (2.5YR 4/4) extremely cobbly sandy clay loam, dark reddish brown (2.5YR 3/4) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common medium roots; common very fine tubular pores; common distinct clay films on faces of peds and in pores; 5 percent stones, 25 percent cobbles and 45 percent gravel; neutral; gradual smooth boundary.

Bt3—18 to 29 inches; reddish brown (5YR 4/4) extremely cobbly sandy loam, dark reddish brown (5YR 3/4) moist; massive; soft, friable, nonsticky and nonplastic; common medium roots; few very fine tubular pores; many colloidal stains on sand grains and gravel; 5 percent stones, 25 percent cobbles and 50 percent gravel; slightly alkaline; gradual smooth boundary.

Bk—29 to 60 inches; light reddish brown (5YR 6/4) extremely cobbly sand, reddish brown (5YR 5/4) moist; massive; loose, nonsticky and nonplastic; few medium roots; few interstitial pores; 5 percent stones, 25 percent cobbles, and 50 percent gravel; few calcium carbonate coatings on underside of gravel; slightly alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay

A horizon
Hue: 5YR to 10YR
Value: 3 to 6 dry, 2 to 4 moist
Chroma: 2 to 4
Texture: extremely gravelly sandy clay loam, extremely cobbly fine sandy loam, or very gravelly fine sandy loam

Bt horizon (Btk horizon in some pedons)
Hue: 2.5YR to 10YR
Value: 4 to 6 dry, 3 or 4 moist
Chroma: 2 to 6
Texture: very gravelly clay loam, extremely cobbly sandy clay loam, very gravelly sandy clay loam, and extremely cobbly sandy loam

Bk horizon
Hue: 2.5YR to 10YR
Value: 5 to 8 dry, 4 to 6 moist
Chroma: 2 to 6
Texture: very gravelly sandy loam, very gravelly loamy coarse sand, extremely gravelly loamy sand, extremely cobbly sandy loam, extremely cobbly sand, extremely cobbly loam

Winona Series

Map unit: 228
Depth class: shallow
Drainage class: well drained
Landform: hills and plateaus
Parent material: material derived from travertine
Elevation: 5,900 to 6,300 feet (1,798 to 1,920 meters)
Slope: 8 to 25 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Loamy-skeletal, carbonatic, mesic Lithic Ustollic Calciorthids

Typical Pedon

Winona very channery fine sandy loam, in an area of mapping unit 228, Winona very channery fine sandy loam, 8 to 25 percent slopes; Sandoval County; San Ysidro Quadrangle; about 10 miles northwest of San Ysidro; NAD 83, UTM 13—03 30 477 E—39 42 612 N.

A—0 to 2 inches; brown (7.5YR 5/4) very channery fine sandy loam, dark brown (7.5YR 4/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many very fine roots; 15 percent cobbles and 40 percent channers; coarse fragments are carbonate concretions and travertine fragments coated with pendants of calcium carbonate; violently effervescent; slightly alkaline; clear smooth boundary.
Bk—2 to 13 inches; brown (7.5YR 5/4) very channery loam, dark brown (7.5YR 4/4) moist; weak fine subangular blocky structure; soft, friable, slightly sticky and slightly plastic; common very fine roots; common very fine tubular pores; 45 percent channers with calcium carbonate pendants; violently effervescent; slightly alkaline.
R—13 inches; travertine.

Range in Characteristics

Particle-size control section: 15 to 30 percent clay
Depth to bedrock: 11 to 20 inches

A horizon
Hue: 5YR, 7.5YR, 10YR
Value: 4, 5, or 6 dry, 3 or 4 moist
Chroma: 2, 3, or 4 dry

Bk horizon
Hue: 5YR, 7.5YR, 10YR
Value: 5, 6, or 7 dry; 3, 4, 5, or 6 moist
Chroma: 2, 3, or 4, dry or moist

Witt Series

Map units: 34, 53, 217
Depth class: very deep
Drainage class: well drained
Landform: bajadas, fan terraces, and mesas
Parent material: Eolian material and fan alluvium from basalt
Elevation: 5,200 to 6,700 feet (1,585 to 2,042 meters)
Slope: 1 to 8 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Fine-silty, mixed, mesic Ustollic Haplargids

Typical Pedon

Witt loam, in an area of mapping unit 53, Witt-Harvey association, 1 to 7 percent slopes; Sandoval County; Golden Quadrangle; about 3 miles northwest of Golden; 300 feet south and 900 feet west of the northeast corner of sec. 1, T. 12 N., R. 6 E. NAD 83, UTM 13—03 86 526 E—39 07 226 N.

A—0 to 3 inches; brown (7.5YR 5/4) loam, brown (7.5YR 4/4) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine and medium roots; moderately alkaline; abrupt smooth boundary.
BA—3 to 6 inches; brown (7.5YR 4/4) silt loam, brown (7.5YR 4/4) moist; weak fine subangular blocky structure; hard, very friable, slightly sticky and slightly plastic; common fine and medium roots; mildly alkaline; clear smooth boundary.
Bt1—6 to 11 inches; brown (7.5YR 4/4) silty clay loam, brown (7.5YR 4/4) moist; moderate fine subangular blocky structure; hard, friable, slightly sticky and plastic; common fine and very fine roots; few thin clay films on faces of peds; strongly effervescent; mildly alkaline; clear smooth boundary.
Bt2—11 to 18 inches; light brown (7.5YR 6/4) silty clay loam, brown (7.5YR 4/4) moist; moderate fine and medium subangular blocky structure; hard, firm, sticky and plastic; common fine and very fine roots; few thin clay films on faces of peds; strongly effervescent; moderately alkaline; clear smooth boundary.
Btk—18 to 25 inches; light brown (7.5YR 6/4) silty clay loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; common fine and very fine roots; few thin clay films on faces of peds; strongly effervescent; common medium masses of calcium carbonate; moderately alkaline; clear smooth boundary.

Bk1—25 to 39 inches; light brown (7.5YR 6/4) silt loam, brown (7.5YR 4/4) moist; weak medium and fine subangular blocky structure; slightly hard, friable, sticky and plastic; many fine and very fine roots; strongly effervescent; common medium masses of calcium carbonate; moderately alkaline; abrupt smooth boundary.
Bk2—39 to 53 inches; pinkish white (7.5YR 8/2) silt loam, pinkish gray (7.5YR 7/2) moist; massive; slightly hard, firm, sticky and plastic; few very fine roots; violently effervescent; many medium masses of calcium carbonate; moderately alkaline; gradual wavy boundary.
C—53 to 60 inches; pink (7.5YR 7/4) silt loam, brown (7.5YR 5/4) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; few very fine roots; violently effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 18 to 35 percent clay

A horizon
Hue: 5YR, 7.5YR, 10YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 2 to 4
Texture: very fine sandy loam or loam

Bt horizon
Hue: 5YR, 7.5YR, 10YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 2 to 6
Texture: silty clay loam, silt loam, and loam

Bk horizon
Hue: 5YR or 7.5YR
Value: 5 to 8 dry, 4 to 7 moist
Chroma: 2 to 4
Texture: loam, silt loam, silty clay loam, or very fine sandy loam

Note: A C horizon is present in some pedons.

Zia Series

Map units: 66, 91, 93, 111, 114, 190, 207, 211, 234, 410
Depth class: very deep
Drainage class: somewhat excessively well drained
Landform: alluvial fans, stream terraces, summits of mesas and plateaus
Parent material: eolian material and fan and stream alluvium derived from sandstone
Elevation: 5,000 to 6,900 feet (1,524 to 2,103 meters)
Slope: 0 to 25 percent
Climatic data:
Mean annual precipitation: 10 to 13 inches (254 to 330 millimeters)
Mean annual air temperature: 52 to 54 degrees F. (11.1 to 12.2 degrees C.)
Frost-free period: 120 to 140 days

Taxonomic class: Coarse-loamy, mixed, calcareous, mesic Ustic Torriorthents

Typical Pedon

Zia sandy loam, in an area of mapping unit 211, Zia-Clovis association, 2 to 10 percent slopes; Sandoval County; Arroyo de las Calabacillas Quadrangle; about 6

miles east of Alamo Ranch Headquarters; 1,400 feet west and 300 feet north of the southeast corner of sec. 21, T. 13 N., R. 1 E. NAD 83, UTM 13—03 33 005 E—39 11 510 N.

A—0 to 5 inches; pale brown (10YR 6/3) sandy loam, dark brown (10YR 3/3) moist; weak medium granular structure; soft, friable, slightly sticky and slightly plastic; common very fine and few fine roots; 5 percent gravel; slightly effervescent; slightly alkaline; clear smooth boundary.

Bw—5 to 14 inches; pale brown (10YR 6/3) sandy loam, brown (10YR 4/3) moist; weak fine subangular blocky structure; soft, friable, slightly sticky and slightly plastic; few fine and very fine roots; strongly effervescent; slightly alkaline; clear smooth boundary.

C1—14 to 33 inches; light gray (10YR 7/2) sandy loam, brown (10YR 5/3) moist; massive; hard, friable, slightly sticky and slightly plastic; few fine and very fine roots; strongly effervescent; slightly alkaline; gradual smooth boundary.

C2—33 to 46 inches; very pale brown (10YR 7/3) sandy clay loam, yellowish brown (10YR 5/4) moist; massive; hard, firm, sticky and plastic; few fine and very fine roots; 5 percent gravel; violently effervescent; calcium carbonate as very few fine irregular masses; moderately alkaline; clear smooth boundary.

C3—46 to 60 inches; light yellowish brown (10YR 6/4) sandy loam, brown (10YR 5/3) moist; massive; soft, friable, slightly sticky and slightly plastic; 10 percent gravel; strongly effervescent; moderately alkaline.

Range in Characteristics

Particle-size control section: 8 to 18 percent clay

A horizon

Hue: 5YR to 10YR
Value: 4 to 7 dry, 3 to 5 moist
Chroma: 2 to 6
Texture: loamy sand, sandy loam, fine sandy loam, or loam

Bw or C horizon

Hue: 5YR to 10YR
Value: 4 to 8 dry, 3 to 7 moist
Chroma: 2 to 6
Texture: fine sandy loam or sandy loam. The C horizon contains strata of loamy sand or sandy clay loam in most pedons.

Factors of Soil Formation

Soil is a collection of natural bodies occurring on the earth's surface and is capable of supporting plants. Its properties result from the extent to which physical, chemical, and biological processes have affected the material from which soil is derived, the parent material. The main processes active in the soils of the Sandoval County area are: weathering of soil particles and rock material through dissolution and disintegration; accumulation and oxidation of organic matter in surface layers; formation of soil structure and surface crusting; movement of dissolved soil constituents with soil water, and precipitation of soil constituents from soil water; and movement of clay particles with soil water downward through the soil.

Most of these soil processes enhance plant growth, and some bring about hindrances to plant growth. Some soil processes are dependent upon other processes having reached a certain stage. Soil processes, or their lack, give the present soil its characteristics and are governed by five soil-forming factors: *time, parent material, climate, relief*, and *living organisms*. Understanding and recognizing soil-forming processes that occur affords the soil user the ability to predict the capability of soils for many uses.

Climate

The *climate* of an area is greatly responsible for the types of soil processes and for the rate at which these processes occur. The main features of climate affecting soil processes are precipitation and temperature.

The climate of the Sandoval County area at present is semi-arid continental. The lowest areas have annual precipitation of about eight inches and mean annual air temperature of about 55 degrees. These being the driest are areas of least vegetation. The small amount of organic matter produced by the vegetation is rapidly oxidized, resulting in soils with light colored surface horizons as in Sheppard and Grieta series.

With increased temperature, chemical and biochemical reactions are hastened. In addition, freeze-thaw cycles speed the weathering of soil and rock particles. The temperature also greatly affects evaporation of water from the soil and transpiration of water from plants.

As the amount of precipitation increases, the potential amount of vegetation on a soil increases. The number of days per year that the soil is moist during the frost-free period determines how much vegetation can be supported and the time during which soil processes occur. The depth to which water penetrates the soil is also very important as it determines the maximum depth of root penetration and the depth beyond which soil transforming processes are greatly slowed. If there is not enough precipitation for water to move through the entire soil and enter the ground water system, calcium carbonate deposits are precipitated at the depth of maximum water penetration.

In the cold, wet, mountainous areas of the Sandoval County area, soils such as Redondo and Calaveras series support stands of large trees. These areas receive 25 or more inches of precipitation per year and the average annual air temperature is about 40 degrees F. The soils in these areas are moist more days per year than most

other soils in the Sandoval County area. The cooler temperatures allow for a buildup of organic matter in the surface layers of these soils.

Older soils in the area have been influenced by past climates. Past climates were similar to the present one, but slightly more moist and cooler. Similar soil processes took place, at an accelerated rate when compared to present conditions. For this reason, some soils in the driest part of the Sandoval County area have strongly developed features such as the petrocalcic horizon of the Pastura series, and the calcic and argillic horizons of the Clovis series.

Living Organisms

The life associated with a soil greatly influences the processes within, the features and the characteristics of a soil.

The vegetation supported by a soil is part of this life. Plant roots provide channels for water flow into depths of soils which otherwise might receive little water. Plant material provides the bulk of the organic portion of soil that is important to fertility. Plant life is very important in retaining soils in place, protecting them from erosion. A good plant cover will reduce evaporation of water from the soil surface and reduce runoff, providing a soil with more moist days each year. The plant cover also shades the soil surface and causes the soil to stay cooler than areas exposed to direct sunlight.

Soil insects, worms, and rodents affect aeration and intake rate by mixing and burrowing. Some animals affect the vegetation on the soil by their eating habits. Large animals, especially in dry areas where soil crusts form, enhance seed germination by walking across the soil surface, providing in their hoof prints a favorable seedbed.

Microscopic organisms function importantly in nutrient cycling. Fungi, bacteria, nematodes, and others process organic material and release nutrients for further plant growth. They also add acids, gases, and other chemical compounds that affect soil processes.

Many soils have been changed as a result of human intervention. People change vegetation on soils, animal and microbial life of soils, soil climate, and relief, through urban development, farming, ranching, logging, and sundry enterprises.

Topography

Soil *topography* has a profound influence on the development of soil features. Its many facets, including degree of slope, direction of slope, shape and roughness of slope, influence the climate of a soil and the extent of erosive forces affecting a soil.

On steep soils, erosion potential is greatest and soil features develop slowly. As organic matter accumulations and weathered soil material washes away, new soil parent material or bedrock nears the surface. If the erosion is moderate or severe, it is accompanied by a decrease in vegetation and an increase in runoff water, which in turn enhances the erosion.

Soils on very slight or level slopes often receive depositions of soil material. This process also slows the development of soil features, since soil material is buried too deeply before soil transforming processes are able to cause features to develop. This process is accompanied by an increase in amount of vegetation since along with new material, the soil receives run-on water.

The climate of a soil is affected greatly by the runoff or run-on water it sheds or receives.

Soils with a concave slope such as San Mateo or Sparank series receive a great amount of their moisture from adjacent, steeper slopes. Soils with more slope shed various amounts of water, depending on their steepness, amount of vegetation, and surface roughness. Soils with a very gravelly surface composed of angular pebbles

protruding from the surface can retain precipitation, even with a steep slope. A very gravelly surface of rounded, imbedded gravel however will shed water rapidly and deprive the soil of moisture.

On steep slopes there is a wide difference in climate between adjacent north-facing and south-facing slopes. Less direct sunlight on north-facing slopes results in an evapotranspiration rate and temperatures lower than that on south-facing slopes. This accounts for more days during which the soil is moist and more vegetation on north-facing slopes.

Topography has been an important factor in developing the landforms of this area. The following are landforms recognized in the survey area and some of the soils associated with them. Landforms are not static; they are continually being created and eroded.

Alluvial Fans

Alluvial fans originate from upslope landscapes. Sediment loads are deposited when slope gradients change from upland positions to less sloping landforms. An inherent feature of fan development is the continuously changing pattern of channels and loci of deposition. Over a long period of time, these changes ensure the maintenance of fans formed by distributing material widely over the surface. The soils on this landscape position are generally very deep with soil textures highly variable depending on the local geology from which they are formed. In this survey, the soil series found on alluvial fan positions are the Querencia series.

Dunes

This landform has developed from Holocene-age and present-day eolian sands. These relatively small transverse dunes formed perpendicular to the prevailing winds. Most dunes in this area are stable due to the establishment of vegetation that restricts their activity. *Dunes* can be found as a component on most of the other landforms portrayed in this section. These soils can be very deep and located in large dune fields or as a shallow mantle over bedrock controlled surfaces. The Mespun series is found on dunes.

Escarpments

Escarpments are a familiar feature in the survey area. They are relatively steep slopes or cliffs produced by erosion and faulting. Due to the steep slopes the soils formed on this landform are generally shallow. Examples of soil series on escarpments are the Skyvillage and Santa Fe series.

Fan Remnants

On this position, soils exhibit different degrees of pedogenic (soil) development. The degree of development depends upon the amounts of translocated calcium carbonate and/or silicified clays, which are related to the age of the soil.

Fan remnants have been dissected or downcut to the point at which flooding rarely occurs. This landform has two important components. One is the summit, where erosional activity is relatively low. This area will show the different degrees of soil development and age. The second component is the side slope, where erosional activity is cutting uphill into the more stable summit. In most areas in the survey, the surface has a thick eolian mantle that is being eroded.

Soils on fan remnants vary greatly in their makeup. The Pinitos series can be found in the survey area on fan remnants.

Flood Plains

This landform is formed by early Holocene-age to present-day stream alluvium. In this survey area, floodwaters flow at low to very low gradients along valley floors and

are elongated in nature. The soils on these flood plains receive periodic depositions of fresh alluvium, causing an irregular decrease in organic carbon and weak to no soil development. Soils on this landform are predominantly very deep with soil textures highly variable depending on the local geology they are formed from. The Jocity and Trail soils are formed in flood plains found along the Rio Grande and Jemez Rivers.

Mesas and Cuestas

These landforms have two important components. The first consists of the mesa summit and the cuesta dipslope. They are both nearly level to gently sloping, bedrock-controlled surfaces that are generally stable. The Bond and Hagerman series are found on these surfaces. The soils are characterized by well-developed argillic horizons.

The second component is the escarpment, where erosional activity is cutting back into the more stable summit. Soils on this component have little or no horizon development due to the steep slopes where erosional activity is greatest. Typical soils representing this escarpment component are the Vessilla and Skyvillage series.

Mesas differ from cuestas in that an escarpment on all sides terminates the mesa summit, while a cuesta will generally have one or more sides that grade into the surrounding terrain following gentle slopes.

Stream Terraces

This position is the erosional remnant of the active flood plains that existed during the late Pleistocene to Holocene ages. The slopes are in the same general direction as the current flood plain. The soils in this position are underlain by stratified sand, gravel, loamy, silty, or clayey sediments and, in some cases, buried paleosols.

The soils on stream terraces have been stable for a sufficient time period to form cambic horizons. Formation of soil structure and accumulations of calcium carbonate and sometimes gypsum characterize a cambic horizon. This position is still subject to some flooding during major events. These rare flooding occurrences and the thin alluvial deposits from the floodwaters do not inhibit soil development. Typical soils that represent stream terraces are the Zia and Councelor series.

Mountains

The mountain slopes consist of multiple landforms and positions and may be formed by several processes are therefore not considered a geomorphic surface. Soil development on these landforms is highly dependent on the nature of the bedrock such as its chemical composition, grain size, and hardness. The most influential soil-forming factors in determining how soil developed on hills and mountains are time and the slope gradient of the bedrock.

Soils on this landform vary greatly in horizon development, from soils with no development to soils with well-developed argillic horizons. Soils that have little or no horizon development are usually found on the steeper slopes where erosional activity is greatest. Soils that have well-developed horizons are generally on gently sloping to moderately steep slopes where erosion is slight to moderate. The Redondo and Palon series are examples of soils found in the Jemez Mountains.

The interaction of all the facets of soil topography can account for wide soil variations over short distances.

Parent Material

A complex geologic history, ranging from formation of sedimentary rocks while great seas covered the earth, to volcanism and mountain forming processes provided a great many rock formations in the Sandoval County area, the constituents of which to a great extent, determined the chemical, mineralogical, and textural attributes of

the soils. Unless already unconsolidated, it is the decomposition and disintegration of these rocks which give rise to the *parent material* of soil.

Parent materials in the Sandoval County area fall into two broad categories. The first is material that, after weathering from rock, is not moved, but remains in place and is subject to soil-forming processes. The second category is unconsolidated rock-derived material that has been transported by water, wind, or by force of gravity.

Soils formed in non-transported materials have mineralogical, chemical and textural traits, which are directly related to the rock from which the material is derived. There are many examples of such soils in the Sandoval County area. The Bond, Hagerman, Skyvillage, Vessilla, and Sedgran series all contain high amounts of sand-sized quartz, inherited from their weathered sandstone parent material. Soils developed from weathered shale, such as Menefee, Sandoval, Camino, and Cucho series contain a great deal of silt- and clay-sized particles of various clay minerals, feldspars, and some quartz. Other soils formed in place from weathered rock material include the Sedgran and Osha series from weathered granite, the Redondo series from weathered tuff, and the Deama series from weathered limestone.

Soils formed in transported materials can have particles weathered from one rock type, a few or many types, depending on the method and distance of transport. *Colluvial* soils are formed in material moved by the force of gravity, which is transported a relatively short distance, down slopes. The Wauquie series formed in material moved down slopes after weathering from granite and shale. Alanos series formed in transported weathered tuff, and Palon series are formed in weathered rhyolite that has moved down slopes.

The second type of transported soil parent material is *eolian*, or wind blown sediments. These are materials that begin as particles on the surface of other soils, and end up comprising the entire depth of a new soil. The Pinavetes, Sheppard, and Royosa series, when found in upland areas, are derived from eolian sand.

Alluvium is the third type of transported soil parent material found in the Sandoval County area. It is material that has been moved and deposited by streams and rivers. Alluvium is rarely derived from one rock type, and its sediments generally are of diverse mineralogy diversified. Often alluvial sediments are sorted according to texture. It is deposited in layers, which are often well defined and contrasting in texture, color, and organic matter content. Alluvium is found throughout the Sandoval County area and its age varies greatly. Recent deposits of alluvium are found along the Rio Grande, Rio Puerco and their tributaries. Soils such as the Gilco, Aga, San Mateo, Peralta, Sparank, Jocity, and Sparham series are formed in recent alluvium and display well defined layering. Older alluvium, much of which was deposited by the ancestral Rio Grande and its tributaries is locally extensive in the survey area. Soil development processes have obliterated most evidence of layering in these soils. Some soils formed in old alluvium are Sheppard, Bamac, Espiritu, Cascajo, and Grieta series.

Many soils in the Sandoval County area are formed in more than one kind of parent material. Mountain soils, such as Laventana series, are often formed in a mantle of colluvium overlying in situ material weathered from bedrock. Soils atop basalt mesas, like Prieta series formed in in situ weathered basalt material mixed with eolian silt. Fragua series formed in eolian sands mixed with weathered sandstone, and sometimes have a cap of colluvial basalt particles. All soils in the area receive eolian deposits, in varying amounts. Often this is in minor yearly contributions of calcareous dust, which over many years can bring about a highly calcareous soil.

In addition to being the initial material on which soil processes act, the parent material partly affects which and how fast soil-transforming processes occur. This is affected mainly by the rate that the parent material weathers, its mineralogy and the particle size of its weathering products.

Time

The formation of parent material (the unconsolidated mineral and organic material which when exposed at the earth's surface give rise to soil) by the weathering of geologic deposits requires a great amount of *time*. In addition, soil processes require a period of time before bringing about soil properties significantly different from properties inherited from the parent material. Many soil processes are dependent on the previous operation of other, different soil processes.

Therefore, the amount of time that a soil has been in place is very important to its present character. In the Sandoval County area, soils in the Rio Grande and Rio Puerco valleys have been there a short time, resulting in soils like Gilco, Aga, Jocity, and Sparank series that have little evidence of operating soil processes except for the accumulation of a small amount of organic matter in the surface layer. These and other young soils resemble very closely the original parent material from which they were derived.

Older soils have developed features, such as argillic horizons, calcic horizons, cambic horizons, which indicate the relative length of time a soil has been in place, and which processes have been operational in the soil. The older a soil becomes, the less it resembles the parent material from which it was derived.

Recognition of horizons and features, with knowledge of how their accompanying processes affect soil fertility, soil bulk density and other properties give great insight into the value of soil for specific uses. All of the five soil-forming factors occur in wide variation throughout the Sandoval County area, resulting in a great variety of soils. These soils represent a great natural resource and provide for a multiplicity of land uses. Knowledge of soils and their formation can help the user to protect and use the resources wisely.

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Glossary

ABC soil. A soil having an A, a B, and a C horizon.

AC soil. A soil having only an A and a C horizon. Commonly, such soil formed in recent alluvium or on steep, rocky slopes.

Aeration, soil. The exchange of air in soil with air from the atmosphere. The air in a well aerated soil is similar to that in the atmosphere; the air in a poorly aerated soil is considerably higher in carbon dioxide and lower in oxygen.

Aggregate, soil. Many fine particles held in a single mass or cluster. Natural soil aggregates, such as granules, blocks, or prisms, are called peds. Clods are aggregates produced by tillage or logging.

Alkali (sodic) soil. A soil having so high a degree of alkalinity (pH 8.5 or higher) or so high a percentage of exchangeable sodium (15 percent or more of the total exchangeable bases), or both, that plant growth is restricted.

Alluvial cone. The material washed down the sides of mountains and hills by ephemeral streams and deposited at the mouth of gorges in the form of a moderately steep, conical mass descending equally in all directions from the point of issue.

Alluvial fan. The fanlike deposit of a stream where it issues from a gorge upon a plain or of a tributary stream near or at its junction with its main stream.

Alluvium. Material, such as sand, silt, or clay, deposited on land by streams.

Animal unit month (AUM). The amount of forage required by one mature cow of approximately 1,000 pounds weight, with or without a calf, for 1 month.

Aquic conditions. Current soil wetness characterized by saturation, reduction, and redoximorphic features.

Argillic horizon. A subsoil horizon characterized by an accumulation of illuvial clay.

Arroyo. The flat-floored channel of an ephemeral stream, commonly with very steep to vertical banks cut in alluvium.

Aspect. The direction in which a slope faces.

Association, soil. A group of soils or miscellaneous areas geographically associated in a characteristic repeating pattern and defined and delineated as a single map unit.

Available water capacity (available moisture capacity). The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil. The capacity, in inches, in a 60-inch profile or to a limiting layer is expressed as:

Very low	0 to 3
Low	3 to 6
Moderate	6 to 9
High	9 to 12
Very high	more than 12

Backslope. The position that forms the steepest and generally linear, middle portion of a hillslope. In profile, backslopes are commonly bounded by a convex shoulder above and a concave footslope below.

Badland. Steep or very steep, commonly nonstony, barren land dissected by many intermittent drainage channels. Badland is most common in semiarid and arid regions where streams are entrenched in soft geologic material. Local relief generally ranges from 25 to 500 feet. Runoff potential is very high, and geologic erosion is active.

Bajada. A broad alluvial slope extending from the base of a mountain range out into a basin and formed by coalescence of separate alluvial fans.

Base saturation. The degree to which material having cation-exchange properties is saturated with exchangeable bases (sum of Ca, Mg, Na, and K), expressed as a percentage of the total cation-exchange capacity.

Base slope. A geomorphic component of hills consisting of the concave to linear (perpendicular to the contour) slope that, regardless of the lateral shape, forms an apron or wedge at the bottom of a hillside dominated by colluvium and slope-wash sediments (for example, slope alluvium).

Bedding planes. Fine strata, less than 5 millimeters thick, in unconsolidated alluvial, eolian, lacustrine, or marine sediment.

Bedrock. The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

Bedrock-controlled topography. A landscape where the configuration and relief of the landforms are determined or strongly influenced by the underlying bedrock.

Bench terrace. A raised, level or nearly level strip of earth constructed on or nearly on a contour, supported by a barrier of rocks or similar material, and designed to make the soil suitable for tillage and to prevent accelerated erosion.

Blowout. A shallow depression from which all or most of the soil material has been removed by the wind. A blowout has a flat or irregular floor formed by a resistant layer or by an accumulation of pebbles or cobbles. In some blowouts the water table is exposed.

Bottom land. The normal flood plain of a stream, subject to flooding.

Boulders. Rock fragments larger than 2 feet (60 centimeters) in diameter.

Breaks. The steep and very steep broken land at the border of an upland summit that is dissected by ravines.

Brush management. Use of mechanical, chemical, or biological methods to make conditions favorable for reseeding or to reduce or eliminate competition from woody vegetation and thus allow understory grasses and forbs to recover. Brush management increases forage production and thus reduces the hazard of erosion. It can improve the habitat for some species of wildlife.

Butte. An isolated small mountain or hill with steep or precipitous sides and a top variously flat, rounded, or pointed that may be a residual mass isolated by erosion or an exposed volcanic neck.

Calcareous soil. A soil containing enough calcium carbonate (commonly combined with magnesium carbonate) to effervesce visibly when treated with cold, dilute hydrochloric acid.

Caliche. A more or less cemented deposit of calcium carbonate in soils of warm-temperate, subhumid to arid areas. Caliche occurs as soft, thin layers in the soil or as hard, thick beds directly beneath the solum, or it is exposed at the surface by erosion.

California bearing ratio (CBR). The load-supporting capacity of a soil as compared to that of standard crushed limestone, expressed as a ratio. First standardized in California. A soil having a CBR of 16 supports 16 percent of the load that would be supported by standard crushed limestone, per unit area, with the same degree of distortion.

Canopy. The leafy crown of trees or shrubs. (See “Crown.”)

Canyon. A long, deep, narrow, very steep sided valley with high, precipitous walls in an area of high local relief.

Capillary water. Water held as a film around soil particles and in tiny spaces between particles. Surface tension is the adhesive force that holds capillary water in the soil.

Catena. A sequence, or "chain," of soils on a landscape that formed in similar kinds of parent material but have different characteristics as a result of differences in relief and drainage.

Cation. An ion carrying a positive charge of electricity. The common soil cations are calcium, potassium, magnesium, sodium, and hydrogen.

Cation-exchange capacity. The total amount of exchangeable cations that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value. The term, as applied to soils, is synonymous with base-exchange capacity but is more precise in meaning.

Catsteps. Very small, irregular terraces on steep hillsides, especially in pasture, formed by the trampling of cattle or the slippage of saturated soil.

Cement rock. Shaly limestone used in the manufacture of cement.

Channery soil material. Soil material that has, by volume, 15 to 35 percent thin, flat fragments of sandstone, shale, slate, limestone, or schist as much as 6 inches (15 centimeters) along the longest axis. A single piece is called a "channer."

Chemical treatment. Control of unwanted vegetation through the use of chemicals.

Chiseling. Tillage with an implement having one or more soil-penetrating points that shatter or loosen hard, compacted layers to a depth below normal plow depth.

Clay. As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Clay depletions. Low-chroma zones having a low content of iron, manganese, and clay because of the chemical reduction of iron and manganese and the removal of iron, manganese, and clay. A type of redoximorphic depletion.

Clay film. A thin coating of oriented clay on the surface of a soil aggregate or lining pores or root channels. Synonyms: clay coating, clay skin.

Claypan. A slowly permeable soil horizon that contains much more clay than the horizons above it. A claypan is commonly hard when dry and plastic or stiff when wet.

Climax plant community. The stabilized plant community on a particular site. The plant cover reproduces itself and does not change so long as the environment remains the same.

Coarse textured soil. Sand or loamy sand.

Cobble (or cobblestone). A rounded or partly rounded fragment of rock 3 to 10 inches (7.6 to 25 centimeters) in diameter.

Cobbly soil material. Material that has 15 to 35 percent, by volume, rounded or partially rounded rock fragments 3 to 10 inches (7.6 to 25 centimeters) in diameter. Very cobbly soil material has 35 to 60 percent of these rock fragments, and extremely cobbly soil material has more than 60 percent.

COLE (coefficient of linear extensibility). See Linear extensibility.

Colluvium. Soil material or rock fragments, or both, moved by creep, slide, or local wash and deposited at the base of steep slopes.

Complex slope. Irregular or variable slope. Planning or establishing terraces, diversions, and other water-control structures on a complex slope is difficult.

Complex, soil. A map unit of two or more kinds of soil or miscellaneous areas in such an intricate pattern or so small in area that it is not practical to map them separately at the selected scale of mapping. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas.

Concretions. Cemented bodies with crude internal symmetry organized around a point, a line, or a plane. They typically take the form of concentric layers visible to the naked eye. Calcium carbonate, iron oxide, and manganese oxide are common

compounds making up concretions. If formed in place, concretions of iron oxide or manganese oxide are generally considered a type of redoximorphic concentration.

Conglomerate. A coarse grained, clastic rock composed of rounded or subangular rock fragments more than 2 millimeters in diameter. It commonly has a matrix of sand and finer textured material. Conglomerate is the consolidated equivalent of gravel.

Conservation tillage. A tillage system that does not invert the soil and that leaves a protective amount of crop residue on the surface throughout the year.

Consistence, soil. Refers to the degree of cohesion and adhesion of soil material and its resistance to deformation when ruptured. Consistence includes resistance of soil material to rupture and to penetration; plasticity, toughness, and stickiness of puddled soil material; and the manner in which the soil material behaves when subject to compression. Terms describing consistence are defined in the "Soil Survey Manual."

Control section. The part of the soil on which classification is based. The thickness varies among different kinds of soil, but for many it is that part of the soil profile between depths of 10 inches and 40 or 80 inches.

Coppice dune. A small dune of fine grained soil material stabilized around shrubs or small trees.

Corrosion. Soil-induced electrochemical or chemical action that dissolves or weakens concrete or uncoated steel.

Cover crop. A close-growing crop grown primarily to improve and protect the soil between periods of regular crop production, or a crop grown between trees and vines in orchards and vineyards.

Cropping system. Growing crops according to a planned system of rotation and management practices.

Crop residue management. Returning crop residue to the soil, which helps to maintain soil structure, organic matter content, and fertility and helps to control erosion.

Cuesta. A hill or ridge that has a gentle slope on one side and a steep slope on the other; specifically, an asymmetric, homoclinal ridge capped by resistant rock layers of slight or moderate dip.

Culmination of the mean annual increment (CMAI). The average annual increase per acre in the volume of a stand. Computed by dividing the total volume of the stand by its age. As the stand increases in age, the mean annual increment continues to increase until mortality begins to reduce the rate of increase. The point where the stand reaches its maximum annual rate of growth is called the culmination of the mean annual increment.

Deferred grazing. Postponing grazing or resting grazing land for a prescribed period.

Depth, soil. Generally, the thickness of the soil over bedrock. Very deep soils are more than 60 inches deep over bedrock; deep soils, 40 to 60 inches; moderately deep, 20 to 40 inches; shallow, 10 to 20 inches; and very shallow, less than 10 inches.

Desert pavement. On a desert surface, a layer of gravel or larger fragments that was emplaced by upward movement of the underlying sediments or that remains after finer particles have been removed by running water or the wind.

Dip slope. A slope of the land surface, roughly determined by and approximately conforming to the dip of the underlying bedrock.

Diversion (or diversion terrace). A ridge of earth, generally a terrace, built to protect downslope areas by diverting runoff from its natural course.

Drainage class (natural). Refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed. Alterations of the water regime by human activities, either through drainage or irrigation, are not a

consideration unless they have significantly changed the morphology of the soil. Seven classes of natural soil drainage are recognized—*excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained,* and *very poorly drained*. These classes are defined in the "Soil Survey Manual."

Drainage, surface. Runoff, or surface flow of water, from an area.

Draw. A small stream valley that generally is more open and has broader bottom land than a ravine or gulch.

Duff. A generally firm organic layer on the surface of mineral soils. It consists of fallen plant material that is in the process of decomposition and includes everything from the litter on the surface to underlying pure humus.

Ecological site. An area where climate, soil, and relief are sufficiently uniform to produce a distinct natural plant community. An ecological site is the product of all the environmental factors responsible for its development. It is typified by an association of species that differ from those on other ecological sites in kind and/or proportion of species or in total production.

Eluviation. The movement of material in true solution or colloidal suspension from one place to another within the soil. Soil horizons that have lost material through eluviation are eluvial; those that have received material are illuvial.

Endosaturation. A type of saturation of the soil in which all horizons between the upper boundary of saturation and a depth of 2 meters are saturated.

Eolian soil material. Earthy parent material accumulated through wind action; commonly refers to sandy material in dunes or to loess in blankets on the surface.

Ephemeral stream. A stream, or reach of a stream, that flows only in direct response to precipitation. It receives no long-continued supply from melting snow or other source, and its channel is above the water table at all times.

Episaturation. A type of saturation indicating a perched water table in a soil in which saturated layers are underlain by one or more unsaturated layers within 2 meters of the surface.

Erosion. The wearing away of the land surface by water, wind, ice, or other geologic agents and by such processes as gravitational creep.

Erosion (geologic). Erosion caused by geologic processes acting over long geologic periods and resulting in the wearing away of mountains and the building up of such landscape features as flood plains and coastal plains. Synonym: natural erosion.

Erosion (accelerated). Erosion much more rapid than geologic erosion, mainly as a result of human or animal activities or of a catastrophe in nature, such as a fire, that exposes the surface.

Escarpment. A relatively continuous and steep slope or cliff breaking the general continuity of more gently sloping land surfaces and resulting from erosion or faulting. Synonym: scarp.

Extrusive rock. Igneous rock derived from deep-seated molten matter (magma) emplaced on the earth's surface.

Fan remnant. A relict alluvial fan, no longer a site of active deposition, incised by younger and lower alluvial surfaces.

Fertility, soil. The quality that enables a soil to provide plant nutrients, in adequate amounts and in proper balance, for the growth of specified plants when light, moisture, temperature, tilth, and other growth factors are favorable.

Fibric soil material (peat). The least decomposed of all organic soil material. Peat contains a large amount of well preserved fiber that is readily identifiable according to botanical origin. Peat has the lowest bulk density and the highest water content at saturation of all organic soil material.

Field moisture capacity. The moisture content of a soil, expressed as a percentage of the ovendry weight, after the gravitational, or free, water has drained away; the field moisture content 2 or 3 days after a soaking rain; also called *normal field capacity, normal moisture capacity,* or *capillary capacity*.

Fine textured soil. Sandy clay, silty clay, or clay.

First bottom. The normal flood plain of a stream, subject to frequent or occasional flooding.

Flaggy soil material. Material that has, by volume, 15 to 35 percent flagstones. Very flaggy soil material has 35 to 60 percent flagstones, and extremely flaggy soil material has more than 60 percent flagstones.

Flagstone. A thin fragment of sandstone, limestone, slate, shale, or (rarely) schist 6 to 15 inches (15 to 38 centimeters) long.

Flood plain. A nearly level alluvial plain that borders a stream and is subject to flooding unless protected artificially.

Fluvial. Of or pertaining to rivers; produced by river action, as a fluvial plain.

Foothill. A steeply sloping upland that has relief of as much as 1,000 feet (300 meters) and fringes a mountain range or high-plateau escarpment.

Footslope. The position that forms the inner, gently inclined surface at the base of a hillslope. In profile, footslopes are commonly concave. A footslope is a transition zone between upslope sites of erosion and transport (shoulders and backslopes) and downslope sites of deposition (toeslopes).

Forb. Any herbaceous plant not a grass or a sedge.

Forest cover. All trees and other woody plants (underbrush) covering the ground in a forest.

Forest type. A stand of trees similar in composition and development because of given physical and biological factors by which it may be differentiated from other stands.

Genesis, soil. The mode of origin of the soil. Refers especially to the processes or soil-forming factors responsible for the formation of the solum, or true soil, from the unconsolidated parent material.

Gilgai. Commonly, a succession of microbasins and microknolls in nearly level areas or of microvalleys and microridges parallel with the slope. Typically, the microrelief of clayey soils that shrink and swell considerably with changes in moisture content.

Gleyed soil. Soil that formed under poor drainage, resulting in the reduction of iron and other elements in the profile and in gray colors.

Grassed waterway. A natural or constructed waterway, typically broad and shallow, seeded to grass as protection against erosion. Conducts surface water away from cropland.

Gravel. Rounded or angular fragments of rock as much as 3 inches (2 millimeters to 7.6 centimeters) in diameter. An individual piece is a pebble.

Gravelly soil material. Material that has 15 to 35 percent, by volume, rounded or angular rock fragments, not prominently flattened, as much as 3 inches (7.6 centimeters) in diameter.

Green manure crop (agronomy). A soil-improving crop grown to be plowed under in an early stage of maturity or soon after maturity.

Ground water. Water filling all the unblocked pores of the material below the water table.

Gully. A miniature valley with steep sides cut by running water and through which water ordinarily runs only after rainfall. The distinction between a gully and a rill is one of depth. A gully generally is an obstacle to farm machinery and is too deep to be obliterated by ordinary tillage; a rill is of lesser depth and can be smoothed over by ordinary tillage.

Hard bedrock. Bedrock that cannot be excavated except by blasting or by the use of special equipment that is not commonly used in construction.

Head slope. A geomorphic component of hills consisting of a laterally concave area of a hillside, especially at the head of a drainageway. The overland waterflow is converging.

Hemic soil material (mucky peat). Organic soil material intermediate in degree of decomposition between the less decomposed fibric material and the more decomposed sapric material.

High-residue crops. Such crops as small grain and corn used for grain. If properly managed, residue from these crops can be used to control erosion until the next crop in the rotation is established. These crops return large amounts of organic matter to the soil.

Hill. A natural elevation of the land surface, rising as much as 1,000 feet above surrounding lowlands, commonly of limited summit area and having a well defined outline; hillsides generally have slopes of more than 15 percent. The distinction between a hill and a mountain is arbitrary and is dependent on local usage.

Horizon, soil. A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes. In the identification of soil horizons, an uppercase letter represents the major horizons. Numbers or lowercase letters that follow represent subdivisions of the major horizons. An explanation of the subdivisions is given in the "Soil Survey Manual." The major horizons of mineral soil are as follows:

O horizon.—An organic layer of fresh and decaying plant residue.
A horizon.—The mineral horizon at or near the surface in which an accumulation of humified organic matter is mixed with the mineral material. Also, a plowed surface horizon, most of which was originally part of a B horizon.
E horizon.—The mineral horizon in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these.
B horizon.—The mineral horizon below an A horizon. The B horizon is in part a layer of transition from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics, such as (1) accumulation of clay, sesquioxides, humus, or a combination of these; (2) prismatic or blocky structure; (3) redder or browner colors than those in the A horizon; or (4) a combination of these.
C horizon.—The mineral horizon or layer, excluding indurated bedrock, that is little affected by soil-forming processes and does not have the properties typical of the overlying soil material. The material of a C horizon may be either like or unlike that in which the solum formed. If the material is known to differ from that in the solum, an Arabic numeral, commonly a 2, precedes the letter C.
Cr horizon.—Soft, consolidated bedrock beneath the soil.
R layer.—Consolidated bedrock beneath the soil. The bedrock commonly underlies a C horizon, but it can be directly below an A or a B horizon.

Humus. The well decomposed, more or less stable part of the organic matter in mineral soils.

Hydrologic soil groups. Refers to soils grouped according to their runoff potential. The soil properties that influence this potential are those that affect the minimum rate of water infiltration on a bare soil during periods after prolonged wetting when the soil is not frozen. These properties are depth to a seasonal high water table, the infiltration rate and permeability after prolonged wetting, and depth to a very slowly permeable layer. The slope and the kind of plant cover are not considered but are separate factors in predicting runoff.

Igneous rock. Rock formed by solidification from a molten or partially molten state. Major varieties include plutonic and volcanic rock. Examples are andesite, basalt, and granite.

Illuviation. The movement of soil material from one horizon to another in the soil profile. Generally, material is removed from an upper horizon and deposited in a lower horizon.

Impervious soil. A soil through which water, air, or roots penetrate slowly or not at all. No soil is absolutely impervious to air and water all the time.

Infiltration. The downward entry of water into the immediate surface of soil or other material, as contrasted with percolation, which is movement of water through soil layers or material.

Infiltration capacity. The maximum rate at which water can infiltrate into a soil under a given set of conditions.

Infiltration rate. The rate at which water penetrates the surface of the soil at any given instant, usually expressed in inches per hour. The rate can be limited by the infiltration capacity of the soil or the rate at which water is applied at the surface.

Intake rate. The average rate of water entering the soil under irrigation. Most soils have a fast initial rate; the rate decreases with application time. Therefore, intake rate for design purposes is not a constant but is a variable depending on the net irrigation application. The rate of water intake, in inches per hour, is expressed as follows:

Less than 0.2	very low
0.2 to 0.4	low
0.4 to 0.75	moderately low
0.75 to 1.25	moderate
1.25 to 1.75	moderately high
1.75 to 2.5	high
More than 2.5	very high

Interfluve. An elevated area between two drainageways that sheds water to those drainageways.

Intermittent stream. A stream, or reach of a stream, that flows for prolonged periods only when it receives ground-water discharge or long, continued contributions from melting snow or other surface and shallow subsurface sources.

Invaders. On range, plants that encroach into an area and grow after the climax vegetation has been reduced by grazing. Generally, plants invade following disturbance of the surface.

Iron depletions. Low-chroma zones having a low content of iron and manganese oxide because of chemical reduction and removal, but having a clay content similar to that of the adjacent matrix. A type of redoximorphic depletion.

Irrigation. Application of water to soils to assist in production of crops. Methods of irrigation are:

Basin.—Water is applied rapidly to nearly level plains surrounded by levees or dikes.

Border.—Water is applied at the upper end of a strip in which the lateral flow of water is controlled by small earth ridges called border dikes, or borders.

Controlled flooding.—Water is released at intervals from closely spaced field ditches and distributed uniformly over the field.

Corrugation.—Water is applied to small, closely spaced furrows or ditches in fields of close-growing crops or in orchards so that it flows in only one direction.

Drip (or trickle).—Water is applied slowly and under low pressure to the surface of the soil or into the soil through such applicators as emitters, porous tubing, or perforated pipe.

Furrow.—Water is applied in small ditches made by cultivation implements. Furrows are used for tree and row crops.

Sprinkler.—Water is sprayed over the soil surface through pipes or nozzles from a pressure system.

Subirrigation.—Water is applied in open ditches or tile lines until the water table is raised enough to wet the soil.

Wild flooding.—Water, released at high points, is allowed to flow onto an area without controlled distribution.

Karst (topography). The relief of an area underlain by limestone that dissolves in differing degrees, thus forming numerous depressions or small basins.

Knoll. A small, low, rounded hill rising above adjacent landforms.

K_{sat}. Saturated hydraulic conductivity. (See "Permeability.")

Lacustrine deposit. Material deposited in lake water and exposed when the water level is lowered or the elevation of the land is raised.

Landslide. The rapid downhill movement of a mass of soil and loose rock, generally when wet or saturated. The speed and distance of movement, as well as the amount of soil and rock material, vary greatly.

Leaching. The removal of soluble material from soil or other material by percolating water.

Linear extensibility. Refers to the change in length of an unconfined clod as moisture content is decreased from a moist to a dry state. Linear extensibility is used to determine the shrink-swell potential of soils. It is an expression of the volume change between the water content of the clod at $^1/_3$- or $^1/_{10}$-bar tension (33kPa or 10kPa tension) and oven dryness. Volume change is influenced by the amount and type of clay minerals in the soil. The volume change is the percent change for the whole soil. If it is expressed as a fraction, the resulting value is COLE, coefficient of linear extensibility.

Liquid limit. The moisture content at which the soil passes from a plastic to a liquid state.

Loam. Soil material that is 7 to 27 percent clay particles, 28 to 50 percent silt particles, and less than 52 percent sand particles.

Loess. Fine grained material, dominantly of silt-sized particles, deposited by wind.

Low-residue crops. Such crops as corn used for silage, peas, beans, and potatoes. Residue from these crops is not adequate to control erosion until the next crop in the rotation is established. These crops return little organic matter to the soil.

Low strength. The soil is not strong enough to support loads.

Marl. An earthy, unconsolidated deposit consisting chiefly of calcium carbonate mixed with clay in approximately equal amounts.

Masses. Concentrations of substances in the soil matrix that do not have a clearly defined boundary with the surrounding soil material and cannot be removed as a discrete unit. Common compounds making up masses are calcium carbonate, gypsum or other soluble salts, iron oxide, and manganese oxide. Masses consisting of iron oxide or manganese oxide generally are considered a type of redoximorphic concentration.

Mechanical treatment. Use of mechanical equipment for seeding, brush management, and other management practices.

Medium textured soil. Very fine sandy loam, loam, silt loam, or silt.

Mesa. A broad, nearly flat topped and commonly isolated upland mass characterized by summit widths that are more than the heights of bounding erosional scarps.

Metamorphic rock. Rock of any origin altered in mineralogical composition, chemical composition, or structure by heat, pressure, and movement. Nearly all such rocks are crystalline.

Mineral soil. Soil that is mainly mineral material and low in organic material. Its bulk density is more than that of organic soil.

Miscellaneous area. An area that has little or no natural soil and supports little or no vegetation.

Major Land Resource Area. These are geographically associated land resource units. Identification of these large areas is important in statewide agricultural planning and has value in interstate, regional, and national planning.

Moderately coarse textured soil. Coarse sandy loam, sandy loam, or fine sandy loam.

Moderately fine textured soil. Clay loam, sandy clay loam, or silty clay loam.

Mollic epipedon. A thick, dark, humus-rich surface horizon (or horizons) that has high base saturation and pedogenic soil structure. It may include the upper part of the subsoil.

Morphology, soil. The physical makeup of the soil, including the texture, structure, porosity, consistence, color, and other physical, mineral, and biological properties of the various horizons, and the thickness and arrangement of those horizons in the soil profile.

Mottling, soil. Irregular spots of different colors that vary in number and size. Descriptive terms are as follows: abundance—*few, common,* and *many;* size—*fine, medium,* and *coarse;* and contrast—*faint, distinct,* and *prominent*. The size measurements are of the diameter along the greatest dimension. *Fine* indicates less than 5 millimeters (about 0.2 inch); *medium,* from 5 to 15 millimeters (about 0.2 to 0.6 inch); and *coarse,* more than 15 millimeters (about 0.6 inch).

Mountain. A natural elevation of the land surface, rising more than 1,000 feet above surrounding lowlands, commonly of restricted summit area (relative to a plateau) and generally having steep sides. A mountain can occur as a single, isolated mass or in a group forming a chain or range.

Mudstone. Sedimentary rock formed by induration of silt and clay in approximately equal amounts.

Munsell notation. A designation of color by degrees of three simple variables—hue, value, and chroma. For example, a notation of 10YR 6/4 is a color with hue of 10YR, value of 6, and chroma of 4.

Natric horizon. A special kind of argillic horizon that contains enough exchangeable sodium to have an adverse effect on the physical condition of the subsoil.

Neutral soil. A soil having a pH value of 6.6 to 7.3. (See “Reaction, soil.”)

Nodules. Cemented bodies lacking visible internal structure. Calcium carbonate, iron oxide, and manganese oxide are common compounds making up nodules. If formed in place, nodules of iron oxide or manganese oxide are considered types of redoximorphic concentrations.

Nose slope. A geomorphic component of hills consisting of the projecting end (laterally convex area) of a hillside. The overland waterflow is predominantly divergent.

Nutrient, plant. Any element taken in by a plant essential to its growth. Plant nutrients are mainly nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, copper, boron, and zinc obtained from the soil and carbon, hydrogen, and oxygen obtained from the air and water.

Organic matter. Plant and animal residue in the soil in various stages of decomposition. The content of organic matter in the surface layer is described as follows:

Very low	less than 0.5 percent
Low	0.5 to 1.0 percent
Moderately low	1.0 to 2.0 percent
Moderate	2.0 to 4.0 percent
High	4.0 to 8.0 percent
Very high	more than 8.0 percent

Pan. A compact, dense layer in a soil that impedes the movement of water and the growth of roots. For example, *hardpan, fragipan, claypan, plowpan,* and *traffic pan*.

Paleosols. A soil that formed on a landscape in the past with distinctive morphological features resulting from a soil-forming environment that no longer exists at the site.

Parent material. The unconsolidated organic and mineral material in which soil forms.

Ped. An individual natural soil aggregate, such as a granule, a prism, or a block.

Pedisediment. A thin layer of alluvial material that mantles an erosion surface and has been transported to its present position from higher lying areas of the erosion surface.

Pedon. The smallest volume that can be called "a soil." A pedon is three dimensional and large enough to permit study of all horizons. Its area ranges from about 10 to 100 square feet (1 square meter to 10 square meters), depending on the variability of the soil.

Percolation. The movement of water through the soil.

Permeability. The quality of the soil that enables water or air to move downward through the profile. The rate at which a saturated soil transmits water is accepted as a measure of this quality. In soil physics, the rate is referred to as "saturated hydraulic conductivity," which is defined in the "Soil Survey Manual." In line with conventional usage in the engineering profession and with traditional usage in published soil surveys, this rate of flow continues to be expressed as "permeability." Terms describing permeability, measured in inches per hour, are as follows:

Extremely slow	0.0 to 0.01 inch
Very slow	0.01 to 0.06 inch
Slow	0.06 to 0.2 inch
Moderately slow	0.2 to 0.6 inch
Moderate	0.6 inch to 2.0 inches
Moderately rapid	2.0 to 6.0 inches
Rapid	6.0 to 20 inches
Very rapid	more than 20 inches

Phase, soil. A subdivision of a soil series based on features that affect its use and management, such as slope, stoniness, and flooding.

pH value. A numerical designation of acidity and alkalinity in soil. (See "Reaction, soil.")

Plasticity index. The numerical difference between the liquid limit and the plastic limit; the range of moisture content within which the soil remains plastic.

Plastic limit. The moisture content at which a soil changes from semisolid to plastic.

Plateau. An extensive upland mass with relatively flat summit area that is considerably elevated (more than 100 meters) above adjacent lowlands and separated from them on one or more sides by escarpments.

Playa. The generally dry and nearly level lake plain that occupies the lowest parts of closed depressional areas, such as those on intermontane basin floors. Temporary flooding occurs primarily in response to precipitation and runoff.

Plowpan. A compacted layer formed in the soil directly below the plowed layer.

Ponding. Standing water on soils in closed depressions. Unless the soils are artificially drained, the water can be removed only by percolation or evapotranspiration.

Poorly graded. Refers to a coarse grained soil or soil material consisting mainly of particles of nearly the same size. Because there is little difference in size of the particles, density can be increased only slightly by compaction.

Potential native plant community. See "Climax plant community."

Potential rooting depth (effective rooting depth). Depth to which roots could penetrate if the content of moisture in the soil were adequate. The soil has no properties restricting the penetration of roots to this depth.

Prescribed burning. Deliberately burning an area for specific management purposes, under the appropriate conditions of weather and soil moisture and at the proper time of day.

Productivity, soil. The capability of a soil for producing a specified plant or sequence of plants under specific management.

Profile, soil. A vertical section of the soil extending through all its horizons and into the parent material.

Proper grazing use. Grazing at an intensity that maintains enough cover to protect the soil and maintain or improve the quantity and quality of the desirable vegetation. This practice increases the vigor and reproduction capacity of the key plants and promotes the accumulation of litter and mulch necessary to conserve soil and water.

Rangeland. Land on which the potential natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs suitable for grazing or browsing. It includes natural grasslands, savannas, many wetlands, some deserts, tundras, and areas that support certain forb and shrub communities.

Reaction, soil. A measure of acidity or alkalinity of a soil, expressed in pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline. The degrees of acidity or alkalinity, expressed as pH values, are:

Ultra acid	less than 3.5
Extremely acid	3.5 to 4.4
Very strongly acid	4.5 to 5.0
Strongly acid	5.1 to 5.5
Moderately acid	5.6 to 6.0
Slightly acid	6.1 to 6.5
Neutral	6.6 to 7.3
Slightly alkaline	7.4 to 7.8
Moderately alkaline	7.9 to 8.4
Strongly alkaline	8.5 to 9.0
Very strongly alkaline	9.1 and higher

Redoximorphic concentrations. Nodules, concretions, soft masses, pore linings, and other features resulting from the accumulation of iron or manganese oxide. An indication of chemical reduction and oxidation resulting from saturation.

Redoximorphic depletions. Low-chroma zones from which iron and manganese oxide or a combination of iron and manganese oxide and clay has been removed. These zones are indications of the chemical reduction of iron resulting from saturation.

Redoximorphic features. Redoximorphic concentrations, redoximorphic depletions, reduced matrices, a positive reaction to alpha,alpha-dipyridyl, and other features indicating the chemical reduction and oxidation of iron and manganese compounds resulting from saturation.

Reduced matrix. A soil matrix that has low chroma in situ because of chemically reduced iron (Fe II). The chemical reduction results from nearly continuous wetness. The matrix undergoes a change in hue or chroma within 30 minutes after exposure to air as the iron is oxidized (Fe III). A type of redoximorphic feature.

Regolith. The unconsolidated mantle of weathered rock and soil material on the earth's surface; the loose earth material above the solid rock.

Relief. The elevations or inequalities of a land surface, considered collectively.
Residuum (residual soil material). Unconsolidated, weathered or partly weathered mineral material that accumulated as consolidated rock disintegrated in place.
Rill. A steep-sided channel resulting from accelerated erosion. A rill generally is a few inches deep and not wide enough to be an obstacle to farm machinery.
Rock fragments. Rock or mineral fragments having a diameter of 2 millimeters or more; for example, pebbles, cobbles, stones, and boulders.
Root zone. The part of the soil that can be penetrated by plant roots.
Runoff. The precipitation discharged into stream channels from an area. The water that flows off the surface of the land without sinking into the soil is called surface runoff. Water that enters the soil before reaching surface streams is called ground-water runoff or seepage flow from ground water.
Saline soil. A soil containing soluble salts in an amount that impairs growth of plants. A saline soil does not contain excess exchangeable sodium.
Salinity. The degree to which a soil is affected by soluble salts. Salinity is expressed as a electrical conductivity (EC) of a saturation extract. The solution resistance is measured in mmhos/cm. The degrees of salinity and their respective ratios are:

Non saline	0-2
Very slightly saline	2-4
Slightly saline	4-8
Moderately saline	8-16
Strongly saline	>16

Sand. As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85 percent or more sand and not more than 10 percent clay.
Sandstone. Sedimentary rock containing dominantly sand-sized particles.
Sapric soil material (muck). The most highly decomposed of all organic soil material. Muck has the least amount of plant fiber, the highest bulk density, and the lowest water content at saturation of all organic soil material.
Saprolite. Unconsolidated residual material underlying the soil and grading to hard bedrock below.
Saturation. Wetness characterized by zero or positive pressure of the soil water. Under conditions of saturation, the water will flow from the soil matrix into an unlined auger hole.
Second bottom. The first terrace above the normal flood plain (or first bottom) of a river.
Sedimentary rock. Rock made up of particles deposited from suspension in water. The chief kinds of sedimentary rock are conglomerate, formed from gravel; sandstone, formed from sand; shale, formed from clay; and limestone, formed from soft masses of calcium carbonate. There are many intermediate types. Some wind-deposited sand is consolidated into sandstone.
Series, soil. A group of soils that have profiles that are almost alike, except for differences in texture of the surface layer. All the soils of a series have horizons that are similar in composition, thickness, and arrangement.
Shale. Sedimentary rock formed by the hardening of a clay deposit.
Sheet erosion. The removal of a fairly uniform layer of soil material from the land surface by the action of rainfall and surface runoff.
Shrink-Swell. Soil volume changes due to increases or decreases in moisture content. Linear extensibility is used to determine the shrink-swell potential of soils. It is an expression of the volume change between the water content of the clod at $^1/_3$- or $^1/_{10}$-bar tension (33kPa or 10kPa tension) and oven dryness. Volume change is influenced by the amount and type of clay minerals in the soil. The volume change is the percent change for the whole soil. If it is expressed as a

fraction, the resulting value is COLE, coefficient of linear extensibility. The Shrink-swell classes are defined as follows:

Class	LEP
Low	<3
Moderate	3-6
High	6-9
Very High	>9

Shoulder. The position that forms the uppermost inclined surface near the top of a hillslope. It is a transition from backslope to summit. The surface is dominantly convex in profile and erosional in origin.

Side slope. A geomorphic component of hills consisting of a laterally planar area of a hillside. The overland waterflow is predominantly parallel.

Silt. As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). As a soil textural class, soil that is 80 percent or more silt and less than 12 percent clay.

Siltstone. Sedimentary rock made up of dominantly silt-sized particles.

Similar soils. Soils that share limits of diagnostic criteria, behave and perform in a similar manner, and have similar conservation needs or management requirements for the major land uses in the survey area.

Sinkhole. A depression in the landscape where limestone has been dissolved.

Site index. A designation of the quality of a forest site based on the height of the dominant stand at an arbitrarily chosen age. For example, if the average height attained by dominant and codominant trees in a fully stocked stand at the age of 50 years is 75 feet, the site index is 75.

Slickensides. Polished and grooved surfaces produced by one mass sliding past another. In soils, slickensides may occur at the bases of slip surfaces on the steeper slopes; on faces of blocks, prisms, and columns; and in swelling clayey soils, where there is marked change in moisture content.

Slick spot. A small area of soil having a puddled, crusted, or smooth surface and an excess of exchangeable sodium. The soil generally is silty or clayey, is slippery when wet, and is low in productivity.

Slope. The inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 20 percent is a drop of 20 feet in 100 feet of horizontal distance.

Sodic (alkali) soil. A soil having so high a degree of alkalinity (pH 8.5 or higher) or so high a percentage of exchangeable sodium (15 percent or more of the total exchangeable bases), or both, that plant growth is restricted.

Sodicity. The degree to which a soil is affected by exchangeable sodium. Sodicity is expressed as a sodium adsorption ratio (SAR) of a saturation extract, or the ratio of Na^{+} to $Ca^{++} + Mg^{++}$. The degrees of sodicity and their respective ratios are:

Slight	less than 13:1
Moderate	13-30:1
Strong	more than 30:1

Sodium adsorption ratio (SAR). A measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration.

Soft bedrock. Bedrock that can be excavated with trenching machines, backhoes, small rippers, and other equipment commonly used in construction.

Soil. A natural, three-dimensional body at the earth's surface. It is capable of supporting plants and has properties resulting from the integrated effect of

climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.

Soil separates. Mineral particles less than 2 millimeters in equivalent diameter and ranging between specified size limits. The names and sizes, in millimeters, of separates recognized in the United States are as follows:

Very coarse sand	2.0 to 1.0
Coarse sand	1.0 to 0.5
Medium sand	0.5 to 0.25
Fine sand	0.25 to 0.10
Very fine sand	0.10 to 0.05
Silt	0.05 to 0.002
Clay	less than 0.002

Solum. The upper part of a soil profile, above the C horizon, in which the processes of soil formation are active. The solum in soil consists of the A, E, and B horizons. Generally, the characteristics of the material in these horizons are unlike those of the material below the solum. The living roots and plant and animal activities are largely confined to the solum.

Stone line. A concentration of coarse fragments in a soil. Generally, it is indicative of an old weathered surface. In a cross section, the line may be one fragment or more thick. It generally overlies material that weathered in place and is overlain by recent sediment of variable thickness.

Stones. Rock fragments 10 to 24 inches (25 to 60 centimeters) in diameter if rounded or 15 to 24 inches (38 to 60 centimeters) in length if flat.

Stony. Refers to a soil containing stones in numbers that interfere with or prevent tillage.

Structure, soil. The arrangement of primary soil particles into compound particles or aggregates. The principal forms of soil structure are—*platy* (laminated), *prismatic* (vertical axis of aggregates longer than horizontal), *columnar* (prisms with rounded tops), *blocky* (angular or subangular), and *granular*. *Structureless* soils are either *single grained* (each grain by itself, as in dune sand) or *massive* (the particles adhering without any regular cleavage, as in many hardpans).

Subsoil. Technically, the B horizon; roughly, the part of the solum below plow depth.

Subsoiling. Tilling a soil below normal plow depth, ordinarily to shatter a hardpan or claypan.

Substratum. The part of the soil below the solum.

Subsurface layer. Any surface soil horizon (A, E, AB, or EB) below the surface layer.

Summit. The topographically highest position of a hillslope. It has a nearly level (planar or only slightly convex) surface.

Surface layer. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, ranging in depth from 4 to 10 inches (10 to 25 centimeters). Frequently designated as the “plow layer,” or the “Ap horizon.”

Surface soil. The A, E, AB, and EB horizons, considered collectively. It includes all subdivisions of these horizons.

Talus. Fragments of rock and other soil material accumulated by gravity at the foot of cliffs or steep slopes.

Taxadjuncts. Soils that cannot be classified in a series recognized in the classification system. Such soils are named for a series they strongly resemble and are designated as taxadjuncts to that series because they differ in ways too small to be of consequence in interpreting their use and behavior. Soils are recognized as taxadjuncts only when one or more of their characteristics are slightly outside the range defined for the family of the series for which the soils are named.

Terrace (geologic). An old alluvial plain, ordinarily flat or undulating, bordering a river, a lake, or the sea.

Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are *sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay,* and *clay*. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

Tilth, soil. The physical condition of the soil as related to tillage, seedbed preparation, seedling emergence, and root penetration.

Toeslope. The position that forms the gently inclined surface at the base of a hillslope. Toeslopes in profile are commonly gentle and linear and are constructional surfaces forming the lower part of a hillslope continuum that grades to valley or closed-depression floors.

Topsoil. The upper part of the soil, which is the most favorable material for plant growth. It is ordinarily rich in organic matter and is used to topdress roadbanks, lawns, and land affected by mining.

Trace elements. Chemical elements, for example, zinc, cobalt, manganese, copper, and iron, in soils in extremely small amounts. They are essential to plant growth.

Tuff. A compacted deposit that is 50 percent or more volcanic ash and dust.

Upland. Land at a higher elevation, in general, than the alluvial plain or stream terrace; land above the lowlands along streams.

Valley fill. In glaciated regions, material deposited in stream valleys by glacial meltwater. In nonglaciated regions, alluvium deposited by heavily loaded streams.

Variegation. Refers to patterns of contrasting colors assumed to be inherited from the parent material rather than to be the result of poor drainage.

Water bars. Smooth, shallow ditches or depressional areas that are excavated at an angle across a sloping road. They are used to reduce the downward velocity of water and divert it off and away from the road surface. Water bars can easily be driven over if constructed properly.

Weathering. All physical and chemical changes produced in rocks or other deposits at or near the earth's surface by atmospheric agents. These changes result in disintegration and decomposition of the material.

Well graded. Refers to soil material consisting of coarse grained particles that are well distributed over a wide range in size or diameter. Such soil normally can be easily increased in density and bearing properties by compaction. Contrasts with poorly graded soil.

Wilting point (or permanent wilting point). The moisture content of soil, on an ovendry basis, at which a plant (specifically a sunflower) wilts so much that it does not recover when placed in a humid, dark chamber.

Windthrow. The uprooting and tipping over of trees by the wind.

Tables

Table 1.--Temperature and precipitation

(Recorded in the period 1971-2000 at Cuba, NM #2241)

Month	Temperature						Precipitation				
	Average daily maximum	Average daily minimum	Average	2 years in 10 will have		Average number of growing degree days*	Average	2 years in 10 will have--		Average number of days with 0.10 inch or more	Average snowfall
				Maximum temperature higher than--	Minimum temperature lower than--			Less than--	More than--		
	°F	°F	°F	°F	°F	Units	In.	In.	In.		In.
January-----	42.0	7.7	24.8	61	-24	1	0.82	0.16	1.44	2	8.5
February----	46.0	13.7	29.8	63	-19	6	0.50	0.10	0.87	2	5.1
March-------	53.5	20.8	37.2	71	-2	42	0.90	0.22	1.53	2	3.9
April-------	61.6	25.8	43.7	77	6	148	0.63	0.08	1.14	2	1.6
May---------	70.9	33.7	52.3	85	18	374	0.87	0.18	1.47	2	0.0
June--------	81.4	40.7	61.1	94	25	631	0.80	0.14	1.36	2	0.0
July--------	85.1	48.7	66.9	95	34	832	1.91	0.94	2.85	5	0.0
August------	82.7	48.3	65.5	93	35	773	2.20	1.36	2.94	6	0.0
September---	76.2	39.7	57.9	89	21	538	1.41	0.48	2.29	3	0.0
October-----	65.7	27.4	46.5	80	8	222	1.10	0.38	1.76	3	0.6
November----	51.9	17.3	34.6	71	-7	26	0.89	0.16	1.61	2	2.7
December----	44.1	10.2	27.1	62	-15	1	0.53	0.05	0.91	1	5.2
Yearly:											
Average---	63.4	27.8	45.6	---	---	---	---	---	---	---	---
Extreme---	100	-38	---	96	-25	---	---	---	---	---	---
Total-----	---	---	---	---	---	3594	12.57	9.48	14.18	32	27.6

* A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minimum daily temperatures, dividing the sum by 2, and subtracting the temperature below which growth is minimal for the principal crops in the area (40 degrees F.)

Table 1.--Temperature and precipitation--continued

(Recorded in the period 1971-2000 at Jemez Springs, NM #4369)

Month	Temperature						Precipitation				
	Average daily maximum	Average daily minimum	Average	2 years in 10 will have		Average number of growing degree days*	Average	2 years in 10 will have--		Average number of days with 0.10 inch or more	Average snowfall
				Maximum temperature higher than--	Minimum temperature lower than--			Less than--	More than--		
	°F	°F	°F	°F	°F	Units	In.	In.	In.		In.
January-----	46.2	19.8	33.0	63	-2	13	1.25	0.36	2.07	3	9.5
February----	51.7	23.9	37.8	68	3	46	0.88	0.34	1.46	2	6.3
March-------	58.3	28.9	43.6	74	12	146	1.26	0.46	1.99	3	4.5
April-------	66.8	34.5	50.6	81	19	326	0.97	0.18	1.72	2	2.3
May---------	75.4	42.1	58.8	89	29	583	1.14	0.40	1.89	3	0.2
June--------	86.0	50.5	68.3	98	37	842	1.01	0.28	1.70	2	0.0
July--------	88.5	55.6	72.0	98	46	984	2.47	1.63	3.24	6	0.0
August------	85.4	54.4	69.9	95	45	923	2.98	1.93	3.88	7	0.0
September---	79.5	47.8	63.7	91	32	707	1.94	0.92	2.79	4	0.0
October-----	69.1	37.9	53.5	84	21	422	1.53	0.21	2.89	3	0.3
November----	55.4	27.6	41.5	73	8	114	1.25	0.46	1.95	3	2.9
December----	47.1	20.9	34.0	63	0	20	0.95	0.17	1.63	2	6.4
Yearly:											
Average---	67.5	37.0	52.2	---	---	---	---	---	---	---	---
Extreme---	101	-18	---	99	-5	---	---	---	---	---	---
Total-----	---	---	---	---	---	5124	17.63	13.03	20.72	40	32.5

Table 1.--Temperature and precipitation--continued

(Recorded in the period 1971-2000 at Torreon Navajo Mission, NM #9031)

Month	Temperature						Precipitation				
	Average daily maximum	Average daily minimum	Average	2 years in 10 will have		Average number of growing degree days*	Average	2 years in 10 will have--		Average number of days with 0.10 inch or more	Average snowfall
				Maximum temperature higher than--	Minimum temperature lower than--			Less than--	More than--		
	°F	°F	°F	°F	°F	Units	In.	In.	In.		In.
January-----	42.0	15.3	28.6	60	-10	4	0.61	0.19	0.98	2	5.7
February----	47.9	20.8	34.4	65	-3	21	0.43	0.19	0.63	1	3.7
March-------	57.1	25.6	41.3	75	9	107	0.73	0.20	1.13	2	2.4
April-------	65.9	31.3	48.6	82	14	275	0.63	0.08	1.13	1	1.3
May---------	75.3	40.0	57.6	89	23	547	0.78	0.09	1.51	2	0.4
June--------	86.3	49.0	67.6	98	32	814	0.59	0.05	1.05	1	0.0
July--------	88.9	55.5	72.2	99	38	993	1.56	0.78	2.27	4	0.0
August------	85.9	54.4	70.1	96	42	932	1.86	0.85	2.77	5	0.0
September---	79.1	46.8	63.0	92	30	685	1.29	0.48	2.11	3	0.0
October-----	67.5	35.1	51.3	83	15	359	1.07	0.19	1.83	3	0.6
November----	52.5	23.7	38.1	71	2	67	0.78	0.26	1.23	2	2.3
December----	43.3	16.2	29.8	61	-6	4	0.47	0.06	0.83	1	4.1
Yearly:											
Average---	66.0	34.5	50.2	---	---	---	---	---	---	---	---
Extreme---	101	-33	---	99	-14	---	---	---	---	---	---
Total-----	---	---	---	---	---	4808	10.80	8.63	12.87	27	20.5

Table 1.--Temperature and precipitation--continued

(Recorded in the period 1971-2000 at Wolf Canyon, NM #9820)

Month	Temperature						Precipitation				
	Average daily maximum	Average daily minimum	Average	2 years in 10 will have		Average number of growing degree days*	Average	2 years in 10 will have--		Average number of days with 0.10 inch or more	Average snowfall
				Maximum temperature higher than--	Minimum temperature lower than--			Less than--	More than--		
	oF	oF	oF	oF	oF	Units	In.	In.	In.		In.
January-----	37.5	7.6	22.5	55	-18	0	2.03	0.59	3.52	5	26.6
February----	40.2	11.1	25.7	57	-15	0	1.57	0.78	2.33	4	21.8
March-------	45.7	17.3	31.5	62	-5	6	2.13	0.80	3.44	5	24.8
April-------	53.7	22.7	38.2	70	3	50	1.39	0.36	2.40	3	13.0
May---------	62.9	28.9	45.9	77	16	194	1.40	0.49	2.30	4	3.3
June--------	73.2	35.1	54.2	85	22	421	1.21	0.23	2.00	3	0.0
July--------	75.7	41.7	58.7	86	30	577	3.17	1.97	4.37	8	0.0
August------	72.8	41.6	57.2	82	31	527	3.85	2.47	5.02	8	0.0
September---	67.4	35.0	51.2	80	20	336	2.12	1.10	3.02	4	0.2
October-----	57.6	25.6	41.6	73	9	101	2.03	0.76	3.14	4	4.5
November----	44.8	16.1	30.5	64	-9	5	1.83	0.81	2.77	4	14.7
December----	38.4	9.2	23.8	56	-15	0	1.55	0.57	2.32	4	19.1
Yearly:											
Average---	55.8	24.3	40.1	---	---	---	---	---	---	---	---
Extreme---	89	-36	---	86	-21	---	---	---	---	---	---
Total-----	---	---	---	---	---	2218	24.28	20.06	28.03	56	128.1

Table 2.--Freeze dates in spring and fall

(Recorded in the period 1971-2000 at Cuba, NM #2241)

Probability	Temperature		
	24 °F or lower	28 °F or lower	32 °F or lower
Last freezing temperature in spring:			
1 year in 10 later than--	May 31	June 18	June 29
2 years in 10 later than--	May 25	June 12	June 25
5 years in 10 later than--	May 13	June 2	June 15
First freezing temperature in fall:			
1 year in 10 earlier than--	September 19	September 14	August 30
2 years in 10 earlier than--	September 24	September 18	September 4
5 years in 10 earlier than--	October 3	September 26	September 15

Table 2.--Freeze dates in spring and fall--continued

(Recorded in the period 1971-2000 at Jemez Springs, NM #4369)

Probability	Temperature		
	24 °F or lower	28 °F or lower	32 °F or lower
1 year in 10 later than--	April 20	May 6	May 19
2 years in 10 later than--	April 15	April 30	May 15
5 years in 10 later than--	April 5	April 19	May 6
First freezing temperature in fall:			
1 year in 10 earlier than--	October 21	October 4	September 26
2 years in 10 earlier than--	October 26	October 10	October 1
5 years in 10 earlier than--	November 5	October 22	October 10

Table 2.--Freeze dates in spring and fall--continued

(Recorded in the period 1971-2000 at Torreon Navajo Mission, NM #9031)

Probability	Temperature		
	24 °F or lower	28 °F or lower	32 °F or lower
Last freezing temperature in spring:			
1 year in 10 later than--	May 13	May 19	June 4
2 years in 10 later than--	May 6	May 13	May 29
5 years in 10 later than--	April 23	May 4	May 18
First freezing temperature in fall:			
1 year in 10 earlier than--	October 8	September 28	September 20
2 years in 10 earlier than--	October 14	October 4	September 25
5 years in 10 earlier than--	October 24	October 15	October 5

Table 2.--Freeze dates in spring and fall--continued

(Recorded in the period 1971-2000 at Wolf Canyon, NM #9820)

Probability	Temperature		
	24 °F or lower	28 °F or lower	32 °F or lower
Last freezing temperature in spring:			
1 year in 10 later than--	June 14	June 28	July 10
2 years in 10 later than--	June 7	June 22	July 5
5 years in 10 later than--	May 24	June 12	June 26
First freezing temperature in fall:			
1 year in 10 earlier than--	September 13	September 5	August 15
2 years in 10 earlier than--	September 19	September 10	August 22
5 years in 10 earlier than--	September 29	September 18	September 3

Table 3.--Growing season

(Recorded for the period 1971-2000 at Cuba, NM #2241)

Probability	Daily minimum temperature		
	Higher than 24 °F	Higher than 28 °F	Higher than 32 oF
	Days	Days	Days
9 years in 10	117	97	70
8 years in 10	125	103	77
5 years in 10	141	116	92
2 years in 10	156	128	106
1 year in 10	165	134	114

Table 3.--Growing season--continued

(Recorded for the period 1971-2000 at Jemez Springs, NM #4369)

Probability	Daily minimum temperature		
	Higher than 24 °F	Higher than 28 °F	Higher than 32 oF
	Days	Days	Days
9 years in 10	187	153	136
8 years in 10	196	164	143
5 years in 10	213	186	156
2 years in 10	230	207	169
1 year in 10	239	218	176

Table 3.--Growing season--continued

(Recorded for the period 1971-2000 at Torreon Navajo Mission, NM #9031)

Probability	Daily minimum temperature		
	Higher than 24 °F	Higher than 28 °F	Higher than 32 oF
	Days	Days	Days
9 years in 10	159	139	117
8 years in 10	167	147	124
5 years in 10	183	163	139
2 years in 10	199	180	154
1 year in 10	208	188	162

Table 3.--Growing season--continued

(Recorded for the period 1971-2000 at Wolf Canyon, NM #9820)

Probability	Daily minimum temperature		
	Higher than 24 °F	Higher than 28 °F	Higher than 32 oF
	Days	Days	Days
9 years in 10	97	76	44
8 years in 10	107	83	52
5 years in 10	127	98	69
2 years in 10	146	112	86
1 year in 10	157	120	95

Table 4.--Acreage and proportionate extent of the soils

Map symbol	Soil name	Los Alamos County	Rio Arriba County	Sandoval County	Total	
					Area	Extent
		Acres	Acres	Acres	Acres	Pct.
1	Silver-Clovis loams, 1 to 7 percent slopes	---	---	10,489	10,489	0.7
2	Clovis-Prieta-Silver association, 3 to 15 percent slopes	---	---	9,027	9,027	0.6
3	Montecito-Orejas complex, 1 to 7 percent slopes	---	---	5,000	5,000	0.3
4	Montecito complex, 3 to 30 percent slopes	---	---	22,532	22,532	1.5
10	Trail silty clay loam, 0 to 1 percent slopes	---	---	757	757	*
11	Trail fine sandy loam, 0 to 1 percent slopes	---	---	1,994	1,994	0.1
13	Sandoval-Querencia association, 2 to 7 percent slopes	---	---	11,436	11,436	0.8
15	Camino-Sandoval complex, 1 to 8 percent slopes	---	---	17,038	17,038	1.1
16	Rock outcrop-Prieta complex, 3 to 15 percent slopes	1,039	---	155	1,194	*
17	Vessilla-Menefee-Rock outcrop complex, 3 to 15 percent slopes	---	---	30,571	30,571	2.0
18	Sparham clay, 0 to 3 percent slopes	---	---	2,927	2,927	0.2
20	Gilco clay loam, 0 to 1 percent slopes	---	---	1,111	1,111	*
21	Rock outcrop-Hackroy complex, 1 to 8 percent slopes	2,907	---	8,060	10,967	0.7
22	Aga silty clay loam, 0 to 1 percent slopes	---	---	531	531	*
23	Hickman clay loam, 1 to 3 percent slopes	---	---	3,263	3,263	0.2
24	Orlie-Sparham association, 0 to 5 percent slopes	---	---	22,785	22,785	1.5
25	Gilco loam, 0 to 1 percent slopes	---	---	3,601	3,601	0.2
26	Orlie loam, 0 to 8 percent slopes	---	---	4,577	4,577	0.3
27	Aga loam, 0 to 1 percent slopes	---	---	1,950	1,950	0.1
29	Trail loamy sand, 0 to 1 percent slopes	---	---	925	925	*
31	Riverwash	---	---	9,415	9,415	0.6
33	Pits	---	---	1,310	1,310	*
34	Ildefonso-Witt association, 1 to 8 percent slopes	---	---	10,220	10,220	0.7
41	Dune land	---	---	792	792	*
47	Cascajo very gravelly sandy loam, 12 to 30 percent slopes	---	---	9,700	9,700	0.6
51	Sparham clay loam, 0 to 1 percent slopes	---	---	871	871	*
52	Totavi loamy sand, 0 to 5 percent slopes	2,422	---	2,885	5,307	0.4
53	Witt-Harvey association, 1 to 7 percent slopes	---	---	18,540	18,540	1.2
54	Harvey-Cascajo association, 5 to 15 percent slopes	---	---	33,134	33,134	2.2
55	La Fonda loam, 1 to 5 percent slopes	---	---	4,734	4,734	0.3
56	Ildefonso cobbly loam, 15 to 35 percent slopes	---	---	12,889	12,889	0.9
57	Badland	---	32	17,590	17,622	1.2
58	Deama-Elpedro association, 5 to 30 percent slopes	---	---	2,525	2,525	0.2

Table 4.--Acreage and proportionate extent of the soils--continued

Map symbol	Soil name	Los Alamos County	Rio Arriba County	Sandoval County	Total	
					Area	Extent
		Acres	Acres	Acres	Acres	Pct.
59	Harvey-Ildefonso-La Fonda association, 3 to 15 percent slopes	---	---	7,884	7,884	0.5
63	Placitas gravelly loam, 8 to 40 percent slopes	---	---	8,545	8,545	0.6
64	Skyvillage-Ildefonso association, 8 to 40 percent slopes	---	---	3,604	3,604	0.2
65	Ildefonso-Harvey association, 10 to 35 percent slopes	---	---	12,168	12,168	0.8
66	Zia sandy loam, 3 to 6 percent slopes	---	---	16,387	16,387	1.1
67	Sandoval-Poley complex, 3 to 30 percent slopes	---	---	24,938	24,938	1.7
68	Penistaja-Querencia complex, 2 to 7 percent slopes	---	---	10,942	10,942	0.7
71	Palon cobbly sandy loam, 15 to 35 percent slopes	---	324	3,041	3,365	0.2
72	Palon very cobbly sandy loam, 35 to 65 percent slopes	---	---	6,267	6,267	0.4
74	Origo-Pavo association, 5 to 35 percent slopes	---	41	7,713	7,754	0.5
75	Origo very cobbly sandy loam, 35 to 65 percent slopes	---	112	5,576	5,688	0.4
82	Calaveras loam, 15 to 35 percent slopes	782	---	6,872	7,654	0.5
83	Calaveras-Rubble land association, 35 to 60 percent slopes	683	616	9,769	11,068	0.7
85	Redondo coarse sandy loam, 15 to 35 percent slopes	---	1,366	5,260	6,626	0.4
86	Redondo cobbly coarse sandy loam, 35 to 80 percent slopes	---	583	9,245	9,828	0.7
87	Redondo-Rubble land association, 35 to 80 percent slopes	---	---	6,569	6,569	0.4
88	Totavi-Jemez-Rock outcrop association, 0 to 15 percent slopes	---	---	3,037	3,037	0.2
91	Zia sandy loam, 1 to 3 percent slopes	---	---	2,157	2,157	0.1
92	Galisteo silty clay loam, moderately saline, sodic, 0 to 1 percent slopes	---	---	611	611	*
93	Zia loamy sand, 1 to 4 percent slopes	---	---	449	449	*
95	El Rancho loam, 0 to 2 percent slopes	---	---	1,025	1,025	*
97	El Rancho clay loam, 0 to 2 percent slopes	---	---	726	726	*
100	Orejas-Rock outcrop complex, 15 to 40 percent slopes	---	---	8,199	8,199	0.5
101	Blancot-Lybrook association, 0 to 8 percent slopes	---	---	4,207	4,207	0.3
102	Sparham clay loam, 1 to 3 percent slopes	---	---	3,955	3,955	0.3
104	Cochiti-Montecito association, 1 to 30 percent slopes	---	---	8,422	8,422	0.6

Table 4.--Acreage and proportionate extent of the soils--continued

Map symbol	Soil name	Los Alamos County	Rio Arriba County	Sandoval County	Total	
					Area	Extent
		Acres	Acres	Acres	Acres	Pct.
105	Badland-Menefee complex, 15 to 35 percent slopes	---	---	3,210	3,210	0.2
106	Stumble association, 1 to 40 percent slopes	---	---	4,110	4,110	0.3
108	Embudo gravelly sandy loam, 1 to 15 percent slopes	---	---	2,897	2,897	0.2
109	Embudo-Tijeras association, 1 to 9 percent slopes	---	---	1,582	1,582	0.1
110	Rock outcrop-Saido complex, 5 to 40 percent slopes	---	---	12,327	12,327	0.8
111	Rock outcrop-Zia complex, 8 to 25 percent slopes	---	---	26,249	26,249	1.8
112	Tijeras gravelly fine sandy loam, 1 to 5 percent slopes	---	---	1,396	1,396	*
114	Zia-San Mateo association, 0 to 9 percent slopes	---	---	8,577	8,577	0.6
120	Pinavetes loamy sand, 3 to 5 percent slopes	---	---	24,241	24,241	1.6
124	Rock outcrop	6,717	---	24,005	30,722	2.1
129	Menefee clay loam, 5 to 35 percent slopes	---	---	9,783	9,783	0.7
130	Pinavetes-Galisteo, moderately saline, sodic, association, 0 to 5 percent slopes	---	---	3,355	3,355	0.2
142	Grieta fine sandy loam, 1 to 4 percent slopes	---	---	22,273	22,273	1.5
143	Clovis fine sandy loam, 1 to 4 percent slopes	---	---	25,914	25,914	1.7
145	Grieta-Sheppard loamy fine sands, 2 to 9 percent slopes	---	---	23,425	23,425	1.6
146	Sedmar loamy sand, 1 to 15 percent slopes	---	---	4,934	4,934	0.3
150	Doakum-Betonnie fine sandy loams, 0 to 8 percent slopes	---	---	18,541	18,541	1.2
162	Hackroy-Nyjack association, 1 to 5 percent slopes	1,442	---	1,983	3,425	0.2
163	Jemez loam, 1 to 15 percent slopes	1,143	---	---	1,143	*
170	San Mateo loam, 0 to 3 percent slopes	---	---	21,186	21,186	1.4
180	Councelor-Eslendo-Mespun complex, 5 to 30 percent slopes	---	---	7,491	7,491	0.5
183	Sheppard loamy fine sand, 8 to 15 percent slopes	---	---	8,866	8,866	0.6
185	Frijoles very fine sandy loam, 1 to 8 percent slopes	877	---	1,440	2,317	0.2
190	Zia-Skyvillage-Rock outcrop complex, 5 to 40 percent slopes	---	---	64,749	64,749	4.3
191	Sheppard loamy fine sand, 3 to 8 percent slopes	---	---	23,005	23,005	1.5
200	Sedillo very cobbly sandy loam, 5 to 25 percent slopes, stony	---	---	1,511	1,511	0.1
201	Rock outcrop-Sedgran association, 25 to 55 percent slopes	---	---	1,035	1,035	*
206	Pinitos loam, 1 to 15 percent slopes	---	---	10,400	10,400	0.7

Table 4.--Acreage and proportionate extent of the soils--continued

Map symbol	Soil name	Los Alamos County	Rio Arriba County	Sandoval County	Total	
					Area	Extent
		Acres	Acres	Acres	Acres	Pct.
207	Penistaja-Zia complex, 1 to 8 percent slopes-	---	---	3,665	3,665	0.2
208	Sedillo very gravelly fine sandy loam, 25 to 55 percent slopes	---	---	12,969	12,969	0.9
210	Ildefonso very stony loam, 25 to 70 percent slopes, rubbly	---	---	5,794	5,794	0.4
211	Zia-Clovis association, 2 to 10 percent slopes	---	---	35,490	35,490	2.4
213	Pinavetes-Rock outcrop complex, 15 to 35 percent slopes	---	---	31,747	31,747	2.1
215	Ess-Rock outcrop complex, 5 to 45 percent slopes	---	---	1,867	1,867	0.1
217	Witt loam, 1 to 8 percent slopes	---	---	9,158	9,158	0.6
218	Ildefonso very cobbly loam, 1 to 15 percent slopes	---	---	10,976	10,976	0.7
220	Rock outcrop-Vessilla-Menefee complex, 30 to 40 percent slopes	---	---	2,390	2,390	0.2
226	Galisteo loam, moderately saline, sodic, 1 to 3 percent slopes	---	---	3,529	3,529	0.2
227	Hagerman-Bond association, 1 to 8 percent slopes	---	---	2,585	2,585	0.2
228	Winona very channery fine sandy loam, 8 to 25 percent slopes	---	---	905	905	*
230	Skyvillage-Sandoval-Rock outcrop complex, 3 to 20 percent slopes	---	---	20,241	20,241	1.4
231	Querencia loam, 1 to 8 percent slopes	---	---	22,450	22,450	1.5
234	Querencia-Zia complex, 2 to 8 percent slopes-	---	---	22,125	22,125	1.5
235	Sandoval fine sandy loam, 3 to 15 percent slopes	---	---	56,947	56,947	3.8
236	Sparank clay loam, moderately saline, sodic, 0 to 1 percent slopes	---	---	18,728	18,728	1.3
237	Sparank silty clay loam, 0 to 3 percent slopes	---	---	12,797	12,797	0.9
240	Penistaja-Hagerman association, 1 to 5 percent slopes	1,220	---	13,547	14,767	1.0
250	Pinavetes loamy fine sand, 5 to 15 percent slopes	---	---	4,970	4,970	0.3
262	Pastura loam, 1 to 4 percent slopes	---	---	800	800	*
270	Blancot-Councelor-Tsosie association, 0 to 5 percent slopes	---	---	59,888	59,888	4.0
281	Carjo loam, 1 to 9 percent slopes	4,140	---	---	4,140	0.3
282	Tocal very fine sandy loam, 3 to 8 percent slopes	620	---	2,017	2,637	0.2
283	Mirand-Alanos complex, 5 to 40 percent slopes	725	---	4,819	5,544	0.4
290	Alanos-Rock outcrop complex, 20 to 40 percent slopes	196	---	---	196	*
300	Waumac-Bamac association, 1 to 7 percent slopes	---	---	11,926	11,926	0.8

Table 4.--Acreage and proportionate extent of the soils--continued

Map symbol	Soil name	Los Alamos County	Rio Arriba County	Sandoval County	Total	
					Area	Extent
		Acres	Acres	Acres	Acres	Pct.
301	Vastine-Jarola silt loams, 0 to 5 percent slopes	---	---	5,650	5,650	0.4
302	Tranquilar-Jarmillo complex, 1 to 8 percent slopes	---	---	7,970	7,970	0.5
304	Cosey-Jarmillo association, 2 to 20 percent slopes	---	---	8,805	8,805	0.6
307	Flugle-Waumac complex, 1 to 8 percent slopes	---	---	10,085	10,085	0.7
308	Cajete gravelly loam, 0 to 8 percent slopes	---	---	1,652	1,652	0.1
311	Cosey-Tranquilar-Calaveras association, 5 to 20 percent slopes	---	---	4,086	4,086	0.3
312	Royosa sand, 1 to 8 percent slopes	---	---	10,273	10,273	0.7
314	Fragua-Waumac-Royosa complex, 1 to 8 percent slopes	---	---	14,200	14,200	0.9
317	Elpedro loam, 1 to 8 percent slopes	---	---	9,095	9,095	0.6
319	Bamac-Rock outcrop complex, 15 to 55 percent slopes	---	---	7,489	7,489	0.5
320	Sparham silt loam, 0 to 3 percent slopes	---	---	4,202	4,202	0.3
321	Waumac-Royosa association, 1 to 15 percent slopes	---	---	4,265	4,265	0.3
322	Fragua very cobbly fine sandy loam, 15 to 70 percent slopes	---	---	11,873	11,873	0.8
324	Rock outcrop-Atarque-Menefee complex, 5 to 25 percent slopes	---	---	7,190	7,190	0.5
325	Rock outcrop-Vessilla-Espiritu complex, 25 to 65 percent slopes	---	---	3,724	3,724	0.2
342	Waumac-Vessilla-Rock outcrop complex, 5 to 40 percent slopes	---	---	3,887	3,887	0.3
345	Espiritu-Bamac association, 15 to 55 percent slopes	---	---	20,283	20,283	1.4
346	Espiritu, cobbly-Bamac association, 15 to 40 percent slopes	---	---	8,824	8,824	0.6
348	Wauquie-Rock outcrop complex, 25 to 45 percent slopes	---	---	5,575	5,575	0.4
353	Cochiti-Espiritu association, 15 to 55 percent slopes	---	---	11,691	11,691	0.8
354	Waumac Variant very gravelly sandy loam, 1 to 15 percent slopes	---	---	646	646	*
358	Deama-Elpedro-Rock outcrop complex, 10 to 55 percent slopes	---	---	5,329	5,329	0.4
396	Atarque-Menefee-Rock outcrop complex, 25 to 45 percent slopes	---	---	5,797	5,797	0.4
397	Rock outcrop-Cucho-Vessilla complex, 25 to 70 percent slopes	---	---	3,837	3,837	0.3
398	Espiritu-Cucho association, 8 to 55 percent slopes	---	---	2,342	2,342	0.2
399	Cucho-Teco complex, 8 to 40 percent slopes	---	---	2,921	2,921	0.2
405	Charo complex, 1 to 5 percent slopes	---	---	1,785	1,785	0.1

Table 4.--Acreage and proportionate extent of the soils--continued

Map symbol	Soil name	Los Alamos County	Rio Arriba County	Sandoval County	Total	
					Area	Extent
		Acres	Acres	Acres	Acres	Pct.
409	Santa Fe very gravelly sandy loam, 15 to 40 percent slopes, stony	---	---	3,447	3,447	0.2
410	Zia loam, 0 to 1 percent slopes	---	---	1,082	1,082	*
414	Wauquie very gravelly fine sandy loam, 8 to 25 percent slopes	---	---	3,191	3,191	0.2
417	Jocity loam, 0 to 2 percent slopes	---	---	994	994	*
418	Jocity clay loam, 0 to 2 percent slopes	---	---	2,213	2,213	0.1
419	Santa Fe-Wauquie-Rock outcrop complex, 25 to 70 percent slopes	---	---	4,684	4,684	0.3
420	Pinavetes loamy sand, 1 to 3 percent slopes	---	---	570	570	*
421	Gilco loam, moderately saline, sodic, 0 to 1 percent slopes	---	---	277	277	*
422	Vessilla-Menefee-Orlie association, 0 to 30 percent slopes	---	77	26,463	26,540	1.8
423	Gilco loam, 1 to 4 percent slopes	---	---	1,446	1,446	*
426	Aga loam, moderately saline, sodic, 0 to 1 percent slopes	---	---	239	239	*
427	Aga loam, 1 to 3 percent slopes	---	---	733	733	*
428	Aga loam, moderately saline, sodic, 1 to 3 percent slopes	---	---	527	527	*
430	Trail loam, 1 to 3 percent slopes	---	---	929	929	*
431	Trail loamy sand, 1 to 4 percent slopes	---	---	1,401	1,401	*
433	Peralta loam, 0 to 1 percent slopes	---	---	745	745	*
434	Peralta loam, 1 to 3 percent slopes	---	---	503	503	*
437	Peralta loam, moderately saline, sodic, 1 to 3 percent slopes	---	---	1,689	1,689	0.1
500	Rock outcrop-Osha-Rubble land complex, 40 to 70 percent slopes	---	---	2,686	2,686	0.2
503	Cajete-Cypher association, 8 to 50 percent slopes	1,668	---	4,046	5,714	0.4
504	Orejas-Guaje complex, 1 to 15 percent slopes	---	---	8,858	8,858	0.6
600	Rock outcrop-Cypher complex, 35 to 60 percent slopes	---	---	2,045	2,045	0.1
601	Laventana gravelly sandy loam, 3 to 15 percent slopes	---	---	587	587	*
603	Laventana-Mirand very cobbly loams, 15 to 55 percent slopes	---	---	4,185	4,185	0.3
604	Cypher-Mirand complex, 15 to 55 percent slopes	---	---	1,523	1,523	0.1
608	Osha association, 3 to 55 percent slopes	---	---	3,909	3,909	0.3
823	Gilco loam, 1 to 4 percent slopes, unprotected	---	---	1,222	1,222	*
827	Aga loam, 1 to 3 percent slopes, unprotected	---	---	1,445	1,445	*
830	Trail loam, 1 to 3 percent slopes, unprotected	---	---	857	857	*
831	Trail loamy sand, 1 to 3 percent slopes, unprotected	---	---	1,905	1,905	0.1

Table 4.--Acreage and proportionate extent of the soils--continued

Map symbol	Soil name	Los Alamos County	Rio Arriba County	Sandoval County	Total	
					Area	Extent
		Acres	Acres	Acres	Acres	Pct.
835	Peralta loam, 1 to 3 percent slopes, unprotected	---	---	2,205	2,205	0.1
842	Peralta clay loam, moderately saline, sodic, 0 to 2 percent slopes, unprotected	---	---	511	511	*
850	Water	4	---	3,392	3,396	0.2
DAM	Dam	---	---	466	466	*
	Total	26,585	3,151	1,466,168	1,495,904	100.0

* Less than 0.1 percent.

Table 5.--Irrigated and nonirrigated yields by map unit component

(Yields in the "N" columns are for nonirrigated areas; those in the "I" columns are for irrigated areas. Yields are those that can be expected under a high level of management. Absence of a yield indicates that the soil is not suited to the crop or the crop generally is not grown on the soil.)

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
1:								
Silver	6e	4e	---	---	---	---	---	---
Clovis	6c	---	---	---	---	---	---	---
2:								
Clovis	6c	---	---	---	---	---	---	---
Prieta	7s	---	---	---	---	---	---	---
Silver	6e	---	---	---	---	---	---	---
3:								
Montecito	6e	---	---	---	---	---	---	---
Orejas	7s	---	---	---	---	---	---	---
4:								
Montecito	6e	---	---	---	---	---	---	---
Montecito, bouldery	7s	---	---	---	---	---	---	---
10:								
Trail	7s	4e	---	6.00	---	---	---	12.00
11:								
Trail	7s	4e	---	6.00	---	---	---	12.00
13:								
Sandoval	7s	---	---	---	---	---	---	---
Querencia	6c	---	---	---	---	---	---	---
15:								
Camino	6c	---	---	---	---	---	---	---
Sandoval	7s	---	---	---	---	---	---	---
16:								
Rock outcrop	8s	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
16:								
Prieta	7s	---	---	---	---	---	---	---
17:								
Vessilla	7s	---	---	---	---	---	---	---
Menefee	7s	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
18:								
Sparham	6c	3s	---	1.50	---	---	---	---
20:								
Gilco	7c	2e	---	7.50	---	6.00	---	15.00
21:								
Rock outcrop	8s	---	---	---	---	---	---	---
Hackroy	7s	---	---	---	---	---	---	---
22:								
Aga	7c	2s	---	7.00	---	---	---	14.00
23:								
Hickman	6c	3e	---	2.00	---	---	---	6.00
24:								
Orlie	6c	---	---	---	---	---	---	---
Sparham	6c	3s	---	1.50	---	---	---	---
25:								
Gilco	7e	2e	---	7.50	---	6.00	---	15.00
26:								
Orlie	6c	---	---	---	---	---	---	---
27:								
Aga	7c	2s	---	7.00	---	---	---	14.00
29:								
Trail	7s	4s	---	4.00	---	---	---	8.00
31:								
Riverwash	8w	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
33:								
Pits	8s	---	---	---	---	---	---	---
34:								
Ildefonso	7s	---	---	---	---	---	---	---
Witt	6e	---	---	---	---	---	---	---
41:								
Dune land	8e	---	---	---	---	---	---	---
47:								
Cascajo	7e	---	---	---	---	---	---	---
51:								
Sparham	6c	3e	---	3.50	---	3.00	---	9.00
52:								
Totavi	4s	---	---	---	---	---	---	---
53:								
Witt	6e	---	---	---	---	---	---	---
Harvey	7e	---	---	---	---	---	---	---
54:								
Harvey	7e	---	---	---	---	---	---	---
Cascajo	7s	---	---	---	---	---	---	---
55:								
La Fonda	6c	---	---	---	---	---	---	---
56:								
Ildefonso	7e	---	---	---	---	---	---	---
57:								
Badland	8	---	---	---	---	---	---	---
58:								
Deama	7e	---	---	---	---	---	---	---
Elpedro	6e	---	---	---	---	---	---	---
59:								
Harvey	7e	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
59:								
Ildefonso	7s	---	---	---	---	---	---	---
La Fonda	6c	---	---	---	---	---	---	---
63:								
Placitas	7e	---	---	---	---	---	---	---
64:								
Skyvillage	7s	---	---	---	---	---	---	---
Ildefonso	6e	---	---	---	---	---	---	---
65:								
Ildefonso	6e	---	---	---	---	---	---	---
Harvey	7e	---	---	---	---	---	---	---
66:								
Zia	6c	---	---	---	---	---	---	---
67:								
Sandoval	7s	---	---	---	---	---	---	---
Poley	6e	---	---	---	---	---	---	---
68:								
Penistaja	6e	---	---	---	---	---	---	---
Querencia	6c	---	---	---	---	---	---	---
71:								
Palon	7c	---	---	---	---	---	---	---
72:								
Palon	7c	---	---	---	---	---	---	---
74:								
Origo	7s	---	---	---	---	---	---	---
Pavo	7c	---	---	---	---	---	---	---
75:								
Origo	7e	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
82:								
Calaveras	7c	---	---	---	---	---	---	---
83:								
Calaveras	7e	---	---	---	---	---	---	---
Rubble land	8s	---	---	---	---	---	---	---
85:								
Redondo	7c	---	---	---	---	---	---	---
86:								
Redondo	7c	---	---	---	---	---	---	---
87:								
Redondo	7e	---	---	---	---	---	---	---
Rubble land	8s	---	---	---	---	---	---	---
88:								
Totavi	6s	---	---	---	---	---	---	---
Jemez	7c	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
91:								
Zia	6c	2e	---	6.00	---	5.00	---	8.00
92:								
Galisteo, moderately saline, sodic	6c	4s	---	---	---	---	---	---
93:								
Zia	6c	2e	---	6.00	---	5.00	---	12.00
95:								
El Rancho	6c	2e	---	7.00	---	---	---	14.00
97:								
El Rancho	6c	2e	---	7.00	---	---	---	14.00
100:								
Orejas	7s	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
101:								
Blancot	6c	---	---	---	---	---	---	---
Lybrook	7s	---	---	---	---	---	---	---
102:								
Sparham	6c	3s	---	1.50	---	---	---	6.00
104:								
Cochiti	6e	---	---	---	---	---	---	---
Montecito	6e	---	---	---	---	---	---	---
105:								
Badland	8	---	---	---	---	---	---	---
Menefee	7e	---	---	---	---	---	---	---
106:								
Stumble	7c	---	---	---	---	---	---	---
Stumble, sandy	7c	---	---	---	---	---	---	---
108:								
Embudo	7c	---	---	---	---	---	---	---
109:								
Embudo	7e	---	---	---	---	---	---	---
Tijeras	7c	---	---	---	---	---	---	---
110:								
Rock outcrop	8s	---	---	---	---	---	---	---
Saido	7e	---	---	---	---	---	---	---
111:								
Rock outcrop	8s	---	---	---	---	---	---	---
Zia	6e	---	---	---	---	---	---	---
112:								
Tijeras	7c	---	---	---	---	---	---	---
114:								
San Mateo	6e	2e	---	5.00	---	---	---	13.00

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
114:								
Zia	6c	---	---	---	---	---	---	---
120:								
Pinavetes	6e	---	---	---	---	---	---	---
124:								
Rock outcrop	8s	---	---	---	---	---	---	---
129:								
Menefee	7e	---	---	---	---	---	---	---
130:								
Pinavetes	6e	---	---	---	---	---	---	---
Galisteo, moderately saline, sodic	6c	---	---	---	---	---	---	---
142:								
Grieta	7e	---	---	---	---	---	---	---
143:								
Clovis	6c	---	---	---	---	---	---	---
145:								
Grieta	7e	---	---	---	---	---	---	---
Sheppard	7s	---	---	---	---	---	---	---
146:								
Sedmar	7c	---	---	---	---	---	---	---
150:								
Doakum	6c	---	---	---	---	---	---	---
Betonnie	6c	---	---	---	---	---	---	---
162:								
Hackroy	7s	---	---	---	---	---	---	---
Nyjack	6c	---	---	---	---	---	---	---
163:								
Jemez	7c	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
170:								
San Mateo	6e	2e	---	5.00	---	---	---	10.00
180:								
Councelor	6c	---	---	---	---	---	---	---
Eslendo	7e	---	---	---	---	---	---	---
Mespun	7s	---	---	---	---	---	---	---
183:								
Sheppard	7s	---	---	---	---	---	---	---
185:								
Frijoles	6e	---	---	---	---	---	---	---
190:								
Zia	6c	---	---	---	---	---	---	---
Skyvillage	7s	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
191:								
Sheppard	7s	---	---	---	---	---	---	---
200:								
Sedillo	7s	---	---	---	---	---	---	---
201:								
Rock outcrop	8s	---	---	---	---	---	---	---
Sedgran	7e	---	---	---	---	---	---	---
206:								
Pinitos	7c	---	---	---	---	---	---	---
207:								
Penistaja	6c	---	---	---	---	---	---	---
Zia	6c	3e	---	6.00	---	5.00	---	8.00
208:								
Sedillo	7e	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
210:								
Ildefonso	7e	---	---	---	---	---	---	---
211:								
Zia	6c	---	---	---	---	---	---	---
Clovis	6c	---	---	---	---	---	---	---
213:								
Pinavetes	6e	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
215:								
Ess	7c	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
217:								
Witt	6e	---	---	---	---	---	---	---
218:								
Ildefonso	7s	---	---	---	---	---	---	---
220:								
Rock outcrop	8s	---	---	---	---	---	---	---
Vessilla	7e	---	---	---	---	---	---	---
Menefee	7e	---	---	---	---	---	---	---
226:								
Galisteo, moderately saline, sodic	6c	---	---	---	---	---	---	---
227:								
Hagerman	6c	---	---	---	---	---	---	---
Bond	6c	---	---	---	---	---	---	---
228:								
Winona	7e	---	---	---	---	---	---	---
230:								
Skyvillage	7s	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
230:								
Sandoval	7s	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
231:								
Querencia	6c	---	---	---	---	---	---	---
234:								
Querencia	6c	---	---	---	---	---	---	---
Zia	6c	---	---	---	---	---	---	---
235:								
Sandoval	7s	---	---	---	---	---	---	---
236:								
Sparank, moderately saline, sodic	7s	---	---	---	---	---	---	---
237:								
Sparank	6c	2e	---	5.00	---	---	---	10.00
240:								
Penistaja	6c	---	---	---	---	---	---	---
Hagerman	6c	---	---	---	---	---	---	---
250:								
Pinavetes	6e	---	---	---	---	---	---	---
262:								
Pastura	7s	---	---	---	---	---	---	---
270:								
Blancot	6c	---	---	---	---	---	---	---
Councelor	6c	---	---	---	---	---	---	---
Tsosie	6c	---	---	---	---	---	---	---
281:								
Carjo	5c	---	---	---	---	---	---	---
282:								
Tocal	7s	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
283:								
Mirand	7c	---	---	---	---	---	---	---
Alanos	7c	---	---	---	---	---	---	---
290:								
Alanos	7c	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
300:								
Waumac	6s	---	---	---	---	---	---	---
Bamac	6e	---	---	---	---	---	---	---
301:								
Vastine	7c	---	---	---	---	---	---	---
Jarola	7c	---	---	---	---	---	---	---
302:								
Tranquilar	7c	---	---	---	---	---	---	---
Jarmillo	7c	---	---	---	---	---	---	---
304:								
Cosey	7c	---	---	---	---	---	---	---
Jarmillo	7c	---	---	---	---	---	---	---
307:								
Flugle	6c	---	---	---	---	---	---	---
Waumac	6s	---	---	---	---	---	---	---
308:								
Cajete	7c	---	---	---	---	---	---	---
311:								
Cosey	7c	---	---	---	---	---	---	---
Tranquilar	7c	---	---	---	---	---	---	---
Calaveras	7c	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
312:								
Royosa	6e	---	---	---	---	---	---	---
314:								
Fragua	6c	---	---	---	---	---	---	---
Waumac	6s	---	---	---	---	---	---	---
Royosa	6e	---	---	---	---	---	---	---
317:								
Elpedro	6e	---	---	---	---	---	---	---
319:								
Bamac	7e	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
320:								
Sparham	6c	3s	---	1.50	---	---	---	---
321:								
Waumac	6s	---	---	---	---	---	---	---
Royosa	6e	---	---	---	---	---	---	---
322:								
Fragua	6e	---	---	---	---	---	---	---
324:								
Rock outcrop	8s	---	---	---	---	---	---	---
Atarque	7s	---	---	---	---	---	---	---
Menefee	7e	---	---	---	---	---	---	---
325:								
Rock outcrop	8s	---	---	---	---	---	---	---
Espiritu	7e	---	---	---	---	---	---	---
Vessilla	7e	---	---	---	---	---	---	---
342:								
Waumac	6s	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
342:								
Vessilla	7s	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
345:								
Espiritu	7e	---	---	---	---	---	---	---
Bamac	7e	---	---	---	---	---	---	---
346:								
Espiritu, cobbly	6e	---	---	---	---	---	---	---
Bamac	6e	---	---	---	---	---	---	---
348:								
Wauquie	7s	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
353:								
Cochiti	6e	---	---	---	---	---	---	---
Espiritu	7e	---	---	---	---	---	---	---
354:								
Waumac Variant	7s	---	---	---	---	---	---	---
358:								
Deama	7e	---	---	---	---	---	---	---
Elpedro	7e	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
396:								
Atarque	7e	---	---	---	---	---	---	---
Menefee	7s	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
397:								
Rock outcrop	8s	---	---	---	---	---	---	---
Cucho	7e	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
397:								
Vessilla	7e	---	---	---	---	---	---	---
398:								
Espiritu	7e	---	---	---	---	---	---	---
Cucho	7e	---	---	---	---	---	---	---
399:								
Cucho	6e	---	---	---	---	---	---	---
Teco	6e	---	---	---	---	---	---	---
405:								
Charo	7c	---	---	---	---	---	---	---
Charo, noncobbly	7c	---	---	---	---	---	---	---
409:								
Santa Fe	7s	---	---	---	---	---	---	---
410:								
Zia	6c	3e	---	7.50	---	6.00	---	15.00
414:								
Wauquie	7s	---	---	---	---	---	---	---
417:								
Jocity	7c	2e	---	6.00	---	---	---	12.00
418:								
Jocity	7c	2e	---	6.00	---	---	---	12.00
419:								
Santa Fe	7e	---	---	---	---	---	---	---
Wauquie	7e	---	---	---	---	---	---	---
Rock outcrop	8s	---	---	---	---	---	---	---
420:								
Pinavetes	6c	3s	---	6.00	---	4.00	---	8.00
421:								
Gilco, moderately saline, sodic	7c	4s	---	4.00	---	3.00	---	8.00

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
422:								
Vessilla	7s	---	---	---	---	---	---	---
Menefee	7s	---	---	---	---	---	---	---
Orlie	6c	---	---	---	---	---	---	---
423:								
Gilco	7e	4e	---	6.00	---	5.00	---	12.00
426:								
Aga, moderately saline, sodic	7c	4s	---	3.00	---	---	---	6.00
427:								
Aga	7c	2e	---	4.50	---	---	---	9.00
428:								
Aga, moderately saline, sodic	7c	4s	---	3.00	---	---	---	6.00
430:								
Trail	7s	4e	---	7.00	---	4.50	---	14.00
431:								
Trail	7s	4e	---	7.00	---	4.50	---	14.00
433:								
Peralta	7c	3e	---	5.00	---	---	---	10.00
434:								
Peralta	7c	3e	---	5.00	---	---	---	10.00
437:								
Peralta, moderately saline, sodic	7s	4s	---	4.00	---	---	---	10.00
500:								
Rock outcrop	8s	---	---	---	---	---	---	---
Osha	7c	---	---	---	---	---	---	---
Rubble land	8s	---	---	---	---	---	---	---
503:								
Cajete	7c	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
503:								
Cypher	7c	---	---	---	---	---	---	---
504:								
Orejas	7s	---	---	---	---	---	---	---
Guaje	6s	---	---	---	---	---	---	---
600:								
Rock outcrop	8s	---	---	---	---	---	---	---
Cypher	7c	---	---	---	---	---	---	---
601:								
Laventana	7c	---	---	---	---	---	---	---
603:								
Laventana	7c	---	---	---	---	---	---	---
Mirand	7c	---	---	---	---	---	---	---
604:								
Cypher	7c	---	---	---	---	---	---	---
Mirand	7c	---	---	---	---	---	---	---
608:								
Osha, steep	7c	---	---	---	---	---	---	---
Osha	7c	---	---	---	---	---	---	---
823:								
Gilco, unprotected	7e	4e	---	6.00	---	5.00	---	10.00
827:								
Aga, unprotected	7c	2e	---	---	---	---	---	---
830:								
Trail, unprotected	7s	4e	---	7.00	---	4.50	---	14.00
831:								
Trail, unprotected	7s	4s	---	4.00	---	---	---	6.00
835:								
Peralta, unprotected	7c	---	---	---	---	---	---	---

Table 5.--Irrigated and nonirrigated yields by map unit component

Map symbol and soil name	Land capability		Alfalfa hay		Sweet corn		Pasture	
	N	I	N	I	N	I	N	I
			Tons	Tons	Tons	Tons	AUM	AUM
842:								
Peralta, moderately saline, sodic, unprotected	7s	4s	---	4.00	---	---	---	11.00
850:								
Water	---	---	---	---	---	---	---	---
DAM:								
Dam	---	---	---	---	---	---	---	---

Table 6.--Prime and other important farmland

(Only the soils considered prime or important farmland are listed. Urban or built-up areas of the soils listed are not considered prime or important farmland. If a soil is prime or important farmland only under certain conditions, the conditions are specified in parentheses after the soil name.)

Map symbol	Map unit name	Farmland Classification
20	Gilco clay loam, 0 to 1 percent slopes	Prime farmland if irrigated
22	Aga silty clay loam, 0 to 1 percent slopes	Prime farmland if irrigated
25	Gilco loam, 0 to 1 percent slopes	Prime farmland if irrigated
27	Aga loam, 0 to 1 percent slopes	Prime farmland if irrigated
91	Zia sandy loam, 1 to 3 percent slopes	Prime farmland if irrigated
95	El Rancho loam, 0 to 2 percent slopes	Prime farmland if irrigated
97	El Rancho clay loam, 0 to 2 percent slopes	Prime farmland if irrigated
410	Zia loam, 0 to 1 percent slopes	Prime farmland if irrigated
417	Jocity loam, 0 to 2 percent slopes	Prime farmland if irrigated
418	Jocity clay loam, 0 to 2 percent slopes	Prime farmland if irrigated
433	Peralta loam, 0 to 1 percent slopes	Prime farmland if irrigated

Table 7.--Rangeland productivity

(Only the soils that support rangeland vegetation suitable for grazing are rated.)

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
1:				
Silver	Loamy	950	663	375
Clovis	Loamy	950	663	375
2:				
Clovis	Loamy	950	663	375
Prieta	Malpais	1,100	763	425
Silver	Loamy	950	663	375
3:				
Montecito	---	---	---	---
Orejas	---	---	---	---
4:				
Montecito	---	---	---	---
Montecito, bouldery	---	---	---	---
10:				
Trail	Bottomland	4,000	2,400	800
11:				
Trail	Bottomland	4,000	2,400	800
13:				
Sandoval	Shallow	850	575	300
Querencia	Loamy	950	663	375
15:				
Camino	Clayey	1,200	1,000	800
Sandoval	Shallow	850	575	300
16:				
Rock outcrop	---	---	---	---
Prieta	Malpais	1,100	763	425

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
17:				
Vessilla	---	---	---	---
Menefee	---	---	---	---
Rock outcrop	---	---	---	---
18:				
Sparham	Clayey	1,200	800	600
20:				
Gilco	Bottomland	4,000	2,400	800
21:				
Rock outcrop	---	---	---	---
Hackroy	---	---	---	---
22:				
Aga	Bottomland	4,000	2,400	800
23:				
Hickman	Swale	1,700	1,300	800
24:				
Orlie	Loamy	1,100	750	600
Sparham	Clayey	1,200	800	600
25:				
Gilco	Bottomland	4,000	2,400	800
26:				
Orlie	Loamy	1,100	750	600
27:				
Aga	Bottomland	4,000	2,400	800
29:				
Trail	Deep Sand	4,000	2,400	800
31:				
Riverwash	---	---	---	---
33:				
Pits	---	---	---	---

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
34:				
Ildefonso	Limy	950	675	375
Witt	Loamy	950	663	375
41:				
Dune land	---	---	---	---
47:				
Cascajo	Gravelly	900	650	375
51:				
Sparham	Clayey	4,000	2,400	800
52:				
Totavi	---	---	---	---
53:				
Witt	Loamy	1,500	950	400
Harvey	Limy	1,500	950	400
54:				
Harvey	Limy	1,500	1,000	400
Cascajo	Gravelly	1,100	1,000	400
55:				
La Fonda	Loamy	1,500	950	400
56:				
Ildefonso	Breaks	1,300	800	300
57:				
Badland	---	---	---	---
58:				
Deama	---	---	---	---
Elpedro	---	---	---	---
59:				
Harvey	Limy	1,500	950	400
Ildefonso	Breaks	1,300	800	300

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
59:				
La Fonda	Loamy	1,500	950	400
63:				
Placitas	Gravelly	1,100	750	400
64:				
Skyvillage	Shallow Sandstone	700	575	275
Ildefonso	Breaks	1,300	800	300
65:				
Ildefonso	Breaks	1,300	800	300
Harvey	Limy	1,500	950	400
66:				
Zia	Sandy	850	500	325
67:				
Sandoval	Shallow	850	525	300
Poley	Foothills	750	550	375
68:				
Penistaja	Loamy	950	663	375
Querencia	Loamy	950	663	375
71:				
Palon	---	---	---	---
72:				
Palon	---	---	---	---
74:				
Origo	---	---	---	---
Pavo	Mountain Loam	1,400	1,150	900
75:				
Origo	---	---	---	---
82:				
Calaveras	---	---	---	---

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
83:				
Calaveras	---	---	---	---
Rubble land	---	---	---	---
85:				
Redondo	---	---	---	---
86:				
Redondo	---	---	---	---
87:				
Redondo	---	---	---	---
Rubble land	---	---	---	---
88:				
Totavi	---	---	---	---
Jemez	---	---	---	---
Rock outcrop	---	---	---	---
91:				
Zia	Sandy	860	575	325
92:				
Galisteo, moderately saline, sodic	Salty Bottomland	1,500	1,050	600
93:				
Zia	Sandy	860	550	325
95:				
El Rancho	Loamy	950	663	375
97:				
El Rancho	Loamy	950	663	375
100:				
Orejas	---	---	---	---
Rock outcrop	---	---	---	---
101:				
Blancot	Loamy	800	550	300

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
101:				
Lybrook	Salt Flats	700	500	300
102:				
Sparham	Bottomland	4,000	2,400	800
104:				
Cochiti	---	---	---	---
Montecito	---	---	---	---
105:				
Badland	---	---	---	---
Menefee	---	---	---	---
106:				
Stumble	Gravelly Sand	600	400	300
Stumble, sandy	Deep Sand	900	800	400
108:				
Embudo	Sandy	900	650	400
109:				
Embudo	Sandy	900	650	400
Tijeras	Sandy	900	650	400
110:				
Rock outcrop	---	---	---	---
Saido	Gyp Upland	750	475	200
111:				
Rock outcrop	---	---	---	---
Zia	Foothills	750	650	375
112:				
Tijeras	Sandy	900	650	400
114:				
San Mateo	Swale	1,350	1,050	600
Zia	Sandy	950	675	375

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
120:				
Pinavetes	Deep Sand	900	600	275
124:				
Rock outcrop	---	---	---	---
129:				
Menefee	---	---	---	---
130:				
Pinavetes	Deep Sand	900	600	275
Galisteo, moderately saline, sodic	Salty Bottomland	1,500	1,050	600
142:				
Grieta	Loamy	950	663	375
143:				
Clovis	Loamy	950	663	375
145:				
Grieta	Loamy	950	663	375
Sheppard	Deep Sand	900	600	300
146:				
Sedmar	---	---	---	---
150:				
Doakum	Loamy	800	550	300
Betonnie	Sandy	900	600	300
162:				
Hackroy	---	---	---	---
Nyjack	---	---	---	---
163:				
Jemez	---	---	---	---
170:				
San Mateo	Swale	1,350	975	600
180:				
Councelor	Sandy	900	600	300

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
180:				
Eslendo	Shallow	500	300	150
Mespun	Deep Sand	800	525	250
183:				
Sheppard	Deep Sand	900	600	300
185:				
Frijoles	---	---	---	---
190:				
Zia	Sandy	750	650	500
Skyvillage	Shallow Sandstone	700	500	275
Rock outcrop	---	---	---	---
191:				
Sheppard	Deep Sand	900	600	300
200:				
Sedillo	Gravelly	900	625	350
201:				
Rock outcrop	---	---	---	---
Sedgran	Hills	750	600	350
206:				
Pinitos	---	---	---	---
207:				
Penistaja	Loamy	950	663	375
Zia	Loamy	950	650	375
208:				
Sedillo	Gravelly	750	575	375
210:				
Ildefonso	Limy	900	625	375
211:				
Zia	Sandy	860	525	325

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
211:				
Clovis	Loamy	950	663	375
213:				
Pinavetes	Deep Sand	900	600	300
Rock outcrop	---	---	---	---
215:				
Ess	Subalpine Grassland	1,800	1,500	1,200
Rock outcrop	---	---	---	---
217:				
Witt	Loamy	950	663	375
218:				
Ildefonso	Limy	950	625	375
220:				
Rock outcrop	---	---	---	---
Vessilla	---	---	---	---
Menefee	---	---	---	---
226:				
Galisteo, moderately saline, sodic	Salty Bottomland	1,500	1,050	600
227:				
Hagerman	Loamy	950	663	375
Bond	Shallow Sandstone	700	500	275
228:				
Winona	Shallow Sandstone	850	575	300
230:				
Skyvillage	Shallow Sandstone	700	500	275
Sandoval	Shallow	850	575	300
Rock outcrop	---	---	---	---
231:				
Querencia	Loamy	950	663	375

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
234:				
Querencia	Loamy	950	663	375
Zia	Sandy	860	600	325
235:				
Sandoval	Shallow	850	575	300
236:				
Sparank, moderately saline, sodic-	Salty Bottomland	1,500	1,000	550
237:				
Sparank	Clayey Bottomland	3,200	2,250	1,250
240:				
Penistaja	Loamy	950	663	375
Hagerman	Loamy	950	663	375
250:				
Pinavetes	Deep Sand	900	600	275
262:				
Pastura	Shallow Limy Savannah	900	800	450
270:				
Blancot	Loamy	800	550	300
Councelor	Sandy	900	600	300
Tsosie	Salt Flats	700	500	300
281:				
Carjo	---	---	---	---
282:				
Tocal	---	---	---	---
283:				
Mirand	---	---	---	---
Alanos	---	---	---	---
290:				
Alanos	---	---	---	---

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
290:				
Rock outcrop	---	---	---	---
300:				
Waumac	Sandy	860	600	325
Bamac	Foothills	860	600	325
301:				
Vastine	Mountain Loam	1,400	1,150	900
Jarola	Mountain Meadow	1,400	1,150	900
302:				
Tranquilar	Mountain Grassland	2,000	1,400	1,000
Jarmillo	Mountain Loam	1,400	1,100	800
304:				
Cosey	Mountain Loam	1,400	1,100	800
Jarmillo	Mountain Loam	1,400	1,100	800
307:				
Flugle	Savannah	875	550	300
Waumac	Sandy	860	600	325
308:				
Cajete	Mountain Grassland	2,000	1,400	1,000
311:				
Cosey	Mountain Loam	1,400	1,100	800
Tranquilar	Mountain Grassland	2,000	1,400	1,000
Calaveras	---	---	---	---
312:				
Royosa	Deep Sand	900	600	275
314:				
Fragua	Foothills	900	600	300
Waumac	Sandy	900	600	300

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
314:				
Royosa	Deep Sand	900	600	275
317:				
Elpedro	---	---	---	---
319:				
Bamac	Foothills	750	500	375
Rock outcrop	---	---	---	---
320:				
Sparham	Clayey	1,200	800	600
321:				
Waumac	Sandy	900	600	300
Royosa	Deep Sand	900	600	275
322:				
Fragua	Foothills	---	---	---
324:				
Rock outcrop	---	---	---	---
Atarque	Shallow Sandstone	700	475	275
Menefee	Shallow	850	575	300
325:				
Rock outcrop	---	---	---	---
Espiritu	Foothills	---	---	---
Vessilla	---	---	---	---
342:				
Waumac	Sandy	900	600	300
Vessilla	---	750	525	300
Rock outcrop	---	---	---	---
345:				
Espiritu	Foothills	750	575	375

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
345:				
Bamac	Foothills	750	575	375
346:				
Espiritu, cobbly	Foothills	---	---	---
Bamac	Foothills	---	---	---
348:				
Wauquie	---	---	---	---
Rock outcrop	---	---	---	---
353:				
Cochiti	---	---	---	---
Espiritu	Foothills	---	---	---
354:				
Waumac Variant	---	---	---	---
358:				
Deama	---	---	---	---
Elpedro	---	---	---	---
Rock outcrop	---	---	---	---
396:				
Atarque	Shallow Sandstone	---	---	---
Menefee	---	---	---	---
Rock outcrop	---	---	---	---
397:				
Rock outcrop	---	---	---	---
Cucho	---	---	---	---
Vessilla	---	---	---	---
398:				
Espiritu	Foothills	750	525	375
Cucho	---	---	---	---

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
399:				
Cucho	---	---	---	---
Teco	Clayey	800	525	250
405:				
Charo	---	---	---	---
Charo, noncobbly	Mountain Grassland	2,000	1,400	1,000
409:				
Santa Fe	---	---	---	---
410:				
Zia	Loamy	950	625	375
414:				
Wauquie	---	---	---	---
417:				
Jocity	Bottomland	4,000	2,400	800
418:				
Jocity	Bottomland	4,000	2,400	800
419:				
Santa Fe	---	---	---	---
Wauquie	---	---	---	---
Rock outcrop	---	---	---	---
420:				
Pinavetes	Deep Sand	900	600	275
421:				
Gilco, moderately saline, sodic	Salty Bottomland	600	400	200
422:				
Vessilla	---	---	---	---
Menefee	---	---	---	---
Orlie	Loamy	1,100	850	600

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
423:				
Gilco	Bottomland	4,000	2,400	800
426:				
Aga, moderately saline, sodic	Bottomland	4,000	2,400	800
427:				
Aga	Bottomland	4,000	2,400	800
428:				
Aga, moderately saline, sodic	Salty Bottomland	2,000	1,500	1,000
430:				
Trail	Bottomland	4,000	2,400	800
431:				
Trail	Deep Sand	4,000	2,400	800
433:				
Peralta	Bottomland	4,000	2,400	800
434:				
Peralta	Bottomland	4,000	2,400	800
437:				
Peralta, moderately saline, sodic-	Salty Bottomland	900	600	300
500:				
Rock outcrop	---	---	---	---
Osha	---	---	---	---
Rubble land	---	---	---	---
503:				
Cajete	---	---	---	---
Cypher	---	---	---	---
504:				
Orejas	---	---	---	---
Guaje	---	---	---	---
600:				
Rock outcrop	---	---	---	---

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
600:				
Cypher	---	---	---	---
601:				
Laventana	---	---	---	---
603:				
Laventana	---	---	---	---
Mirand	---	---	---	---
604:				
Cypher	---	---	---	---
Mirand	---	---	---	---
608:				
Osha, steep	---	---	---	---
Osha	---	---	---	---
823:				
Gilco, unprotected	Bottomland	4,000	2,400	800
827:				
Aga, unprotected	Bottomland	4,000	2,400	800
830:				
Trail, unprotected	Bottomland	4,000	2,400	800
831:				
Trail, unprotected	Bottomland	4,000	2,400	800
835:				
Peralta, unprotected	Bottomland	4,000	2,400	800
842:				
Peralta, moderately saline, sodic, unprotected	Salty Bottomland	900	600	300
850:				
Water	---	---	---	---

Table 7.--Rangeland productivity--continued

Map symbol and soil name	Ecological site	Total dry-weight production		
		Favorable year	Normal year	Unfavorable year
		Lb./acre	Lb./acre	Lb./acre
DAM:				
Dam	---	---	---	---

Table 8.--Forestland productivity

Only those map units which produce harvestable timber are shown

Map symbol and soil name	Potential productivity			Trees to manage
	Common trees	Site index	Volume of wood fiber	
			cu ft/ac	
52:				
Totavi	oneseed juniper	---	0	ponderosa pine
	ponderosa pine	75	57	
	Utah juniper	---	0	
71:				
Palon	Douglas-fir	71	0	Douglas-fir, ponderosa pine, white fir
	ponderosa pine	79	72	
	white fir	---	0	
72:				
Palon	Douglas-fir	65	0	Douglas-fir, ponderosa pine, white fir
	ponderosa pine	62	43	
	white fir	---	0	
74:				
Origo	Douglas-fir	66	57	Douglas-fir, white fir
	limber pine	---	0	
	quaking aspen	---	0	
	white fir	---	0	
Pavo	---	---	---	---
75:				
Origo	Douglas-fir	66	57	Douglas-fir, Engelmann spruce, white fir
	Engelmann spruce	79	72	
	white fir	---	0	
82:				
Calaveras	Douglas-fir	71	57	ponderosa pine
	limber pine	---	0	
	ponderosa pine	---	0	
	white fir	---	0	
83:				
Calaveras	Douglas-fir	77	57	ponderosa pine
	limber pine	---	0	
	ponderosa pine	---	0	
	white fir	---	0	
Rubble land	---	---	---	---
85:				
Redondo	Engelmann spruce	68	57	Engelmann spruce
86:				
Redondo	Engelmann spruce	74	72	Engelmann spruce
87:				
Redondo	Engelmann spruce	74	72	Engelmann spruce
Rubble land	---	---	---	---
88:				
Totavi	oneseed juniper	---	0	ponderosa pine
	ponderosa pine	75	57	

Table 8.--Forestland productivity--continued

Map symbol and soil name	Potential productivity			Trees to manage
	Common trees	Site index	Volume of wood fiber	
			cu ft/ac	
88:				
Jemez	Douglas-fir	74	0	Douglas-fir, ponderosa pine, white fir
	ponderosa pine	74	57	
	white fir	---	0	
Rock outcrop	---	---	---	---
146:				
Sedmar	Gambel oak	---	0	ponderosa pine
	ponderosa pine	52	43	
162:				
Hackroy	oneseed juniper	---	0	oneseed juniper, twoneedle pinyon
	twoneedle pinyon	20	0	
Nyjack	oneseed juniper	---	0	ponderosa pine
	ponderosa pine	60	43	
	twoneedle pinyon	---	0	
163:				
Jemez	Douglas-fir	74	0	Douglas-fir, ponderosa pine, white fir
	ponderosa pine	74	57	
	white fir	---	0	
281:				
Carjo	ponderosa pine	52	43	ponderosa pine
282:				
Tocal	Douglas-fir	---	0	ponderosa pine
	ponderosa pine	58	43	
	white fir	---	0	
283:				
Mirand	ponderosa pine	57	43	ponderosa pine
Alanos	Douglas-fir	---	0	Douglas-fir, ponderosa pine
	ponderosa pine	65	57	
290:				
Alanos	Douglas-fir	---	0	Douglas-fir, ponderosa pine
	ponderosa pine	65	57	
Rock outcrop	---	---	---	---
311:				
Cosey	---	---	---	---
Tranquilar	---	---	---	---
Calaveras	Douglas-fir	71	57	ponderosa pine
	limber pine	---	0	
	ponderosa pine	---	0	
	white fir	---	0	
405:				
Charo	ponderosa pine	66	57	ponderosa pine
	Rocky Mountain juniper	---	0	
	twoneedle pinyon	---	0	

Table 8.--Forestland productivity--continued

Map symbol and soil name	Potential productivity			Trees to manage
	Common trees	Site index	Volume of wood fiber	
			cu ft/ac	
405:				
Charo, noncobbly	---	---	---	---
500:				
Rock outcrop	---	---	---	---
Osha	ponderosa pine	48	29	ponderosa pine
Rubble land	---	---	---	---
503:				
Cajete	ponderosa pine	53	43	ponderosa pine
Cypher	ponderosa pine	50	43	ponderosa pine
600:				
Rock outcrop	---	---	---	---
Cypher	ponderosa pine	45	29	ponderosa pine
601:				
Laventana	ponderosa pine	74	57	ponderosa pine
603:				
Laventana	ponderosa pine	55	43	ponderosa pine
Mirand	ponderosa pine	76	57	ponderosa pine
604:				
Cypher	ponderosa pine	46	29	ponderosa pine
Mirand	ponderosa pine	76	57	ponderosa pine
608:				
Osha, steep	ponderosa pine	52	43	ponderosa pine
Osha	ponderosa pine	64	43	ponderosa pine

Table 9A.--Camp areas, picnic areas, and playgrounds

(The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table.)

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
1:							
Silver	55	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Slope	0.50
						Dusty	0.50
Clovis	35	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Slope	0.50
						Dusty	0.50
2:							
Clovis	35	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Slope	1.00
						Dusty	0.50
Prieta	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Dusty	0.50	Dusty	0.50	Gravel content	1.00
		Slow water movement	0.21	Slow water movement	0.21	Large stones content	1.00
		Large stones content	0.18	Large stones content	0.18	Slope	1.00
		Gravel content	0.08	Gravel content	0.08	Dusty	0.50
Silver	20	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Slope	1.00
						Dusty	0.50
3:							
Montecito	60	Not limited		Not limited		Somewhat limited	
						Slope	0.50
						Large stones content	0.01

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
3:							
Orejas	30	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Large stones content	0.02	Large stones content	0.02	Large stones content	0.99
						Gravel content	0.86
						Slope	0.50
4:							
Montecito	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Large stones content	0.01
Montecito, bouldery-	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Large stones content	1.00
		Large stones content	0.68	Large stones content	0.68	Slope	1.00
		Dusty	0.50	Dusty	0.50	Gravel content	1.00
		Gravel content	0.05	Gravel content	0.05	Dusty	0.50
10:							
Trail	85	Very limited		Not limited		Not limited	
		Flooding	1.00				
11:							
Trail	85	Very limited		Not limited		Somewhat limited	
		Flooding	1.00			Flooding	0.60
13:							
Sandoval	65	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
						Slope	0.88
Querencia	20	Not limited		Not limited		Somewhat limited	
						Slope	0.88

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
15:							
Camino	40	Somewhat limited		Somewhat limited		Somewhat limited	
		Slow water movement	0.41	Slow water movement	0.41	Slope	0.50
						Slow water movement	0.41
Sandoval	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
						Slope	0.88
16:							
Rock outcrop	50	Not rated		Not rated		Not rated	
Prieta	30	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Large stones content	1.00	Large stones content	1.00	Slope	1.00
		Dusty	0.50	Dusty	0.50	Large stones content	1.00
		Slow water movement	0.21	Slow water movement	0.21	Gravel content	0.56
		Slope	0.04	Slope	0.04	Dusty	0.50
17:							
Vessilla	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	0.04	Slope	0.04	Slope	1.00
Menefee	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	0.04	Slope	0.04	Slope	1.00
Rock outcrop	20	Not rated		Not rated		Not rated	
18:							
Sparham	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Sodium content	1.00	Sodium content	1.00
		Sodium content	1.00	Too clayey	0.50	Flooding	0.60
		Too clayey	0.50			Too clayey	0.50

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
20:							
Gilco	85	Very limited		Not limited		Somewhat limited	
		Flooding	1.00			Gravel content	0.04
21:							
Rock outcrop	60	Not rated		Not rated		Not rated	
Hackroy	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slow water movement	0.41	Slow water movement	0.41	Slope	0.88
						Slow water movement	0.41
22:							
Aga	85	Very limited		Not limited		Not limited	
		Flooding	1.00				
23:							
Hickman	85	Very limited		Not limited		Not limited	
		Flooding	1.00				
24:							
Orlie	45	Not limited		Not limited		Somewhat limited	
						Slope	0.12
						Gravel content	0.08
Sparham	35	Very limited		Very limited		Very limited	
		Flooding	1.00	Sodium content	1.00	Sodium content	1.00
		Sodium content	1.00	Too clayey	0.50	Flooding	0.60
		Too clayey	0.50	Slow water movement	0.41	Too clayey	0.50
		Slow water movement	0.41			Slow water movement	0.41
						Gravel content	0.04
25:							
Gilco	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50				

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
26:							
Orlie	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Slope	0.50
						Dusty	0.50
27:							
Aga	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50				
29:							
Trail	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Too sandy	0.81	Too sandy	0.81
		Too sandy	0.81				
31:							
Riverwash	90	Very limited		Very limited		Very limited	
		Flooding	1.00	Too sandy	1.00	Too sandy	1.00
		Too sandy	1.00	Flooding	0.40	Flooding	1.00
						Gravel content	0.21
33:							
Pits	100	Not rated		Not rated		Not rated	
34:							
Ildefonso	55	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Gravel content	0.99
						Large stones content	0.92
						Slope	0.88
						Dusty	0.50
Witt	30	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Dusty	0.50
						Slope	0.12
41:							
Dune land	100	Very limited		Very limited		Very limited	
		Too sandy	1.00	Too sandy	1.00	Too sandy	1.00
		Slope	0.16	Slope	0.16	Slope	1.00

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
47:							
Cascajo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.98	Gravel content	0.98	Slope	1.00
						Large stones content	0.61
51:							
Sparham	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Depth to saturated zone	1.00
		Flooding	1.00	Sodium content	1.00	Sodium content	1.00
		Sodium content	1.00	Slow water movement	0.41	Flooding	0.60
		Slow water movement	0.41	Salinity	0.13	Slow water movement	0.41
		Salinity	0.13			Salinity	0.13
52:							
Totavi	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Too sandy	0.81	Too sandy	0.81
		Too sandy	0.81			Slope	0.12
53:							
Witt	55	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Slope	0.50
						Dusty	0.50
Harvey	30	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Slope	0.50
						Dusty	0.50
54:							
Harvey	45	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.16	Slope	0.16	Slope	1.00
		Too sandy	0.01	Too sandy	0.01	Too sandy	0.01
Cascajo	40	Somewhat limited		Somewhat limited		Very limited	
		Gravel content	0.71	Gravel content	0.71	Gravel content	1.00
		Slope	0.16	Slope	0.16	Slope	1.00
						Large stones content	0.08

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
55:							
La Fonda	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Dusty	0.50
						Slope	0.12
56:							
Ildefonso	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Dusty	0.50	Dusty	0.50	Gravel content	0.97
						Large stones content	0.84
						Dusty	0.50
57:							
Badland	90	Not rated		Not rated		Not rated	
58:							
Deama	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Large stones content	1.00	Large stones content	1.00	Large stones content	1.00
		Gravel content	0.03	Gravel content	0.03	Gravel content	1.00
		Large stones content	0.02	Large stones content	0.02	Large stones content	0.99
Elpedro	35	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Slope	1.00
		Slope	0.04	Slope	0.04	Dusty	0.50
59:							
Harvey	35	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Slope	1.00
						Dusty	0.50
Ildefonso	35	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Slope	1.00
		Slope	0.37	Slope	0.37	Dusty	0.50
						Gravel content	0.11
						Large stones content	0.08

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
59:							
La Fonda	15	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Slope	0.88
						Dusty	0.50
63:							
Placitas	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Dusty	0.50	Dusty	0.50	Gravel content	1.00
		Gravel content	0.08	Gravel content	0.08	Depth to bedrock	0.71
						Dusty	0.50
64:							
Skyvillage	40	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
Ildefonso	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.76	Large stones content	0.76	Gravel content	1.00
		Gravel content	0.11	Gravel content	0.11	Large stones content	0.76
						Large stones content	0.05
65:							
Ildefonso	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.99	Gravel content	0.99	Slope	1.00
		Large stones content	0.76	Large stones content	0.76	Large stones content	0.76
						Large stones content	0.32
Harvey	30	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00
		Dusty	0.50	Dusty	0.50	Dusty	0.50
66:							
Zia	85	Not limited		Not limited		Somewhat limited	
						Slope	0.88

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
67:							
Sandoval	40	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Dusty	0.50	Dusty	0.50	Dusty	0.50
Poley	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.75	Gravel content	0.75	Slope	1.00
		Dusty	0.50	Dusty	0.50	Large stones content	0.92
						Dusty	0.50
68:							
Penistaja	45	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.79	Too sandy	0.79	Slope	0.88
						Too sandy	0.79
Querencia	35	Not limited		Not limited		Somewhat limited	
						Slope	0.88
71:							
Palon	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.99
						Large stones content	0.46
72:							
Palon	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
74:							
Origo	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Gravel content	0.45	Gravel content	0.45	Gravel content	1.00
						Large stones content	0.08
Pavo	25	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
75:							
Origo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
82:							
Calaveras	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.01
83:							
Calaveras	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Rubble land	20	Not rated		Not rated		Not rated	
85:							
Redondo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
86:							
Redondo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.78
						Large stones content	0.20
87:							
Redondo	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.49
						Large stones content	0.20
Rubble land	25	Not rated		Not rated		Not rated	
88:							
Totavi	45	Very limited		Not limited		Somewhat limited	
		Flooding	1.00			Slope	0.12
						Gravel content	0.04

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
88:							
Jemez	30	Somewhat limited		Somewhat limited		Very limited	
		Slow water movement	0.21	Slow water movement	0.21	Slope	1.00
		Slope	0.16	Slope	0.16	Depth to bedrock	0.71
						Slow water movement	0.21
Rock outcrop	15	Not rated		Not rated		Not rated	
91:							
Zia	85	Not limited		Not limited		Not limited	
92:							
Galisteo, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Salinity	1.00	Salinity	1.00	Salinity	1.00
		Slow water movement	0.41	Slow water movement	0.41	Slow water movement	0.41
93:							
Zia	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Too sandy	0.81
						Slope	0.12
95:							
El Rancho	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Dusty	0.50
97:							
El Rancho	85	Not limited		Not limited		Not limited	
100:							
Orejas	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Large stones content	0.18	Large stones content	0.18	Large stones content	1.00
						Gravel content	0.99
Rock outcrop	40	Not rated		Not rated		Not rated	

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
101:							
Blancot	55	Not limited		Not limited		Somewhat limited	
						Slope	0.88
Lybrook	25	Very limited		Very limited		Very limited	
		Sodium content	1.00	Sodium content	1.00	Sodium content	1.00
102:							
Sparham	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Sodium content	1.00	Sodium content	1.00
		Sodium content	1.00			Flooding	0.60
						Gravel content	0.04
104:							
Cochiti	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Dusty	0.50	Dusty	0.50	Gravel content	0.68
		Slow water movement	0.41	Slow water movement	0.41	Dusty	0.50
						Slow water movement	0.41
						Large stones content	0.01
Montecito	30	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Dusty	0.50
						Slope	0.12
105:							
Badland	50	Not rated		Not rated		Not rated	
Menefee	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
106:							
Stumble	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.92	Gravel content	0.92	Slope	1.00

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
106:							
Stumble, sandy------	30	Very limited		Somewhat limited		Very limited	
		Flooding	1.00	Too sandy	0.79	Gravel content	1.00
		Too sandy	0.79	Gravel content	0.03	Slope	1.00
		Gravel content	0.03			Too sandy	0.79
108:							
Embudo--------------	85	Somewhat limited		Somewhat limited		Very limited	
		Gravel content	0.01	Gravel content	0.01	Gravel content	1.00
		Slope	0.01	Slope	0.01	Slope	1.00
109:							
Embudo--------------	50	Not limited		Not limited		Very limited	
						Slope	1.00
						Gravel content	0.78
Tijeras-------------	35	Not limited		Not limited		Somewhat limited	
						Gravel content	0.78
						Slope	0.50
110:							
Rock outcrop--------	45	Not rated		Not rated		Not rated	
Saido---------------	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Dusty	0.50	Dusty	0.50	Dusty	0.50
		Salinity	0.13	Salinity	0.13	Salinity	0.13
111:							
Rock outcrop--------	50	Not rated		Not rated		Not rated	
Zia-----------------	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
112:							
Tijeras-------------	85	Not limited		Not limited		Somewhat limited	
						Gravel content	0.85
						Slope	0.12
						Large stones content	0.01

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
114:							
San Mateo	40	Very limited		Not limited		Not limited	
		Flooding	1.00				
Zia	40	Not limited		Not limited		Somewhat limited	
						Slope	0.88
120:							
Pinavetes	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Too sandy	0.81
						Slope	0.50
124:							
Rock outcrop	90	Not rated		Not rated		Not rated	
129:							
Menefee	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
130:							
Pinavetes	45	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Too sandy	0.81
						Slope	0.12
Galisteo, moderately saline, sodic	40	Very limited		Very limited		Very limited	
		Sodium content	1.00	Sodium content	1.00	Sodium content	1.00
		Salinity	1.00	Salinity	1.00	Salinity	1.00
		Flooding	1.00	Slow water movement	0.41	Slow water movement	0.41
		Slow water movement	0.41				
142:							
Grieta	85	Not limited		Not limited		Somewhat limited	
						Slope	0.12
143:							
Clovis	85	Not limited		Not limited		Somewhat limited	
						Slope	0.12

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
145:							
Grieta	55	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.79	Too sandy	0.79	Too sandy	0.79
						Slope	0.50
Sheppard	40	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.79	Too sandy	0.79	Slope	1.00
						Too sandy	0.79
146:							
Sedmar	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Too sandy	0.81	Too sandy	0.81	Slope	1.00
		Slope	0.01	Slope	0.01	Too sandy	0.81
150:							
Doakum	55	Not limited		Not limited		Somewhat limited	
						Slope	0.12
Betonnie	35	Not limited		Not limited		Very limited	
						Slope	1.00
						Gravel content	0.08
162:							
Hackroy	45	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slow water movement	0.41	Slow water movement	0.41	Slow water movement	0.41
						Slope	0.12
Nyjack	40	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Dusty	0.50
						Slope	0.12
						Depth to bedrock	0.01
163:							
Jemez	85	Somewhat limited		Somewhat limited		Very limited	
		Slow water movement	0.21	Slow water movement	0.21	Slope	1.00
		Slope	0.01	Slope	0.01	Slow water movement	0.21
						Depth to bedrock	0.01

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
170:							
San Mateo	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Sodium content	1.00	Sodium content	1.00
		Sodium content	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50				
180:							
Councelor	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Eslendo	30	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
Mespun	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Too sandy	0.31	Too sandy	0.31	Too sandy	0.31
183:							
Sheppard	85	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.79	Too sandy	0.79	Slope	1.00
		Slope	0.63	Slope	0.63	Too sandy	0.79
185:							
Frijoles	90	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Slope	0.88
						Dusty	0.50
190:							
Zia	35	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00
Skyvillage	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
Rock outcrop	15	Not rated		Not rated		Not rated	
191:							
Sheppard	85	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.79	Too sandy	0.79	Slope	1.00
						Too sandy	0.79

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
200:							
Sedillo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.06	Gravel content	0.06	Slope	1.00
						Large stones content	0.74
201:							
Rock outcrop	55	Not rated		Not rated		Not rated	
Sedgran	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Gravel content	1.00	Gravel content	1.00	Depth to bedrock	1.00
		Too sandy	0.70	Too sandy	0.70	Too sandy	0.70
						Large stones content	0.68
206:							
Pinitos	85	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Slope	1.00
						Dusty	0.50
207:							
Penistaja	60	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Dusty	0.50
						Slope	0.12
Zia	25	Not limited		Not limited		Somewhat limited	
						Slope	0.88
208:							
Sedillo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	1.00	Gravel content	1.00	Slope	1.00

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
210:							
Ildefonso	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Large stones content	1.00
		Dusty	0.50	Dusty	0.50	Slope	1.00
		Large stones content	0.32	Large stones content	0.32	Gravel content	1.00
		Gravel content	0.09	Gravel content	0.09	Dusty	0.50
211:							
Zia	45	Not limited		Not limited		Very limited	
						Slope	1.00
Clovis	30	Not limited		Not limited		Somewhat limited	
						Slope	0.88
213:							
Pinavetes	55	Very limited		Very limited		Very limited	
		Slope	1.00	Too sandy	1.00	Slope	1.00
		Too sandy	1.00	Slope	1.00	Too sandy	1.00
Rock outcrop	30	Not rated		Not rated		Not rated	
215:							
Ess	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.18	Large stones content	0.18	Gravel content	1.00
		Gravel content	0.08	Gravel content	0.08	Large stones content	1.00
Rock outcrop	30	Not rated		Not rated		Not rated	
217:							
Witt	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Slope	0.88
						Dusty	0.50

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
218:							
Ildefonso	85	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Large stones content	1.00
		Large stones content	0.18	Large stones content	0.18	Gravel content	1.00
		Gravel content	0.01	Gravel content	0.01	Slope	1.00
		Slope	0.01	Slope	0.01	Dusty	0.50
220:							
Rock outcrop	40	Not rated		Not rated		Not rated	
Vessilla	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
						Large stones content	0.01
Menefee	20	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
226:							
Galisteo, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Sodium content	1.00	Sodium content	1.00	Sodium content	1.00
		Salinity	1.00	Salinity	1.00	Salinity	1.00
		Dusty	0.50	Dusty	0.50	Dusty	0.50
227:							
Hagerman	65	Not limited		Not limited		Somewhat limited	
						Depth to bedrock	0.16
						Slope	0.12
Bond	20	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Too sandy	0.31	Too sandy	0.31	Slope	0.88
						Too sandy	0.31
						Large stones content	0.01

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
228:							
Winona	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Gravel content	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Gravel content	0.96	Gravel content	0.96	Depth to bedrock	1.00
						Large stones content	0.32
230:							
Skyvillage	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	0.63	Slope	0.63	Slope	1.00
Sandoval	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	0.63	Slope	0.63	Slope	1.00
Rock outcrop	20	Not rated		Not rated		Not rated	
231:							
Querencia	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Slope	0.88
						Dusty	0.50
234:							
Querencia	60	Not limited		Not limited		Somewhat limited	
						Slope	0.88
Zia	20	Not limited		Not limited		Somewhat limited	
						Slope	0.88
235:							
Sandoval	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	0.04	Slope	0.04	Slope	1.00

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
236:							
Sparank, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Sodium content	1.00	Sodium content	1.00	Sodium content	1.00
		Salinity	1.00	Salinity	1.00	Salinity	1.00
		Flooding	1.00	Slow water movement	0.41	Flooding	0.60
		Slow water movement	0.41			Slow water movement	0.41
237:							
Sparank	85	Very limited		Not limited		Somewhat limited	
		Flooding	1.00			Flooding	0.60
240:							
Penistaja	45	Not limited		Not limited		Somewhat limited	
						Slope	0.12
Hagerman	35	Not limited		Not limited		Somewhat limited	
						Depth to bedrock	0.90
						Slope	0.12
250:							
Pinavetes	90	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.79	Too sandy	0.79	Slope	1.00
		Slope	0.16	Slope	0.16	Too sandy	0.79
262:							
Pastura	90	Very limited		Very limited		Very limited	
		Depth to cemented pan	1.00	Depth to cemented pan	1.00	Depth to cemented pan	1.00
		Dusty	0.50	Dusty	0.50	Dusty	0.50
						Slope	0.12
270:							
Blancot	40	Not limited		Not limited		Somewhat limited	
						Slope	0.50
Councelor	30	Not limited		Not limited		Not limited	
Tsosie	25	Somewhat limited		Somewhat limited		Somewhat limited	
		Salinity	0.50	Salinity	0.50	Salinity	0.50

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
281:							
Carjo	90	Somewhat limited		Somewhat limited		Somewhat limited	
		Slow water movement	0.96	Slow water movement	0.96	Slow water movement	0.96
						Slope	0.88
						Depth to bedrock	0.84
282:							
Tocal	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slow water movement	0.96	Slow water movement	0.96	Slope	1.00
						Slow water movement	0.96
283:							
Mirand	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Slow water movement	0.21	Slow water movement	0.21	Slow water movement	0.21
Alanos	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Slow water movement	0.96	Slow water movement	0.96	Gravel content	1.00
		Gravel content	0.01	Gravel content	0.01	Slow water movement	0.96
						Large stones content	0.88
290:							
Alanos	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Slow water movement	0.96	Slow water movement	0.96	Slow water movement	0.96
Rock outcrop	30	Not rated		Not rated		Not rated	
300:							
Waumac	50	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Too sandy	0.81
						Slope	0.50

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
300:							
Bamac	35	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.81	Too sandy	0.81	Gravel content	1.00
		Gravel content	0.22	Gravel content	0.22	Too sandy	0.81
						Slope	0.50
						Large stones content	0.01
301:							
Vastine	45	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Depth to saturated zone	0.19	Depth to saturated zone	0.39
		Depth to saturated zone	0.39				
Jarola	40	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Slow water movement	0.21	Depth to saturated zone	0.39
		Depth to saturated zone	0.39	Depth to saturated zone	0.19	Slow water movement	0.21
		Slow water movement	0.21			Slope	0.12
302:							
Tranquilar	50	Somewhat limited		Somewhat limited		Somewhat limited	
		Slow water movement	0.96	Slow water movement	0.96	Slow water movement	0.96
						Slope	0.88
Jarmillo	30	Not limited		Not limited		Somewhat limited	
						Slope	0.88
304:							
Cosey	45	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.37	Slope	0.37	Slope	1.00
		Slow water movement	0.21	Slow water movement	0.21	Slow water movement	0.21
Jarmillo	40	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.37	Slope	0.37	Slope	1.00

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
307:							
Flugle	60	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Dusty	0.50
						Slope	0.12
Waumac	25	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Slope	0.88
						Too sandy	0.81
308:							
Cajete	85	Not limited		Not limited		Somewhat limited	
						Gravel content	0.78
						Slope	0.50
311:							
Cosey	35	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00
		Slow water movement	0.21	Slow water movement	0.21	Slow water movement	0.21
						Large stones content	0.01
Tranquilar	30	Somewhat limited		Somewhat limited		Very limited	
		Slow water movement	0.96	Slow water movement	0.96	Slope	1.00
						Slow water movement	0.96
Calaveras	25	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00
312:							
Royosa	90	Very limited		Very limited		Very limited	
		Too sandy	1.00	Too sandy	1.00	Too sandy	1.00
						Slope	0.88
314:							
Fragua	40	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.76	Too sandy	0.76	Slope	0.88
						Too sandy	0.76

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
314:							
Waumac	30	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.79	Too sandy	0.79	Slope	0.88
						Too sandy	0.79
Royosa	25	Very limited		Very limited		Very limited	
		Too sandy	1.00	Too sandy	1.00	Too sandy	1.00
						Slope	0.88
317:							
Elpedro	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Slope	0.88
						Dusty	0.50
319:							
Bamac	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	1.00	Gravel content	1.00	Slope	1.00
		Too sandy	0.81	Too sandy	0.81	Too sandy	0.81
Rock outcrop	25	Not rated		Not rated		Not rated	
320:							
Sparham	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Sodium content	1.00	Sodium content	1.00
		Sodium content	1.00	Slow water movement	0.41	Flooding	0.60
		Slow water movement	0.41			Slow water movement	0.41
321:							
Waumac	60	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.79	Too sandy	0.79	Slope	1.00
		Slope	0.01	Slope	0.01	Too sandy	0.79
Royosa	30	Very limited		Very limited		Very limited	
		Too sandy	1.00	Too sandy	1.00	Too sandy	1.00
						Slope	0.88

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
322:							
Fragua	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Gravel content	0.13	Gravel content	0.13	Gravel content	1.00
		Large stones content	0.02	Large stones content	0.02	Large stones content	0.99
		Too sandy	0.01	Too sandy	0.01	Too sandy	0.01
324:							
Rock outcrop	30	Not rated		Not rated		Not rated	
Atarque	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
Menefee	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
						Gravel content	0.44
325:							
Rock outcrop	35	Not rated		Not rated		Not rated	
Espiritu	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.45	Gravel content	0.45	Slope	1.00
						Large stones content	0.16
Vessilla	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Gravel content	0.54	Gravel content	0.54	Depth to bedrock	1.00
						Large stones content	0.01
342:							
Waumac	35	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00
		Too sandy	0.79	Too sandy	0.79	Too sandy	0.79

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
342:							
Vessilla	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.01
Rock outcrop	20	Not rated		Not rated		Not rated	
345:							
Espiritu	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Gravel content	0.38	Gravel content	0.38	Gravel content	1.00
						Large stones content	0.08
Bamac	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	1.00	Gravel content	1.00	Slope	1.00
		Too sandy	0.81	Too sandy	0.81	Too sandy	0.81
						Large stones content	0.01
346:							
Espiritu, cobbly	70	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Large stones content	1.00
		Large stones content	0.96	Large stones content	0.96	Slope	1.00
						Gravel content	0.99
Bamac	20	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	1.00	Gravel content	1.00	Slope	1.00
		Too sandy	0.81	Too sandy	0.81	Too sandy	0.81
348:							
Wauquie	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.99	Gravel content	0.99	Slope	1.00
						Large stones content	0.68

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
348:							
Rock outcrop--------	20	Not rated		Not rated		Not rated	
353:							
Cochiti-------------	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	1.00	Gravel content	1.00	Slope	1.00
		Dusty	0.50	Dusty	0.50	Large stones content	0.95
		Large stones content	0.01	Large stones content	0.01	Dusty	0.50
Espiritu------------	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Dusty	0.50	Dusty	0.50	Gravel content	1.00
		Gravel content	0.33	Gravel content	0.33	Dusty	0.50
						Large stones content	0.16
354:							
Waumac Variant------	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Gravel content	1.00
		Gravel content	1.00	Gravel content	1.00	Depth to bedrock	1.00
		Slope	0.01	Slope	0.01	Slope	1.00
358:							
Deama---------------	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Gravel content	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Gravel content	0.98	Gravel content	0.98	Depth to bedrock	1.00
						Large stones content	0.20
Elpedro-------------	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.78	Gravel content	0.78	Slope	1.00
		Dusty	0.50	Dusty	0.50	Dusty	0.50
Rock outcrop--------	25	Not rated		Not rated		Not rated	

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
396:							
Atarque	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Gravel content	1.00	Gravel content	1.00	Depth to bedrock	1.00
						Large stones content	0.32
Menefee	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
						Gravel content	0.89
Rock outcrop	25	Not rated		Not rated		Not rated	
397:							
Rock outcrop	30	Not rated		Not rated		Not rated	
Cucho	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.92	Gravel content	0.92	Slope	1.00
						Depth to bedrock	0.03
Vessilla	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Gravel content	0.01	Gravel content	0.01	Gravel content	1.00
398:							
Espiritu	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.38	Gravel content	0.38	Slope	1.00
						Large stones content	0.08
Cucho	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.99	Gravel content	0.99	Slope	1.00
						Depth to bedrock	0.03

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
399:							
Cucho	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.99	Gravel content	0.99	Slope	1.00
						Depth to bedrock	0.03
Teco	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Slow water movement	0.41	Slow water movement	0.41	Gravel content	1.00
		Gravel content	0.03	Gravel content	0.03	Large stones content	0.68
						Slow water movement	0.41
405:							
Charo	50	Somewhat limited		Somewhat limited		Very limited	
		Slow water movement	0.96	Slow water movement	0.96	Gravel content	1.00
		Large stones content	0.76	Large stones content	0.76	Slow water movement	0.96
		Gravel content	0.01	Gravel content	0.01	Large stones content	0.76
						Depth to bedrock	0.65
						Large stones content	0.46
Charo, noncobbly	40	Somewhat limited		Somewhat limited		Somewhat limited	
		Slow water movement	0.96	Slow water movement	0.96	Slow water movement	0.96
						Large stones content	0.01
						Gravel content	0.01
409:							
Santa Fe	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Gravel content	0.83	Gravel content	0.83	Depth to bedrock	1.00
						Large stones content	0.01

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
410:							
Zia	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Dusty	0.50
414:							
Wauquie	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Gravel content	0.18	Gravel content	0.18	Gravel content	1.00
						Large stones content	0.16
417:							
Jocity	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50				
418:							
Jocity	85	Very limited		Not limited		Not limited	
		Flooding	1.00				
419:							
Santa Fe	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Gravel content	0.61	Gravel content	0.61	Depth to bedrock	1.00
		Large stones content	0.12	Large stones content	0.12	Large stones content	1.00
Wauquie	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	1.00	Gravel content	1.00	Slope	1.00
		Large stones content	0.02	Large stones content	0.02	Large stones content	0.99
Rock outcrop	20	Not rated		Not rated		Not rated	
420:							
Pinavetes	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Too sandy	0.81

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
421:							
Gilco, moderately saline, sodic	90	Very limited		Very limited		Very limited	
		Sodium content	1.00	Sodium content	1.00	Sodium content	1.00
		Salinity	1.00	Salinity	1.00	Salinity	1.00
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50				
422:							
Vessilla	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
						Large stones content	0.01
Menefee	30	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
						Slope	1.00
Orlie	25	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Slope	0.50
						Dusty	0.50
423:							
Gilco	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50			Slope	0.12
						Gravel content	0.04
426:							
Aga, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Sodium content	1.00	Sodium content	1.00	Sodium content	1.00
		Salinity	1.00	Salinity	1.00	Salinity	1.00
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50				
427:							
Aga	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50				

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
428:							
Aga, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Sodium content	1.00	Sodium content	1.00	Sodium content	1.00
		Salinity	1.00	Salinity	1.00	Salinity	1.00
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50				
430:							
Trail	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50				
431:							
Trail	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Too sandy	0.81	Too sandy	0.81
		Too sandy	0.81				
433:							
Peralta	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Salinity	0.50	Salinity	0.50
		Salinity	0.50				
434:							
Peralta	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Salinity	0.50	Salinity	0.50
		Salinity	0.50				
437:							
Peralta, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Sodium content	1.00	Sodium content	1.00	Sodium content	1.00
		Salinity	1.00	Salinity	1.00	Salinity	1.00
		Flooding	1.00				
500:							
Rock outcrop	40	Not rated		Not rated		Not rated	
Osha	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.42	Gravel content	0.42	Slope	1.00
Rubble land	20	Not rated		Not rated		Not rated	

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
503:							
Cajete	65	Very limited		Very limited		Very limited	
		Gravel content	1.00	Gravel content	1.00	Gravel content	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
Cypher	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Gravel content	0.96	Gravel content	0.96	Depth to bedrock	1.00
						Large stones content	0.32
504:							
Orejas	40	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	0.16	Slope	0.16	Slope	1.00
		Large stones content	0.12	Large stones content	0.12	Large stones content	1.00
						Gravel content	0.97
Guaje	35	Not limited		Not limited		Somewhat limited	
						Slope	0.88
						Gravel content	0.78
600:							
Rock outcrop	50	Not rated		Not rated		Not rated	
Cypher	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Large stones content	0.35	Large stones content	0.35	Large stones content	1.00
		Gravel content	0.01	Gravel content	0.01	Gravel content	1.00
601:							
Laventana	85	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.04	Slope	0.04	Slope	1.00
						Gravel content	0.94
603:							
Laventana	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
603:							
Mirand	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Slow water movement	0.96	Slow water movement	0.96	Slope	1.00
		Gravel content	0.36	Gravel content	0.36	Slow water movement	0.96
						Large stones content	0.46
604:							
Cypher	55	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
Mirand	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Slow water movement	0.96	Slow water movement	0.96	Slope	1.00
		Gravel content	0.28	Gravel content	0.28	Slow water movement	0.96
						Large stones content	0.38
608:							
Osha, steep	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.78
Osha	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Gravel content	0.01	Gravel content	0.01	Slope	1.00
823:							
Gilco, unprotected	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50			Slope	0.12
						Gravel content	0.04
827:							
Aga, unprotected	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50				

Table 9A.--Camp areas, picnic areas, and playgrounds--continued

Map symbol and soil name	Pct. of map unit	Camp areas		Picnic areas		Playgrounds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
830:							
Trail, unprotected--	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Dusty	0.50	Dusty	0.50
		Dusty	0.50				
831:							
Trail, unprotected--	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Too sandy	0.81	Too sandy	0.81
		Too sandy	0.81				
835:							
Peralta, unprotected	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Salinity	0.50	Flooding	0.60
		Salinity	0.50			Salinity	0.50
842:							
Peralta, moderately saline, sodic, unprotected--------	85	Very limited		Very limited		Very limited	
		Sodium content	1.00	Sodium content	1.00	Sodium content	1.00
		Salinity	1.00	Salinity	1.00	Salinity	1.00
		Flooding	1.00				
850:							
Water----------	95	Not rated		Not rated		Not rated	
DAM:							
Dam----------	100	Not rated		Not rated		Not rated	

Table 9B.--Paths, trails, and golf fairways

(The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table.)

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
1:							
Silver	55	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
Clovis	35	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
2:							
Clovis	35	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
Prieta	35	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Depth to bedrock	1.00
		Large stones content	0.18	Large stones content	0.18	Droughty	1.00
						Large stones content	1.00
						Gravel content	0.08
						Slope	0.04
Silver	20	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
3:							
Montecito	60	Not limited		Not limited		Somewhat limited	
						Large stones content	0.01
Orejas	30	Somewhat limited		Somewhat limited		Very limited	
		Large stones content	0.02	Large stones content	0.02	Depth to bedrock	1.00
						Droughty	1.00
						Large stones content	0.99

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
4:							
Montecito----------	45	Somewhat limited		Not limited		Very limited	
		Slope	0.08			Slope	1.00
						Large stones content	0.01
Montecito, bouldery-	35	Somewhat limited		Somewhat limited		Very limited	
		Large stones content	0.68	Large stones content	0.68	Large stones content	1.00
		Dusty	0.50	Dusty	0.50	Slope	1.00
		Slope	0.08			Gravel content	0.05
10:							
Trail---------------	85	Not limited		Not limited		Somewhat limited	
						Droughty	0.27
11:							
Trail---------------	85	Not limited		Not limited		Somewhat limited	
						Flooding	0.60
						Droughty	0.08
13:							
Sandoval------------	65	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	0.59
Querencia----------	20	Not limited		Not limited		Not limited	
15:							
Camino--------------	40	Not limited		Not limited		Not limited	
Sandoval------------	35	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	0.25
16:							
Prieta--------------	30	Very limited		Very limited		Very limited	
		Large stones content	1.00	Large stones content	1.00	Depth to bedrock	1.00
		Dusty	0.50	Dusty	0.50	Droughty	0.99
						Large stones content	0.08
						Slope	0.04

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
17:							
Vessilla	35	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	1.00
						Slope	0.04
Menefee	25	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	0.99
						Slope	0.04
18:							
Sparham	85	Somewhat limited		Somewhat limited		Very limited	
		Too clayey	0.50	Too clayey	0.50	Too clayey	1.00
						Sodium content	1.00
						Flooding	0.60
20:							
Gilco	85	Not limited		Not limited		Not limited	
21:							
Hackroy	25	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	1.00
22:							
Aga	85	Not limited		Not limited		Not limited	
23:							
Hickman	85	Not limited		Not limited		Not limited	
24:							
Orlie	45	Not limited		Not limited		Not limited	
Sparham	35	Somewhat limited		Somewhat limited		Very limited	
		Too clayey	0.50	Too clayey	0.50	Too clayey	1.00
						Sodium content	1.00
						Flooding	0.60
25:							
Gilco	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
26:							
Orlie	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
27:							
Aga	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
29:							
Trail	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Droughty	0.69
34:							
Ildefonso	55	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Large stones content	0.92
						Droughty	0.07
Witt	30	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
47:							
Cascajo	85	Somewhat limited		Not limited		Very limited	
		Slope	0.68			Droughty	1.00
						Slope	1.00
						Gravel content	0.98
						Large stones content	0.61
51:							
Sparham	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Depth to saturated zone	1.00
						Sodium content	1.00
						Flooding	0.60
						Salinity	0.13
52:							
Totavi	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Droughty	0.69

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
53:							
Witt	55	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
Harvey	30	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
54:							
Harvey	45	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.01	Too sandy	0.01	Slope	0.16
Cascajo	40	Not limited		Not limited		Very limited	
						Droughty	1.00
						Gravel content	0.71
						Slope	0.16
						Large stones content	0.08
55:							
La Fonda	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
56:							
Ildefonso	85	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Dusty	0.50	Slope	1.00
		Dusty	0.50			Large stones content	0.84
						Droughty	0.01
58:							
Deama	45	Very limited		Very limited		Very limited	
		Large stones content	1.00	Large stones content	1.00	Depth to bedrock	1.00
		Slope	0.92	Large stones content	0.02	Slope	1.00
		Large stones content	0.02			Droughty	1.00
						Carbonate content	1.00
						Large stones content	0.99

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
58:							
Elpedro	35	Very limited		Very limited		Somewhat limited	
		Water erosion	1.00	Water erosion	1.00	Slope	0.04
		Dusty	0.50	Dusty	0.50		
59:							
Harvey	35	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
Ildefonso	35	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Droughty	0.65
						Slope	0.37
						Large stones content	0.08
La Fonda	15	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
63:							
Placitas	85	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.98	Dusty	0.50	Droughty	1.00
		Dusty	0.50			Slope	1.00
						Depth to bedrock	0.71
						Gravel content	0.08
64:							
Skyvillage	40	Somewhat limited		Not limited		Very limited	
		Slope	0.08			Depth to bedrock	1.00
						Slope	1.00
						Droughty	0.91
Ildefonso	35	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.98	Large stones content	0.76	Slope	1.00
		Large stones content	0.76			Droughty	0.88
						Gravel content	0.11
						Large stones content	0.05

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
65:							
Ildefonso	50	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.92	Large stones content	0.76	Slope	1.00
		Large stones content	0.76			Gravel content	0.99
						Droughty	0.92
						Large stones content	0.32
Harvey	30	Very limited		Very limited		Somewhat limited	
		Water erosion	1.00	Water erosion	1.00	Slope	0.84
		Dusty	0.50	Dusty	0.50		
66:							
Zia	85	Not limited		Not limited		Not limited	
67:							
Sandoval	40	Very limited		Very limited		Very limited	
		Water erosion	1.00	Water erosion	1.00	Depth to bedrock	1.00
		Dusty	0.50	Dusty	0.50	Slope	1.00
		Slope	0.08			Droughty	0.98
Poley	35	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Slope	1.00
						Large stones content	0.92
						Gravel content	0.75
68:							
Penistaja	45	Somewhat limited		Somewhat limited		Not limited	
		Too sandy	0.79	Too sandy	0.79		
Querencia	35	Not limited		Not limited		Not limited	
71:							
Palon	85	Very limited		Not limited		Very limited	
		Slope	1.00			Slope	1.00
						Droughty	0.98
						Large stones content	0.46

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
72:							
Palon	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Droughty	0.99
74:							
Origo	50	Very limited		Not limited		Very limited	
		Slope	1.00			Slope	1.00
						Droughty	1.00
						Gravel content	0.45
						Large stones content	0.08
Pavo	25	Very limited		Very limited		Somewhat limited	
		Water erosion	1.00	Water erosion	1.00	Slope	0.84
75:							
Origo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Droughty	0.77
82:							
Calaveras	85	Very limited		Very limited		Very limited	
		Water erosion	1.00	Water erosion	1.00	Slope	1.00
		Slope	1.00			Droughty	0.64
83:							
Calaveras	60	Very limited		Very limited		Very limited	
		Slope	1.00	Water erosion	1.00	Slope	1.00
		Water erosion	1.00	Slope	1.00	Droughty	0.56
85:							
Redondo	85	Very limited		Not limited		Very limited	
		Slope	1.00			Slope	1.00
						Droughty	0.06
86:							
Redondo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Droughty	1.00
						Large stones content	0.20

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
87:							
Redondo	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Droughty	0.91
						Large stones content	0.20
88:							
Totavi	45	Not limited		Not limited		Somewhat limited	
						Droughty	0.20
Jemez	30	Very limited		Very limited		Somewhat limited	
		Water erosion	1.00	Water erosion	1.00	Depth to bedrock	0.71
						Slope	0.16
91:							
Zia	85	Not limited		Not limited		Not limited	
92:							
Galisteo, moderately saline, sodic	85	Not limited		Not limited		Very limited	
						Salinity	1.00
93:							
Zia	85	Somewhat limited		Somewhat limited		Not limited	
		Too sandy	0.81	Too sandy	0.81		
95:							
El Rancho	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
97:							
El Rancho	85	Not limited		Not limited		Not limited	
100:							
Orejas	40	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Large stones content	0.18	Depth to bedrock	1.00
		Large stones content	0.18	Slope	0.08	Slope	1.00
						Droughty	1.00
						Large stones content	1.00

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
101:							
Blancot	55	Not limited		Not limited		Not limited	
Lybrook	25	Not limited		Not limited		Very limited	
						Sodium content	1.00
102:							
Sparham	85	Not limited		Not limited		Very limited	
						Sodium content	1.00
						Flooding	0.60
104:							
Cochiti	50	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Slope	1.00
		Slope	0.08			Droughty	0.07
						Large stones content	0.01
Montecito	30	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
105:							
Menefee	30	Very limited		Very limited		Very limited	
		Water erosion	1.00	Water erosion	1.00	Depth to bedrock	1.00
		Slope	1.00			Slope	1.00
						Droughty	1.00
106:							
Stumble	50	Very limited		Not limited		Very limited	
		Slope	1.00			Slope	1.00
						Droughty	0.98
						Gravel content	0.92
Stumble, sandy	30	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.79	Too sandy	0.79	Droughty	1.00
						Gravel content	0.03
108:							
Embudo	85	Not limited		Not limited		Somewhat limited	
						Gravel content	0.01
						Slope	0.01

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
109:							
Embudo	50	Not limited		Not limited		Somewhat limited	
						Droughty	0.50
Tijeras	35	Not limited		Not limited		Somewhat limited	
						Droughty	0.01
110:							
Saido	40	Very limited		Very limited		Very limited	
		Water erosion	1.00	Water erosion	1.00	Slope	1.00
		Slope	0.92	Dusty	0.50	Salinity	0.13
		Dusty	0.50				
111:							
Zia	35	Somewhat limited		Not limited		Very limited	
		Slope	0.08			Slope	1.00
112:							
Tijeras	85	Not limited		Not limited		Somewhat limited	
						Large stones content	0.01
114:							
San Mateo	40	Not limited		Not limited		Not limited	
Zia	40	Not limited		Not limited		Not limited	
120:							
Pinavetes	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Droughty	0.99
129:							
Menefee	85	Somewhat limited		Not limited		Very limited	
		Slope	0.50			Depth to bedrock	1.00
						Slope	1.00
						Droughty	0.17
130:							
Pinavetes	45	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Droughty	0.69

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
130:							
Galisteo, moderately saline, sodic------	40	Not limited		Not limited		Very limited	
						Salinity	1.00
						Sodium content	1.00
142:							
Grieta----------	85	Not limited		Not limited		Not limited	
143:							
Clovis----------	85	Not limited		Not limited		Not limited	
145:							
Grieta----------	55	Somewhat limited		Somewhat limited		Not limited	
		Too sandy	0.79	Too sandy	0.79		
Sheppard----------	40	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.79	Too sandy	0.79	Droughty	0.09
146:							
Sedmar----------	85	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.81	Too sandy	0.81	Depth to bedrock	1.00
						Droughty	1.00
						Slope	0.01
150:							
Doakum----------	55	Not limited		Not limited		Not limited	
Betonnie----------	35	Not limited		Not limited		Not limited	
162:							
Hackroy----------	45	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	1.00
Nyjack----------	40	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Depth to bedrock	0.01
163:							
Jemez----------	85	Not limited		Not limited		Somewhat limited	
						Depth to bedrock	0.01
						Slope	0.01

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
170:							
San Mateo	85	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Sodium content	1.00
180:							
Councelor	40	Somewhat limited		Not limited		Very limited	
		Slope	0.18			Slope	1.00
Eslendo	30	Somewhat limited		Not limited		Very limited	
		Slope	0.18			Depth to bedrock	1.00
						Slope	1.00
						Droughty	0.99
Mespun	25	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.31	Too sandy	0.31	Slope	1.00
		Slope	0.18			Droughty	0.29
183:							
Sheppard	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.79	Too sandy	0.79	Slope	0.63
						Droughty	0.09
185:							
Frijoles	90	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Droughty	1.00
190:							
Zia	35	Not limited		Not limited		Somewhat limited	
						Slope	0.84
Skyvillage	25	Somewhat limited		Not limited		Very limited	
		Slope	0.92			Depth to bedrock	1.00
						Slope	1.00
						Droughty	0.96
191:							
Sheppard	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.79	Too sandy	0.79	Droughty	0.09

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
200:							
Sedillo	85	Not limited		Not limited		Very limited	
						Droughty	1.00
						Slope	1.00
						Large stones content	0.74
						Gravel content	0.06
201:							
Sedgran	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Too sandy	0.70	Too sandy	0.70	Slope	1.00
						Droughty	1.00
						Gravel content	1.00
						Large stones content	0.68
206:							
Pinitos	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
207:							
Penistaja	60	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
Zia	25	Not limited		Not limited		Not limited	
208:							
Sedillo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	1.00
						Droughty	0.89
210:							
Ildefonso	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Dusty	0.50	Dusty	0.50	Large stones content	1.00
		Large stones content	0.32	Large stones content	0.32	Droughty	0.34
						Gravel content	0.09

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
211:							
Zia	45	Not limited		Not limited		Not limited	
Clovis	30	Not limited		Not limited		Not limited	
213:							
Pinavetes	55	Very limited		Very limited		Very limited	
		Too sandy	1.00	Too sandy	1.00	Slope	1.00
		Slope	1.00			Droughty	1.00
						Too sandy	0.50
215:							
Ess	60	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Large stones content	0.18	Large stones content	1.00
		Large stones content	0.18			Slope	1.00
						Droughty	0.65
						Gravel content	0.08
217:							
Witt	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
218:							
Ildefonso	85	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Large stones content	1.00
		Large stones content	0.18	Large stones content	0.18	Droughty	0.80
						Gravel content	0.01
						Slope	0.01
220:							
Vessilla	30	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.78	Depth to bedrock	1.00
						Slope	1.00
						Droughty	1.00
						Large stones content	0.01

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
220:							
Menefee	20	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.78	Depth to bedrock	1.00
						Slope	1.00
						Droughty	0.99
226:							
Galisteo, moderately saline, sodic	85	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Salinity	1.00
						Sodium content	1.00
227:							
Hagerman	65	Not limited		Not limited		Somewhat limited	
						Depth to bedrock	0.16
Bond	20	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.31	Too sandy	0.31	Depth to bedrock	1.00
						Droughty	1.00
						Large stones content	0.01
228:							
Winona	85	Somewhat limited		Not limited		Very limited	
		Slope	0.08			Depth to bedrock	1.00
						Droughty	1.00
						Slope	1.00
						Carbonate content	1.00
						Gravel content	0.96
230:							
Skyvillage	35	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	1.00
						Slope	0.63
Sandoval	25	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	0.99
						Slope	0.63

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
231:							
Querencia	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
234:							
Querencia	60	Not limited		Not limited		Not limited	
Zia	20	Not limited		Not limited		Not limited	
235:							
Sandoval	85	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	0.05
						Slope	0.04
236:							
Sparank, moderately saline, sodic	85	Not limited		Not limited		Very limited	
						Salinity	1.00
						Sodium content	1.00
						Flooding	0.60
237:							
Sparank	85	Not limited		Not limited		Somewhat limited	
						Flooding	0.60
240:							
Penistaja	45	Not limited		Not limited		Not limited	
Hagerman	35	Not limited		Not limited		Somewhat limited	
						Depth to bedrock	0.90
250:							
Pinavetes	90	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.79	Too sandy	0.79	Droughty	0.63
						Slope	0.16
262:							
Pastura	90	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Depth to cemented pan	1.00
						Droughty	1.00

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
270:							
Blancot	40	Not limited		Not limited		Not limited	
Councelor	30	Not limited		Not limited		Not limited	
Tsosie	25	Not limited		Not limited		Somewhat limited	
						Salinity	0.50
281:							
Carjo	90	Not limited		Not limited		Somewhat limited	
						Depth to bedrock	0.84
282:							
Tocal	85	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	0.87
283:							
Mirand	45	Very limited		Very limited		Very limited	
		Water erosion	1.00	Water erosion	1.00	Slope	1.00
		Slope	0.18				
Alanos	30	Somewhat limited		Not limited		Very limited	
		Slope	0.92			Slope	1.00
						Large stones content	0.88
						Droughty	0.38
						Gravel content	0.01
290:							
Alanos	50	Very limited		Very limited		Very limited	
		Water erosion	1.00	Water erosion	1.00	Slope	1.00
		Slope	1.00	Slope	0.22	Droughty	0.21
300:							
Waumac	50	Somewhat limited		Somewhat limited		Not limited	
		Too sandy	0.81	Too sandy	0.81		
Bamac	35	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.81	Too sandy	0.81	Droughty	1.00
						Gravel content	0.22
						Large stones content	0.01

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
301:							
Vastine	45	Not limited		Not limited		Somewhat limited Depth to saturated zone	0.19
Jarola	40	Not limited		Not limited		Somewhat limited Depth to saturated zone	0.19
302:							
Tranquilar	50	Not limited		Not limited		Not limited	
Jarmillo	30	Not limited		Not limited		Not limited	
304:							
Cosey	45	Very limited Water erosion	1.00	Very limited Water erosion	1.00	Somewhat limited Slope	0.37
Jarmillo	40	Very limited Water erosion	1.00	Very limited Water erosion	1.00	Somewhat limited Slope	0.37
307:							
Flugle	60	Somewhat limited Dusty	0.50	Somewhat limited Dusty	0.50	Not limited	
Waumac	25	Somewhat limited Too sandy	0.81	Somewhat limited Too sandy	0.81	Not limited	
308:							
Cajete	85	Not limited		Not limited		Somewhat limited Droughty	0.20
311:							
Cosey	35	Very limited Water erosion	1.00	Very limited Water erosion	1.00	Somewhat limited Slope Large stones content	0.84 0.01
Tranquilar	30	Not limited		Not limited		Not limited	
Calaveras	25	Very limited Water erosion	1.00	Very limited Water erosion	1.00	Somewhat limited Slope	0.84

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
312:							
Royosa	90	Very limited		Very limited		Somewhat limited	
		Too sandy	1.00	Too sandy	1.00	Droughty	0.95
						Too sandy	0.50
314:							
Fragua	40	Somewhat limited		Somewhat limited		Not limited	
		Too sandy	0.76	Too sandy	0.76		
Waumac	30	Somewhat limited		Somewhat limited		Not limited	
		Too sandy	0.79	Too sandy	0.79		
Royosa	25	Very limited		Very limited		Somewhat limited	
		Too sandy	1.00	Too sandy	1.00	Droughty	0.92
317:							
Elpedro	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
319:							
Bamac	60	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Too sandy	0.81	Slope	1.00
		Too sandy	0.81	Slope	0.78	Droughty	1.00
						Gravel content	1.00
320:							
Sparham	85	Not limited		Not limited		Very limited	
						Sodium content	1.00
						Flooding	0.60
321:							
Waumac	60	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.79	Too sandy	0.79	Slope	0.01
Royosa	30	Very limited		Very limited		Somewhat limited	
		Too sandy	1.00	Too sandy	1.00	Droughty	0.92
322:							
Fragua	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.02	Large stones content	0.02	Large stones content	0.99
		Too sandy	0.01	Too sandy	0.01	Gravel content	0.13

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
324:							
Atarque	25	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Slope	1.00
						Droughty	0.99
Menefee	25	Somewhat limited		Not limited		Very limited	
		Slope	0.08			Depth to bedrock	1.00
						Droughty	1.00
						Slope	1.00
325:							
Espiritu	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.45
						Droughty	0.21
						Large stones content	0.16
Vessilla	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
						Slope	1.00
						Droughty	1.00
						Gravel content	0.54
						Large stones content	0.01
342:							
Waumac	35	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.79	Too sandy	0.79	Slope	0.84
Vessilla	25	Somewhat limited		Not limited		Very limited	
		Slope	0.92			Depth to bedrock	1.00
						Droughty	1.00
						Slope	1.00
345:							
Espiritu	50	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.78	Slope	1.00
						Droughty	0.47
						Gravel content	0.38
						Large stones content	0.08

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
345:							
Bamac	35	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Too sandy	0.81	Slope	1.00
		Too sandy	0.81	Slope	0.78	Droughty	1.00
						Gravel content	1.00
						Large stones content	0.01
346:							
Espiritu, cobbly	70	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Large stones content	0.96	Slope	1.00
		Large stones content	0.96	Slope	0.08	Large stones content	1.00
						Droughty	0.92
Bamac	20	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Too sandy	0.81	Slope	1.00
		Too sandy	0.81	Slope	0.08	Droughty	1.00
						Gravel content	1.00
348:							
Wauquie	60	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.78	Slope	1.00
						Gravel content	0.99
						Large stones content	0.68
						Droughty	0.58
353:							
Cochiti	50	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Dusty	0.50	Slope	1.00
		Dusty	0.50	Slope	0.08	Gravel content	1.00
		Large stones content	0.01	Large stones content	0.01	Large stones content	0.95
						Droughty	0.66
Espiritu	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Dusty	0.50	Dusty	0.50	Droughty	1.00
						Gravel content	0.33
						Large stones content	0.16

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
354:							
Waumac Variant------	85	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	1.00
						Gravel content	1.00
						Slope	0.01
358:							
Deama---------------	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
						Droughty	1.00
						Slope	1.00
						Carbonate content	1.00
						Gravel content	0.98
Elpedro-------------	25	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.56	Slope	1.00
		Dusty	0.50	Dusty	0.50	Gravel content	0.78
396:							
Atarque-------------	30	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.78	Depth to bedrock	1.00
						Slope	1.00
						Gravel content	1.00
						Droughty	0.41
						Large stones content	0.32
Menefee-------------	30	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.78	Depth to bedrock	1.00
						Slope	1.00
						Droughty	0.72
397:							
Cucho---------------	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.92
						Depth to bedrock	0.03

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
397:							
Vessilla	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
						Slope	1.00
						Droughty	1.00
						Gravel content	0.01
398:							
Espiritu	45	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.44	Slope	1.00
						Droughty	0.91
						Gravel content	0.38
						Large stones content	0.08
Cucho	35	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.78	Slope	1.00
						Gravel content	0.99
						Depth to bedrock	0.03
399:							
Cucho	45	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.08	Slope	1.00
						Gravel content	0.99
						Depth to bedrock	0.03
Teco	35	Somewhat limited		Not limited		Very limited	
		Slope	0.98			Slope	1.00
						Large stones content	0.68
						Gravel content	0.03
405:							
Charo	50	Somewhat limited		Somewhat limited		Somewhat limited	
		Large stones content	0.76	Large stones content	0.76	Depth to bedrock	0.65
						Large stones content	0.46
						Gravel content	0.01

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
405:							
Charo, noncobbly----	40	Not limited		Not limited		Somewhat limited	
						Depth to bedrock	0.01
						Large stones content	0.01
409:							
Santa Fe----------	85	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.08	Depth to bedrock	1.00
						Slope	1.00
						Droughty	1.00
						Gravel content	0.83
						Large stones content	0.01
410:							
Zia----------	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
414:							
Wauquie----------	85	Somewhat limited		Not limited		Very limited	
		Slope	0.08			Slope	1.00
						Droughty	0.82
						Gravel content	0.18
						Large stones content	0.16
417:							
Jocity----------	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
418:							
Jocity----------	85	Not limited		Not limited		Not limited	
419:							
Santa Fe----------	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Large stones content	0.12	Large stones content	0.12	Slope	1.00
						Droughty	1.00
						Large stones content	1.00
						Gravel content	0.61

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
419:							
Wauquie	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.02	Large stones content	0.02	Droughty	1.00
						Gravel content	1.00
						Large stones content	0.99
420:							
Pinavetes	85	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.81	Too sandy	0.81	Droughty	1.00
421:							
Gilco, moderately saline, sodic	90	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Salinity	1.00
						Sodium content	1.00
422:							
Vessilla	35	Somewhat limited		Not limited		Very limited	
		Slope	0.18			Depth to bedrock	1.00
						Droughty	1.00
						Slope	1.00
						Large stones content	0.01
Menefee	30	Not limited		Not limited		Very limited	
						Depth to bedrock	1.00
						Droughty	0.99
Orlie	25	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
423:							
Gilco	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
426:							
Aga, moderately saline, sodic	85	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Salinity	1.00
						Sodium content	1.00

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
427:							
Aga	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
428:							
Aga, moderately saline, sodic	85	Somewhat limited		Somewhat limited		Very limited	
		Dusty	0.50	Dusty	0.50	Salinity	1.00
						Sodium content	1.00
430:							
Trail	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Droughty	0.08
431:							
Trail	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Droughty	0.20
433:							
Peralta	85	Not limited		Not limited		Somewhat limited	
						Salinity	0.50
434:							
Peralta	85	Not limited		Not limited		Somewhat limited	
						Salinity	0.50
437:							
Peralta, moderately saline, sodic	85	Not limited		Not limited		Very limited	
						Salinity	1.00
						Sodium content	1.00
500:							
Osha	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Droughty	1.00
						Gravel content	0.42
503:							
Cajete	65	Somewhat limited		Not limited		Very limited	
		Slope	0.32			Gravel content	1.00
						Slope	1.00
						Droughty	0.99

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
503:							
Cypher	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
						Slope	1.00
						Droughty	1.00
						Gravel content	0.96
						Large stones content	0.32
504:							
Orejas	40	Somewhat limited		Somewhat limited		Very limited	
		Large stones content	0.12	Large stones content	0.12	Depth to bedrock	1.00
						Droughty	1.00
						Large stones content	1.00
						Slope	0.16
Guaje	35	Not limited		Not limited		Somewhat limited	
						Droughty	0.99
600:							
Cypher	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Large stones content	0.35	Large stones content	0.35	Slope	1.00
						Droughty	1.00
						Large stones content	1.00
						Gravel content	0.01
601:							
Laventana	85	Not limited		Not limited		Somewhat limited	
						Droughty	0.30
						Slope	0.04
603:							
Laventana	50	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.96	Slope	1.00
						Droughty	0.01

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
603:							
Mirand	35	Somewhat limited		Not limited		Very limited	
		Slope	0.50			Slope	1.00
						Large stones content	0.46
						Gravel content	0.36
604:							
Cypher	55	Very limited		Not limited		Very limited	
		Slope	1.00			Depth to bedrock	1.00
						Slope	1.00
						Droughty	1.00
Mirand	30	Very limited		Somewhat limited		Very limited	
		Slope	1.00	Slope	0.78	Slope	1.00
						Large stones content	0.38
						Gravel content	0.28
608:							
Osha, steep	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Droughty	1.00
Osha	30	Somewhat limited		Not limited		Very limited	
		Slope	0.32			Droughty	1.00
						Slope	1.00
						Gravel content	0.01
823:							
Gilco, unprotected	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
827:							
Aga, unprotected	85	Somewhat limited		Somewhat limited		Not limited	
		Dusty	0.50	Dusty	0.50		
830:							
Trail, unprotected	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Dusty	0.50	Dusty	0.50	Droughty	0.01

Table 9B.--Paths, trails, and golf fairways--continued

Map symbol and soil name	Pct. of map unit	Paths and trails		Off-road motorcycle trails		Golf fairways	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
831:							
Trail, unprotected--	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Too sandy	0.81	Too sandy	0.81	Droughty	0.87
835:							
Peralta, unprotected	85	Not limited		Not limited		Somewhat limited	
						Flooding	0.60
						Salinity	0.50
842:							
Peralta, moderately saline, sodic, unprotected--------	85	Not limited		Not limited		Very limited	
						Salinity	1.00
						Sodium content	1.00

Table 10A.--Dwellings and small commercial buildings

(The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table.)

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
1:							
Silver	55	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Clovis	35	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
2:							
Clovis	35	Not limited		Not limited		Somewhat limited	
						Slope	0.50
Prieta	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Slope	1.00
		Large stones content	0.43	Large stones content	0.43	Shrink-swell	0.50
		Slope	0.04	Slope	0.04	Large stones content	0.43
Silver	20	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Slope	0.50
						Shrink-swell	0.50
3:							
Montecito	60	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Orejas	30	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Large stones content	0.67	Large stones content	0.67	Large stones content	0.67
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
4:							
Montecito	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Montecito, bouldery-	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
10:							
Trail	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		
11:							
Trail	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		
13:							
Sandoval	65	Somewhat limited		Very limited		Somewhat limited	
		Shrink-swell	0.50	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Shrink-swell	0.50
						Slope	0.12
Querencia	20	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
						Slope	0.12
15:							
Camino	40	Very limited		Very limited		Very limited	
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
Sandoval	35	Somewhat limited		Very limited		Somewhat limited	
		Shrink-swell	0.50	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Shrink-swell	0.50
						Slope	0.12

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
16:							
Rock outcrop--------	50	Not rated		Not rated		Not rated	
Prieta--------------	30	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Slope	1.00
		Large stones content	0.06	Large stones content	0.06	Shrink-swell	0.50
		Slope	0.04	Slope	0.04	Large stones content	0.06
17:							
Vessilla------------	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Slope	0.04	Slope	0.04	Slope	1.00
Menefee-------------	25	Somewhat limited		Very limited		Very limited	
		Shrink-swell	0.50	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Slope	1.00
		Slope	0.04	Slope	0.04	Shrink-swell	0.50
Rock outcrop--------	20	Not rated		Not rated		Not rated	
18:							
Sparham-------------	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
20:							
Gilco---------------	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		
21:							
Rock outcrop--------	60	Not rated		Not rated		Not rated	

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
21:							
Hackroy	25	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Shrink-swell	1.00	Depth to hard bedrock	1.00
		Shrink-swell	1.00	Depth to hard bedrock	1.00	Shrink-swell	1.00
						Slope	0.12
22:							
Aga	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.47		
23:							
Hickman	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
24:							
Orlie	45	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Sparham	35	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
25:							
Gilco	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		
26:							
Orlie	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
27:							
Aga	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.47		

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
29:							
Trail	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		
31:							
Riverwash	90	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
33:							
Pits	100	Not rated		Not rated		Not rated	
34:							
Ildefonso	55	Somewhat limited		Somewhat limited		Somewhat limited	
		Large stones content	0.70	Large stones content	0.70	Large stones content	0.70
						Slope	0.12
Witt	30	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
41:							
Dune land	100	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.16	Slope	0.16	Slope	1.00
47:							
Cascajo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
51:							
Sparham	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Depth to saturated zone	1.00
		Shrink-swell	1.00	Shrink-swell	0.50	Shrink-swell	1.00
52:							
Totavi	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
53:							
Witt	55	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Harvey	30	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
54:							
Harvey	45	Somewhat limited		Somewhat limited		Very limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Slope	1.00
		Slope	0.16	Slope	0.16	Shrink-swell	0.50
Cascajo	40	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.16	Slope	0.16	Slope	1.00
55:							
La Fonda	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
56:							
Ildefonso	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.53	Large stones content	0.53	Large stones content	0.53
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
57:							
Badland	90	Not rated		Not rated		Not rated	
58:							
Deama	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
		Large stones content	0.01	Large stones content	0.01	Large stones content	0.01
Elpedro	35	Somewhat limited		Somewhat limited		Very limited	
		Shrink-swell	0.50	Slope	0.04	Slope	1.00
		Slope	0.04			Shrink-swell	0.50

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
59:							
Harvey	35	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Slope	0.50
						Shrink-swell	0.50
Ildefonso	35	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.37	Slope	0.37	Slope	1.00
		Large stones content	0.02	Large stones content	0.02	Large stones content	0.02
La Fonda	15	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
						Slope	0.12
63:							
Placitas	85	Very limited		Very limited		Very limited	
		Slope	1.00	Depth to hard bedrock	1.00	Slope	1.00
		Depth to hard bedrock	0.71	Slope	1.00	Depth to hard bedrock	0.71
64:							
Skyvillage	40	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Slope	1.00
		Slope	1.00	Slope	1.00	Depth to hard bedrock	1.00
Ildefonso	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
65:							
Ildefonso	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Harvey	30	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00
		Shrink-swell	0.50			Shrink-swell	0.50
66:							
Zia	85	Not limited		Not limited		Somewhat limited	
						Slope	0.12

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
67:							
Sandoval	40	Very limited		Very limited		Very limited	
		Slope	1.00	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Shrink-swell	0.50	Slope	1.00	Slope	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Poley	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50			Shrink-swell	0.50
68:							
Penistaja	45	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
						Slope	0.12
Querencia	35	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
						Slope	0.12
71:							
Palon	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.05	Large stones content	0.05	Large stones content	0.05
72:							
Palon	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	1.00	Large stones content	1.00	Large stones content	1.00
74:							
Origo	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.55	Large stones content	0.55	Large stones content	0.55
Pavo	25	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
75:							
Origo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.99	Large stones content	0.99	Large stones content	0.99
82:							
Calaveras	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
83:							
Calaveras	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.01	Large stones content	0.01	Large stones content	0.01
Rubble land	20	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	1.00	Large stones content	1.00	Large stones content	1.00
85:							
Redondo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
86:							
Redondo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.53	Large stones content	0.53	Large stones content	0.53
87:							
Redondo	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Rubble land	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	1.00	Large stones content	1.00	Large stones content	1.00
88:							
Totavi	45	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
88:							
Jemez	30	Somewhat limited		Very limited		Very limited	
		Depth to hard bedrock	0.71	Depth to hard bedrock	1.00	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Depth to hard bedrock	0.71
		Slope	0.16	Slope	0.16	Shrink-swell	0.50
Rock outcrop	15	Not rated		Not rated		Not rated	
91:							
Zia	85	Not limited		Not limited		Not limited	
92:							
Galisteo, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
93:							
Zia	85	Not limited		Not limited		Not limited	
95:							
El Rancho	85	Somewhat limited		Not limited		Somewhat limited	
		Shrink-swell	0.50			Shrink-swell	0.50
97:							
El Rancho	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
100:							
Orejas	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Large stones content	0.61	Large stones content	0.61	Large stones content	0.61
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Rock outcrop	40	Not rated		Not rated		Not rated	
101:							
Blancot	55	Not limited		Not limited		Somewhat limited	
						Slope	0.12

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
101:							
Lybrook	25	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
102:							
Sparham	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
104:							
Cochiti	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Montecito	30	Not limited		Not limited		Not limited	
105:							
Badland	50	Not rated		Not rated		Not rated	
Menefee	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Shrink-swell	0.50
106:							
Stumble	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Stumble, sandy	30	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
						Slope	0.50
108:							
Embudo	85	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.01	Slope	0.01	Slope	1.00
109:							
Embudo	50	Not limited		Not limited		Somewhat limited	
						Slope	0.50
Tijeras	35	Not limited		Not limited		Not limited	

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
110:							
Rock outcrop--------	45	Not rated		Not rated		Not rated	
Saido----------	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
111:							
Rock outcrop--------	50	Not rated		Not rated		Not rated	
Zia----------	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
112:							
Tijeras----------	85	Not limited		Not limited		Not limited	
114:							
San Mateo----------	40	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Zia----------	40	Not limited		Not limited		Somewhat limited	
						Slope	0.12
120:							
Pinavetes----------	85	Not limited		Not limited		Not limited	
124:							
Rock outcrop--------	90	Not rated		Not rated		Not rated	
129:							
Menefee----------	85	Very limited		Very limited		Very limited	
		Slope	1.00	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Shrink-swell	0.50	Slope	1.00	Slope	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Shrink-swell	0.50
130:							
Pinavetes----------	45	Not limited		Not limited		Not limited	

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
130:							
Galisteo, moderately saline, sodic------	40	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
142:							
Grieta----------	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
143:							
Clovis----------	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
145:							
Grieta----------	55	Not limited		Not limited		Not limited	
Sheppard----------	40	Not limited		Not limited		Somewhat limited	
						Slope	0.50
146:							
Sedmar----------	85	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Slope	0.01	Slope	0.01	Slope	1.00
150:							
Doakum----------	55	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Betonnie----------	35	Not limited		Not limited		Somewhat limited	
						Slope	0.88
162:							
Hackroy----------	45	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Shrink-swell	1.00	Depth to hard bedrock	1.00
		Shrink-swell	1.00	Depth to hard bedrock	1.00	Shrink-swell	1.00
Nyjack----------	40	Not limited		Somewhat limited		Not limited	
				Depth to soft bedrock	0.01		

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
163:							
Jemez	85	Somewhat limited		Very limited		Very limited	
		Shrink-swell	0.50	Depth to hard bedrock	1.00	Slope	1.00
		Depth to hard bedrock	0.01	Shrink-swell	0.50	Shrink-swell	0.50
		Slope	0.01	Slope	0.01	Depth to hard bedrock	0.01
170:							
San Mateo	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
180:							
Councelor	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Eslendo	30	Very limited		Very limited		Very limited	
		Slope	1.00	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Shrink-swell	0.50	Slope	1.00	Slope	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Mespun	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
183:							
Sheppard	85	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.63	Slope	0.63	Slope	1.00
185:							
Frijoles	90	Not limited		Not limited		Somewhat limited	
						Slope	0.12
190:							
Zia	35	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
190:							
Skyvillage----------	25	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
Rock outcrop--------	15	Not rated		Not rated		Not rated	
191:							
Sheppard------------	85	Not limited		Not limited		Somewhat limited	
						Slope	0.50
200:							
Sedillo-------------	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
201:							
Rock outcrop--------	55	Not rated		Not rated		Not rated	
Sedgran-------------	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
206:							
Pinitos-------------	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Slope	0.88
						Shrink-swell	0.50
207:							
Penistaja-----------	60	Somewhat limited		Not limited		Somewhat limited	
		Shrink-swell	0.50			Shrink-swell	0.50
Zia-----------------	25	Not limited		Not limited		Somewhat limited	
						Slope	0.12
208:							
Sedillo-------------	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
210:							
Ildefonso	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.97	Large stones content	0.97	Large stones content	0.97
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
211:							
Zia	45	Not limited		Not limited		Somewhat limited	
						Slope	0.50
Clovis	30	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
						Slope	0.12
213:							
Pinavetes	55	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Rock outcrop	30	Not rated		Not rated		Not rated	
215:							
Ess	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Large stones content	0.33	Shrink-swell	0.50
		Large stones content	0.33			Large stones content	0.33
Rock outcrop	30	Not rated		Not rated		Not rated	
217:							
Witt	85	Not limited		Not limited		Somewhat limited	
						Slope	0.12
218:							
Ildefonso	85	Somewhat limited		Somewhat limited		Very limited	
		Large stones content	0.71	Large stones content	0.71	Slope	1.00
		Slope	0.01	Slope	0.01	Large stones content	0.71

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
220:							
Rock outcrop--------	40	Not rated		Not rated		Not rated	
Vessilla----------	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
Menefee----------	20	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Shrink-swell	0.50
226:							
Galisteo, moderately saline, sodic------	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
227:							
Hagerman----------	65	Somewhat limited		Very limited		Somewhat limited	
		Shrink-swell	0.50	Depth to hard bedrock	1.00	Shrink-swell	0.50
		Depth to hard bedrock	0.15	Shrink-swell	0.50	Depth to hard bedrock	0.15
Bond----------	20	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
						Slope	0.12
228:							
Winona----------	85	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Slope	1.00
		Slope	1.00	Slope	1.00	Depth to hard bedrock	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
230:							
Skyvillage----------	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Slope	0.63	Slope	0.63	Slope	1.00
Sandoval----------	25	Somewhat limited		Very limited		Very limited	
		Slope	0.63	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Shrink-swell	0.50	Slope	0.63	Slope	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Rock outcrop--------	20	Not rated		Not rated		Not rated	
231:							
Querencia----------	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
						Slope	0.12
234:							
Querencia----------	60	Somewhat limited		Not limited		Somewhat limited	
		Shrink-swell	0.50			Shrink-swell	0.50
						Slope	0.12
Zia-----------------	20	Not limited		Not limited		Somewhat limited	
						Slope	0.12
235:							
Sandoval----------	85	Somewhat limited		Very limited		Very limited	
		Shrink-swell	0.50	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Slope	1.00
		Slope	0.04	Slope	0.04	Shrink-swell	0.50
236:							
Sparank, moderately saline, sodic------	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
237:							
Sparank	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
240:							
Penistaja	45	Somewhat limited		Not limited		Somewhat limited	
		Shrink-swell	0.50			Shrink-swell	0.50
Hagerman	35	Somewhat limited		Very limited		Somewhat limited	
		Depth to hard bedrock	0.90	Depth to hard bedrock	1.00	Depth to hard bedrock	0.90
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
250:							
Pinavetes	90	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.16	Slope	0.16	Slope	1.00
262:							
Pastura	90	Somewhat limited		Very limited		Somewhat limited	
		Shrink-swell	0.50	Depth to thin cemented pan	1.00	Depth to thin cemented pan	1.00
		Depth to thin cemented pan	0.50	Shrink-swell	0.50	Shrink-swell	0.50
270:							
Blancot	40	Not limited		Not limited		Not limited	
Councelor	30	Not limited		Not limited		Not limited	
Tsosie	25	Somewhat limited		Not limited		Somewhat limited	
		Shrink-swell	0.50			Shrink-swell	0.50
281:							
Carjo	90	Very limited		Very limited		Very limited	
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
		Depth to hard bedrock	0.84	Depth to hard bedrock	1.00	Depth to hard bedrock	0.84
						Slope	0.12

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
282:							
Tocal	85	Somewhat limited		Very limited		Somewhat limited	
		Shrink-swell	0.50	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Slope	0.50
						Shrink-swell	0.50
283:							
Mirand	45	Very limited		Very limited		Very limited	
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
Alanos	30	Very limited		Very limited		Very limited	
		Slope	1.00	Shrink-swell	1.00	Slope	1.00
		Shrink-swell	0.50	Slope	1.00	Shrink-swell	0.50
290:							
Alanos	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
Rock outcrop	30	Not rated		Not rated		Not rated	
300:							
Waumac	50	Not limited		Not limited		Not limited	
Bamac	35	Not limited		Not limited		Not limited	
301:							
Vastine	45	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Depth to saturated zone	0.39	Depth to saturated zone	1.00	Depth to saturated zone	0.39
Jarola	40	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Depth to saturated zone	1.00	Shrink-swell	0.50
		Depth to saturated zone	0.39	Shrink-swell	0.50	Depth to saturated zone	0.39

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
302:							
Tranquilar----------	50	Very limited		Very limited		Very limited	
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
				Depth to saturated zone	0.99	Slope	0.12
Jarmillo----------	30	Not limited		Somewhat limited		Somewhat limited	
				Shrink-swell	0.50	Slope	0.12
304:							
Cosey----------	45	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.37	Shrink-swell	0.50	Slope	1.00
				Slope	0.37		
Jarmillo----------	40	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.37	Slope	0.37	Slope	1.00
307:							
Flugle----------	60	Not limited		Not limited		Not limited	
Waumac----------	25	Not limited		Not limited		Somewhat limited	
						Slope	0.12
308:							
Cajete----------	85	Not limited		Not limited		Not limited	
311:							
Cosey----------	35	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
		Large stones content	0.03	Large stones content	0.03	Large stones content	0.03
Tranquilar----------	30	Very limited		Very limited		Very limited	
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
				Depth to saturated zone	0.99	Slope	0.88
Calaveras----------	25	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
312:							
Royosa	90	Not limited		Not limited		Somewhat limited	
						Slope	0.12
314:							
Fragua	40	Not limited		Not limited		Somewhat limited	
						Slope	0.12
Waumac	30	Not limited		Not limited		Somewhat limited	
						Slope	0.12
Royosa	25	Not limited		Not limited		Somewhat limited	
						Slope	0.12
317:							
Elpedro	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
						Slope	0.12
319:							
Bamac	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Rock outcrop	25	Not rated		Not rated		Not rated	
320:							
Sparham	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
321:							
Waumac	60	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.01	Slope	0.01	Slope	1.00
Royosa	30	Not limited		Not limited		Somewhat limited	
						Slope	0.12
322:							
Fragua	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
324:							
Rock outcrop	30	Not rated		Not rated		Not rated	

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
324:							
Atarque	25	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Menefee	25	Very limited		Very limited		Very limited	
		Slope	1.00	Depth to soft bedrock	1.00	Slope	1.00
		Shrink-swell	0.50	Slope	1.00	Depth to soft bedrock	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Shrink-swell	0.50
325:							
Rock outcrop	35	Not rated		Not rated		Not rated	
Espiritu	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Vessilla	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
342:							
Waumac	35	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.84	Slope	0.84	Slope	1.00
Vessilla	25	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
Rock outcrop	20	Not rated		Not rated		Not rated	
345:							
Espiritu	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50			Shrink-swell	0.50

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
345:							
Bamac	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
346:							
Espiritu, cobbly	70	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Large stones content	0.01	Shrink-swell	0.50
		Large stones content	0.01			Large stones content	0.01
Bamac	20	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
348:							
Wauquie	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Rock outcrop	20	Not rated		Not rated		Not rated	
353:							
Cochiti	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Espiritu	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
354:							
Waumac Variant	85	Somewhat limited		Very limited		Very limited	
		Depth to soft bedrock	0.50	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Slope	0.01	Slope	0.01	Slope	1.00
358:							
Deama	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Slope	1.00
		Slope	1.00	Slope	1.00	Depth to hard bedrock	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
358:							
Elpedro	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Rock outcrop	25	Not rated		Not rated		Not rated	
396:							
Atarque	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Menefee	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Shrink-swell	0.50
Rock outcrop	25	Not rated		Not rated		Not rated	
397:							
Rock outcrop	30	Not rated		Not rated		Not rated	
Cucho	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
				Depth to soft bedrock	0.03		
Vessilla	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
398:							
Espiritu	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
398:							
Cucho	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
				Depth to soft bedrock	0.03		
399:							
Cucho	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
				Depth to soft bedrock	0.03		
Teco	35	Very limited		Very limited		Very limited	
		Shrink-swell	1.00	Shrink-swell	1.00	Slope	1.00
		Slope	1.00	Slope	1.00	Shrink-swell	1.00
405:							
Charo	50	Very limited		Very limited		Very limited	
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
		Depth to hard bedrock	0.64	Depth to hard bedrock	1.00	Depth to hard bedrock	0.64
Charo, noncobbly	40	Somewhat limited		Very limited		Somewhat limited	
		Shrink-swell	0.50	Depth to hard bedrock	1.00	Shrink-swell	0.50
		Depth to hard bedrock	0.01	Shrink-swell	0.50	Depth to hard bedrock	0.01
409:							
Santa Fe	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
410:							
Zia	85	Not limited		Not limited		Not limited	

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
414:							
Wauquie	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50			Shrink-swell	0.50
417:							
Jocity	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
				Depth to saturated zone	0.15		
418:							
Jocity	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Depth to saturated zone	0.15	Shrink-swell	0.50
419:							
Santa Fe	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
		Large stones content	0.01	Large stones content	0.01	Large stones content	0.01
Wauquie	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.08	Large stones content	0.08	Large stones content	0.08
Rock outcrop	20	Not rated		Not rated		Not rated	
420:							
Pinavetes	85	Not limited		Not limited		Not limited	
421:							
Gilco, moderately saline, sodic	90	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
422:							
Vessilla	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
Menefee	30	Somewhat limited		Very limited		Somewhat limited	
		Shrink-swell	0.50	Depth to soft bedrock	1.00	Depth to soft bedrock	1.00
		Depth to soft bedrock	0.50	Shrink-swell	0.50	Slope	0.50
						Shrink-swell	0.50
Orlie	25	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
423:							
Gilco	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		
426:							
Aga, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		
427:							
Aga	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.47		
428:							
Aga, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
430:							
Trail	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
431:							
Trail	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
433:							
Peralta	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.99		
434:							
Peralta	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.99		
437:							
Peralta, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.99		
500:							
Rock outcrop	40	Not rated		Not rated		Not rated	
Osha	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
				Depth to hard bedrock	0.93		
Rubble land	20	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	1.00	Large stones content	1.00	Large stones content	1.00
503:							
Cajete	65	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
503:							
Cypher	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
504:							
Orejas	40	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Slope	1.00
		Slope	0.16	Slope	0.16	Shrink-swell	0.50
Guaje	35	Not limited		Not limited		Somewhat limited	
						Slope	0.12
600:							
Rock outcrop	50	Not rated		Not rated		Not rated	
Cypher	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
601:							
Laventana	85	Somewhat limited		Somewhat limited		Very limited	
		Shrink-swell	0.50	Shrink-swell	0.50	Slope	1.00
		Slope	0.04	Depth to hard bedrock	0.42	Shrink-swell	0.50
				Slope	0.04		
603:							
Laventana	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Shrink-swell	0.50	Shrink-swell	0.50
				Depth to hard bedrock	0.32		
Mirand	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
604:							
Cypher	55	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to hard bedrock	1.00
Mirand	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	1.00	Shrink-swell	1.00	Shrink-swell	1.00
608:							
Osha, steep	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Osha	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
823:							
Gilco, unprotected	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		
827:							
Aga, unprotected	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.47		
830:							
Trail, unprotected	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		
831:							
Trail, unprotected	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
				Depth to saturated zone	0.15		

Table 10A.--Dwellings and small commercial buildings--continued

Map symbol and soil name	Pct. of map unit	Dwellings without basements		Dwellings with basements		Small commercial buildings	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
835:							
Peralta, unprotected	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Depth to saturated zone	0.99	Shrink-swell	0.50
				Shrink-swell	0.50		
842:							
Peralta, moderately saline, sodic, unprotected	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Flooding	1.00
		Shrink-swell	0.50	Depth to saturated zone	0.99	Shrink-swell	0.50
				Shrink-swell	0.50		
850:							
Water	95	Not rated		Not rated		Not rated	
DAM:							
Dam	100	Not rated		Not rated		Not rated	

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping

(The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table.)

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
1:							
Silver	55	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Cutbanks cave	0.10		
		Shrink-swell	0.50				
Clovis	35	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
2:							
Clovis	35	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		
Prieta	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Shrink-swell	0.50	Large stones content	0.43	Droughty	1.00
		Large stones content	0.43	Cutbanks cave	0.10	Large stones content	1.00
		Slope	0.04	Slope	0.04	Gravel content	0.08
						Slope	0.04
Silver	20	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Cutbanks cave	0.10		
		Shrink-swell	0.50				
3:							
Montecito	60	Very limited		Somewhat limited		Somewhat limited	
		Low strength	1.00	Cutbanks cave	0.10	Large stones content	0.01
		Shrink-swell	0.50				

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
3:							
Orejas	30	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Large stones content	0.67	Large stones content	0.67	Droughty	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Large stones content	0.99
4:							
Montecito	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Large stones content	0.01
Montecito, bouldery-	35	Very limited		Very limited		Very limited	
		Low strength	1.00	Slope	1.00	Large stones content	1.00
		Slope	1.00	Cutbanks cave	0.10	Slope	1.00
		Shrink-swell	0.50			Gravel content	0.05
10:							
Trail	85	Somewhat limited		Very limited		Somewhat limited	
		Flooding	0.40	Cutbanks cave	1.00	Droughty	0.27
				Depth to saturated zone	0.15		
11:							
Trail	85	Very limited		Very limited		Somewhat limited	
		Flooding	1.00	Cutbanks cave	1.00	Flooding	0.60
				Flooding	0.60	Droughty	0.08
				Depth to saturated zone	0.15		
13:							
Sandoval	65	Very limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Low strength	1.00	Cutbanks cave	0.10	Droughty	0.59
		Shrink-swell	0.50				
Querencia	20	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
15:							
Camino	40	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Too clayey	0.12		
		Shrink-swell	1.00	Cutbanks cave	0.10		
Sandoval	35	Very limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Low strength	1.00	Cutbanks cave	0.10	Droughty	0.25
		Shrink-swell	0.50				
16:							
Prieta	30	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	0.99
		Large stones content	0.06	Large stones content	0.06	Large stones content	0.08
		Slope	0.04	Slope	0.04	Slope	0.04
17:							
Vessilla	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	0.04	Cutbanks cave	0.10	Droughty	1.00
				Slope	0.04	Slope	0.04
Menefee	25	Somewhat limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	0.99
		Frost action	0.50	Slope	0.04	Slope	0.04
		Slope	0.04				
18:							
Sparham	85	Very limited		Somewhat limited		Very limited	
		Flooding	1.00	Flooding	0.60	Too clayey	1.00
		Low strength	1.00	Cutbanks cave	0.10	Sodium content	1.00
		Shrink-swell	0.50			Flooding	0.60

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
20:							
Gilco	85	Somewhat limited		Somewhat limited		Not limited	
		Flooding	0.40	Depth to saturated zone	0.15		
				Cutbanks cave	0.10		
21:							
Hackroy	25	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Low strength	1.00	Cutbanks cave	0.10	Droughty	1.00
		Shrink-swell	1.00				
		Frost action	0.50				
22:							
Aga	85	Somewhat limited		Very limited		Not limited	
		Flooding	0.40	Cutbanks cave	1.00		
				Depth to saturated zone	0.47		
23:							
Hickman	85	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Cutbanks cave	0.10		
		Shrink-swell	0.50				
		Flooding	0.40				
24:							
Orlie	45	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Cutbanks cave	0.10		
		Shrink-swell	0.50				
		Frost action	0.50				
Sparham	35	Very limited		Somewhat limited		Very limited	
		Flooding	1.00	Flooding	0.60	Too clayey	1.00
		Low strength	1.00	Too clayey	0.12	Sodium content	1.00
		Shrink-swell	1.00	Cutbanks cave	0.10	Flooding	0.60
25:							
Gilco	85	Somewhat limited		Somewhat limited		Not limited	
		Flooding	0.40	Depth to saturated zone	0.15		
				Cutbanks cave	0.10		

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
26:							
Orlie	85	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Cutbanks cave	0.10		
		Shrink-swell	0.50				
		Frost action	0.50				
27:							
Aga	85	Somewhat limited		Very limited		Not limited	
		Flooding	0.40	Cutbanks cave	1.00		
				Depth to saturated zone	0.47		
29:							
Trail	85	Somewhat limited		Very limited		Somewhat limited	
		Flooding	0.40	Cutbanks cave	1.00	Droughty	0.69
				Depth to saturated zone	0.15		
34:							
Ildefonso	55	Somewhat limited		Somewhat limited		Somewhat limited	
		Large stones content	0.70	Large stones content	0.70	Large stones content	0.92
				Cutbanks cave	0.10	Droughty	0.07
Witt	30	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
		Frost action	0.50				
47:							
Cascajo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Droughty	1.00
				Slope	1.00	Slope	1.00
						Gravel content	0.98
						Large stones content	0.61
51:							
Sparham	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Depth to saturated zone	1.00
		Flooding	1.00	Flooding	0.60	Sodium content	1.00
		Low strength	1.00	Too clayey	0.12	Flooding	0.60
		Shrink-swell	1.00	Cutbanks cave	0.10	Salinity	0.13

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
52:							
Totavi	85	Somewhat limited		Very limited		Somewhat limited	
		Flooding	0.40	Cutbanks cave	1.00	Droughty	0.69
53:							
Witt	55	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
		Frost action	0.50				
Harvey	30	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Cutbanks cave	0.10		
		Shrink-swell	0.50				
54:							
Harvey	45	Somewhat limited		Somewhat limited		Somewhat limited	
		Shrink-swell	0.50	Slope	0.16	Slope	0.16
		Slope	0.16	Cutbanks cave	0.10		
Cascajo	40	Somewhat limited		Very limited		Very limited	
		Slope	0.16	Cutbanks cave	1.00	Droughty	1.00
				Slope	0.16	Gravel content	0.71
						Slope	0.16
						Large stones content	0.08
55:							
La Fonda	85	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
56:							
Ildefonso	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.53	Large stones content	0.53	Large stones content	0.84
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	0.01

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
58:							
Deama	45	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	1.00
		Large stones content	0.01	Large stones content	0.01	Carbonate content	1.00
						Large stones content	0.99
Elpedro	35	Very limited		Somewhat limited		Somewhat limited	
		Low strength	1.00	Cutbanks cave	0.10	Slope	0.04
		Shrink-swell	0.50	Slope	0.04		
		Frost action	0.50				
		Slope	0.04				
59:							
Harvey	35	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Cutbanks cave	0.10		
		Shrink-swell	0.50				
Ildefonso	35	Somewhat limited		Very limited		Somewhat limited	
		Slope	0.37	Cutbanks cave	1.00	Droughty	0.65
		Large stones content	0.02	Slope	0.37	Slope	0.37
				Large stones content	0.02	Large stones content	0.08
La Fonda	15	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
63:							
Placitas	85	Very limited		Very limited		Very limited	
		Slope	1.00	Depth to hard bedrock	1.00	Droughty	1.00
		Depth to hard bedrock	0.71	Cutbanks cave	1.00	Slope	1.00
				Slope	1.00	Depth to bedrock	0.71
						Gravel content	0.08

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
64:							
Skyvillage	40	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	0.10	Droughty	0.91
Ildefonso	35	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Slope	1.00
				Slope	1.00	Droughty	0.88
						Gravel content	0.11
						Large stones content	0.05
65:							
Ildefonso	50	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Slope	1.00
				Slope	1.00	Gravel content	0.99
						Droughty	0.92
						Large stones content	0.32
Harvey	30	Somewhat limited		Somewhat limited		Somewhat limited	
		Slope	0.84	Slope	0.84	Slope	0.84
		Shrink-swell	0.50	Cutbanks cave	0.10		
66:							
Zia	85	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		
67:							
Sandoval	40	Very limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Low strength	1.00	Slope	1.00	Slope	1.00
		Slope	1.00	Cutbanks cave	0.10	Droughty	0.98
		Shrink-swell	0.50				
Poley	35	Very limited		Very limited		Very limited	
		Low strength	1.00	Cutbanks cave	1.00	Slope	1.00
		Slope	1.00	Slope	1.00	Large stones content	0.92
		Shrink-swell	0.50			Gravel content	0.75

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
68:							
Penistaja	45	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
Querencia	35	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
71:							
Palon	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	0.10	Droughty	0.98
		Large stones content	0.05	Large stones content	0.05	Large stones content	0.46
72:							
Palon	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	1.00	Large stones content	1.00	Droughty	0.99
		Frost action	0.50	Cutbanks cave	0.10		
74:							
Origo	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.55	Large stones content	0.55	Droughty	1.00
		Frost action	0.50	Cutbanks cave	0.10	Gravel content	0.45
						Large stones content	0.08
Pavo	25	Somewhat limited		Very limited		Somewhat limited	
		Slope	0.84	Cutbanks cave	1.00	Slope	0.84
		Frost action	0.50	Slope	0.84		
75:							
Origo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.99	Cutbanks cave	1.00	Droughty	0.77
		Frost action	0.50	Large stones content	0.99		

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
82:							
Calaveras	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	0.10	Droughty	0.64
83:							
Calaveras	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	0.10	Droughty	0.56
		Large stones content	0.01	Large stones content	0.01		
85:							
Redondo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	1.00	Droughty	0.06
86:							
Redondo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.53	Large stones content	0.53	Droughty	1.00
		Frost action	0.50	Cutbanks cave	0.10	Large stones content	0.20
87:							
Redondo	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	0.10	Droughty	0.91
						Large stones content	0.20
88:							
Totavi	45	Somewhat limited		Very limited		Somewhat limited	
		Flooding	0.40	Cutbanks cave	1.00	Droughty	0.20
Jemez	30	Somewhat limited		Very limited		Somewhat limited	
		Depth to hard bedrock	0.71	Depth to hard bedrock	1.00	Depth to bedrock	0.71
		Shrink-swell	0.50	Slope	0.16	Slope	0.16
		Frost action	0.50	Cutbanks cave	0.10		
		Slope	0.16				

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
91:							
Zia	85	Not limited		Very limited		Not limited	
				Cutbanks cave	1.00		
92:							
Galisteo, moderately saline, sodic	85	Very limited		Somewhat limited		Very limited	
		Low strength	1.00	Too clayey	0.12	Salinity	1.00
		Shrink-swell	1.00	Cutbanks cave	0.10		
93:							
Zia	85	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		
95:							
El Rancho	85	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
97:							
El Rancho	85	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
		Frost action	0.50				
100:							
Orejas	40	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.61	Large stones content	0.61	Droughty	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Large stones content	1.00
101:							
Blancot	55	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		
Lybrook	25	Very limited		Somewhat limited		Very limited	
		Low strength	1.00	Cutbanks cave	0.10	Sodium content	1.00
		Shrink-swell	0.50				

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
102:							
Sparham	85	Very limited		Somewhat limited		Very limited	
		Flooding	1.00	Flooding	0.60	Sodium content	1.00
		Low strength	1.00	Cutbanks cave	0.10	Flooding	0.60
		Shrink-swell	0.50				
104:							
Cochiti	50	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Slope	1.00
		Frost action	0.50	Slope	1.00	Droughty	0.07
				Too clayey	0.50	Large stones content	0.01
Montecito	30	Not limited		Very limited		Not limited	
				Cutbanks cave	1.00		
105:							
Menefee	30	Very limited		Very limited		Very limited	
		Slope	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Depth to soft bedrock	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	1.00
		Frost action	0.50				
106:							
Stumble	50	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Slope	1.00
				Slope	1.00	Droughty	0.98
						Gravel content	0.92
Stumble, sandy	30	Somewhat limited		Very limited		Very limited	
		Flooding	0.40	Cutbanks cave	1.00	Droughty	1.00
						Gravel content	0.03
108:							
Embudo	85	Somewhat limited		Very limited		Somewhat limited	
		Slope	0.01	Cutbanks cave	1.00	Gravel content	0.01
				Slope	0.01	Slope	0.01
109:							
Embudo	50	Not limited		Very limited		Somewhat limited	
				Cutbanks cave	1.00	Droughty	0.50

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
109:							
Tijeras	35	Not limited		Very limited		Somewhat limited	
				Cutbanks cave	1.00	Droughty	0.01
110:							
Saido	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Salinity	0.13
111:							
Zia	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	0.10		
112:							
Tijeras	85	Not limited		Very limited		Somewhat limited	
				Cutbanks cave	1.00	Large stones content	0.01
114:							
San Mateo	40	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
		Flooding	0.40				
Zia	40	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		
120:							
Pinavetes	85	Not limited		Very limited		Somewhat limited	
				Cutbanks cave	1.00	Droughty	0.99
129:							
Menefee	85	Very limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Low strength	1.00	Slope	1.00	Slope	1.00
		Slope	1.00	Cutbanks cave	0.10	Droughty	0.17
		Shrink-swell	0.50				
		Frost action	0.50				
130:							
Pinavetes	45	Not limited		Very limited		Somewhat limited	
				Cutbanks cave	1.00	Droughty	0.69

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
130:							
Galisteo, moderately saline, sodic	40	Very limited		Somewhat limited		Very limited	
		Low strength	1.00	Too clayey	0.12	Salinity	1.00
		Shrink-swell	1.00	Cutbanks cave	0.10	Sodium content	1.00
		Flooding	0.40				
142:							
Grieta	85	Somewhat limited		Very limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	1.00		
		Frost action	0.50				
143:							
Clovis	85	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
145:							
Grieta	55	Somewhat limited		Somewhat limited		Not limited	
		Frost action	0.50	Cutbanks cave	0.10		
Sheppard	40	Not limited		Very limited		Somewhat limited	
				Cutbanks cave	1.00	Droughty	0.09
146:							
Sedmar	85	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	0.01	Cutbanks cave	0.10	Droughty	1.00
				Slope	0.01	Slope	0.01
150:							
Doakum	55	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
Betonnie	35	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
162:							
Hackroy	45	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Low strength	1.00	Cutbanks cave	0.10	Droughty	1.00
		Shrink-swell	1.00				
		Frost action	0.50				
Nyjack	40	Somewhat limited		Very limited		Somewhat limited	
		Frost action	0.50	Cutbanks cave	1.00	Depth to bedrock	0.01
				Depth to soft bedrock	0.01		
163:							
Jemez	85	Somewhat limited		Very limited		Somewhat limited	
		Shrink-swell	0.50	Depth to hard bedrock	1.00	Depth to bedrock	0.01
		Frost action	0.50	Cutbanks cave	0.10	Slope	0.01
		Depth to hard bedrock	0.01	Slope	0.01		
		Slope	0.01				
170:							
San Mateo	85	Very limited		Somewhat limited		Very limited	
		Low strength	1.00	Cutbanks cave	0.10	Sodium content	1.00
		Shrink-swell	0.50				
		Flooding	0.40				
180:							
Councelor	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	0.10		
Eslendo	30	Very limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	0.99
Mespun	25	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Slope	1.00
				Slope	1.00	Droughty	0.29

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
183:							
Sheppard	85	Somewhat limited		Very limited		Somewhat limited	
		Slope	0.63	Cutbanks cave	1.00	Slope	0.63
				Slope	0.63	Droughty	0.09
185:							
Frijoles	90	Somewhat limited		Very limited		Very limited	
		Frost action	0.50	Cutbanks cave	1.00	Droughty	1.00
190:							
Zia	35	Somewhat limited		Somewhat limited		Somewhat limited	
		Slope	0.84	Slope	0.84	Slope	0.84
				Cutbanks cave	0.10		
Skyvillage	25	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	0.10	Droughty	0.96
191:							
Sheppard	85	Not limited		Very limited		Somewhat limited	
				Cutbanks cave	1.00	Droughty	0.09
200:							
Sedillo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Droughty	1.00
				Slope	1.00	Slope	1.00
						Large stones content	0.74
						Gravel content	0.06
201:							
Sedgran	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	0.10	Droughty	1.00
						Gravel content	1.00
						Large stones content	0.68

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
206:							
Pinitos	85	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Cutbanks cave	0.10		
		Shrink-swell	0.50				
		Frost action	0.50				
207:							
Penistaja	60	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
Zia	25	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		
208:							
Sedillo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	1.00	Gravel content	1.00
						Droughty	0.89
210:							
Ildefonso	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.97	Large stones content	0.97	Large stones content	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	0.34
						Gravel content	0.09
211:							
Zia	45	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		
Clovis	30	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
213:							
Pinavetes	55	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	1.00	Droughty	1.00
						Too sandy	0.50

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
215:							
Ess	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Large stones content	1.00
		Shrink-swell	0.50	Large stones content	0.33	Slope	1.00
		Frost action	0.50	Cutbanks cave	0.10	Droughty	0.65
		Large stones content	0.33			Gravel content	0.08
217:							
Witt	85	Somewhat limited		Somewhat limited		Not limited	
		Frost action	0.50	Cutbanks cave	0.10		
218:							
Ildefonso	85	Somewhat limited		Somewhat limited		Very limited	
		Large stones content	0.71	Large stones content	0.71	Large stones content	1.00
		Slope	0.01	Cutbanks cave	0.10	Droughty	0.80
				Slope	0.01	Gravel content	0.01
						Slope	0.01
220:							
Vessilla	30	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	0.10	Droughty	1.00
						Large stones content	0.01
Menefee	20	Very limited		Very limited		Very limited	
		Slope	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Depth to soft bedrock	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	0.99
		Frost action	0.50				

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
226:							
Galisteo, moderately saline, sodic------	85	Very limited		Somewhat limited		Very limited	
		Low strength	1.00	Cutbanks cave	0.10	Salinity	1.00
		Shrink-swell	0.50			Sodium content	1.00
227:							
Hagerman----------	65	Very limited		Very limited		Somewhat limited	
		Low strength	1.00	Depth to hard bedrock	1.00	Depth to bedrock	0.16
		Shrink-swell	0.50	Cutbanks cave	0.10		
		Depth to hard bedrock	0.15				
Bond----------	20	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	1.00
		Low strength	0.22			Large stones content	0.01
228:							
Winona----------	85	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Droughty	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Slope	1.00
						Carbonate content	1.00
						Gravel content	0.96
230:							
Skyvillage----------	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	0.63	Slope	0.63	Droughty	1.00
				Cutbanks cave	0.10	Slope	0.63
Sandoval----------	25	Somewhat limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Slope	0.63	Slope	0.63	Droughty	0.99
		Shrink-swell	0.50	Cutbanks cave	0.10	Slope	0.63

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
231:							
Querencia	85	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
234:							
Querencia	60	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
Zia	20	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		
235:							
Sandoval	85	Very limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Low strength	1.00	Cutbanks cave	0.10	Droughty	0.05
		Shrink-swell	0.50	Slope	0.04	Slope	0.04
		Slope	0.04				
236:							
Sparank, moderately saline, sodic	85	Very limited		Somewhat limited		Very limited	
		Flooding	1.00	Flooding	0.60	Salinity	1.00
		Low strength	1.00	Too clayey	0.12	Sodium content	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Flooding	0.60
237:							
Sparank	85	Very limited		Somewhat limited		Somewhat limited	
		Flooding	1.00	Flooding	0.60	Flooding	0.60
		Low strength	1.00	Cutbanks cave	0.10		
		Shrink-swell	0.50				
240:							
Penistaja	45	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
Hagerman	35	Very limited		Very limited		Somewhat limited	
		Low strength	1.00	Depth to hard bedrock	1.00	Depth to bedrock	0.90
		Depth to hard bedrock	0.90	Cutbanks cave	0.10		
		Shrink-swell	0.50				

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
250:							
Pinavetes	90	Somewhat limited		Very limited		Somewhat limited	
		Slope	0.16	Cutbanks cave	1.00	Droughty	0.63
				Slope	0.16	Slope	0.16
262:							
Pastura	90	Somewhat limited		Very limited		Very limited	
		Depth to thin cemented pan	1.00	Depth to thin cemented pan	1.00	Depth to cemented pan	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	1.00
270:							
Blancot	40	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		
Councelor	30	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		
Tsosie	25	Very limited		Somewhat limited		Somewhat limited	
		Low strength	1.00	Cutbanks cave	0.10	Salinity	0.50
		Shrink-swell	0.50				
281:							
Carjo	90	Very limited		Very limited		Somewhat limited	
		Low strength	1.00	Depth to hard bedrock	1.00	Depth to bedrock	0.84
		Shrink-swell	1.00	Too clayey	0.12		
		Depth to hard bedrock	0.84	Cutbanks cave	0.10		
		Frost action	0.50				
282:							
Tocal	85	Somewhat limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	0.87
		Frost action	0.50				
283:							
Mirand	45	Very limited		Very limited		Very limited	
		Low strength	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	1.00	Too clayey	0.50		
		Slope	1.00	Cutbanks cave	0.10		

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
283:							
Alanos	30	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Slope	1.00
		Shrink-swell	0.50	Slope	1.00	Large stones content	0.88
		Frost action	0.50	Too clayey	0.12	Droughty	0.38
						Gravel content	0.01
290:							
Alanos	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	1.00	Cutbanks cave	1.00	Droughty	0.21
		Frost action	0.50	Too clayey	0.12		
300:							
Waumac	50	Somewhat limited		Very limited		Not limited	
		Frost action	0.50	Cutbanks cave	1.00		
Bamac	35	Not limited		Very limited		Very limited	
				Cutbanks cave	1.00	Droughty	1.00
						Gravel content	0.22
						Large stones content	0.01
301:							
Vastine	45	Very limited		Very limited		Somewhat limited	
		Frost action	1.00	Depth to saturated zone	1.00	Depth to saturated zone	0.19
		Flooding	0.40	Cutbanks cave	1.00		
		Depth to saturated zone	0.19				
Jarola	40	Somewhat limited		Very limited		Somewhat limited	
		Shrink-swell	0.50	Depth to saturated zone	1.00	Depth to saturated zone	0.19
		Frost action	0.50	Cutbanks cave	1.00		
		Flooding	0.40				
		Depth to saturated zone	0.19				

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
302:							
Tranquilar----------	50	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Depth to saturated zone	0.99		
		Shrink-swell	1.00	Too clayey	0.50		
		Frost action	0.50	Cutbanks cave	0.10		
Jarmillo----------	30	Somewhat limited		Somewhat limited		Not limited	
		Frost action	0.50	Cutbanks cave	0.10		
304:							
Cosey---------------	45	Somewhat limited		Very limited		Somewhat limited	
		Frost action	0.50	Cutbanks cave	1.00	Slope	0.37
		Slope	0.37	Slope	0.37		
		Low strength	0.22				
Jarmillo----------	40	Somewhat limited		Somewhat limited		Somewhat limited	
		Frost action	0.50	Slope	0.37	Slope	0.37
		Slope	0.37	Cutbanks cave	0.10		
307:							
Flugle--------------	60	Somewhat limited		Somewhat limited		Not limited	
		Frost action	0.50	Cutbanks cave	0.10		
Waumac--------------	25	Somewhat limited		Somewhat limited		Not limited	
		Frost action	0.50	Cutbanks cave	0.10		
308:							
Cajete--------------	85	Somewhat limited		Very limited		Somewhat limited	
		Frost action	0.50	Cutbanks cave	1.00	Droughty	0.20
311:							
Cosey---------------	35	Somewhat limited		Very limited		Somewhat limited	
		Slope	0.84	Cutbanks cave	1.00	Slope	0.84
		Shrink-swell	0.50	Slope	0.84	Large stones content	0.01
		Frost action	0.50	Large stones content	0.03		
		Large stones content	0.03				

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
311:							
Tranquilar	30	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Depth to saturated zone	0.99		
		Shrink-swell	1.00	Too clayey	0.50		
		Frost action	0.50	Cutbanks cave	0.10		
Calaveras	25	Somewhat limited		Very limited		Somewhat limited	
		Slope	0.84	Cutbanks cave	1.00	Slope	0.84
		Frost action	0.50	Slope	0.84		
312:							
Royosa	90	Not limited		Very limited		Somewhat limited	
				Cutbanks cave	1.00	Droughty	0.95
						Too sandy	0.50
314:							
Fragua	40	Somewhat limited		Somewhat limited		Not limited	
		Frost action	0.50	Cutbanks cave	0.10		
Waumac	30	Somewhat limited		Somewhat limited		Not limited	
		Frost action	0.50	Cutbanks cave	0.10		
Royosa	25	Not limited		Very limited		Somewhat limited	
				Cutbanks cave	1.00	Droughty	0.92
317:							
Elpedro	85	Somewhat limited		Somewhat limited		Not limited	
		Shrink-swell	0.50	Cutbanks cave	0.10		
		Frost action	0.50				
319:							
Bamac	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	1.00	Droughty	1.00
						Gravel content	1.00
320:							
Sparham	85	Very limited		Somewhat limited		Very limited	
		Flooding	1.00	Flooding	0.60	Sodium content	1.00
		Low strength	1.00	Too clayey	0.12	Flooding	0.60
		Shrink-swell	1.00	Cutbanks cave	0.10		

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
321:							
Waumac	60	Somewhat limited		Somewhat limited		Somewhat limited	
		Frost action	0.50	Cutbanks cave	0.10	Slope	0.01
		Slope	0.01	Slope	0.01		
Royosa	30	Not limited		Very limited		Somewhat limited	
				Cutbanks cave	1.00	Droughty	0.92
322:							
Fragua	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	1.00	Large stones content	0.99
						Gravel content	0.13
324:							
Atarque	25	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	0.99
Menefee	25	Very limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Droughty	1.00
		Low strength	1.00	Cutbanks cave	0.10	Slope	1.00
		Shrink-swell	0.50				
		Frost action	0.50				
325:							
Espiritu	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	1.00	Gravel content	0.45
		Frost action	0.50			Droughty	0.21
						Large stones content	0.16

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
325:							
Vessilla	25	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	0.10	Droughty	1.00
						Gravel content	0.54
						Large stones content	0.01
342:							
Waumac	35	Somewhat limited		Somewhat limited		Somewhat limited	
		Slope	0.84	Slope	0.84	Slope	0.84
		Frost action	0.50	Cutbanks cave	0.10		
Vessilla	25	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Droughty	1.00
				Cutbanks cave	0.10	Slope	1.00
345:							
Espiritu	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	1.00	Droughty	0.47
		Frost action	0.50			Gravel content	0.38
						Large stones content	0.08
Bamac	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	1.00	Droughty	1.00
						Gravel content	1.00
						Large stones content	0.01

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
346:							
Espiritu, cobbly----	70	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	1.00	Large stones content	1.00
		Frost action	0.50	Large stones content	0.01	Droughty	0.92
		Large stones content	0.01				
Bamac----------	20	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	1.00	Droughty	1.00
						Gravel content	1.00
348:							
Wauquie----------	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	1.00	Gravel content	0.99
						Large stones content	0.68
						Droughty	0.58
353:							
Cochiti----------	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	1.00	Gravel content	1.00
						Large stones content	0.95
						Droughty	0.66
Espiritu----------	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	1.00	Droughty	1.00
						Gravel content	0.33
						Large stones content	0.16

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
354:							
Waumac Variant------	85	Somewhat limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Frost action	0.50	Cutbanks cave	0.10	Droughty	1.00
		Slope	0.01	Slope	0.01	Gravel content	1.00
						Slope	0.01
358:							
Deama---------------	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Droughty	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Slope	1.00
						Carbonate content	1.00
						Gravel content	0.98
Elpedro-------------	25	Very limited		Very limited		Very limited	
		Low strength	1.00	Slope	1.00	Slope	1.00
		Slope	1.00	Cutbanks cave	0.10	Gravel content	0.78
		Shrink-swell	0.50				
		Frost action	0.50				
396:							
Atarque-------------	30	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Gravel content	1.00
		Low strength	0.22			Droughty	0.41
						Large stones content	0.32
Menefee-------------	30	Very limited		Very limited		Very limited	
		Slope	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Depth to soft bedrock	1.00	Slope	1.00	Slope	1.00
		Low strength	1.00	Cutbanks cave	0.10	Droughty	0.72
		Shrink-swell	0.50				
		Frost action	0.50				

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
397:							
Cucho	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	1.00	Gravel content	0.92
		Frost action	0.50	Depth to soft bedrock	0.03	Depth to bedrock	0.03
Vessilla	25	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	0.10	Droughty	1.00
						Gravel content	0.01
398:							
Espiritu	45	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Slope	1.00
		Frost action	0.50	Slope	1.00	Droughty	0.91
						Gravel content	0.38
						Large stones content	0.08
Cucho	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Low strength	1.00	Cutbanks cave	0.10	Gravel content	0.99
		Shrink-swell	0.50	Depth to soft bedrock	0.03	Depth to bedrock	0.03
		Frost action	0.50				
399:							
Cucho	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Low strength	1.00	Cutbanks cave	0.10	Gravel content	0.99
		Shrink-swell	0.50	Depth to soft bedrock	0.03	Depth to bedrock	0.03
		Frost action	0.50				
Teco	35	Very limited		Very limited		Very limited	
		Low strength	1.00	Cutbanks cave	1.00	Slope	1.00
		Shrink-swell	1.00	Slope	1.00	Large stones content	0.68
		Slope	1.00	Too clayey	0.12	Gravel content	0.03
		Frost action	0.50				

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
405:							
Charo	50	Very limited		Very limited		Somewhat limited	
		Low strength	1.00	Depth to hard bedrock	1.00	Depth to bedrock	0.65
		Shrink-swell	1.00	Too clayey	0.50	Large stones content	0.46
		Depth to hard bedrock	0.64	Cutbanks cave	0.10	Gravel content	0.01
Charo, noncobbly	40	Very limited		Very limited		Somewhat limited	
		Low strength	1.00	Depth to hard bedrock	1.00	Depth to bedrock	0.01
		Shrink-swell	0.50	Too clayey	0.50	Large stones content	0.01
		Depth to hard bedrock	0.01	Cutbanks cave	0.10		
409:							
Santa Fe	85	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	1.00
						Gravel content	0.83
						Large stones content	0.01
410:							
Zia	85	Not limited		Somewhat limited		Not limited	
				Cutbanks cave	0.10		
414:							
Wauquie	85	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Slope	1.00
		Shrink-swell	0.50	Slope	1.00	Droughty	0.82
		Frost action	0.50			Gravel content	0.18
						Large stones content	0.16

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
417:							
Jocity	85	Very limited		Very limited		Not limited	
		Low strength	1.00	Cutbanks cave	1.00		
		Shrink-swell	0.50	Depth to saturated zone	0.15		
		Flooding	0.40				
418:							
Jocity	85	Very limited		Very limited		Not limited	
		Low strength	1.00	Cutbanks cave	1.00		
		Shrink-swell	0.50	Depth to saturated zone	0.15		
		Flooding	0.40				
419:							
Santa Fe	40	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	1.00
		Large stones content	0.01	Large stones content	0.01	Large stones content	1.00
						Gravel content	0.61
Wauquie	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	1.00	Droughty	1.00
		Large stones content	0.08	Large stones content	0.08	Gravel content	1.00
						Large stones content	0.99
420:							
Pinavetes	85	Not limited		Very limited		Very limited	
				Cutbanks cave	1.00	Droughty	1.00
421:							
Gilco, moderately saline, sodic	90	Somewhat limited		Somewhat limited		Very limited	
		Flooding	0.40	Depth to saturated zone	0.15	Salinity	1.00
				Cutbanks cave	0.10	Sodium content	1.00

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
422:							
Vessilla	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Droughty	1.00
				Cutbanks cave	0.10	Slope	1.00
						Large stones content	0.01
Menefee	30	Somewhat limited		Very limited		Very limited	
		Depth to soft bedrock	1.00	Depth to soft bedrock	1.00	Depth to bedrock	1.00
		Shrink-swell	0.50	Cutbanks cave	0.10	Droughty	0.99
		Frost action	0.50				
Orlie	25	Very limited		Somewhat limited		Not limited	
		Low strength	1.00	Cutbanks cave	0.10		
		Shrink-swell	0.50				
		Frost action	0.50				
423:							
Gilco	85	Somewhat limited		Somewhat limited		Not limited	
		Flooding	0.40	Depth to saturated zone	0.15		
				Cutbanks cave	0.10		
426:							
Aga, moderately saline, sodic	85	Somewhat limited		Very limited		Very limited	
		Flooding	0.40	Cutbanks cave	1.00	Salinity	1.00
				Depth to saturated zone	0.15	Sodium content	1.00
427:							
Aga	85	Somewhat limited		Very limited		Not limited	
		Flooding	0.40	Cutbanks cave	1.00		
				Depth to saturated zone	0.47		

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
428:							
Aga, moderately saline, sodic------	85	Somewhat limited		Very limited		Very limited	
		Flooding	0.40	Cutbanks cave	1.00	Salinity	1.00
				Depth to saturated zone	0.15	Sodium content	1.00
430:							
Trail---------------	85	Somewhat limited		Very limited		Somewhat limited	
		Flooding	0.40	Cutbanks cave	1.00	Droughty	0.08
431:							
Trail---------------	85	Somewhat limited		Very limited		Somewhat limited	
		Flooding	0.40	Cutbanks cave	1.00	Droughty	0.20
433:							
Peralta-------------	85	Somewhat limited		Very limited		Somewhat limited	
		Flooding	0.40	Cutbanks cave	1.00	Salinity	0.50
				Depth to saturated zone	0.99		
434:							
Peralta-------------	85	Somewhat limited		Very limited		Somewhat limited	
		Flooding	0.40	Cutbanks cave	1.00	Salinity	0.50
				Depth to saturated zone	0.99		
437:							
Peralta, moderately saline, sodic------	85	Somewhat limited		Very limited		Very limited	
		Flooding	0.40	Cutbanks cave	1.00	Salinity	1.00
				Depth to saturated zone	0.99	Sodium content	1.00
500:							
Osha----------------	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	1.00	Droughty	1.00
				Depth to hard bedrock	0.93	Gravel content	0.42

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
503:							
Cajete	65	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Gravel content	1.00
		Frost action	0.50	Slope	1.00	Slope	1.00
						Droughty	0.99
Cypher	25	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	0.10	Droughty	1.00
						Gravel content	0.96
						Large stones content	0.32
504:							
Orejas	40	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Shrink-swell	0.50	Slope	0.16	Droughty	1.00
		Slope	0.16	Cutbanks cave	0.10	Large stones content	1.00
						Slope	0.16
Guaje	35	Not limited		Very limited		Somewhat limited	
				Cutbanks cave	1.00	Droughty	0.99
600:							
Cypher	35	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50	Cutbanks cave	0.10	Droughty	1.00
						Large stones content	1.00
						Gravel content	0.01

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
601:							
Laventana	85	Somewhat limited		Very limited		Somewhat limited	
		Shrink-swell	0.50	Cutbanks cave	1.00	Droughty	0.30
		Frost action	0.50	Depth to hard bedrock	0.42	Slope	0.04
		Slope	0.04	Slope	0.04		
603:							
Laventana	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	0.50	Cutbanks cave	1.00	Droughty	0.01
		Frost action	0.50	Depth to hard bedrock	0.32		
Mirand	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	1.00	Too clayey	0.50	Large stones content	0.46
		Low strength	1.00	Cutbanks cave	0.10	Gravel content	0.36
604:							
Cypher	55	Very limited		Very limited		Very limited	
		Depth to hard bedrock	1.00	Depth to hard bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Frost action	0.50			Droughty	1.00
Mirand	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Shrink-swell	1.00	Too clayey	0.12	Large stones content	0.38
		Low strength	0.22	Cutbanks cave	0.10	Gravel content	0.28
608:							
Osha, steep	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
				Cutbanks cave	1.00	Droughty	1.00
Osha	30	Very limited		Very limited		Very limited	
		Slope	1.00	Cutbanks cave	1.00	Droughty	1.00
				Slope	1.00	Slope	1.00
				Dense layer	0.50	Gravel content	0.01

Table 10B.--Roads and streets, shallow excavations, and lawns and landscaping--continued

Map symbol and soil name	Pct. of map unit	Local roads and streets		Shallow excavations		Lawns and landscaping	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
823:							
Gilco, unprotected--	85	Somewhat limited		Somewhat limited		Not limited	
		Flooding	0.40	Depth to saturated zone	0.15		
				Cutbanks cave	0.10		
827:							
Aga, unprotected----	85	Somewhat limited		Very limited		Not limited	
		Flooding	0.40	Cutbanks cave	1.00		
				Depth to saturated zone	0.47		
830:							
Trail, unprotected--	85	Somewhat limited		Very limited		Somewhat limited	
		Flooding	0.40	Cutbanks cave	1.00	Droughty	0.01
				Depth to saturated zone	0.15		
831:							
Trail, unprotected--	85	Somewhat limited		Very limited		Somewhat limited	
		Flooding	0.40	Cutbanks cave	1.00	Droughty	0.87
				Depth to saturated zone	0.15		
835:							
Peralta, unprotected	85	Very limited		Very limited		Somewhat limited	
		Flooding	1.00	Depth to saturated zone	0.99	Flooding	0.60
		Shrink-swell	0.50	Flooding	0.60	Salinity	0.50
				Cutbanks cave	0.10		
842:							
Peralta, moderately saline, sodic, unprotected--------	85	Somewhat limited		Very limited		Very limited	
		Shrink-swell	0.50	Depth to saturated zone	0.99	Salinity	1.00
		Flooding	0.40	Cutbanks cave	0.10	Sodium content	1.00

Table 11A.--Sewage disposal

(The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table.)

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
1:					
Silver	55	Very limited		Somewhat limited	
		Slow water movement	1.00	Slope	0.32
Clovis	35	Somewhat limited		Very limited	
		Slow water movement	0.46	Seepage	1.00
				Slope	0.32
2:					
Clovis	35	Very limited		Very limited	
		Slow water movement	1.00	Seepage	1.00
				Slope	0.92
Prieta	35	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Large stones content	0.43	Slope	1.00
		Slope	0.04	Large stones content	1.00
Silver	20	Very limited		Somewhat limited	
		Slow water movement	1.00	Slope	0.92
3:					
Montecito	60	Very limited		Somewhat limited	
		Slow water movement	1.00	Slope	0.32
Orejas	30	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Large stones content	0.67	Large stones content	1.00
				Slope	0.32
4:					
Montecito	45	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Slow water movement	0.46	Seepage	0.53
Montecito, bouldery-	35	Very limited		Very limited	
		Slow water movement	1.00	Seepage	1.00
		Slope	1.00	Slope	1.00

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
10:					
Trail	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40		
11:					
Trail	85	Very limited		Very limited	
		Flooding	1.00	Flooding	1.00
		Depth to saturated zone	0.40	Seepage	1.00
13:					
Sandoval	65	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
				Slope	0.68
Querencia	20	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Slope	0.68
				Seepage	0.53
15:					
Camino	40	Very limited		Somewhat limited	
		Slow water movement	1.00	Slope	0.32
		Depth to bedrock	0.73	Depth to soft bedrock	0.32
Sandoval	35	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
				Slope	0.68
16:					
Rock outcrop	50	Not rated		Not rated	
Prieta	30	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Large stones content	0.06	Slope	1.00
		Slope	0.04	Large stones content	0.58
17:					
Vessilla	35	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Seepage, bottom layer	1.00	Slope	1.00
		Slope	0.04		

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
17:					
Menefee	25	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	0.04	Slope	1.00
Rock outcrop	20	Not rated		Not rated	
18:					
Sparham	85	Very limited		Very limited	
		Flooding	1.00	Flooding	1.00
		Slow water movement	1.00		
20:					
Gilco	85	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Seepage	0.53
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40		
21:					
Rock outcrop	60	Not rated		Not rated	
Hackroy	25	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
				Slope	0.68
22:					
Aga	85	Somewhat limited		Very limited	
		Depth to saturated zone	0.94	Seepage	1.00
		Slow water movement	0.46	Flooding	0.40
		Flooding	0.40	Depth to saturated zone	0.40
23:					
Hickman	85	Very limited		Somewhat limited	
		Slow water movement	1.00	Seepage	0.53
		Flooding	0.40	Flooding	0.40
24:					
Orlie	45	Very limited		Somewhat limited	
		Slow water movement	1.00	Seepage	0.53
				Slope	0.08
Sparham	35	Very limited		Very limited	
		Flooding	1.00	Flooding	1.00
		Slow water movement	1.00		

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
25:					
Gilco	85	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Seepage	0.53
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40		
26:					
Orlie	85	Very limited		Somewhat limited	
		Slow water movement	1.00	Slope	0.32
27:					
Aga	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Depth to saturated zone	0.94	Flooding	0.40
		Flooding	0.40	Depth to saturated zone	0.40
29:					
Trail	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40		
31:					
Riverwash	90	Very limited		Very limited	
		Flooding	1.00	Flooding	1.00
		Filtering capacity	1.00	Seepage	1.00
		Seepage, bottom layer	1.00		
33:					
Pits	100	Not rated		Not rated	
34:					
Ildefonso	55	Somewhat limited		Somewhat limited	
		Large stones content	0.70	Slope	0.68
		Slow water movement	0.46	Seepage	0.53
				Large stones content	0.29
Witt	30	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Seepage	0.53
				Slope	0.08

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
41:					
Dune land	100	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Slope	1.00
		Slope	0.16		
47:					
Cascajo	85	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
51:					
Sparham	85	Very limited		Very limited	
		Flooding	1.00	Flooding	1.00
		Slow water movement	1.00	Depth to saturated zone	1.00
		Depth to saturated zone	1.00		
52:					
Totavi	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Flooding	0.40
		Flooding	0.40	Slope	0.08
53:					
Witt	55	Very limited		Somewhat limited	
		Slow water movement	1.00	Seepage	0.53
				Slope	0.32
Harvey	30	Very limited		Very limited	
		Slow water movement	1.00	Seepage	1.00
				Slope	0.32
54:					
Harvey	45	Somewhat limited		Very limited	
		Slow water movement	0.46	Slope	1.00
		Slope	0.16	Seepage	0.53
Cascajo	40	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Slope	0.16	Slope	1.00
55:					
La Fonda	85	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Seepage	0.53
				Slope	0.08

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
56:					
Ildefonso	85	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Large stones content	0.53	Seepage	0.53
		Slow water movement	0.46	Large stones content	0.12
57:					
Badland	90	Not rated		Not rated	
58:					
Deama	45	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
		Large stones content	0.01	Seepage	0.53
Elpedro	35	Very limited		Very limited	
		Slow water movement	1.00	Slope	1.00
		Slope	0.04	Seepage	0.53
59:					
Harvey	35	Very limited		Somewhat limited	
		Slow water movement	1.00	Slope	0.92
				Seepage	0.53
Ildefonso	35	Somewhat limited		Very limited	
		Slope	0.37	Slope	1.00
		Large stones content	0.02	Seepage	1.00
La Fonda	15	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Slope	0.68
				Seepage	0.53
63:					
Placitas	85	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
				Seepage	1.00
64:					
Skyvillage	40	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
				Seepage	1.00
Ildefonso	35	Very limited		Very limited	
		Slope	1.00	Slope	1.00
				Seepage	1.00

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
65:					
Ildefonso	50	Very limited		Very limited	
		Slope	1.00	Slope	1.00
				Seepage	1.00
Harvey	30	Somewhat limited		Very limited	
		Slope	0.84	Slope	1.00
		Slow water movement	0.46	Seepage	1.00
66:					
Zia	85	Not limited		Very limited	
				Seepage	1.00
				Slope	0.68
67:					
Sandoval	40	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	1.00	Slope	1.00
Poley	35	Very limited		Very limited	
		Slow water movement	1.00	Seepage	1.00
		Slope	1.00	Slope	1.00
68:					
Penistaja	45	Very limited		Somewhat limited	
		Slow water movement	1.00	Slope	0.68
				Seepage	0.53
Querencia	35	Somewhat limited		Very limited	
		Slow water movement	0.46	Seepage	1.00
				Slope	0.68
71:					
Palon	85	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
		Large stones content	0.05	Large stones content	0.26
72:					
Palon	85	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
		Large stones content	1.00	Large stones content	1.00

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
74:					
Origo	50	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
		Large stones content	0.55	Large stones content	0.94
Pavo	25	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
		Slow water movement	1.00	Slope	1.00
		Slope	0.84		
75:					
Origo	85	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
		Large stones content	0.99	Large stones content	1.00
82:					
Calaveras	85	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
83:					
Calaveras	60	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
		Large stones content	0.01		
Rubble land	20	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Large stones content	1.00
		Large stones content	1.00	Seepage	1.00
		Seepage, bottom layer	1.00		
85:					
Redondo	85	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
86:					
Redondo	85	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
		Large stones content	0.53	Large stones content	0.37
87:					
Redondo	50	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
				Large stones content	0.02
Rubble land	25	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Large stones content	1.00
		Large stones content	1.00	Seepage	1.00
		Seepage, bottom layer	1.00		
88:					
Totavi	45	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Flooding	0.40
		Flooding	0.40	Slope	0.08
Jemez	30	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slow water movement	1.00	Slope	1.00
		Slope	0.16	Seepage	0.53
Rock outcrop	15	Not rated		Not rated	
91:					
Zia	85	Not limited		Very limited	
				Seepage	1.00
92:					
Galisteo, moderately saline, sodic	85	Very limited		Not limited	
		Slow water movement	1.00		
93:					
Zia	85	Not limited		Very limited	
				Seepage	1.00
				Slope	0.08

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
95:					
El Rancho	85	Somewhat limited		Very limited	
		Slow water movement	0.46	Seepage	1.00
97:					
El Rancho	85	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Seepage	0.53
100:					
Orejas	40	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
		Large stones content	0.61	Large stones content	1.00
Rock outcrop	40	Not rated		Not rated	
101:					
Blancot	55	Very limited		Very limited	
		Slow water movement	1.00	Seepage	1.00
				Slope	0.68
Lybrook	25	Very limited		Not limited	
		Slow water movement	1.00		
102:					
Sparham	85	Very limited		Very limited	
		Flooding	1.00	Flooding	1.00
		Slow water movement	1.00		
104:					
Cochiti	50	Very limited		Very limited	
		Slow water movement	1.00	Seepage	1.00
		Slope	1.00	Slope	1.00
Montecito	30	Not limited		Very limited	
				Seepage	1.00
				Slope	0.08
105:					
Badland	50	Not rated		Not rated	
Menefee	30	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	1.00	Slope	1.00
106:					
Stumble	50	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
106:					
Stumble, sandy------	30	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Flooding	0.40	Slope	0.92
				Flooding	0.40
108:					
Embudo--------------	85	Somewhat limited		Very limited	
		Slope	0.01	Seepage	1.00
				Slope	1.00
109:					
Embudo--------------	50	Not limited		Very limited	
				Seepage	1.00
				Slope	0.92
Tijeras-------------	35	Not limited		Very limited	
				Seepage	1.00
				Slope	0.32
110:					
Rock outcrop--------	45	Not rated		Not rated	
Saido---------------	40	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Slow water movement	0.46	Seepage	0.53
111:					
Rock outcrop--------	50	Not rated		Not rated	
Zia-----------------	35	Very limited		Very limited	
		Slope	1.00	Slope	1.00
				Seepage	1.00
112:					
Tijeras-------------	85	Not limited		Very limited	
				Seepage	1.00
				Slope	0.08
114:					
San Mateo-----------	40	Very limited		Somewhat limited	
		Slow water movement	1.00	Flooding	0.40
		Flooding	0.40		
Zia-----------------	40	Not limited		Very limited	
				Seepage	1.00
				Slope	0.68
120:					
Pinavetes-----------	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
				Slope	0.32
124:					
Rock outcrop--------	90	Not rated		Not rated	

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
129:					
Menefee	85	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	1.00	Slope	1.00
130:					
Pinavetes	45	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
				Slope	0.08
Galisteo, moderately saline, sodic	40	Very limited		Somewhat limited	
		Slow water movement	1.00	Flooding	0.40
		Flooding	0.40		
142:					
Grieta	85	Somewhat limited		Very limited	
		Slow water movement	0.46	Seepage	1.00
				Slope	0.08
143:					
Clovis	85	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Seepage	0.53
				Slope	0.08
145:					
Grieta	55	Not limited		Very limited	
				Seepage	1.00
				Slope	0.32
Sheppard	40	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
				Slope	0.92
146:					
Sedmar	85	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
		Slope	0.01	Slope	1.00
150:					
Doakum	55	Very limited		Somewhat limited	
		Slow water movement	1.00	Seepage	0.53
				Slope	0.08
Betonnie	35	Not limited		Very limited	
				Seepage	1.00
				Slope	1.00

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
162:					
Hackroy	45	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
				Slope	0.08
Nyjack	40	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slow water movement	1.00	Seepage	1.00
				Slope	0.08
163:					
Jemez	85	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slow water movement	1.00	Slope	1.00
		Slope	0.01	Seepage	0.53
170:					
San Mateo	85	Very limited		Somewhat limited	
		Slow water movement	1.00	Flooding	0.40
		Flooding	0.40		
180:					
Councelor	40	Very limited		Very limited	
		Slow water movement	1.00	Seepage	1.00
		Slope	1.00	Slope	1.00
Eslendo	30	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	1.00	Slope	1.00
Mespun	25	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Slope	1.00	Slope	1.00
183:					
Sheppard	85	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	0.63	Seepage	1.00
185:					
Frijoles	90	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
				Slope	0.68
190:					
Zia	35	Somewhat limited		Very limited	
		Slope	0.84	Seepage	1.00
				Slope	1.00

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
190:					
Skyvillage	25	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Seepage	1.00
				Slope	1.00
Rock outcrop	15	Not rated		Not rated	
191:					
Sheppard	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
				Slope	0.92
200:					
Sedillo	85	Very limited		Very limited	
		Slope	1.00	Seepage	1.00
				Slope	1.00
201:					
Rock outcrop	55	Not rated		Not rated	
Sedgran	35	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
				Seepage	1.00
206:					
Pinitos	85	Very limited		Very limited	
		Slow water movement	1.00	Slope	1.00
207:					
Penistaja	60	Somewhat limited		Very limited	
		Slow water movement	0.46	Seepage	1.00
				Slope	0.08
Zia	25	Not limited		Very limited	
				Seepage	1.00
				Slope	0.68
208:					
Sedillo	85	Very limited		Very limited	
		Slope	1.00	Slope	1.00
				Seepage	1.00
210:					
Ildefonso	85	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Large stones content	0.97	Large stones content	1.00
		Slow water movement	0.46	Seepage	0.53

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
211:					
Zia	45	Somewhat limited		Very limited	
		Slow water movement	0.46	Seepage	1.00
				Slope	0.92
Clovis	30	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Slope	0.68
				Seepage	0.53
213:					
Pinavetes	55	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
Rock outcrop	30	Not rated		Not rated	
215:					
Ess	60	Very limited		Very limited	
		Slope	1.00	Seepage	1.00
		Slow water movement	0.46	Slope	1.00
		Large stones content	0.33	Large stones content	1.00
Rock outcrop	30	Not rated		Not rated	
217:					
Witt	85	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Slope	0.68
				Seepage	0.53
218:					
Ildefonso	85	Somewhat limited		Very limited	
		Large stones content	0.71	Seepage	1.00
		Slope	0.01	Large stones content	1.00
				Slope	1.00
220:					
Rock outcrop	40	Not rated		Not rated	
Vessilla	30	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00		
Menefee	20	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	1.00	Slope	1.00

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
226:					
Galisteo, moderately saline, sodic	85	Very limited		Not limited	
		Slow water movement	1.00		
227:					
Hagerman	65	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slow water movement	1.00	Slope	0.08
Bond	20	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
				Slope	0.68
228:					
Winona	85	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
				Seepage	0.53
230:					
Skyvillage	35	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	0.63	Slope	1.00
Sandoval	25	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	0.63	Slope	1.00
Rock outcrop	20	Not rated		Not rated	
231:					
Querencia	85	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Slope	0.68
				Seepage	0.53
234:					
Querencia	60	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Slope	0.68
				Seepage	0.53
Zia	20	Not limited		Very limited	
				Seepage	1.00
				Slope	0.68
235:					
Sandoval	85	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	0.04	Slope	1.00

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
236:					
Sparank, moderately saline, sodic	85	Very limited		Very limited	
		Flooding	1.00	Flooding	1.00
		Slow water movement	1.00		
237:					
Sparank	85	Very limited		Very limited	
		Flooding	1.00	Flooding	1.00
		Slow water movement	1.00		
240:					
Penistaja	45	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Seepage	0.53
				Slope	0.08
Hagerman	35	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slow water movement	1.00	Slope	0.08
250:					
Pinavetes	90	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Slope	0.16	Slope	1.00
262:					
Pastura	90	Very limited		Very limited	
		Depth to cemented pan	1.00	Depth to cemented pan	1.00
				Seepage	0.53
				Slope	0.08
270:					
Blancot	40	Not limited		Very limited	
				Seepage	1.00
				Slope	0.32
Councelor	30	Not limited		Very limited	
				Seepage	1.00
Tsosie	25	Very limited		Very limited	
		Slow water movement	1.00	Seepage	1.00
281:					
Carjo	90	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
				Slope	0.68

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
282:					
Tocal	85	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
				Slope	0.92
				Seepage	0.53
283:					
Mirand	45	Very limited		Very limited	
		Slow water movement	1.00	Slope	1.00
		Slope	1.00		
Alanos	30	Very limited		Very limited	
		Slow water movement	1.00	Slope	1.00
		Slope	1.00	Large stones content	0.03
290:					
Alanos	50	Very limited		Very limited	
		Slow water movement	1.00	Slope	1.00
		Slope	1.00	Seepage	0.53
Rock outcrop	30	Not rated		Not rated	
300:					
Waumac	50	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
				Slope	0.32
Bamac	35	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Slope	0.32
301:					
Vastine	45	Very limited		Very limited	
		Depth to saturated zone	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Depth to saturated zone	1.00
		Slow water movement	0.46	Flooding	0.40
		Flooding	0.40		
Jarola	40	Very limited		Very limited	
		Depth to saturated zone	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Depth to saturated zone	1.00
		Slow water movement	0.46	Flooding	0.40
		Flooding	0.40	Slope	0.08

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
302:					
Tranquilar	50	Very limited		Very limited	
		Slow water movement	1.00	Depth to saturated zone	1.00
		Depth to saturated zone	1.00	Slope	0.68
Jarmillo	30	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
		Slow water movement	1.00	Slope	0.68
304:					
Cosey	45	Very limited		Very limited	
		Slow water movement	1.00	Slope	1.00
		Slope	0.37	Seepage	0.53
Jarmillo	40	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
		Slope	0.37	Slope	1.00
307:					
Flugle	60	Not limited		Very limited	
				Seepage	1.00
				Slope	0.08
Waumac	25	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
				Slope	0.68
308:					
Cajete	85	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
				Slope	0.32
311:					
Cosey	35	Very limited		Very limited	
		Slow water movement	1.00	Slope	1.00
		Slope	0.84	Seepage	0.53
		Large stones content	0.03		
Tranquilar	30	Very limited		Very limited	
		Slow water movement	1.00	Depth to saturated zone	1.00
		Depth to saturated zone	1.00	Slope	1.00
				Seepage	0.53

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
311:					
Calaveras	25	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
		Slope	0.84	Slope	1.00
		Slow water movement	0.46		
312:					
Royosa	90	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Slope	0.68
314:					
Fragua	40	Not limited		Very limited	
				Seepage	1.00
				Slope	0.68
Waumac	30	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
				Slope	0.68
Royosa	25	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Slope	0.68
317:					
Elpedro	85	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Slope	0.68
				Seepage	0.53
319:					
Bamac	60	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
		Seepage, bottom layer	1.00		
Rock outcrop	25	Not rated		Not rated	
320:					
Sparham	85	Very limited		Very limited	
		Flooding	1.00	Flooding	1.00
		Slow water movement	1.00		
321:					
Waumac	60	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
		Slope	0.01	Slope	1.00

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
321:					
Royosa	30	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
		Filtering capacity	1.00	Slope	0.68
322:					
Fragua	85	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
		Depth to bedrock	0.94	Depth to soft bedrock	0.84
324:					
Rock outcrop	30	Not rated		Not rated	
Atarque	25	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
				Seepage	0.53
Menefee	25	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	1.00	Slope	1.00
325:					
Rock outcrop	35	Not rated		Not rated	
Espiritu	25	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Slow water movement	0.46	Seepage	0.53
				Large stones content	0.01
Vessilla	25	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
342:					
Waumac	35	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
		Slope	0.84	Slope	1.00
Vessilla	25	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
		Slope	1.00	Slope	1.00
Rock outcrop	20	Not rated		Not rated	

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
345:					
Espiritu	50	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Slow water movement	0.46	Seepage	1.00
Bamac	35	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
		Seepage, bottom layer	1.00		
346:					
Espiritu, cobbly	70	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Slow water movement	0.46	Seepage	1.00
		Large stones content	0.01	Large stones content	0.39
Bamac	20	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
		Seepage, bottom layer	1.00		
348:					
Wauquie	60	Very limited		Very limited	
		Slope	1.00	Slope	1.00
				Seepage	1.00
Rock outcrop	20	Not rated		Not rated	
353:					
Cochiti	50	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
Espiritu	45	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
354:					
Waumac Variant	85	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Seepage, bottom layer	1.00	Slope	1.00
		Slope	0.01		

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
358:					
Deama	35	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
				Seepage	0.53
Elpedro	25	Very limited		Very limited	
		Slow water movement	1.00	Slope	1.00
		Slope	1.00	Seepage	0.53
Rock outcrop	25	Not rated		Not rated	
396:					
Atarque	30	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
Menefee	30	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	1.00	Slope	1.00
Rock outcrop	25	Not rated		Not rated	
397:					
Rock outcrop	30	Not rated		Not rated	
Cucho	25	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	1.00	Slope	1.00
		Slow water movement	1.00		
Vessilla	25	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00		
398:					
Espiritu	45	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Slow water movement	0.46	Seepage	1.00
Cucho	35	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	1.00	Slope	1.00
		Slow water movement	1.00		

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
399:					
Cucho	45	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
		Slope	1.00	Slope	1.00
		Slow water movement	1.00		
Teco	35	Very limited		Very limited	
		Slow water movement	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
405:					
Charo	50	Very limited		Very limited	
		Slow water movement	1.00	Depth to hard bedrock	1.00
		Depth to bedrock	1.00	Slope	0.08
Charo, noncobbly	40	Very limited		Very limited	
		Slow water movement	1.00	Depth to hard bedrock	1.00
		Depth to bedrock	1.00		
409:					
Santa Fe	85	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
410:					
Zia	85	Not limited		Very limited	
				Seepage	1.00
414:					
Wauquie	85	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Slow water movement	0.46	Seepage	1.00
417:					
Jocity	85	Very limited		Very limited	
		Slow water movement	1.00	Seepage	1.00
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40		
418:					
Jocity	85	Very limited		Very limited	
		Slow water movement	1.00	Seepage	1.00
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40		

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
419:					
Santa Fe	40	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
		Large stones content	0.01	Seepage	0.53
				Large stones content	0.02
Wauquie	30	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Large stones content	0.08	Seepage	1.00
				Large stones content	0.78
Rock outcrop	20	Not rated		Not rated	
420:					
Pinavetes	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
421:					
Gilco, moderately saline, sodic	90	Somewhat limited		Very limited	
		Slow water movement	0.46	Seepage	1.00
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40		
422:					
Vessilla	35	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
		Slope	1.00	Slope	1.00
Menefee	30	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to soft bedrock	1.00
				Slope	0.92
Orlie	25	Very limited		Somewhat limited	
		Slow water movement	1.00	Slope	0.32
423:					
Gilco	85	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Seepage	0.53
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40	Slope	0.08

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
426:					
Aga, moderately saline, sodic------	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40		
427:					
Aga-----------------	85	Somewhat limited		Very limited	
		Depth to saturated zone	0.94	Seepage	1.00
		Slow water movement	0.46	Flooding	0.40
		Flooding	0.40	Depth to saturated zone	0.40
428:					
Aga, moderately saline, sodic------	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40		
430:					
Trail---------------	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Flooding	0.40	Flooding	0.40
431:					
Trail---------------	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Flooding	0.40	Flooding	0.40
433:					
Peralta-------------	85	Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00
		Slow water movement	0.46	Seepage	0.53
		Flooding	0.40	Flooding	0.40
434:					
Peralta-------------	85	Very limited		Very limited	
		Depth to saturated zone	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Depth to saturated zone	1.00
		Slow water movement	0.46	Flooding	0.40
		Flooding	0.40		

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
437:					
Peralta, moderately saline, sodic	85	Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00
		Slow water movement	0.46	Seepage	0.53
		Flooding	0.40	Flooding	0.40
500:					
Rock outcrop	40	Not rated		Not rated	
Osha	30	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Depth to hard bedrock	0.93
		Depth to bedrock	0.98		
Rubble land	20	Very limited		Very limited	
		Filtering capacity	1.00	Slope	1.00
		Slope	1.00	Large stones content	1.00
		Large stones content	1.00	Seepage	1.00
		Seepage, bottom layer	1.00		
503:					
Cajete	65	Very limited		Very limited	
		Seepage, bottom layer	1.00	Slope	1.00
		Slope	1.00	Seepage	1.00
Cypher	25	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
504:					
Orejas	40	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	0.16	Slope	1.00
Guaje	35	Not limited		Very limited	
				Seepage	1.00
				Slope	0.68
600:					
Rock outcrop	50	Not rated		Not rated	

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
600:					
Cypher	35	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
				Seepage	0.53
601:					
Laventana	85	Somewhat limited		Very limited	
		Depth to bedrock	0.78	Slope	1.00
		Slow water movement	0.46	Seepage	0.53
		Slope	0.04	Depth to hard bedrock	0.42
603:					
Laventana	50	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Depth to bedrock	0.73	Seepage	0.53
		Slow water movement	0.46	Depth to hard bedrock	0.32
Mirand	35	Very limited		Very limited	
		Slow water movement	1.00	Slope	1.00
		Slope	1.00		
604:					
Cypher	55	Very limited		Very limited	
		Depth to bedrock	1.00	Depth to hard bedrock	1.00
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
Mirand	30	Very limited		Very limited	
		Slow water movement	1.00	Slope	1.00
		Slope	1.00		
608:					
Osha, steep	60	Very limited		Very limited	
		Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00
Osha	30	Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00
		Slope	1.00	Slope	1.00
823:					
Gilco, unprotected	85	Somewhat limited		Somewhat limited	
		Slow water movement	0.46	Seepage	0.53
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40	Slope	0.08

Table 11A.--Sewage disposal--continued

Map symbol and soil name	Pct. of map unit	Septic tank absorption fields		Sewage lagoons	
		Rating class and limiting features	Value	Rating class and limiting features	Value
827:					
Aga, unprotected----	85	Somewhat limited		Very limited	
		Depth to saturated zone	0.94	Seepage	1.00
		Slow water movement	0.46	Flooding	0.40
		Flooding	0.40	Depth to saturated zone	0.40
830:					
Trail, unprotected--	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40		
831:					
Trail, unprotected--	85	Very limited		Very limited	
		Filtering capacity	1.00	Seepage	1.00
		Depth to saturated zone	0.40	Flooding	0.40
		Flooding	0.40		
835:					
Peralta, unprotected	85	Very limited		Very limited	
		Flooding	1.00	Flooding	1.00
		Depth to saturated zone	1.00	Depth to saturated zone	1.00
		Slow water movement	0.46	Seepage	0.53
842:					
Peralta, moderately saline, sodic, unprotected--------	85	Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00
		Slow water movement	0.46	Seepage	0.53
		Flooding	0.40	Flooding	0.40
850:					
Water----------	95	Not rated		Not rated	
DAM:					
Dam----------	100	Not rated		Not rated	

Table 11B.--Landfills

(The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table.)

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
1:							
Silver	55	Not limited		Not limited		Not limited	
Clovis	35	Not limited		Not limited		Not limited	
2:							
Clovis	35	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
Prieta	35	Very limited		Somewhat limited		Very limited	
		Depth to bedrock	1.00	Slope	0.04	Depth to bedrock	1.00
		Large stones content	0.43			Large stones content	0.43
		Slope	0.04			Gravel content	0.05
						Slope	0.04
Silver	20	Not limited		Not limited		Not limited	
3:							
Montecito	60	Not limited		Not limited		Not limited	
Orejas	30	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Large stones content	0.67			Large stones content	0.67
		Too clayey	0.50			Too clayey	0.50
						Gravel content	0.01
4:							
Montecito	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Montecito, bouldery-	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
10:							
Trail	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Seepage	1.00
		Too sandy	0.50	Flooding	0.40	Too sandy	0.50
		Flooding	0.40				
11:							
Trail	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Seepage	1.00
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Too sandy	0.50
		Too sandy	0.50				
13:							
Sandoval	65	Very limited		Not limited		Very limited	
		Depth to bedrock	1.00			Depth to bedrock	1.00
Querencia	20	Not limited		Not limited		Not limited	
15:							
Camino	40	Very limited		Not limited		Very limited	
		Depth to bedrock	1.00			Hard to compact	1.00
						Depth to bedrock	0.32
Sandoval	35	Very limited		Not limited		Very limited	
		Depth to bedrock	1.00			Depth to bedrock	1.00
16:							
Rock outcrop	50	Not rated		Not rated		Not rated	
Prieta	30	Very limited		Somewhat limited		Very limited	
		Depth to bedrock	1.00	Slope	0.04	Depth to bedrock	1.00
		Large stones content	0.06			Gravel content	0.07
		Slope	0.04			Large stones content	0.06
						Slope	0.04

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
17:							
Vessilla	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Seepage, bottom layer	1.00	Slope	0.04	Seepage	0.52
		Slope	0.04			Slope	0.04
Menefee	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	0.04	Slope	0.04	Slope	0.04
Rock outcrop	20	Not rated		Not rated		Not rated	
18:							
Sparham	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Sodium content	1.00
		Excess sodium	1.00			Too clayey	0.50
		Too clayey	0.50				
20:							
Gilco	85	Very limited		Very limited		Not limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00		
		Flooding	0.40	Flooding	0.40		
21:							
Rock outcrop	60	Not rated		Not rated		Not rated	
Hackroy	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Too clayey	1.00			Too clayey	1.00
						Hard to compact	1.00
22:							
Aga	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Too sandy	1.00
		Too sandy	1.00	Flooding	0.40	Seepage	1.00
		Flooding	0.40				

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
23:							
Hickman	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Too clayey	0.50	Flooding	0.40	Too clayey	0.50
		Flooding	0.40				
24:							
Orlie	45	Not limited		Not limited		Not limited	
Sparham	35	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Too clayey	1.00
		Too clayey	1.00			Sodium content	1.00
		Excess sodium	1.00				
25:							
Gilco	85	Very limited		Very limited		Not limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00		
		Flooding	0.40	Flooding	0.40		
26:							
Orlie	85	Not limited		Not limited		Not limited	
27:							
Aga	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Too sandy	1.00
		Too sandy	1.00	Flooding	0.40	Seepage	1.00
		Flooding	0.40				
29:							
Trail	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Seepage	1.00
		Too sandy	0.50	Flooding	0.40	Too sandy	0.50
		Flooding	0.40				
31:							
Riverwash	90	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Too sandy	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	1.00
		Too sandy	1.00				

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
33:							
Pits	100	Not rated		Not limited		Not rated	
34:							
Ildefonso	55	Somewhat limited		Not limited		Somewhat limited	
		Large stones content	0.93			Large stones content	0.93
Witt	30	Not limited		Not limited		Not limited	
41:							
Dune land	100	Very limited		Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Too sandy	1.00
		Too sandy	1.00	Slope	0.16	Seepage	1.00
		Slope	0.16			Slope	0.16
47:							
Cascajo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Seepage	1.00
		Too sandy	0.50			Slope	1.00
		Large stones content	0.06			Gravel content	0.90
						Too sandy	0.50
						Large stones content	0.06
51:							
Sparham	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Depth to saturated zone	1.00
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Sodium content	1.00
		Excess sodium	1.00			Too clayey	0.50
		Too clayey	0.50				
52:							
Totavi	85	Very limited		Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	1.00
		Too sandy	0.50	Flooding	0.40	Too sandy	0.50
		Flooding	0.40				

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
53:							
Witt	55	Not limited		Not limited		Not limited	
Harvey	30	Not limited		Not limited		Not limited	
54:							
Harvey	45	Somewhat limited		Somewhat limited		Somewhat limited	
		Slope	0.16	Slope	0.16	Slope	0.16
Cascajo	40	Very limited		Somewhat limited		Very limited	
		Too sandy	1.00	Slope	0.16	Too sandy	1.00
		Slope	0.16			Seepage	1.00
						Gravel content	0.84
						Slope	0.16
55:							
La Fonda	85	Not limited		Not limited		Not limited	
56:							
Ildefonso	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.83			Large stones content	0.83
						Gravel content	0.01
57:							
Badland	90	Not rated		Very limited		Not rated	
				Depth to bedrock	1.00		
				Slope	1.00		
58:							
Deama	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Large stones content	0.01			Carbonate content	1.00
						Gravel content	0.09
						Large stones content	0.01
Elpedro	35	Somewhat limited		Somewhat limited		Somewhat limited	
		Slope	0.04	Slope	0.04	Slope	0.04

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
59:							
Harvey	35	Not limited		Not limited		Not limited	
Ildefonso	35	Very limited		Somewhat limited		Very limited	
		Too sandy	1.00	Slope	0.37	Too sandy	1.00
		Large stones content	0.56			Seepage	1.00
		Slope	0.37			Large stones content	0.56
						Slope	0.37
						Gravel content	0.36
La Fonda	15	Not limited		Not limited		Not limited	
63:							
Placitas	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Slope	1.00	Depth to bedrock	1.00
		Slope	1.00			Slope	1.00
						Gravel content	0.98
						Seepage	0.52
64:							
Skyvillage	40	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Slope	1.00	Depth to bedrock	1.00
		Slope	1.00			Slope	1.00
						Seepage	0.52
Ildefonso	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.86
						Seepage	0.52
65:							
Ildefonso	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.95
						Seepage	0.52
Harvey	30	Somewhat limited		Somewhat limited		Somewhat limited	
		Slope	0.84	Slope	0.84	Slope	0.84
						Seepage	0.52

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
66:							
Zia	85	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
67:							
Sandoval	40	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Slope	1.00	Depth to bedrock	1.00
		Slope	1.00			Slope	1.00
Poley	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Seepage	0.52
68:							
Penistaja	45	Not limited		Not limited		Not limited	
Querencia	35	Not limited		Not limited		Not limited	
71:							
Palon	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Gravel content	0.67
		Large stones content	0.12			Seepage	0.52
						Large stones content	0.12
72:							
Palon	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Large stones	1.00
		Large stones	1.00			Seepage	0.52
						Gravel content	0.01

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
74:							
Origo	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Large stones content	0.67
		Large stones content	0.67			Seepage	0.52
						Gravel content	0.39
Pavo	25	Very limited		Very limited		Somewhat limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Slope	0.84
		Slope	0.84	Slope	0.84	Seepage	0.52
75:							
Origo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Large stones content	0.99
		Large stones content	0.99			Seepage	0.52
						Gravel content	0.01
82:							
Calaveras	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Gravel content	0.71
		Large stones content	0.02			Seepage	0.52
						Large stones content	0.02
83:							
Calaveras	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	0.52
		Large stones content	0.19			Large stones content	0.19
						Gravel content	0.05

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
83:							
Rubble land---	20	Not rated		Very limited		Very limited	
				Slope	1.00	Slope	1.00
				Seepage	1.00	Seepage	1.00
						Large stones	1.00
85:							
Redondo---	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	0.52
						Gravel content	0.14
86:							
Redondo---	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Large stones content	0.93
		Large stones content	0.93			Seepage	0.52
						Gravel content	0.07
87:							
Redondo---	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	0.52
						Gravel content	0.08
Rubble land---	25	Not rated		Very limited		Very limited	
				Slope	1.00	Slope	1.00
				Seepage	1.00	Seepage	1.00
						Large stones	1.00
88:							
Totavi---	45	Very limited		Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	1.00
		Too sandy	0.50	Flooding	0.40	Too sandy	0.50
		Flooding	0.40				

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
88:							
Jemez	30	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	0.16	Slope	0.16	Slope	0.16
Rock outcrop	15	Not rated		Not rated		Not rated	
91:							
Zia	85	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
92:							
Galisteo, moderately saline, sodic	85	Not limited		Not limited		Very limited	
						Hard to compact	1.00
93:							
Zia	85	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
95:							
El Rancho	85	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
97:							
El Rancho	85	Not limited		Not limited		Not limited	
100:							
Orejas	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Large stones content	0.61			Large stones content	0.61
		Too clayey	0.50			Too clayey	0.50
						Gravel content	0.01
Rock outcrop	40	Not rated		Not rated		Not rated	
101:							
Blancot	55	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
Lybrook	25	Not limited		Not limited		Not limited	

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
102:							
Sparham	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Sodium content	1.00
		Excess sodium	1.00			Too clayey	0.50
		Too clayey	0.50				
104:							
Cochiti	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.87
						Seepage	0.52
Montecito	30	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
105:							
Badland	50	Not rated		Very limited		Not rated	
				Slope	1.00		
				Depth to bedrock	1.00		
Menefee	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
106:							
Stumble	50	Very limited		Very limited		Very limited	
		Too sandy	1.00	Slope	1.00	Too sandy	1.00
		Slope	1.00			Seepage	1.00
						Slope	1.00
Stumble, sandy	30	Very limited		Somewhat limited		Very limited	
		Too sandy	1.00	Flooding	0.40	Too sandy	1.00
		Flooding	0.40			Seepage	1.00
108:							
Embudo	85	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.50	Slope	0.01	Seepage	1.00
		Slope	0.01			Too sandy	0.50
						Slope	0.01

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
109:							
Embudo	50	Somewhat limited		Not limited		Very limited	
		Too sandy	0.50			Seepage	1.00
						Too sandy	0.50
Tijeras	35	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
						Gravel content	0.14
110:							
Rock outcrop	45	Not rated		Not rated		Not rated	
Saido	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
111:							
Rock outcrop	50	Not rated		Not rated		Not rated	
Zia	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Seepage	0.52
112:							
Tijeras	85	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
						Gravel content	0.01
114:							
San Mateo	40	Somewhat limited		Somewhat limited		Not limited	
		Flooding	0.40	Flooding	0.40		
Zia	40	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
120:							
Pinavetes	85	Very limited		Not limited		Very limited	
		Too sandy	1.00			Too sandy	1.00
						Seepage	1.00
124:							
Rock outcrop	90	Not rated		Not rated		Not rated	

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
129:							
Menefee	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Too clayey	0.50			Too clayey	0.50
130:							
Pinavetes	45	Somewhat limited		Not limited		Very limited	
		Too sandy	0.50			Seepage	1.00
						Too sandy	0.50
Galisteo, moderately saline, sodic	40	Somewhat limited		Somewhat limited		Very limited	
		Flooding	0.40	Flooding	0.40	Hard to compact	1.00
142:							
Grieta	85	Not limited		Not limited		Not limited	
143:							
Clovis	85	Not limited		Not limited		Not limited	
145:							
Grieta	55	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
Sheppard	40	Somewhat limited		Not limited		Very limited	
		Too sandy	0.50			Seepage	1.00
						Too sandy	0.50
146:							
Sedmar	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Seepage, bottom layer	1.00	Slope	0.01	Seepage	1.00
		Too sandy	0.50			Too sandy	0.50
		Slope	0.01			Slope	0.01
150:							
Doakum	55	Not limited		Not limited		Not limited	
Betonnie	35	Not limited		Not limited		Somewhat limited	
						Seepage	0.52

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
162:							
Hackroy	45	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Too clayey	1.00			Too clayey	1.00
						Hard to compact	1.00
Nyjack	40	Very limited		Not limited		Very limited	
		Depth to bedrock	1.00			Depth to bedrock	1.00
						Seepage	0.52
163:							
Jemez	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	0.01	Slope	0.01	Slope	0.01
170:							
San Mateo	85	Somewhat limited		Somewhat limited		Not limited	
		Flooding	0.40	Flooding	0.40		
180:							
Councelor	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Seepage	0.52
Eslendo	30	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Slope	1.00	Depth to bedrock	1.00
		Slope	1.00			Slope	1.00
Mespun	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Seepage	1.00
		Too sandy	0.50			Slope	1.00
						Too sandy	0.50
183:							
Sheppard	85	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.63	Slope	0.63	Seepage	1.00
		Too sandy	0.50			Slope	0.63
						Too sandy	0.50
185:							
Frijoles	90	Not limited		Not limited		Very limited	
						Seepage	1.00
						Gravel content	1.00

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
190:							
Zia	35	Somewhat limited		Somewhat limited		Somewhat limited	
		Slope	0.84	Slope	0.84	Slope	0.84
						Seepage	0.52
Skyvillage	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Slope	1.00	Depth to bedrock	1.00
		Slope	1.00			Slope	1.00
						Seepage	0.52
Rock outcrop	15	Not rated		Not rated		Not rated	
191:							
Sheppard	85	Somewhat limited		Not limited		Very limited	
		Too sandy	0.50			Seepage	1.00
						Too sandy	0.50
200:							
Sedillo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.91
						Seepage	0.52
201:							
Rock outcrop	55	Not rated		Not rated		Not rated	
Sedgran	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00			Slope	1.00
		Too sandy	0.50			Seepage	1.00
						Gravel content	0.94
						Too sandy	0.50
206:							
Pinitos	85	Not limited		Not limited		Not limited	
207:							
Penistaja	60	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
Zia	25	Not limited		Not limited		Somewhat limited	
						Seepage	0.52

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
208:							
Sedillo	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	1.00
						Seepage	0.52
210:							
Ildefonso	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.97			Large stones content	0.97
						Gravel content	0.01
211:							
Zia	45	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
Clovis	30	Not limited		Not limited		Not limited	
213:							
Pinavetes	55	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Too sandy	1.00			Too sandy	1.00
						Seepage	1.00
Rock outcrop	30	Not rated		Not rated		Not rated	
215:							
Ess	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Large stones content	0.14			Gravel content	0.36
						Large stones content	0.14
Rock outcrop	30	Not rated		Not rated		Not rated	
217:							
Witt	85	Not limited		Not limited		Not limited	

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
218:							
Ildefonso	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Large stones content	0.70	Slope	0.01	Large stones content	0.70
		Slope	0.01			Seepage	0.52
						Gravel content	0.03
						Slope	0.01
220:							
Rock outcrop	40	Not rated		Not rated		Not rated	
Vessilla	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Seepage, bottom layer	1.00			Seepage	0.52
Menefee	20	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
226:							
Galisteo, moderately saline, sodic	85	Not limited		Not limited		Not limited	
227:							
Hagerman	65	Very limited		Not limited		Very limited	
		Depth to bedrock	1.00			Depth to bedrock	1.00
Bond	20	Very limited		Not limited		Very limited	
		Depth to bedrock	1.00			Depth to bedrock	1.00
228:							
Winona	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Slope	1.00	Depth to bedrock	1.00
		Slope	1.00			Slope	1.00
						Carbonate content	1.00
						Gravel content	0.93

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
102:							
230:							
Skyvillage	35	Very limited		Somewhat limited		Very limited	
		Depth to bedrock	1.00	Slope	0.63	Depth to bedrock	1.00
		Slope	0.63			Slope	0.63
						Seepage	0.52
Sandoval	25	Very limited		Somewhat limited		Very limited	
		Depth to bedrock	1.00	Slope	0.63	Depth to bedrock	1.00
		Slope	0.63			Slope	0.63
Rock outcrop	20	Not rated		Not rated		Not rated	
231:							
Querencia	85	Not limited		Not limited		Not limited	
234:							
Querencia	60	Not limited		Not limited		Not limited	
Zia	20	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
235:							
Sandoval	85	Very limited		Somewhat limited		Very limited	
		Depth to bedrock	1.00	Slope	0.04	Depth to bedrock	1.00
		Slope	0.04			Slope	0.04
236:							
Sparank, moderately saline, sodic	85	Very limited		Very limited		Not limited	
		Flooding	1.00	Flooding	1.00		
237:							
Sparank	85	Very limited		Very limited		Not limited	
		Flooding	1.00	Flooding	1.00		
240:							
Penistaja	45	Not limited		Not limited		Not limited	
Hagerman	35	Very limited		Not limited		Very limited	
		Depth to bedrock	1.00			Depth to bedrock	1.00

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
250:							
Pinavetes	90	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.50	Slope	0.16	Seepage	1.00
		Slope	0.16			Too sandy	0.50
						Slope	0.16
262:							
Pastura	90	Somewhat limited		Not limited		Very limited	
		Depth to thin cemented pan	0.50			Depth to cemented pan	1.00
270:							
Blancot	40	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
Councelor	30	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
Tsosie	25	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
281:							
Carjo	90	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Seepage	1.00	Depth to bedrock	1.00
		Seepage, bottom layer	1.00	Depth to bedrock	1.00	Too clayey	1.00
		Too clayey	1.00			Hard to compact	1.00
282:							
Tocal	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
283:							
Mirand	45	Very limited		Very limited		Very limited	
		Too clayey	1.00	Slope	1.00	Too clayey	1.00
		Slope	1.00			Hard to compact	1.00
						Slope	1.00
Alanos	30	Very limited		Very limited		Very limited	
		Too clayey	1.00	Slope	1.00	Too clayey	1.00
		Slope	1.00			Slope	1.00
						Gravel content	0.92

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
290:							
Alanos	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Too clayey	1.00			Too clayey	1.00
						Gravel content	1.00
Rock outcrop	30	Not rated		Not rated		Not rated	
300:							
Waumac	50	Very limited		Very limited		Somewhat limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	0.52
Bamac	35	Very limited		Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	1.00
		Too sandy	0.50			Gravel content	0.90
						Too sandy	0.50
301:							
Vastine	45	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Gravel content	0.90
		Too sandy	0.50	Flooding	0.40	Depth to saturated zone	0.86
		Flooding	0.40			Too sandy	0.50
Jarola	40	Very limited		Very limited		Somewhat limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Depth to saturated zone	0.86
		Seepage, bottom layer	1.00	Flooding	0.40		
		Flooding	0.40				
302:							
Tranquilar	50	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Too clayey	1.00
		Too clayey	1.00			Hard to compact	1.00
						Depth to saturated zone	0.24

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
302:							
Jarmillo	30	Very limited		Very limited		Somewhat limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Too clayey	0.50
		Too clayey	0.50				
304:							
Cosey	45	Somewhat limited		Somewhat limited		Somewhat limited	
		Too clayey	0.50	Slope	0.37	Too clayey	0.50
		Slope	0.37			Slope	0.37
						Gravel content	0.05
Jarmillo	40	Very limited		Very limited		Somewhat limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	0.52
		Slope	0.37	Slope	0.37	Slope	0.37
307:							
Flugle	60	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
Waumac	25	Very limited		Very limited		Somewhat limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	0.52
308:							
Cajete	85	Very limited		Very limited		Somewhat limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Gravel content	0.69
						Seepage	0.52
311:							
Cosey	35	Somewhat limited		Somewhat limited		Somewhat limited	
		Slope	0.84	Slope	0.84	Slope	0.84
		Large stones content	0.65			Large stones content	0.65
		Too clayey	0.50			Too clayey	0.50

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
311:							
Tranquilar----------	30	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Too clayey	1.00
		Too clayey	1.00			Hard to compact	1.00
						Depth to saturated zone	0.24
Calaveras----------	25	Very limited		Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	1.00
		Slope	0.84	Slope	0.84	Slope	0.84
		Too sandy	0.50			Too sandy	0.50
		Large stones content	0.01			Gravel content	0.08
						Large stones content	0.01
312:							
Royosa--------------	90	Very limited		Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	1.00
		Too sandy	0.50			Too sandy	0.50
314:							
Fragua--------------	40	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
Waumac--------------	30	Very limited		Very limited		Somewhat limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	0.52
Royosa--------------	25	Very limited		Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Too sandy	1.00
		Too sandy	1.00			Seepage	1.00
317:							
Elpedro-------------	85	Not limited		Not limited		Not limited	

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
319:							
Bamac	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	1.00
		Too sandy	0.50			Gravel content	0.99
						Too sandy	0.50
Rock outcrop	25	Not rated		Not rated		Not rated	
320:							
Sparham	85	Very limited		Very limited		Very limited	
		Flooding	1.00	Flooding	1.00	Too clayey	1.00
		Too clayey	1.00			Sodium content	1.00
		Excess sodium	1.00				
321:							
Waumac	60	Very limited		Very limited		Somewhat limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	0.52
		Slope	0.01	Slope	0.01	Slope	0.01
Royosa	30	Very limited		Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Too sandy	1.00
		Too sandy	1.00			Seepage	1.00
322:							
Fragua	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00			Seepage	1.00
		Too sandy	0.50			Depth to bedrock	0.84
						Too sandy	0.50
324:							
Rock outcrop	30	Not rated		Not rated		Not rated	
Atarque	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
324:							
Menefee	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
		Too clayey	0.50			Too clayey	0.50
325:							
Rock outcrop	35	Not rated		Not rated		Not rated	
Espiritu	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.67
Vessilla	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
						Seepage	0.52
						Gravel content	0.07
342:							
Waumac	35	Very limited		Very limited		Somewhat limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Slope	0.84
		Slope	0.84	Slope	0.84	Seepage	0.52
Vessilla	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Seepage, bottom layer	1.00	Slope	1.00	Slope	1.00
		Slope	1.00			Seepage	0.52
Rock outcrop	20	Not rated		Not rated		Not rated	
345:							
Espiritu	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Seepage	0.52
						Gravel content	0.18

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
345:							
Bamac	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	1.00
		Too sandy	0.50			Gravel content	0.98
						Too sandy	0.50
346:							
Espiritu, cobbly	70	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Too sandy	0.50			Seepage	1.00
		Large stones content	0.01			Gravel content	0.74
						Too sandy	0.50
						Large stones content	0.01
Bamac	20	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	1.00
		Too sandy	0.50			Gravel content	0.58
						Too sandy	0.50
348:							
Wauquie	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	1.00
						Seepage	0.52
Rock outcrop	20	Not rated		Not rated		Not rated	
353:							
Cochiti	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Too sandy	0.50			Seepage	1.00
						Gravel content	1.00
						Too sandy	0.50

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
353:							
Espiritu	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Too sandy	0.50			Seepage	1.00
						Gravel content	0.99
						Too sandy	0.50
354:							
Waumac Variant	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Seepage, bottom layer	1.00	Slope	0.01	Gravel content	1.00
		Slope	0.01			Seepage	0.52
						Slope	0.01
358:							
Deama	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Slope	1.00	Slope	1.00	Slope	1.00
						Carbonate content	1.00
						Gravel content	0.99
Elpedro	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
Rock outcrop	25	Not rated		Not rated		Not rated	
396:							
Atarque	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Too clayey	0.50			Too clayey	0.50
Menefee	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Too clayey	0.50			Too clayey	0.50
Rock outcrop	25	Not rated		Not rated		Not rated	
397:							
Rock outcrop	30	Not rated		Not rated		Not rated	

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
397:							
Cucho	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Too clayey	0.50			Gravel content	0.69
						Too clayey	0.50
Vessilla	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Seepage, bottom layer	1.00			Seepage	0.52
398:							
Espiritu	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
						Gravel content	0.95
						Seepage	0.52
Cucho	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Too clayey	0.50			Too clayey	0.50
399:							
Cucho	45	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Too clayey	0.50			Too clayey	0.50
Teco	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Hard to compact	1.00
						Slope	1.00
405:							
Charo	50	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Too clayey	1.00			Too clayey	1.00
						Hard to compact	1.00
Charo, noncobbly	40	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Too clayey	1.00			Too clayey	1.00

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
409:							
Santa Fe	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
						Gravel content	0.76
						Seepage	0.52
410:							
Zia	85	Not limited		Not limited		Somewhat limited	
						Seepage	0.52
414:							
Wauquie	85	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Seepage	1.00
						Slope	1.00
						Gravel content	0.42
417:							
Jocity	85	Very limited		Very limited		Not limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00		
		Flooding	0.40	Flooding	0.40		
418:							
Jocity	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Seepage	1.00
		Flooding	0.40	Flooding	0.40		
419:							
Santa Fe	40	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Large stones content	0.01			Gravel content	0.40
						Large stones content	0.01

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
419:							
Wauquie	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Too sandy	1.00			Too sandy	1.00
		Large stones content	0.08			Seepage	1.00
						Gravel content	1.00
						Large stones content	0.08
Rock outcrop	20	Not rated		Not rated		Not rated	
420:							
Pinavetes	85	Very limited		Not limited		Very limited	
		Too sandy	1.00			Too sandy	1.00
						Seepage	1.00
421:							
Gilco, moderately saline, sodic	90	Very limited		Very limited		Not limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00		
		Flooding	0.40	Flooding	0.40		
422:							
Vessilla	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Seepage, bottom layer	1.00	Slope	1.00	Slope	1.00
		Slope	1.00			Seepage	0.52
Menefee	30	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
Orlie	25	Not limited		Not limited		Not limited	
423:							
Gilco	85	Very limited		Very limited		Not limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00		
		Flooding	0.40	Flooding	0.40		

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
426:							
Aga, moderately saline, sodic------	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Too sandy	1.00
		Too sandy	1.00	Flooding	0.40	Seepage	1.00
		Flooding	0.40				
427:							
Aga-----------------	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Seepage	1.00
		Too sandy	0.50	Flooding	0.40	Too sandy	0.50
		Flooding	0.40				
428:							
Aga, moderately saline, sodic------	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Seepage	1.00
		Too sandy	0.50	Flooding	0.40	Too sandy	0.50
		Flooding	0.40				
430:							
Trail---------------	85	Somewhat limited		Somewhat limited		Very limited	
		Flooding	0.40	Flooding	0.40	Seepage	1.00
431:							
Trail---------------	85	Somewhat limited		Somewhat limited		Very limited	
		Too sandy	0.50	Flooding	0.40	Seepage	1.00
		Flooding	0.40			Too sandy	0.50
433:							
Peralta-------------	85	Very limited		Very limited		Somewhat limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Too sandy	0.50
		Too sandy	0.50	Flooding	0.40	Depth to saturated zone	0.47
		Flooding	0.40				

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
434:							
Peralta	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Too sandy	0.50
		Too sandy	0.50	Flooding	0.40	Depth to saturated zone	0.47
		Flooding	0.40				
437:							
Peralta, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Sodium content	1.00
		Excess sodium	1.00	Flooding	0.40	Too sandy	0.50
		Too sandy	0.50			Depth to saturated zone	0.47
		Flooding	0.40				
500:							
Rock outcrop	40	Not rated		Not rated		Not rated	
Osha	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00	Seepage	1.00	Seepage	1.00
		Seepage, bottom layer	1.00	Depth to bedrock	0.94	Gravel content	1.00
		Too sandy	0.50			Depth to bedrock	0.94
						Too sandy	0.50
Rubble land	20	Not rated		Very limited		Very limited	
				Slope	1.00	Slope	1.00
				Seepage	1.00	Seepage	1.00
						Large stones	1.00
503:							
Cajete	65	Very limited		Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Slope	1.00
		Slope	1.00	Slope	1.00	Gravel content	0.90
						Seepage	0.52

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
5.3:							
Cypher	25	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Seepage, bottom layer	1.00			Gravel content	0.93
						Seepage	0.52
504:							
Orejas	40	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Depth to bedrock	1.00	Depth to bedrock	1.00
		Too clayey	0.50	Slope	0.16	Too clayey	0.50
		Slope	0.16			Slope	0.16
						Gravel content	0.14
Guaje	35	Not limited		Not limited		Very limited	
						Gravel content	1.00
						Seepage	0.52
600:							
Rock outcrop	50	Not rated		Not rated		Not rated	
Cypher	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
						Gravel content	0.77
601:							
Laventana	85	Very limited		Somewhat limited		Somewhat limited	
		Depth to bedrock	1.00	Depth to bedrock	0.42	Gravel content	0.93
		Slope	0.04	Slope	0.04	Depth to bedrock	0.42
						Slope	0.04
603:							
Laventana	50	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Depth to bedrock	1.00	Depth to bedrock	0.32	Gravel content	0.53
						Depth to bedrock	0.32
Mirand	35	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Too clayey	0.50			Too clayey	0.50

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
604:							
Cypher	55	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Depth to bedrock	1.00
		Depth to bedrock	1.00	Depth to bedrock	1.00	Slope	1.00
		Seepage, bottom layer	1.00			Gravel content	1.00
						Seepage	0.52
Mirand	30	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Too clayey	1.00			Too clayey	1.00
608:							
Osha, steep	60	Very limited		Very limited		Very limited	
		Slope	1.00	Slope	1.00	Slope	1.00
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	1.00
		Too sandy	0.50			Gravel content	1.00
						Too sandy	0.50
Osha	30	Very limited		Very limited		Very limited	
		Seepage, bottom layer	1.00	Seepage	1.00	Seepage	1.00
		Slope	1.00	Slope	1.00	Gravel content	1.00
		Too sandy	0.50			Slope	1.00
						Too sandy	0.50
823:							
Gilco, unprotected	85	Very limited		Very limited		Not limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00		
		Flooding	0.40	Flooding	0.40		
827:							
Aga, unprotected	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Seepage	1.00
		Too sandy	0.50	Flooding	0.40	Too sandy	0.50
		Flooding	0.40				

Table 11B.—Landfills--continued

Map symbol and soil name	Pct. of map unit	Trench sanitary landfill		Area sanitary landfill		Daily cover for landfill	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
830:							
Trail, unprotected--	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Seepage	1.00
		Too sandy	0.50	Flooding	0.40	Too sandy	0.50
		Flooding	0.40				
831:							
Trail, unprotected--	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Too sandy	1.00
		Too sandy	1.00	Flooding	0.40	Seepage	1.00
		Flooding	0.40				
835:							
Peralta, unprotected	85	Very limited		Very limited		Somewhat limited	
		Flooding	1.00	Flooding	1.00	Depth to saturated zone	0.47
		Depth to saturated zone	1.00	Depth to saturated zone	1.00		
842:							
Peralta, moderately saline, sodic, unprotected--------	85	Very limited		Very limited		Very limited	
		Depth to saturated zone	1.00	Depth to saturated zone	1.00	Sodium content	1.00
		Excess sodium	1.00	Flooding	0.40	Too clayey	0.50
		Too clayey	0.50			Depth to saturated zone	0.47
		Flooding	0.40				
850:							
Water----------	95	Not rated		Not rated		Not rated	
DAM:							
Dam----------	100	Not rated		Not rated		Not rated	

Table 12A.--Source of gravel and sand

(The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The ratings given for the thickest layer are for the thickest layer above and excluding the bottom layer. The numbers in the value columns range from 0.00 to 0.99. The greater the value, the greater the likelihood that the bottom layer or thickest layer of the soil is a source of sand or gravel. See text for further explanation of ratings in this table.)

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
1:					
Silver	55	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Clovis	35	Poor		Poor	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.00
2:					
Clovis	35	Poor		Poor	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.00
Prieta	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Silver	20	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
3:					
Montecito	60	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Orejas	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
4:					
Montecito	45	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Montecito, bouldery-	35	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
10:					
Trail	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.03
		Thickest layer	0.00	Bottom layer	0.06
11:					
Trail	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.10

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
13:					
Sandoval	65	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Querencia	20	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
15:					
Camino	40	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Sandoval	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
16:					
Rock outcrop	50	Not rated		Not rated	
Prieta	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
17:					
Vessilla	35	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
Menefee	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Rock outcrop	20	Not rated		Not rated	
18:					
Sparham	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
20:					
Gilco	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
21:					
Rock outcrop	60	Not rated		Not rated	
Hackroy	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
22:					
Aga	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.42

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
23:					
Hickman	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
24:					
Orlie	45	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Sparham	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
25:					
Gilco	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.01
26:					
Orlie	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
27:					
Aga	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.30
		Thickest layer	0.00	Bottom layer	0.79
29:					
Trail	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.10
31:					
Riverwash	90	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.84
		Thickest layer	0.00	Thickest layer	0.89
33:					
Pits	100	Not rated		Not rated	
34:					
Ildefonso	55	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Witt	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
41:					
Dune land	100	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.93
		Thickest layer	0.00	Thickest layer	0.93
47:					
Cascajo	85	Poor		Poor	
		Thickest layer	0.00	Bottom layer	0.00
		Bottom layer	0.00	Thickest layer	0.00

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
51:					
Sparham	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
52:					
Totavi	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.10
		Thickest layer	0.00	Thickest layer	0.10
53:					
Witt	55	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Harvey	30	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
54:					
Harvey	45	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Cascajo	40	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.57
		Thickest layer	0.00	Bottom layer	0.57
55:					
La Fonda	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
56:					
Ildefonso	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
57:					
Badland	90	Not rated		Not rated	
58:					
Deama	45	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Elpedro	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
59:					
Harvey	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Ildefonso	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
59:					
La Fonda	15	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
63:					
Placitas	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03
64:					
Skyvillage	40	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
Ildefonso	35	Poor		Fair	
		Thickest layer	0.00	Bottom layer	0.03
		Bottom layer	0.00	Thickest layer	0.03
65:					
Ildefonso	50	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.04
		Thickest layer	0.00	Thickest layer	0.04
Harvey	30	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
66:					
Zia	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03
67:					
Sandoval	40	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Poley	35	Poor		Poor	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.00
68:					
Penistaja	45	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Querencia	35	Poor		Poor	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.00
71:					
Palon	85	Poor		Fair	
		Thickest layer	0.00	Bottom layer	0.03
		Bottom layer	0.00	Thickest layer	0.03
72:					
Palon	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
74:					
Origo	50	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03
Pavo	25	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03
75:					
Origo	85	Poor		Poor	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.00
82:					
Calaveras	85	Fair		Fair	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.25	Thickest layer	0.03
83:					
Calaveras	60	Poor		Poor	
		Thickest layer	0.00	Thickest layer	0.00
		Bottom layer	0.00	Bottom layer	0.00
Rubble land	20	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
85:					
Redondo	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.07
		Thickest layer	0.00	Thickest layer	0.07
86:					
Redondo	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
87:					
Redondo	50	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.07
		Thickest layer	0.00	Thickest layer	0.07
Rubble land	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
88:					
Totavi	45	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.04
		Thickest layer	0.00	Bottom layer	0.10
Jemez	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Rock outcrop	15	Not rated		Not rated	

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
91:					
Zia	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.03
92:					
Galisteo, moderately saline, sodic	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
93:					
Zia	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.10
95:					
El Rancho	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
97:					
El Rancho	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
100:					
Orejas	40	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Rock outcrop	40	Not rated		Not rated	
101:					
Blancot	55	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03
Lybrook	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
102:					
Sparham	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
104:					
Cochiti	50	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
Montecito	30	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.03
		Thickest layer	0.00	Bottom layer	0.03
105:					
Badland	50	Not rated		Not rated	

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
105:					
Menefee	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
106:					
Stumble	50	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.10
		Thickest layer	0.00	Bottom layer	0.58
Stumble, sandy	30	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.10
		Thickest layer	0.00	Bottom layer	0.47
108:					
Embudo	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.03
		Thickest layer	0.00	Bottom layer	0.10
109:					
Embudo	50	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.06
		Thickest layer	0.00	Bottom layer	0.12
Tijeras	35	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.06
110:					
Rock outcrop	45	Not rated		Not rated	
Saido	40	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
111:					
Rock outcrop	50	Not rated		Not rated	
Zia	35	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.03
112:					
Tijeras	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
114:					
San Mateo	40	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.03
Zia	40	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
120:					
Pinavetes	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.49
		Thickest layer	0.00	Bottom layer	0.79

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
124:					
Rock outcrop	90	Not rated		Not rated	
129:					
Menefee	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
130:					
Pinavetes	45	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.10
		Thickest layer	0.00	Thickest layer	0.10
Galisteo, moderately saline, sodic	40	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
142:					
Grieta	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.10
143:					
Clovis	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
145:					
Grieta	55	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.06
		Thickest layer	0.00	Thickest layer	0.06
Sheppard	40	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.06
		Thickest layer	0.00	Thickest layer	0.06
146:					
Sedmar	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.10
150:					
Doakum	55	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Betonnie	35	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03
162:					
Hackroy	45	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Nyjack	40	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
163:					
Jemez	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
170:					
San Mateo	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
180:					
Councelor	40	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
Eslendo	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Mespun	25	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.02
		Thickest layer	0.00	Bottom layer	0.07
183:					
Sheppard	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.06
		Thickest layer	0.00	Thickest layer	0.06
185:					
Frijoles	90	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.04
		Thickest layer	0.00	Bottom layer	0.04
190:					
Zia	35	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03
Skyvillage	25	Poor		Poor	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.00
Rock outcrop	15	Not rated		Not rated	
191:					
Sheppard	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.06
		Thickest layer	0.00	Thickest layer	0.06
200:					
Sedillo	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.06
201:					
Rock outcrop	55	Not rated		Not rated	
Sedgran	35	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.12

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
206:					
Pinitos	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
207:					
Penistaja	60	Poor		Poor	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.00
Zia	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
208:					
Sedillo	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
210:					
Ildefonso	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
211:					
Zia	45	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03
Clovis	30	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.01
213:					
Pinavetes	55	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.79
		Thickest layer	0.00	Thickest layer	0.79
Rock outcrop	30	Not rated		Not rated	
215:					
Ess	60	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Rock outcrop	30	Not rated		Not rated	
217:					
Witt	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
218:					
Ildefonso	85	Poor		Poor	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.00
220:					
Rock outcrop	40	Not rated		Not rated	

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
220:					
Vessilla	30	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
Menefee	20	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
226:					
Galisteo, moderately saline, sodic	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
227:					
Hagerman	65	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Bond	20	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
228:					
Winona	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
230:					
Skyvillage	35	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
Sandoval	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Rock outcrop	20	Not rated		Not rated	
231:					
Querencia	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
234:					
Querencia	60	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Zia	20	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03
235:					
Sandoval	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
236:					
Sparank, moderately saline, sodic	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
237:					
Sparank	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
240:					
Penistaja	45	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Hagerman	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
250:					
Pinavetes	90	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.06
		Thickest layer	0.00	Bottom layer	0.07
262:					
Pastura	90	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
270:					
Blancot	40	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
Councelor	30	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.04
Tsosie	25	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
281:					
Carjo	90	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
282:					
Tocal	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
283:					
Mirand	45	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
283:					
Alanos	30	Fair		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.50	Thickest layer	0.00
290:					
Alanos	50	Fair		Poor	
		Thickest layer	0.00	Bottom layer	0.00
		Bottom layer	0.12	Thickest layer	0.00
Rock outcrop	30	Not rated		Not rated	
300:					
Waumac	50	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Bamac	35	Poor		Fair	
		Thickest layer	0.00	Thickest layer	0.10
		Bottom layer	0.00	Bottom layer	0.10
301:					
Vastine	45	Fair		Fair	
		Thickest layer	0.00	Thickest layer	0.00
		Bottom layer	0.38	Bottom layer	0.10
Jarola	40	Fair		Fair	
		Thickest layer	0.00	Thickest layer	0.00
		Bottom layer	0.05	Bottom layer	0.03
302:					
Tranquilar	50	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Jarmillo	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
304:					
Cosey	45	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Jarmillo	40	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
307:					
Flugle	60	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.02
Waumac	25	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.10

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
308:					
Cajete	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.03
		Thickest layer	0.00	Bottom layer	0.79
311:					
Cosey	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Tranquilar	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Calaveras	25	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.10
312:					
Royosa	90	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.07
		Thickest layer	0.00	Thickest layer	0.79
314:					
Fragua	40	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.03
		Thickest layer	0.00	Bottom layer	0.04
Waumac	30	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.06
Royosa	25	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.31
		Thickest layer	0.00	Thickest layer	0.31
317:					
Elpedro	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
319:					
Bamac	60	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.12
		Thickest layer	0.00	Thickest layer	0.12
Rock outcrop	25	Not rated		Not rated	
320:					
Sparham	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
321:					
Waumac	60	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.06

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
321:					
Royosa	30	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.31
		Thickest layer	0.00	Thickest layer	0.31
322:					
Fragua	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.06
		Thickest layer	0.00	Thickest layer	0.06
324:					
Rock outcrop	30	Not rated		Not rated	
Atarque	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Menefee	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
325:					
Rock outcrop	35	Not rated		Not rated	
Espiritu	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Vessilla	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
342:					
Waumac	35	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.06
Vessilla	25	Poor		Poor	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.00
Rock outcrop	20	Not rated		Not rated	
345:					
Espiritu	50	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.04
Bamac	35	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.10
		Thickest layer	0.00	Bottom layer	0.10
346:					
Espiritu, cobbly	70	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.10
Bamac	20	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.10
		Thickest layer	0.00	Thickest layer	0.12

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
348:					
Wauquie	60	Fair		Fair	
		Bottom layer	0.00	Thickest layer	0.03
		Thickest layer	0.25	Bottom layer	0.10
Rock outcrop	20	Not rated		Not rated	
353:					
Cochiti	50	Fair		Fair	
		Thickest layer	0.00	Thickest layer	0.00
		Bottom layer	0.25	Bottom layer	0.10
Espiritu	45	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.10
354:					
Waumac Variant	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
358:					
Deama	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Elpedro	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Rock outcrop	25	Not rated		Not rated	
396:					
Atarque	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Menefee	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Rock outcrop	25	Not rated		Not rated	
397:					
Rock outcrop	30	Not rated		Not rated	
Cucho	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Vessilla	25	Poor		Poor	
		Thickest layer	0.00	Thickest layer	0.00
		Bottom layer	0.00	Bottom layer	0.00
398:					
Espiritu	45	Poor		Fair	
		Thickest layer	0.00	Thickest layer	0.00
		Bottom layer	0.00	Bottom layer	0.04

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
398:					
Cucho	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
399:					
Cucho	45	Poor		Poor	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.00
Teco	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
405:					
Charo	50	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Charo, noncobbly	40	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
409:					
Santa Fe	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
410:					
Zia	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.03
414:					
Wauquie	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.04
417:					
Jocity	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.10
418:					
Jocity	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.02
419:					
Santa Fe	40	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Wauquie	30	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.03
		Thickest layer	0.00	Bottom layer	0.29
Rock outcrop	20	Not rated		Not rated	

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
420:					
Pinavetes	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.10
		Thickest layer	0.00	Bottom layer	0.79
421:					
Gilco, moderately saline, sodic	90	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.01
422:					
Vessilla	35	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03
Menefee	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Orlie	25	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
423:					
Gilco	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
426:					
Aga, moderately saline, sodic	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.07
		Thickest layer	0.00	Bottom layer	0.79
427:					
Aga	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.02
428:					
Aga, moderately saline, sodic	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.07
430:					
Trail	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.10
431:					
Trail	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.10
433:					
Peralta	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.01

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
434:					
Peralta	85	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.06
		Thickest layer	0.00	Thickest layer	0.10
437:					
Peralta, moderately saline, sodic	85	Poor		Poor	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.00
500:					
Rock outcrop	40	Not rated		Not rated	
Osha	30	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.14
		Thickest layer	0.00	Thickest layer	0.14
Rubble land	20	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
503:					
Cajete	65	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.05
Cypher	25	Poor		Fair	
		Thickest layer	0.00	Thickest layer	0.00
		Bottom layer	0.00	Bottom layer	0.03
504:					
Orejas	40	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Guaje	35	Poor		Fair	
		Bottom layer	0.00	Bottom layer	0.03
		Thickest layer	0.00	Thickest layer	0.03
600:					
Rock outcrop	50	Not rated		Not rated	
Cypher	35	Poor		Poor	
		Thickest layer	0.00	Bottom layer	0.00
		Bottom layer	0.00	Thickest layer	0.00
601:					
Laventana	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
603:					
Laventana	50	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
Mirand	35	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00

Table 12A.--Source of gravel and sand--continued

Map symbol and soil name	Pct. of map unit	Potential source of gravel		Potential source of sand	
		Rating class	Value	Rating class	Value
604:					
Cypher	55	Poor		Fair	
		Thickest layer	0.00	Thickest layer	0.00
		Bottom layer	0.00	Bottom layer	0.03
Mirand	30	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
608:					
Osha, steep	60	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.06
		Thickest layer	0.00	Bottom layer	0.10
Osha	30	Fair		Fair	
		Thickest layer	0.25	Thickest layer	0.06
		Bottom layer	0.25	Bottom layer	0.13
823:					
Gilco, unprotected	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
827:					
Aga, unprotected	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.06
830:					
Trail, unprotected	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.00
		Thickest layer	0.00	Bottom layer	0.02
831:					
Trail, unprotected	85	Poor		Fair	
		Bottom layer	0.00	Thickest layer	0.10
		Thickest layer	0.00	Bottom layer	0.79
835:					
Peralta, unprotected	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
842:					
Peralta, moderately saline, sodic, unprotected	85	Poor		Poor	
		Bottom layer	0.00	Bottom layer	0.00
		Thickest layer	0.00	Thickest layer	0.00
850:					
Water	95	Not rated		Not rated	
DAM:					
Dam	100	Not rated		Not rated	

Table 12B.--Source of reclamation material, roadfill, and topsoil

(The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The numbers in the value columns range from 0.00 to 0.99. The smaller the value, the greater the limitation. See text for further explanation of ratings in this table.)

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
1:							
Silver	55	Fair		Poor		Fair	
		Organic matter content low	0.02	Low strength	0.00	Too clayey	0.57
		Too clayey	0.98	Shrink-swell	0.87		
		Water erosion	0.99				
Clovis	35	Fair		Fair		Good	
		Organic matter content low	0.08	Shrink-swell	0.99		
		Carbonate content	0.97				
		Water erosion	0.99				
2:							
Clovis	35	Fair		Good		Fair	
		Organic matter content low	0.02			Too clayey	0.61
		Carbonate content	0.97				
		Too clayey	0.98				
		Water erosion	0.99				
Prieta	35	Poor		Poor		Poor	
		Stone content	0.00	Depth to bedrock	0.00	Rock fragments	0.00
		Droughty	0.00	Stone content	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Shrink-swell	0.87	Too clayey	0.64
		Organic matter content low	0.50			Slope	0.96
		Too clayey	0.98				
Silver	20	Fair		Poor		Fair	
		Organic matter content low	0.08	Low strength	0.00	Too clayey	0.64
		Too clayey	0.98	Shrink-swell	0.87		
		Water erosion	0.99				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
3:							
Montecito	60	Fair		Poor		Fair	
		Organic matter content low	0.02	Low strength	0.00	Too clayey	0.52
		Too clayey	0.98	Shrink-swell	0.87		
Orejas	30	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Rock fragments	0.00
		Depth to bedrock	0.00	Shrink-swell	0.87	Depth to bedrock	0.00
		Organic matter content low	0.32	Cobble content	0.92	Too clayey	0.61
		Cobble content	0.33				
		Too clayey	0.98				
4:							
Montecito	45	Fair		Fair		Poor	
		Organic matter content low	0.02	Shrink-swell	0.87	Slope	0.00
		Too clayey	0.98	Slope	0.92	Too clayey	0.57
		Water erosion	0.99			Rock fragments	0.99
Montecito, bouldery-	35	Fair		Poor		Poor	
		Organic matter content low	0.50	Low strength	0.00	Slope	0.00
		Too clayey	0.98	Slope	0.92	Too clayey	0.64
		Water erosion	0.99	Shrink-swell	0.98	Rock fragments	0.95
10:							
Trail	85	Poor		Good		Good	
		Too alkaline	0.00				
		Organic matter content low	0.50				
		Droughty	0.79				
		Water erosion	0.99				
11:							
Trail	85	Poor		Good		Fair	
		Too alkaline	0.00			Too sandy	0.14
		Too sandy	0.14				
		Organic matter content low	0.50				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
13:							
Sandoval	65	Poor		Poor		Poor	
		Depth to bedrock	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Droughty	0.00	Low strength	0.00	Too clayey	0.52
		Organic matter content low	0.02	Shrink-swell	0.87		
		Too clayey	0.98				
Querencia	20	Fair		Fair		Good	
		Organic matter content low	0.05	Shrink-swell	0.87		
		Water erosion	0.99				
15:							
Camino	40	Poor		Poor		Poor	
		Too clayey	0.00	Low strength	0.00	Too clayey	0.00
		Organic matter content low	0.02	Shrink-swell	0.12		
		Water erosion	0.99	Depth to bedrock	0.68		
Sandoval	35	Poor		Poor		Poor	
		Depth to bedrock	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Too alkaline	0.00	Low strength	0.00	Sodium content	0.10
		Droughty	0.02	Shrink-swell	0.87	Too clayey	0.64
		Sodium content	0.10				
		Organic matter content low	0.50				
		Too clayey	0.98				
16:							
Rock outcrop	50	Not rated		Not rated		Not rated	
Prieta	30	Poor		Poor		Poor	
		Stone content	0.00	Depth to bedrock	0.00	Rock fragments	0.00
		Droughty	0.00	Stone content	0.02	Depth to bedrock	0.00
		Depth to bedrock	0.00	Shrink-swell	0.87	Too clayey	0.64
		Organic matter content low	0.50			Slope	0.96
		Too clayey	0.98				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
17:							
Vessilla	35	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00			Slope	0.96
		Organic matter content low	0.12				
Menefee	25	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00			Too clayey	0.64
		Organic matter content low	0.50			Slope	0.96
		Too clayey	0.98				
Rock outcrop	20	Not rated		Not rated		Not rated	
18:							
Sparham	85	Fair		Poor		Fair	
		Too clayey	0.08	Low strength	0.00	Too clayey	0.06
		Organic matter content low	0.24	Shrink-swell	0.87	Sodium content	0.60
		Sodium content	0.60				
		Salinity	0.97				
		Water erosion	0.99				
20:							
Gilco	85	Fair		Good		Fair	
		Organic matter content low	0.08			Rock fragments	0.98
		Water erosion	0.99				
21:							
Rock outcrop	60	Not rated		Not rated		Not rated	
Hackroy	25	Poor		Poor		Poor	
		Too clayey	0.00	Depth to bedrock	0.00	Too clayey	0.00
		Droughty	0.00	Low strength	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Shrink-swell	0.12		
		Organic matter content low	0.08				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
22:							
Aga	85	Fair		Good		Good	
		Organic matter content low	0.08				
		Water erosion	0.99				
23:							
Hickman	85	Fair		Poor		Fair	
		Organic matter content low	0.50	Low strength	0.00	Too clayey	0.64
		Too clayey	0.98	Shrink-swell	0.87		
24:							
Orlie	45	Fair		Fair		Fair	
		Organic matter content low	0.08	Shrink-swell	0.87	Too clayey	0.72
		Too clayey	0.98			Rock fragments	0.99
Sparham	35	Poor		Poor		Poor	
		Too clayey	0.00	Low strength	0.00	Too clayey	0.00
		Sodium content	0.00	Shrink-swell	0.12	Sodium content	0.00
		Organic matter content low	0.50			Salinity	0.00
		Salinity	0.88				
25:							
Gilco	85	Fair		Good		Good	
		Organic matter content low	0.32				
		Water erosion	0.99				
26:							
Orlie	85	Fair		Poor		Fair	
		Organic matter content low	0.18	Low strength	0.00	Too clayey	0.64
		Too clayey	0.98	Shrink-swell	0.87		
		Water erosion	0.99				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
27:							
Aga	85	Poor		Good		Poor	
		Too sandy	0.00			Too sandy	0.00
		Organic matter content low	0.08				
		Droughty	0.81				
		Water erosion	0.99				
29:							
Trail	85	Poor		Good		Good	
		Wind erosion	0.00				
		Too alkaline	0.00				
		Organic matter content low	0.08				
		Droughty	0.35				
31:							
Riverwash	90	Poor		Good		Poor	
		Too sandy	0.00			Too sandy	0.00
		Droughty	0.00			Rock fragments	0.32
		Organic matter content low	0.12				
33:							
Pits	100	Not rated		Not rated		Not rated	
34:							
Ildefonso	55	Fair		Poor		Poor	
		Cobble content	0.08	Cobble content	0.00	Hard to reclaim (rock fragments)	0.00
		Organic matter content low	0.08			Rock fragments	0.00
		Droughty	0.83			Carbonate content	0.98
		Carbonate content	0.97				
Witt	30	Fair		Fair		Good	
		Organic matter content low	0.08	Shrink-swell	0.87		
		Water erosion	0.37				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
41:							
Dune land	100	Poor		Good		Poor	
		Too sandy	0.00			Too sandy	0.00
		Wind erosion	0.00			Slope	0.84
		Droughty	0.00				
		Organic matter content low	0.00				
47:							
Cascajo	85	Poor		Fair		Poor	
		Droughty	0.00	Slope	0.32	Hard to reclaim (rock fragments)	0.00
		Organic matter content low	0.00	Cobble content	0.94	Rock fragments	0.00
		Too sandy	0.01			Slope	0.00
		Cobble content	0.94			Too sandy	0.01
51:							
Sparham	85	Poor		Poor		Poor	
		Too clayey	0.00	Wetness depth	0.00	Too clayey	0.00
		Organic matter content low	0.08	Low strength	0.00	Wetness depth	0.00
		Salinity	0.88	Shrink-swell	0.66	Sodium content	0.00
						Salinity	0.00
52:							
Totavi	85	Poor		Good		Fair	
		Wind erosion	0.00			Too sandy	0.01
		Too sandy	0.01				
		Organic matter content low	0.08				
		Droughty	0.35				
53:							
Witt	55	Fair		Fair		Good	
		Organic matter content low	0.08	Shrink-swell	0.87		
		Water erosion	0.90				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
53:							
Harvey	30	Fair		Poor		Fair	
		Organic matter content low	0.68	Low strength	0.00	Too clayey	0.67
		Carbonate content	0.97	Shrink-swell	0.99		
		Too clayey	0.98				
		Water erosion	0.99				
54:							
Harvey	45	Fair		Fair		Fair	
		Organic matter content low	0.05	Shrink-swell	0.89	Slope	0.84
		Carbonate content	0.97				
Cascajo	40	Poor		Good		Poor	
		Too sandy	0.00			Too sandy	0.00
		Droughty	0.00			Rock fragments	0.00
		Organic matter content low	0.02			Hard to reclaim (rock fragments)	0.00
		Carbonate content	0.97			Slope	0.84
						Carbonate content	0.99
55:							
La Fonda	85	Fair		Fair		Good	
		Organic matter content low	0.08	Shrink-swell	0.87		
		Water erosion	0.99				
56:							
Ildefonso	85	Fair		Poor		Poor	
		Organic matter content low	0.08	Slope	0.00	Slope	0.00
		Cobble content	0.52	Cobble content	0.02	Hard to reclaim (rock fragments)	0.00
		Carbonate content	0.97	Shrink-swell	0.87	Rock fragments	0.00
		Droughty	0.99			Carbonate content	0.99
		Stone content	0.99				
57:							
Badland	90	Not rated		Not rated		Not rated	

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
58:							
Deama	45	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Carbonate content	0.00	Slope	0.08	Depth to bedrock	0.00
		Depth to bedrock	0.00	Shrink-swell	0.87	Rock fragments	0.00
		Stone content	0.05			Carbonate content	0.08
Elpedro	35	Poor		Fair		Fair	
		Organic matter content low	0.00	Shrink-swell	0.98	Too clayey	0.52
		Water erosion	0.90			Slope	0.96
		Too clayey	0.98				
59:							
Harvey	35	Fair		Poor		Fair	
		Organic matter content low	0.08	Low strength	0.00	Too clayey	0.55
		Carbonate content	0.97	Shrink-swell	0.87	No carbonate limitation	0.99
		Too clayey	0.98				
		Water erosion	0.99				
Ildefonso	35	Poor		Fair		Poor	
		Droughty	0.00	Cobble content	0.29	Hard to reclaim (rock fragments)	0.00
		Organic matter content low	0.02			Rock fragments	0.00
		Cobble content	0.44			Slope	0.63
		Carbonate content	0.97				
La Fonda	15	Fair		Fair		Good	
		Organic matter content low	0.08	Shrink-swell	0.87		
		Water erosion	0.99				
63:							
Placitas	85	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Rock fragments	0.00
		Organic matter content low	0.08	Slope	0.02	Slope	0.00
		Depth to bedrock	0.29			Depth to bedrock	0.29
		Carbonate content	0.80			Carbonate content	0.99

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
64:							
Skyvillage	40	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Slope	0.92	Slope	0.00
		Organic matter content low	0.50				
Ildefonso	35	Fair		Fair		Poor	
		Organic matter content low	0.08	Slope	0.02	Rock fragments	0.00
		Droughty	0.12			Hard to reclaim (rock fragments)	0.00
		Carbonate content	0.97			Slope	0.00
65:							
Ildefonso	50	Fair		Fair		Poor	
		Droughty	0.09	Slope	0.08	Rock fragments	0.00
		Organic matter content low	0.50			Hard to reclaim (rock fragments)	0.00
		Carbonate content	0.97			Slope	0.00
Harvey	30	Fair		Fair		Fair	
		Organic matter content low	0.08			Slope	0.16
		Carbonate content	0.97			Carbonate content	0.99
		Water erosion	0.99				
66:							
Zia	85	Fair		Good		Good	
		Organic matter content low	0.08				
67:							
Sandoval	40	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Low strength	0.00	Slope	0.00
		Too alkaline	0.00	Shrink-swell	0.87	Too clayey	0.64
		Organic matter content low	0.50	Slope	0.92		
		Too clayey	0.98				
		Water erosion	0.99				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
66:							
Poley	35	Fair		Fair		Poor	
		Organic matter content low	0.02	Shrink-swell	0.99	Hard to reclaim (rock fragments)	0.00
		Too clayey	0.98			Slope	0.00
						Too clayey	0.55
						Rock fragments	0.98
68:							
Penistaja	45	Poor		Fair		Good	
		Wind erosion	0.00	Shrink-swell	0.87		
		Organic matter content low	0.02				
Querencia	35	Fair		Fair		Good	
		Organic matter content low	0.50	Shrink-swell	0.99		
71:							
Palon	85	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Slope	0.00
		Organic matter content low	0.08	Cobble content	0.39	Hard to reclaim (rock fragments)	0.00
		Cobble content	0.98			Rock fragments	0.00
72:							
Palon	85	Poor		Poor		Poor	
		Stone content	0.00	Slope	0.00	Slope	0.00
		Droughty	0.02	Stone content	0.00	Rock fragments	0.00
		Organic matter content low	0.50	Cobble content	0.00	Hard to reclaim (rock fragments)	0.00
		Cobble content	0.52				
		Too acid	0.74				
74:							
Origo	50	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Slope	0.00
		Organic matter content low	0.08	Cobble content	0.00	Hard to reclaim (rock fragments)	0.00
		Too acid	0.50			Rock fragments	0.00
		Cobble content	0.73				
		Stone content	0.99				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
74:							
Pavo	25	Fair		Good		Fair	
		Organic matter content low	0.50			Slope	0.16
		Too acid	0.99				
		Water erosion	0.99				
75:							
Origo	85	Fair		Poor		Poor	
		Too acid	0.16	Slope	0.00	Slope	0.00
		Droughty	0.18	Cobble content	0.00	Hard to reclaim (rock fragments)	0.00
		Organic matter content low	0.18	Stone content	0.56	Rock fragments	0.00
		Cobble content	0.37				
		Stone content	0.54				
82:							
Calaveras	85	Fair		Poor		Poor	
		Droughty	0.06	Slope	0.00	Slope	0.00
		Organic matter content low	0.18	Cobble content	0.99	Hard to reclaim (rock fragments)	0.00
		Water erosion	0.99			Rock fragments	0.00
		Cobble content	0.99				
83:							
Calaveras	60	Fair		Poor		Poor	
		Organic matter content low	0.02	Slope	0.00	Slope	0.00
		Droughty	0.07	Cobble content	0.61	Hard to reclaim (rock fragments)	0.00
		Cobble content	0.88			Rock fragments	0.00
		Water erosion	0.99				
Rubble land	20	Not rated		Poor		Not rated	
				Slope	0.00		
				Stone content	0.00		
				Cobble content	0.13		

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
85:							
Redondo	85	Fair		Poor		Poor	
		Organic matter content low	0.05	Slope	0.00	Slope	0.00
		Droughty	0.39			Hard to reclaim (rock fragments)	0.00
		Too acid	0.84			Rock fragments	0.00
86:							
Redondo	85	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Slope	0.00
		Organic matter content low	0.05	Cobble content	0.00	Hard to reclaim (rock fragments)	0.00
		Cobble content	0.14			Rock fragments	0.00
		Too acid	0.84				
87:							
Redondo	50	Fair		Poor		Poor	
		Droughty	0.05	Slope	0.00	Hard to reclaim (rock fragments)	0.00
		Organic matter content low	0.50	Cobble content	0.66	Rock fragments	0.00
		Too acid	0.84			Slope	0.00
Rubble land	25	Not rated		Poor		Not rated	
				Slope	0.00		
				Stone content	0.00		
				Cobble content	0.50		
88:							
Totavi	45	Fair		Good		Fair	
		Too sandy	0.01			Too sandy	0.01
		Organic matter content low	0.08				
		Droughty	0.71				
Jemez	30	Fair		Poor		Fair	
		Organic matter content low	0.02	Depth to bedrock	0.00	Depth to bedrock	0.29
		Depth to bedrock	0.29	Shrink-swell	0.87	Slope	0.84
		Droughty	0.63				
		Water erosion	0.99				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
88:							
Rock outcrop--------	15	Not rated		Not rated		Not rated	
91:							
Zia-----------------	85	Fair		Good		Good	
		Organic matter content low	0.08				
92:							
Galisteo, moderately saline, sodic------	85	Poor		Poor		Poor	
		Too clayey	0.00	Low strength	0.00	Too clayey	0.00
		Too alkaline	0.00	Shrink-swell	0.15	Salinity	0.00
		Organic matter content low	0.12			Sodium content	0.22
		Sodium content	0.22				
		Salinity	0.50				
		Water erosion	0.99				
93:							
Zia-----------------	85	Poor		Good		Good	
		Wind erosion	0.00				
		Organic matter content low	0.08				
95:							
El Rancho-----------	85	Fair		Fair		Good	
		Organic matter content low	0.02	Shrink-swell	0.99		
		Water erosion	0.99				
97:							
El Rancho-----------	85	Fair		Fair		Good	
		Organic matter content low	0.08	Shrink-swell	0.87		

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
100:							
Orejas	40	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Rock fragments	0.00
		Organic matter content low	0.32	Shrink-swell	0.87	Depth to bedrock	0.00
		Stone content	0.38			Too clayey	0.61
		Cobble content	0.96				
		Too clayey	0.98				
Rock outcrop	40	Not rated		Not rated		Not rated	
101:							
Blancot	55	Poor		Good		Good	
		Too alkaline	0.00				
		Organic matter content low	0.02				
Lybrook	25	Poor		Poor		Fair	
		Too alkaline	0.00	Low strength	0.00	Sodium content	0.22
		Organic matter content low	0.02	Shrink-swell	0.87	Too clayey	0.60
		Salinity	0.03				
		Sodium content	0.22				
		Too clayey	0.98				
		Water erosion	0.99				
102:							
Sparham	85	Poor		Poor		Poor	
		Sodium content	0.00	Low strength	0.00	Sodium content	0.00
		Organic matter content low	0.08	Shrink-swell	0.87	Salinity	0.00
		Salinity	0.88			Too clayey	0.64
		Too clayey	0.98				
		Water erosion	0.99				
104:							
Cochiti	50	Fair		Fair		Poor	
		Organic matter content low	0.02	Slope	0.92	Rock fragments	0.00
		Droughty	0.74	Shrink-swell	0.96	Hard to reclaim (rock fragments)	0.00
		Too acid	0.99			Slope	0.00

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
104:							
Montecito	30	Fair		Good		Good	
		Organic matter content low	0.02				
		Water erosion	0.99				
105:							
Badland	50	Not rated		Not rated		Not rated	
Menefee	30	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Depth to bedrock	0.00
		Organic matter content low	0.50			Too clayey	0.64
		Too clayey	0.98				
		Water erosion	0.99				
106:							
Stumble	50	Poor		Poor		Poor	
		Too sandy	0.00	Slope	0.00	Too sandy	0.00
		Droughty	0.00			Slope	0.00
		Organic matter content low	0.02			Rock fragments	0.50
Stumble, sandy	30	Poor		Good		Poor	
		Too sandy	0.00			Too sandy	0.00
		Wind erosion	0.00			Rock fragments	0.02
		Droughty	0.00			Hard to reclaim (rock fragments)	0.97
		Organic matter content low	0.08				
108:							
Embudo	85	Fair		Good		Fair	
		Organic matter content low	0.02			Rock fragments	0.98
		Droughty	0.96				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
109:							
Embudo	50	Fair		Good		Fair	
		Organic matter content low	0.02			Rock fragments	0.50
		Droughty	0.16			Hard to reclaim (rock fragments)	0.92
Tijeras	35	Fair		Good		Poor	
		Organic matter content low	0.02			Rock fragments	0.00
		Droughty	0.63			Hard to reclaim (rock fragments)	0.00
110:							
Rock outcrop	45	Not rated		Not rated		Not rated	
Saido	40	Fair		Fair		Poor	
		Organic matter content low	0.02	Slope	0.08	Slope	0.00
		Water erosion	0.90	Shrink-swell	0.87	Salinity	0.88
111:							
Rock outcrop	50	Not rated		Not rated		Not rated	
Zia	35	Fair		Fair		Poor	
		Organic matter content low	0.08	Slope	0.92	Slope	0.00
112:							
Tijeras	85	Fair		Good		Poor	
		Organic matter content low	0.05			Rock fragments	0.00
						Hard to reclaim (rock fragments)	0.92
114:							
San Mateo	40	Poor		Fair		Poor	
		Too alkaline	0.00	Shrink-swell	0.87	Salinity	0.00
		Salinity	0.03				
		Organic matter content low	0.08				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
114:							
Zia	40	Fair		Good		Good	
		Organic matter content low	0.08				
120:							
Pinavetes	85	Poor		Good		Poor	
		Too sandy	0.00			Too sandy	0.00
		Wind erosion	0.00				
		Droughty	0.00				
		Too alkaline	0.00				
		Organic matter content low	0.50				
124:							
Rock outcrop	90	Not rated		Not rated		Not rated	
129:							
Menefee	85	Poor		Poor		Poor	
		Depth to bedrock	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Droughty	0.04	Low strength	0.00	Slope	0.00
		Organic matter content low	0.12	Slope	0.50	Too clayey	0.57
		Too clayey	0.98	Shrink-swell	0.87		
130:							
Pinavetes	45	Poor		Good		Fair	
		Wind erosion	0.00			Too sandy	0.01
		Too alkaline	0.00				
		Too sandy	0.01				
		Organic matter content low	0.08				
		Droughty	0.35				
Galisteo, moderately saline, sodic	40	Poor		Poor		Poor	
		Too clayey	0.00	Low strength	0.00	Too clayey	0.00
		Sodium content	0.00	Shrink-swell	0.12	Sodium content	0.00
		Too alkaline	0.00			Salinity	0.00
		Organic matter content low	0.08				
		Salinity	0.50				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
142:							
Grieta	85	Fair		Fair		Fair	
		Organic matter content low	0.08	Shrink-swell	0.97	Carbonate content	0.99
		Carbonate content	0.97				
143:							
Clovis	85	Fair		Fair		Fair	
		Organic matter content low	0.01	Shrink-swell	0.87	Carbonate content	0.85
		Carbonate content	0.80				
145:							
Grieta	55	Poor		Good		Good	
		Wind erosion	0.00				
		Organic matter content low	0.08				
Sheppard	40	Poor		Good		Fair	
		Wind erosion	0.00			Too sandy	0.02
		Too sandy	0.02				
		Organic matter content low	0.02				
		Droughty	0.94				
146:							
Sedmar	85	Poor		Poor		Poor	
		Wind erosion	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Droughty	0.00				
		Depth to bedrock	0.00				
		Organic matter content low	0.50				
150:							
Doakum	55	Poor		Fair		Fair	
		Organic matter content low	0.00	Shrink-swell	0.87	Salinity	0.50
		Too alkaline	0.00				
		Water erosion	0.99				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
150:							
Betonnie	35	Poor		Good		Good	
		Organic matter content low	0.00				
		Too alkaline	0.00				
162:							
Hackroy	45	Poor		Poor		Poor	
		Too clayey	0.00	Depth to bedrock	0.00	Too clayey	0.00
		Droughty	0.00	Low strength	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Shrink-swell	0.12		
		Organic matter content low	0.08				
Nyjack	40	Fair		Poor		Fair	
		Organic matter content low	0.08	Depth to bedrock	0.00	Rock fragments	0.12
		Too acid	0.99			Depth to bedrock	0.99
		Water erosion	0.99				
		Depth to bedrock	0.99				
163:							
Jemez	85	Fair		Poor		Fair	
		Organic matter content low	0.32	Depth to bedrock	0.00	Too clayey	0.61
		Too clayey	0.98	Shrink-swell	0.87	Depth to bedrock	0.99
		Water erosion	0.99				
		Depth to bedrock	0.99				
170:							
San Mateo	85	Poor		Poor		Fair	
		Too alkaline	0.00	Low strength	0.00	Too clayey	0.60
		Organic matter content low	0.05	Shrink-swell	0.87		
		Too clayey	0.98				
		Water erosion	0.99				
180:							
Councelor	40	Fair		Fair		Poor	
		Organic matter content low	0.02	Slope	0.82	Slope	0.00

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
180:							
Eslendo	30	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Slope	0.82	Slope	0.00
		Organic matter content low	0.08			Too clayey	0.55
		Too clayey	0.98				
Mespun	25	Poor		Fair		Poor	
		Wind erosion	0.00	Slope	0.82	Slope	0.00
		Organic matter content low	0.12			Too sandy	0.38
		Too sandy	0.38				
		Droughty	0.74				
183:							
Sheppard	85	Poor		Good		Fair	
		Wind erosion	0.00			Too sandy	0.02
		Too sandy	0.02			Slope	0.37
		Organic matter content low	0.05				
		Droughty	0.94				
185:							
Frijoles	90	Poor		Good		Poor	
		Droughty	0.00			Hard to reclaim (rock fragments)	0.00
		Organic matter content low	0.01			Rock fragments	0.00
		Water erosion	0.37				
190:							
Zia	35	Fair		Good		Fair	
		Organic matter content low	0.08			Slope	0.16
Skyvillage	25	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Slope	0.08	Slope	0.00
		Organic matter content low	0.50				
Rock outcrop	15	Not rated		Not rated		Not rated	

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
191:							
Sheppard	85	Poor		Good		Fair	
		Wind erosion	0.00			Too sandy	0.02
		Too sandy	0.02				
		Organic matter content low	0.02				
		Droughty	0.94				
200:							
Sedillo	85	Poor		Good		Poor	
		Droughty	0.00			Hard to reclaim (rock fragments)	0.00
		Organic matter content low	0.12			Rock fragments	0.00
		Carbonate content	0.80			Slope	0.00
						Carbonate content	0.98
201:							
Rock outcrop	55	Not rated		Not rated		Not rated	
Sedgran	35	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Rock fragments	0.00
		Too sandy	0.06			Depth to bedrock	0.00
		Organic matter content low	0.08			Too sandy	0.06
206:							
Pinitos	85	Fair		Poor		Fair	
		Organic matter content low	0.02	Low strength	0.00	Too clayey	0.61
		Too clayey	0.98	Shrink-swell	0.87		
		Water erosion	0.99				
207:							
Penistaja	60	Fair		Good		Good	
		Organic matter content low	0.08				
		Water erosion	0.37				
Zia	25	Fair		Good		Good	
		Organic matter content low	0.08				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
208:							
Sedillo	85	Fair		Poor		Poor	
		Organic matter content low	0.08	Slope	0.00	Slope	0.00
		Droughty	0.12			Hard to reclaim (rock fragments)	0.00
		Carbonate content	0.80			Rock fragments	0.00
						Carbonate content	0.93
210:							
Ildefonso	85	Poor		Poor		Poor	
		Stone content	0.00	Slope	0.00	Slope	0.00
		Organic matter content low	0.08	Stone content	0.00	Rock fragments	0.00
		Droughty	0.71	Shrink-swell	0.87	Hard to reclaim (rock fragments)	0.00
		Carbonate content	0.97			Carbonate content	0.99
211:							
Zia	45	Fair		Good		Good	
		Organic matter content low	0.24				
Clovis	30	Fair		Fair		Fair	
		Organic matter content low	0.08	Shrink-swell	0.87	Carbonate content	0.88
		Carbonate content	0.80				
213:							
Pinavetes	55	Poor		Poor		Poor	
		Too sandy	0.00	Slope	0.00	Slope	0.00
		Wind erosion	0.00			Too sandy	0.00
		Droughty	0.00				
		Too alkaline	0.00				
		Organic matter content low	0.08				
Rock outcrop	30	Not rated		Not rated		Not rated	

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
215:							
Ess	60	Fair		Poor		Poor	
		Organic matter content low	0.40	Slope	0.00	Rock fragments	0.00
		Droughty	0.64	Cobble content	0.23	Hard to reclaim (rock fragments)	0.00
		Stone content	0.97	Stone content	0.94	Slope	0.00
		No cobble limitation	0.99				
Rock outcrop	30	Not rated		Not rated		Not rated	
217:							
Witt	85	Fair		Good		Good	
		Organic matter content low	0.08				
		Water erosion	0.37				
218:							
Ildefonso	85	Fair		Poor		Poor	
		Organic matter content low	0.08	Cobble content	0.00	Hard to reclaim (rock fragments)	0.00
		Droughty	0.17			Rock fragments	0.00
		Cobble content	0.66			Carbonate content	0.99
		Carbonate content	0.97				
220:							
Rock outcrop	40	Not rated		Not rated		Not rated	
Vessilla	30	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Depth to bedrock	0.00
		Organic matter content low	0.12				
Menefee	20	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Depth to bedrock	0.00
		Organic matter content low	0.50			Too clayey	0.64
		Too clayey	0.98				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
226:							
Galisteo, moderately saline, sodic	85	Poor		Poor		Poor	
		Sodium content	0.00	Low strength	0.00	Sodium content	0.00
		Too alkaline	0.00	Shrink-swell	0.87	Salinity	0.00
		Too clayey	0.08			Too clayey	0.05
		Organic matter content low	0.08				
		Salinity	0.50				
		Water erosion	0.99				
227:							
Hagerman	65	Fair		Poor		Fair	
		Organic matter content low	0.18	Depth to bedrock	0.00	Too clayey	0.58
		Depth to bedrock	0.84	Low strength	0.00	Depth to bedrock	0.84
		Too clayey	0.98	Shrink-swell	0.87		
Bond	20	Poor		Poor		Poor	
		Wind erosion	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Droughty	0.00	Low strength	0.78		
		Depth to bedrock	0.00	Shrink-swell	0.87		
		Organic matter content low	0.82				
228:							
Winona	85	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Rock fragments	0.00
		Carbonate content	0.00	Shrink-swell	0.87	Depth to bedrock	0.00
		Depth to bedrock	0.00	Slope	0.92	Slope	0.00
		Organic matter content low	0.50			Carbonate content	0.00
						Salinity	0.50
230:							
Skyvillage	35	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00			Slope	0.37

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
230:							
Sandoval	25	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00			Slope	0.37
		Too alkaline	0.00			Too clayey	0.64
		Organic matter content low	0.50				
		Too clayey	0.98				
Rock outcrop	20	Not rated		Not rated		Not rated	
231:							
Querencia	85	Fair		Fair		Good	
		Organic matter content low	0.08	Shrink-swell	0.87		
		Water erosion	0.99				
234:							
Querencia	60	Fair		Good		Good	
		Organic matter content low	0.08				
		Water erosion	0.99				
Zia	20	Fair		Good		Good	
		Organic matter content low	0.08				
235:							
Sandoval	85	Poor		Poor		Poor	
		Depth to bedrock	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Too alkaline	0.00	Low strength	0.00	Sodium content	0.10
		Sodium content	0.10	Shrink-swell	0.87	Too clayey	0.64
		Droughty	0.11			Slope	0.96
		Organic matter content low	0.50				
		Too clayey	0.98				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
236:							
Sparank, moderately saline, sodic	85	Poor		Poor		Poor	
		Sodium content	0.00	Low strength	0.00	Sodium content	0.00
		Too alkaline	0.00	Shrink-swell	0.34	Salinity	0.00
		Organic matter content low	0.50			Too clayey	0.64
		Salinity	0.50				
		Too clayey	0.98				
		Water erosion	0.99				
237:							
Sparank	85	Fair		Poor		Fair	
		Organic matter content low	0.50	Low strength	0.00	Sodium content	0.60
		Sodium content	0.60	Shrink-swell	0.87	Too clayey	0.64
		Too clayey	0.98				
		Water erosion	0.99				
240:							
Penistaja	45	Fair		Good		Good	
		Organic matter content low	0.08				
Hagerman	35	Fair		Poor		Fair	
		Organic matter content low	0.02	Depth to bedrock	0.00	Depth to bedrock	0.10
		Depth to bedrock	0.10	Low strength	0.00	Too clayey	0.52
		Droughty	0.66	Shrink-swell	0.87		
		Too clayey	0.98				
250:							
Pinavetes	90	Poor		Good		Fair	
		Wind erosion	0.00			Too sandy	0.38
		Too alkaline	0.00			Slope	0.84
		Organic matter content low	0.08				
		Too sandy	0.38				
		Droughty	0.40				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
262:							
Pastura	90	Poor		Poor		Poor	
		Droughty	0.00	Depth to cemented pan	0.00	Depth to cemented pan	0.00
		Depth to cemented pan	0.00	Shrink-swell	0.87	Rock fragments	0.50
		Organic matter content low	0.88				
		Water erosion	0.99				
270:							
Blancot	40	Fair		Good		Fair	
		Organic matter content low	0.01			Sodium content	0.40
		Sodium content	0.40				
Councelor	30	Fair		Good		Good	
		Organic matter content low	0.08				
Tsosie	25	Poor		Fair		Fair	
		Too alkaline	0.00			Salinity	0.50
		Organic matter content low	0.05			Sodium content	0.60
		Sodium content	0.60			Too clayey	0.64
		Too clayey	0.98				
		Water erosion	0.99				
281:							
Carjo	90	Poor		Poor		Poor	
		Too clayey	0.00	Depth to bedrock	0.00	Too clayey	0.00
		Depth to bedrock	0.16	Low strength	0.00	Depth to bedrock	0.16
		Droughty	0.36	Shrink-swell	0.75		
		Water erosion	0.37				
		Organic matter content low	0.50				
282:							
Tocal	85	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Shrink-swell	0.70		
		Water erosion	0.37				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
283:							
Mirand	45	Poor		Poor		Poor	
		Too clayey	0.00	Low strength	0.00	Too clayey	0.00
		Organic matter content low	0.08	Shrink-swell	0.59	Slope	0.00
		Too acid	0.74	Slope	0.82		
Alanos	30	Fair		Fair		Poor	
		Organic matter content low	0.02	Slope	0.08	Rock fragments	0.00
		Droughty	0.68	Shrink-swell	0.41	Slope	0.00
		Too clayey	0.98	Low strength	0.78	Hard to reclaim (rock fragments)	0.08
						Too clayey	0.55
290:							
Alanos	50	Poor		Poor		Poor	
		Too clayey	0.00	Slope	0.00	Slope	0.00
		Organic matter content low	0.01	Shrink-swell	0.22	Too clayey	0.00
		Droughty	0.45			Hard to reclaim (rock fragments)	0.00
		Too acid	0.84			Rock fragments	0.00
		Water erosion	0.99				
Rock outcrop	30	Not rated		Not rated		Not rated	
300:							
Waumac	50	Poor		Good		Good	
		Wind erosion	0.00				
		Organic matter content low	0.08				
Bamac	35	Poor		Good		Poor	
		Droughty	0.00			Rock fragments	0.00
		Too sandy	0.01			Too sandy	0.01
		Organic matter content low	0.08			Hard to reclaim (rock fragments)	0.01

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
301:							
Vastine	45	Fair		Fair		Poor	
		Too sandy	0.01	Wetness depth	0.53	Rock fragments	0.00
		Organic matter content low	0.08			Hard to reclaim (rock fragments)	0.00
		Water erosion	0.90			Too sandy	0.01
		Droughty	0.91			Wetness depth	0.53
Jarola	40	Fair		Fair		Poor	
		Organic matter content low	0.08	Wetness depth	0.53	Hard to reclaim (rock fragments)	0.00
		Water erosion	0.90	Shrink-swell	0.99	Rock fragments	0.12
		Too acid	0.99			Wetness depth	0.53
302:							
Tranquilar	50	Poor		Poor		Poor	
		Too clayey	0.00	Low strength	0.00	Too clayey	0.00
		Too acid	0.16	Shrink-swell	0.16	Too acid	0.68
		Organic matter content low	0.24	Wetness depth	0.98	Wetness depth	0.98
		Water erosion	0.99				
Jarmillo	30	Fair		Poor		Good	
		Organic matter content low	0.08	Low strength	0.00		
		Too acid	0.99				
		Water erosion	0.99				
304:							
Cosey	45	Fair		Fair		Poor	
		Organic matter content low	0.02	Shrink-swell	0.97	Hard to reclaim (rock fragments)	0.00
		Water erosion	0.90			Rock fragments	0.00
		Too acid	0.99			Slope	0.63
Jarmillo	40	Fair		Good		Fair	
		Organic matter content low	0.08			Slope	0.63
		Water erosion	0.90				
		Too acid	0.99				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
307:							
Flugle	60	Poor		Good		Fair	
		Organic matter content low	0.00			Too sandy	0.98
		Too sandy	0.98				
		Water erosion	0.99				
Waumac	25	Poor		Good		Good	
		Wind erosion	0.00				
		Organic matter content low	0.08				
308:							
Cajete	85	Fair		Good		Poor	
		Droughty	0.14			Rock fragments	0.00
		Organic matter content low	0.82			Hard to reclaim (rock fragments)	0.00
311:							
Cosey	35	Fair		Fair		Poor	
		Organic matter content low	0.02	Cobble content	0.55	Hard to reclaim (rock fragments)	0.00
		Cobble content	0.68	Shrink-swell	0.96	Rock fragments	0.00
		Water erosion	0.90			Slope	0.16
		Too clayey	0.98			Too clayey	0.52
		Droughty	0.99				
Tranquilar	30	Poor		Poor		Poor	
		Too clayey	0.00	Low strength	0.00	Too clayey	0.00
		Too acid	0.16	Shrink-swell	0.25	Too acid	0.68
		Organic matter content low	0.50	Wetness depth	0.98	Wetness depth	0.98
		Water erosion	0.90				
Calaveras	25	Fair		Good		Poor	
		Organic matter content low	0.01			Hard to reclaim (rock fragments)	0.00
		Droughty	0.76			Rock fragments	0.00
		Too acid	0.84			Slope	0.16
		Water erosion	0.90				
		Stone content	0.99				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
312:							
Royosa	90	Poor		Good		Fair	
		Wind erosion	0.00			Too sandy	0.38
		Organic matter content low	0.08				
		Droughty	0.13				
		Too sandy	0.38				
314:							
Fragua	40	Poor		Good		Good	
		Wind erosion	0.00				
		Organic matter content low	0.02				
Waumac	30	Poor		Good		Good	
		Wind erosion	0.00				
		Organic matter content low	0.08				
Royosa	25	Poor		Good		Poor	
		Too sandy	0.00			Too sandy	0.00
		Wind erosion	0.00				
		Droughty	0.09				
		Organic matter content low	0.50				
317:							
Elpedro	85	Fair		Fair		Fair	
		Organic matter content low	0.02	Shrink-swell	0.87	Too clayey	0.55
		Too clayey	0.92				
		Water erosion	0.99				
319:							
Bamac	60	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Slope	0.00
		Organic matter content low	0.01			Rock fragments	0.00
		Too sandy	0.06			Hard to reclaim (rock fragments)	0.00
						Too sandy	0.06
Rock outcrop	25	Not rated		Not rated		Not rated	

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
320:							
Sparham	85	Poor		Poor		Poor	
		Too clayey	0.00	Low strength	0.00	Too clayey	0.00
		Sodium content	0.00	Shrink-swell	0.12	Sodium content	0.00
		Organic matter content low	0.08			Salinity	0.00
		Salinity	0.88				
		Water erosion	0.90				
321:							
Waumac	60	Poor		Good		Good	
		Wind erosion	0.00				
		Organic matter content low	0.08				
Royosa	30	Poor		Good		Poor	
		Too sandy	0.00			Too sandy	0.00
		Wind erosion	0.00				
		Droughty	0.09				
		Organic matter content low	0.50				
322:							
Fragua	85	Fair		Poor		Poor	
		Too sandy	0.02	Slope	0.00	Slope	0.00
		Organic matter content low	0.08	Depth to bedrock	0.16	Too sandy	0.02
		Droughty	0.62				
324:							
Rock outcrop	30	Not rated		Not rated		Not rated	
Atarque	25	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Shrink-swell	0.87	Slope	0.00
		Organic matter content low	0.08				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
324:							
Menefee	25	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Slope	0.92	Slope	0.00
		Organic matter content low	0.50			Too clayey	0.64
		Too clayey	0.98				
325:							
Rock outcrop	35	Not rated		Not rated		Not rated	
Espiritu	25	Fair		Poor		Poor	
		Organic matter content low	0.08	Slope	0.00	Slope	0.00
		Droughty	0.88	Shrink-swell	0.87	Hard to reclaim (rock fragments)	0.00
				Cobble content	0.90	Rock fragments	0.00
Vessilla	25	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Depth to bedrock	0.00
		Organic matter content low	0.18			Rock fragments	0.00
342:							
Waumac	35	Poor		Good		Fair	
		Wind erosion	0.00			Slope	0.16
		Organic matter content low	0.08				
Vessilla	25	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Slope	0.08	Slope	0.00
		Organic matter content low	0.12				
Rock outcrop	20	Not rated		Not rated		Not rated	

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
345:							
Espiritu----------	50	Poor		Poor		Poor	
		Organic matter content low	0.00	Slope	0.00	Slope	0.00
		Droughty	0.70	Cobble content	0.99	Rock fragments	0.00
				Shrink-swell	0.99	Hard to reclaim (rock fragments)	0.46
Bamac----------	35	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Slope	0.00
		Too sandy	0.01			Rock fragments	0.00
		Organic matter content low	0.02			Hard to reclaim (rock fragments)	0.00
						Too sandy	0.01
346:							
Espiritu, cobbly----	70	Fair		Poor		Poor	
		Droughty	0.04	Slope	0.00	Slope	0.00
		Organic matter content low	0.08	Cobble content	0.70	Rock fragments	0.00
						Hard to reclaim (rock fragments)	0.00
Bamac----------	20	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Slope	0.00
		Too sandy	0.06			Rock fragments	0.00
		Organic matter content low	0.18			Hard to reclaim (rock fragments)	0.00
						Too sandy	0.06
348:							
Wauquie----------	60	Fair		Poor		Poor	
		Droughty	0.14	Slope	0.00	Slope	0.00
		Organic matter content low	0.18			Hard to reclaim (rock fragments)	0.00
						Rock fragments	0.00
Rock outcrop--------	20	Not rated		Not rated		Not rated	

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
353:							
Cochiti	50	Fair		Poor		Poor	
		Organic matter content low	0.02	Slope	0.00	Slope	0.00
		Droughty	0.17			Hard to reclaim (rock fragments)	0.00
		Too clayey	0.50			Rock fragments	0.00
						Too clayey	0.30
Espiritu	45	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Slope	0.00
		Too sandy	0.02	Cobble content	0.99	Hard to reclaim (rock fragments)	0.00
		Organic matter content low	0.08			Rock fragments	0.00
						Too sandy	0.02
354:							
Waumac Variant	85	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Rock fragments	0.00
		Depth to bedrock	0.00			Depth to bedrock	0.00
		Organic matter content low	0.08				
358:							
Deama	35	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Rock fragments	0.00
		Carbonate content	0.00	Slope	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Shrink-swell	0.87	Carbonate content	0.00
		Organic matter content low	0.82			Slope	0.00
Elpedro	25	Fair		Poor		Poor	
		Organic matter content low	0.18	Low strength	0.00	Slope	0.00
		Too clayey	0.92	Slope	0.00	Too clayey	0.55
		Water erosion	0.99	Shrink-swell	0.87		
Rock outcrop	25	Not rated		Not rated		Not rated	

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
396:							
Atarque	30	Poor		Poor		Poor	
		Depth to bedrock	0.00	Depth to bedrock	0.00	Slope	0.00
		Droughty	0.00	Slope	0.00	Depth to bedrock	0.00
		Organic matter content low	0.02	Low strength	0.78		
				Shrink-swell	0.87		
Menefee	30	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Depth to bedrock	0.00
		Organic matter content low	0.12	Low strength	0.00	Too clayey	0.57
		Too clayey	0.98	Shrink-swell	0.87		
Rock outcrop	25	Not rated		Not rated		Not rated	
397:							
Rock outcrop	30	Not rated		Not rated		Not rated	
Cucho	25	Fair		Poor		Poor	
		Organic matter content low	0.01	Depth to bedrock	0.00	Slope	0.00
		Droughty	0.49	Slope	0.00	Rock fragments	0.00
		Too clayey	0.92	Shrink-swell	0.87	Too clayey	0.48
		Depth to bedrock	0.97			Depth to bedrock	0.97
Vessilla	25	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Slope	0.00	Slope	0.00
		Organic matter content low	0.18			Rock fragments	0.50
398:							
Espiritu	45	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Hard to reclaim (rock fragments)	0.00
		Organic matter content low	0.02			Rock fragments	0.00
						Slope	0.00

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
398:							
Cucho	35	Fair		Poor		Poor	
		Organic matter content low	0.08	Depth to bedrock	0.00	Slope	0.00
		Too clayey	0.92	Low strength	0.00	Too clayey	0.52
		Depth to bedrock	0.97	Slope	0.00	Depth to bedrock	0.97
		Water erosion	0.99	Shrink-swell	0.87		
399:							
Cucho	45	Fair		Poor		Poor	
		Organic matter content low	0.08	Depth to bedrock	0.00	Slope	0.00
		Too clayey	0.92	Low strength	0.00	Too clayey	0.52
		Depth to bedrock	0.97	Slope	0.00	Depth to bedrock	0.97
				Shrink-swell	0.87		
Teco	35	Poor		Poor		Poor	
		Too clayey	0.00	Low strength	0.00	Too clayey	0.00
		Organic matter content low	0.18	Slope	0.02	Slope	0.00
				Shrink-swell	0.48		
405:							
Charo	50	Poor		Poor		Poor	
		Too clayey	0.00	Depth to bedrock	0.00	Too clayey	0.00
		Organic matter content low	0.02	Low strength	0.00	Depth to bedrock	0.35
		Droughty	0.27	Shrink-swell	0.12		
		Depth to bedrock	0.35				
Charo, noncobbly	40	Poor		Poor		Poor	
		Too clayey	0.00	Depth to bedrock	0.00	Too clayey	0.00
		Organic matter content low	0.08	Low strength	0.00	Depth to bedrock	0.99
		Depth to bedrock	0.99	Shrink-swell	0.87	Rock fragments	0.99
		Water erosion	0.99				
409:							
Santa Fe	85	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Rock fragments	0.00
		Organic matter content low	0.50			Depth to bedrock	0.00

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
410:							
Zia	85	Fair		Good		Good	
		Organic matter content low	0.08				
		Water erosion	0.99				
414:							
Wauquie	85	Fair		Fair		Poor	
		Organic matter content low	0.08	Slope	0.92	Rock fragments	0.00
		Droughty	0.09	Cobble content	0.99	Slope	0.00
						Hard to reclaim (rock fragments)	0.05
417:							
Jocity	85	Poor		Fair		Fair	
		Too alkaline	0.00	Shrink-swell	0.95	Too clayey	0.64
		Organic matter content low	0.08				
		Too clayey	0.98				
		Water erosion	0.99				
418:							
Jocity	85	Fair		Good		Fair	
		Organic matter content low	0.08			Too clayey	0.61
		Too clayey	0.98				
419:							
Santa Fe	40	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Rock fragments	0.00
				Shrink-swell	0.87	Depth to bedrock	0.00
Wauquie	30	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Slope	0.00
		Organic matter content low	0.02	Cobble content	0.50	Hard to reclaim (rock fragments)	0.00
						Rock fragments	0.00
Rock outcrop	20	Not rated		Not rated		Not rated	

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
420:							
Pinavetes	85	Poor		Good		Poor	
		Too sandy	0.00			Too sandy	0.00
		Wind erosion	0.00				
		Droughty	0.00				
		Too alkaline	0.00				
		Organic matter content low	0.08				
421:							
Gilco, moderately saline, sodic	90	Poor		Good		Poor	
		Sodium content	0.00			Sodium content	0.00
		Organic matter content low	0.08			Salinity	0.00
		Water erosion	0.37				
		Salinity	0.50				
422:							
Vessilla	35	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00	Slope	0.82	Slope	0.00
		Organic matter content low	0.12				
Menefee	30	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Depth to bedrock	0.00
		Depth to bedrock	0.00			Too clayey	0.64
		Organic matter content low	0.50				
		Too clayey	0.98				
Orlie	25	Fair		Poor		Fair	
		Organic matter content low	0.08	Low strength	0.00	Too clayey	0.55
		Too clayey	0.98	Shrink-swell	0.87		
		Water erosion	0.99				
423:							
Gilco	85	Fair		Good		Fair	
		Organic matter content low	0.08			Rock fragments	0.98
		Water erosion	0.99				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
426:							
Aga, moderately saline, sodic------	85	Poor		Good		Poor	
		Sodium content	0.00			Sodium content	0.00
		Organic matter content low	0.02			Salinity	0.00
		Too sandy	0.38			Too sandy	0.38
		Salinity	0.50				
		Droughty	0.81				
		Water erosion	0.99				
427:							
Aga-----------------	85	Fair		Good		Good	
		Organic matter content low	0.02				
		Water erosion	0.99				
428:							
Aga, moderately saline, sodic------	85	Poor		Good		Poor	
		Sodium content	0.00			Sodium content	0.00
		Organic matter content low	0.02			Salinity	0.00
		Water erosion	0.37			Too sandy	0.38
		Too sandy	0.38				
		Salinity	0.50				
		Droughty	0.97				
430:							
Trail---------------	85	Poor		Good		Fair	
		Too alkaline	0.00			Too sandy	0.01
		Too sandy	0.01				
		Organic matter content low	0.08				
		Droughty	0.48				
		Water erosion	0.99				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
431:							
Trail	85	Poor		Good		Good	
		Wind erosion	0.00				
		Too alkaline	0.00				
		Organic matter content low	0.08				
		Droughty	0.88				
433:							
Peralta	85	Fair		Fair		Fair	
		Organic matter content low	0.08	Wetness depth	0.89	Sodium content	0.40
		Sodium content	0.40			Salinity	0.50
		Water erosion	0.99			Wetness depth	0.89
434:							
Peralta	85	Fair		Fair		Fair	
		Too sandy	0.01	Wetness depth	0.89	Too sandy	0.01
		Organic matter content low	0.02			Sodium content	0.40
		Water erosion	0.37			Salinity	0.50
		Sodium content	0.40			Wetness depth	0.89
437:							
Peralta, moderately saline, sodic	85	Poor		Fair		Poor	
		Sodium content	0.00	Wetness depth	0.89	Sodium content	0.00
		Organic matter content low	0.08			Salinity	0.00
		Salinity	0.50			Wetness depth	0.89
		Water erosion	0.99				
500:							
Rock outcrop	40	Not rated		Not rated		Not rated	
Osha	30	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Slope	0.00
		Too sandy	0.01	Depth to bedrock	0.07	Hard to reclaim (rock fragments)	0.00
		Organic matter content low	0.08			Rock fragments	0.00
						Too sandy	0.01

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
500:							
Rubble land---------	20	Not rated		Poor		Not rated	
				Slope	0.00		
				Stone content	0.00		
				Cobble content	0.00		
503:							
Cajete--------------	65	Fair		Fair		Poor	
		Droughty	0.04	Slope	0.68	Rock fragments	0.00
		Organic matter content low	0.82			Slope	0.00
						Hard to reclaim (rock fragments)	0.20
Cypher--------------	25	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Rock fragments	0.00
		Organic matter content low	0.32			Depth to bedrock	0.00
		Too acid	0.95				
504:							
Orejas--------------	40	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Rock fragments	0.00
		Depth to bedrock	0.00	Shrink-swell	0.87	Depth to bedrock	0.00
		Organic matter content low	0.12			Too clayey	0.57
		Too clayey	0.98			Slope	0.84
Guaje---------------	35	Fair		Good		Poor	
		Droughty	0.01			Rock fragments	0.00
		Organic matter content low	0.05			Hard to reclaim (rock fragments)	0.00
		Carbonate content	0.97				
600:							
Rock outcrop--------	50	Not rated		Not rated		Not rated	

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
600:							
Cypher	35	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Rock fragments	0.00
		Organic matter content low	0.18			Depth to bedrock	0.00
		Too acid	0.95				
601:							
Laventana	85	Fair		Fair		Poor	
		Organic matter content low	0.08	Depth to bedrock	0.58	Rock fragments	0.00
		Droughty	0.28	Shrink-swell	0.87	Hard to reclaim (rock fragments)	0.00
		Too acid	0.99			Slope	0.96
603:							
Laventana	50	Fair		Poor		Poor	
		Organic matter content low	0.02	Slope	0.00	Slope	0.00
		Droughty	0.70	Depth to bedrock	0.68	Rock fragments	0.00
		Too acid	0.74	Shrink-swell	0.87	Hard to reclaim (rock fragments)	0.00
Mirand	35	Poor		Poor		Poor	
		Too clayey	0.00	Low strength	0.00	Slope	0.00
		Organic matter content low	0.12	Shrink-swell	0.12	Too clayey	0.00
				Slope	0.50	Rock fragments	0.18
604:							
Cypher	55	Poor		Poor		Poor	
		Droughty	0.00	Depth to bedrock	0.00	Slope	0.00
		Depth to bedrock	0.00	Slope	0.00	Rock fragments	0.00
		Organic matter content low	0.02			Depth to bedrock	0.00
		Too acid	0.74				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
604:							
Mirand	30	Poor		Poor		Poor	
		Too clayey	0.00	Slope	0.00	Slope	0.00
		Organic matter content low	0.12	Shrink-swell	0.12	Too clayey	0.00
				Low strength	0.78	Rock fragments	0.32
						Hard to reclaim (rock fragments)	0.88
608:							
Osha, steep	60	Poor		Poor		Poor	
		Droughty	0.00	Slope	0.00	Slope	0.00
		Organic matter content low	0.02			Hard to reclaim (rock fragments)	0.00
		Too acid	0.99			Rock fragments	0.00
Osha	30	Poor		Fair		Poor	
		Droughty	0.00	Slope	0.68	Hard to reclaim (dense layer)	0.00
		Organic matter content low	0.08			Hard to reclaim (rock fragments)	0.00
						Rock fragments	0.00
						Slope	0.00
823:							
Gilco, unprotected	85	Fair		Good		Fair	
		Organic matter content low	0.08			Rock fragments	0.98
		Water erosion	0.99				
827:							
Aga, unprotected	85	Fair		Good		Good	
		Organic matter content low	0.01				
		Water erosion	0.99				
830:							
Trail, unprotected	85	Poor		Good		Good	
		Too alkaline	0.00				
		Organic matter content low	0.08				
		Droughty	0.96				
		Water erosion	0.99				

Table 12B.--Source of reclamation material, roadfill, and topsoil--continued

Map symbol and soil name	Pct. of map unit	Potential source of reclamation material		Potential source of roadfill		Potential source of topsoil	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
831:							
Trail, unprotected--	85	Poor		Good		Fair	
		Wind erosion	0.00			Too sandy	0.01
		Too alkaline	0.00				
		Too sandy	0.01				
		Droughty	0.03				
		Organic matter content low	0.08				
835:							
Peralta, unprotected	85	Fair		Fair		Fair	
		Organic matter content low	0.08	Wetness depth	0.89	Salinity	0.50
		Water erosion	0.99	Shrink-swell	0.93	Wetness depth	0.89
842:							
Peralta, moderately saline, sodic, unprotected--------	85	Poor		Fair		Poor	
		Sodium content	0.00	Shrink-swell	0.87	Sodium content	0.00
		Organic matter content low	0.08	Wetness depth	0.89	Salinity	0.00
		Salinity	0.50			Wetness depth	0.89
850:							
Water----------	95	Not rated		Not rated		Not rated	
DAM:							
Dam----------	100	Not rated		Not rated		Not rated	

Table 13.--Ponds and embankments

(The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the limitation. See text for further explanation of ratings in this table.)

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
1:							
Silver	55	Somewhat limited Seepage	 0.04	Somewhat limited Piping	 0.01	Very limited Depth to water	 1.00
Clovis	35	Very limited Seepage	 1.00	Somewhat limited Piping Seepage	 0.80 0.01	Very limited Depth to water	 1.00
2:							
Clovis	35	Very limited Seepage	 1.00	Somewhat limited Piping Seepage	 0.99 0.01	Very limited Depth to water	 1.00
Prieta	35	Very limited Depth to bedrock	 1.00	Very limited Thin layer Large stones content	 1.00 0.43	Very limited Depth to water	 1.00
Silver	20	Somewhat limited Seepage	 0.04	Somewhat limited Piping	 0.01	Very limited Depth to water	 1.00
3:							
Montecito	60	Somewhat limited Seepage	 0.04	Somewhat limited Piping	 0.01	Very limited Depth to water	 1.00
Orejas	30	Very limited Depth to bedrock	 1.00	Very limited Thin layer Large stones content	 1.00 0.67	Very limited Depth to water	 1.00
4:							
Montecito	45	Somewhat limited Seepage Slope	 0.72 0.06	Somewhat limited Piping	 0.31	Very limited Depth to water	 1.00
Montecito, bouldery-	35	Very limited Seepage Slope	 1.00 0.06	Somewhat limited Piping Seepage	 0.75 0.03	Very limited Depth to water	 1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
10:							
Trail	85	Very limited Seepage	 1.00	Somewhat limited Seepage	 0.06	Very limited Depth to water	 1.00
11:							
Trail	85	Very limited Seepage	 1.00	Somewhat limited Seepage	 0.10	Very limited Depth to water	 1.00
13:							
Sandoval	65	Somewhat limited Depth to bedrock	 0.66	Very limited Thin layer Piping	 1.00 0.08	Very limited Depth to water	 1.00
Querencia	20	Somewhat limited Seepage	 0.72	Somewhat limited Piping	 0.38	Very limited Depth to water	 1.00
15:							
Camino	40	Somewhat limited Depth to bedrock	 0.01	Somewhat limited Hard to pack Thin layer	 0.46 0.08	Very limited Depth to water	 1.00
Sandoval	35	Somewhat limited Depth to bedrock	 0.58	Very limited Thin layer Piping	 1.00 0.96	Very limited Depth to water	 1.00
16:							
Rock outcrop	50	Not rated		Not rated		Not rated	
Prieta	30	Very limited Depth to bedrock	 1.00	Very limited Thin layer Large stones content	 1.00 0.06	Very limited Depth to water	 1.00
17:							
Vessilla	35	Very limited Depth to bedrock	 1.00	Very limited Thin layer Seepage	 1.00 0.03	Very limited Depth to water	 1.00
Menefee	25	Somewhat limited Depth to bedrock	 0.84	Very limited Thin layer	 1.00	Very limited Depth to water	 1.00
Rock outcrop	20	Not rated		Not rated		Not rated	

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
18:							
Sparham	85	Somewhat limited		Very limited		Very limited	
		Seepage	0.04	Piping	1.00	Depth to water	1.00
				Salinity	0.03		
20:							
Gilco	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.41	Depth to water	1.00
21:							
Rock outcrop	60	Not rated		Not rated		Not rated	
Hackroy	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
				Hard to pack	0.06		
22:							
Aga	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.42	Cutbanks cave	1.00
						Depth to saturated zone	0.90
23:							
Hickman	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.05	Depth to water	1.00
24:							
Orlie	45	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.23	Depth to water	1.00
Sparham	35	Not limited		Very limited		Very limited	
				Piping	1.00	Depth to water	1.00
				Salinity	0.12		
25:							
Gilco	85	Somewhat limited		Very limited		Very limited	
		Seepage	0.72	Piping	0.99	Depth to water	1.00
				Seepage	0.01		
26:							
Orlie	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.04	Piping	0.01	Depth to water	1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
27:							
Aga	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.79	Cutbanks cave	1.00
						Depth to saturated zone	0.90
29:							
Trail	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00
31:							
Riverwash	90	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.93	Depth to water	1.00
33:							
Pits	100	Somewhat limited		Not rated		Not rated	
		Seepage	0.07				
34:							
Ildefonso	55	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Large stones content	0.70	Depth to water	1.00
				Seepage	0.03		
Witt	30	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.55	Depth to water	1.00
41:							
Dune land	100	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.93	Depth to water	1.00
47:							
Cascajo	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.25	Depth to water	1.00
		Slope	0.15				
51:							
Sparham	85	Somewhat limited		Very limited		Somewhat limited	
		Seepage	0.04	Depth to saturated zone	1.00	Slow refill	0.96
				Piping	1.00	Salinity and saturated zone	0.50
				Salinity	0.12	Cutbanks cave	0.10

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
52:							
Totavi	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00
53:							
Witt	55	Somewhat limited		Very limited		Very limited	
		Seepage	0.72	Piping	0.99	Depth to water	1.00
Harvey	30	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Piping	0.75	Depth to water	1.00
				Seepage	0.03		
54:							
Harvey	45	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.66	Depth to water	1.00
Cascajo	40	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.79	Depth to water	1.00
55:							
La Fonda	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.50	Depth to water	1.00
56:							
Ildefonso	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Large stones content	0.53	Depth to water	1.00
		Slope	0.28	Seepage	0.05		
57:							
Badland	90	Very limited		Not rated		Not rated	
		Depth to bedrock	1.00				
		Slope	1.00				
58:							
Deama	45	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.21	Piping	1.00		
				Large stones content	0.01		
Elpedro	35	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.31	Depth to water	1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
59:							
Harvey	35	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.12	Depth to water	1.00
Ildefonso	35	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.79	Depth to water	1.00
		Slope	0.01	Large stones content	0.02		
La Fonda	15	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.39	Depth to water	1.00
63:							
Placitas	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Thin layer	0.93	Depth to water	1.00
		Depth to bedrock	0.93	Seepage	0.03		
		Slope	0.24				
64:							
Skyvillage	40	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.06	Seepage	0.03		
Ildefonso	35	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
		Slope	0.24				
65:							
Ildefonso	50	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.04	Depth to water	1.00
		Slope	0.21				
Harvey	30	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
		Slope	0.01				
66:							
Zia	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
67:							
Sandoval	40	Somewhat limited		Very limited		Very limited	
		Depth to bedrock	0.80	Thin layer	1.00	Depth to water	1.00
		Slope	0.06	Piping	0.06		
Poley	35	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Piping	0.70	Depth to water	1.00
		Slope	0.03	Seepage	0.03		
68:							
Penistaja	45	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.40	Depth to water	1.00
Querencia	35	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.01	Depth to water	1.00
71:							
Palon	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Large stones content	0.05	Depth to water	1.00
		Slope	0.28	Seepage	0.03		
72:							
Palon	85	Very limited		Very limited		Very limited	
		Seepage	1.00	Large stones content	1.00	Depth to water	1.00
		Slope	1.00	Seepage	0.38		
74:							
Origo	50	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Large stones content	0.55	Depth to water	1.00
		Slope	0.28	Seepage	0.03		
Pavo	25	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
		Slope	0.01				
75:							
Origo	85	Very limited		Very limited		Very limited	
		Seepage	1.00	Large stones content	0.99	Depth to water	1.00
		Slope	1.00	Seepage	0.10		

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
82:							
Calaveras	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.25	Depth to water	1.00
		Slope	0.28				
83:							
Calaveras	60	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.06	Depth to water	1.00
		Slope	0.99	Large stones content	0.01		
Rubble land	20	Very limited		Very limited		Very limited	
		Seepage	1.00	Large stones content	1.00	Depth to water	1.00
		Slope	0.99	Seepage	1.00		
85:							
Redondo	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.07	Depth to water	1.00
		Slope	0.28				
86:							
Redondo	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Large stones content	0.53	Depth to water	1.00
		Slope	1.00	Seepage	0.50		
87:							
Redondo	50	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.07	Depth to water	1.00
		Slope	1.00				
Rubble land	25	Very limited		Very limited		Very limited	
		Seepage	1.00	Large stones content	1.00	Depth to water	1.00
		Slope	1.00	Seepage	1.00		
88:							
Totavi	45	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
88:							
Jemez	30	Somewhat limited		Somewhat limited		Very limited	
		Depth to bedrock	0.93	Thin layer	0.93	Depth to water	1.00
		Seepage	0.04	Piping	0.31		
Rock outcrop	15	Not rated		Not rated		Not rated	
91:							
Zia	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
92:							
Galisteo, moderately saline, sodic	85	Not limited		Very limited		Very limited	
				Hard to pack	1.00	Depth to water	1.00
				Salinity	0.50		
93:							
Zia	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00
95:							
El Rancho	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
97:							
El Rancho	85	Somewhat limited		Not limited		Very limited	
		Seepage	0.72			Depth to water	1.00
100:							
Orejas	40	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.41	Large stones content	0.61		
Rock outcrop	40	Not rated		Not rated		Not rated	
101:							
Blancot	55	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Piping	0.88	Depth to water	1.00
				Seepage	0.03		

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
101:							
Lybrook	25	Somewhat limited		Very limited		Very limited	
		Seepage	0.04	Piping	1.00	Depth to water	1.00
				Salinity	0.97		
102:							
Sparham	85	Somewhat limited		Very limited		Very limited	
		Seepage	0.04	Piping	1.00	Depth to water	1.00
				Salinity	0.12		
104:							
Cochiti	50	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
		Slope	0.06				
Montecito	30	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
105:							
Badland	50	Very limited		Not rated		Not rated	
		Depth to bedrock	1.00				
		Slope	0.28				
Menefee	30	Somewhat limited		Very limited		Very limited	
		Depth to bedrock	0.84	Thin layer	1.00	Depth to water	1.00
		Slope	0.28	Piping	0.08		
106:							
Stumble	50	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.58	Depth to water	1.00
		Slope	0.28				
Stumble, sandy	30	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.47	Depth to water	1.00
108:							
Embudo	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00
109:							
Embudo	50	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.12	Depth to water	1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
109:							
Tijeras	35	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.06	Depth to water	1.00
110:							
Rock outcrop	45	Not rated		Not rated		Not rated	
Saido	40	Somewhat limited		Very limited		Very limited	
		Seepage	0.72	Piping	1.00	Depth to water	1.00
		Slope	0.21				
111:							
Rock outcrop	50	Not rated		Not rated		Not rated	
Zia	35	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
		Slope	0.06				
112:							
Tijeras	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
114:							
San Mateo	40	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.04	Salinity	0.97	Depth to water	1.00
				Seepage	0.03		
Zia	40	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.01	Depth to water	1.00
120:							
Pinavetes	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.79	Depth to water	1.00
124:							
Rock outcrop	90	Not rated		Not rated		Not rated	
129:							
Menefee	85	Somewhat limited		Very limited		Very limited	
		Depth to bedrock	0.58	Thin layer	1.00	Depth to water	1.00
		Slope	0.12				

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
130:							
Pinavetes	45	Very limited Seepage	1.00	Somewhat limited Seepage	0.10	Very limited Depth to water	1.00
Galisteo, moderately saline, sodic	40	Not limited		Very limited Hard to pack Salinity	1.00 0.50	Very limited Depth to water	1.00
142:							
Grieta	85	Very limited Seepage	1.00	Somewhat limited Seepage	0.10	Very limited Depth to water	1.00
143:							
Clovis	85	Somewhat limited Seepage	0.72	Not limited		Very limited Depth to water	1.00
145:							
Grieta	55	Very limited Seepage	1.00	Somewhat limited Seepage	0.06	Very limited Depth to water	1.00
Sheppard	40	Very limited Seepage	1.00	Somewhat limited Seepage	0.06	Very limited Depth to water	1.00
146:							
Sedmar	85	Very limited Depth to bedrock	1.00	Very limited Thin layer Seepage	1.00 0.10	Very limited Depth to water	1.00
150:							
Doakum	55	Somewhat limited Seepage	0.72	Somewhat limited Piping	0.46	Very limited Depth to water	1.00
Betonnie	35	Very limited Seepage	1.00	Somewhat limited Seepage	0.03	Very limited Depth to water	1.00
162:							
Hackroy	45	Very limited Depth to bedrock	1.00	Very limited Thin layer Hard to pack	1.00 0.08	Very limited Depth to water	1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
162:							
Nyjack	40	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Piping	0.71	Depth to water	1.00
		Depth to bedrock	0.01	Thin layer	0.52		
				Seepage	0.03		
163:							
Jemez	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Thin layer	0.52	Depth to water	1.00
		Depth to bedrock	0.52	Piping	0.11		
170:							
San Mateo	85	Somewhat limited		Very limited		Very limited	
		Seepage	0.04	Piping	1.00	Depth to water	1.00
180:							
Councelor	40	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
		Slope	0.08				
Eslendo	30	Somewhat limited		Very limited		Very limited	
		Depth to bedrock	0.84	Thin layer	1.00	Depth to water	1.00
		Slope	0.08				
Mespun	25	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.07	Depth to water	1.00
		Slope	0.08				
183:							
Sheppard	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.06	Depth to water	1.00
		Slope	0.01				
185:							
Frijoles	90	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.04	Depth to water	1.00
190:							
Zia	35	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
		Slope	0.01				

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
190:							
Skyvillage	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.21	Seepage	0.01		
Rock outcrop	15	Not rated		Not rated		Not rated	
191:							
Sheppard	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.06	Depth to water	1.00
200:							
Sedillo	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.06	Depth to water	1.00
		Slope	0.03				
201:							
Rock outcrop	55	Not rated		Not rated		Not rated	
Sedgran	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.88	Seepage	0.12		
206:							
Pinitos	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.04	Piping	0.01	Depth to water	1.00
207:							
Penistaja	60	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.01	Depth to water	1.00
Zia	25	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.01	Depth to water	1.00
208:							
Sedillo	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
		Slope	0.88				

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
210:							
Ildefonso	85	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.99	Large stones content	0.97	Depth to water	1.00
		Seepage	0.72				
211:							
Zia	45	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
Clovis	30	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Seepage	0.01	Depth to water	1.00
213:							
Pinavetes	55	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.79	Depth to water	1.00
		Slope	0.28				
Rock outcrop	30	Not rated		Not rated		Not rated	
215:							
Ess	60	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Large stones content	0.33	Depth to water	1.00
		Slope	0.28				
Rock outcrop	30	Not rated		Not rated		Not rated	
217:							
Witt	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.50	Depth to water	1.00
218:							
Ildefonso	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Large stones content	0.71	Depth to water	1.00
				Seepage	0.03		
220:							
Rock outcrop	40	Not rated		Not rated		Not rated	

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
220:							
Vessilla	30	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.72	Seepage	0.03		
Menefee	20	Somewhat limited		Very limited		Very limited	
		Depth to bedrock	0.84	Thin layer	1.00	Depth to water	1.00
		Slope	0.72				
226:							
Galisteo, moderately saline, sodic	85	Somewhat limited		Very limited		Very limited	
		Seepage	0.04	Piping	1.00	Depth to water	1.00
				Salinity	0.50		
227:							
Hagerman	65	Somewhat limited		Somewhat limited		Very limited	
		Depth to bedrock	0.74	Thin layer	0.74	Depth to water	1.00
		Seepage	0.04	Piping	0.06		
Bond	20	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
228:							
Winona	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.06				
230:							
Skyvillage	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.01	Seepage	0.03		
Sandoval	25	Somewhat limited		Very limited		Very limited	
		Depth to bedrock	0.84	Thin layer	1.00	Depth to water	1.00
		Slope	0.01	Piping	0.04		
Rock outcrop	20	Not rated		Not rated		Not rated	
231:							
Querencia	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.50	Depth to water	1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
234:							
Querencia	60	Somewhat limited		Not limited		Very limited	
		Seepage	0.72			Depth to water	1.00
Zia	20	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
235:							
Sandoval	85	Somewhat limited		Very limited		Very limited	
		Depth to bedrock	0.50	Thin layer	1.00	Depth to water	1.00
				Piping	0.95		
236:							
Sparank, moderately saline, sodic	85	Somewhat limited		Very limited		Very limited	
		Seepage	0.04	Piping	1.00	Depth to water	1.00
				Salinity	0.50		
237:							
Sparank	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.04	Piping	0.40	Depth to water	1.00
240:							
Penistaja	45	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.52	Depth to water	1.00
Hagerman	35	Somewhat limited		Somewhat limited		Very limited	
		Depth to bedrock	0.98	Thin layer	0.98	Depth to water	1.00
		Seepage	0.04	Piping	0.03		
250:							
Pinavetes	90	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.07	Depth to water	1.00
262:							
Pastura	90	Very limited		Very limited		Very limited	
		Depth to cemented pan	1.00	Thin layer	1.00	Depth to water	1.00
		Seepage	0.01	Piping	0.50		

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
270:							
Blancot	40	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Piping	0.60	Depth to water	1.00
				Seepage	0.03		
Councelor	30	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.04	Depth to water	1.00
Tsosie	25	Very limited		Very limited		Very limited	
		Seepage	1.00	Piping	1.00	Depth to water	1.00
				Seepage	0.03		
281:							
Carjo	90	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Thin layer	0.96	Depth to water	1.00
		Depth to bedrock	0.96	Piping	0.01		
282:							
Tocal	85	Somewhat limited		Very limited		Very limited	
		Depth to bedrock	0.69	Thin layer	1.00	Depth to water	1.00
				Piping	0.76		
283:							
Mirand	45	Somewhat limited		Not limited		Very limited	
		Slope	0.08			Depth to water	1.00
		Seepage	0.04				
Alanos	30	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.21	Seepage	0.50	Depth to water	1.00
		Seepage	0.04				
290:							
Alanos	50	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.50	Seepage	0.12	Depth to water	1.00
Rock outcrop	30	Not rated		Not rated		Not rated	
300:							
Waumac	50	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.01	Depth to water	1.00
Bamac	35	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
301:							
Vastine	45	Very limited		Very limited		Very limited	
		Seepage	1.00	Depth to saturated zone	0.99	Cutbanks cave	1.00
				Seepage	0.38	Depth to saturated zone	0.01
Jarola	40	Very limited		Very limited		Very limited	
		Seepage	1.00	Depth to saturated zone	0.99	Cutbanks cave	1.00
				Seepage	0.05	Depth to saturated zone	0.01
302:							
Tranquilar	50	Not limited		Somewhat limited		Very limited	
				Depth to saturated zone	0.68	Slow refill	1.00
				Hard to pack	0.31	Depth to saturated zone	0.14
						Cutbanks cave	0.10
Jarmillo	30	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Piping	0.75	Depth to water	1.00
304:							
Cosey	45	Somewhat limited		Not limited		Very limited	
		Seepage	0.72			Depth to water	1.00
		Slope	0.01				
Jarmillo	40	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
		Slope	0.01				
307:							
Flugle	60	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.02	Depth to water	1.00
Waumac	25	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00
308:							
Cajete	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.79	Depth to water	1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
311:							
Cosey	35	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Seepage	0.32	Depth to water	1.00
		Slope	0.01	Large stones content	0.03		
Tranquilar	30	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Depth to saturated zone	0.68	Slow refill	1.00
						Depth to saturated zone	0.14
						Cutbanks cave	0.10
Calaveras	25	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00
		Slope	0.01				
312:							
Royosa	90	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.79	Depth to water	1.00
314:							
Fragua	40	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.04	Depth to water	1.00
Waumac	30	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.06	Depth to water	1.00
Royosa	25	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.31	Depth to water	1.00
317:							
Elpedro	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.22	Depth to water	1.00
319:							
Bamac	60	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.12	Depth to water	1.00
		Slope	0.72				
Rock outcrop	25	Not rated		Not rated		Not rated	

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
320:							
Sparham	85	Not limited		Very limited		Very limited	
				Piping	1.00	Depth to water	1.00
				Salinity	0.12		
321:							
Waumac	60	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.06	Depth to water	1.00
Royosa	30	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.31	Depth to water	1.00
322:							
Fragua	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Thin layer	0.26	Depth to water	1.00
		Slope	0.94	Seepage	0.06		
		Depth to bedrock	0.01				
324:							
Rock outcrop	30	Not rated		Not rated		Not rated	
Atarque	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.03				
Menefee	25	Somewhat limited		Very limited		Very limited	
		Depth to bedrock	0.87	Thin layer	1.00	Depth to water	1.00
		Slope	0.06	Piping	0.02		
325:							
Rock outcrop	35	Not rated		Not rated		Not rated	
Espiritu	25	Somewhat limited		Not limited		Very limited	
		Slope	0.97			Depth to water	1.00
		Seepage	0.72				
Vessilla	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.88				

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
342:							
Waumac	35	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.06	Depth to water	1.00
		Slope	0.01				
Vessilla	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.21	Seepage	0.01		
Rock outcrop	20	Not rated		Not rated		Not rated	
345:							
Espiritu	50	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.04	Depth to water	1.00
		Slope	0.72				
Bamac	35	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00
		Slope	0.72				
346:							
Espiritu, cobbly	70	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00
		Slope	0.41	Large stones content	0.01		
Bamac	20	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.12	Depth to water	1.00
		Slope	0.41				
348:							
Wauquie	60	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.25	Depth to water	1.00
		Slope	0.72				
Rock outcrop	20	Not rated		Not rated		Not rated	
353:							
Cochiti	50	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.25	Depth to water	1.00
		Slope	0.41				

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
353:							
Espiritu	45	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00
		Slope	0.88				
354:							
Waumac Variant	85	Somewhat limited		Very limited		Very limited	
		Depth to bedrock	0.78	Thin layer	1.00	Depth to water	1.00
				Seepage	0.03		
358:							
Deama	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.88				
Elpedro	25	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.09	Depth to water	1.00
		Slope	0.64				
Rock outcrop	25	Not rated		Not rated		Not rated	
396:							
Atarque	30	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.72				
Menefee	30	Somewhat limited		Very limited		Very limited	
		Slope	0.72	Thin layer	1.00	Depth to water	1.00
		Depth to bedrock	0.69				
Rock outcrop	25	Not rated		Not rated		Not rated	
397:							
Rock outcrop	30	Not rated		Not rated		Not rated	
Cucho	25	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.99	Thin layer	0.61	Depth to water	1.00
		Seepage	0.04				
		Depth to bedrock	0.02				
Vessilla	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.97	Seepage	0.01		

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
398:							
Espiritu	45	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.04	Depth to water	1.00
		Slope	0.59				
Cucho	35	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.72	Thin layer	0.61	Depth to water	1.00
		Seepage	0.04				
		Depth to bedrock	0.02				
399:							
Cucho	45	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.41	Thin layer	0.61	Depth to water	1.00
		Seepage	0.04				
		Depth to bedrock	0.02				
Teco	35	Very limited		Not limited		Very limited	
		Seepage	1.00			Depth to water	1.00
		Slope	0.24				
405:							
Charo	50	Somewhat limited		Somewhat limited		Very limited	
		Depth to bedrock	0.91	Thin layer	0.91	Depth to water	1.00
				Hard to pack	0.26		
Charo, noncobbly	40	Somewhat limited		Somewhat limited		Very limited	
		Depth to bedrock	0.56	Thin layer	0.56	Depth to water	1.00
				Hard to pack	0.03		
409:							
Santa Fe	85	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.41				
410:							
Zia	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
414:							
Wauquie	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.04	Depth to water	1.00
		Slope	0.06				

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
417:							
Jocity	85	Very limited		Very limited		Very limited	
		Seepage	1.00	Piping	1.00	Depth to water	1.00
				Seepage	0.10		
418:							
Jocity	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Piping	0.92	Depth to water	1.00
				Seepage	0.02		
419:							
Santa Fe	40	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.99	Seepage	0.06		
				Large stones content	0.01		
Wauquie	30	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.79	Depth to water	1.00
		Slope	0.88	Large stones content	0.08		
Rock outcrop	20	Not rated		Not rated		Not rated	
420:							
Pinavetes	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.79	Depth to water	1.00
421:							
Gilco, moderately saline, sodic	90	Somewhat limited		Very limited		Very limited	
		Seepage	0.72	Piping	1.00	Depth to water	1.00
				Salinity	0.50		
				Seepage	0.01		
422:							
Vessilla	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.08	Seepage	0.03		
Menefee	30	Somewhat limited		Very limited		Very limited	
		Depth to bedrock	0.84	Thin layer	1.00	Depth to water	1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
422:							
Orlie	25	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.04	Piping	0.01	Depth to water	1.00
423:							
Gilco	85	Somewhat limited		Very limited		Very limited	
		Seepage	0.72	Piping	1.00	Depth to water	1.00
426:							
Aga, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Seepage	1.00	Piping	1.00	Depth to water	1.00
				Seepage	0.79		
				Salinity	0.50		
427:							
Aga	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.02	Cutbanks cave	1.00
						Depth to saturated zone	0.90
428:							
Aga, moderately saline, sodic	85	Very limited		Very limited		Very limited	
		Seepage	1.00	Piping	1.00	Depth to water	1.00
				Salinity	0.50		
				Seepage	0.07		
430:							
Trail	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00
431:							
Trail	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
433:							
Peralta	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Depth to saturated zone	0.86	Cutbanks cave	1.00
				Piping	0.60	Slow refill	0.28
				Seepage	0.01	Depth to saturated zone	0.06
						Salinity and saturated zone	0.06
434:							
Peralta	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Depth to saturated zone	0.86	Cutbanks cave	1.00
				Piping	0.60	Depth to saturated zone	0.06
				Seepage	0.10	Salinity and saturated zone	0.06
437:							
Peralta, moderately saline, sodic	85	Somewhat limited		Very limited		Very limited	
		Seepage	0.72	Piping	1.00	Cutbanks cave	1.00
				Depth to saturated zone	0.86	Salinity and saturated zone	0.78
				Salinity	0.50	Slow refill	0.28
				Seepage	0.01	Depth to saturated zone	0.06
500:							
Rock outcrop	40	Not rated		Not rated		Not rated	
Osha	30	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Thin layer	0.34	Depth to water	1.00
		Slope	1.00	Seepage	0.14		
		Depth to bedrock	0.33				
Rubble land	20	Very limited		Very limited		Very limited	
		Seepage	1.00	Large stones content	1.00	Depth to water	1.00
		Slope	1.00	Seepage	1.00		

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
503:							
Cajete	65	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.05	Depth to water	1.00
		Slope	0.10				
Cypher	25	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.88	Seepage	0.03		
504:							
Orejas	40	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
Guaje	35	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.03	Depth to water	1.00
600:							
Rock outcrop	50	Not rated		Not rated		Not rated	
Cypher	35	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.99				
601:							
Laventana	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Thin layer	0.11	Depth to water	1.00
		Depth to bedrock	0.10				
603:							
Laventana	50	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.82	Thin layer	0.08	Depth to water	1.00
		Seepage	0.72				
		Depth to bedrock	0.08				
Mirand	35	Somewhat limited		Somewhat limited		Very limited	
		Slope	0.12	Piping	0.01	Depth to water	1.00
		Seepage	0.04				
604:							
Cypher	55	Very limited		Very limited		Very limited	
		Depth to bedrock	1.00	Thin layer	1.00	Depth to water	1.00
		Slope	0.28	Seepage	0.03		

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
604:							
Mirand	30	Somewhat limited		Not limited		Very limited	
		Slope	0.72			Depth to water	1.00
608:							
Osha, steep	60	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.10	Depth to water	1.00
		Slope	0.97				
Osha	30	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.25	Depth to water	1.00
		Slope	0.10				
823:							
Gilco, unprotected	85	Somewhat limited		Somewhat limited		Very limited	
		Seepage	0.72	Piping	0.50	Depth to water	1.00
827:							
Aga, unprotected	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.06	Cutbanks cave	1.00
						Depth to saturated zone	0.90
830:							
Trail, unprotected	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.02	Depth to water	1.00
831:							
Trail, unprotected	85	Very limited		Somewhat limited		Very limited	
		Seepage	1.00	Seepage	0.79	Depth to water	1.00
835:							
Peralta, unprotected	85	Somewhat limited		Somewhat limited		Somewhat limited	
		Seepage	0.72	Depth to saturated zone	0.86	Slow refill	0.28
						Cutbanks cave	0.10
						Depth to saturated zone	0.06
						Salinity and saturated zone	0.06

Table 13.--Ponds and embankments--continued

Map symbol and soil name	Pct. of map unit	Pond reservoir areas		Embankments, dikes, and levees		Aquifer-fed excavated ponds	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
842:							
Peralta, moderately saline, sodic, unprotected	85	Somewhat limited		Very limited		Somewhat limited	
		Seepage	0.72	Piping	1.00	Salinity and saturated zone	0.78
				Depth to saturated zone	0.86	Slow refill	0.28
				Salinity	0.50	Cutbanks cave	0.10
						Depth to saturated zone	0.06
850:							
Water	95	Not rated		Not rated		Not rated	
DAM:							
Dam	100	Not rated		Not rated		Not rated	

Table 14.--Engineering properties

(Absence of an entry indicates that the data were not estimated.)

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
1:												
Silver----------	0-4	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	4-8	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	8-20	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	20-39	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	39-60	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
Clovis----------	0-3	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	3-20	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	20-40	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	40-60	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
2:												
Clovis----------	0-3	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	3-24	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	24-60	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
Prieta----------	0-3	Very stony loam	GC	A-2-4	20-50	0	50-70	40-60	30-50	15-35	15-30	5-20
	3-10	Very stony clay loam	GC	A-2-6	20-50	0	50-70	40-60	35-55	15-35	30-40	10-15
	10-14	Very stony clay loam	SC	A-2-6	15-35	0	65-85	55-75	40-60	20-40	30-40	10-15
	14-19	Very stony clay loam	GC	A-2-6	30-50	0	50-70	40-60	35-55	15-35	30-40	10-15
	19-60	Bedrock			---	---	---	---	---	---	---	---
Silver----------	0-8	Loam	CL	A-6	0	0-5	95-100	90-100	80-100	50-60	25-40	10-25
	8-30	Silty clay loam	CL	A-6	0	0-3	95-100	85-100	80-100	70-90	35-45	15-25
	30-60	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
3:												
Montecito-------	0-3	Fine sandy loam	SC-SM	A-4	0	0-9	90-100	85-100	75-85	35-50	20-30	4-7
	3-18	Clay loam	CL	A-6	0	0-6	90-100	85-100	80-95	70-90	35-50	15-25
	18-60	Clay loam	CL	A-6	0	0-3	90-100	85-100	80-95	70-90	35-50	15-25
Orejas----------	0-2	Cobbly loam	GC	A-6	0	15-40	60-80	60-80	50-70	30-50	20-35	10-20
	2-5	Very cobbly clay loam	GC	A-2-6	0	25-50	45-65	45-65	40-60	20-40	25-40	10-20
	5-14	Very cobbly clay loam	GC	A-2-6	0	30-50	45-65	45-65	40-60	20-40	25-40	10-20
	14-17	Very cobbly clay loam	GC	A-2-6	0	25-55	45-65	45-65	40-60	20-40	25-40	10-20
	17-19	Very gravelly clay loam	SC	A-2-6	0	0-15	80-100	50-70	40-60	20-40	25-40	10-20
	19-60	Bedrock			---	---	---	---	---	---	---	---
4:												
Montecito-------	0-3	Fine sandy loam	SC-SM	A-4	0	0-10	90-100	85-100	75-85	35-50	20-30	4-7
	3-22	Clay loam	CL	A-6	0	0-5	90-100	85-100	80-95	70-90	35-50	15-25
	22-60	Loam	CL	A-6	0	0-5	90-100	85-95	80-95	50-60	25-40	10-25
Montecito, bouldery-------	0-5	Extremely bouldery loam	GC-GM	A-1-b	10-35	20-45	30-50	30-45	25-40	15-25	20-30	4-7
	5-28	Clay loam	CL	A-6	0-3	0-6	90-100	85-95	80-90	70-90	35-50	15-25
	28-45	Loam	CL	A-6	0	0-5	90-100	85-95	80-90	50-60	25-40	10-25
	45-60	Sandy loam	SC-SM	A-2-4	0	0-5	90-100	85-95	60-80	25-45	20-30	4-7
10:												
Trail-----------	0-6	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	6-30	Stratified loamy sand to sandy loam	SM	A-2-4	0	0	100	100	60-80	20-40	16-24	2-6
	30-45	Sand	SW-SM	A-2-4, A-3	0	0	100	100	60-80	0-20	0-0	NP
	45-60	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
11:												
Trail-----------	0-9	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	9-36	Stratified loamy sand to sandy loam	SM	A-2-4	0	0	100	100	60-80	20-40	15-20	NP-4
	36-60	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
13:												
Sandoval--------	0-2	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	2-6	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	6-10	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	10-15	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	15-60	Bedrock			---	---	---	---	---	---	---	---

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
13:												
Querencia-------	0-4	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	4-12	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	12-24	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	24-60	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
15:												
Camino----------	0-2	Silty clay loam	CL	A-6	0	0	100	100	92-100	75-90	35-45	15-25
	2-5	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	5-20	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	20-51	Clay	CH	A-7-6	0	0	100	90-100	90-100	70-90	50-60	25-35
	51-60	Bedrock			---	---	---	---	---	---	---	---
Sandoval--------	0-2	Fine sandy loam	SC-SM	A-4	0	0-3	95-100	90-100	75-85	35-50	20-30	4-7
	2-17	Clay loam	CL	A-6	0	0	95-100	90-100	85-95	70-90	35-50	15-25
	17-60	Bedrock			---	---	---	---	---	---	---	---
16:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
Prieta----------	0-5	Stony silt loam	SC, CL	A-4, A-6	0-15	0	80-100	70-90	60-80	40-60	20-30	10-15
	5-15	Very stony clay loam	SC	A-2-6	25-45	0	55-75	35-55	25-45	10-30	30-40	10-15
	15-19	Very stony clay loam	GC	A-2-6	30-50	0	50-70	40-60	30-50	10-30	30-40	10-15
	19-60	Bedrock			---	---	---	---	---	---	---	---
17:												
Vessilla--------	0-5	Sandy loam	SC-SM	A-2-4	0	0-5	100	100	60-80	25-45	20-30	4-7
	5-11	Sandy loam	SC-SM	A-2-4	0	0-6	90-100	85-100	55-75	25-45	20-30	4-7
	11-60	Bedrock			---	---	---	---	---	---	---	---
Menefee---------	0-3	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	3-10	Clay loam	CL	A-6	0	0	90-100	85-100	80-100	65-85	35-50	15-25
	10-60	Bedrock			---	---	---	---	---	---	---	---
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
18:												
Sparham---------	0-7	Clay	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	7-20	Clay, clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	20-29	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	29-47	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	47-53	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	53-60	Clay loam	CL	A-6	0	0	100	85-100	80-90	70-90	35-50	15-25
20:												
Gilco-----------	0-6	Clay loam	CL	A-6	0	0	90-100	80-100	80-90	70-90	35-50	15-25
	6-60	Stratified fine sandy loam to loam	CL, SC-SM	A-6, A-4	0	0	90-100	80-100	80-90	50-60	25-40	10-25
21:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
Hackroy---------	0-3	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	3-12	Clay	CH	A-7-6	0	0	95-100	95-100	90-100	70-90	50-60	25-35
	12-60	Bedrock			---	---	---	---	---	---	---	---
22:												
Aga-------------	0-8	Silty clay loam	CL	A-6	0	0	100	100	95-100	85-95	35-40	15-20
	8-24	Loam	CL	A-4	0	0	95-100	90-100	65-95	40-70	20-25	5-10
	24-60	Sand	SW-SM, SM	A-3, A-2	0	0	90-100	85-100	50-80	5-30	0-0	NP
23:												
Hickman---------	0-4	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	4-12	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	12-49	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	49-60	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
24:												
Orlie-----------	0-2	Fine sandy loam	SC-SM	A-4	0	0	90-100	75-100	70-90	35-50	20-30	4-7
	2-25	Clay loam	CL	A-6	0	0	85-100	85-100	75-95	70-90	35-50	15-25
	25-60	Stratified sandy clay loam to clay loam	SC	A-6	0	0	90-100	85-100	75-90	40-50	25-35	10-20
Sparham---------	0-3	Clay	CH	A-7-6	0	0	90-100	85-95	80-90	70-90	50-60	25-35
	3-60	Silty clay	CL	A-7-6	0	0	100	85-100	80-100	75-95	40-50	15-25

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
25:												
Gilco----------	0-4	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	4-34	Stratified silt loam to loam to fine sandy loam	CL, CL-ML, SC-SM	A-6, A-4	0	0	100	100	80-100	50-60	20-40	4-25
	34-60	Stratified fine sandy loam to loam	CL-ML	A-4	0	0	100	100	80-100	50-60	20-30	4-7
26:												
Orlie----------	0-2	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	2-13	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	13-22	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	22-36	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-50	15-25
	36-50	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	50-60	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-50	15-25
27:												
Aga----------	0-10	Loam	CL	A-4	0	0	100	100	70-95	45-70	20-30	5-10
	10-23	Loam	CL	A-4	0	0	95-100	90-100	65-95	40-70	20-25	5-10
	23-43	Sand	SW-SM	A-2-4	0	0	100	100	65-80	0-20	0-0	NP
	43-60	Sand	SW-SM	A-2-4	0	0	100	85-95	65-80	0-20	0-0	NP
29:												
Trail----------	0-6	Loamy sand	SM	A-2-4	0	0	100	100	60-80	20-40	15-20	NP-4
	6-60	Stratified loamy sand to sandy loam	SM	A-2-4	0	0	100	100	60-80	20-40	14-23	2-4
31:												
Riverwash-------	0-6	Sand	SP-SM	A-3	0	0-4	79-100	78-100	59-77	4-7	0-14	NP
	6-60	Stratified coarse sand to sandy loam	SW-SM, SP, SP-SM	A-1, A-2, A-3	0	0-6	81-100	57-100	40-75	3-11	10-15	NP-3
33:												
Pits----------	0-60	Variable			---	---	---	---	---	---	---	---
34:												
Ildefonso-------	0-3	Cobbly loam	SC	A-6	3-10	15-30	65-85	60-75	40-60	30-50	25-35	10-20
	3-17	Cobbly loam	CL, GC	A-6	0	15-30	65-85	65-80	45-65	45-55	25-35	10-20
	17-60	Stratified very cobbly sandy loam to very cobbly loam	GC	A-2-4	0	43-65	50-70	40-60	20-30	15-30	20-30	6-13
Witt----------	0-3	Very fine sandy loam	CL, SC	A-4	0	0	100	100	80-100	40-60	25-35	5-15
	3-27	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	27-60	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
41:												
Dune land-------	0-6	Sand	SW-SM	A-2-4, A-3	0	0	100	100	50-70	0-15	5-15	NP
	6-60	Sand, fine sand	SM	A-2-4	0	0	100	100	50-80	0-25	5-15	NP
47:												
Cascajo---------	0-2	Very gravelly sandy loam	SC-SM	A-2-4	0	10-25	65-85	30-50	25-45	20-40	20-30	4-7
	2-5	Very gravelly sandy loam	SC-SM	A-2-4	0	10-25	70-90	35-50	25-45	20-40	20-30	4-7
	5-11	Very gravelly sandy loam	SC-SM	A-2-4	0	0-10	65-85	45-65	40-60	25-45	20-30	4-7
	11-23	Very gravelly loamy sand	SM	A-2-4	0	0-10	60-80	40-50	35-45	20-40	15-20	NP-4
	23-30	Very gravelly loamy sand	SM	A-1-b	0	0-20	55-75	35-55	30-45	15-35	15-20	NP-4
	30-60	Extremely cobbly loamy sand	GM	A-1-a	0	25-60	30-50	15-25	15-25	10-20	15-20	NP-4
51:												
Sparham---------	0-6	Clay loam	CL	A-6	0	0	100	90-100	85-95	65-85	35-50	15-25
	6-20	Clay loam	CL	A-6	0	0	100	95-100	90-100	70-90	35-50	15-25
	20-36	Clay	CH	A-7-6	0	0	100	95-100	90-100	70-90	50-60	25-35
	36-60	Clay loam	CL	A-6	0	0	100	95-100	90-100	70-90	35-50	15-25
52:												
Totavi----------	0-15	Loamy sand	SM	A-2-4	0	0	100	85-100	60-80	15-35	10-20	NP-4
	15-19	Loamy sand	SM	A-2-4	0	0	100	85-100	60-80	15-35	10-20	NP-4
	19-60	Loamy sand	SM	A-2-4	0	0	100	85-100	60-80	15-35	10-20	NP-4

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
53:												
Witt	0-3	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	3-6	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	6-11	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	11-18	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	18-25	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	25-39	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	39-53	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	53-60	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
Harvey	0-10	Loam	CL	A-6	0	0	95-100	90-100	85-100	50-60	25-40	10-25
	10-28	Clay loam	CL	A-6	0	0	95-100	90-100	85-95	70-90	35-50	15-25
	28-42	Sandy clay loam	SC	A-6	0	0	90-100	85-95	75-90	40-50	25-35	10-20
	42-60	Sandy loam	SC-SM	A-2-4	0	0	95-100	90-100	60-80	25-45	20-30	4-7
54:												
Harvey	0-2	Fine sandy loam	SC-SM	A-4	0	0	95-100	90-100	75-85	35-50	20-30	4-7
	2-11	Fine sandy loam	SC-SM	A-4	0	0	100	95-100	75-85	35-50	20-30	4-7
	11-23	Clay loam	CL	A-6	0	0	90-100	85-95	80-90	70-90	35-50	15-25
	23-60	Sandy clay loam	SC	A-6	0	0	95-100	90-100	75-90	40-50	25-35	10-20
Cascajo	0-3	Very gravelly sandy loam	SC-SM	A-2-4	0	0-15	65-85	45-60	40-60	25-45	20-30	4-7
	3-9	Very gravelly sandy loam	SC-SM	A-2-4	0	0-15	70-90	50-65	45-65	25-45	20-30	4-7
	9-28	Very gravelly sand	SW-SM	A-1-b	0	0-15	60-80	40-60	35-45	0-20	0-0	NP
	28-60	Very gravelly sand	SW-SM	A-1-b	0	5-25	70-90	40-60	30-50	0-20	0-0	NP
55:												
La Fonda	0-4	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	4-26	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	26-60	Loam, clay loam	CL	A-6	0	0	100	95-100	85-100	50-60	25-40	10-25
56:												
Ildefonso	0-3	Cobbly loam	CL	A-6	0-5	15-30	70-85	60-80	45-65	40-60	25-40	10-25
	3-9	Cobbly loam	CL	A-6	0	10-30	70-85	65-80	50-70	50-65	25-40	10-25
	9-15	Very gravelly loam	SC	A-6	0	0-10	75-95	50-65	40-60	35-55	25-40	10-25
	15-60	Very cobbly loam	GC	A-2-6	5-10	35-55	40-55	40-55	25-35	20-35	25-40	10-25
57:												
Badland	0-60	Bedrock			---	---	---	---	---	---	---	---
58:												
Deama	0-7	Very stony silt loam	ML	A-4	10-25	0-15	60-80	55-75	50-70	45-65	25-30	4-7
	7-14	Very cobbly silt loam	ML	A-4	5-12	5-20	70-85	50-65	50-65	45-65	25-30	4-7
	14-60	Bedrock			---	---	---	---	---	---	---	---
Elpedro	0-5	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	5-12	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	12-19	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	19-25	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	25-36	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	36-45	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	45-60	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
59:												
Harvey	0-4	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	4-10	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	10-18	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	18-41	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	41-60	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
Ildefonso	0-2	Cobbly loam	CL	A-6	0	0-15	85-100	75-95	70-90	50-60	25-40	10-25
	2-8	Very gravelly loam	SC	A-4	0	0-20	80-100	40-60	40-55	40-50	20-30	7-10
	8-13	Very gravelly loam	SC	A-4	0	5-20	75-95	35-55	35-50	30-50	20-30	7-10
	13-32	Very cobbly sandy loam	GM	A-2-4	0	20-45	55-75	35-55	30-50	25-45	15-25	NP-4
	32-40	Very cobbly sandy loam	GM	A-2-4	0	20-50	50-70	35-55	30-50	25-45	15-25	NP-4
	40-60	Extremely cobbly sand	GW-GM	A-1-a	0	35-60	30-50	15-25	10-20	0-20	0-0	NP

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
59:												
La Fonda--------	0-3	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	3-7	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	7-14	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	14-26	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	26-42	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	42-60	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
63:												
Placitas--------	0-5	Gravelly loam	SC	A-2-4	0	0	100	60-80	45-60	15-35	20-30	5-20
	5-10	Very gravelly sandy loam	SM	A-1-b	0	0	100	50-70	30-50	10-30	10-25	NP-4
	10-27	Very gravelly sandy loam	SW-SM	A-1-b	0	0	100	35-55	15-35	0-20	10-25	NP-4
	27-60	Bedrock			---	---	---	---	---	---	---	---
64:												
Skyvillage------	0-4	Fine sandy loam	SC-SM	A-4	0	0-5	95-100	90-100	75-85	35-50	20-30	4-7
	4-11	Fine sandy loam	SC-SM	A-4	0	0-5	95-100	85-100	75-85	35-50	20-30	4-7
	11-18	Sandy loam	SC-SM	A-2-4	0	0-5	95-100	90-100	60-80	25-45	20-30	4-7
	18-60	Bedrock			---	---	---	---	---	---	---	---
Ildefonso-------	0-3	Gravelly sandy loam	SC-SM	A-2-4	0-3	0-15	70-85	55-75	50-70	25-45	20-30	4-7
	3-14	Very gravelly sandy loam	SM	A-2-4	0-3	5-15	65-85	40-60	35-55	25-45	15-25	NP-4
	14-60	Very gravelly sandy loam	GM	A-2-4	0-3	10-25	40-60	35-55	30-50	25-45	15-25	NP-4
65:												
Ildefonso-------	0-6	Very gravelly sandy loam	GM	A-1-a	0-3	0-25	40-55	35-50	25-35	10-20	15-25	NP-4
	6-38	Very gravelly sandy loam	GM	A-1-b	0-3	0-25	40-60	35-55	25-40	10-30	15-25	NP-4
	38-60	Very gravelly loam, very gravelly sandy loam	GM	A-1-b	0-3	10-25	40-60	35-55	25-50	10-40	15-25	NP-4
Harvey----------	0-4	Loam	CL	A-6	0	0	95-100	90-100	85-100	50-60	25-40	10-25
	4-23	Loam	CL	A-6	0	0	95-100	90-100	85-100	50-60	25-40	10-25
	23-36	Loam	CL	A-6	0	0	90-100	85-95	80-90	50-60	25-40	10-25
	36-60	Sandy loam	SC-SM	A-2-4	0	0	95-100	90-100	60-80	25-45	20-30	4-7
66:												
Zia-------------	0-4	Sandy loam	SC-SM	A-2-4	0	0	100	90-100	60-80	25-45	20-30	4-7
	4-60	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
67:												
Sandoval--------	0-2	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	2-11	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	11-60	Bedrock			---	---	---	---	---	---	---	---
Poley-----------	0-3	Very cobbly loam	SC	A-2-4	0	15-35	65-85	35-55	30-50	20-40	15-30	5-15
	3-12	Clay loam	CL	A-6	0	0	100	80-100	80-90	70-90	35-50	15-25
	12-17	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	17-21	Clay loam	CL	A-6	0	0	100	80-100	80-90	70-90	35-50	15-25
	21-40	Clay loam	CL	A-6	0	0-5	95-100	80-100	80-90	70-90	35-50	15-25
	40-60	Very gravelly sandy loam	GM	A-2-4	0	25-50	50-70	50-70	30-50	20-40	10-25	NP-4
68:												
Penistaja-------	0-2	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-5
	2-15	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	15-27	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	27-38	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	38-60	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
Querencia-------	0-2	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	2-40	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	40-60	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
71:												
Palon-----------	0-6	Cobbly sandy loam	SC-SM	A-2-4	0-3	9-20	75-90	60-80	50-70	15-35	20-30	4-7
	6-27	Very cobbly sandy loam	SM	A-1-b	0-3	20-34	55-75	40-60	40-50	10-30	15-25	NP-4
	27-60	Extremely cobbly sandy loam	GW-GM	A-1-a	0-10	20-40	40-70	20-40	15-35	5-15	10-25	NP-4

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
72:												
Palon	0-2	Slightly decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	2-4	Very cobbly sandy loam	GM	A-2-4	0-15	20-35	50-70	45-65	35-55	20-40	15-25	NP-4
	4-10	Extremely cobbly sandy loam	GW-GM	A-1-a	10-30	25-50	30-50	20-35	15-35	5-15	15-25	NP-4
	10-32	Extremely cobbly sandy loam	GM	A-1-a	15-35	20-50	30-45	20-40	15-35	10-20	15-25	NP-4
	32-53	Very cobbly sandy loam	GM	A-1-b	10-25	15-40	40-60	35-55	30-50	15-35	15-25	NP-4
	53-60	Very cobbly sandy loam	GM	A-1-b	5-20	10-35	50-70	45-65	35-55	15-35	15-25	NP-4
74:												
Origo	0-7	Very cobbly sandy loam	SM	A-1-b	0-3	0-15	75-90	50-70	40-60	15-35	10-20	NP-4
	7-28	Extremely cobbly sandy loam	GM	A-1-b	0	30-55	45-65	25-45	20-40	10-30	10-20	NP-4
	28-60	Extremely cobbly sandy loam	GM	A-1-b	0-15	25-40	50-65	30-45	15-35	10-30	10-20	NP-4
Pavo	0-9	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	9-12	Sandy loam	SC-SM	A-2-4	0	0-10	90-100	85-95	60-80	25-45	20-30	4-7
	12-25	Sandy loam	SC-SM	A-2-4	0	0	100	80-100	60-80	25-45	20-30	4-7
	25-35	Sandy loam	SC-SM	A-2-4	0	0-5	100	90-100	60-80	25-45	20-30	4-7
	35-45	Fine sandy loam	SC-SM	A-4	0	0	100	90-100	75-85	35-50	20-30	4-7
	45-50	Gravelly clay loam	CL, SC	A-6	0	0	90-100	60-80	60-70	40-60	35-50	15-25
	50-60	Sandy loam	SC-SM	A-2-4	0	0	85-100	75-95	60-80	25-45	20-30	4-7
75:												
Origo	0-1	Slightly decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	1-6	Very cobbly sandy loam	GM	A-1-b	0-15	25-50	40-60	35-55	30-50	15-35	15-30	NP-4
	6-12	Very cobbly sandy loam	GM	A-1-b	0-15	20-50	40-60	35-55	25-45	15-35	15-30	NP-4
	12-32	Very cobbly sandy loam	GM	A-1-b	0-15	25-50	40-60	35-55	20-40	10-30	15-30	NP-4
	32-56	Very cobbly sandy loam	GM	A-1-b	0-15	25-50	40-60	40-60	30-50	10-30	15-30	NP-4
	56-60	Very cobbly loamy sand	GM	A-1-b	0-15	25-50	40-60	40-60	30-50	10-20	5-15	NP-4
82:												
Calaveras	0-2	Loam	SC	A-6	0	0-5	95-100	85-95	55-75	35-55	25-40	10-25
	2-6	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	6-40	Very cobbly sandy loam	GP-GC	A-1-b	0-3	14-23	30-50	25-45	15-40	5-30	20-30	4-7
	40-60	Extremely cobbly coarse sandy loam	GC-GM	A-1-b	0-3	30-55	45-60	30-45	20-40	15-35	20-30	4-7
83:												
Calaveras	0-6	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	6-12	Sandy loam	SC-SM	A-4	0	0-5	95-100	85-95	55-75	35-55	20-30	4-7
	12-24	Very cobbly loam, very cobbly sandy loam	GC-GM	A-1-b	0-5	14-23	45-65	40-60	20-35	15-25	20-30	4-7
	24-60	Extremely cobbly coarse sandy loam, extremely cobbly loamy coarse sand	GC-GM	A-1-b	0-5	30-50	40-60	30-45	20-40	15-35	20-30	4-7
Rubble land	0-60	Fragmental material	GW	A-1-a	40-60	20-40	0-15	0-5	0-5	0	0-0	NP

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
85:												
Redondo---------	0-2	Coarse sandy loam	SM	A-2-4	0	0	100	100	50-70	20-40	15-25	NP-4
	2-7	Coarse sandy loam	SM	A-2-4	0	0	100	100	50-70	20-40	15-25	NP-4
	7-15	Coarse sandy loam	SM	A-2-4	0	0-5	95-100	95-100	50-70	20-40	15-25	NP-4
	15-22	Coarse sandy loam	SM	A-2-4	0	0	100	95-100	50-70	20-40	15-25	NP-4
	22-29	Gravelly coarse sandy loam	SM	A-2-4	0	0	100	65-85	50-70	20-40	10-20	NP-4
	29-38	Very gravelly coarse sandy loam	SM	A-1-b	0-10	0-15	75-95	45-65	35-55	10-30	5-15	NP-4
	38-54	Extremely gravelly coarse sandy loam	SW-SM	A-1-a	0-15	0-15	70-90	10-30	0-20	0-10	5-15	NP-4
	54-60	Extremely cobbly coarse sandy loam	SW-SM	A-1-a	5-25	15-35	50-70	0-20	0-20	0-10	5-15	NP-4
86:												
Redondo---------	0-8	Cobbly coarse sandy loam	SM	A-2-4	0	10-20	80-90	70-80	50-70	20-40	15-25	NP-4
	8-13	Very cobbly coarse sandy loam	SM	A-2-4	0-5	10-30	70-80	50-70	40-60	20-40	15-25	NP-4
	13-34	Extremely cobbly coarse sandy loam	GW-GM	A-1-a	0-10	20-60	45-65	25-45	20-30	5-15	10-20	NP-4
	34-60	Extremely cobbly coarse sandy loam	GC-GM	A-1-a	0	40-80	25-45	20-40	15-25	5-15	10-20	NP-4
87:												
Redondo---------	0-6	Cobbly loam	CL, SC	A-4	0	10-20	80-90	70-90	60-80	40-60	20-30	5-15
	6-13	Very cobbly coarse sandy loam	SM	A-1-b	0	15-35	65-85	50-70	40-60	15-35	10-20	NP-4
	13-60	Very cobbly coarse sandy loam	SM	A-1-b	0	15-35	65-85	50-65	40-60	15-35	10-20	NP-4
Rubble land-----	0-60	Fragmental material	GW	A-1-a	50-60	20-30	0-10	0-5	0-5	0	0-0	NP
88:												
Totavi----------	0-12	Sandy loam	SC-SM	A-2-4	0	0	95-100	80-100	60-80	25-45	20-30	4-7
	12-60	Loamy sand	SM	A-2-4	0	0	100	85-100	55-75	15-35	10-20	NP-4
Jemez-----------	0-6	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	6-13	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	13-19	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	19-27	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	27-60	Bedrock			---	---	---	---	---	---	---	---
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
91:												
Zia-------------	0-16	Sandy loam	SC-SM	A-2-4	0	0	100	90-100	60-80	25-45	20-30	4-7
	16-22	Loamy sand	SM	A-2-4	0	0	100	100	60-80	15-35	15-20	NP-4
	22-35	Sandy loam	SC-SM	A-2-4	0	0	100	90-100	60-80	25-45	20-30	4-7
	35-60	Fine sandy loam	SC-SM	A-4	0	0	98-100	85-100	75-85	35-50	20-30	4-7
92:												
Galisteo, moderately saline, sodic--	0-12	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	12-60	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
93:												
Zia-------------	0-8	Loamy sand	SM	A-2-4	0	0	100	90-100	60-80	15-35	15-20	NP-4
	8-60	Sandy loam	SC-SM	A-2-4	0	0	100	90-100	60-80	25-45	20-30	4-7
95:												
El Rancho-------	0-5	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	5-20	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	20-38	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	38-60	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
97:												
El Rancho-------	0-8	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	8-60	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
100:												
Orejas----------	0-5	Very stony loam	GC	A-2-4	5-25	10-30	50-70	50-70	40-50	20-40	20-30	7-10
	5-15	Very cobbly clay loam	GC	A-2-6	0-15	15-40	50-70	50-70	30-40	25-35	30-40	10-15
	15-19	Very cobbly clay loam	GC	A-2-6	0	20-50	50-70	45-65	30-45	25-40	30-40	10-15
	19-60	Bedrock			---	---	---	---	---	---	---	---
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
101:												
Blancot---------	0-2	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	2-5	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	5-14	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	30-40	15-25
	14-23	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	23-40	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	40-49	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	49-60	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
Lybrook---------	0-1	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	1-5	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	5-21	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	21-30	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	30-60	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
102:												
Sparham---------	0-7	Clay loam	CL	A-6	0	0	100	80-100	75-95	65-85	35-50	15-25
	7-29	Clay loam	CL	A-6	0	0	95-100	85-100	80-90	65-85	35-50	15-25
	29-60	Clay loam, silty clay loam	CL	A-6	0	0	100	90-100	85-95	75-95	35-45	15-25
104:												
Cochiti---------	0-7	Gravelly loam	CL	A-6	0	0-10	80-100	70-90	70-80	50-60	25-40	10-20
	7-12	Gravelly clay loam	CL	A-6	0	0-10	80-100	60-80	60-80	55-75	35-50	15-25
	12-20	Very gravelly clay	CH, SC	A-7-6	0	0-10	80-95	50-60	50-60	45-55	50-60	25-35
	20-29	Very gravelly clay loam	SC	A-6	0	0-10	80-95	50-60	50-60	40-50	35-50	15-25
	29-60	Very gravelly sandy loam	SC-SM	A-1-b	0	0-10	80-100	35-55	25-35	20-35	20-30	4-7
Montecito-------	0-3	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	3-9	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	9-15	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	15-22	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	22-37	Sandy loam, loam	SC-SM	A-2-4	0	0	90-100	85-100	60-80	25-45	20-30	4-7
	37-60	Gravelly sandy loam	SM	A-2-4	0	0	85-100	65-85	40-60	20-40	15-25	NP-4
105:												
Badland---------	0-60	Bedrock			---	---	---	---	---	---	---	---
Menefee---------	0-4	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	4-10	Clay loam	CL	A-6	0	0	90-100	85-100	80-100	70-90	35-50	15-25
	10-60	Bedrock			---	---	---	---	---	---	---	---
106:												
Stumble---------	0-4	Very gravelly fine sandy loam	SM	A-1-b	0	0	80-100	45-65	35-55	15-35	15-25	NP-4
	4-10	Gravelly fine sandy loam	SC-SM	A-4	0	0	90-100	65-85	55-75	35-50	20-30	4-7
	10-24	Loamy sand	SM	A-2-4	0	0	100	85-100	60-80	20-40	10-20	NP-4
	24-60	Gravelly coarse sand	SW-SM	A-2-4, A-3	0	0	90-100	70-90	65-80	0-20	0-0	NP
Stumble, sandy--	0-4	Gravelly loamy sand	SM	A-1-b	0	0	85-100	65-80	30-50	10-15	15-20	NP-4
	4-18	Loamy sand	SM	A-2-4	0	0	90-100	80-95	50-65	10-20	15-20	NP-4
	18-60	Gravelly coarse sand, gravelly loamy sand	SW-SM	A-1-b	0	0	80-100	65-80	20-40	5-10	10-15	NP-4

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
108:												
Embudo----------	0-6	Gravelly sandy loam	SC-SM	A-2-4	0	0	80-100	65-85	60-80	25-45	20-30	4-7
	6-30	Sandy loam	SC-SM	A-2-4	0	0	90-100	85-90	60-80	25-45	20-30	4-7
	30-60	Loamy sand	SC-SM	A-2-4	0	0	90-100	85-90	55-65	15-35	20-30	4-7
109:												
Embudo----------	0-4	Gravelly sandy loam	SC-SM	A-2-4	0	0	90-100	70-90	60-80	25-45	20-30	4-7
	4-12	Gravelly fine sandy loam	SC-SM	A-4	0	0	90-100	75-95	75-85	35-50	20-30	4-7
	12-30	Gravelly coarse sandy loam	SC-SM	A-2-4	0	0	85-95	70-90	60-80	15-35	20-30	4-7
	30-60	Gravelly loamy coarse sand	SM	A-2-4	0	0	90-100	60-80	55-65	10-20	10-20	NP-4
Tijeras---------	0-4	Gravelly fine sandy loam	SM	A-2-4	0	0	100	70-90	50-70	30-40	15-25	NP-4
	4-10	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	10-20	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	20-26	Gravelly sandy loam	SM	A-2-4	0	0	100	70-90	50-70	25-35	15-25	NP-4
	26-60	Very gravelly coarse sandy loam	SM	A-2-4	0	0	80-100	40-60	35-55	5-25	15-25	NP-4
110:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
Saido-----------	0-5	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	5-9	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	9-15	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	15-25	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	25-60	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
111:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
Zia-------------	0-5	Sandy loam	SC-SM	A-2-4	0	0	100	95-100	60-80	25-45	20-30	4-7
	5-60	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
112:												
Tijeras---------	0-3	Gravelly fine sandy loam	SC-SM	A-4	0	0-10	85-100	70-85	60-80	30-50	20-30	4-7
	3-14	Sandy clay loam	SC	A-6	0	0	95-100	80-95	70-90	30-50	25-35	10-20
	14-60	Gravelly sandy loam	SC-SM	A-2-4	0	0	85-100	60-80	40-60	25-45	20-30	4-7
114:												
San Mateo-------	0-7	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	7-60	Stratified sandy loam to loam to clay loam to silty clay loam	CL, SC	A-6	0	0	100	90-100	80-100	40-60	25-40	10-25
Zia-------------	0-3	Fine sandy loam	SC-SM	A-4	0	0	100	90-100	75-85	35-50	20-30	4-7
	3-60	Fine sandy loam	SC-SM	A-4	0	0	100	95-100	75-85	35-50	20-30	4-7
120:												
Pinavetes-------	0-10	Loamy sand	SM	A-2	0	0	100	100	60-80	15-35	15-20	NP-4
	10-35	Sand	SW-SM	A-3	0	0	100	100	65-80	0-20	0-0	NP
	35-60	Sand	SW-SM	A-3	0	0	100	85-100	65-80	0-20	0-0	NP
124:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
129:												
Menefee---------	0-5	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	5-10	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	10-17	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	17-60	Bedrock			---	---	---	---	---	---	---	---
130:												
Pinavetes-------	0-2	Loamy sand	SM	A-2-4	0	0	100	100	60-80	10-30	15-20	NP-4
	2-60	Loamy sand	SM	A-2-4	0	0	100	100	60-80	10-30	15-20	NP-4
Galisteo, moderately saline, sodic--	0-2	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	2-60	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
142:												
Grieta----------	0-3	Fine sandy loam	SC-SM	A-4	0	0	100	90-100	75-85	35-50	20-30	4-7
	3-11	Fine sandy loam	SC-SM	A-4	0	0	90-100	85-100	75-85	35-50	20-30	4-7
	11-34	Sandy clay loam	SC	A-6	0	0	100	90-100	75-90	40-50	25-35	10-20
	34-48	Sandy clay loam	SC	A-6	0	0	90-100	90-100	75-90	40-50	25-35	10-20
	48-60	Loamy sand	SM	A-2-4	0	0	90-100	90-100	60-80	15-35	10-20	NP-4
143:												
Clovis----------	0-3	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	3-7	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	7-12	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	12-22	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	22-34	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	34-60	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
145:												
Grieta----------	0-7	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
	7-14	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-25
	14-21	Sandy clay loam	SC	A-6	0	0	90-100	90-100	75-90	40-50	25-35	10-25
	21-38	Coarse sandy loam	SC-SM	A-2-4	0	0	90-100	85-100	55-75	20-40	15-30	4-7
	38-50	Coarse sandy loam	SC-SM	A-2-4	0	0	100	95-100	55-75	20-40	15-30	4-7
	50-60	Coarse sandy loam	SC-SM	A-2-4	0	0	100	95-100	55-75	20-40	15-30	4-7
Sheppard--------	0-5	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	5-15	NP-4
	5-27	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	5-15	NP-4
	27-60	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	5-15	NP-4
146:												
Sedmar----------	0-3	Loamy sand	SM	A-2-4	0	0	100	100	60-80	20-40	5-15	NP-4
	3-13	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	13-18	Loamy sand	SM	A-2-4	0	0	100	100	60-80	20-40	5-15	NP-4
	18-60	Bedrock			---	---	---	---	---	---	---	---
150:												
Doakum----------	0-5	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	5-11	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	11-17	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	17-24	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	24-31	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	31-44	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	44-60	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
Betonnie--------	0-2	Fine sandy loam	SC-SM	A-4	0	0	90-100	80-95	75-85	35-50	20-30	4-7
	2-4	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	4-12	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	12-18	Sandy loam	SC-SM	A-2-4	0	0	95-100	80-95	60-80	25-45	20-30	4-7
	18-34	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	34-60	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
162:												
Hackroy---------	0-3	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	3-13	Clay	CH	A-7-6	0	0	95-100	95-100	85-95	70-90	50-60	25-35
	13-60	Bedrock			---	---	---	---	---	---	---	---
Nyjack----------	0-3	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	3-13	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	13-24	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	24-39	Gravelly sandy loam	SC-SM	A-2-4	0	0	75-95	65-85	60-80	25-45	2-30	4-7
	39-60	Bedrock			---	---	---	---	---	---	---	---
163:												
Jemez-----------	0-3	Loam	CL	A-6	0	0	100	90-100	80-100	50-60	25-40	10-25
	3-24	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	24-39	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	39-60	Bedrock			---	---	---	---	---	---	---	---
170:												
San Mateo-------	0-2	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	2-10	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	10-23	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	23-32	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	32-54	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	54-60	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
180:												
Councelor-------	0-2	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	2-7	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	30-50	20-30	4-7
	7-37	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	30-50	20-30	4-7
	37-40	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	40-60	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
Eslendo---------	0-3	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	3-10	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	10-60	Bedrock			---	---	---	---	---	---	---	---
Mespun----------	0-6	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
	6-60	Loamy sand	SM	A-2-4	0	0	100	100	60-80	15-35	15-20	NP-4
183:												
Sheppard--------	0-4	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
	4-45	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
	45-60	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
185:												
Frijoles--------	0-3	Very fine sandy loam	CL-ML	A-4	0	0	100	100	80-100	45-60	20-30	4-7
	3-8	Very gravelly clay loam	CL	A-6	0	0	90-100	55-75	50-70	45-65	35-50	15-25
	8-13	Very gravelly clay loam	CL, SC	A-6	0	0	80-100	45-65	45-55	40-55	35-50	15-25
	13-20	Extremely gravelly sandy loam	SC-SM	A-1-b	0	0	60-80	20-40	20-30	15-25	20-30	4-7
	20-60	Fragmental material	SP	A-1-a	0	0	80-90	0-10	0-5	0-5	0-10	NP
190:												
Zia---------	0-5	Sandy loam	SC-SM	A-2-4	0	0	100	85-100	60-80	25-45	20-30	4-7
	5-28	Sandy loam	SC-SM	A-2-4	0	0	100	95-100	60-80	25-45	20-30	4-7
	28-60	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
Skyvillage------	0-2	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	2-11	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	11-16	Fine sandy loam	SC-SM	A-4	0	0	100	85-100	75-85	35-50	20-30	4-7
	16-60	Bedrock			---	---	---	---	---	---	---	---
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
191:												
Sheppard--------	0-3	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
	3-27	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
	27-60	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
200:												
Sedillo---------	0-4	Very cobbly sandy loam	SM	A-1-b	3-6	14-17	70-90	50-70	25-45	10-30	15-25	NP-4
	4-13	Very gravelly sandy clay loam	SC	A-2-4	0-3	5-15	80-100	50-70	30-50	20-40	20-30	5-15
	13-60	Extremely gravelly coarse sandy loam	SW-SM	A-1-a	0-10	10-20	70-90	30-50	10-20	5-15	15-25	NP-4
201:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
Sedgran---------	0-4	Extremely gravelly loamy coarse sand	SW-SM	A-1-a	0	10-35	70-90	25-45	10-30	0-10	10-20	NP-4
	4-13	Very gravelly loamy coarse sand	SW-SM	A-1-b	0	0-10	90-100	45-65	20-40	5-20	10-20	NP-4
	13-60	Bedrock			---	---	---	---	---	---	---	---
206:												
Pinitos---------	0-4	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	4-10	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	10-27	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	27-39	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	39-60	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
207:												
Penistaja-------	0-3	Very fine sandy loam	CL-ML, SC-SM	A-4	0	0	100	100	80-100	40-60	20-30	4-7
	3-29	Sandy clay loam, clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	29-60	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
Zia-------------	0-5	Fine sandy loam	SC-SM	A-4	0	0	100	90-100	75-85	35-50	20-30	4-7
	5-60	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
208:												
Sedillo---------	0-2	Very gravelly fine sandy loam	SM	A-1-a	0	0	100	35-55	20-40	10-20	10-20	NP-4
	2-8	Very gravelly sandy clay loam	SC	A-2-4	0	0	100	40-60	30-40	20-30	15-30	5-15
	8-12	Very gravelly sandy loam	SM	A-1-a	0	0	100	40-60	20-40	10-20	10-20	NP-4
	12-60	Extremely gravelly sandy loam	SW-SM	A-1-a	0	0	100	30-50	15-35	5-15	10-20	NP-4
210:												
Ildefonso-------	0-3	Very stony loam	GC	A-6	35-50	0-10	40-65	35-55	35-50	35-45	20-30	4-20
	3-9	Very stony loam	GC	A-6	35-50	0-5	40-60	40-55	35-55	30-50	20-30	4-20
	9-60	Very stony loam	GC	A-6	35-50	5-15	45-55	40-55	40-50	35-50	20-30	4-20
211:												
Zia-------------	0-5	Sandy loam	SC-SM	A-2-4	0	0	100	90-100	60-80	25-45	20-30	4-7
	5-14	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	14-33	Sandy loam	SC-SM	A-2-4	0	0	100	95-100	60-80	25-45	20-30	4-7
	33-46	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	46-60	Sandy loam	SC-SM	A-2-4	0	0	100	90-100	60-80	25-45	20-30	4-7
Clovis----------	0-5	Fine sandy loam	SC-SM	A-4	0	0	100	100	70-90	40-60	20-30	4-7
	5-60	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
213:												
Pinavetes-------	0-7	Sand	SW-SM	A-2-4, A-3	0	0	100	100	50-70	0-20	0-0	NP
	7-60	Stratified sand to loamy sand	SW-SM	A-2-4, A-3	0	0	100	100	71-76	0-20	0-0	NP
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
215:												
Ess-------------	0-7	Very cobbly sandy loam	GC-GM	A-2-4	0-10	20-40	50-70	40-60	35-55	25-45	20-30	4-7
	7-15	Very cobbly sandy loam	GC-GM	A-2-4	0-10	20-35	55-75	45-65	40-55	25-45	20-30	4-7
	15-29	Very cobbly sandy clay loam	GC	A-6	0-15	15-35	50-70	40-60	40-50	35-45	25-35	10-20
	29-60	Very cobbly loam	GC	A-6	0-10	10-30	60-80	35-55	35-50	30-50	25-40	10-25
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
217:												
Witt------------	0-2	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	2-9	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	9-60	Stratified very fine sandy loam to loam	CL, SC	A-6	0	0	100	100	85-100	40-60	25-40	10-25
218:												
Ildefonso-------	0-4	Very cobbly loam	GC	A-6	0-10	25-45	50-70	45-65	40-60	35-55	20-35	10-20
	4-8	Very cobbly loam	GC	A-6	0-10	30-50	45-65	40-60	40-60	30-50	20-35	10-20
	8-60	Very cobbly sandy loam	GC-GM	A-2-4	0-10	25-45	50-70	45-60	25-35	25-35	15-25	4-7
220:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
Vessilla--------	0-2	Sandy loam	SC-SM	A-2-4	0	0-10	100	100	60-80	25-45	20-30	4-7
	2-10	Sandy loam	SC-SM	A-2-4	0	0-10	90-100	85-100	50-70	20-40	20-30	4-7
	10-60	Bedrock			---	---	---	---	---	---	---	---

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
220:												
Menefee---------	0-2	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	2-10	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	10-60	Bedrock			---	---	---	---	---	---	---	---
226:												
Galisteo, moderately saline, sodic--	0-10	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	10-60	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
227:												
Hagerman--------	0-4	Fine sandy loam	SC-SM	A-4	0	0	95-100	90-100	75-85	35-50	20-30	4-7
	4-34	Clay loam	CL	A-6	0	0	95-100	90-100	85-95	70-90	35-50	15-25
	34-60	Bedrock			---	---	---	---	---	---	---	---
Bond------------	0-4	Loamy fine sand	SM	A-2-4	0	0-10	90-100	85-100	50-85	15-45	15-20	NP-4
	4-12	Sandy clay loam	CL	A-6	0	0-10	90-100	90-100	75-90	50-70	25-35	10-20
	12-60	Bedrock			---	---	---	---	---	---	---	---
228:												
Winona----------	0-2	Very channery fine sandy loam	SW-SM	A-1-a	0	10-20	60-80	35-55	15-35	5-15	10-20	NP-4
	2-13	Very channery loam	SC	A-2-4	0	0	70-90	45-65	35-45	15-35	15-35	5-15
	13-60	Bedrock			---	---	---	---	---	---	---	---
230:												
Skyvillage------	0-6	Sandy loam	SC-SM	A-2-4	0	0-5	95-100	85-100	60-80	25-45	20-30	4-7
	6-11	Sandy loam	SC-SM	A-2-4	0	0-5	95-100	85-100	60-80	25-45	20-30	4-7
	11-60	Bedrock			---	---	---	---	---	---	---	---
Sandoval--------	0-2	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	2-10	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	10-60	Bedrock			---	---	---	---	---	---	---	---
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
231:												
Querencia-------	0-3	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	3-21	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	21-60	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
234:												
Querencia-------	0-3	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	3-25	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	25-60	Stratified loam to fine sandy loam	SC	A-4	0	0	100	100	80-90	40-50	20-40	5-15
Zia-------------	0-11	Sandy loam	SC-SM	A-2-4	0	0	100	90-100	60-80	25-45	20-30	4-7
	11-60	Sandy loam	SC-SM	A-2-4	0	0	100	95-100	60-80	25-45	20-30	4-7
235:												
Sandoval--------	0-2	Fine sandy loam	SC-SM	A-4	0	0	100	95-100	75-85	35-50	20-30	4-7
	2-16	Clay loam	CL	A-6	0	0	95-100	90-100	85-95	70-90	35-50	15-25
	16-19	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	19-60	Bedrock			---	---	---	---	---	---	---	---
236:												
Sparank, moderately saline, sodic--	0-2	Clay loam	CL	A-6	0	0	100	90-100	85-95	70-90	35-50	15-25
	2-10	Silty clay	CL	A-7-6	0	0	100	95-100	90-100	75-95	40-50	15-25
	10-24	Silty clay	CL	A-7-6	0	0	100	95-100	90-100	75-95	40-50	15-25
	24-40	Silty clay loam	CL	A-6	0	0	100	90-100	85-95	70-90	35-45	15-25
	40-44	Silty clay	CL	A-7-6	0	0	100	95-100	90-100	75-95	40-50	15-25
	44-60	Silty clay	CL	A-7-6	0	0	100	90-100	85-95	75-95	40-50	15-25
237:												
Sparank---------	0-4	Silty clay loam	CL	A-6	0	0	100	90-100	90-100	75-90	35-45	15-25
	4-60	Silty clay loam	CL	A-6	0	0	100	95-100	90-100	75-90	35-45	15-25
240:												
Penistaja-------	0-5	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	5-14	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	14-29	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	29-60	Stratified sandy clay loam to fine sandy loam to loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
240:												
Hagerman--------	0-2	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	2-9	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	9-24	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	24-60	Bedrock			---	---	---	---	---	---	---	---
250:												
Pinavetes-------	0-4	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
	4-60	Loamy sand	SM	A-2-4	0	0	100	100	55-75	15-35	15-20	NP-4
262:												
Pastura---------	0-3	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	3-10	Gravelly loam	CL, SC	A-6	0	0	80-100	75-90	70-90	45-60	25-40	10-25
	10-14	Gravelly loam	CL	A-6	0	0	90-100	75-95	65-85	50-60	25-40	10-25
	14-60	Cemented material			---	---	---	---	---	---	---	---
270:												
Blancot---------	0-2	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	2-12	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	12-21	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	21-60	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
Councelor-------	0-2	Fine sandy loam	SC-SM	A-2-4	0	0	100	100	60-70	30-40	20-30	4-7
	2-60	Fine sandy loam, sandy loam	SC-SM	A-4	0	0	100	90-100	65-90	30-50	20-30	4-7
Tsosie----------	0-2	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	2-10	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	10-20	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	20-26	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	26-36	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	36-44	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	44-55	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	55-60	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
281:												
Carjo-----------	0-4	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	4-12	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	12-20	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	20-25	Very fine sandy loam	CL-ML, SC-SM	A-4	0	0	100	100	80-90	40-60	20-30	4-7
	25-60	Bedrock			---	---	---	---	---	---	---	---
282:												
Tocal-----------	0-5	Very fine sandy loam	CL-ML, SC-SM	A-4	0	0	100	100	80-90	40-60	20-30	4-7
	5-8	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	8-11	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	11-14	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	14-60	Bedrock			---	---	---	---	---	---	---	---
283:												
Mirand----------	0-2	Slightly decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	2-6	Loam	CL	A-6	0	0	95-100	90-100	85-100	50-60	25-40	10-25
	6-11	Clay loam	CL	A-6	0	0	90-100	85-95	80-95	70-90	35-50	15-25
	11-17	Gravelly clay loam	CL	A-6	0	0	90-100	80-95	75-90	65-85	35-50	15-25
	17-27	Clay loam	CL	A-6	0	0	90-100	85-95	80-90	70-90	35-50	15-25
	27-47	Clay	CH	A-7-6	0	0	90-100	80-100	80-95	70-90	50-60	25-35
	47-60	Clay loam	CL	A-6	0	0	95-100	85-100	80-95	70-90	35-50	15-25
Alanos----------	0-6	Cobbly loam	GC	A-6	0-5	15-30	65-85	60-70	40-60	25-50	25-40	10-25
	6-9	Cobbly loam	GC	A-6	0-5	15-30	65-85	60-70	40-60	25-50	25-40	10-25
	9-30	Extremely gravelly clay loam	GC, GP-GC	A-2-6	0-10	5-20	15-45	15-35	10-30	5-15	35-50	15-25
	30-60	Very gravelly clay	GC	A-7-6	0-10	0-10	55-75	50-60	40-60	30-50	50-60	25-35
290:												
Alanos----------	0-4	Loam	CL	A-6	0	0	90-100	85-95	80-90	50-60	25-40	10-25
	4-9	Loam	CL	A-6	0	0	90-100	85-95	80-90	50-60	25-40	10-25
	9-18	Very gravelly loam	SC	A-2-6	0	0	65-85	35-55	30-40	30-40	25-40	10-25
	18-26	Extremely gravelly clay	GC	A-2-7	0	10-30	35-55	15-35	10-30	10-20	50-60	25-35
	26-60	Extremely gravelly clay	GC	A-2-7	0	10-30	35-55	15-35	10-30	10-20	50-60	25-35

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
290:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
300:												
Waumac----------	0-3	Loamy sand	SM	A-2-4	0	0	100	100	60-80	20-40	15-20	NP-4
	3-31	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	31-60	Gravelly fine sandy loam	SC-SM	A-2-4	0	0	100	70-90	40-60	20-40	20-30	4-7
Bamac-----------	0-6	Gravelly loamy sand	SM	A-1-b	0	0-10	60-80	55-75	40-60	10-25	15-20	NP-4
	6-60	Stratified very gravelly coarse sand to very gravelly loamy sand	GW-GM	A-1	0	0-8	43-66	40-65	32-54	9-17	15-20	NP-4
301:												
Vastine---------	0-4	Silt loam	ML	A-6	0	0	100	100	89-99	73-83	31-45	10-17
	4-11	Loam	CL	A-6	0	0	100	100	84-94	60-70	26-41	10-17
	11-24	Loam	CL	A-6	0	0	76-100	75-100	63-94	45-70	26-39	10-17
	24-60	Very gravelly loamy sand	GP-GC	A-1	0	0-1	31-54	28-52	22-43	6-13	16-23	2-6
Jarola----------	0-9	Silt loam	CL, ML	A-6	0	0	100	100	89-99	73-83	28-43	10-17
	9-11	Silt loam	CL	A-6	0	0	100	100	89-99	73-83	27-40	10-17
	11-17	Silty clay loam	CL	A-6, A-7	0	0	100	100	96-100	85-92	38-47	19-25
	17-21	Clay loam	CL	A-6, A-7	0	0	100	100	88-95	68-75	37-46	19-25
	21-42	Gravelly sandy clay loam	SC	A-6	0	0	63-100	62-100	50-92	27-55	31-42	13-21
	42-60	Very gravelly sandy loam	SM, GC-GM	A-2-4, A-1-b	0	0	39-59	36-57	26-47	13-26	16-27	2-10
302:												
Tranquilar------	0-4	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	4-8	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	8-11	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	11-13	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	13-20	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	20-34	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	34-42	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	42-50	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	50-60	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
Jarmillo--------	0-4	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	4-13	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	13-20	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	20-26	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	26-36	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	36-41	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	41-51	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	51-60	Very fine sandy loam	CL-ML	A-4	0	0	100	100	80-90	40-60	20-30	4-7
304:												
Cosey-----------	0-9	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	9-15	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	15-28	Gravelly loam	CL	A-6	0	0-15	80-100	60-80	55-65	55-65	25-40	10-25
	28-34	Very gravelly sandy clay loam	SC	A-2-6	0	0-15	80-100	35-55	30-50	15-35	25-35	10-20
	34-60	Extremely cobbly clay loam	GC	A-2-6	0	35-60	50-70	25-35	25-35	25-35	35-50	15-25
Jarmillo--------	0-17	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	17-33	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	33-60	Sandy loam, loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
307:												
Flugle----------	0-3	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	3-7	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	7-12	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	12-19	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	19-60	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
Waumac----------	0-3	Loamy sand	SM	A-2-4	0	0	95-100	95-100	65-85	20-40	15-20	NP-4
	3-60	Stratified fine sandy loam to sandy loam	SC-SM	A-4	0	0	92-100	92-100	65-85	30-50	20-30	4-7

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
308:												
Cajete----------	0-7	Gravelly loam	CL	A-6	0	0	80-100	70-90	70-80	50-60	25-40	10-25
	7-15	Gravelly loam	CL	A-6	0	0	80-100	70-90	70-80	50-60	25-40	10-25
	15-33	Very gravelly sandy loam	SC-SM	A-2-4	0	0	75-95	50-70	45-55	25-45	20-30	4-7
	33-45	Very gravelly sand	SW-SM	A-1-b	0	0	70-90	40-60	30-50	0-15	0-0	NP
	45-49	Extremely gravelly sand	SW-SM	A-1-a	0	0	70-90	30-50	10-30	0-15	0-0	NP
	49-60	Very gravelly sand	SW-SM	A-1-a	0	0	80-90	40-60	10-30	0-15	0-0	NP
311:												
Cosey-----------	0-13	Silt loam	ML	A-4	0-2	0-10	90-100	90-100	80-90	65-80	25-30	4-7
	13-24	Gravelly loam	SC	A-2-6	0-2	0-10	65-75	60-70	50-60	25-45	25-40	10-25
	24-60	Extremely cobbly clay loam	GC	A-2-6	0-15	35-65	30-45	30-45	25-45	15-35	35-50	15-25
Tranquilar------	0-14	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	14-20	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	20-42	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	42-60	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
Calaveras-------	0-4	Silt loam	ML	A-4	0	0	100	90-100	90-100	70-90	25-30	4-7
	4-11	Silt loam	ML	A-4	0	0	100	85-100	85-95	70-85	25-30	4-7
	11-17	Gravelly silt loam	ML	A-4	0-10	0	90-100	65-85	60-80	55-75	25-30	4-7
	17-30	Very cobbly loam	SC	A-6	0-10	10-30	65-85	45-65	40-60	35-55	25-40	10-25
	30-39	Extremely cobbly coarse sandy loam	GC-GM	A-2-4	0-10	15-40	45-65	30-40	25-35	25-35	20-30	4-7
	39-60	Extremely cobbly loamy sand	GM	A-1-b	0-15	15-40	50-70	35-45	20-40	15-35	15-20	NP-4
312:												
Royosa----------	0-5	Sand	SW-SM	A-2-4, A-3	0	0	100	100	65-80	0-20	0-0	NP
	5-16	Sand	SW-SM	A-2-4, A-3	0	0	100	100	65-80	0-20	0-0	NP
	16-60	Loamy sand	SM	A-2-4	0	0	100	100	60-80	10-30	10-20	NP-4
314:												
Fragua----------	0-3	Loamy sand	SM	A-2-4	0	0	100	100	60-80	15-35	10-20	NP-4
	3-8	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	8-24	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	24-60	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
Waumac----------	0-3	Loamy fine sand	SM	A-2-4	0	0	100	95-100	65-85	20-40	15-20	NP-4
	3-60	Fine sandy loam	SC-SM	A-4	0	0	100	95-100	75-85	35-50	20-30	4-7
Royosa----------	0-7	Fine sand	SW-SM	A-2-4, A-3	0	0	100	100	65-80	0-20	0-0	NP
	7-60	Fine sand	SW-SM	A-2-4, A-3	0	0	100	100	65-80	0-20	0-0	NP
317:												
Elpedro---------	0-2	Loam	CL	A-6	0	0	95-100	90-100	85-95	50-60	25-40	10-25
	2-22	Silty clay loam	CL	A-6	0	0	95-100	90-100	90-100	75-90	35-45	15-25
	22-60	Loam	CL	A-6	0	0	95-100	90-100	85-95	50-60	25-40	10-25
319:												
Bamac-----------	0-4	Very gravelly loamy sand	GM	A-1-b	0	0	40-50	35-50	25-45	15-25	10-20	NP-4
	4-10	Loamy sand	SM	A-2-4	0	0-3	90-100	85-95	50-65	5-20	10-20	NP-4
	10-21	Very gravelly loamy coarse sand	GC-GM, GM	A-1-b	0	0	40-50	35-45	30-40	5-25	10-20	NP-4
	21-37	Very gravelly loamy coarse sand	SM	A-1-b	0	0	65-85	35-55	30-50	15-25	10-20	NP-4
	37-60	Very gravelly loamy coarse sand	SM	A-1-b	0	0	65-85	40-60	30-50	15-25	10-20	NP-4
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
320:												
Sparham---------	0-9	Silt loam	ML	A-4	0	0	100	95-100	90-100	70-90	25-30	4-7
	9-32	Silty clay	CL	A-7-6	0	0	95-100	90-100	85-95	75-95	40-50	15-25
	32-60	Silty clay	CL	A-7-6	0	0	90-100	80-95	75-95	65-85	40-50	15-25
321:												
Waumac----------	0-3	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
	3-60	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
321:												
Royosa----------	0-12	Fine sand	SW-SM	A-2-4	0	0	100	100	65-80	0-20	0-0	NP
	12-60	Fine sand	SW-SM	A-2-4	0	0	100	100	65-80	0-20	0-0	NP
322:												
Fragua----------	0-3	Very cobbly fine sandy loam	GC-GM	A-4	0-5	20-30	60-80	45-65	40-60	35-50	20-30	4-7
	3-16	Sandy loam, fine sandy loam, very fine sandy loam	SC-SM	A-4	0	0-5	95-100	90-100	75-85	35-50	20-30	4-7
	16-45	Loamy fine sand	SM	A-2-4	0	0-5	95-100	90-100	65-85	20-40	10-20	NP-4
	45-60	Bedrock			---	---	---	---	---	---	---	---
324:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
Atarque---------	0-3	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	3-9	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	9-14	Sandy clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
	14-60	Bedrock			---	---	---	---	---	---	---	---
Menefee---------	0-2	Gravelly loam	CL	A-6	0	0	90-100	80-90	70-90	50-60	25-40	10-25
	2-9	Clay loam	CL	A-6	0	0	95-100	90-100	85-100	70-90	35-50	15-25
	9-60	Bedrock			---	---	---	---	---	---	---	---
325:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
Espiritu--------	0-2	Very gravelly fine sandy loam	SC-SM	A-2-4	0-5	5-15	65-75	50-65	30-40	25-35	20-30	4-7
	2-20	Very gravelly sandy clay loam	GC	A-6	0-5	10-30	55-75	40-55	40-50	35-45	25-35	10-20
	20-60	Very gravelly loam	SC	A-6	0-5	10-30	65-85	40-50	35-45	30-45	25-40	10-25
Vessilla--------	0-1	Very gravelly sandy loam	SM	A-1-b	0	0-10	80-100	50-70	40-60	10-30	15-25	NP-4
	1-10	Gravelly loam	CL, SC	A-4	0	0-10	85-100	60-80	50-70	40-60	20-35	4-15
	10-60	Bedrock			---	---	---	---	---	---	---	---
342:												
Waumac----------	0-5	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
	5-60	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
Vessilla--------	0-3	Fine sandy loam	SC-SM	A-2-4	0	0-5	95-100	85-95	70-80	30-40	20-30	4-7
	3-13	Fine sandy loam	SC-SM	A-2-4	0	0-5	95-100	85-95	60-80	25-40	20-30	4-7
	13-60	Bedrock			---	---	---	---	---	---	---	---
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
345:												
Espiritu--------	0-6	Very gravelly fine sandy loam	SC-SM	A-4	0	0-20	75-90	50-70	40-50	35-45	20-30	4-7
	6-15	Very gravelly sandy clay loam	SC	A-6	0	0-20	80-100	50-70	45-55	35-45	25-35	10-20
	15-22	Very gravelly sandy clay loam	SC	A-6	0	0-20	70-90	45-60	45-55	35-45	25-35	10-20
	22-29	Very cobbly sandy clay loam	GC	A-6	0	15-30	60-70	45-55	40-50	35-45	25-35	10-20
	29-38	Very cobbly sandy clay loam	GC	A-6	0	15-30	60-80	40-60	40-60	35-45	25-35	10-20
	38-46	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	46-60	Very gravelly sandy loam	SC-SM	A-2-4	0	0-5	75-95	55-65	55-65	25-45	20-30	4-7
Bamac-----------	0-3	Very gravelly loamy sand	GM	A-1-b	0	0-10	45-55	40-50	35-45	15-25	10-20	NP-4
	3-30	Very gravelly loamy sand	GM, SW-SM	A-1-b	0	0-5	55-65	50-55	30-50	5-15	10-20	NP-4
	30-60	Stratified very gravelly loamy sand to loamy sand	SM	A-1-a	0	0-9	70-90	35-55	20-35	5-25	10-20	NP-4

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
346:												
Espiritu, cobbly	0-2	Extremely cobbly sandy loam	GC-GM	A-1-b	10-20	45-60	20-50	15-45	15-25	10-20	20-30	4-7
	2-24	Very gravelly sandy clay loam	SC	A-6	0-3	10-30	65-85	45-55	40-50	35-45	25-35	10-20
	24-36	Extremely gravelly sandy loam	GC-GM	A-2-4	0-3	15-30	50-70	30-50	30-45	25-45	20-30	4-7
	36-60	Very gravelly loamy sand	GM	A-2-4	0-3	15-30	55-75	35-55	30-50	20-40	15-20	NP-4
Bamac----------	0-3	Very gravelly loamy sand	GM	A-1-b	0	0-5	45-55	40-50	35-50	15-25	10-20	NP-4
	3-30	Very gravelly coarse sand, very gravelly loamy sand, very gravelly loamy coarse sand	GW-GM	A-1-b	0	0-5	45-55	40-50	20-40	5-15	10-20	NP-4
	30-45	Loamy sand	SM	A-2-4	0	0	100	100	60-80	20-40	10-20	NP-4
	45-60	Very gravelly loamy sand	GM	A-2-4	0	0-10	45-55	40-55	35-50	15-35	10-20	NP-4
348:												
Wauquie---------	0-2	Extremely gravelly sandy clay loam	SW-SC	A-2-4	0-10	10-20	60-80	30-45	20-30	5-15	15-25	4-15
	2-16	Very gravelly clay loam	SC	A-2-6	0-5	5-15	75-95	50-65	30-50	10-20	30-40	10-15
	16-40	Very gravelly sandy loam	GC-GM	A-1-b	0-3	5-15	35-55	30-50	20-40	5-15	10-25	NP-4
	40-60	Extremely gravelly loamy sand	SW-SM	A-1-a	0-3	10-20	60-80	30-45	10-20	5-10	5-15	NP-4
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
353:												
Cochiti---------	0-4	Extremely gravelly loam	GC	A-2-6	0-5	15-30	20-35	15-30	15-25	10-20	25-40	10-25
	4-22	Very gravelly clay loam	GC	A-6	0-2	10-15	45-60	40-55	35-50	30-45	35-50	15-25
	22-60	Very gravelly loamy sand	GC-GM, GM	A-1-b	0-2	10-15	35-55	30-50	20-40	10-20	15-20	NP-4
Espiritu--------	0-3	Very gravelly loam	SC	A-6	0-5	5-15	70-90	50-70	40-60	30-50	25-40	10-25
	3-16	Very gravelly sandy clay loam	SC	A-6	0-5	5-15	75-95	50-70	40-60	30-50	25-35	10-20
	16-60	Extremely gravelly loamy sand	SM	A-1-a	0	15-25	60-80	30-45	20-40	5-20	10-20	NP-4
354:												
Waumac Variant--	0-3	Very gravelly sandy loam	SM	A-1-b	0	0	85-100	35-60	20-40	10-30	15-25	NP-4
	3-12	Very gravelly sandy loam	SM	A-1-b	0	0	85-100	35-65	20-40	10-30	15-25	NP-4
	12-60	Bedrock			---	---	---	---	---	---	---	---
358:												
Deama-----------	0-3	Very gravelly loam	GC	A-2-6	0-5	5-15	50-60	40-50	35-45	25-35	25-40	10-25
	3-19	Very gravelly loam	GC	A-2-6	0-3	5-15	50-60	40-50	35-45	25-35	25-40	10-25
	19-60	Bedrock			---	---	---	---	---	---	---	---
Elpedro---------	0-3	Very gravelly loam	CL, SC	A-6	0	0-5	80-90	50-65	45-65	40-60	25-40	10-25
	3-37	Silty clay loam	CL	A-6	0	0	95-100	90-100	85-95	75-90	35-45	15-25
	37-60	Loam, silt loam	CL	A-6	0	0	95-100	90-100	85-100	50-60	25-40	10-25
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
396:												
Atarque---------	0-2	Extremely gravelly sandy loam	GC-GM	A-1-a	0-3	10-20	35-55	25-45	15-25	5-15	20-30	4-7
	2-16	Clay loam	CL, SC	A-6	0	0	100	100	80-95	40-60	35-50	15-25
	16-60	Bedrock			---	---	---	---	---	---	---	---
Menefee---------	0-2	Gravelly clay loam	CL	A-6	0	0-5	80-100	70-80	60-80	50-70	35-50	15-25
	2-14	Clay loam	CL	A-6	0	0	100	90-100	85-100	70-90	35-50	15-25
	14-60	Bedrock			---	---	---	---	---	---	---	---
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
397:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
Cucho-----------	0-2	Very gravelly clay loam	SC	A-6	0	0	70-90	45-65	40-60	35-55	35-50	15-25
	2-9	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	9-37	Very gravelly clay loam	SC	A-6	0	0	75-95	40-60	35-55	30-50	35-50	15-25
	37-60	Bedrock			---	---	---	---	---	---	---	---
Vessilla--------	0-2	Gravelly fine sandy loam	SC-SM	A-1-b	0	0	100	65-85	40-60	15-25	20-30	4-7
	2-11	Gravelly fine sandy loam	SC-SM	A-2-4	0	0	100	70-90	45-65	15-30	20-30	4-7
	11-60	Bedrock			---	---	---	---	---	---	---	---
398:												
Espiritu--------	0-4	Very gravelly fine sandy loam	SC-SM	A-4	0	5-15	70-90	50-70	35-55	30-50	20-30	4-7
	4-24	Very gravelly sandy clay loam	SC	A-2-6	0	5-15	70-90	50-70	40-60	25-45	25-35	10-20
	24-60	Extremely gravelly sandy loam	SC-SM	A-2-4	0	15-25	65-85	30-40	25-40	25-35	20-30	4-7
Cucho-----------	0-2	Very gravelly clay loam	SC	A-6	0	0	65-85	40-60	40-50	40-50	35-50	15-25
	2-37	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	37-60	Bedrock			---	---	---	---	---	---	---	---
399:												
Cucho-----------	0-2	Very gravelly clay loam	SC	A-6	0	0	80-100	40-60	35-55	30-50	35-50	15-25
	2-37	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	37-60	Bedrock			---	---	---	---	---	---	---	---
Teco------------	0-1	Very cobbly fine sandy loam	SM	A-2-4	0	10-30	70-90	55-75	45-65	20-40	15-25	NP-4
	1-7	Sandy clay	ML	A-7	0	0	100	100	75-95	60-80	35-55	15-20
	7-23	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	23-40	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	40-45	Very gravelly fine sandy loam	SM	A-1-b	0	5-15	80-95	50-70	20-40	10-20	15-25	NP-4
	45-60	Channery sandy clay loam	SC	A-2-4	0	0	85-100	65-85	45-65	20-40	20-30	4-15
405:												
Charo-----------	0-5	Cobbly loam	CL	A-6	0-5	5-20	70-80	60-70	50-60	45-55	25-40	10-25
	5-12	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	12-15	Clay	CH	A-7-6	0	0	100	100	95-100	70-90	50-60	25-35
	15-25	Clay	CH	A-7-6	0	0-10	90-100	90-100	85-95	70-90	50-60	25-35
	25-28	Clay	CH	A-7-6	0	0-10	90-100	80-95	70-90	65-85	50-60	25-35
	28-60	Bedrock			---	---	---	---	---	---	---	---
Charo, noncobbly	0-8	Loam	CL	A-6	0-2	0-10	90-100	85-95	75-90	50-60	30-35	10-15
	8-38	Clay	CL, CH	A-7-6	0-2	0-10	90-100	85-95	80-90	70-90	40-60	20-30
	38-60	Bedrock			---	---	---	---	---	---	---	---
409:												
Santa Fe--------	0-3	Very gravelly sandy loam	SC-SM	A-1-b	0-5	0-5	90-100	45-65	25-45	10-20	20-30	4-7
	3-8	Very gravelly sandy clay loam	SC	A-2-6	0	5-15	80-100	45-65	35-55	15-35	25-35	10-20
	8-60	Bedrock			---	---	---	---	---	---	---	---

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
410:												
Zia----------	0-10	Loam	CL	A-6	0	0	100	95-100	85-100	50-60	25-40	10-25
	10-60	Stratified sandy loam to fine sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	16-27	4-7
414:												
Wauquie---------	0-3	Very gravelly fine sandy loam	SM	A-1-b	0-3	5-15	75-90	50-70	25-40	10-20	15-25	NP-4
	3-30	Very gravelly sandy clay loam	SC	A-2-4	0-3	10-20	70-90	50-60	25-45	10-30	20-30	4-15
	30-60	Stratified very gravelly sandy loam to very gravelly loamy coarse sand	SW-SM	A-1-b	0-5	16-30	70-90	45-65	15-35	11-25	10-25	NP-4
417:												
Jocity----------	0-10	Loam	CL	A-4	0	0	100	100	85-100	50-60	20-30	4-10
	10-26	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	30-40	10-15
	26-32	Loam	CL	A-4	0	0	100	100	85-100	50-60	25-35	4-15
	32-50	Sandy clay loam	SM	A-4	0	0	100	100	75-90	40-50	10-15	NP-4
	50-56	Sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	25-45	20-30	4-7
	56-60	Loamy sand	SM	A-2-4	0	0	100	100	60-80	15-35	15-20	NP-4
418:												
Jocity----------	0-12	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	12-30	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	30-60	Stratified loamy sand to sandy loam	SC-SM	A-2-4	0	0	100	100	60-80	20-40	15-25	NP-7
419:												
Santa Fe--------	0-9	Extremely cobbly coarse sandy loam	SP-SC	A-1-a	0-5	20-45	50-70	30-50	10-25	5-15	20-30	4-7
	9-16	Very gravelly sandy clay loam	SC	A-2-6	0-5	5-15	80-100	50-70	25-45	10-20	25-35	10-20
	16-60	Bedrock			---	---	---	---	---	---	---	---
Wauquie---------	0-4	Extremely cobbly fine sandy loam	SW-SM	A-1-a	0-10	15-30	60-80	15-35	5-15	0-10	10-20	NP-4
	4-11	Extremely cobbly sandy clay loam	SW-SC	A-2-4	0-10	15-35	60-80	15-35	5-15	0-15	15-25	4-15
	11-18	Extremely cobbly sandy clay loam	SW-SC	A-2-4	0-10	15-35	60-80	15-35	5-15	0-15	15-25	5-15
	18-29	Extremely cobbly sandy loam	SW-SM	A-1-a	0-10	15-35	60-80	10-30	5-15	0-10	15-25	NP-4
	29-60	Extremely cobbly sand	SW-SM	A-1-a	0-10	15-35	60-80	10-30	0-15	0-10	0-0	NP
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
420:												
Pinavetes-------	0-10	Loamy sand	SM	A-2-4	0	0	100	100	60-80	15-35	15-20	NP-4
	10-60	Sand	SW-SM	A-2-4	0	0	100	100	60-80	0-20	10-15	NP-3
421:												
Gilco, moderately saline, sodic--	0-7	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	7-19	Very fine sandy loam	SC-SM	A-4	0	0	100	100	80-90	30-50	20-30	4-7
	19-60	Stratified fine sandy loam to loam	SC-SM, SC	A-4	0	0	84-100	83-100	80-90	40-60	25-35	4-12
422:												
Vessilla--------	0-1	Sandy loam	SC-SM	A-2-4	0	0-10	90-100	90-100	60-80	25-45	20-30	4-7
	1-15	Sandy loam	SC-SM	A-2-4	0	0-10	90-100	90-100	60-80	25-45	20-30	4-7
	15-60	Bedrock			---	---	---	---	---	---	---	---
Menefee---------	0-3	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	3-10	Clay loam	CL	A-6	0	0	90-100	85-100	85-100	70-90	35-50	15-25
	10-60	Bedrock			---	---	---	---	---	---	---	---

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
422:												
Orlie	0-4	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	4-14	Clay loam, silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
	14-60	Silty clay loam	CL	A-6	0	0	100	100	95-100	75-90	35-45	15-25
423:												
Gilco	0-8	Loam	CL	A-6	0	0	85-100	80-100	80-90	50-60	25-40	10-25
	8-14	Loam	CL	A-6	0	0	90-100	85-100	80-90	50-60	25-40	10-25
	14-60	Stratified fine sandy loam to silt loam	CL	A-4	0	0	80-100	80-100	80-90	50-60	20-30	4-12
426:												
Aga, moderately saline, sodic	0-8	Loam	CL	A-6	0	0	100	100	85-95	65-80	25-35	10-25
	8-20	Loam	CL	A-6	0	0	100	100	85-95	55-70	25-35	10-25
	20-36	Loamy sand	SM	A-2-4	0	0	100	95-100	55-75	10-30	0-0	NP
	36-60	Gravelly sand	SW-SM	A-2-4, A-3	0	0	80-100	70-90	65-80	0-20	0-0	NP
427:												
Aga	0-8	Loam	CL	A-6	0	0	100	100	70-95	45-70	25-40	10-25
	8-28	Loam	CL	A-6	0	0	95-100	90-100	65-95	40-70	25-40	10-25
	28-60	Loamy fine sand	SM	A-2-4	0	0	95-100	90-100	50-80	20-40	15-20	NP-4
428:												
Aga, moderately saline, sodic	0-4	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	4-16	Very fine sandy loam	SC-SM	A-4	0	0	100	100	80-90	40-50	20-30	4-7
	16-22	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	22-60	Stratified sand to loamy sand	SM	A-2-4	0	0	100	95-100	60-80	18-30	0-0	NP
430:												
Trail	0-10	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	10-34	Loamy sand	SM	A-4	0	0	100	100	65-85	35-50	15-20	NP-4
	34-60	Stratified sand to fine sandy loam	SW-SM	A-2-4, A-3	0	0	100	100	60-80	0-20	0-0	NP
431:												
Trail	0-10	Loamy sand	SM	A-2-4	0	0	100	100	60-80	20-40	15-20	NP-4
	10-60	Stratified loamy sand to sand to gravelly sand to fine sandy loam	SC-SM	A-2-4	0	0	100	90-100	60-80	0-40	5-20	NP-7
433:												
Peralta	0-10	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	10-60	Stratified very fine sandy loam to fine sandy loam to loamy fine sand	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
434:												
Peralta	0-10	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	10-16	Very fine sandy loam	CL-ML	A-4	0	0	100	100	75-85	40-60	20-30	4-7
	16-20	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	20-28	Fine sandy loam	SC-SM	A-4	0	0	100	100	75-85	35-50	20-30	4-7
	28-40	Loamy sand	SM	A-2-4	0	0	100	100	65-85	15-35	15-20	NP-4
	40-45	Silt loam	ML	A-4	0	0	100	100	90-100	70-90	25-30	4-7
	45-60	Loamy fine sand	SM	A-2-4	0	0	100	100	65-85	20-40	15-20	NP-4
437:												
Peralta, moderately saline, sodic	0-4	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	4-60	Stratified loam to fine sandy loam to loamy sand	SC-SM	A-4	0	0	100	100	75-85	35-50	16-30	4-7
500:												
Rock outcrop	0-60	Bedrock			---	---	---	---	---	---	---	---

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
500:												
Osha----------	0-10	Very gravelly coarse sandy loam	SM	A-1-b	0-2	0-5	80-95	50-70	40-60	15-35	10-25	NP-4
	10-20	Very gravelly coarse sandy loam	SM	A-1-b	0	0	70-90	50-70	40-60	15-35	10-25	NP-4
	20-43	Extremely gravelly loamy coarse sand, extremely gravelly coarse sandy loam	SW-SM	A-1-a	0	0	55-75	25-45	15-35	5-15	0-10	NP
	43-60	Bedrock			---	---	---	---	---	---	---	---
Rubble land-----	0-60	Fragmental material	GW	A-1-a	50-70	20-40	0-10	0-5	0-5	0	0-0	NP
503:												
Cajete----------	0-8	Extremely gravelly coarse sandy loam	SW-SC	A-1-a	0	0	55-75	30-50	5-15	5-10	20-30	4-7
	8-60	Very gravelly sandy loam	SC-SM	A-1-b	0	0	55-70	50-65	30-50	15-30	20-30	4-7
Cypher----------	0-3	Very gravelly loam	GC	A-6	0-3	10-15	40-60	35-55	30-50	30-50	25-40	10-25
	3-11	Very gravelly sandy loam	GC-GM	A-2-4	0-3	10-25	70-90	40-60	30-50	25-45	20-30	4-7
	11-15	Extremely gravelly sandy loam	GC-GM	A-2-4	0-10	10-30	40-60	30-40	25-35	20-35	20-30	4-7
	15-60	Bedrock			---	---	---	---	---	---	---	---
504:												
Orejas----------	0-2	Very cobbly loam	GC	A-2-4	0	15-45	50-70	50-70	40-50	20-45	20-30	7-10
	2-9	Very cobbly clay loam	SC	A-6	0	10-25	70-90	60-75	50-70	30-50	30-40	10-15
	9-17	Very gravelly clay loam	SC	A-2-6	0	0-10	75-90	50-70	50-70	25-50	30-40	10-15
	17-60	Bedrock			---	---	---	---	---	---	---	---
Guaje-----------	0-4	Gravelly sandy loam	SC-SM	A-2-4	0	0	90-100	70-90	60-80	25-45	15-25	4-7
	4-12	Gravelly sandy loam	SC-SM	A-2-4	0	0-15	75-95	60-80	50-70	25-45	15-25	4-7
	12-17	Very gravelly sandy loam	GC-GM	A-1-b	0	0-10	35-55	30-50	20-35	10-30	15-25	NP-7
	17-45	Extremely gravelly sandy loam	SC-SM	A-1-b	0	0-10	80-100	25-45	10-25	5-20	15-25	NP-7
	45-60	Very gravelly sandy loam	SC-SM	A-2-4	0	0-10	80-100	35-55	30-50	25-35	15-25	NP-7
600:												
Rock outcrop----	0-60	Bedrock			---	---	---	---	---	---	---	---
Cypher----------	0-4	Very cobbly loam	GC	A-2-6	0-5	30-55	45-65	45-55	35-55	25-45	25-40	10-25
	4-14	Very gravelly loam	GC	A-2-6	0-5	10-15	40-60	35-55	25-45	20-35	25-40	10-25
	14-16	Very gravelly loam	GC	A-2-6	0-5	10-15	40-60	35-55	25-45	20-35	25-40	10-25
	16-60	Bedrock			---	---	---	---	---	---	---	---
601:												
Laventana-------	0-5	Gravelly sandy loam	SC-SM	A-2-4	0	0-5	90-100	70-85	60-80	25-45	20-30	4-7
	5-9	Very gravelly loam	SC	A-2-4	0	0-10	85-100	45-65	40-60	20-40	20-35	4-15
	9-50	Very gravelly loam, very gravelly sandy clay loam	SC	A-2-4	0	0-5	60-80	45-55	30-50	15-35	15-35	4-15
	50-60	Bedrock			---	---	---	---	---	---	---	---

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
603:												
Laventana-------	0-1	Slightly decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	1-5	Very cobbly loam	GC	A-2-4	0-5	25-45	50-70	40-55	35-45	25-35	20-30	7-10
	5-12	Gravelly silt loam	CL-ML, SC-SM	A-4	0	0-10	75-95	65-85	55-65	40-60	20-30	4-7
	12-20	Very cobbly loam	GC	A-4	0	15-30	60-80	50-70	40-60	30-50	20-30	7-10
	20-31	Very gravelly loam	SC	A-2-4	0	0-20	70-90	40-60	35-55	20-40	20-30	7-10
	31-51	Very gravelly loam	SC	A-2-4	0	0-20	65-85	40-60	30-50	20-40	20-30	7-10
	51-60	Bedrock			---	---	---	---	---	---	---	---
Mirand----------	0-6	Very cobbly loam	SC	A-4	0-3	11-20	65-85	50-65	45-55	30-50	20-30	4-20
	6-27	Cobbly clay	CH, CL	A-7-6	0-2	0-15	80-90	70-80	70-80	50-70	40-60	20-30
	27-60	Sandy clay	ML	A-6, A-7	0-3	0-10	85-100	80-100	75-95	60-80	35-55	15-20
604:												
Cypher----------	0-1	Slightly decomposed plant material	PT	A-8	0	0	100	100	---	---	---	---
	1-4	Very gravelly loam	GC	A-2-6	0	5-15	40-60	35-55	30-40	25-35	25-40	10-25
	4-11	Very gravelly loam	GC	A-6	0	5-15	60-80	40-60	40-50	35-45	25-40	10-25
	11-19	Extremely gravelly sandy loam	GC-GM	A-1-b	0	5-15	40-60	10-20	10-20	10-20	20-30	4-7
	19-60	Bedrock			---	---	---	---	---	---	---	---
Mirand----------	0-4	Very cobbly loam	SC	A-4	0-3	11-17	70-90	50-65	45-65	35-45	20-35	4-20
	4-60	Cobbly clay	CL, SC	A-7-6	0-3	0-20	80-90	70-85	60-80	40-60	40-50	10-30
608:												
Osha, steep-----	0-3	Gravelly coarse sandy loam	SC-SM	A-2-4	0	0	90-100	70-90	50-70	15-35	15-25	NP-4
	3-8	Gravelly coarse sandy loam	SC-SM	A-2-4	0	0	100	70-90	50-70	15-35	15-25	NP-4
	8-16	Gravelly coarse sandy loam	SC-SM	A-2-4	0	0	85-100	70-90	50-70	15-35	15-25	NP-4
	16-32	Extremely gravelly coarse sandy loam	SW-SM	A-1-a	0	0	65-85	15-35	15-25	0-10	10-20	NP-4
	32-60	Extremely gravelly loamy coarse sand	SW-SM	A-1-a	0	0	50-70	10-30	5-15	0-10	5-15	NP
Osha------------	0-8	Gravelly coarse sandy loam	SM	A-1-b	0	0	80-100	65-85	30-45	20-30	15-20	NP-4
	8-16	Gravelly coarse sandy loam, very gravelly coarse sandy loam	GC-GM	A-1-b	0	0	35-55	30-50	20-35	10-30	15-20	NP-10
	16-32	Extremely gravelly coarse sandy loam	GC-GM	A-1-a	0	0	35-55	30-50	10-20	0-10	15-20	NP-10
	32-60	Extremely gravelly loamy coarse sand	GW, GP-GM	A-1-a	0	0	30-50	25-45	5-15	0-10	10-20	NP-4
823:												
Gilco, unprotected----	0-8	Loam	CL	A-6	0	0	85-100	80-100	80-90	50-60	25-40	10-25
	8-60	Stratified fine sandy loam to loam to silt loam	CL	A-6	0	0	85-100	80-100	80-90	50-60	25-40	10-25
827:												
Aga, unprotected	0-8	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	8-28	Loam	CL	A-6	0	0	95-100	90-100	80-90	50-60	25-40	10-25
	28-60	Loamy fine sand	SM	A-2-4	0	0	90-100	90-100	65-85	20-40	15-20	NP-4

Table 14.--Engineering properties--continued

Map symbol and soil name	Depth	USDA texture	Classification		Fragments		Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO	>10 inches	3-10 inches	4	10	40	200		
	In.				Pct.	Pct.					Pct.	
830:												
Trail, unprotected----	0-8	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	8-60	Stratified loamy sand to sand to sandy loam	SM	A-2-4	0	0	100	100	60-80	0-40	15-20	NP-7
831:												
Trail, unprotected----	0-10	Loamy sand	SM	A-2-4	0	0	100	100	60-80	20-40	15-20	NP-4
	10-30	Loamy sand	SM	A-2-4	0	0	100	100	60-80	20-40	15-20	NP-4
	30-60	Stratified sand to gravelly sand to sandy loam	SW-SM	A-2-4, A-3	0	0	100	90-100	60-80	0-20	0-0	NP
835:												
Peralta, unprotected----	0-6	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	6-16	Loam	CL	A-6	0	0	100	100	85-100	50-60	25-40	10-25
	16-60	Stratified sandy loam to clay loam	SC	A-6	0	0	100	100	75-90	40-50	25-35	10-20
842:												
Peralta, moderately saline, sodic, unprotected----	0-10	Clay loam	CL	A-6	0	0	100	100	90-100	70-90	35-50	15-25
	10-60	Stratified sandy clay loam to sandy loam to clay loam	CL	A-6	0	0	100	100	85-100	50-60	25-35	10-20
850:												
Water----------	---	---	---	---	---	---	---	---	---	---	---	---
DAM:												
Dam----------	---	---	---	---	---	---	---	---	---	---	---	---

Table 15.--Physical soil properties

(Entries under "Erosion factors--T" apply to the entire profile. Entries under "Wind erodibility group" and "Wind erodibility index" apply only to the surface layer. Absence of an entry indicates that data were not estimated.)

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
1:														
Silver	0-4	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	5	5	56
	4-8	5-20	45-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.37	.37			
	8-20	5-20	45-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	20-39	25-45	25-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	39-60	25-45	25-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
Clovis	0-3	35-50	30-45	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	1.0-2.0	.37	.37	5	5	56
	3-20	25-40	20-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	20-40	50-70	10-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	40-60	60-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
2:														
Clovis	0-3	35-50	30-45	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	1.0-2.0	.37	.37	5	5	56
	3-24	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	24-60	55-75	10-35	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
Prieta	0-3	35-50	30-45	15-25	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.5-1.0	.10	.37	1	8	0
	3-10	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-1.0	.10	.32			
	10-14	25-45	25-45	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	14-19	25-45	25-45	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	19-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Silver	0-8	30-50	30-45	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	5	5	56
	8-30	5-20	45-60	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.37	.37			
	30-60	5-20	45-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
3:														
Montecito	0-3	55-75	10-25	10-20	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	5	3	86
	3-18	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	18-60	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
Orejas	0-2	30-50	30-45	20-27	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	0.5-1.0	.20	.37	1	7	38
	2-5	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-1.0	.10	.32			
	5-14	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	14-17	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	17-19	25-45	25-45	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	19-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
4:														
Montecito	0-3	60-75	15-35	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	5	3	86
	3-22	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	22-60	35-50	30-45	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
Montecito, bouldery-	0-5	35-50	30-50	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.5-1.0	.05	.28	5	8	0
	5-28	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	28-45	30-50	30-45	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
	45-60	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
10:														
Trail	0-6	10-20	45-60	28-35	1.15-1.35	6-20	0.19-0.21	3.0-5.9	0.5-1.0	.37	.37	5	4L	86
	6-30	60-85	2-25	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-1.0	.17	.17			
	30-45	90-100	0-5	0-5	1.55-1.65	6-20	0.03-0.05	0.0-2.9	0.0-0.5	.10	.10			
	45-60	75-90	0-15	5-10	1.45-1.55	6-20	0.09-0.10	0.0-2.9	0.0-0.5	.20	.20			
11:														
Trail	0-9	55-80	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	5	3	86
	9-36	75-95	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-1.0	.17	.17			
	36-60	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
13:														
Sandoval	0-2	55-75	10-25	10-20	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.5	.28	.28	2	3	86
	2-6	25-45	30-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	6-10	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	10-15	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	15-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
Querencia	0-4	50-70	10-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.5-1.5	.32	.32	5	4L	86
	4-12	30-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	12-24	30-50	30-45	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
	24-60	30-50	30-45	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
15:														
Camino	0-2	10-20	45-55	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.37	.37	4	4L	86
	2-5	15-40	15-40	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	5-20	15-40	15-40	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	20-51	15-40	15-40	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	51-60	---	---	---	---	0.00-0.2	---	---	---	---	---			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
15:														
Sandoval	0-2	55-75	10-25	10-18	1.45-1.55	2-6	0.13-0.15	0.0-2.9	1.0-2.0	.28	.28	2	3	86
	2-17	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	17-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
16:														
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
Prieta	0-5	15-35	50-70	15-25	1.15-1.35	0.6-2	0.13-0.15	3.0-5.9	0.5-1.0	.24	.43	1	7	38
	5-15	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-1.0	.10	.32			
	15-19	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	19-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
17:														
Vessilla	0-5	55-75	15-35	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24	1	3	86
	5-11	55-75	15-35	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	11-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Menefee	0-3	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	1.0-2.0	.32	.32	2	4L	86
	3-10	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	10-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
18:														
Sparham	0-7	20-45	15-35	40-50	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.5	.32	.32	5	4	86
	7-20	20-40	20-40	28-55	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32			
	20-29	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	29-47	5-20	45-60	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	47-53	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	53-60	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
20:														
Gilco	0-6	25-40	25-40	27-32	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32	5	4L	86
	6-60	35-70	25-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.0-0.5	.37	.37			
21:														
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
Hackroy	0-3	55-75	5-30	10-18	1.45-1.55	2-6	0.11-0.13	0.0-2.9	1.0-2.0	.24	.24	1	3	86
	3-12	20-45	20-40	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	12-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
22:														
Aga	0-8	5-20	45-60	28-35	1.55-1.65	0.2-0.6	0.19-0.21	3.0-5.9	0.5-0.8	.37	.37	3	4L	86
	8-24	35-50	30-50	8-18	1.45-1.55	0.6-2	0.14-0.16	0.0-2.9	0.1-0.3	.37	.37			
	24-60	90-100	0-10	0-12	1.40-1.50	6-20	0.07-0.09	0.0-2.9	0.1-0.3	.17	.17			
23:														
Hickman	0-4	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	2.0-4.0	.32	.32	5	4L	86
	4-12	50-70	5-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	1.0-1.5	.32	.32			
	12-49	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	49-60	50-75	5-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
24:														
Orlie	0-2	60-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	2.0-3.0	.28	.28	5	3	86
	2-25	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32			
	25-60	25-60	10-45	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
Sparham	0-3	10-40	20-40	40-55	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.5-1.5	.20	.20	5	4	86
	3-60	0-15	40-55	40-50	1.20-1.30	0.06-0.2	0.15-0.17	6.0-8.9	0.0-1.0	.24	.24			
25:														
Gilco	0-4	30-50	30-50	10-18	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	5	4L	86
	4-34	15-75	20-70	10-18	1.35-1.45	0.6-2	0.13-0.15	0.0-2.9	0.0-0.5	.37	.37			
	34-60	35-70	15-50	10-18	1.35-1.45	0.6-2	0.13-0.15	0.0-2.9	0.0-0.5	.37	.37			
26:														
Orlie	0-2	30-50	30-55	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	2.0-3.0	.37	.37	5	6	48
	2-13	30-45	25-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.5	.32	.32			
	13-22	30-45	25-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32			
	22-36	10-20	45-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.37	.37			
	36-50	30-45	25-45	28-35	1.35-1.50	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	50-60	10-20	45-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
27:														
Aga	0-10	35-50	35-50	10-20	1.35-1.45	0.6-2	0.14-0.18	0.0-2.9	0.5-1.0	.37	.37	3	4L	86
	10-23	35-50	35-50	8-18	1.35-1.45	0.6-2	0.14-0.16	0.0-2.9	0.0-0.5	.37	.37			
	23-43	90-100	0-10	0-5	1.55-1.65	6-20	0.03-0.05	0.0-2.9	0.0-0.5	.17	.17			
	43-60	90-100	0-10	0-5	1.55-1.65	6-20	0.03-0.05	0.0-2.9	0.0-0.5	.17	.17			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
29:														
Trail	0-6	75-90	0-20	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-1.0	.17	.17	5	2	134
	6-60	55-85	10-30	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
31:														
Riverwash	0-6	95-100	0-10	0-1	1.65-1.75	6-20	0.03-0.04	0.0-2.9	0.0-0.1	.10	.10	2	5	220
	6-60	70-100	0-20	0-5	1.15-1.25	6-20	0.04-0.06	0.0-2.9	0.0-0.5	.10	.10			
33:														
Pits	0-60	---	---	---	---	0.2-0.6	---	---	---	---	---	--	8	0
34:														
Ildefonso	0-3	30-50	30-45	15-25	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	1.0-2.0	.20	.37	3	6	48
	3-17	30-50	30-45	15-25	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	0.5-1.0	.20	.37			
	17-60	35-70	15-50	10-20	1.40-1.50	0.6-2	0.06-0.08	0.0-2.9	0.0-0.5	.10	.32			
Witt	0-3	55-70	15-35	5-15	1.40-1.50	0.6-2	0.15-0.17	0.0-2.9	0.5-1.0	.55	.55	5	5	56
	3-27	30-50	30-45	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-1.0	.37	.37			
	27-60	30-50	35-45	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
41:														
Dune land	0-6	90-100	0-10	0-1	1.65-1.75	6-20	0.03-0.04	0.0-2.9	0.0-0.1	.10	.10	5	1	220
	6-60	90-100	0-10	0-1	1.65-1.75	6-20	0.03-0.05	0.0-2.9	0.0-0.0	.10	.10			
47:														
Cascajo	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.5-1.0	.10	.24	3	6	48
	2-5	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.5-1.0	.10	.24			
	5-11	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	11-23	75-95	0-15	5-10	1.45-1.55	6-20	0.04-0.06	0.0-2.9	0.0-0.5	.05	.17			
	23-30	75-95	0-15	5-10	1.45-1.55	6-20	0.04-0.06	0.0-2.9	0.0-0.5	.05	.17			
	30-60	75-95	0-15	5-10	1.45-1.55	6-20	0.01-0.03	0.0-2.9	0.0-0.5	.02	.17			
51:														
Sparham	0-6	25-45	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32	5	4	86
	6-20	25-45	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	20-36	20-40	20-40	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	36-60	25-45	25-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
52:														
Totavi	0-15	75-90	0-15	5-10	1.50-1.60	6-20	0.06-0.08	0.0-2.9	0.0-1.0	.17	.17	5	2	134
	15-19	75-90	0-15	5-10	1.50-1.60	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
	19-60	75-90	0-15	5-10	1.50-1.60	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
53:														
Witt	0-3	35-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	5	5	56
	3-6	5-25	60-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.5-1.0	.43	.43			
	6-11	0-15	50-70	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.37	.37			
	11-18	0-15	50-70	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.37	.37			
	18-25	0-15	50-70	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	25-39	0-20	55-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.0-0.5	.43	.43			
	39-53	0-20	55-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.0-0.5	.43	.43			
	53-60	0-20	55-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.0-0.5	.43	.43			
Harvey	0-10	30-50	30-45	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	5	4L	86
	10-28	25-45	25-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	28-42	50-70	10-30	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	42-60	55-75	10-35	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
54:														
Harvey	0-2	55-75	5-30	5-18	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	5	3	86
	2-11	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-1.0	.28	.28			
	11-23	30-45	30-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	23-60	50-70	10-30	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
Cascajo	0-3	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.5-1.0	.10	.24	2	6	48
	3-9	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.5-1.0	.10	.24			
	9-28	90-100	0-10	0-5	1.55-1.65	6-20	0.02-0.03	0.0-2.9	0.0-0.5	.02	.10			
	28-60	90-100	0-10	0-5	1.55-1.65	6-20	0.02-0.03	0.0-2.9	0.0-0.5	.02	.10			
55:														
La Fonda	0-4	30-50	30-45	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	1.0-2.0	.37	.37	5	4L	86
	4-26	30-50	30-45	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-1.0	.37	.37			
	26-60	25-45	25-45	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
56:														
Ildefonso	0-3	30-50	30-45	15-25	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	1.0-2.0	.20	.37	3	6	48
	3-9	30-50	30-45	15-25	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	0.5-1.2	.20	.37			
	9-15	30-50	30-45	15-25	1.35-1.45	0.6-2	0.08-0.10	3.0-5.9	0.0-1.0	.10	.37			
	15-60	30-50	30-45	15-25	1.35-1.45	0.6-2	0.08-0.10	3.0-5.9	0.0-0.5	.10	.37			
57:														
Badland	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	4	86
58:														
Deama	0-7	15-35	50-70	15-27	1.15-1.35	0.6-2	0.09-0.11	3.0-5.9	1.0-3.0	.15	.43	1	6	48
	7-14	15-35	50-70	15-27	1.15-1.35	0.6-2	0.09-0.11	3.0-5.9	0.5-1.0	.15	.43			
	14-60	---	---	---	---	0.00-0.2	---	---	---	---	---			
Elpedro	0-5	30-50	30-50	15-22	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	5	5	56
	5-12	0-20	50-70	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	12-19	0-20	50-70	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	19-25	0-20	50-70	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	25-36	0-20	50-70	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	36-45	0-30	55-75	15-27	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.0-0.5	.43	.43			
	45-60	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.0-0.0	.37	.37			
59:														
Harvey	0-4	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	5	4L	86
	4-10	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-1.0	.37	.37			
	10-18	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	18-41	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	41-60	50-70	5-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
Ildefonso	0-2	30-50	30-50	15-25	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	1.0-2.0	.20	.37	3	6	48
	2-8	30-50	30-50	15-25	1.35-1.45	0.6-2	0.08-0.10	3.0-5.9	0.5-1.5	.10	.37			
	8-13	30-50	30-50	15-25	1.35-1.45	0.6-2	0.08-0.10	3.0-5.9	0.5-1.0	.10	.37			
	13-32	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	32-40	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	40-60	90-100	0-10	0-5	1.55-1.65	6-20	0.01-0.02	0.0-2.9	0.0-0.5	.02	.10			
La Fonda	0-3	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	1.0-2.0	.37	.37	5	4L	86
	3-7	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.5	.37	.37			
	7-14	25-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32			
	14-26	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-1.0	.37	.37			
	26-42	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
	42-60	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
63:														
Placitas	0-5	30-50	30-50	10-20	1.35-1.45	0.6-2	0.10-0.12	0.0-2.9	1.0-2.0	.20	.37	2	6	48
	5-10	55-75	10-30	5-15	1.45-1.55	2-6	0.06-0.08	0.0-2.9	0.0-1.0	.10	.24			
	10-27	55-75	10-30	5-15	1.45-1.55	2-6	0.04-0.06	0.0-2.9	0.0-0.5	.10	.24			
	27-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
64:														
Skyvillage	0-4	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	1.0-2.0	.28	.28	1	3	86
	4-11	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-1.0	.28	.28			
	11-18	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	18-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Ildefonso	0-3	55-75	10-30	5-15	1.45-1.55	2-6	0.08-0.09	0.0-2.9	0.5-1.0	.15	.24	3	5	56
	3-14	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-1.0	.10	.24			
	14-60	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
65:														
Ildefonso	0-6	55-75	10-30	8-18	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.5-1.0	.10	.24	3	6	48
	6-38	55-75	10-30	8-18	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-1.0	.10	.24			
	38-60	40-75	10-40	8-18	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
Harvey	0-4	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	5	4L	86
	4-23	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37			
	23-36	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
	36-60	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
66:														
Zia	0-4	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24	5	3	86
	4-60	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
67:														
Sandoval	0-2	30-50	30-50	15-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	1.0-2.0	.37	.37	2	4L	86
	2-11	25-40	30-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	11-60	---	---	---	---	0.00-0.02	---	---	---	---	---			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
67:														
Poley	0-3	30-50	30-50	15-25	1.35-1.45	0.6-2	0.08-0.10	3.0-5.9	0.5-1.5	.10	.37	4	6	48
	3-12	25-40	25-40	28-35	1.35-1.45	0.06-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32			
	12-17	25-40	25-40	28-35	1.35-1.45	0.06-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	17-21	25-40	25-40	28-35	1.35-1.45	0.06-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	21-40	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	40-60	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
68:														
Penistaja	0-2	75-90	0-20	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.5-1.0	.20	.20	5	2	134
	2-15	50-70	5-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-1.0	.32	.32			
	15-27	50-70	5-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	27-38	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	38-60	50-70	5-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
Querencia	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.5	.28	.28	5	3	86
	2-40	50-70	10-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-1.0	.32	.32			
	40-60	55-75	15-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
71:														
Palon	0-6	55-75	15-35	5-15	1.45-1.55	2-6	0.08-0.10	0.0-2.9	1.0-3.0	.15	.24	2	5	56
	6-27	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-1.0	.10	.24			
	27-60	55-75	15-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.05	.24			
72:														
Palon	0-2	55-75	15-30	0-15	0.20-1.00	20-60	0.15-0.45	---	60-70	---	---	2	6	48
	2-4	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	1.0-3.0	.10	.24			
	4-10	55-75	15-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.5-1.5	.05	.24			
	10-32	55-75	15-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-1.0	.05	.24			
	32-53	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	53-60	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
74:														
Origo	0-7	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	1.0-3.0	.10	.24	2	6	48
	7-28	55-75	15-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-1.0	.05	.24			
	28-60	55-75	15-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.05	.24			
Pavo	0-9	30-50	30-50	15-25	1.35-1.45	2-6	0.16-0.18	0.0-2.9	1.0-3.0	.37	.37	5	5	56
	9-12	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.5	.24	.24			
	12-25	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-1.0	.24	.24			
	25-35	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	35-45	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.28	.28			
	45-50	25-75	20-45	28-35	1.35-1.45	0.2-0.6	0.13-0.15	3.0-5.9	0.0-0.5	.15	.32			
	50-60	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.0	.24	.24			
75:														
Origo	0-1	---	---	0-15	0.20-1.00	20-60	0.15-0.45	---	60-70	---	---	2	6	48
	1-6	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	1.0-3.0	.10	.24			
	6-12	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-2.0	.10	.24			
	12-32	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-1.0	.10	.24			
	32-56	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	56-60	75-90	0-20	5-10	1.45-1.55	6-20	0.04-0.06	0.0-2.9	0.0-0.5	.05	.20			
82:														
Calaveras	0-2	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	2	5	56
	2-6	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24			
	6-40	55-75	15-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	40-60	55-75	15-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.05	.24			
83:														
Calaveras	0-6	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	1.0-1.5	.37	.37	2	5	56
	6-12	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24			
	12-24	30-75	15-35	10-20	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	24-60	55-80	5-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.05	.24			
Rubble land	0-60	---	---	0-0	2.00-2.35	20-99	0.00-0.02	0.0-2.9	0.0-0.1	---	---	--	8	0
85:														
Redondo	0-2	55-75	15-30	5-10	1.55-1.65	2-6	0.10-0.12	0.0-2.9	2.0-5.0	.20	.20	3	3	86
	2-7	55-75	15-30	5-10	1.55-1.65	2-6	0.10-0.12	0.0-2.9	1.0-3.0	.20	.20			
	7-15	55-75	15-30	5-10	1.55-1.65	2-6	0.10-0.12	0.0-2.9	0.5-1.5	.20	.20			
	15-22	55-75	15-30	5-10	1.55-1.65	2-6	0.10-0.12	0.0-2.9	0.0-1.0	.20	.20			
	22-29	55-75	15-30	5-10	1.55-1.65	2-6	0.09-0.10	0.0-2.9	0.0-0.5	.10	.20			
	29-38	55-75	15-30	5-10	1.55-1.65	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.05	.20			
	38-54	55-75	15-30	5-10	1.55-1.65	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.02	.20			
	54-60	55-75	15-30	5-10	1.55-1.65	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.02	.20			
86:														
Redondo	0-8	55-75	15-30	5-10	1.50-1.60	2-6	0.08-0.10	0.0-2.9	1.0-2.0	.10	.20	3	5	56
	8-13	55-75	15-30	5-10	1.50-1.60	2-6	0.05-0.07	0.0-2.9	0.0-1.0	.05	.20			
	13-34	55-75	15-30	5-10	1.50-1.60	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.02	.20			
	34-60	55-75	15-30	5-10	1.50-1.60	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.02	.20			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
87:														
Redondo	0-6	30-50	30-50	10-20	1.35-1.45	2-6	0.11-0.13	0.0-2.9	1.0-2.0	.20	.37	3	6	48
	6-13	55-75	15-30	5-10	1.50-1.60	2-6	0.04-0.06	0.0-2.9	0.5-1.5	.05	.20			
	13-60	55-75	15-30	5-10	1.50-1.60	2-6	0.04-0.06	0.0-2.9	0.0-1.0	.05	.20			
Rubble land	0-60	---	---	0-0	2.00-2.35	20-99	0.00-0.02	0.0-2.9	0.0-0.1	---	---	--	8	0
88:														
Totavi	0-12	55-75	15-30	5-10	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-1.0	.24	.24	5	3	86
	12-60	75-90	0-20	5-10	1.50-1.60	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
Jemez	0-6	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	2	5	56
	6-13	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37			
	13-19	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	19-27	45-65	10-25	20-35	1.35-1.45	0.2-0.6	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	27-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
91:														
Zia	0-16	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24	5	3	86
	16-22	75-90	0-20	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-1.0	.17	.17			
	22-35	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	35-60	55-75	15-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
92:														
Galisteo, moderately saline, sodic	0-12	5-20	45-65	30-40	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	1.0-2.0	.37	.37	5	4L	86
	12-60	15-40	20-40	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
93:														
Zia	0-8	75-85	0-20	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.5-1.0	.17	.17	5	2	134
	8-60	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
95:														
El Rancho	0-5	30-50	30-50	18-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	5	4L	86
	5-20	50-70	5-25	20-27	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	20-38	50-70	5-25	20-27	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	38-60	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
97:														
El Rancho	0-8	25-40	25-40	30-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32	5	4L	86
	8-60	45-70	5-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
100:														
Orejas	0-5	35-50	30-50	15-25	1.35-1.45	0.6-2	0.08-0.10	3.0-5.9	0.5-1.0	.10	.37	1	7	38
	5-15	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	15-19	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	19-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
101:														
Blancot	0-2	55-75	15-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	5	3	86
	2-5	25-40	25-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32			
	5-14	25-40	25-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	14-23	25-40	25-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	23-40	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	40-49	10-20	45-60	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.0	.37	.37			
	49-60	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.0	.24	.24			
Lybrook	0-1	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32	5	4L	86
	1-5	10-20	45-60	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	5-21	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	21-30	5-20	45-60	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	30-60	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.14-0.18	3.0-5.9	0.0-0.5	.32	.32			
102:														
Sparham	0-7	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.5	.32	.32	5	4	86
	7-29	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	29-60	10-40	35-60	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
104:														
Cochiti	0-7	30-50	30-45	15-25	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	0.5-1.0	.20	.37	4	6	48
	7-12	25-40	25-40	30-40	1.35-1.45	0.2-0.6	0.13-0.15	6.0-8.9	0.5-1.0	.15	.32			
	12-20	10-40	15-40	40-60	1.15-1.35	0.06-0.2	0.06-0.08	6.0-8.9	0.0-0.5	.05	.20			
	20-29	25-40	25-40	30-40	1.35-1.45	0.2-0.6	0.09-0.11	6.0-8.9	0.0-0.5	.10	.32			
	29-60	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
104:														
Montecito	0-3	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.5	.37	.37	5	5	56
	3-9	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32			
	9-15	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	15-22	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	22-37	40-75	10-40	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	37-60	55-75	10-35	5-15	1.45-1.55	2-6	0.08-0.10	0.0-2.9	0.0-0.5	.15	.24			
105:														
Badland	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	4	86
Menefee	0-4	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.5	.37	.37	2	4L	86
	4-10	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	10-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
106:														
Stumble	0-4	55-75	10-30	5-15	1.45-1.55	2-6	0.06-0.08	0.0-2.9	0.5-1.0	.10	.28	2	6	48
	4-10	55-75	10-30	5-15	1.45-1.55	2-6	0.09-0.11	0.0-2.9	0.0-1.0	.15	.28			
	10-24	75-90	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
	24-60	85-100	0-15	0-5	1.55-1.65	20-20	0.01-0.03	0.0-2.9	0.0-0.5	.05	.10			
Stumble, sandy	0-4	75-90	0-15	5-10	1.40-1.50	6-20	0.03-0.05	0.0-2.9	0.5-0.9	.10	.20	2	2	134
	4-18	75-90	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.1-0.3	.17	.20			
	18-60	75-100	0-15	1-6	1.45-1.55	20-20	0.01-0.03	0.0-2.9	0.1-0.3	.05	.10			
108:														
Embudo	0-6	55-75	15-30	5-15	1.45-1.55	2-6	0.08-0.09	0.0-2.9	0.0-0.5	.15	.24	3	5	56
	6-30	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	30-60	75-90	0-15	5-10	1.50-1.60	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
109:														
Embudo	0-4	55-75	15-30	5-15	1.45-1.55	2-6	0.08-0.09	0.0-2.9	0.5-1.0	.15	.24	3	5	56
	4-12	55-75	15-30	5-12	1.45-1.55	2-6	0.09-0.11	0.0-2.9	0.5-1.0	.15	.28			
	12-30	55-75	15-30	5-15	1.45-1.55	2-6	0.07-0.09	0.0-2.9	0.0-0.5	.10	.20			
	30-60	75-90	0-15	5-10	1.50-1.60	6-20	0.03-0.05	0.0-2.9	0.0-0.5	.10	.15			
Tijeras	0-4	55-75	15-30	5-15	1.45-1.55	2-6	0.09-0.11	0.0-2.9	0.0-1.0	.15	.28	4	5	56
	4-10	50-65	5-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-1.0	.32	.32			
	10-20	50-70	5-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	20-26	55-75	15-30	5-15	1.45-1.55	2-6	0.07-0.09	0.0-2.9	0.0-0.5	.15	.24			
	26-60	55-75	15-30	5-15	1.50-1.60	2-6	0.03-0.05	0.0-2.9	0.0-0.5	.05	.20			
110:														
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
Saido	0-5	0-30	55-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.5-1.5	.43	.43	2	4L	86
	5-9	0-30	55-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.5-1.0	.43	.43			
	9-15	0-30	55-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.0-1.0	.43	.43			
	15-25	0-30	55-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.0-0.5	.43	.43			
	25-60	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
111:														
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
Zia	0-5	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24	5	3	86
	5-60	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
112:														
Tijeras	0-3	55-75	10-30	5-15	1.45-1.55	2-6	0.09-0.11	0.0-2.9	0.0-1.0	.15	.28	4	5	56
	3-14	50-70	5-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	14-60	55-75	15-30	5-15	1.45-1.55	2-6	0.09-0.11	0.0-2.9	0.0-0.5	.15	.24			
114:														
San Mateo	0-7	55-75	15-30	10-20	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24	5	3	86
	7-60	10-75	5-60	15-35	1.35-1.45	0.2-0.6	0.15-0.17	3.0-5.9	0.0-0.5	.32	.32			
Zia	0-3	55-75	15-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	5	3	86
	3-60	55-75	15-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
120:														
Pinavetes	0-10	75-90	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.5-1.0	.17	.17	2	2	134
	10-35	90-100	0-10	0-5	1.55-1.65	6-20	0.03-0.05	0.0-2.9	0.0-1.0	.10	.10			
	35-60	90-100	0-10	0-5	1.55-1.65	6-20	0.03-0.05	0.0-2.9	0.0-0.5	.10	.10			
124:														
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
129:														
Menefee	0-5	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.5	.32	.32	2	4L	86
	5-10	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	10-17	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	17-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
130:														
Pinavetes	0-2	75-90	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.5-1.0	.17	.17	2	2	134
	2-60	75-90	0-10	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
Galisteo, moderately saline, sodic	0-2	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	1.0-2.0	.32	.32	5	4L	86
	2-60	20-40	20-40	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
142:														
Grieta	0-3	55-75	5-25	10-18	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28	5	3	86
	3-11	55-75	5-25	10-18	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
	11-34	50-75	5-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	34-48	50-75	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	48-60	75-90	0-15	5-10	1.50-1.60	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
143:														
Clovis	0-3	55-75	15-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	1.0-2.0	.28	.28	5	3	86
	3-7	50-65	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.5-1.0	.32	.32			
	7-12	50-65	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	12-22	50-65	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	22-34	50-65	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	34-60	50-65	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
145:														
Grieta	0-7	75-95	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20	5	2	134
	7-14	50-70	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	14-21	50-70	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	21-38	55-75	10-30	5-15	1.45-1.55	2-6	0.09-0.11	0.0-2.9	0.0-0.5	.20	.20			
	38-50	55-75	10-30	5-15	1.45-1.55	2-6	0.09-0.11	0.0-2.9	0.0-0.5	.20	.20			
	50-60	55-75	10-30	5-15	1.45-1.55	2-6	0.09-0.11	0.0-2.9	0.0-0.5	.20	.20			
Sheppard	0-5	75-90	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20	5	2	134
	5-27	75-90	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20			
	27-60	75-95	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20			
146:														
Sedmar	0-3	75-95	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.5-1.0	.17	.17	1	2	134
	3-13	55-75	10-30	5-15	1.45-1.55	6-20	0.11-0.13	0.0-2.9	0.0-1.0	.24	.24			
	13-18	75-95	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
	18-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
150:														
Doakum	0-5	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	5	3	86
	5-11	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	11-17	50-75	10-30	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	17-24	50-75	10-30	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	24-31	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	31-44	30-50	30-50	10-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
	44-60	30-50	30-50	10-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.0	.37	.37			
Betonnie	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	5	3	86
	2-4	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28			
	4-12	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
	12-18	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	18-34	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	34-60	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.0	.24	.24			
162:														
Hackroy	0-3	55-75	10-30	10-18	1.45-1.55	2-6	0.11-0.13	0.0-2.9	1.0-2.0	.24	.24	1	3	86
	3-13	15-40	20-40	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	13-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
Nyjack	0-3	30-50	30-50	20-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	3	6	48
	3-13	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	13-24	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	24-39	55-75	10-30	5-15	1.45-1.55	2-6	0.08-0.10	0.0-2.9	0.0-0.5	.15	.24			
	39-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
163:														
Jemez	0-3	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	2	5	56
	3-24	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	24-39	50-70	5-25	25-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	39-60	---	---	---	---	0.00-0.01	---	---	---	---	---			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
170:														
San Mateo----------	0-2	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.5	.37	.37	5	4L	86
	2-10	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	10-23	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	23-32	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	32-54	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.15-0.17	3.0-5.9	0.0-0.5	.32	.32			
	54-60	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.15-0.17	3.0-5.9	0.0-0.5	.32	.32			
180:														
Councelor----------	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28	5	3	86
	2-7	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
	7-37	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
	37-40	25-45	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	40-60	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
Eslendo----------	0-3	25-45	30-50	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32	2	6	48
	3-10	25-45	30-50	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	10-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
Mespun----------	0-6	75-90	5-20	2-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20	5	2	134
	6-60	70-85	5-20	3-8	1.45-1.55	6-20	0.07-0.09	0.0-2.9	0.0-0.5	.17	.17			
183:														
Sheppard----------	0-4	75-95	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20	5	2	134
	4-45	75-95	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20			
	45-60	75-95	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20			
185:														
Frijoles----------	0-3	55-75	10-30	5-15	1.40-1.50	2-6	0.15-0.17	0.0-2.9	1.0-2.0	.55	.55	2	3	86
	3-8	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-1.0	.10	.32			
	8-13	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	13-20	55-75	10-30	10-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.05	.28			
	20-60	55-75	10-30	10-15	1.00-1.10	20-99	0.00-0.01	0.0-2.9	0.0-0.5	---	---			
190:														
Zia----------	0-5	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24	5	3	86
	5-28	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-1.0	.24	.24			
	28-60	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
Skyvillage----------	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	1.0-2.0	.28	.28	1	3	86
	2-11	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-1.0	.28	.28			
	11-16	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
	16-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Rock outcrop--------	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
191:														
Sheppard----------	0-3	75-95	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20	5	2	134
	3-27	75-95	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20			
	27-60	75-95	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20			
200:														
Sedillo----------	0-4	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	1.0-2.0	.10	.24	2	6	48
	4-13	50-70	5-25	20-30	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	0.0-1.0	.10	.32			
	13-60	55-75	10-30	5-15	1.50-1.60	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.02	.20			
201:														
Rock outcrop--------	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
Sedgran----------	0-4	75-95	0-15	5-10	1.50-1.60	6-20	0.01-0.03	0.0-2.9	0.5-1.0	.02	.15	1	8	0
	4-13	75-95	0-15	5-10	1.50-1.60	6-20	0.03-0.05	0.0-2.9	0.0-0.5	.05	.15			
	13-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
206:														
Pinitos----------	0-4	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	5	4	86
	4-10	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	10-27	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	27-39	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	39-60	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
207:														
Penistaja----------	0-3	55-75	15-30	5-15	1.45-1.55	2-6	0.15-0.17	0.0-2.9	1.0-2.0	.55	.55	5	3	86
	3-29	30-70	5-35	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-1.0	.32	.32			
	29-60	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
Zia----------	0-5	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	5	3	86
	5-60	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
208:														
Sedillo----------	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.06-0.08	0.0-2.9	0.5-1.0	.10	.28	3	6	48
	2-8	50-70	10-30	20-30	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	0.0-1.0	.10	.32			
	8-12	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	12-60	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.05	.24			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
210:														
Ildefonso	0-3	30-50	30-50	15-25	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	1.0-2.0	.10	.37	3	7	38
	3-9	30-50	30-50	15-25	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.5-1.0	.10	.37			
	9-60	30-50	30-50	15-25	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-0.5	.10	.37			
211:														
Zia	0-5	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24	5	3	86
	5-14	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-1.0	.24	.24			
	14-33	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	33-46	50-70	10-25	20-30	1.35-1.45	0.6-2	0.14-0.16	0.0-2.9	0.0-0.5	.32	.32			
	46-60	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
Clovis	0-5	55-75	10-30	10-17	1.45-1.55	2-6	0.13-0.15	0.0-2.9	1.0-2.0	.28	.28	5	3	86
	5-60	50-70	5-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
213:														
Pinavetes	0-7	90-100	0-15	0-5	1.55-1.65	6-20	0.03-0.05	0.0-2.9	0.5-1.0	.10	.10	2	1	220
	7-60	75-100	0-15	0-5	1.55-1.65	6-20	0.04-0.06	0.0-2.9	0.0-0.5	.10	.10			
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
215:														
Ess	0-7	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	1.0-2.0	.10	.24	3	8	0
	7-15	55-75	10-30	8-18	1.45-1.55	2-6	0.05-0.07	0.0-2.9	1.0-1.5	.10	.24			
	15-29	50-70	10-25	20-30	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	0.5-1.0	.10	.32			
	29-60	30-50	30-50	10-20	1.35-1.45	0.6-2	0.08-0.10	0.0-2.9	0.0-0.5	.10	.37			
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
217:														
Witt	0-2	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	5	5	56
	2-9	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
	9-60	35-70	10-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.0-0.5	.55	.55			
218:														
Ildefonso	0-4	30-50	30-50	15-25	1.35-1.45	0.6-6	0.08-0.10	3.0-5.9	1.0-2.0	.10	.37	3	7	38
	4-8	30-50	30-50	15-25	1.35-1.45	0.6-6	0.08-0.10	3.0-5.9	0.5-1.0	.10	.37			
	8-60	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
220:														
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
Vessilla	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24	1	3	86
	2-10	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	10-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Menefee	0-2	25-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.5	.32	.32	2	4L	86
	2-10	25-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	10-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
226:														
Galisteo, moderately saline, sodic	0-10	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	1.0-2.0	.37	.37	5	4L	86
	10-60	10-20	40-60	35-40	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
227:														
Hagerman	0-4	55-75	10-30	10-20	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	2	3	86
	4-34	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	34-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Bond	0-4	75-95	0-25	4-9	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.5-1.0	.20	.20	1	2	134
	4-12	50-70	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.5-1.0	.32	.32			
	12-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
228:														
Winona	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.03-0.05	0.0-2.9	1.0-2.0	.05	.28	1	6	48
	2-13	30-50	30-50	15-25	1.35-1.45	0.6-2	0.08-0.10	3.0-5.9	0.0-1.0	.10	.37			
	13-60	---	---	---	---	0.00-0.2	---	---	---	---	---			
230:														
Skyvillage	0-6	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	1.0-2.0	.24	.24	1	3	86
	6-11	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-1.0	.24	.24			
	11-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Sandoval	0-2	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	1.0-2.0	.32	.32	2	4L	86
	2-10	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	10-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
231:														
Querencia----------	0-3	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.5	.37	.37	5	4L	86
	3-21	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-1.0	.37	.37			
	21-60	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
234:														
Querencia----------	0-3	55-75	10-30	10-20	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.5	.28	.28	5	3	86
	3-25	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-1.0	.37	.37			
	25-60	30-70	10-50	12-20	1.40-1.50	0.6-2	0.14-0.16	0.0-2.9	0.0-0.5	.32	.32			
Zia----------	0-11	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24	5	3	86
	11-60	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
235:														
Sandoval----------	0-2	55-75	10-30	10-18	1.45-1.55	2-6	0.13-0.15	0.0-2.9	1.0-2.0	.28	.28	2	3	86
	2-16	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	16-19	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	19-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
236:														
Sparank, moderately saline, sodic------	0-2	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	1.0-2.0	.32	.32	5	4L	86
	2-10	0-15	40-55	40-50	1.20-1.30	0.06-0.2	0.15-0.17	6.0-8.9	0.5-1.5	.24	.24			
	10-24	0-15	40-55	40-50	1.20-1.30	0.06-0.2	0.15-0.17	6.0-8.9	0.5-1.0	.24	.24			
	24-40	10-20	45-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.37	.37			
	40-44	0-15	40-55	40-50	1.20-1.30	0.06-0.2	0.15-0.17	6.0-8.9	0.0-0.5	.24	.24			
	44-60	0-15	40-55	40-50	1.20-1.30	0.06-0.2	0.15-0.17	6.0-8.9	0.0-0.5	.24	.24			
237:														
Sparank----------	0-4	10-20	45-60	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	1.0-2.0	.37	.37	5	4L	86
	4-60	10-20	45-60	28-35	1.15-1.35	0.06-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.37	.37			
240:														
Penistaja----------	0-5	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	1.0-2.0	.28	.28	5	3	86
	5-14	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.5	.32	.32			
	14-29	50-70	10-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-1.0	.32	.32			
	29-60	30-75	10-50	15-25	1.40-1.50	0.6-2	0.14-0.16	0.0-2.9	0.0-0.5	.32	.32			
Hagerman----------	0-2	55-75	10-30	10-20	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	2	3	86
	2-9	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	9-24	25-40	25-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	24-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
250:														
Pinavetes----------	0-4	75-95	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.5-1.0	.20	.20	2	2	134
	4-60	75-95	10-20	3-7	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
262:														
Pastura----------	0-3	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	1.0-2.0	.37	.37	1	4L	86
	3-10	30-50	30-50	20-27	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	0.0-1.5	.20	.37			
	10-14	30-50	30-50	20-27	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	0.0-0.5	.20	.37			
	14-60	---	---	---	---	0.00-0.6	---	---	---	---	---			
270:														
Blancot----------	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	5	3	86
	2-12	50-70	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	12-21	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	21-60	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
Councelor----------	0-2	55-75	10-30	5-15	1.50-1.60	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28	5	3	86
	2-60	55-75	10-30	5-15	1.50-1.60	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
Tsosie----------	0-2	20-45	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.5	.32	.32	5	4L	86
	2-10	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37			
	10-20	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	20-26	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	26-36	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	36-44	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	44-55	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	55-60	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
281:														
Carjo----------	0-4	30-50	30-50	10-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	2.0-4.0	.37	.37	2	5	56
	4-12	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	1.0-1.5	.32	.32			
	12-20	20-40	15-40	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	20-25	55-75	10-30	5-10	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.55	.55			
	25-60	---	---	---	---	0.00-0.01	---	---	---	---	---			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
282:														
Tocal----------	0-5	55-75	10-30	5-15	1.45-1.55	0.6-2	0.15-0.17	0.0-2.9	1.0-2.0	.55	.55	2	3	86
	5-8	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32			
	8-11	15-40	10-35	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-1.0	.20	.20			
	11-14	15-35	50-70	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.0-0.5	.43	.43			
	14-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
283:														
Mirand----------	0-2	30-50	30-50	20-27	0.20-1.00	20-60	0.15-0.45	---	60-70	---	---	5	5	56
	2-6	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	1.0-3.0	.37	.37			
	6-11	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.5	.32	.32			
	11-17	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.17-0.19	3.0-5.9	0.0-1.0	.20	.32			
	17-27	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	27-47	15-40	10-40	40-55	1.15-1.35	0.2-0.6	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	47-60	20-40	20-40	28-35	1.35-1.45	0.01-0.06	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
Alanos----------	0-6	30-50	30-50	15-25	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	0.5-1.0	.20	.37	3	7	38
	6-9	30-50	30-50	15-25	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	0.0-0.5	.20	.37			
	9-30	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.05-0.07	3.0-5.9	0.0-0.5	.05	.32			
	30-60	10-40	20-40	40-50	1.15-1.35	0.06-0.2	0.07-0.09	6.0-8.9	0.0-0.5	.05	.20			
290:														
Alanos----------	0-4	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	3	6	48
	4-9	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37			
	9-18	30-50	30-50	15-25	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-0.5	.10	.37			
	18-26	10-40	20-40	40-50	1.15-1.25	0.06-0.2	0.04-0.06	6.0-8.9	0.0-0.5	.02	.20			
	26-60	10-30	20-40	40-50	1.15-1.25	0.06-0.2	0.04-0.06	6.0-8.9	0.0-0.5	.02	.20			
Rock outcrop--------	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
300:														
Waumac----------	0-3	75-95	0-15	5-10	1.55-1.65	6-20	0.06-0.08	0.0-2.9	0.5-1.0	.17	.17	5	2	134
	3-31	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
	31-60	55-75	10-30	5-15	1.45-1.55	2-6	0.09-0.10	0.0-2.9	0.0-0.5	.15	.28			
Bamac----------	0-6	75-95	0-15	5-10	1.55-1.65	6-20	0.04-0.06	0.0-2.9	0.5-1.0	.10	.17	3	4	86
	6-60	75-100	0-20	5-10	1.55-1.65	6-20	0.02-0.04	0.0-2.9	0.0-0.5	.05	.17			
301:														
Vastine----------	0-4	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	2.0-4.0	.43	.43	4	6	48
	4-11	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-2.0	.37	.37			
	11-24	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-1.0	.37	.37			
	24-60	75-95	0-15	5-10	1.45-1.55	6-20	0.02-0.04	0.0-2.9	0.0-0.5	.05	.17			
Jarola----------	0-9	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	1.0-3.0	.43	.43	5	5	56
	9-11	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.5-1.5	.43	.43			
	11-17	10-20	45-60	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.37	.37			
	17-21	30-50	30-50	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	21-42	50-70	10-25	20-30	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	0.0-0.5	.15	.32			
	42-60	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
302:														
Tranquilar----------	0-4	5-20	40-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	2.0-4.0	.37	.37	5	7	38
	4-8	5-20	40-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	1.0-2.0	.37	.37			
	8-11	5-20	40-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.5	.37	.37			
	11-13	5-20	40-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.5	.37	.37			
	13-20	10-40	15-40	40-60	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-1.0	.20	.20			
	20-34	10-40	15-40	40-60	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	34-42	10-40	15-40	40-60	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	42-50	10-40	15-40	40-60	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	50-60	10-40	15-40	40-60	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
Jarmillo----------	0-4	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	2.0-4.0	.37	.37	5	5	56
	4-13	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	1.0-2.0	.37	.37			
	13-20	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37			
	20-26	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.0-0.5	.37	.37			
	26-36	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.0-0.5	.37	.37			
	36-41	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
	41-51	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	51-60	55-75	10-30	8-18	1.45-1.55	2-6	0.15-0.17	0.0-2.9	0.0-0.5	.55	.55			
304:														
Cosey----------	0-9	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	1.0-3.0	.43	.43	4	5	56
	9-15	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	1.0-1.5	.43	.43			
	15-28	30-50	30-50	10-20	1.35-1.45	0.6-2	0.11-0.13	0.0-2.9	0.0-1.0	.20	.37			
	28-34	50-75	5-25	20-35	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	0.0-0.5	.10	.32			
	34-60	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.05-0.07	3.0-5.9	0.0-0.5	.05	.32			
Jarmillo----------	0-17	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	2.0-4.0	.43	.43	5	5	56
	17-33	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-2.0	.24	.24			
	33-60	30-75	10-40	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
307:														
Flugle	0-3	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	1.0-3.0	.37	.37	5	5	56
	3-7	50-75	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	7-12	50-75	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	12-19	50-75	10-25	20-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	19-60	55-75	10-30	10-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.0	.28	.28			
Waumac	0-3	75-95	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.5-1.0	.17	.17	5	2	134
	3-60	55-75	10-30	5-15	1.45-1.55	2-6	0.12-0.14	0.0-2.9	0.0-0.5	.28	.28			
308:														
Cajete	0-7	30-50	30-50	15-25	1.35-1.45	0.6-2	0.12-0.14	3.0-5.9	1.0-2.0	.20	.37	3	6	48
	7-15	30-50	30-50	15-25	1.35-1.45	0.6-2	0.12-0.14	3.0-5.9	1.0-1.5	.20	.37			
	15-33	55-75	10-30	5-15	1.45-1.55	2-6	0.06-0.08	0.0-2.9	0.5-1.0	.10	.24			
	33-45	90-100	0-10	0-5	1.55-1.65	6-20	0.01-0.03	0.0-2.9	0.5-1.0	.02	.10			
	45-49	90-100	0-10	0-5	1.55-1.65	6-20	0.01-0.03	0.0-2.9	0.0-0.5	.02	.10			
	49-60	90-100	0-10	0-5	1.55-1.65	6-20	0.01-0.03	0.0-2.9	0.0-0.5	.02	.10			
311:														
Cosey	0-13	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	1.0-3.0	.43	.43	4	5	56
	13-24	30-50	30-50	10-20	1.35-1.45	0.6-2	0.11-0.13	0.0-2.9	0.0-0.5	.20	.37			
	24-60	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.04-0.06	3.0-5.9	0.0-0.5	.05	.32			
Tranquilar	0-14	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	2.0-4.0	.43	.43	5	5	56
	14-20	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.0-2.0	.43	.43			
	20-42	10-40	10-40	40-60	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-1.0	.20	.20			
	42-60	10-40	10-40	40-60	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
Calaveras	0-4	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	1.0-1.5	.43	.43	3	5	56
	4-11	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.5-1.0	.43	.43			
	11-17	10-35	50-75	15-25	1.15-1.35	0.6-2	0.15-0.17	3.0-5.9	0.0-1.0	.24	.43			
	17-30	30-50	30-50	10-20	1.35-1.45	0.6-2	0.07-0.09	0.0-2.9	0.0-0.5	.10	.37			
	30-39	55-75	10-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.02	.20			
	39-60	75-95	0-15	5-10	1.45-1.55	6-20	0.01-0.03	0.0-2.9	0.0-0.5	.02	.17			
312:														
Royosa	0-5	90-100	0-15	0-5	1.55-1.65	20-20	0.03-0.05	0.0-2.9	1.0-2.0	.10	.10	2	1	220
	5-16	90-100	0-15	0-5	1.55-1.65	20-20	0.03-0.05	0.0-2.9	0.5-1.5	.10	.10			
	16-60	75-95	5-20	0-10	1.50-1.60	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
314:														
Fragua	0-3	75-95	0-15	5-10	1.50-1.60	6-20	0.07-0.09	0.0-2.9	1.0-2.0	.17	.17	5	2	134
	3-8	55-75	10-30	10-18	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	8-24	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	24-60	55-75	10-30	10-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
Waumac	0-3	75-95	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.5-1.0	.20	.20	5	2	134
	3-60	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
Royosa	0-7	90-100	0-10	0-5	1.55-1.65	6-20	0.05-0.07	0.0-2.9	1.0-2.0	.17	.17	2	1	220
	7-60	90-100	0-10	0-5	1.55-1.65	6-20	0.05-0.07	0.0-2.9	0.0-1.0	.17	.17			
317:														
Elpedro	0-2	30-50	30-50	15-22	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	5	5	56
	2-22	0-20	50-70	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	22-60	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
319:														
Bamac	0-4	75-90	0-15	5-10	1.50-1.60	6-20	0.03-0.05	0.0-2.9	0.5-1.0	.05	.17	4	5	56
	4-10	75-90	0-15	5-10	1.50-1.60	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
	10-21	75-95	0-15	5-10	1.55-1.65	6-20	0.02-0.04	0.0-2.9	0.0-0.5	.05	.15			
	21-37	75-95	0-15	5-10	1.55-1.65	6-20	0.02-0.04	0.0-2.9	0.0-0.5	.05	.15			
	37-60	75-95	0-15	5-10	1.55-1.65	6-20	0.02-0.04	0.0-2.9	0.0-0.5	.05	.15			
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
320:														
Sparham	0-9	10-35	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.5-1.5	.43	.43	5	6	48
	9-32	0-20	40-55	40-50	1.20-1.30	0.06-0.2	0.15-0.17	6.0-8.9	0.0-1.0	.24	.24			
	32-60	0-20	40-55	40-50	1.20-1.30	0.06-0.2	0.15-0.17	6.0-8.9	0.0-0.5	.24	.24			
321:														
Waumac	0-3	75-95	0-15	5-10	1.50-1.60	6-20	0.08-0.10	0.0-2.9	0.5-1.0	.20	.20	5	2	134
	3-60	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
321:														
Royosa	0-12	90-100	0-15	0-5	1.55-1.65	6-20	0.05-0.07	0.0-2.9	1.0-2.0	.17	.17	2	1	220
	12-60	90-100	0-15	0-5	1.55-1.65	6-20	0.05-0.07	0.0-2.9	0.0-1.0	.17	.17			
322:														
Fragua	0-3	55-75	10-30	10-15	1.45-1.55	2-6	0.06-0.08	0.0-2.9	1.0-2.0	.10	.28	5	6	48
	3-16	55-75	10-30	10-18	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
	16-45	75-90	0-15	5-10	1.50-1.60	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.17	.17			
	45-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
324:														
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
Atarque	0-3	55-75	10-30	10-18	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24	1	3	86
	3-9	50-75	5-20	25-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	9-14	50-75	5-20	25-35	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	14-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Menefee	0-2	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.5	.20	.37	1	4L	86
	2-9	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	9-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
325:														
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
Espiritu	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.06-0.08	0.0-2.9	1.0-2.0	.10	.28	3	6	48
	2-20	50-70	5-25	25-35	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-0.5	.10	.32			
	20-60	30-50	30-50	15-25	1.35-1.45	0.6-2	0.08-0.10	3.0-5.9	0.0-0.5	.10	.37			
Vessilla	0-1	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.5-1.0	.10	.24	1	6	48
	1-10	30-50	30-50	10-20	1.35-1.45	0.6-2	0.11-0.13	0.0-2.9	0.0-0.5	.20	.37			
	10-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
342:														
Waumac	0-5	75-90	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.5-1.0	.20	.20	5	2	134
	5-60	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
Vessilla	0-3	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.5-1.0	.28	.28	1	3	86
	3-13	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
	13-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
345:														
Espiritu	0-6	55-75	10-30	5-15	1.45-1.55	2-6	0.06-0.08	0.0-2.9	1.0-2.0	.10	.28	3	6	48
	6-15	50-70	5-25	25-35	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-0.5	.10	.32			
	15-22	50-70	5-25	20-30	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-0.5	.10	.32			
	22-29	50-70	5-25	20-30	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	0.0-0.5	.10	.32			
	29-38	50-70	5-25	20-30	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	0.0-0.5	.10	.32			
	38-46	---	---	10-20	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
	46-60	55-75	10-30	10-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.0	.10	.24			
Bamac	0-3	75-90	0-15	5-10	1.55-1.65	6-20	0.02-0.03	0.0-2.9	0.5-1.0	.05	.17	4	5	56
	3-30	75-90	0-15	5-10	1.55-1.65	6-20	0.02-0.04	0.0-2.9	0.0-0.5	.05	.17			
	30-60	75-90	0-15	5-10	1.55-1.65	6-20	0.02-0.04	0.0-2.9	0.0-0.5	.05	.17			
346:														
Espiritu, cobbly	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	1.0-2.0	.05	.24	3	8	0
	2-24	50-70	5-25	25-35	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-0.5	.10	.32			
	24-36	55-75	10-30	10-18	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.10	.24			
	36-60	75-90	0-15	5-10	1.45-1.55	6-20	0.04-0.06	0.0-2.9	0.0-0.5	.05	.17			
Bamac	0-3	75-90	0-15	5-10	1.55-1.65	6-20	0.02-0.03	0.0-2.9	0.5-1.0	.05	.17	3	5	56
	3-30	75-100	0-20	5-10	1.55-1.65	6-20	0.02-0.04	0.0-2.9	0.0-0.5	.10	.15			
	30-45	75-90	0-15	5-10	1.55-1.65	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
	45-60	75-90	0-15	5-10	1.55-1.65	6-20	0.02-0.04	0.0-2.9	0.0-0.5	.05	.17			
348:														
Wauquie	0-2	50-70	5-25	20-30	1.35-1.45	0.6-2	0.03-0.05	3.0-5.9	0.5-1.0	.05	.32	3	6	48
	2-16	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	16-40	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	40-60	75-90	0-15	5-10	1.45-1.55	6-20	0.03-0.04	0.0-2.9	0.0-0.5	.02	.17			
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
353:														
Cochiti	0-4	30-50	30-50	15-25	1.35-1.45	0.6-2	0.02-0.04	3.0-5.9	0.5-1.0	.05	.37	4	8	0
	4-22	20-40	20-40	30-40	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	22-60	75-90	0-15	5-10	1.45-1.55	6-20	0.04-0.06	0.0-2.9	0.0-0.5	.05	.17			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
353:														
Espiritu----------	0-3	30-50	30-50	15-25	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	1.0-2.0	.10	.37	3	8	0
	3-16	50-70	5-25	25-35	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	0.0-0.5	.10	.32			
	16-60	75-90	0-15	5-10	1.50-1.60	6-20	0.02-0.04	0.0-2.9	0.0-0.5	.02	.17			
354:														
Waumac Variant------	0-3	55-80	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.5-1.0	.10	.24	2	6	48
	3-12	55-80	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	12-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
358:														
Deama----------	0-3	30-50	30-50	18-27	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	1.0-3.0	.10	.37	1	6	48
	3-19	30-50	30-50	18-27	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	0.5-1.0	.10	.37			
	19-60	---	---	---	---	0.00-0.2	---	---	---	---	---			
Elpedro----------	0-3	30-50	30-50	15-22	1.35-1.45	0.6-2	0.08-0.10	3.0-5.9	0.5-1.0	.10	.37	5	7	38
	3-37	0-20	50-70	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	37-60	10-50	30-80	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
Rock outcrop--------	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
396:														
Atarque----------	0-2	55-75	10-30	10-18	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.05	.24	1	8	0
	2-16	20-40	20-40	25-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	16-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Menefee----------	0-2	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.13-0.15	3.0-5.9	0.5-1.5	.20	.32	2	4L	86
	2-14	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	14-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
Rock outcrop--------	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
397:														
Rock outcrop--------	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
Cucho----------	0-2	20-40	20-45	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.5-1.0	.10	.32	3	8	0
	2-9	20-40	20-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	9-37	20-40	20-45	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	37-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
Vessilla----------	0-2	55-75	10-30	5-15	1.45-1.55	2-6	0.09-0.10	0.0-2.9	0.5-1.0	.15	.28	1	5	56
	2-11	55-75	10-30	5-15	1.45-1.55	2-6	0.09-0.10	0.0-2.9	0.0-0.5	.15	.28			
	11-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
398:														
Espiritu----------	0-4	55-75	10-30	10-18	1.45-1.55	2-6	0.07-0.09	0.0-2.9	1.0-2.0	.10	.28	3	6	48
	4-24	50-70	5-25	25-35	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-0.5	.10	.32			
	24-60	55-75	10-30	10-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.05	.24			
Cucho----------	0-2	20-40	20-45	28-35	1.35-1.45	0.2-0.6	0.10-0.12	3.0-5.9	0.5-1.0	.10	.32	3	8	0
	2-37	0-20	45-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
	37-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
399:														
Cucho----------	0-2	20-40	20-45	28-35	1.35-1.45	0.2-0.6	0.10-0.12	3.0-5.9	0.5-1.0	.10	.32	3	8	0
	2-37	20-40	20-45	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	37-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
Teco----------	0-1	55-75	10-30	5-15	1.45-1.55	2-6	0.06-0.08	0.0-2.9	0.5-1.5	.10	.28	5	6	48
	1-7	45-60	0-15	35-55	1.35-1.45	0.2-0.6	0.15-0.17	6.0-8.9	0.5-1.0	.32	.32			
	7-23	10-40	15-40	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-1.0	.20	.20			
	23-40	10-40	15-45	40-50	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	40-45	55-75	10-30	5-15	1.45-1.55	2-6	0.06-0.08	0.0-2.9	0.0-0.5	.10	.28			
	45-60	50-70	10-30	20-30	1.35-1.45	0.6-2	0.09-0.11	3.0-5.9	0.0-0.5	.15	.32			
405:														
Charo----------	0-5	30-50	30-50	20-27	1.35-1.45	0.6-2	0.11-0.13	3.0-5.9	0.5-1.0	.20	.37	2	8	0
	5-12	10-30	20-40	40-60	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.5-1.0	.20	.20			
	12-15	10-30	20-40	40-60	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	15-25	10-30	20-40	40-60	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	25-28	10-30	20-40	40-60	1.15-1.35	0.06-0.2	0.14-0.16	6.0-8.9	0.0-0.5	.20	.20			
	28-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Charo, noncobbly----	0-8	30-50	30-50	20-27	1.30-1.40	0.6-2	0.16-0.18	0.0-2.9	0.5-0.9	.37	.43	2	6	48
	8-38	10-30	20-40	40-60	1.35-1.45	0.06-0.2	0.15-0.18	3.0-5.9	0.1-0.3	.28	.28			
	38-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
409:														
Santa Fe----------	0-3	55-75	10-30	10-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	1.0-2.0	.10	.24	1	6	48
	3-8	50-75	10-25	20-35	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	0.0-1.0	.10	.32			
	8-60	---	---	---	---	0.00-0.01	---	---	---	---	---			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
410:														
Zia	0-10	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	5	4L	86
	10-60	55-75	10-30	5-15	1.45-1.55	2-6	0.12-0.14	0.0-2.9	0.0-0.5	.28	.28			
414:														
Wauquie	0-3	55-75	10-30	5-15	1.45-1.55	2-6	0.06-0.08	0.0-2.9	0.5-1.0	.10	.28	3	6	48
	3-30	50-70	10-25	20-30	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	0.0-0.5	.10	.32			
	30-60	55-90	5-35	5-10	1.50-1.60	6-20	0.04-0.06	0.0-2.9	0.0-0.5	.05	.20			
417:														
Jocity	0-10	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	5	4L	86
	10-26	5-20	45-65	28-35	1.15-1.35	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.37	.37			
	26-32	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.0-0.5	.37	.37			
	32-50	50-70	10-25	20-30	1.35-1.45	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.32	.32			
	50-56	55-75	15-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	56-60	75-90	0-20	5-10	1.45-1.55	6-20	0.07-0.09	0.0-2.9	0.0-0.5	.17	.17			
418:														
Jocity	0-12	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32	5	4L	86
	12-30	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.32	.32			
	30-60	55-90	5-35	3-10	1.45-1.55	2-20	0.08-0.10	0.0-2.9	0.0-0.5	.24	.24			
419:														
Santa Fe	0-9	55-75	10-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	1.0-2.0	.05	.24	1	8	0
	9-16	50-75	5-25	20-35	1.35-1.45	0.6-2	0.06-0.08	3.0-5.9	0.0-1.0	.10	.32			
	16-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Wauquie	0-4	55-75	10-30	5-15	1.45-1.55	2-6	0.03-0.05	0.0-2.9	0.5-1.0	.05	.28	3	8	0
	4-11	50-75	10-25	20-30	1.35-1.45	0.6-2	0.03-0.05	3.0-5.9	0.0-1.0	.05	.32			
	11-18	50-75	10-25	20-30	1.35-1.45	0.6-2	0.03-0.05	3.0-5.9	0.0-0.5	.05	.32			
	18-29	55-75	10-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.05	.24			
	29-60	90-100	0-10	0-5	1.55-1.65	6-20	0.01-0.01	0.0-2.9	0.0-0.5	.02	.10			
Rock outcrop	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
420:														
Pinavetes	0-10	75-90	0-15	3-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.5-1.0	.17	.17	2	2	134
	10-60	90-100	0-15	0-5	1.55-1.65	6-20	0.03-0.05	0.0-2.9	0.0-0.5	.10	.10			
421:														
Gilco, moderately saline, sodic	0-7	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	5	4L	86
	7-19	55-75	10-30	10-18	1.40-1.50	2-6	0.14-0.16	0.0-2.9	0.0-0.5	.55	.55			
	19-60	30-70	10-50	10-18	1.40-1.50	0.6-2	0.14-0.16	0.0-2.9	0.0-0.5	.32	.32			
422:														
Vessilla	0-1	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.5-1.0	.24	.24	1	3	86
	1-15	55-75	10-30	5-15	1.45-1.55	2-6	0.11-0.13	0.0-2.9	0.0-0.5	.24	.24			
	15-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Menefee	0-3	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.5	.32	.32	2	4L	86
	3-10	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	10-60	---	---	---	---	0.00-0.02	---	---	---	---	---			
Orlie	0-4	30-50	30-50	20-27	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	2.0-3.0	.37	.37	5	6	48
	4-14	5-45	25-65	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.5	.37	.37			
	14-60	5-20	45-65	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-0.5	.37	.37			
423:														
Gilco	0-8	30-50	30-50	10-18	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	5	4L	86
	8-14	30-50	30-50	10-18	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.0-0.5	.37	.37			
	14-60	15-70	20-70	10-18	1.35-1.45	0.6-2	0.15-0.17	0.0-2.9	0.0-0.5	.32	.32			
426:														
Aga, moderately saline, sodic	0-8	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	3	4L	86
	8-20	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.0-0.5	.37	.37			
	20-36	75-90	0-25	0-10	1.50-1.60	6-20	0.03-0.05	0.0-2.9	0.0-0.5	.10	.10			
	36-60	90-100	0-10	0-5	1.55-1.65	6-20	0.03-0.05	0.0-2.9	0.0-0.5	.05	.10			
427:														
Aga	0-8	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	3	4L	86
	8-28	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.0-0.5	.37	.37			
	28-60	75-90	0-25	0-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
428:														
Aga, moderately saline, sodic------	0-4	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	3	4L	86
	4-16	55-75	10-35	5-15	1.45-1.55	0.6-2	0.15-0.17	0.0-2.9	0.0-0.5	.55	.55			
	16-22	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.0-0.5	.37	.37			
	22-60	70-100	0-30	0-10	1.55-1.65	6-20	0.04-0.06	0.0-2.9	0.0-0.5	.17	.17			
430:														
Trail----------	0-10	30-50	30-50	10-20	1.35-1.45	2-6	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	5	4L	86
	10-34	75-90	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
	34-60	55-100	0-40	0-5	1.45-1.55	6-20	0.03-0.05	0.0-2.9	0.0-0.5	.10	.10			
431:														
Trail----------	0-10	75-95	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.5-1.0	.17	.17	5	2	134
	10-60	50-100	0-45	0-10	1.45-1.55	2-20	0.06-0.12	0.0-2.9	0.0-0.5	.17	.17			
433:														
Peralta----------	0-10	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.0	.37	.37	5	4L	86
	10-60	55-95	0-30	10-20	1.45-1.55	0.6-2	0.13-0.15	0.0-2.9	0.0-0.5	.24	.24			
434:														
Peralta----------	0-10	30-50	30-50	15-25	1.35-1.45	0.6-2	0.16-0.18	3.0-5.9	0.5-1.5	.37	.37	5	4L	86
	10-16	55-75	10-30	5-15	1.45-1.55	2-6	0.15-0.17	0.0-2.9	0.5-1.0	.55	.55			
	16-20	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.0-1.0	.32	.32			
	20-28	55-75	10-30	5-15	1.45-1.55	2-6	0.13-0.15	0.0-2.9	0.0-1.0	.28	.28			
	28-40	75-95	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
	40-45	10-40	50-75	15-25	1.15-1.35	0.6-2	0.19-0.21	3.0-5.9	0.0-0.5	.43	.43			
	45-60	75-95	0-15	5-10	1.45-1.55	6-20	0.09-0.10	0.0-2.9	0.0-0.5	.20	.20			
437:														
Peralta, moderately saline, sodic------	0-4	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	5	4L	86
	4-60	35-95	0-50	5-15	1.45-1.55	0.6-2	0.13-0.15	0.0-2.9	0.0-0.5	.28	.28			
500:														
Rock outcrop--------	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
Osha----------	0-10	55-75	10-30	5-10	1.50-1.60	2-6	0.04-0.06	0.0-2.9	1.0-2.0	.05	.20	3	5	56
	10-20	55-75	10-30	5-10	1.50-1.65	2-6	0.03-0.05	0.0-2.9	0.5-1.5	.05	.20			
	20-43	55-95	1-30	3-7	1.50-1.60	6-20	0.01-0.03	0.0-2.9	0.0-0.5	.05	.15			
	43-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Rubble land---------	0-60	---	---	0-0	---	20-99	0.00-0.02	0.0-2.9	0.0-0.1	---	---	--	8	0
503:														
Cajete----------	0-8	55-75	10-30	8-15	1.50-1.60	2-6	0.02-0.04	0.0-2.9	1.0-2.0	.05	.24	2	8	0
	8-60	55-75	10-30	10-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.5-1.0	.10	.24			
Cypher----------	0-3	30-50	30-50	10-20	1.35-1.45	0.6-2	0.07-0.09	0.0-2.9	0.5-1.0	.10	.37	1	7	38
	3-11	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	11-15	55-75	10-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.05	.24			
	15-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
504:														
Orejas----------	0-2	30-50	30-50	15-25	1.35-1.45	0.6-2	0.08-0.10	3.0-5.9	0.5-1.0	.10	.37	1	7	38
	2-9	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	9-17	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.09-0.11	3.0-5.9	0.0-0.5	.10	.32			
	17-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Guaje----------	0-4	55-75	10-30	5-15	0.85-0.95	2-6	0.08-0.09	0.0-2.9	1.0-2.0	.15	.24	2	5	56
	4-12	55-75	10-30	5-15	0.85-0.95	2-6	0.08-0.09	0.0-2.9	0.5-1.0	.15	.24			
	12-17	55-75	10-30	5-15	0.85-0.95	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
	17-45	55-75	10-30	5-15	1.20-1.30	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.05	.24			
	45-60	55-75	10-30	5-15	1.25-1.35	2-6	0.05-0.07	0.0-2.9	0.0-0.5	.10	.24			
600:														
Rock outcrop--------	0-60	---	---	---	---	0.00-0.01	---	---	---	---	---	1	8	0
Cypher----------	0-4	30-50	30-50	10-20	1.35-1.45	0.6-2	0.08-0.10	0.0-2.9	0.5-1.0	.10	.37	1	7	38
	4-14	30-50	30-50	10-25	1.35-1.45	0.6-2	0.08-0.10	0.0-2.9	0.0-0.5	.10	.37			
	14-16	30-50	30-50	10-25	1.35-1.45	0.6-2	0.08-0.10	0.0-2.9	0.0-0.5	.10	.37			
	16-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
601:														
Laventana----------	0-5	55-75	10-30	5-15	1.45-1.55	2-6	0.08-0.10	0.0-2.9	1.0-2.0	.15	.24	3	5	56
	5-9	30-50	30-50	10-20	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-1.0	.10	.37			
	9-50	30-70	10-40	20-35	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-0.5	.10	.32			
	50-60	---	---	---	---	0.00-0.01	---	---	---	---	---			

Table 15.--Physical soil properties

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Permeability (Ksat)	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In.	Pct.	Pct.	Pct.	g/cc	In./hr.	In./in.	Pct.	Pct.					
603:														
Laventana	0-1	30-50	30-50	15-25	0.20-1.00	20-60	0.15-0.45	---	60-70	---	---	3	8	0
	1-5	30-50	30-50	15-25	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	1.0-2.0	.10	.37			
	5-12	10-40	50-75	15-25	1.15-1.35	0.6-2	0.13-0.15	3.0-5.9	0.0-1.0	.24	.43			
	12-20	30-50	30-50	20-25	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-0.5	.10	.37			
	20-31	30-50	30-50	20-27	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-0.5	.10	.37			
	31-51	30-50	30-50	15-25	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.0-0.5	.10	.37			
	51-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Mirand	0-6	30-50	30-50	20-27	1.35-1.45	0.6-2	0.08-0.10	3.0-5.9	1.0-3.0	.10	.37	5	8	0
	6-27	10-35	20-40	40-60	1.15-1.35	0.06-0.2	0.10-0.12	6.0-8.9	0.0-1.0	.10	.20			
	27-60	45-60	0-15	35-50	1.35-1.45	0.2-0.6	0.15-0.17	6.0-8.9	0.0-0.5	.32	.32			
604:														
Cypher	0-1	30-50	30-50	10-20	0.20-1.00	20-60	0.15-0.45	---	60-70	---	---	1	7	38
	1-4	30-50	30-50	10-20	1.35-1.45	0.6-2	0.08-0.10	0.0-2.9	0.5-1.0	.10	.37			
	4-11	30-50	30-50	10-25	1.35-1.45	0.6-2	0.09-0.11	0.0-2.9	0.0-0.5	.10	.37			
	11-19	55-75	10-30	5-15	1.45-1.55	2-6	0.02-0.04	0.0-2.9	0.0-0.5	.05	.24			
	19-60	---	---	---	---	0.00-0.01	---	---	---	---	---			
Mirand	0-4	30-50	30-50	20-27	1.35-1.45	0.6-2	0.07-0.09	3.0-5.9	0.5-1.5	.10	.37	5	8	0
	4-60	10-35	20-40	40-50	1.15-1.35	0.06-0.2	0.10-0.12	6.0-8.9	0.0-0.5	.10	.20			
608:														
Osha, steep	0-3	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	1.0-2.0	.10	.20	3	6	48
	3-8	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-2.0	.10	.20			
	8-16	55-75	10-30	5-15	1.45-1.55	2-6	0.05-0.07	0.0-2.9	0.0-1.0	.10	.20			
	16-32	55-75	10-30	5-15	1.45-1.55	2-6	0.01-0.03	0.0-2.9	0.0-0.5	.05	.20			
	32-60	75-95	0-20	0-5	1.45-1.55	6-20	0.01-0.03	0.0-2.9	0.0-0.5	.05	.15			
Osha	0-8	55-75	10-30	4-10	1.60-1.65	2-6	0.08-0.10	0.0-2.9	0.5-1.5	.10	.20	3	5	56
	8-16	55-75	10-30	6-12	1.60-1.65	2-6	0.04-0.07	0.0-2.9	0.1-0.3	.10	.20			
	16-32	55-75	10-30	6-12	1.70-1.75	2-6	0.02-0.04	0.0-2.9	0.1-0.3	.02	.20			
	32-60	75-95	0-20	4-8	1.90-1.95	6-20	0.01-0.03	0.0-2.9	0.1-0.3	.02	.15			
823:														
Gilco, unprotected	0-8	30-50	30-50	10-18	1.35-1.45	0.6-2	0.15-0.17	0.0-2.9	0.5-1.0	.37	.43	5	4L	86
	8-60	10-70	10-70	10-18	1.35-1.45	0.6-2	0.15-0.17	0.0-2.9	0.0-0.5	.37	.37			
827:														
Aga, unprotected	0-8	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	3	4L	86
	8-28	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.0-0.5	.37	.37			
	28-60	75-95	0-15	5-10	1.45-1.55	6-20	0.08-0.10	0.0-2.9	0.0-0.5	.20	.20			
830:														
Trail, unprotected	0-8	30-50	30-50	10-20	1.35-1.45	2-20	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	5	3	86
	8-60	55-100	0-40	0-10	1.45-1.55	2-20	0.03-0.13	0.0-2.9	0.0-0.5	.17	.17			
831:														
Trail, unprotected	0-10	75-95	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-1.0	.17	.17	5	2	134
	10-30	75-95	0-15	5-10	1.45-1.55	6-20	0.06-0.08	0.0-2.9	0.0-0.5	.17	.17			
	30-60	55-100	0-30	0-5	1.45-1.55	6-20	0.03-0.05	0.0-2.9	0.0-0.5	.10	.10			
835:														
Peralta, unprotected	0-6	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.5-1.0	.37	.37	5	4L	86
	6-16	30-50	30-50	10-20	1.35-1.45	0.6-2	0.16-0.18	0.0-2.9	0.0-1.0	.37	.37			
	16-60	30-75	5-40	15-35	1.40-1.50	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.24	.24			
842:														
Peralta, moderately saline, sodic, unprotected	0-10	20-40	20-40	28-35	1.35-1.45	0.2-0.6	0.19-0.21	3.0-5.9	0.5-1.0	.32	.32	5	4L	86
	10-60	25-75	5-45	15-35	1.40-1.50	0.6-2	0.14-0.16	3.0-5.9	0.0-0.5	.28	.28			
850:														
Water	---	---	---	---	---	---	---	---	---	---	---	--	---	---
DAM:														
Dam	---	---	---	---	---	---	---	---	---	---	---	--	---	---

Table 16.--Chemical properties of the soils

(Absence of an entry indicates that data were not estimated.)

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
1:							
Silver	0-4	11-18	6.6-7.3	0-5	0	0.0-2.0	0-2
	4-8	16-24	7.4-7.8	0-5	0	0.0-2.0	0-2
	8-20	16-23	7.4-7.8	0-5	0	0.0-2.0	0-2
	20-39	16-23	7.4-7.8	0-5	0	0.0-2.0	0-2
	39-60	16-23	7.4-7.8	5-10	0	0.0-2.0	0-2
Clovis	0-3	12-18	6.6-7.8	5-10	0	0.0-2.0	0-2
	3-20	16-23	6.6-7.8	5-10	0	0.0-2.0	0-2
	20-40	12-20	7.9-8.4	15-20	0	0.0-2.0	0-2
	40-60	4.0-11	7.9-8.4	15-20	0	0.0-2.0	0-2
2:							
Clovis	0-3	12-18	6.6-7.8	5-10	0	0.0-2.0	0-2
	3-24	16-23	6.6-8.4	10-15	0	0.0-2.0	0-2
	24-60	4.0-11	7.9-8.4	15-20	0	0.0-2.0	0-2
Prieta	0-3	11-18	6.6-7.3	0-5	0	0.0-2.0	0-2
	3-10	16-24	7.4-7.8	0-5	0	0.0-2.0	0-2
	10-14	16-23	7.9-8.4	0-5	0	0.0-2.0	0-2
	14-19	16-23	7.9-8.4	10-14	0	0.0-2.0	0-2
	19-60	---	---	---	---	---	---
Silver	0-8	11-18	6.6-7.3	0-5	0	0.0-2.0	0-2
	8-30	16-24	7.4-7.8	0-5	0	0.0-2.0	0-2
	30-60	16-23	7.4-7.8	0-5	0	0.0-2.0	0-2
3:							
Montecito	0-3	6.5-13	6.6-7.3	0-5	0	0.0-2.0	0-2
	3-18	15-19	7.4-7.8	5-10	0	0.0-2.0	0-2
	18-60	15-19	7.9-8.4	5-10	0	0.0-2.0	0-2
Orejas	0-2	11-16	7.4-7.8	0	0	0.0-2.0	0
	2-5	15-19	6.6-7.3	5-10	0	0.0-2.0	0
	5-14	15-19	7.9-8.4	5-10	0	0.0-2.0	0
	14-17	15-19	7.9-8.4	5-10	0	0.0-2.0	0
	17-19	15-19	7.9-8.4	5-10	0	0.0-2.0	0
	19-60	---	---	---	---	---	---
4:							
Montecito	0-3	3.7-10	6.6-7.3	0-5	0	0.0-2.0	0-2
	3-22	15-19	7.4-8.4	5-10	0	0.0-2.0	0-2
	22-60	8.7-14	7.4-8.4	0-5	0	0.0-2.0	0-2

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
4:							
Montecito, bouldery--	0-5	3.7-10	6.6-7.3	0-2	0	0.0-2.0	0-2
	5-28	15-19	7.4-8.4	0-5	0	0.0-2.0	0-2
	28-45	8.7-14	7.4-8.4	0-10	0	0.0-2.0	0-2
	45-60	3.2-8.7	7.4-8.4	0-10	0	0.0-2.0	0-2
10:							
Trail----------	0-6	18-23	7.9-8.4	1-5	0	0.0-4.0	0-5
	6-30	3.1-7.8	8.5-9.0	1-5	0	0.0-4.0	0-5
	30-45	0.0-4.0	8.5-8.9	1-5	0	0.0-4.0	0-5
	45-60	3.1-7.4	8.5-8.9	1-5	0	0.0-4.0	0-5
11:							
Trail----------	0-9	4.0-11	7.9-8.4	1-5	0	0.0-4.0	0-5
	9-36	3.1-7.8	8.5-9.0	1-5	0	0.0-4.0	0-5
	36-60	3.1-11	8.5-9.0	1-5	0	0.0-4.0	0-5
13:							
Sandoval----------	0-2	7.4-15	7.9-9.0	0-5	0-5	2.0-4.0	0-5
	2-6	14-23	7.9-8.4	0-5	0-5	2.0-4.0	0-5
	6-10	14-22	7.9-8.4	5-10	0-5	2.0-4.0	0-5
	10-15	14-22	7.9-8.4	5-10	0-5	2.0-4.0	0-5
	15-60	---	---	---	---	---	---
Querencia----------	0-4	14-21	7.9-8.4	0-5	0	0.0-2.0	0-5
	4-12	16-24	7.9-8.4	5-10	0	0.0-2.0	0-5
	12-24	9.8-17	7.9-8.4	5-10	0	0.0-2.0	0-5
	24-60	9.8-17	7.9-8.4	5-10	0	0.0-2.0	0-5
15:							
Camino----------	0-2	19-24	7.4-7.8	0-5	0	0.0-2.0	0-5
	2-5	22-31	7.9-8.4	0-5	0	0.0-2.0	0-5
	5-20	22-31	7.9-8.4	0-5	0	0.0-2.0	0-5
	20-51	22-31	7.9-8.4	5-10	0	2.0-4.0	0
	51-60	---	---	---	---	---	---
Sandoval----------	0-2	7.8-14	8.5-9.0	0-5	5-10	2.0-4.0	8-13
	2-17	14-23	7.9-8.4	5-10	5-10	2.0-4.0	8-13
	17-60	---	---	---	---	---	---
16:							
Rock outcrop---------	0-60	---	---	---	---	---	---

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
16:							
Prieta	0-5	11-18	6.6-7.3	0-5	0	0.0-2.0	0-5
	5-15	16-24	7.4-7.8	0-5	0	0.0-2.0	0-5
	15-19	16-23	7.9-8.4	3-8	0	0.0-2.0	0-5
	19-60	---	---	---	---	---	---
17:							
Vessilla	0-5	4.0-11	7.9-8.4	5-10	0	0.0-2.0	0
	5-11	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0
	11-60	---	---	---	---	---	---
Menefee	0-3	19-25	7.9-8.4	0-2	0	0.0-2.0	0
	3-10	14-23	7.9-8.4	0-5	0	0.0-2.0	0
	10-60	---	---	---	---	---	---
Rock outcrop	0-60	---	---	---	---	---	---
18:							
Sparham	0-7	18-24	6.6-7.3	0-5	0	2.0-4.0	5-10
	7-20	18-34	7.4-7.8	0-5	0	2.0-4.0	5-10
	20-29	14-23	7.9-8.4	5-10	0	2.0-16.0	5-30
	29-47	14-22	7.4-7.8	5-10	0	2.0-16.0	5-30
	47-53	14-22	7.9-8.4	5-10	0	2.0-16.0	5-30
	53-60	14-22	7.9-8.4	5-10	0	2.0-16.0	5-30
20:							
Gilco	0-6	18-21	6.6-8.4	0-5	0	0.0-4.0	0-5
	6-60	5.7-14	6.6-8.4	5-10	0	0.0-4.0	0-5
21:							
Rock outcrop	0-60	---	---	---	---	---	---
Hackroy	0-3	7.3-13	6.6-7.8	0	0	0.0-2.0	0
	3-12	21-26	6.6-7.8	0	0	0.0-2.0	0
	12-60	---	---	---	---	---	---
22:							
Aga	0-8	18-23	6.6-8.4	0-5	0	0.0-2.0	0-5
	8-24	5.4-12	6.6-8.4	5-10	0	2.0-4.0	0-5
	24-60	0.0-8.3	6.6-8.4	5-10	0	2.0-4.0	0-5

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
23:							
Hickman	0-4	20-26	7.9-8.4	0	0	0.0-2.0	0-5
	4-12	14-24	7.4-7.8	5-10	0	0.0-2.0	0-5
	12-49	14-23	7.4-7.8	5-10	0	0.0-2.0	0-5
	49-60	10-22	7.9-8.4	5-10	0	0.0-2.0	0-5
24:							
Orlie	0-2	4.6-12	7.9-8.4	0	0	0.0-2.0	0
	2-25	15-20	7.9-8.4	0-5	0	0.0-2.0	0
	25-60	11-16	7.9-8.4	5-10	0	2.0-4.0	0
Sparham	0-3	25-36	6.6-7.8	0-5	0	2.0-4.0	5-10
	3-60	19-32	7.4-8.4	5-10	0	2.0-16.0	5-30
25:							
Gilco	0-4	7.4-13	7.9-8.4	0-5	0	0.0-4.0	0-5
	4-34	5.7-12	7.9-8.4	5-10	0	0.0-4.0	0-5
	34-60	5.7-12	7.9-8.4	5-10	0	0.0-4.0	0-5
26:							
Orlie	0-2	8.1-15	7.9-8.4	0	0	0.0-2.0	0
	2-13	15-21	7.9-8.4	0-5	0	0.0-2.0	0
	13-22	15-20	7.9-8.4	0-5	0	0.0-2.0	0
	22-36	15-19	7.9-8.4	5-10	0	2.0-4.0	0
	36-50	15-19	7.9-8.4	5-10	0	2.0-4.0	0
	50-60	15-19	7.9-8.4	5-10	0	2.0-4.0	0
27:							
Aga	0-10	7.4-14	7.9-8.4	0-5	0	0.0-2.0	0-5
	10-23	4.7-12	7.9-8.4	5-10	0	2.0-4.0	0-5
	23-43	0.0-4.0	7.9-8.4	5-10	0	2.0-4.0	0-5
	43-60	0.0-4.0	7.9-8.4	5-10	0	2.0-4.0	0-5
29:							
Trail	0-6	3.1-7.8	7.9-8.4	1-5	0	0.0-2.0	0-5
	6-60	3.1-7.4	8.5-9.0	1-5	0	0.0-2.0	0-5
31:							
Riverwash	0-6	0.0-0.9	6.6-7.3	0-1	0-1	0.0-1.0	0-1
	6-60	---	6.6-7.3	0	0	0.0-2.0	0-1
33:							
Pits	0-60	---	---	---	---	---	---

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
34:							
Ildefonso	0-3	12-18	7.4-8.4	5-10	0	0.0-2.0	0-5
	3-17	11-18	7.9-8.4	15-20	0	0.0-4.0	0-5
	17-60	7.0-14	7.9-8.4	15-20	0	0.0-4.0	0-5
Witt	0-3	4.6-12	7.4-7.8	0-5	0	0.0-2.0	0-5
	3-27	9.8-18	7.9-8.4	0-5	0	0.0-2.0	0-5
	27-60	9.8-17	7.9-8.4	10-20	0	0.0-2.0	0-5
41:							
Dune Land	0-6	---	6.6-7.3	0-1	0-1	0.0-1.0	0-1
	6-60	---	6.6-7.3	0-1	0-1	0.0-1.0	0-1
47:							
Cascajo	0-2	4.6-12	7.4-7.8	0-10	0	0.0-2.0	0
	2-5	4.6-12	7.9-8.4	0-10	0	0.0-2.0	0
	5-11	4.0-11	7.9-8.4	0-10	0	0.0-2.0	0
	11-23	4.0-8.1	7.9-8.4	0-10	0	0.0-2.0	0
	23-30	4.0-8.1	7.9-8.4	0-5	0	0.0-2.0	0
	30-60	4.0-8.1	7.9-8.4	0-5	0	0.0-2.0	0
51:							
Sparham	0-6	18-23	6.6-7.3	0-5	0	2.0-8.0	0-5
	6-20	14-23	7.4-7.8	5-10	0	2.0-8.0	0-5
	20-36	19-30	7.9-8.4	5-10	0	2.0-16.0	5-30
	36-60	14-22	7.9-8.4	5-10	0	2.0-16.0	5-30
52:							
Totavi	0-15	2.5-7.3	6.6-7.3	0	0	0.0-2.0	0
	15-19	2.5-6.7	6.6-7.3	0	0	0.0-2.0	0
	19-60	2.5-6.7	6.6-7.3	0	0	0.0-2.0	0
53:							
Witt	0-3	8.1-15	7.9-8.4	0-5	0	0.0-2.0	0
	3-6	11-18	7.4-7.8	0-5	0	0.0-2.0	0
	6-11	16-24	7.4-7.8	0-5	0	0.0-2.0	0
	11-18	16-24	7.9-8.4	0-5	0	0.0-2.0	0
	18-25	16-23	7.9-8.4	3-8	0	0.0-2.0	0
	25-39	9.8-17	7.9-8.4	5-15	0	0.0-2.0	0
	39-53	9.8-17	7.9-8.4	5-15	0	0.0-2.0	0
	53-60	9.8-17	7.9-8.4	5-15	0	0.0-2.0	0

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
53:							
Harvey	0-10	11-18	7.4-8.4	5-10	0	0.0-2.0	0
	10-28	16-24	7.4-8.4	5-10	0	0.0-2.0	0
	28-42	12-23	7.9-8.4	15-20	0	0.0-2.0	0
	42-60	4.0-11	7.9-8.4	15-20	0	0.0-2.0	0
54:							
Harvey	0-2	4.6-14	7.4-8.4	5-10	0	0.0-2.0	0
	2-11	4.0-12	7.4-8.4	5-10	0	0.0-2.0	0
	11-23	16-23	7.9-8.4	15-20	0	0.0-2.0	0
	23-60	12-23	7.9-8.4	15-20	0	0.0-2.0	0
Cascajo	0-3	4.6-12	7.4-8.4	5-10	0-1	0.0-2.0	0
	3-9	4.6-12	7.4-8.4	5-10	0-1	0.0-2.0	0
	9-28	0.0-4.6	7.4-8.4	15-20	0-1	0.0-2.0	0
	28-60	0.0-4.6	7.9-8.4	15-20	0-1	0.0-2.0	0
55:							
La Fonda	0-4	15-20	7.4-8.4	0-5	0	0.0-2.0	0-5
	4-26	9.8-18	7.4-8.4	0-5	0	0.0-2.0	0-5
	26-60	12-18	7.4-8.4	10-15	0	0.0-2.0	0-5
56:							
Ildefonso	0-3	12-18	7.4-8.4	5-10	0	0.0-2.0	0
	3-9	11-18	7.4-8.4	5-10	0	0.0-2.0	0
	9-15	9.8-18	7.9-8.4	15-20	0	0.0-4.0	0
	15-60	9.8-17	7.9-8.4	15-20	0	0.0-4.0	0
57:							
Badland	0-60	---	---	---	---	---	---
58:							
Deama	0-7	11-24	7.4-8.4	10-30	0	0.0-2.0	0
	7-14	9.5-18	7.4-8.4	40-60	0	0.0-2.0	0
	14-60	---	---	---	---	---	---
Elpedro	0-5	9.0-14	7.4-7.8	5-15	0	0.0-2.0	0
	5-12	15-19	7.4-7.8	5-15	0	0.0-2.0	0
	12-19	15-19	7.9-8.4	5-15	0	0.0-2.0	0
	19-25	15-19	7.9-8.4	5-15	0	0.0-2.0	0
	25-36	15-19	7.4-7.8	5-15	0	0.0-2.0	0
	36-45	8.7-15	7.4-7.8	5-15	0	0.0-2.0	0
	45-60	6.0-11	7.4-7.8	5-15	0	0.0-2.0	0

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
59:							
Harvey	0-4	11-18	7.9-8.4	5-10	0	0.0-2.0	0
	4-10	9.8-18	7.9-8.4	5-10	0	0.0-2.0	0
	10-18	16-23	7.9-8.4	15-20	0	0.0-2.0	0
	18-41	16-23	7.9-8.4	15-20	0	0.0-2.0	0
	41-60	12-20	7.9-8.4	15-20	0	0.0-2.0	0
Ildefonso	0-2	12-18	7.4-8.4	5-10	0	0.0-2.0	0
	2-8	11-18	7.4-8.4	5-10	0	0.0-2.0	0
	8-13	11-18	7.4-8.4	5-10	0	0.0-2.0	0
	13-32	4.0-11	7.9-8.4	15-20	0	0.0-4.0	0
	32-40	4.0-11	7.9-8.4	15-20	0	0.0-4.0	0
	40-60	0.0-4.6	7.9-8.4	15-20	0	0.0-4.0	0
La Fonda	0-3	15-20	7.9-8.4	0-5	0	0.0-2.0	0-5
	3-7	14-19	7.9-8.4	0-5	0	0.0-2.0	0-5
	7-14	19-24	7.9-8.4	0-5	0	0.0-2.0	0-5
	14-26	12-19	7.9-8.4	0-5	0	0.0-2.0	0-5
	26-42	12-18	7.9-8.4	10-15	0	0.0-2.0	0-5
	42-60	12-18	7.9-8.4	10-15	0	0.0-2.0	0-5
63:							
Placitas	0-5	8.3-15	7.9-8.4	0-5	0	0.0-2.0	0-5
	5-10	4.0-12	7.9-8.4	0-5	0	0.0-2.0	0-5
	10-27	4.0-11	7.9-8.4	20-25	0	0.0-2.0	0-5
	27-60	---	---	---	---	---	---
64:							
Skyvillage	0-4	4.2-12	7.9-8.4	0-5	0	0.0-2.0	0
	4-11	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0
	11-18	3.1-11	7.4-7.8	5-10	0	0.0-2.0	0
	18-60	---	---	---	---	---	---
Ildefonso	0-3	4.6-12	7.9-8.4	5-10	0	0.0-2.0	0
	3-14	4.0-12	7.9-8.4	5-10	0	0.0-2.0	0
	14-60	4.0-11	7.9-8.4	15-20	0	0.0-2.0	0
65:							
Ildefonso	0-6	6.7-14	7.4-7.8	5-10	0	0.0-2.0	0
	6-38	5.8-14	7.4-7.8	5-10	0	0.0-2.0	0
	38-60	5.8-13	7.9-8.4	15-20	0	0.0-2.0	0

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
65:							
Harvey	0-4	11-18	7.4-8.4	5-10	0	0.0-2.0	0
	4-23	11-18	7.9-8.4	15-20	0	0.0-2.0	0
	23-36	9.8-17	7.9-8.4	15-20	0	0.0-2.0	0
	36-60	4.0-11	7.9-8.4	15-20	0	0.0-2.0	0
66:							
Zia	0-4	4.0-11	7.4-8.4	0-5	0	0.0-2.0	0-5
	4-60	3.1-11	7.4-8.4	10-15	0	0.0-2.0	0-5
67:							
Sandoval	0-2	11-20	8.5-9.0	0-5	5-10	2.0-4.0	0
	2-11	14-23	7.9-8.4	5-10	5-10	2.0-4.0	0
	11-60	---	---	---	---	---	---
Poley	0-3	11-18	7.4-7.8	0-2	0-1	0.0-2.0	0
	3-12	19-24	7.4-7.8	0-2	0-1	0.0-2.0	0
	12-17	16-24	7.4-7.8	0-2	0-1	0.0-2.0	0
	17-21	16-23	7.9-8.4	0-10	0-1	0.0-2.0	0
	21-40	16-23	7.9-8.4	0-10	0-1	0.0-2.0	0
	40-60	4.0-11	7.4-7.8	0-10	0-1	0.0-2.0	0
68:							
Penistaja	0-2	4.6-8.3	7.4-7.8	0-5	0	0.0-2.0	0-2
	2-15	12-21	7.4-7.8	0-5	0	0.0-2.0	0-2
	15-27	12-20	7.4-7.8	5-10	0	0.0-2.0	0-2
	27-38	16-23	7.9-8.4	5-10	0	0.0-2.0	0-5
	38-60	12-20	7.4-7.8	5-10	0	0.0-2.0	0-5
Querencia	0-2	4.6-12	7.9-8.4	0-5	0	0.0-2.0	0-2
	2-40	12-21	7.9-8.4	5-10	0	0.0-2.0	0-2
	40-60	4.0-11	7.9-8.4	5-10	0	0.0-2.0	0-5
71:							
Palon	0-6	4.2-12	6.6-7.3	0	0	0.0-2.0	0
	6-27	3.2-8.7	6.6-7.3	0	0	0.0-2.0	0
	27-60	3.2-8.7	6.6-7.3	0	0	0.0-2.0	0
72:							
Palon	0-2	73-81	5.1-6.0	0	0	0.0-2.0	0
	2-4	4.2-12	6.6-7.3	0	0	0.0-2.0	0
	4-10	3.7-11	6.6-7.3	0	0	0.0-2.0	0
	10-32	3.2-8.7	6.6-7.3	0	0	0.0-2.0	0
	32-53	3.2-8.7	6.6-7.3	0	0	0.0-2.0	0
	53-60	3.2-8.7	6.6-7.3	0	0	0.0-2.0	0

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
74:							
Origo	0-7	4.2-12	6.6-7.3	0	0	0.0-2.0	0
	7-28	2.2-10	6.1-7.3	0	0	0.0-2.0	0
	28-60	---	4.5-5.0	0	0	0.0-2.0	0
Pavo	0-9	13-21	6.1-6.5	0	0	0.0-2.0	0
	9-12	5.0-13	6.6-7.3	0	0	0.0-2.0	0
	12-25	3.8-10	6.6-7.3	0	0	0.0-2.0	0
	25-35	3.8-10	6.6-7.3	0	0	0.0-2.0	0
	35-45	3.8-10	6.6-7.3	0	0	0.0-2.0	0
	45-50	19-23	6.1-6.5	0	0	0.0-2.0	0
	50-60	3.8-10	6.6-7.3	0	0	0.0-2.0	0
75:							
Origo	0-1	73-81	5.1-6.0	0	0	0.0-2.0	0
	1-6	4.2-12	6.1-6.5	0	0	0.0-2.0	0
	6-12	2.2-11	6.6-7.3	0	0	0.0-2.0	0
	12-32	3.2-8.7	6.6-7.3	0	0	0.0-2.0	0
	32-56	3.2-8.7	4.5-5.0	0	0	0.0-2.0	0
	56-60	1.0-3.2	4.5-5.0	0	0	0.0-2.0	0
82:							
Calaveras	0-2	6.7-13	5.6-7.3	0	0	0.0-2.0	0
	2-6	3.9-10	5.6-7.3	0	0	0.0-2.0	0
	6-40	2.5-9.2	5.6-7.3	0	0	0.0-2.0	0
	40-60	2.5-9.2	5.6-7.3	0	0	0.0-2.0	0
83:							
Calaveras	0-6	10-16	5.6-7.3	0	0	0.0-2.0	0
	6-12	3.9-10	5.6-7.3	0	0	0.0-2.0	0
	12-24	4.3-12	5.6-7.3	0	0	0.0-2.0	0
	24-60	2.5-9.2	5.6-7.3	0	0	0.0-2.0	0
Rubble Land	0-60	---	---	0	0	0	0
85:							
Redondo	0-2	4.6-9.4	6.1-6.5	0	0	0.0-2.0	0
	2-7	4.2-8.6	6.1-6.5	0	0	0.0-2.0	0
	7-15	3.7-7.8	5.6-6.0	0	0	0.0-2.0	0
	15-22	3.2-6.0	5.6-6.0	0	0	0.0-2.0	0
	22-29	3.2-6.0	5.6-6.0	0	0	0.0-2.0	0
	29-38	3.2-6.0	5.6-6.0	0	0	0.0-2.0	0
	38-54	3.2-6.0	5.6-6.0	0	0	0.0-2.0	0
	54-60	3.2-6.0	5.6-6.0	0	0	0.0-2.0	0

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
86:							
Redondo	0-8	4.2-8.1	6.1-6.5	0	0	0.0-2.0	0
	8-13	3.2-6.0	5.6-6.0	0	0	0.0-2.0	0
	13-34	3.2-6.0	5.6-6.0	0	0	0.0-2.0	0
	34-60	3.2-6.0	5.6-6.0	0	0	0.0-2.0	0
87:							
Redondo	0-6	7.3-14	6.1-6.5	0	0	0.0-2.0	0
	6-13	3.7-7.8	5.6-6.0	0	0	0.0-2.0	0
	13-60	3.2-6.0	5.6-6.0	0	0	0.0-2.0	0
Rubble Land	0-60	---	---	0	0	0	0
88:							
Totavi	0-12	2.5-7.3	6.6-7.3	0	0	0.0-2.0	0
	12-60	2.5-6.7	6.6-7.3	0-5	0	0.0-2.0	0
Jemez	0-6	9.0-15	7.4-7.8	0	0	0.0-2.0	0
	6-13	8.7-14	7.4-7.8	0	0	0.0-2.0	0
	13-19	15-19	7.4-7.8	0	0	0.0-2.0	0
	19-27	11-19	7.4-7.8	0	0	0.0-2.0	0
	27-60	---	---	---	---	---	---
Rock outcrop	0-60	---	---	---	---	---	---
91:							
Zia	0-16	4.0-11	7.4-8.4	0-5	0	0.0-2.0	0-5
	16-22	3.1-7.8	7.4-8.4	10-15	0	0.0-2.0	0-5
	22-35	3.1-11	7.4-8.4	10-15	0	0.0-2.0	0-5
	35-60	3.1-11	7.4-8.4	10-15	0	0.0-2.0	0-5
92:							
Galisteo, moderately saline, sodic	0-12	20-28	8.5-9.0	5-10	0	8.0-16.0	5-30
	12-60	19-30	8.5-9.0	5-10	0	8.0-16.0	5-30
93:							
Zia	0-8	4.0-7.8	7.4-8.4	0-5	0	0.0-2.0	0-5
	8-60	3.1-11	7.4-8.4	10-15	0	0.0-2.0	0-5
95:							
El Rancho	0-5	12-19	7.9-8.4	0	0	0.0-2.0	0-5
	5-20	10-18	7.9-8.4	0-5	0	0.0-2.0	0-5
	20-38	10-18	7.9-8.4	0-5	0	0.0-2.0	0-5
	38-60	3.1-11	7.9-8.4	0-5	0	0.0-2.0	0-5

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
97:							
El Rancho	0-8	19-23	7.9-8.4	0-5	0	0.0-2.0	0-5
	8-60	10-22	7.9-8.4	5-10	0	0.0-2.0	0-5
100:							
Orejas	0-5	9.0-15	7.4-7.8	0	0	0.0-2.0	0-5
	5-15	15-19	7.9-8.4	5-10	0	0.0-2.0	0-5
	15-19	15-19	7.9-8.4	5-10	0	0.0-2.0	0-5
	19-60	---	---	---	---	---	---
Rock outcrop	0-60	---	---	---	---	---	---
101:							
Blancot	0-2	4.6-12	7.9-8.4	0-3	0	0.0-2.0	0-5
	2-5	19-24	7.9-8.4	0-3	0	0.0-2.0	0-5
	5-14	16-23	7.9-8.4	0-3	0	0.0-2.0	0-5
	14-23	16-23	7.9-8.4	0-10	0	0.0-2.0	0-5
	23-40	4.0-11	7.9-8.4	0-2	0	2.0-4.0	0-5
	40-49	16-20	7.9-8.4	0-5	0	2.0-4.0	0-5
	49-60	4.0-9.8	8.5-9.0	0-5	0	2.0-4.0	0-5
Lybrook	0-1	18-23	7.9-8.4	0-5	0	2.0-4.0	5-10
	1-5	14-22	7.9-8.4	0-5	0	2.0-4.0	5-10
	5-21	14-22	7.9-8.4	0-5	0	2.0-4.0	5-30
	21-30	14-22	7.9-8.4	0-5	0	2.0-4.0	5-30
	30-60	14-22	9.0-10.0	5-10	0	5.0-25.0	15-50
102:							
Sparham	0-7	18-24	6.6-7.3	0-5	0	2.0-4.0	5-10
	7-29	14-23	7.4-7.8	5-10	0	2.0-16.0	5-30
	29-60	14-22	7.9-8.4	5-10	0	2.0-16.0	5-30
104:							
Cochiti	0-7	9.0-15	6.6-7.3	0	0	0.0-2.0	0
	7-12	16-22	6.1-6.5	0-5	0	0.0-2.0	0
	12-20	21-31	6.6-7.3	0-5	0	0.0-2.0	0
	20-29	16-21	6.6-7.3	0-5	0	0.0-2.0	0
	29-60	3.2-8.7	6.6-7.3	5-10	0	0.0-2.0	0
Montecito	0-3	9.0-16	6.6-7.3	0	0	0.0-2.0	0-2
	3-9	15-20	6.6-7.3	0-5	0	0.0-2.0	0-2
	9-15	15-19	7.4-7.8	0-5	0	0.0-2.0	0-2
	15-22	15-19	7.9-8.4	0-5	0	0.0-2.0	0-2
	22-37	3.2-8.7	7.9-8.4	5-10	0	0.0-2.0	0-2
	37-60	3.2-8.7	7.9-8.4	5-10	0	0.0-2.0	0-2

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
105:							
Badland	0-60	---	---	---	---	---	---
Menefee	0-4	11-18	7.4-8.4	0-2	0-1	0.0-2.0	0
	4-10	14-23	7.4-8.4	0-5	0-1	0.0-2.0	0
	10-60	---	---	---	---	---	---
106:							
Stumble	0-4	4.0-11	7.9-8.4	0-5	0	0.0-2.0	0-5
	4-10	3.1-11	7.4-7.8	5-10	0	0.0-2.0	0-5
	10-24	3.1-7.4	7.9-8.4	5-10	0	0.0-2.0	0-5
	24-60	0.0-4.0	7.9-8.4	5-10	0	0.0-2.0	0-5
Stumble, sandy	0-4	4.0-7.7	7.4-8.4	0-5	0	0.0-2.0	0-5
	4-18	3.6-7.1	7.9-8.4	5-10	0	0.0-2.0	0-5
	18-60	0.9-4.5	7.9-8.4	5-10	0	0.0-2.0	0-5
108:							
Embudo	0-6	4.0-11	6.6-7.8	0	0	0.0-2.0	0-5
	6-30	4.0-11	7.4-8.4	0	0	0.0-2.0	0-5
	30-60	4.0-8.1	7.4-8.4	0	0	0.0-2.0	0-5
109:							
Embudo	0-4	4.6-12	7.9-8.4	0	0	0.0-2.0	0-5
	4-12	4.6-9.7	7.9-8.4	0	0	0.0-2.0	0-5
	12-30	4.0-11	7.9-8.4	0-5	0	0.0-2.0	0-5
	30-60	4.0-8.1	7.9-8.4	0-5	0	0.0-2.0	0-5
Tijeras	0-4	4.0-12	7.9-8.4	0-5	0	0.0-2.0	0-5
	4-10	12-21	7.9-8.4	0-5	0	0.0-2.0	0-5
	10-20	12-20	7.9-8.4	5-10	0	0.0-2.0	0-5
	20-26	4.0-11	7.9-8.4	5-10	0	0.0-2.0	0-5
	26-60	4.0-11	7.9-8.4	5-10	0	0.0-2.0	0-5
110:							
Rock outcrop	0-60	---	---	---	---	---	---
Saido	0-5	11-18	7.9-8.4	0-5	10-20	2.0-8.0	0
	5-9	11-18	7.9-8.4	5-10	60-80	2.0-8.0	0
	9-15	9.8-18	7.9-8.4	5-10	60-80	2.0-8.0	0
	15-25	9.8-17	7.9-8.4	5-10	60-80	2.0-8.0	0
	25-60	9.8-17	7.9-8.4	5-10	30-50	2.0-8.0	0
111:							
Rock outcrop	0-60	---	---	---	---	---	---

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
111:							
Zia	0-5	4.0-11	7.4-8.4	0-5	0	0.0-2.0	0-5
	5-60	3.1-11	7.4-8.4	10-15	0	0.0-2.0	0-5
112:							
Tijeras	0-3	4.0-12	7.9-8.4	0-5	0	0.0-2.0	0-5
	3-14	12-20	7.9-8.4	0-5	0	0.0-2.0	0-5
	14-60	4.0-11	7.9-8.4	5-10	0	0.0-2.0	0-5
114:							
San Mateo	0-7	7.4-14	7.9-8.4	0-5	0	0.0-2.0	0-5
	7-60	8.1-22	8.5-9.0	5-10	0	5.0-30.0	0-5
Zia	0-3	4.0-11	7.4-8.4	0-5	0	0.0-2.0	0-5
	3-60	3.1-11	7.4-8.4	10-15	0	0.0-2.0	0-5
120:							
Pinavetes	0-10	4.0-7.8	7.9-8.4	1-5	0	0.0-2.0	0
	10-35	0.0-4.2	8.5-9.0	1-5	0	0.0-2.0	0
	35-60	0.0-4.0	7.9-8.4	1-5	0	0.0-2.0	0
124:							
Rock outcrop	0-60	---	---	---	---	---	---
129:							
Menefee	0-5	18-24	7.4-8.4	0-2	0-1	0.0-2.0	0
	5-10	14-23	7.4-8.4	0-5	0-1	0.0-2.0	0
	10-17	14-22	7.4-8.4	0-5	0-1	0.0-2.0	0
	17-60	---	---	---	---	---	---
130:							
Pinavetes	0-2	4.0-7.8	7.9-8.4	1-5	0	0.0-2.0	0
	2-60	3.1-7.4	8.5-8.9	1-5	0	0.0-2.0	0
Galisteo, moderately saline, sodic	0-2	19-25	8.5-9.0	5-10	0	8.0-16.0	13-30
	2-60	19-30	8.5-9.0	5-10	0	8.0-16.0	13-30
142:							
Grieta	0-3	7.0-13	7.4-8.4	0-5	0	0.0-2.0	0
	3-11	7.0-13	7.4-8.4	15-20	0	2.0-4.0	0
	11-34	12-23	7.4-8.4	15-20	0	2.0-4.0	0
	34-48	12-23	7.4-8.4	10-15	0	2.0-4.0	0
	48-60	4.0-8.1	7.4-8.4	10-15	0	2.0-4.0	0

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
143:							
Clovis	0-3	4.7-12	7.4-7.8	5-10	0	0.0-2.0	0-1
	3-7	14-24	7.9-8.4	20-25	0	0.0-2.0	0-1
	7-12	12-23	7.9-8.4	20-25	0	0.0-2.0	0-1
	12-22	12-23	7.9-8.4	20-25	0	0.0-2.0	0-1
	22-34	12-23	7.9-8.4	20-25	0	0.0-2.0	0-1
	34-60	12-23	7.9-8.4	20-25	0	0.0-2.0	0-1
145:							
Grieta	0-7	4.0-8.1	7.4-7.8	0-5	0	0.0-2.0	0-2
	7-14	12-23	7.9-8.4	0-10	0	2.0-4.0	0-2
	14-21	12-23	7.9-8.4	0-10	0	2.0-4.0	0-2
	21-38	4.0-11	7.9-8.4	10-15	0	2.0-4.0	0-2
	38-50	4.0-11	7.9-8.4	10-15	0	2.0-4.0	0-2
	50-60	4.0-11	7.9-8.4	10-15	0	2.0-4.0	0-2
Sheppard	0-5	3.1-7.4	7.9-8.4	0-5	0	0.0-2.0	0
	5-27	3.1-7.4	7.9-8.4	0-10	0	0.0-2.0	0
	27-60	3.1-7.4	7.9-8.4	0-10	0	0.0-2.0	0
146:							
Sedmar	0-3	4.0-7.8	6.6-7.3	0	0	0.0-2.0	0
	3-13	3.1-11	6.6-7.3	0	0	0.0-2.0	0
	13-18	3.1-7.4	6.6-7.3	0	0	0.0-2.0	0
	18-60	---	---	---	---	---	---
150:							
Doakum	0-5	4.6-12	7.9-8.4	0-5	0	0.0-2.0	0-2
	5-11	16-23	7.9-8.4	5-10	0	2.0-4.0	0-2
	11-17	12-23	7.9-8.4	5-10	0	2.0-4.0	0-2
	17-24	12-23	8.5-9.0	5-10	0	4.0-8.0	0-5
	24-31	16-23	8.5-9.0	5-10	0	4.0-8.0	0-5
	31-44	7.0-17	8.5-9.0	5-10	0	4.0-8.0	0-5
	44-60	7.0-15	8.5-9.0	5-10	0	4.0-8.0	0-5
Betonnie	0-2	4.6-12	7.9-8.4	0-5	0	0.0-2.0	0-2
	2-4	4.6-12	7.9-8.4	0-5	0	0.0-2.0	0-2
	4-12	4.0-11	7.9-8.4	0-5	0	0.0-2.0	0-2
	12-18	4.0-11	7.9-8.4	0-5	0	0.0-2.0	0-2
	18-34	4.0-11	8.5-9.0	0-10	0	0.0-2.0	0-5
	34-60	4.0-9.8	8.5-9.0	0-10	0	0.0-2.0	0-5

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
162:							
Hackroy	0-3	7.3-13	6.6-7.8	0	0	0.0-2.0	0
	3-13	21-26	6.6-7.8	0	0	0.0-2.0	0
	13-60	---	---	---	---	---	---
Nyjack	0-3	11-15	6.1-6.5	0	0	0.0-2.0	0
	3-13	15-19	6.6-7.3	0	0	0.0-2.0	0
	13-24	15-19	6.6-7.3	0	0	0.0-2.0	0
	24-39	3.2-8.7	6.6-7.3	0	0	0.0-2.0	0
	39-60	---	---	---	---	---	---
163:							
Jemez	0-3	9.0-15	6.6-7.8	0	0	0.0-2.0	0
	3-24	15-19	6.6-7.8	0	0	0.0-2.0	0
	24-39	14-19	6.6-7.8	0	0	0.0-2.0	0
	39-60	---	---	---	---	---	---
170:							
San Mateo	0-2	11-18	7.9-8.4	0-5	0	0.0-2.0	0-5
	2-10	14-23	8.5-9.0	5-10	0	0.0-2.0	0-5
	10-23	14-22	8.5-9.0	5-10	0	0.0-2.0	0-5
	23-32	14-22	7.9-8.4	5-10	0	0.0-2.0	0-5
	32-54	14-22	8.5-9.0	5-10	0	1.0-8.0	5-30
	54-60	14-22	8.5-9.0	5-10	0	1.0-8.0	5-30
180:							
Councelor	0-2	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0-2
	2-7	3.1-11	7.9-8.4	5-10	0	2.0-4.0	0-2
	7-37	3.1-11	7.9-8.4	5-10	0	2.0-4.0	0-2
	37-40	14-22	7.9-8.4	5-10	0	2.0-4.0	0-2
	40-60	3.1-11	7.9-8.4	5-10	0	2.0-4.0	0-2
Eslendo	0-3	18-23	7.9-8.4	0	0	2.0-4.0	0-5
	3-10	14-22	7.9-8.4	0-5	0	2.0-4.0	0-5
	10-60	---	---	---	---	---	---
Mespun	0-6	1.4-7.4	7.9-8.4	5-10	0	0.0-2.0	0
	6-60	2.0-6.1	7.9-8.4	5-10	0	0.0-2.0	0
183:							
Sheppard	0-4	3.1-7.4	7.9-8.4	0-5	0	0.0-2.0	0
	4-45	3.1-7.4	7.9-8.4	0-10	0	0.0-2.0	0
	45-60	3.1-7.4	7.9-8.4	0-10	0	0.0-2.0	0

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
185:							
Frijoles	0-3	4.2-11	6.6-7.3	0	0	0.0-2.0	0
	3-8	8.8-20	6.6-7.3	0	0	0.0-2.0	0
	8-13	15-19	6.6-7.3	0	0	0.0-2.0	0
	13-20	6.0-8.7	6.6-7.3	0-5	0	0.0-2.0	0
	20-60	0.0-1.4	6.6-7.3	0	0	0.0-2.0	0
190:							
Zia	0-5	4.0-11	7.4-8.4	0-5	0	0.0-2.0	0
	5-28	3.1-11	7.4-8.4	5-12	0	0.0-2.0	0
	28-60	3.1-11	7.4-8.4	10-15	0	0.0-2.0	0
Skyvillage	0-2	4.2-12	7.9-8.4	0-5	0	0.0-2.0	0
	2-11	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0
	11-16	3.1-11	7.4-7.8	5-10	0	0.0-2.0	0
	16-60	---	---	---	---	---	---
Rock outcrop	0-60	---	---	---	---	---	---
191:							
Sheppard	0-3	3.1-7.4	7.9-8.4	0-5	0	0.0-2.0	0
	3-27	3.1-7.4	7.9-8.4	0-10	0	0.0-2.0	0
	27-60	3.1-7.4	7.9-8.4	0-10	0	0.0-2.0	0
200:							
Sedillo	0-4	4.7-12	7.4-7.8	0-5	0	0.0-2.0	0-5
	4-13	12-21	7.4-7.8	5-10	0	0.0-2.0	0-5
	13-60	4.0-11	7.4-7.8	15-30	0	0.0-2.0	0-5
201:							
Rock outcrop	0-60	---	---	---	---	---	---
Sedgran	0-4	4.0-7.8	6.6-7.3	0	0	0.0-2.0	0
	4-13	3.1-7.4	7.4-7.8	0	0	0.0-2.0	0
	13-60	---	---	---	---	---	---
206:							
Pinitos	0-4	9.0-15	6.6-7.3	0-5	0	0.0-2.0	0
	4-10	15-19	6.6-7.3	5-10	0	0.0-2.0	0
	10-27	15-19	6.6-7.8	5-10	0	0.0-2.0	0
	27-39	15-19	7.4-7.8	8-12	0	0.0-2.0	0-2
	39-60	15-19	7.4-7.8	8-12	0	0.0-2.0	0-2

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
207:							
Penistaja	0-3	4.7-12	7.4-7.8	0-5	0	0.0-2.0	0-2
	3-29	12-21	7.4-7.8	5-10	0	0.0-2.0	0-2
	29-60	4.0-11	7.4-7.8	5-10	0	0.0-2.0	0-2
Zia	0-5	4.0-11	7.4-8.4	0-5	0	0.0-2.0	0-2
	5-60	3.1-11	7.4-8.4	0-5	0	0.0-2.0	0-2
208:							
Sedillo	0-2	4.6-12	7.4-7.8	0-5	0	0.0-2.0	0-5
	2-8	12-21	7.4-7.8	5-10	0	0.0-2.0	0-5
	8-12	4.0-11	7.4-7.8	20-25	0	0.0-2.0	0-5
	12-60	4.0-11	7.4-7.8	20-25	0	0.0-2.0	0-5
210:							
Ildefonso	0-3	12-18	7.4-8.4	5-10	0	0.0-2.0	0
	3-9	11-18	7.4-8.4	5-10	0	0.0-2.0	0
	9-60	9.8-17	7.9-8.4	15-20	0	0.0-4.0	0
211:							
Zia	0-5	4.0-11	7.4-7.8	0-5	0	0.0-2.0	0-2
	5-14	3.1-11	7.4-7.8	0-5	0	0.0-2.0	0-2
	14-33	3.1-11	7.4-7.8	5-10	0	0.0-2.0	0-2
	33-46	10-19	7.9-8.4	5-10	0	0.0-2.0	0-2
	46-60	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0-2
Clovis	0-5	8.3-13	7.4-8.4	5-10	0	0.0-2.0	0-2
	5-60	12-23	6.6-8.4	20-25	0	0.0-2.0	0-2
213:							
Pinavetes	0-7	0.0-4.2	7.9-8.4	1-5	0	0.0-2.0	0
	7-60	0.0-4.0	8.5-8.9	1-5	0	0.0-2.0	0
Rock outcrop	0-60	---	---	---	---	---	---
215:							
Ess	0-7	5.4-14	6.1-7.8	0	0	0	0
	7-15	7.8-15	6.1-7.8	0	0	0	0
	15-29	15-22	6.1-7.8	0	0	0	0
	29-60	7.2-14	6.1-7.8	0	0	0	0
Rock outcrop	0-60	---	---	---	---	---	---

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
217:							
Witt	0-2	8.1-15	7.9-8.4	0-5	0	0.0-2.0	0-2
	2-9	9.8-17	7.9-8.4	0-5	0	0.0-2.0	0-2
	9-60	7.0-14	7.9-8.4	10-20	0	0.0-2.0	0-2
218:							
Ildefonso	0-4	12-18	7.4-8.4	5-10	0	0.0-2.0	0
	4-8	11-18	7.4-8.4	5-10	0	0.0-2.0	0
	8-60	4.0-11	7.9-8.4	15-20	0	0.0-4.0	0
220:							
Rock outcrop	0-60	---	---	---	---	---	---
Vessilla	0-2	4.0-11	7.9-8.4	5-10	0	0.0-2.0	0
	2-10	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0
	10-60	---	---	---	---	---	---
Menefee	0-2	18-24	7.4-8.4	0-2	0-1	0.0-2.0	0
	2-10	14-23	7.4-8.4	0-5	0-1	0.0-2.0	0
	10-60	---	---	---	---	---	---
226:							
Galisteo, moderately saline, sodic	0-10	14-20	8.5-9.0	5-10	0	8.0-16.0	13-20
	10-60	14-22	8.5-9.0	5-10	0	8.0-16.0	13-20
227:							
Hagerman	0-4	8.1-15	6.6-7.8	0-5	0	0.0-2.0	0
	4-34	16-23	6.6-8.4	2-10	0	0.0-2.0	0
	34-60	---	---	---	---	---	---
Bond	0-4	3.8-7.6	7.4-7.8	0-5	0	0.0-2.0	0
	4-12	14-24	6.6-7.3	5-10	0	0.0-2.0	0
	12-60	---	---	---	---	---	---
228:							
Winona	0-2	4.6-13	7.4-7.8	5-10	0	2.0-4.0	0
	2-13	4.0-17	7.4-7.8	40-50	0	4.0-8.0	0
	13-60	---	---	---	---	---	---
230:							
Skyvillage	0-6	4.2-12	7.9-8.4	0-5	0	0.0-2.0	0
	6-11	3.1-11	7.4-7.8	5-10	0	0.0-2.0	0
	11-60	---	---	---	---	---	---

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
230:							
Sandoval	0-2	19-25	8.5-9.0	0-5	5-10	2.0-4.0	0-5
	2-10	14-23	7.9-8.4	5-10	5-10	2.0-4.0	0-5
	10-60	---	---	---	---	---	---
Rock outcrop	0-60	---	---	---	---	---	---
231:							
Querencia	0-3	11-18	7.9-8.4	0-5	0	0.0-2.0	0-5
	3-21	9.8-18	7.9-8.4	5-10	0	0.0-2.0	0-5
	21-60	9.8-17	7.9-8.4	5-10	0	0.0-2.0	0-5
234:							
Querencia	0-3	8.1-15	7.9-8.4	0-5	0	0.0-2.0	0-5
	3-25	12-19	7.9-8.4	5-10	0	0.0-2.0	0-5
	25-60	8.2-14	7.9-8.4	5-10	0	0.0-2.0	0-5
Zia	0-11	4.0-11	7.4-8.4	0-5	0	0.0-2.0	0-5
	11-60	3.1-11	7.4-8.4	10-15	0	0.0-2.0	0-5
235:							
Sandoval	0-2	7.8-14	8.5-9.0	0-5	5-10	2.0-4.0	8-13
	2-16	14-23	7.9-8.4	5-10	5-10	2.0-4.0	8-13
	16-19	14-22	7.9-8.4	5-10	5-10	2.0-4.0	8-13
	19-60	---	---	---	---	---	---
236:							
Sparank, moderately saline, sodic	0-2	19-25	8.5-9.0	0-5	0	8.0-16.0	13-30
	2-10	25-33	8.5-9.0	5-10	0	8.0-16.0	13-30
	10-24	25-32	7.9-8.4	5-10	0	8.0-16.0	13-30
	24-40	14-23	7.9-8.4	5-10	0	8.0-16.0	13-30
	40-44	19-30	7.9-8.4	5-10	0	8.0-16.0	13-30
	44-60	19-30	8.5-9.0	5-10	0	8.0-16.0	13-30
237:							
Sparank	0-4	19-25	7.4-8.4	0-5	0	2.0-4.0	5-10
	4-60	14-23	7.4-8.4	5-10	0	2.0-4.0	5-10
240:							
Penistaja	0-5	4.7-12	7.4-7.8	0-5	0	0.0-2.0	0-2
	5-14	19-24	7.4-7.8	0-5	0	0.0-2.0	0-2
	14-29	12-21	7.4-7.8	10-15	0	0.0-2.0	0-2
	29-60	9.8-17	7.4-7.8	10-15	0	0.0-2.0	0-2

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
240:							
Hagerman	0-2	8.1-15	7.9-8.4	0-5	0	0.0-2.0	0
	2-9	16-23	7.9-8.4	2-10	0	0.0-2.0	0
	9-24	16-23	7.9-8.4	2-10	0	0.0-2.0	0
	24-60	---	---	---	---	---	---
250:							
Pinavetes	0-4	4.0-7.8	7.9-8.4	1-5	0	0.0-2.0	0-5
	4-60	2.0-5.4	8.5-9.0	1-5	0	0.0-2.0	0-5
262:							
Pastura	0-3	15-20	7.9-8.4	5-10	0-1	0.0-2.0	0-5
	3-10	12-19	7.9-8.4	5-10	0-1	0.0-2.0	0-5
	10-14	12-18	7.9-8.4	10-15	0-1	0.0-2.0	0-5
	14-60	---	---	---	---	---	---
270:							
Blancot	0-2	4.6-12	7.9-8.4	0-5	0	0.0-2.0	0-2
	2-12	12-23	7.9-8.4	5-10	0	0.0-2.0	0-5
	12-21	16-23	7.9-8.4	5-10	0	0.0-2.0	5-13
	21-60	4.0-11	7.9-9.0	10-15	0	2.0-4.0	5-13
Councelor	0-2	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0-5
	2-60	3.1-11	7.9-9.0	5-10	0	2.0-4.0	0-5
Tsosie	0-2	18-24	7.9-8.4	0-5	0	4.0-8.0	5-10
	2-10	11-17	8.5-9.0	5-10	0	4.0-8.0	5-10
	10-20	14-23	8.5-9.0	5-10	0	4.0-8.0	5-10
	20-26	14-22	8.5-9.0	5-10	0	4.0-8.0	5-10
	26-36	14-22	8.5-9.0	5-10	0	4.0-8.0	5-10
	36-44	3.1-11	7.9-8.4	5-10	0	4.0-8.0	5-10
	44-55	3.1-11	8.5-9.0	5-10	0	4.0-8.0	5-10
	55-60	3.1-11	8.5-9.0	5-10	0	4.0-8.0	5-10
281:							
Carjo	0-4	8.1-19	6.6-7.3	0	0	0.0-2.0	0
	4-12	17-21	6.6-7.3	0	0	0.0-2.0	0
	12-20	21-26	6.6-7.3	0	0	0.0-2.0	0
	20-25	3.2-6.0	7.4-7.8	0	0	0.0-2.0	0
	25-60	---	---	---	---	---	---

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
282:							
Tocal	0-5	4.2-11	6.6-7.3	0-1	0-1	0.0-2.0	0-2
	5-8	15-20	6.6-7.3	0-1	0-1	0.0-2.0	0-2
	8-11	21-26	6.6-7.3	0-1	0-1	0.0-2.0	0-2
	11-14	8.7-14	6.6-7.3	0-1	0-1	0.0-2.0	0-2
	14-60	---	---	---	---	---	---
283:							
Mirand	0-2	73-81	5.1-6.0	0	0	0.0-2.0	0
	2-6	13-19	6.6-7.3	0	0	0.0-2.0	0
	6-11	15-21	6.1-6.6	0	0	0.0-2.0	0
	11-17	15-19	6.6-7.3	0	0	0.0-2.0	0
	17-27	15-19	6.6-7.3	0	0	0.0-2.0	0
	27-47	21-28	6.1-6.5	0	0	0.0-2.0	0
	47-60	---	4.5-5.0	0	0	0.0-2.0	0
Alanos	0-6	9.0-15	5.6-7.3	0	0	0.0-2.0	0
	6-9	8.7-14	5.6-7.3	0	0	0.0-2.0	0
	9-30	15-19	5.6-7.3	0	0	0.0-2.0	0
	30-60	21-26	5.6-7.3	0	0	0.0-2.0	0
290:							
Alanos	0-4	9.0-15	6.6-7.3	0	0	0.0-2.0	0
	4-9	9.0-15	6.6-7.3	0	0	0.0-2.0	0
	9-18	8.7-14	5.6-6.0	0	0	0.0-2.0	0
	18-26	21-26	5.6-6.0	0	0	0.0-2.0	0
	26-60	21-26	5.6-6.0	0	0	0.0-2.0	0
Rock outcrop	0-60	---	---	---	---	---	---
300:							
Waumac	0-3	4.0-7.8	7.9-8.4	0-5	0	0.0-2.0	0-5
	3-31	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0-5
	31-60	3.1-11	7.9-8.4	10-15	0	0.0-2.0	0-5
Bamac	0-6	4.0-7.8	7.9-8.4	0-5	0	0.0-2.0	0-5
	6-60	3.1-7.4	7.9-8.4	5-10	0	0.0-2.0	0-5
301:							
Vastine	0-4	14-22	6.6-7.3	0	0	0	0-5
	4-11	8.0-21	6.6-7.3	0	0	0	0-5
	11-24	10-17	6.6-7.3	0	0	0	0-5
	24-60	3.8-7.2	7.4-7.8	0	0	0.0-2.0	0-5

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
301:							
Jarola	0-9	13-21	6.1-6.5	0	0	0.0-2.0	0
	9-11	12-20	6.6-7.3	0	0	0.0-2.0	0
	11-17	19-25	6.6-7.3	0	0	0.0-2.0	0
	17-21	19-23	6.6-7.3	0	0	0.0-2.0	0
	21-42	14-20	6.6-7.3	0	0	0.0-2.0	0
	42-60	3.8-10	6.6-7.3	0	0	0.0-2.0	0
302:							
Tranquilar	0-4	22-29	6.1-6.5	0	0	0.0-2.0	0
	4-8	21-27	6.1-6.5	0	0	0.0-2.0	0
	8-11	19-26	6.1-6.5	0	0	0.0-2.0	0
	11-13	13-26	5.6-6.0	0	0	0.0-2.0	0
	13-20	---	5.1-5.5	0	0	0.0-2.0	0
	20-34	---	4.5-5.0	0	0	0.0-2.0	0
	34-42	---	4.5-5.0	0	0	0.0-2.0	0
	42-50	---	3.5-4.4	0	0	0.0-2.0	0
	50-60	---	4.5-5.0	0	0	0.0-2.0	0
Jarmillo	0-4	10.0-19	6.1-6.5	0	0	0.0-2.0	0
	4-13	9.2-17	6.1-6.5	0	0	0.0-2.0	0
	13-20	8.5-16	6.1-6.5	0	0	0.0-2.0	0
	20-26	7.2-14	6.6-7.3	0	0	0.0-2.0	0
	26-36	7.2-14	6.6-7.3	0	0	0.0-2.0	0
	36-41	3.8-10	6.6-7.3	0	0	0.0-2.0	0
	41-51	19-23	6.6-7.3	0	0	0.0-2.0	0
	51-60	5.8-12	6.6-7.3	0	0	0.0-2.0	0
304:							
Cosey	0-9	13-21	6.1-6.5	0	0	0.0-2.0	0
	9-15	13-20	6.1-6.5	0	0	0.0-2.0	0
	15-28	5.8-16	6.1-6.5	0	0	0.0-2.0	0
	28-34	14-23	6.1-6.5	0	0	0.0-2.0	0
	34-60	19-23	6.1-6.5	0	0	0.0-2.0	0
Jarmillo	0-17	14-22	6.1-6.5	0	0	0.0-2.0	0
	17-33	5.0-14	6.1-6.5	0	0	0.0-2.0	0
	33-60	3.8-10	6.6-7.3	0	0	0.0-2.0	0
307:							
Flugle	0-3	7.3-15	6.6-7.3	0	0	0.0-2.0	0
	3-7	11-19	6.6-7.3	0-5	0	0.0-2.0	0
	7-12	11-19	7.4-7.8	0-10	0	0.0-2.0	0
	12-19	11-19	7.4-7.8	0-10	0	0.0-2.0	0
	19-60	6.0-8.7	7.4-7.8	5-10	0	0.0-2.0	0

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
307:							
Waumac	0-3	4.0-7.8	7.9-8.4	0-5	0	0.0-2.0	0-5
	3-60	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0-5
308:							
Cajete	0-7	10-17	6.6-7.3	0	0	0.0-2.0	0
	7-15	10-16	6.6-7.3	0	0	0.0-2.0	0
	15-33	3.9-10	6.6-7.3	0-5	0	0.0-2.0	0
	33-45	0.0-4.2	6.6-7.3	0-5	0	0.0-2.0	0
	45-49	0.0-3.9	7.4-7.8	0-5	0	0.0-2.0	0
	49-60	0.0-3.9	7.4-7.8	0-5	0	0.0-2.0	0
311:							
Cosey	0-13	13-21	6.1-7.3	0	0	0.0-2.0	0
	13-24	7.2-14	6.1-7.3	0	0	0.0-2.0	0
	24-60	19-23	6.1-7.3	0	0	0.0-2.0	0
Tranquilar	0-14	14-22	6.1-6.5	0	0	0.0-2.0	0
	14-20	8.0-21	5.6-6.5	0	0	0.0-2.0	0
	20-42	---	4.5-5.0	0	0	0.0-2.0	0
	42-60	---	4.5-5.0	0	0	0.0-2.0	0
Calaveras	0-4	10-16	6.1-6.5	0	0	0.0-2.0	0
	4-11	9.2-15	6.1-6.5	0	0	0.0-2.0	0
	11-17	5.9-15	6.1-6.5	0	0	0.0-2.0	0
	17-30	4.3-12	5.6-6.0	0	0	0.0-2.0	0
	30-39	2.5-9.2	6.6-7.3	0	0	0.0-2.0	0
	39-60	2.5-6.7	6.6-7.3	0	0	0.0-2.0	0
312:							
Royosa	0-5	0.0-4.5	7.4-7.8	0-3	0	0.0-2.0	0
	5-16	0.0-4.4	7.4-7.8	0-3	0	0.0-2.0	0
	16-60	0.0-7.4	7.4-7.8	0-3	0	0.0-2.0	0
314:							
Fragua	0-3	4.2-8.1	7.4-7.8	0	0	0.0-2.0	0
	3-8	6.0-10	7.4-7.8	0-5	0	0.0-2.0	0
	8-24	3.2-8.7	7.4-7.8	0-5	0	0.0-2.0	0
	24-60	6.0-8.7	7.4-7.8	5-10	0	0.0-2.0	0
Waumac	0-3	4.0-7.8	7.9-8.4	0-5	0	0.0-2.0	0-2
	3-60	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0-2
Royosa	0-7	0.0-4.5	7.4-7.8	0-3	0	0.0-2.0	0
	7-60	0.0-4.2	7.4-7.8	0-3	0	0.0-2.0	0

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
317:							
Elpedro	0-2	9.0-14	7.4-7.8	5-15	0	0.0-2.0	0-5
	2-22	15-19	7.4-8.4	5-15	0	0.0-2.0	0-5
	22-60	11-15	7.4-8.4	5-15	0	0.0-2.0	0-5
319:							
Bamac	0-4	4.0-7.8	7.9-8.4	0-5	0	0.0-2.0	0-5
	4-10	3.1-7.4	7.9-8.4	5-10	0	0.0-2.0	0-5
	10-21	3.1-7.4	7.9-8.4	5-10	0	0.0-2.0	0-5
	21-37	3.1-7.4	7.9-8.4	5-10	0	0.0-2.0	0-5
	37-60	3.1-7.4	7.9-8.4	5-10	0	0.0-2.0	0-5
Rock outcrop	0-60	---	---	---	---	---	---
320:							
Sparham	0-9	11-18	6.6-7.3	0-5	0	2.0-4.0	5-10
	9-32	19-32	7.4-7.8	5-10	0	2.0-16.0	5-30
	32-60	19-30	7.9-8.4	5-10	0	2.0-16.0	5-30
321:							
Waumac	0-3	4.0-7.8	7.9-8.4	0-5	0	0.0-2.0	0-2
	3-60	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0-2
Royosa	0-12	0.0-4.5	7.4-7.8	0-3	0	0.0-2.0	0
	12-60	0.0-4.2	7.4-7.8	0-3	0	0.0-2.0	0
322:							
Fragua	0-3	7.3-11	7.4-7.8	0	0	0.0-2.0	0
	3-16	6.0-10	7.4-7.8	0-5	0	0.0-2.0	0
	16-45	3.2-6.0	7.4-7.8	5-10	0	0.0-2.0	0
	45-60	---	---	---	---	---	---
324:							
Rock outcrop	0-60	---	---	---	---	---	---
Atarque	0-3	6.5-12	6.6-7.3	0	0	0.0-2.0	0
	3-9	14-19	6.6-7.8	0-5	0	0.0-2.0	0
	9-14	14-19	7.4-7.8	0-10	0	0.0-2.0	0
	14-60	---	---	---	---	---	---
Menefee	0-2	14-19	7.4-8.4	0-5	0-1	0.0-2.0	0
	2-9	14-23	7.4-8.4	0-5	0-1	0.0-2.0	0
	9-60	---	---	---	---	---	---

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
325:							
Rock outcrop	0-60	---	---	---	---	---	---
Espiritu	0-2	4.2-11	7.4-7.8	0	0	0.0-2.0	0-5
	2-20	14-19	7.4-7.8	0	0	0.0-2.0	0-5
	20-60	8.7-14	7.4-7.8	0-5	0	0.0-2.0	0-5
Vessilla	0-1	4.0-11	7.9-8.4	0	0	0.0-2.0	0
	1-10	5.7-14	7.9-8.4	5-10	0	0.0-2.0	0
	10-60	---	---	---	---	---	---
342:							
Waumac	0-5	4.0-7.8	7.9-8.4	0-5	0	0.0-2.0	0-5
	5-60	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0-5
Vessilla	0-3	4.0-11	7.9-8.4	5-10	0	0.0-2.0	0
	3-13	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0
	13-60	---	---	---	---	---	---
Rock outcrop	0-60	---	---	---	---	---	---
345:							
Espiritu	0-6	4.2-11	7.4-7.8	0-1	0	0.0-2.0	0-5
	6-15	14-19	7.4-7.8	0-1	0	0.0-2.0	0-5
	15-22	11-16	7.4-7.8	0-1	0	0.0-2.0	0-5
	22-29	11-16	7.4-7.8	0-5	0	0.0-2.0	0-5
	29-38	11-16	7.4-7.8	0-5	0	0.0-2.0	0-5
	38-46	6.0-11	7.4-7.8	0-1	0	0.0-2.0	0-5
	46-60	6.0-8.7	7.4-7.8	0-1	0	0.0-2.0	0-5
Bamac	0-3	4.0-7.8	7.9-8.4	0-5	0	0.0-2.0	0-5
	3-30	3.1-7.4	7.9-8.4	5-10	0	0.0-2.0	0-5
	30-60	3.1-7.4	7.9-8.4	5-10	0	0.0-2.0	0-5
346:							
Espiritu, cobbly	0-2	4.2-11	7.4-7.8	0	0	0.0-2.0	0-5
	2-24	14-19	7.4-7.8	0-5	0	0.0-2.0	0-5
	24-36	6.0-10	7.4-7.8	5-10	0	0.0-2.0	0-5
	36-60	3.2-6.0	7.4-7.8	5-10	0	0.0-2.0	0-5
Bamac	0-3	4.0-7.8	7.9-8.4	0-5	0	0.0-2.0	0-5
	3-30	3.1-7.4	7.9-8.4	5-10	0	0.0-2.0	0-5
	30-45	3.1-7.4	7.9-8.4	5-10	0	0.0-2.0	0-5
	45-60	3.1-7.4	7.9-8.4	5-10	0	0.0-2.0	0-5

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
348:							
Wauquie	0-2	11-18	6.6-7.3	0-3	0	0.0-2.0	0
	2-16	15-19	6.6-7.3	0-3	0	0.0-2.0	0
	16-40	3.2-8.7	7.4-7.8	0-3	0	0.0-2.0	0
	40-60	3.2-6.0	7.4-7.8	0-3	0	0.0-2.0	0
Rock outcrop	0-60	---	---	---	---	---	---
353:							
Cochiti	0-4	9.0-15	6.6-7.3	0	0	0.0-2.0	0
	4-22	16-21	6.1-7.3	0-5	0	0.0-2.0	0
	22-60	3.2-6.0	6.6-7.8	5-10	0	0.0-2.0	0
Espiritu	0-3	10-17	7.4-7.8	0	0	0.0-2.0	0-5
	3-16	14-19	7.4-7.8	0-5	0	0.0-2.0	0-5
	16-60	3.2-6.0	7.4-7.8	5-10	0	0.0-2.0	0-5
354:							
Waumac Variant	0-3	4.0-11	7.4-7.8	0-5	0	0.0-2.0	0-5
	3-12	3.1-11	7.4-7.8	0-5	0	0.0-2.0	0-5
	12-60	---	---	---	---	---	---
358:							
Deama	0-3	13-24	7.9-8.4	10-30	0	0.0-2.0	0-5
	3-19	11-18	7.9-8.4	40-60	0	0.0-2.0	0-5
	19-60	---	---	---	---	---	---
Elpedro	0-3	9.0-14	7.4-7.8	5-15	0	0.0-2.0	0-5
	3-37	15-19	7.4-8.4	5-15	0	0.0-2.0	0-5
	37-60	11-15	7.4-8.4	5-15	0	0.0-2.0	0-5
Rock outcrop	0-60	---	---	---	---	---	---
396:							
Atarque	0-2	6.5-12	6.6-7.3	0	0	0.0-2.0	0-5
	2-16	14-19	6.6-7.8	0-5	0	0.0-2.0	0-5
	16-60	---	---	---	---	---	---
Menefee	0-2	18-24	7.4-8.4	0-5	0	0.0-2.0	0
	2-14	14-22	7.4-8.4	5-10	0	0.0-2.0	0
	14-60	---	---	---	---	---	---
Rock outcrop	0-60	---	---	---	---	---	---

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
397:							
Rock outcrop	0-60	---	---	---	---	---	---
Cucho	0-2	18-23	7.4-7.8	0-5	0	0.0-2.0	0
	2-9	14-22	6.6-7.3	10-15	0	0.0-2.0	0
	9-37	14-22	7.4-7.8	10-15	0	0.0-2.0	0
	37-60	---	---	---	---	---	---
Vessilla	0-2	4.0-11	7.9-8.4	0	0	0.0-2.0	0
	2-11	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0
	11-60	---	---	---	---	---	---
398:							
Espiritu	0-4	7.3-13	7.4-7.8	0-1	0	0.0-2.0	0-2
	4-24	14-19	7.4-7.8	0-1	0	0.0-2.0	0-2
	24-60	6.0-8.7	7.4-7.8	0-1	0	0.0-2.0	0-2
Cucho	0-2	18-23	7.4-7.8	0-5	0	0.0-2.0	0
	2-37	14-22	6.6-7.8	10-15	0	0.0-2.0	0
	37-60	---	---	---	---	---	---
399:							
Cucho	0-2	18-23	7.4-7.8	0-5	0	0.0-2.0	0
	2-37	14-22	6.6-7.8	10-15	0	0.0-2.0	0
	37-60	---	---	---	---	---	---
Teco	0-1	3.7-11	7.4-7.8	0	0	0.0-2.0	0
	1-7	18-29	7.4-7.8	0-5	0	0.0-2.0	0
	7-23	21-26	7.4-7.8	0-5	0	0.0-2.0	0
	23-40	21-26	7.4-7.8	0-5	0	0.0-2.0	0
	40-45	3.2-8.7	7.4-7.8	8-13	0	0.0-2.0	0
	45-60	11-16	7.4-7.8	5-10	0	4.0-8.0	0
405:							
Charo	0-5	15-20	6.6-7.3	0	0	0.0-2.0	0
	5-12	26-38	6.6-7.3	0	0	0.0-2.0	0
	12-15	26-38	6.6-7.3	0	0	0.0-2.0	0
	15-25	26-38	7.4-7.8	0	0	0.0-2.0	0
	25-28	26-38	7.4-7.8	0	0	0.0-2.0	0
	28-60	---	---	---	---	---	---
Charo, noncobbly	0-8	15-20	6.6-7.3	0	0	0.0-2.0	0
	8-38	26-38	6.6-7.8	0	0	0.0-2.0	0
	38-60	---	---	---	---	---	---

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
409:							
Santa Fe	0-3	9.2-14	6.6-7.3	0	0	0.0-2.0	0
	3-8	14-23	6.6-7.3	0	0	0.0-2.0	0
	8-60	---	---	---	---	---	---
410:							
Zia	0-10	7.4-14	7.4-8.4	0-5	0	0.0-2.0	0-5
	10-60	3.1-11	7.4-8.4	10-15	0	0.0-2.0	0-5
414:							
Wauquie	0-3	3.7-10	6.6-7.3	0-5	0	0.0-2.0	0-5
	3-30	11-16	6.6-7.3	0-5	0	0.0-2.0	0-5
	30-60	3.2-6.0	7.4-7.8	5-10	0	0.0-2.0	0-5
417:							
Jocity	0-10	11-17	7.9-8.4	0	0	2.0-4.0	0
	10-26	14-23	7.9-8.4	1-5	0	2.0-4.0	0
	26-32	8.1-16	7.9-8.4	1-5	0	2.0-4.0	0
	32-50	10-19	7.9-8.4	1-5	0	2.0-4.0	0-5
	50-56	3.1-11	8.5-8.9	1-5	0	2.0-4.0	0-5
	56-60	3.1-7.4	7.9-8.4	1-5	0	2.0-4.0	0-5
418:							
Jocity	0-12	18-23	7.4-8.4	0	0	2.0-4.0	0
	12-30	14-22	7.4-8.4	1-5	0	2.0-4.0	0
	30-60	2.0-7.4	7.9-9.0	1-5	0	2.0-4.0	0-5
419:							
Santa Fe	0-9	5.4-14	6.6-7.3	0	0	0.0-2.0	0
	9-16	14-23	6.6-7.3	0	0	0.0-2.0	0
	16-60	---	---	---	---	---	---
Wauquie	0-4	3.7-10	6.6-7.3	0	0	0.0-2.0	0
	4-11	11-16	6.6-7.3	0-5	0	0.0-2.0	0
	11-18	11-16	6.6-7.3	0-5	0	0.0-2.0	0
	18-29	3.2-8.7	7.4-7.8	0-5	0	0.0-2.0	0
	29-60	0.0-3.2	7.4-7.8	5-10	0	0.0-2.0	0
Rock outcrop	0-60	---	---	---	---	---	---
420:							
Pinavetes	0-10	2.6-7.8	7.9-8.4	1-5	0	0.0-2.0	0-5
	10-60	0.0-4.0	8.5-8.9	1-5	0	0.0-2.0	0-5

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
421:							
Gilco, moderately saline, sodic-------	0-7	7.4-14	7.9-8.4	5-10	0	8.0-16.0	8-13
	7-19	5.7-12	7.9-8.4	5-10	0	8.0-16.0	13-30
	19-60	5.7-12	7.9-8.4	5-10	0	8.0-16.0	13-30
422:							
Vessilla----------	0-1	4.0-11	7.9-8.4	5-10	0	0.0-2.0	0
	1-15	3.1-11	7.9-8.4	5-10	0	0.0-2.0	0
	15-60	---	---	---	---	---	---
Menefee----------	0-3	18-24	7.4-8.4	5-10	0-1	0.0-2.0	0
	3-10	14-23	7.4-8.4	10-15	0-1	0.0-2.0	0
	10-60	---	---	---	---	---	---
Orlie----------	0-4	14-19	7.9-8.4	0	0	0.0-2.0	0
	4-14	8.8-21	7.9-8.4	0-5	0	0.0-2.0	0-2
	14-60	15-19	7.9-8.4	5-10	0	2.0-4.0	0-2
423:							
Gilco----------	0-8	7.4-13	6.6-8.4	0-5	0	0.0-4.0	0-5
	8-14	5.7-12	6.6-8.4	0-5	0	0.0-4.0	0-5
	14-60	5.7-12	6.6-8.4	5-10	0	0.0-4.0	0-5
426:							
Aga, moderately saline, sodic-------	0-8	7.4-14	6.6-8.4	5-10	0	8.0-16.0	13-30
	8-20	5.7-14	7.4-8.4	5-10	0	8.0-16.0	13-30
	20-36	0.0-7.4	7.4-8.4	5-10	0	8.0-16.0	13-30
	36-60	0.0-4.0	7.4-8.4	5-10	0	8.0-16.0	13-30
427:							
Aga----------	0-8	7.4-14	6.6-8.4	0-5	0	0.0-2.0	0-5
	8-28	5.7-14	6.6-8.4	5-10	0	2.0-4.0	0-5
	28-60	0.0-7.4	6.6-8.4	5-10	0	2.0-4.0	0-5
428:							
Aga, moderately saline, sodic-------	0-4	7.4-14	6.6-8.4	5-10	0	8.0-16.0	13-30
	4-16	3.1-11	7.4-8.4	5-10	0	8.0-16.0	13-30
	16-22	5.7-14	7.4-8.4	5-10	0	8.0-16.0	13-30
	22-60	0.0-7.4	7.4-8.4	5-10	0	8.0-16.0	13-30

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
430:							
Trail	0-10	7.4-14	7.9-8.4	1-5	0	0.0-4.0	0-5
	10-34	3.1-7.4	8.5-9.0	1-5	0	0.0-4.0	0-5
	34-60	0.0-4.0	8.5-9.0	1-5	0	0.0-4.0	0-5
431:							
Trail	0-10	4.0-7.8	7.9-8.4	1-5	0	0.0-4.0	0-5
	10-60	0.0-7.4	8.5-9.0	1-5	0	0.0-4.0	0-5
433:							
Peralta	0-10	11-17	7.4-7.8	0-5	0	4.0-8.0	5-13
	10-60	5.7-14	7.9-8.4	5-10	0	4.0-8.0	5-13
434:							
Peralta	0-10	11-18	7.4-7.8	0-5	0	4.0-8.0	5-13
	10-16	4.0-11	7.9-8.4	5-10	0	4.0-8.0	5-13
	16-20	14-23	7.9-8.4	5-10	0	4.0-8.0	5-13
	20-28	3.1-11	7.9-8.4	5-10	0	4.0-8.0	5-13
	28-40	3.1-7.4	7.9-8.4	5-10	0	4.0-8.0	5-13
	40-45	8.1-16	7.9-8.4	5-10	0	4.0-8.0	5-13
	45-60	3.1-7.4	7.4-7.8	5-10	0	4.0-8.0	5-13
437:							
Peralta, moderately saline, sodic	0-4	7.4-14	7.4-7.8	0-5	0	8.0-16.0	13-30
	4-60	3.1-11	7.9-8.4	5-10	0	8.0-16.0	13-30
500:							
Rock outcrop	0-60	---	---	---	---	---	---
Osha	0-10	5.4-10.0	6.6-7.3	0	0	0.0-2.0	0
	10-20	5.0-9.7	6.6-7.3	0	0	0.0-2.0	0
	20-43	2.3-5.2	6.6-7.3	0	0	0.0-2.0	0
	43-60	---	---	---	---	---	---
Rubble Land	0-60	---	---	0	0	0	0
503:							
Cajete	0-8	6.2-11	6.6-7.3	0	0	0.0-2.0	0
	8-60	6.7-10	6.6-7.3	0-5	0	0.0-2.0	0
Cypher	0-3	6.7-13	5.6-6.5	0	0	0.0-2.0	0
	3-11	2.5-9.2	5.6-6.5	0	0	0.0-2.0	0
	11-15	2.5-9.2	5.6-6.5	0	0	0.0-2.0	0
	15-60	---	---	---	---	---	---

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
504:							
Orejas	0-2	9.0-15	6.6-7.3	0	0	0.0-2.0	0-2
	2-9	15-19	7.4-7.8	5-10	0	0.0-2.0	0-2
	9-17	15-19	7.9-8.4	5-10	0	0.0-2.0	0-5
	17-60	---	---	---	---	---	---
Guaje	0-4	4.2-11	7.4-7.8	0-2	0	0.0-2.0	0-2
	4-12	3.9-10	7.4-7.8	0-2	0	0.0-2.0	0-2
	12-17	2.5-9.2	7.9-8.4	15-20	0	0.0-2.0	0-5
	17-45	2.5-9.2	7.9-8.4	15-20	0	0.0-2.0	0-5
	45-60	2.5-9.2	7.9-8.4	15-20	0	0.0-2.0	0-5
600:							
Rock outcrop	0-60	---	---	---	---	---	---
Cypher	0-4	6.7-13	5.6-6.5	0	0	0.0-2.0	0
	4-14	4.3-14	5.6-6.5	0	0	0.0-2.0	0
	14-16	4.3-14	5.6-6.5	0	0	0.0-2.0	0
	16-60	---	---	---	---	---	---
601:							
Laventana	0-5	4.2-11	6.1-6.5	0	0	0.0-2.0	0
	5-9	6.0-11	6.1-6.5	0	0	0.0-2.0	0
	9-50	11-19	6.1-7.3	0	0	0.0-2.0	0
	50-60	---	---	---	---	---	---
603:							
Laventana	0-1	73-81	5.1-6.0	0	0	0.0-2.0	0
	1-5	10-17	6.1-6.5	0	0	0.0-2.0	0
	5-12	8.7-14	6.1-6.5	0	0	0.0-2.0	0
	12-20	11-14	6.1-6.5	0	0	0.0-2.0	0
	20-31	11-15	6.1-6.5	0	0	0.0-2.0	0
	31-51	8.7-14	6.6-7.3	0	0	0.0-2.0	0
	51-60	---	---	---	---	---	---
Mirand	0-6	13-19	6.6-7.3	0	0	0.0-2.0	0
	6-27	21-31	6.6-7.3	0	0	0.0-2.0	0
	27-60	19-26	6.6-7.3	0	0	0.0-2.0	0
604:							
Cypher	0-1	73-81	5.1-6.0	0	0	0.0-2.0	0
	1-4	6.7-13	5.6-6.5	0	0	0.0-2.0	0
	4-11	4.3-14	5.6-6.5	0	0	0.0-2.0	0
	11-19	2.5-9.2	5.6-6.5	0	0	0.0-2.0	0
	19-60	---	---	---	---	---	---

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
604:							
Mirand	0-4	11-17	6.6-7.3	0	0	0.0-2.0	0
	4-60	21-26	6.6-7.3	0	0	0.0-2.0	0
608:							
Osha, steep	0-3	5.4-14	6.6-7.3	0	0	0.0-2.0	0
	3-8	3.4-14	6.1-6.5	0	0	0.0-2.0	0
	8-16	3.8-10	6.6-7.3	0	0	0.0-2.0	0
	16-32	3.8-10	6.6-7.3	0	0	0.0-2.0	0
	32-60	0.0-3.8	6.6-7.3	0	0	0.0-2.0	0
Osha	0-8	4.2-9.7	6.6-7.3	0	0	0.0-2.0	0
	8-16	4.5-8.5	6.6-7.3	0	0	0.0-2.0	0
	16-32	4.5-8.5	6.1-7.3	0	0	0.0-2.0	0
	32-60	3.1-5.8	6.1-7.3	0	0	0.0-2.0	0
823:							
Gilco, unprotected	0-8	7.4-13	6.6-8.4	0-5	0	0.0-4.0	0-5
	8-60	5.7-12	6.6-8.4	5-10	0	0.0-4.0	0-5
827:							
Aga, unprotected	0-8	7.4-14	6.6-8.4	0-5	0	0.0-2.0	0-5
	8-28	5.7-14	6.6-8.4	5-10	0	2.0-4.0	0-5
	28-60	3.1-7.4	6.6-8.4	5-10	0	2.0-4.0	0-5
830:							
Trail, unprotected	0-8	7.4-14	7.9-8.4	1-5	0	0.0-4.0	0-5
	8-60	0.0-7.4	8.5-9.0	1-5	0	0.0-4.0	0-5
831:							
Trail, unprotected	0-10	3.1-7.8	7.9-8.4	1-5	0	0.0-2.0	0-5
	10-30	3.1-7.4	8.5-9.0	1-5	0	0.0-2.0	0-5
	30-60	0.0-4.0	8.5-9.0	1-5	0	0.0-2.0	0-5
835:							
Peralta, unprotected	0-6	7.4-14	7.4-7.8	5-10	0	4.0-8.0	0-5
	6-16	5.7-14	7.9-8.4	5-10	0	4.0-8.0	0-5
	16-60	8.1-22	7.9-8.4	5-10	0	4.0-8.0	0-5
842:							
Peralta, moderately saline, sodic, unprotected	0-10	18-23	7.4-7.8	0-5	0	8.0-16.0	13-30
	10-60	8.1-22	7.9-8.4	5-10	0	8.0-16.0	13-30

Table 16.--Chemical properties of the soils--continued

Map symbol and soil name	Depth	Cation exchange capacity	Soil reaction	Calcium carbonate	Gypsum	Salinity	Sodium adsorption ratio
	In.	meq/100 g	pH	Pct.	Pct.	mmhos/cm	
850:							
Water	---	---	---	---	---	---	---
DAM:							
Dam	---	---	---	---	---	---	---

Table 17.--Soil features

(See text for definitions of terms used in this table. Absence of an entry indicates that the feature is not a concern or that data were not estimated.)

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
1:					
Silver	---	---	Low	High	Low
Clovis	---	---	Low	High	Low
2:					
Clovis	---	---	Low	High	Low
Prieta	Bedrock (lithic)	10-20	Low	High	Low
Silver	---	---	Low	High	Low
3:					
Montecito	---	---	Low	High	Low
Orejas	Bedrock (lithic)	10-20	Low	Moderate	Low
4:					
Montecito	---	---	Low	High	Low
Montecito, bouldery	---	---	Low	High	Low
10:					
Trail	---	---	Low	High	Low
11:					
Trail	---	---	Low	High	Low
13:					
Sandoval	Bedrock (paralithic)	10-20	Low	High	Low
Querencia	---	---	Low	Moderate	Low
15:					
Camino	Bedrock (paralithic)	40-60	Low	High	Low
Sandoval	Bedrock (paralithic)	10-20	Low	High	Low
16:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
Prieta	Bedrock (lithic)	10-20	Low	High	Low
17:					
Vessilla	Bedrock (lithic)	4-20	Low	High	Low
Menefee	Bedrock (paralithic)	8-20	Moderate	High	Moderate
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
18:					
Sparham	---	---	Low	High	Low
20:					
Gilco	---	---	Low	High	Low
21:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
Hackroy	Bedrock (lithic)	8-20	Moderate	Moderate	Low

Table 17.--Soil features--continued

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
22:					
Aga	---	---	Low	High	Low
23:					
Hickman	---	---	Low	High	Low
24:					
Orlie	---	---	Moderate	High	Low
Sparham	---	---	Low	High	Low
25:					
Gilco	---	---	Low	High	Low
26:					
Orlie	---	---	Moderate	High	Low
27:					
Aga	---	---	Low	High	Low
29:					
Trail	---	---	Low	High	Moderate
31:					
Riverwash	---	---	---	---	---
33:					
Pits	---	---	---	---	---
34:					
Ildefonso	---	---	Low	High	Low
Witt	---	---	Moderate	High	Low
41:					
Dune land	---	---	---	---	---
47:					
Cascajo	---	---	Low	High	Low
51:					
Sparham	---	---	Low	High	Low
52:					
Totavi	---	---	Low	Moderate	Low
53:					
Witt	---	---	Moderate	High	Low
Harvey	---	---	Low	High	Low
54:					
Harvey	---	---	Low	High	Low
Cascajo	---	---	Low	High	Low
55:					
La Fonda	---	---	Low	High	Low
56:					
Ildefonso	---	---	Low	High	Low

Table 17.--Soil features--continued

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
57:					
Badland	Bedrock (paralithic)	0-0	Low	High	Moderate
58:					
Deama	Bedrock (lithic)	10-20	Low	Moderate	Low
Elpedro	---	---	Moderate	High	Low
59:					
Harvey	---	---	Low	High	Low
Ildefonso	---	---	Low	High	Low
La Fonda	---	---	Low	High	Low
63:					
Placitas	Bedrock (lithic)	20-40	Low	High	Low
64:					
Skyvillage	Bedrock (lithic)	6-20	Low	Moderate	Low
Ildefonso	---	---	Low	High	Low
65:					
Ildefonso	---	---	Low	High	Low
Harvey	---	---	Low	High	Low
66:					
Zia	---	---	Low	High	Low
67:					
Sandoval	Bedrock (paralithic)	10-20	Low	High	Low
Poley	---	---	Low	High	Low
68:					
Penistaja	---	---	Low	High	Low
Querencia	---	---	Low	Moderate	Low
71:					
Palon	---	---	Moderate	Moderate	Moderate
72:					
Palon	---	---	Moderate	Moderate	Moderate
74:					
Origo	---	---	Moderate	High	High
Pavo	---	---	Moderate	Moderate	Low
75:					
Origo	---	---	Moderate	High	High
82:					
Calaveras	---	---	Moderate	Moderate	Moderate
83:					
Calaveras	---	---	Moderate	Moderate	Moderate
Rubble land	---	---	---	---	---

Table 17.--Soil features--continued

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
85:					
Redondo	---	---	Moderate	Moderate	Moderate
86:					
Redondo	---	---	Moderate	Moderate	Moderate
87:					
Redondo	---	---	Moderate	Moderate	Moderate
Rubble land	---	---	---	---	---
88:					
Totavi	---	---	Low	Moderate	Low
Jemez	Bedrock (lithic)	20-40	Moderate	Moderate	Low
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
91:					
Zia	---	---	Low	High	Low
92:					
Galisteo, moderately saline, sodic	---	---	Low	High	Low
93:					
Zia	---	---	Low	High	Low
95:					
El Rancho	---	---	Low	High	Low
97:					
El Rancho	---	---	Moderate	High	Low
100:					
Orejas	Bedrock (lithic)	10-20	Low	Moderate	Low
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
101:					
Blancot	---	---	Low	High	Low
Lybrook	---	---	Low	High	Low
102:					
Sparham	---	---	Low	High	Low
104:					
Cochiti	---	---	Moderate	Moderate	Low
Montecito	---	---	Low	High	Low
105:					
Badland	Bedrock (paralithic)	0-0	Low	High	Moderate
Menefee	Bedrock (paralithic)	8-20	Moderate	High	Moderate
106:					
Stumble	---	---	Low	High	Low
Stumble, sandy	---	---	Low	High	Low

Table 17.--Soil features--continued

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
108:					
Embudo	---	---	Low	High	Low
109:					
Embudo	---	---	Low	High	Low
Tijeras	---	---	Low	High	Low
110:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
Saido	---	---	Low	High	High
111:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
Zia	---	---	Low	High	Low
112:					
Tijeras	---	---	Low	High	Low
114:					
San Mateo	---	---	Low	High	Low
Zia	---	---	Low	High	Low
120:					
Pinavetes	---	---	Low	Moderate	Low
124:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
129:					
Menefee	Bedrock (paralithic)	8-20	Moderate	High	Moderate
130:					
Pinavetes	---	---	Low	Moderate	Low
Galisteo, moderately saline, sodic	---	---	Low	High	Low
142:					
Grieta	---	---	Moderate	High	Low
143:					
Clovis	---	---	Low	High	Low
145:					
Grieta	---	---	Moderate	High	Low
Sheppard	---	---	Low	High	Moderate
146:					
Sedmar	Bedrock (lithic)	6-20	Low	Moderate	Low
150:					
Doakum	---	---	Low	High	Low
Betonnie	---	---	Low	Moderate	Low
162:					
Hackroy	Bedrock (lithic)	8-20	Moderate	Moderate	Low

Table 17.--Soil features--continued

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
162:					
Nyjack	Bedrock (paralithic)	20-40	Moderate	Moderate	Low
163:					
Jemez	Bedrock (lithic)	20-40	Moderate	Moderate	Low
170:					
San Mateo	---	---	Low	High	Low
180:					
Councelor	---	---	Low	Moderate	Low
Eslendo	Bedrock (paralithic)	4-20	Low	Moderate	Low
Mespun	---	---	Low	Moderate	Low
183:					
Sheppard	---	---	Low	High	Moderate
185:					
Frijoles	Abrupt textural change	15-30	Moderate	Moderate	Low
190:					
Zia	---	---	Low	High	Low
Skyvillage	Bedrock (lithic)	6-20	Low	Moderate	Low
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
191:					
Sheppard	---	---	Low	High	Moderate
200:					
Sedillo	---	---	Low	High	Low
201:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
Sedgran	Bedrock (lithic)	6-20	Low	Low	Low
206:					
Pinitos	---	---	Moderate	Moderate	Low
207:					
Penistaja	---	---	Low	High	Low
Zia	---	---	Low	High	Low
208:					
Sedillo	---	---	Low	High	Low
210:					
Ildefonso	---	---	Low	High	Low
211:					
Zia	---	---	Low	High	Low
Clovis	---	---	Low	High	Low
213:					
Pinavetes	---	---	Low	Moderate	Low
Rock outcrop	Bedrock (lithic)	0-0	---	---	---

Table 17.--Soil features--continued

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
215:					
Ess	---	---	Moderate	Moderate	Moderate
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
217:					
Witt	---	---	Moderate	High	Low
218:					
Ildefonso	---	---	Low	High	Low
220:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
Vessilla	Bedrock (lithic)	4-20	Low	High	Low
Menefee	Bedrock (paralithic)	8-20	Moderate	High	Moderate
226:					
Galisteo, moderately saline, sodic	---	---	Low	High	Low
227:					
Hagerman	Bedrock (lithic)	20-40	Low	High	Low
Bond	Bedrock (lithic)	6-20	Low	High	Low
228:					
Winona	Bedrock (lithic)	5-20	Low	High	Low
230:					
Skyvillage	Bedrock (lithic)	6-20	Low	Moderate	Low
Sandoval	Bedrock (paralithic)	10-20	Low	High	Low
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
231:					
Querencia	---	---	Low	Moderate	Low
234:					
Querencia	---	---	Low	Moderate	Low
Zia	---	---	Low	High	Low
235:					
Sandoval	Bedrock (paralithic)	10-20	Low	High	Low
236:					
Sparank, moderately saline, sodic	---	---	Low	High	Low
237:					
Sparank	---	---	Low	High	Low
240:					
Penistaja	---	---	Low	High	Low
Hagerman	Bedrock (lithic)	20-40	Low	High	Low
250:					
Pinavetes	---	---	Low	Moderate	Low

Table 17.--Soil features--continued

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
262:					
Pastura	Petrocalcic	5-20	Low	High	Low
270:					
Blancot	---	---	Low	High	Low
Councelor	---	---	Low	Moderate	Low
Tsosie	---	---	Low	High	Low
281:					
Carjo	Bedrock (lithic)	20-40	Moderate	Moderate	Low
282:					
Tocal	Bedrock (paralithic)	8-20	Moderate	Moderate	Low
283:					
Mirand	---	---	Low	Moderate	Low
Alanos	---	---	Moderate	Moderate	Moderate
290:					
Alanos	---	---	Moderate	Moderate	Moderate
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
300:					
Waumac	---	---	Moderate	High	Low
Bamac	---	---	Low	High	Low
301:					
Vastine	---	---	High	High	Low
Jarola	---	---	Moderate	Moderate	Moderate
302:					
Tranquilar	---	---	Moderate	High	High
Jarmillo	---	---	Moderate	Moderate	Low
304:					
Cosey	---	---	Moderate	Moderate	Low
Jarmillo	---	---	Moderate	Moderate	Low
307:					
Flugle	---	---	Moderate	High	Low
Waumac	---	---	Moderate	High	Low
308:					
Cajete	---	---	Moderate	Moderate	Low
311:					
Cosey	---	---	Moderate	Moderate	Low
Tranquilar	---	---	Moderate	High	High
Calaveras	---	---	Moderate	Moderate	Moderate
312:					
Royosa	---	---	Low	Moderate	Low

Table 17.--Soil features--continued

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
314:					
Fragua	---	---	Moderate	Low	Low
Waumac	---	---	Moderate	High	Low
Royosa	---	---	Low	Moderate	Low
317:					
Elpedro	---	---	Moderate	High	Low
319:					
Bamac	---	---	Low	High	Low
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
320:					
Sparham	---	---	Low	High	Low
321:					
Waumac	---	---	Moderate	High	Low
Royosa	---	---	Low	Moderate	Low
322:					
Fragua	Bedrock (paralithic)	40-80	Moderate	Low	Low
324:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
Atarque	Bedrock (lithic)	8-20	Low	Moderate	Low
Menefee	Bedrock (paralithic)	8-20	Moderate	High	Moderate
325:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
Espiritu	---	---	Moderate	Low	Low
Vessilla	Bedrock (lithic)	4-20	Moderate	High	Low
342:					
Waumac	---	---	Moderate	High	Low
Vessilla	Bedrock (lithic)	4-20	Low	High	Low
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
345:					
Espiritu	---	---	Moderate	Low	Low
Bamac	---	---	Low	High	Low
346:					
Espiritu, cobbly	---	---	Moderate	Low	Low
Bamac	---	---	Low	High	Low
348:					
Wauquie	---	---	Moderate	Moderate	Low
Rock outcrop	Bedrock (lithic)	0-0	---	---	---

Table 17.--Soil features--continued

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
353:					
Cochiti	---	---	Moderate	Moderate	Low
Espiritu	---	---	Moderate	Low	Low
354:					
Waumac Variant	Bedrock (paralithic)	10-20	Moderate	Low	Low
358:					
Deama	Bedrock (lithic)	10-20	Low	High	Low
Elpedro	---	---	Moderate	High	Low
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
396:					
Atarque	Bedrock (lithic)	8-20	Low	Moderate	Low
Menefee	Bedrock (paralithic)	8-20	Moderate	High	Moderate
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
397:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
Cucho	Bedrock (paralithic)	20-40	Moderate	Moderate	Low
Vessilla	Bedrock (lithic)	4-20	Moderate	High	Low
398:					
Espiritu	---	---	Moderate	Low	Low
Cucho	Bedrock (paralithic)	20-40	Moderate	Moderate	Low
399:					
Cucho	Bedrock (paralithic)	20-40	Moderate	Moderate	Low
Teco	---	---	Moderate	High	Low
405:					
Charo	Bedrock (lithic)	20-40	Low	Moderate	Low
Charo, noncobbly	Bedrock (lithic)	20-40	Low	Moderate	Low
409:					
Santa Fe	Bedrock (lithic)	8-20	Low	Moderate	Low
410:					
Zia	---	---	Low	High	Low
414:					
Wauquie	---	---	Moderate	Moderate	Low
417:					
Jocity	---	---	Low	High	Moderate
418:					
Jocity	---	---	Low	High	Moderate
419:					
Santa Fe	Bedrock (lithic)	8-20	Low	Moderate	Low
Wauquie	---	---	Moderate	Moderate	Low

Table 17.--Soil features--continued

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
419:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
420:					
Pinavetes	---	---	Low	Moderate	Low
421:					
Gilco, moderately saline, sodic	---	---	Low	High	Low
422:					
Vessilla	Bedrock (lithic)	4-20	Low	High	Low
Menefee	Bedrock (paralithic)	8-20	Moderate	High	Moderate
Orlie	---	---	Moderate	High	Low
423:					
Gilco	---	---	Low	High	Low
426:					
Aga, moderately saline, sodic	---	---	Low	High	Low
427:					
Aga	---	---	Low	High	Low
428:					
Aga, moderately saline, sodic	---	---	Low	High	Low
430:					
Trail	---	---	Low	High	Low
431:					
Trail	---	---	Low	High	Low
433:					
Peralta	---	---	Low	High	Moderate
434:					
Peralta	---	---	Low	High	Moderate
437:					
Peralta, moderately saline, sodic	---	---	Low	High	High
500:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
Osha	Bedrock (lithic)	40-60	Low	Low	Low
Rubble land	---	---	---	---	---
503:					
Cajete	---	---	Moderate	Moderate	Low
Cypher	Bedrock (lithic)	10-20	Moderate	Moderate	Moderate
504:					
Orejas	Bedrock (lithic)	10-20	Low	Moderate	Low
Guaje	---	---	Low	High	Low

Table 17.--Soil features--continued

Map symbol and soil name	Restrictive layer		Potential for frost action	Risk of corrosion	
	Kind	Depth to top		Uncoated steel	Concrete
		In.			
600:					
Rock outcrop	Bedrock (lithic)	0-0	---	---	---
Cypher	Bedrock (lithic)	10-20	Moderate	Moderate	Moderate
601:					
Laventana	Bedrock (lithic)	40-60	Moderate	Low	High
603:					
Laventana	Bedrock (lithic)	40-60	Moderate	Low	High
Mirand	---	---	Low	Moderate	Low
604:					
Cypher	Bedrock (lithic)	10-20	Moderate	Moderate	Moderate
Mirand	---	---	Low	Moderate	Low
608:					
Osha, steep	---	---	Low	Low	Low
Osha	---	---	Low	Low	Low
823:					
Gilco, unprotected	---	---	Low	High	Low
827:					
Aga, unprotected	---	---	Low	High	Low
830:					
Trail, unprotected	---	---	Low	High	Low
831:					
Trail, unprotected	---	---	Low	High	Moderate
835:					
Peralta, unprotected	---	---	Low	High	Moderate
842:					
Peralta, moderately saline, sodic, unprotected	---	---	Low	High	High
850:					
Water	---	---	---	---	---
DAM:					
Dam	---	---	---	---	---

Table 18.--Water features

(Depths of layers are in feet. See text for definitions of terms used in this table. Estimates of the frequency of ponding and flooding apply to the whole year rather than to individual months. Absence of an entry indicates that the feature is not a concern or that data were not estimated.)

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
1:									
Silver	C	Jan-Dec	---	---	---	---	None	---	None
Clovis	B	Jan-Dec	---	---	---	---	None	---	None
2:									
Clovis	B	Jan-Dec	---	---	---	---	None	---	None
Prieta	D	Jan-Dec	---	---	---	---	None	---	None
Silver	C	Jan-Dec	---	---	---	---	None	---	None
3:									
Montecito	B	Jan-Dec	---	---	---	---	None	---	None
Orejas	D	Jan-Dec	---	---	---	---	None	---	None
4:									
Montecito	B	Jan-Dec	---	---	---	---	None	---	None
Montecito, bouldery	B	Jan-Dec	---	---	---	---	None	---	None
10:									
Trail	A	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
11:									
Trail	A	March	---	---	---	---	None	Brief	Occasional
		April	4.0-6.0	>6.0	---	---	None	Brief	Occasional
		May	4.0-6.0	>6.0	---	---	None	Brief	Occasional
		June	4.0-6.0	>6.0	---	---	None	Brief	Occasional
		July	4.0-6.0	>6.0	---	---	None	Brief	Occasional
		August	4.0-6.0	>6.0	---	---	None	Brief	Occasional
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
13:									
Sandoval	D	Jan-Dec	---	---	---	---	None	---	None
Querencia	B	Jan-Dec	---	---	---	---	None	---	None
15:									
Camino	C	Jan-Dec	---	---	---	---	None	---	None
Sandoval	D	Jan-Dec	---	---	---	---	None	---	None
16:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
Prieta	D	Jan-Dec	---	---	---	---	None	---	None
17:									
Vessilla	D	Jan-Dec	---	---	---	---	None	---	None
Menefee	D	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
18:									
Sparham	D	July	---	---	---	---	None	Brief	Occasional
		August	---	---	---	---	None	Brief	Occasional
		September	---	---	---	---	None	Brief	Occasional
		October	---	---	---	---	None	Brief	Occasional
20:									
Gilco	B	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
21:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
Hackroy	D	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
22:									
Aga	B	March	---	---	---	---	None	---	Rare
		April	3.5-5.0	>6.0	---	---	None	---	Rare
		May	3.5-5.0	>6.0	---	---	None	---	Rare
		June	3.5-5.0	>6.0	---	---	None	---	Rare
		July	3.5-5.0	>6.0	---	---	None	---	Rare
		August	3.5-5.0	>6.0	---	---	None	---	Rare
		September	3.5-5.0	>6.0	---	---	None	---	None
		October	3.5-5.0	>6.0	---	---	None	---	None
23:									
Hickman	B	March	---	---	---	---	None	---	Rare
		April	---	---	---	---	None	---	Rare
		May	---	---	---	---	None	---	Rare
		June	---	---	---	---	None	---	Rare
		July	---	---	---	---	None	---	Rare
		August	---	---	---	---	None	---	Rare
		Jan-Dec	---	---	---	---	None	---	None
24:									
Orlie	C	Jan-Dec	---	---	---	---	None	---	None
Sparham	D	July	---	---	---	---	None	Brief	Occasional
		August	---	---	---	---	None	Brief	Occasional
		September	---	---	---	---	None	Brief	Occasional
		October	---	---	---	---	None	Brief	Occasional
25:									
Gilco	B	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
26:									
Orlie	C	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
27:									
Aga	B	March	---	---	---	---	None	---	Rare
		April	3.5-5.0	>6.0	---	---	None	---	Rare
		May	3.5-5.0	>6.0	---	---	None	---	Rare
		June	3.5-5.0	>6.0	---	---	None	---	Rare
		July	3.5-5.0	>6.0	---	---	None	---	Rare
		August	3.5-5.0	>6.0	---	---	None	---	Rare
		September	3.5-5.0	>6.0	---	---	None	---	None
		October	3.5-5.0	>6.0	---	---	None	---	None
29:									
Trail	A	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
31:									
Riverwash	D	March	---	---	---	---	None	Long	Frequent
		April	---	---	---	---	None	Long	Frequent
		May	---	---	---	---	None	Long	Frequent
		June	---	---	---	---	None	Long	Frequent
		July	---	---	---	---	None	Long	Frequent
		August	---	---	---	---	None	Long	Frequent
		September	---	---	---	---	None	Long	Frequent
33:									
Pits	---	Jan-Dec	---	---	---	---	None	---	None
34:									
Ildefonso	B	Jan-Dec	---	---	---	---	None	---	None
Witt	B	Jan-Dec	---	---	---	---	None	---	None
41:									
Dune Land	A	Jan-Dec	---	---	---	---	None	---	None
47:									
Cascajo	A	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
51:									
Sparham	C	January	1.6-3.3	3.3-5.0	---	---	None	---	None
		February	1.6-3.3	3.3-5.0	---	---	None	---	None
		March	1.6-3.3	3.3-5.0	---	---	None	---	None
		June	2.5-3.3	3.3-5.0	---	---	None	---	None
		July	0.3-0.8	5.0-5.0	---	---	None	Brief	Occasional
		August	0.3-0.8	4.1-5.0	---	---	None	Brief	Occasional
		September	0.3-0.8	3.3-5.0	---	---	None	Brief	Occasional
		October	0.3-0.8	3.3-5.0	---	---	None	Brief	Occasional
		November	3.0-3.3	3.3-5.0	---	---	None	---	None
		December	3.0-3.3	3.3-5.0	---	---	None	---	None
52:									
Totavi	A	March	---	---	---	---	None	---	Rare
		April	---	---	---	---	None	---	Rare
		May	---	---	---	---	None	---	Rare
		June	---	---	---	---	None	---	Rare
		July	---	---	---	---	None	---	Rare
		August	---	---	---	---	None	---	Rare
		Jan-Dec	---	---	---	---	None	---	None
53:									
Witt	B	Jan-Dec	---	---	---	---	None	---	None
Harvey	B	Jan-Dec	---	---	---	---	None	---	None
54:									
Harvey	B	Jan-Dec	---	---	---	---	None	---	None
Cascajo	A	Jan-Dec	---	---	---	---	None	---	None
55:									
La Fonda	B	Jan-Dec	---	---	---	---	None	---	None
56:									
Ildefonso	B	Jan-Dec	---	---	---	---	None	---	None
57:									
Badland	D	Jan-Dec	---	---	---	---	None	---	None
58:									
Deama	D	Jan-Dec	---	---	---	---	None	---	None
Elpedro	B	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
59:									
Harvey	B	Jan-Dec	---	---	---	---	None	---	None
Ildefonso	B	Jan-Dec	---	---	---	---	None	---	None
La Fonda	B	Jan-Dec	---	---	---	---	None	---	None
63:									
Placitas	C	Jan-Dec	---	---	---	---	None	---	None
64:									
Skyvillage	D	Jan-Dec	---	---	---	---	None	---	None
Ildefonso	B	Jan-Dec	---	---	---	---	None	---	None
65:									
Ildefonso	B	Jan-Dec	---	---	---	---	None	---	None
Harvey	B	Jan-Dec	---	---	---	---	None	---	None
66:									
Zia	B	Jan-Dec	---	---	---	---	None	---	None
67:									
Sandoval	D	Jan-Dec	---	---	---	---	None	---	None
Poley	D	Jan-Dec	---	---	---	---	None	---	None
68:									
Penistaja	B	Jan-Dec	---	---	---	---	None	---	None
Querencia	B	Jan-Dec	---	---	---	---	None	---	None
71:									
Palon	B	Jan-Dec	---	---	---	---	None	---	None
72:									
Palon	B	Jan-Dec	---	---	---	---	None	---	None
74:									
Origo	B	Jan-Dec	---	---	---	---	None	---	None
Pavo	B	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
75:									
Origo	B	Jan-Dec	---	---	---	---	None	---	None
82:									
Calaveras	B	Jan-Dec	---	---	---	---	None	---	None
83:									
Calaveras	B	Jan-Dec	---	---	---	---	None	---	None
Rubble Land	A	Jan-Dec	---	---	---	---	None	---	None
85:									
Redondo	B	Jan-Dec	---	---	---	---	None	---	None
86:									
Redondo	B	Jan-Dec	---	---	---	---	None	---	None
87:									
Redondo	B	Jan-Dec	---	---	---	---	None	---	None
Rubble Land	A	Jan-Dec	---	---	---	---	None	---	None
88:									
Totavi	A	March	---	---	---	---	None	---	Rare
		April	---	---	---	---	None	---	Rare
		May	---	---	---	---	None	---	Rare
		June	---	---	---	---	None	---	Rare
		July	---	---	---	---	None	---	Rare
		August	---	---	---	---	None	---	Rare
		Jan-Dec	---	---	---	---	None	---	None
Jemez	C	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
91:									
Zia	B	Jan-Dec	---	---	---	---	None	---	None
92:									
Galisteo, moderately saline, sodic	D	Jan-Dec	---	---	---	---	None	---	None
93:									
Zia	B	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
95:									
El Rancho	B	Jan-Dec	---	---	---	---	None	---	None
97:									
El Rancho	B	Jan-Dec	---	---	---	---	None	---	None
100:									
Orejas	D	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
101:									
Blancot	B	Jan-Dec	---	---	---	---	None	---	None
Lybrook	D	Jan-Dec	---	---	---	---	None	---	None
102:									
Sparham	D	July	---	---	---	---	None	Brief	Occasional
		August	---	---	---	---	None	Brief	Occasional
		September	---	---	---	---	None	Brief	Occasional
		October	---	---	---	---	None	Brief	Occasional
104:									
Cochiti	C	Jan-Dec	---	---	---	---	None	---	None
Montecito	B	Jan-Dec	---	---	---	---	None	---	None
105:									
Badland	D	Jan-Dec	---	---	---	---	None	---	None
Menefee	D	Jan-Dec	---	---	---	---	None	---	None
106:									
Stumble	A	Jan-Dec	---	---	---	---	None	---	None
Stumble, sandy	A	March	---	---	---	---	None	---	Rare
		April	---	---	---	---	None	---	Rare
		May	---	---	---	---	None	---	Rare
		June	---	---	---	---	None	---	Rare
		July	---	---	---	---	None	---	Rare
		August	---	---	---	---	None	---	Rare
		Jan-Dec	---	---	---	---	None	---	None
108:									
Embudo	B	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
109:									
Embudo	B	Jan-Dec	---	---	---	---	None	---	None
Tijeras	B	Jan-Dec	---	---	---	---	None	---	None
110:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
Saido	B	Jan-Dec	---	---	---	---	None	---	None
111:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
Zia	B	Jan-Dec	---	---	---	---	None	---	None
112:									
Tijeras	B	Jan-Dec	---	---	---	---	None	---	None
114:									
San Mateo	B	March	---	---	---	---	None	---	Rare
		April	---	---	---	---	None	---	Rare
		May	---	---	---	---	None	---	Rare
		June	---	---	---	---	None	---	Rare
		July	---	---	---	---	None	---	Rare
		August	---	---	---	---	None	---	Rare
		Jan-Dec	---	---	---	---	None	---	None
Zia	B	Jan-Dec	---	---	---	---	None	---	None
120:									
Pinavetes	A	Jan-Dec	---	---	---	---	None	---	None
124:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
129:									
Menefee	D	Jan-Dec	---	---	---	---	None	---	None
130:									
Pinavetes	A	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
130:									
Galisteo, moderately saline, sodic	D	March	---	---	---	---	None	---	Rare
		April	---	---	---	---	None	---	Rare
		May	---	---	---	---	None	---	Rare
		June	---	---	---	---	None	---	Rare
		July	---	---	---	---	None	---	Rare
		August	---	---	---	---	None	---	Rare
		Jan-Dec	---	---	---	---	None	---	None
142:									
Grieta	B	Jan-Dec	---	---	---	---	None	---	None
143:									
Clovis	B	Jan-Dec	---	---	---	---	None	---	None
145:									
Grieta	B	Jan-Dec	---	---	---	---	None	---	None
Sheppard	A	Jan-Dec	---	---	---	---	None	---	None
146:									
Sedmar	D	Jan-Dec	---	---	---	---	None	---	None
150:									
Doakum	B	Jan-Dec	---	---	---	---	None	---	None
Betonnie	B	Jan-Dec	---	---	---	---	None	---	None
162:									
Hackroy	D	Jan-Dec	---	---	---	---	None	---	None
Nyjack	C	Jan-Dec	---	---	---	---	None	---	None
163:									
Jemez	C	Jan-Dec	---	---	---	---	None	---	None
170:									
San Mateo	B	March	---	---	---	---	None	---	Rare
		April	---	---	---	---	None	---	Rare
		May	---	---	---	---	None	---	Rare
		June	---	---	---	---	None	---	Rare
		July	---	---	---	---	None	---	Rare
		August	---	---	---	---	None	---	Rare
		Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
180:									
Councelor	B	Jan-Dec	---	---	---	---	None	---	None
Eslendo	D	Jan-Dec	---	---	---	---	None	---	None
Mespun	A	Jan-Dec	---	---	---	---	None	---	None
183:									
Sheppard	A	Jan-Dec	---	---	---	---	None	---	None
185:									
Frijoles	C	Jan-Dec	---	---	---	---	None	---	None
190:									
Zia	B	Jan-Dec	---	---	---	---	None	---	None
Skyvillage	D	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
191:									
Sheppard	A	Jan-Dec	---	---	---	---	None	---	None
200:									
Sedillo	B	Jan-Dec	---	---	---	---	None	---	None
201:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
Sedgran	D	Jan-Dec	---	---	---	---	None	---	None
206:									
Pinitos	B	Jan-Dec	---	---	---	---	None	---	None
207:									
Penistaja	B	Jan-Dec	---	---	---	---	None	---	None
Zia	B	Jan-Dec	---	---	---	---	None	---	None
208:									
Sedillo	B	Jan-Dec	---	---	---	---	None	---	None
210:									
Ildefonso	B	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
211:									
Zia	B	Jan-Dec	---	---	---	---	None	---	None
Clovis	B	Jan-Dec	---	---	---	---	None	---	None
213:									
Pinavetes	A	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
215:									
Ess	B	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
217:									
Witt	B	Jan-Dec	---	---	---	---	None	---	None
218:									
Ildefonso	B	Jan-Dec	---	---	---	---	None	---	None
220:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
Vessilla	D	Jan-Dec	---	---	---	---	None	---	None
Menefee	D	Jan-Dec	---	---	---	---	None	---	None
226:									
Galisteo, moderately saline, sodic	D	Jan-Dec	---	---	---	---	None	---	None
227:									
Hagerman	C	Jan-Dec	---	---	---	---	None	---	None
Bond	D	Jan-Dec	---	---	---	---	None	---	None
228:									
Winona	D	Jan-Dec	---	---	---	---	None	---	None
230:									
Skyvillage	D	Jan-Dec	---	---	---	---	None	---	None
Sandoval	D	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
230:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
231:									
Querencia	B	Jan-Dec	---	---	---	---	None	---	None
234:									
Querencia	B	Jan-Dec	---	---	---	---	None	---	None
Zia	B	Jan-Dec	---	---	---	---	None	---	None
235:									
Sandoval	D	Jan-Dec	---	---	---	---	None	---	None
236:									
Sparank, moderately saline, sodic	D	July	---	---	---	---	None	Brief	Occasional
		August	---	---	---	---	None	Brief	Occasional
		September	---	---	---	---	None	Brief	Occasional
		October	---	---	---	---	None	Brief	Occasional
237:									
Sparank	D	July	---	---	---	---	None	Brief	Occasional
		August	---	---	---	---	None	Brief	Occasional
		September	---	---	---	---	None	Brief	Occasional
		October	---	---	---	---	None	Brief	Occasional
240:									
Penistaja	B	Jan-Dec	---	---	---	---	None	---	None
Hagerman	C	Jan-Dec	---	---	---	---	None	---	None
250:									
Pinavetes	A	Jan-Dec	---	---	---	---	None	---	None
262:									
Pastura	D	Jan-Dec	---	---	---	---	None	---	None
270:									
Blancot	B	Jan-Dec	---	---	---	---	None	---	None
Councelor	B	Jan-Dec	---	---	---	---	None	---	None
Tsosie	B	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
281:									
Carjo	C	Jan-Dec	---	---	---	---	None	---	None
282:									
Tocal	C	Jan-Dec	---	---	---	---	None	---	None
283:									
Mirand	D	Jan-Dec	---	---	---	---	None	---	None
Alanos	C	Jan-Dec	---	---	---	---	None	---	None
290:									
Alanos	B	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
300:									
Waumac	B	Jan-Dec	---	---	---	---	None	---	None
Bamac	A	Jan-Dec	---	---	---	---	None	---	None
301:									
Vastine	B	March	1.0-3.0	>6.0	---	---	None	---	Rare
		April	1.0-3.0	>6.0	---	---	None	---	Rare
		May	1.0-3.0	>6.0	---	---	None	---	Rare
		June	---	---	---	---	None	---	Rare
		July	---	---	---	---	None	---	Rare
		August	---	---	---	---	None	---	Rare
Jarola	C	March	1.0-3.0	>6.0	---	---	None	---	Rare
		April	1.0-3.0	>6.0	---	---	None	---	Rare
		May	1.0-3.0	>6.0	---	---	None	---	Rare
		June	1.0-3.0	>6.0	---	---	None	---	Rare
		July	---	---	---	---	None	---	Rare
		August	---	---	---	---	None	---	Rare
302:									
Tranquilar	C	March	1.5-4.0	>6.0	---	---	None	---	None
		April	1.5-4.0	>6.0	---	---	None	---	None
		May	1.5-4.0	>6.0	---	---	None	---	None
		June	1.5-4.0	>6.0	---	---	None	---	None
		July	1.5-4.0	>6.0	---	---	None	---	None
Jarmillo	B	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
304:									
Cosey	B	Jan-Dec	---	---	---	---	None	---	None
Jarmillo	B	Jan-Dec	---	---	---	---	None	---	None
307:									
Flugle	B	Jan-Dec	---	---	---	---	None	---	None
Waumac	B	Jan-Dec	---	---	---	---	None	---	None
308:									
Cajete	B	Jan-Dec	---	---	---	---	None	---	None
311:									
Cosey	B	Jan-Dec	---	---	---	---	None	---	None
Tranquilar	C	March	1.5-4.0	>6.0	---	---	None	---	None
		April	1.5-4.0	>6.0	---	---	None	---	None
		May	1.5-4.0	>6.0	---	---	None	---	None
		June	1.5-4.0	>6.0	---	---	None	---	None
		July	1.5-4.0	>6.0	---	---	None	---	None
Calaveras	B	Jan-Dec	---	---	---	---	None	---	None
312:									
Royosa	A	Jan-Dec	---	---	---	---	None	---	None
314:									
Fragua	B	Jan-Dec	---	---	---	---	None	---	None
Waumac	B	Jan-Dec	---	---	---	---	None	---	None
Royosa	A	Jan-Dec	---	---	---	---	None	---	None
317:									
Elpedro	B	Jan-Dec	---	---	---	---	None	---	None
319:									
Bamac	A	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
320:									
Sparham	D	July	---	---	---	---	None	Brief	Occasional
		August	---	---	---	---	None	Brief	Occasional
		September	---	---	---	---	None	Brief	Occasional
		October	---	---	---	---	None	Brief	Occasional
321:									
Waumac	B	Jan-Dec	---	---	---	---	None	---	None
Royosa	A	Jan-Dec	---	---	---	---	None	---	None
322:									
Fragua	B	Jan-Dec	---	---	---	---	None	---	None
324:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
Atarque	D	Jan-Dec	---	---	---	---	None	---	None
Menefee	D	Jan-Dec	---	---	---	---	None	---	None
325:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
Espiritu	B	Jan-Dec	---	---	---	---	None	---	None
Vessilla	D	Jan-Dec	---	---	---	---	None	---	None
342:									
Waumac	B	Jan-Dec	---	---	---	---	None	---	None
Vessilla	D	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
345:									
Espiritu	B	Jan-Dec	---	---	---	---	None	---	None
Bamac	A	Jan-Dec	---	---	---	---	None	---	None
346:									
Espiritu, cobbly	B	Jan-Dec	---	---	---	---	None	---	None
Bamac	A	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
348:									
Wauquie	B	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
353:									
Cochiti	C	Jan-Dec	---	---	---	---	None	---	None
Espiritu	B	Jan-Dec	---	---	---	---	None	---	None
354:									
Waumac, variant	D	Jan-Dec	---	---	---	---	None	---	None
358:									
Deama	D	Jan-Dec	---	---	---	---	None	---	None
Elpedro	B	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
396:									
Atarque	D	Jan-Dec	---	---	---	---	None	---	None
Menefee	D	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
397:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
Cucho	C	Jan-Dec	---	---	---	---	None	---	None
Vessilla	D	Jan-Dec	---	---	---	---	None	---	None
398:									
Espiritu	B	Jan-Dec	---	---	---	---	None	---	None
Cucho	C	Jan-Dec	---	---	---	---	None	---	None
399:									
Cucho	C	Jan-Dec	---	---	---	---	None	---	None
Teco	C	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
405:									
Charo	C	Jan-Dec	---	---	---	---	None	---	None
Charo, noncobbly	C	Jan-Dec	---	---	---	---	None	---	None
409:									
Santa Fe	D	Jan-Dec	---	---	---	---	None	---	None
410:									
Zia	B	Jan-Dec	---	---	---	---	None	---	None
414:									
Wauquie	B	Jan-Dec	---	---	---	---	None	---	None
417:									
Jocity	B	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
418:									
Jocity	B	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
419:									
Santa Fe	D	Jan-Dec	---	---	---	---	None	---	None
Wauquie	B	Jan-Dec	---	---	---	---	None	---	None
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
420:									
Pinavetes	A	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
421:									
Gilco, moderately saline, sodic	B	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
422:									
Vessilla	D	Jan-Dec	---	---	---	---	None	---	None
Menefee	D	Jan-Dec	---	---	---	---	None	---	None
Orlie	C	Jan-Dec	---	---	---	---	None	---	None
423:									
Gilco	B	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
426:									
Aga, moderately saline, sodic	B	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
427:									
Aga	B	March	---	---	---	---	None	---	Rare
		April	3.5-5.0	>6.0	---	---	None	---	Rare
		May	3.5-5.0	>6.0	---	---	None	---	Rare
		June	3.5-5.0	>6.0	---	---	None	---	Rare
		July	3.5-5.0	>6.0	---	---	None	---	Rare
		August	3.5-5.0	>6.0	---	---	None	---	Rare
		September	3.5-5.0	>6.0	---	---	None	---	None
		October	3.5-5.0	>6.0	---	---	None	---	None
428:									
Aga, moderately saline, sodic	B	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
430:									
Trail	A	March	---	---	---	---	None	---	Rare
		April	---	---	---	---	None	---	Rare
		May	---	---	---	---	None	---	Rare
		June	---	---	---	---	None	---	Rare
		July	---	---	---	---	None	---	Rare
		August	---	---	---	---	None	---	Rare
		Jan-Dec	---	---	---	---	None	---	None
431:									
Trail	A	March	---	---	---	---	None	---	Rare
		April	---	---	---	---	None	---	Rare
		May	---	---	---	---	None	---	Rare
		June	---	---	---	---	None	---	Rare
		July	---	---	---	---	None	---	Rare
		August	---	---	---	---	None	---	Rare
		Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
433:									
Peralta	C	March	2.0-3.0	>6.0	---	---	None	---	Rare
		April	2.0-3.0	>6.0	---	---	None	---	Rare
		May	2.0-3.0	>6.0	---	---	None	---	Rare
		June	2.0-3.0	>6.0	---	---	None	---	Rare
		July	2.0-3.0	>6.0	---	---	None	---	Rare
		August	2.0-3.0	>6.0	---	---	None	---	Rare
		September	2.0-3.0	>6.0	---	---	None	---	None
		October	2.0-3.0	>6.0	---	---	None	---	None
434:									
Peralta	C	March	2.0-3.0	>6.0	---	---	None	---	Rare
		April	2.0-3.0	>6.0	---	---	None	---	Rare
		May	2.0-3.0	>6.0	---	---	None	---	Rare
		June	2.0-3.0	>6.0	---	---	None	---	Rare
		July	2.0-3.0	>6.0	---	---	None	---	Rare
		August	2.0-3.0	>6.0	---	---	None	---	Rare
		September	2.0-3.0	>6.0	---	---	None	---	None
		October	2.0-3.0	>6.0	---	---	None	---	None
437:									
Peralta, moderately saline, sodic	C	March	2.0-3.0	>6.0	---	---	None	---	Rare
		April	2.0-3.0	>6.0	---	---	None	---	Rare
		May	2.0-3.0	>6.0	---	---	None	---	Rare
		June	2.0-3.0	>6.0	---	---	None	---	Rare
		July	2.0-3.0	>6.0	---	---	None	---	Rare
		August	2.0-3.0	>6.0	---	---	None	---	Rare
		September	2.0-3.0	>6.0	---	---	None	---	None
		October	2.0-3.0	>6.0	---	---	None	---	None
500:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
Osha	B	Jan-Dec	---	---	---	---	None	---	None
Rubble Land	A	Jan-Dec	---	---	---	---	None	---	None
503:									
Cajete	B	Jan-Dec	---	---	---	---	None	---	None
Cypher	D	Jan-Dec	---	---	---	---	None	---	None
504:									
Orejas	D	Jan-Dec	---	---	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
504:									
Guaje	D	Jan-Dec	---	---	---	---	None	---	None
600:									
Rock outcrop	D	Jan-Dec	---	---	---	---	None	---	None
Cypher	D	Jan-Dec	---	---	---	---	None	---	None
601:									
Laventana	B	Jan-Dec	---	---	---	---	None	---	None
603:									
Laventana	B	Jan-Dec	---	---	---	---	None	---	None
Mirand	D	Jan-Dec	---	---	---	---	None	---	None
604:									
Cypher	D	Jan-Dec	---	---	---	---	None	---	None
Mirand	D	Jan-Dec	---	---	---	---	None	---	None
608:									
Osha, steep	B	Jan-Dec	---	---	---	---	None	---	None
Osha	B	Jan-Dec	---	---	---	---	None	---	None
823:									
Gilco, unprotected	B	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
827:									
Aga, unprotected	B	March	---	---	---	---	None	---	Rare
		April	3.5-5.0	>6.0	---	---	None	---	Rare
		May	3.5-5.0	>6.0	---	---	None	---	Rare
		June	3.5-5.0	>6.0	---	---	None	---	Rare
		July	3.5-5.0	>6.0	---	---	None	---	Rare
		August	3.5-5.0	>6.0	---	---	None	---	Rare
		September	3.5-5.0	>6.0	---	---	None	---	None
		October	3.5-5.0	>6.0	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
830:									
Trail, unprotected--------	A	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
831:									
Trail, unprotected--------	A	March	---	---	---	---	None	---	Rare
		April	4.0-6.0	>6.0	---	---	None	---	Rare
		May	4.0-6.0	>6.0	---	---	None	---	Rare
		June	4.0-6.0	>6.0	---	---	None	---	Rare
		July	4.0-6.0	>6.0	---	---	None	---	Rare
		August	4.0-6.0	>6.0	---	---	None	---	Rare
		September	4.0-6.0	>6.0	---	---	None	---	None
		October	4.0-6.0	>6.0	---	---	None	---	None
835:									
Peralta, unprotected------	C	March	2.0-3.0	>6.0	---	---	None	---	None
		April	2.0-3.0	>6.0	---	---	None	Long	Occasional
		May	2.0-3.0	>6.0	---	---	None	Long	Occasional
		June	2.0-3.0	>6.0	---	---	None	Long	Occasional
		July	2.0-3.0	>6.0	---	---	None	---	None
		August	2.0-3.0	>6.0	---	---	None	---	None
		September	2.0-3.0	>6.0	---	---	None	---	None
		October	2.0-3.0	>6.0	---	---	None	---	None
842:									
Peralta, moderately saline, sodic, unprotected----------	C	March	2.0-3.0	>6.0	---	---	None	---	Rare
		April	2.0-3.0	>6.0	---	---	None	---	Rare
		May	2.0-3.0	>6.0	---	---	None	---	Rare
		June	2.0-3.0	>6.0	---	---	None	---	Rare
		July	2.0-3.0	>6.0	---	---	None	---	Rare
		August	2.0-3.0	>6.0	---	---	None	---	Rare
		September	2.0-3.0	>6.0	---	---	None	---	None
		October	2.0-3.0	>6.0	---	---	None	---	None

Table 18.--Water features--continued

Map symbol and soil name	Hydrologic group	Month	Water table		Ponding			Flooding	
			Upper limit	Lower limit	Surface water depth	Duration	Frequency	Duration	Frequency
			Ft.	Ft.	Ft.				
850:									
Water	---	Jan-Dec	---	---	---	---	None	---	None
DAM:									
Dam	---	Jan-Dec	---	---	---	---	None	---	None

Table 19.--Taxonomic classification of the soils

(An asterisk in the first column indicates a taxadjunct to the series. See text for a description of those characteristics that are outside the range of the series.)

Soil name	Family or higher taxonomic class
Aga	Coarse-loamy over sandy or sandy-skeletal, mixed, calcareous, mesic Typic Torrifluvents
Alanos	Clayey-skeletal, mixed Typic Eutroboralfs
Atarque	Loamy, mixed, mesic Lithic Haplustalfs
Bamac	Sandy-skeletal, mixed, mesic Typic Ustorthents
Betonnie	Coarse-loamy, mixed, mesic Ustalfic Haplargids
Blancot	Fine-loamy, mixed, mesic Ustalfic Haplargids
Bond	Loamy, mixed, mesic Lithic Ustollic Haplargids
Cajete	Ashy-skeletal, frigid Mollic Vitrandepts
Calaveras	Loamy-skeletal, mixed, frigid Dystric Eutrochrepts
Camino	Fine, mixed, mesic Ustollic Camborthids
Carjo	Fine, mixed Mollic Eutroboralfs
Cascajo	Sandy-skeletal, mixed, mesic Ustollic Calciorthids
Charo	Fine, mixed Typic Argiborolls
Clovis	Fine-loamy, mixed, mesic Ustollic Haplargids
Cochiti	Clayey-skeletal, mixed, mesic Aridic Haplustalfs
Cosey	Loamy-skeletal, mixed Typic Paleborolls
Councelor	Coarse-loamy, mixed, calcareous, mesic Ustic Torriorthents
Cucho	Fine-silty, mixed, calcareous, mesic Typic Ustorthents
Cypher	Loamy-skeletal, mixed, frigid Lithic Ustochrepts
Deama	Loamy-skeletal, carbonatic, mesic Lithic Calciustolls
Doakum	Fine-loamy, mixed, mesic Ustalfic Haplargids
El Rancho	Fine-loamy, mixed, calcareous, mesic Ustic Torriorthents
Elpedro	Fine-silty, mixed, mesic Aridic Haplustalfs
Embudo	Coarse-loamy, mixed, mesic Typic Camborthids
Eslendo	Loamy, mixed, calcareous, mesic, shallow Ustic Torriorthents
Espiritu	Loamy-skeletal, mixed, mesic Aridic Haplustalfs
Ess	Loamy-skeletal, mixed Argic Cryoborolls
Flugle	Fine-loamy, mixed, mesic Aridic Haplustalfs
Fragua	Coarse-loamy, mixed, mesic Aridic Haplustalfs
Frijoles	Loamy-skeletal over fragmental, mixed, mesic Aridic Haplustalfs
Galisteo	Fine, mixed, calcareous, mesic Ustic Torriorthents
Gilco	Coarse-loamy, mixed, calcareous, mesic Typic Torrifluvents
*Gilco	Coarse-loamy, mixed, calcareous, mesic Typic Torrifluvents
Grieta	Fine-loamy, mixed, mesic Typic Haplargids
Guaje	Medial-skeletal, mesic Aridic Ustochrepts
Hackroy	Clayey, mixed, mesic Lithic Haplustalfs
Hagerman	Fine-loamy, mixed, mesic Ustollic Haplargids
Harvey	Fine-loamy, mixed, mesic Ustollic Calciorthids
Hickman	Fine-loamy, mixed, calcareous, mesic Typic Ustifluvents
Ildefonso	Loamy-skeletal, mixed, mesic Ustollic Calciorthids
Jarmillo	Coarse-loamy, mixed Pachic Haploborolls
Jarola	Fine-loamy, mixed, frigid Typic Argialbolls
Jemez	Fine-loamy, mixed Mollic Eutroboralfs
Jocity	Fine-loamy, mixed, calcareous, mesic Typic Torrifluvents
La Fonda	Fine-loamy, mixed, mesic Ustollic Camborthids
Laventana	Loamy-skeletal, mixed Mollic Eutroboralfs
Lybrook	Fine, mixed, calcareous, mesic Ustic Torriorthents
Menefee	Loamy, mixed, calcareous, mesic, shallow Typic Ustorthents
Mespun	Mixed, mesic Ustic Torripsamments
Mirand	Fine, mixed Mollic Eutroboralfs
Montecito	Fine, mixed, mesic Aridic Haplustalfs
Nyjack	Fine-loamy, mixed, mesic Aridic Haplustalfs
Orejas	Clayey-skeletal, mixed, mesic Lithic Haplustalfs
Origo	loamy-skeletal, mixed Psammentic Cryoboralfs
Orlie	Fine-loamy, mixed, mesic Aridic Haplustalfs
Osha	Loamy-skeletal, mixed Typic Haploborolls
Palon	loamy-skeletal, mixed Psammentic Eutroboralfs
Pastura	Loamy, mixed, mesic, shallow Ustollic Paleorthids
Pavo	Fine-loamy, mixed Cryic Paleborolls
Penistaja	Fine-loamy, mixed, mesic Ustollic Haplargids

Table 19.--Taxonomic classification of the soils--continued

Soil name	Family or higher taxonomic class
Peralta	Coarse-loamy, mixed, calcareous, mesic Typic Ustifluvents
Pinavetes	Mixed, mesic Ustic Torripsamments
Pinitos	Fine-loamy, mixed, mesic Aridic Haplustalfs
Placitas	Loamy-skeletal, mixed, mesic Ustollic Calciorthids
Poley	Fine, mixed, mesic Ustollic Haplargids
Prieta	Clayey-skeletal, mixed, mesic Lithic Ustollic Haplargids
Querencia	Fine-loamy, mixed, mesic Ustollic Camborthids
Redondo	Loamy-skeletal, mixed Typic Cryoboralfs
Royosa	Mixed, mesic Typic Ustipsamments
Saido	Coarse-silty, gypsic, mesic Typic Gypsiorthids
San Mateo	Fine-loamy, mixed, calcareous, mesic Ustic Torrifluvents
Sandoval	Loamy, mixed, calcareous, mesic, shallow Ustic Torriorthents
Santa Fe	Loamy-skeletal, mixed, mesic Lithic Argiustolls
Sedgran	Sandy-skeletal, mixed, mesic Lithic Ustic Torriorthents
Sedillo	Loamy-skeletal, mixed, mesic Ustollic Haplargids
Sedmar	Sandy, mixed, frigid Lithic Ustorthents
Sheppard	Mixed, mesic Typic Torripsamments
Silver	Fine, mixed, mesic Ustollic Haplargids
Skyvillage	Loamy, mixed, calcareous, mesic Lithic Ustic Torriorthents
Sparank	Fine, mixed, calcareous, mesic Ustic Torrifluvents
Sparham	Fine, mixed, calcareous, mesic Typic Ustifluvents
*Sparham	Fine, mixed, calcareous, mesic Typic Ustifluvents
Stumble	Mixed, mesic Typic Torripsamments
Teco	Fine, mixed, mesic Aridic Haplustalfs
Tijeras	Fine-loamy, mixed, mesic Typic Haplargids
Tocal	Clayey, mixed Lithic Eutroboralfs
Totavi	Ashy, frigid Mollic Vitrandepts
Trail	Sandy, mixed, mesic Typic Torrifluvents
Tranquilar	Very-fine, montmorillonitic, frigid Typic Argialbolls
Tsosie	Fine-loamy, mixed, calcareous, mesic Ustic Torriorthents
Vastine	Fine-loamy over sandy or sandy-skeletal, mixed, frigid Typic Haplaquolls
Vessilla	Loamy, mixed, calcareous, mesic Lithic Ustorthents
Waumac	Coarse-loamy, mixed, calcareous, mesic Typic Ustorthents
Waumac Variant	Ashy-skeletal, mesic, shallow Typic Ustorthents
Wauquie	Loamy-skeletal, mixed, mesic Aridic Haplustalfs
Winona	Loamy-skeletal, carbonatic, mesic Lithic Ustollic Calciorthids
Witt	Fine-silty, mixed, mesic Ustollic Haplargids
Zia	Coarse-loamy, mixed, calcareous, mesic Ustic Torriorthents

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Los Alamos National Laboratory's Hydrogeologic Studies of the Pajarito Plateau:

A Synthesis of Hydrogeologic Workplan Activities (1998–2004)

Los Alamos
NATIONAL LABORATORY
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The World's Greatest Science Protecting America

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Los Alamos National Laboratory's Hydrogeologic Studies of the Pajarito Plateau:

A Synthesis of Hydrogeologic Workplan Activities (1998–2004)

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Acknowledgments

This report culminates the implementation of the Hydrogeologic Workplan, approved by the New Mexico Environment Department in March 1998. The Workplan was sponsored by the U.S. Department of Energy and the University of California. It was written by an interdisciplinary group of contributing authors representing various Los Alamos National Laboratory divisions, programs, and projects. Many of these individuals were also contributing authors of this Hydrogeologic Synthesis Report. These authors were members of the Groundwater Integration Team (GIT) that was created to implement the Hydrogeologic Workplan.

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Los Alamos National Laboratory's Hydrogeologic Studies of the Pajarito Plateau: A Synthesis of Hydrogeologic Workplan Activities (1998–2004)

edited by

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ABSTRACT

This report provides a comprehensive description of the hydrogeologic setting beneath the Pajarito Plateau and Los Alamos National Laboratory (LANL). It is based on interpretative synthesis of hydrogeologic and geochemical data collected through December 2004. Since 1998, twenty-five regional aquifer wells and six intermediate-zone wells have been completed for hydrogeologic characterization. Characterization of the hydrogeologic setting was undertaken in order to fulfill regulatory requirements for characterization and monitoring. This report provides the data and information necessary to evaluate the existing monitoring network and, if necessary, to design an enhanced monitoring network.

Los Alamos National Laboratory (LANL) is situated on the Pajarito Plateau, located within the Española Basin section of the Rio Grande Rift. The Española Basin, as well as the Pajarito Plateau on its western edge, is filled with Miocene and Pliocene-age sediments and volcanic rocks. The topographic plateau is formed by Pleistocene Bandelier Formation ash-flow tuffs from the Jemez volcanic field, which cover the basin-fill sediments.

Groundwater occurs in three settings beneath the Pajarito Plateau: alluvial groundwater, intermediate-perched saturated zones, and the regional aquifer. Alluvial groundwater occurs to a limited and variable extent in the alluvium lining canyon bottoms. Alluvial groundwater provides pathways for LANL-derived contamination introduced into canyons to migrate to significant lateral distances and infiltrate to greater depths.

Flow and transport of water in the vadose zone varies by rock type. Most of the plateau is covered with nonwelded to moderately welded Tshirege and Otowi Member ash-flow tuffs of the Bandelier Tuff. Unsaturated flow and transport through these nonwelded to moderately welded tuffs occurs predominantly through the porous matrix. On the western edge of the plateau, both fracture and matrix-dominated flow can occur, depending on the degree of welding (or matrix conductivity) of the tuff. In contrast to the flow behavior in the Bandelier Tuff units, much of the vadose zone flow through the basalt units is almost certainly fracture dominated. Beneath the Pajarito Plateau, perched water bodies in the vadose zone may be important components of subsurface pathways that facilitate movement of contaminated fluids from the ground surface to the water table of the

regional aquifer. Perched water is most often found in Puye fanglomerates, the Cerros del Rio basalt, and in units of the Bandelier Tuff.

The regional aquifer beneath the Pajarito Plateau is part of an aquifer which extends throughout the Española Basin (an area roughly 6000 km2). This aquifer is the primary source of water for the Laboratory, the communities of Santa Fe, Española, Los Alamos, and numerous pueblos. The sources of recharge to the regional aquifer are diffuse recharge in the Sierra de los Valles and focused recharge from wet canyons on the Pajarito Plateau. Natural discharge from the regional aquifer is primarily into the Rio Grande directly or to springs that flow into the Rio Grande. The aquifer is under water-table conditions across much of the Plateau, but exhibits more confined aquifer behavior near the Rio. Hydraulic properties are highly anisotropic, with vertical hydraulic conductivities much smaller than horizontal hydraulic conductivites, resulting in a muted response at the water table to supply-well pumping at greater depths. Flow modeling simulations suggest that flow beneath the Rio Grande (west to east) has been induced by production at the Buckman wellfield just east of the Rio Grande, which supplies the city of Santa Fe. Because of the heterogeneous nature of the aquifer, groundwater velocity varies considerably over short distances. The fastest velocities are in the basalts where fracture flow is assumed.

Imprinted on the natural variations in chemistry along flowpaths is the presence of contaminants historically released since the early 1940s when Laboratory operations commenced. The impacts to groundwater at the Laboratory have occurred mainly where effluent discharges have caused increased infiltration of water. The movement of groundwater contaminants is best seen through the distribution of conservative (that is, non-reactive) chemical species. Under many conditions, compounds like RDX, tritium, perchlorate, and nitrate move readily with the groundwater. In many settings, chemical reactions do not retard the movement of these compounds or decrease their concentrations, although the activity of tritium does decrease due to radioactive decay. For some compounds or constituents (uranium, strontium-90, barium, some HE compounds, and solvents), movement is slowed or their concentrations are decreased by adsorption or cation exchange, precipitation or dissolution, chemical reactions like oxidation/reduction, or radioactive decay. Other constituents (americium-241, plutonium, and cesium-137) are nearly immobile because they are strongly adsorbed onto sediment particles.

The distribution of tritium in the regional aquifer supports the conceptual model that surface effluent discharges have caused the cases where Laboratory contaminants are found at depth. In most cases, the highest regional aquifer tritium values are found near where effluent discharges have occurred, but are much lower than values observed in overlying alluvial or intermediate perched groundwater. The lower regional aquifer values may be due to dilution of recharge by other groundwater sources as well as radioactive decay due to recharge times of decades.

The conceptual models of the hydrologic system beneath the Pajarito Plateau have been translated into numerical models. A site-wide model for performing first-order analysis of travel time through the vadose zone across the entire Pajarito Plateau was used to identify areas where contaminant pathways are likely to exist. Results indicated that the predicted travel times on mesas are variable, but for the

most part are greater than 1000 years, ranging from 1000–5000 years in the eastern portions of the Laboratory to 20,000 to 30,000 years in the western region. Two factors control these results: infiltration rate and hydrostratigraphy. Generally, travel times less than 100 years are predicted in the portions of canyons with net infiltration of 300 mm/yr to 1000 mm/yr, especially in locations where the Bandelier Tuff is thin.

The regional aquifer model has been applied to predict fate and transport of contaminants in the regional aquifer, in order to optimally place monitoring wells and inform risk assessment studies; and to provide guidance in prioritization of data collection activities.

Armed with the understanding gained from the Hydrogeologic Workplan activities, it is now possible to develop improved groundwater monitoring strategies or conduct more cost-effective detailed studies of individual canyons where initial studies have suggested that groundwater risk may exist.

1.0 INTRODUCTION

This report provides a comprehensive description of the hydrogeologic setting beneath the Pajarito Plateau and Los Alamos National Laboratory (LANL). It is based on interpretative synthesis of hydrogeologic data collected through December, 2004. Characterization of the hydrogeologic setting was undertaken in order to fulfill regulatory requirements for characterization and monitoring. This report provides the data and information necessary to evaluate the existing monitoring network and, if necessary, to design an enhanced monitoring network. Monitoring network evaluation and design are not addressed in this report. Recommendations included in this report are for scientific interest only, and are not necessary to comply with the regulatory requirements.

LANL is located in Los Alamos, Santa Fe, and Sandoval counties of north-central New Mexico, roughly 25 mi northwest of Santa Fe (Figure 1-1). It is owned by the Department of Energy (DOE) and co-operated by DOE and the University of California (UC). Work at LANL began in 1943 with the mission to design, develop, and test nuclear weapons.

Beginning in 1945, the US Geological Survey (USGS) became involved in various studies to develop the water supply at LANL (LANL 1995). Special studies to protect and monitor groundwater quality were initiated by LANL in 1949. Thus, groundwater monitoring has been conducted at LANL for over 50 years. The first monitoring network was limited to the water supply wells, a handful of test wells, and springs. The monitoring network evolved as environmental programs, such as those managed by LANL's Environmental Restoration (ER) organization (now Environmental Stewardship—Environmental Remediation & Surveillance Program [ENV-ERS]), added more wells, primarily in the shallow alluvial systems, as potential monitoring points.

In 1997, LANL personnel began a site-wide hydrogeologic characterization program, which is described in the Hydrogeologic Workplan (LANL 1998). The primary objective of the characterization program was to sufficiently refine the understanding of the hydrogeologic systems so that, if appropriate, an enhanced monitoring network could be designed. The Hydrogeologic Workplan was implemented, resulting in installation of 25 regional aquifer wells. Data from sampling and measurements taken at these wells have provided information about the subsurface geologic environment, including the vadose zone and intermediate perched and regional aquifer groundwater. This report is a synthesis of data from Hydrogeologic Workplan activities and all other groundwater-related investigations conducted at LANL since 1997. Collection and analysis of groundwater data is ongoing at LANL, associated with site-specific (not site-wide) investigations. It is considered unlikely that information from wells drilled after December 2004 will significantly change the understanding of the site-wide hydrogeologic setting described in this report. In some cases, analysis and interpretation of data lags behind data collection, and what is presented here does not include analysis of all data collected up to December 2004. Analysis of the data collected as part of the site-wide characterization has sufficiently improved the understanding of the hydrogeologic system and the ability to design and implement an integrated site-wide groundwater monitoring program.

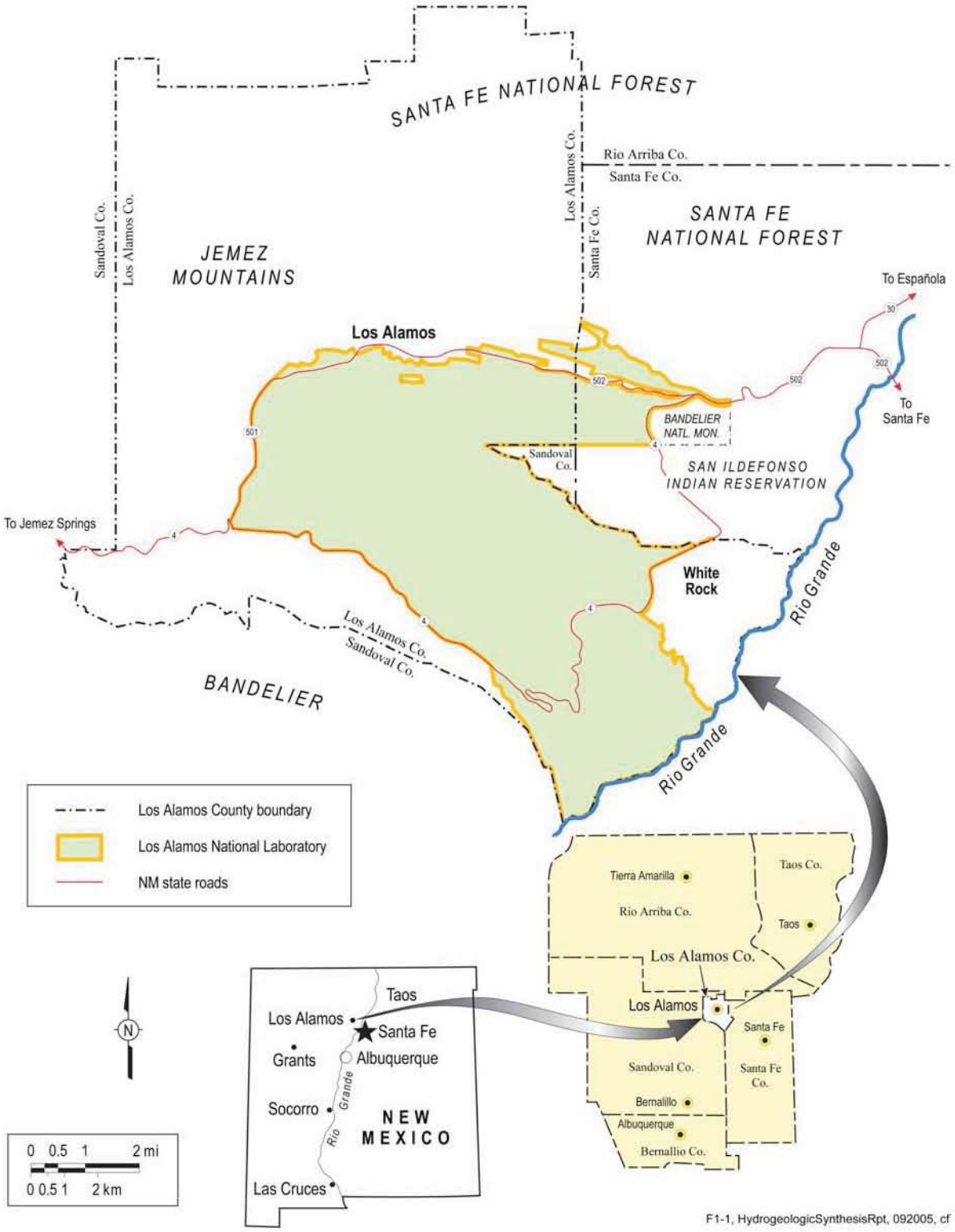

Figure 1-1. Location of Los Alamos National Laboratory.

1.1 Technical Objectives of the Hydrogeologic Workplan

The primary technical objective of the Hydrogeologic Workplan was to collect data necessary to evaluate and, if necessary, enhance the groundwater monitoring network at LANL. The technical objectives of the Hydrogeologic Workplan were intended to be comprehensive with respect to groundwater regulatory requirements for characterization and monitoring, described in Appendix 1-A. The regulatory requirements included

- Resource Conservation and Recovery Act (RCRA) operating permit which requires monitoring for RCRA units, unless a groundwater monitoring waiver is demonstrated.
- New Mexico Environment Department (NMED) letters requiring a better understanding of the hydrogeologic regime in order evaluate groundwater monitoring waivers submitted by LANL.
- RCRA permits Hazardous and Solid Waste Amendments (HSWA) module requirements to characterize the hydrogeologic setting.

Specifically, NMED identified four issues that needed to be resolved in order to evaluate the groundwater monitoring waivers submitted by LANL (Appendix 1-A):

- Individual zones of saturation beneath LANL had not been adequately delineated and the "hydraulic interconnection" between these was not understood.
- The recharge area(s) for the regional and intermediate aquifers and any associated effects of fracture-fault zones with regard to contaminant transport and hydrology had not been identified.
- The groundwater flow direction(s) of the regional aquifer and intermediate aquifers, as influenced by pumping of production wells, were unknown.
- Aquifer characteristics could not be determined without additional monitoring wells installed within specific intervals of the various aquifers beneath the facility.

Table 1-1 is a crosswalk of HSWA module requirements for groundwater characterization, how they have been addressed, and which sections of this report contain that information.

1.2 Hydrogeologic Characterization Overview

In order to establish the data quality objectives that guided the development of the Hydrogeologic Workplan (LANL 1998), the information needed to evaluate and design a monitoring network was articulated. Groundwater at LANL occurs in three modes: alluvial, perched intermediate groundwater in the vadose zone, and the regional aquifer. Figure 1-2 shows the relationship between the Pajarito Plateau topography and modes of groundwater. In general, to monitor the quality of water that has the potential to be impacted by releases of hazardous or radioactive wastes, there must be an understanding of the following:

Table 1-1.
Crosswalk Between HSWA Permit Requirements* and Synthesis Report Section

HSWA Permit Reference	Permit Requirement	Synthesis Report Sections
Task III.A.1.a	A description of the regional and facility specific geologic and hydrogeologic characteristics affecting groundwater flow beneath the facility	Section 2.2, Section 2.4
Task III.A.1.b	An analysis of any topographic features that might influence the groundwater flow system	Section 2.1.3
Task III.A.1.c	An analysis of fractures within the tuff, addressing tectonic trend fractures versus cooling fractures	Section 2.5.4
Task III.A.1.d	Based on field data, tests, (gamma and neutron logging of existing and new wells, piezometers, and borings) and cores, a representative and accurate classification and description of the hydrogeologic units which may be part of the migration pathways at the facility (e.g., the aquifers and any intervening saturated and unsaturated units)	Section 2.3; Section 4.2.12
Task III.A.1.e	Based on field studies and cores, structural geology and hydrogeologic cross sections showing the extent (depth, thickness, lateral extent) of hydrogeologic units which may be part of the migration pathway identifying Unconsolidated sand and gravel deposits Zones of fracturing or channeling in consolidated and unconsolidated deposits Zones of high or low permeability that might direct and restrict the flow of contaminants	Section 2.3; Section 4.1.2; Section 4.2.12
Task III.A.1.f	Based on data obtained from groundwater monitoring wells and piezometers installed upgradient and downgradient of the potential contaminant source, a representative description of water level or fluid pressure monitoring	Section 2.4.2
Task III.A.1.g	A description of manmade influences that may affect the hydrogeology of the site	Section 2.7.6
Task III.A.1.h	Analysis of available geophysical information and remote sensing information such as infrared photography and Landsat imagery	Appendix 2-A
Task III.A.2.d	Characterize rock and soil units above the water table including saturated hydraulic conductivity	Section 2.2, Section 2.3, Section 2.4.1
Task III.A.2.e	Characterize rock and soil units above the water table including porosity	Section 2.2, Section 2.3, Section 2.4.1
Task III.A.2.j	Characterize rock and soil units above the water table including depth of water table	Section 2.2, Section 2.3, Section 2.4.1
Task III.A.2.k	Characterize rock and soil units above the water table including moisture content	Section 2.2, Section 2.3, Section 2.4.1
Task III.A.2.l	Characterize rock and soil units above the water table including effect of stratification on unsaturated flow	Section 2.4.1

Table 1-1.
Crosswalk Between HSWA Permit Requirements* and Synthesis Report Section (continued)

HSWA Permit Reference	Permit Requirement	Synthesis Report Sections
Task III.A.2.m	Characterize rock and soil units above the water table including infiltration	Section 2.4.1
Task III.A.2.n	Characterize rock and soil units above the water table including evapotranspiration	Section 2.4.1; Section 2.4.2
Task III.A.2.o	Characterize rock and soil units above the water table including residual contaminants in soil	Section 2.4.1, Appendix 3-A
Task III.A.2.r	Characterize rock and soil units above the water table including water balance scenarios	Section 2.4.1
Task III.C.1.a	A description of horizontal and vertical extent of any immiscible or dissolved groundwater plume(s) originating from the facility	Appendix 3-A
Task III.C.1.b	The horizontal and vertical direction of contaminant movement in groundwater	Section 3.2; Section 4.1; Section 4.2.11; Section 4.2.12
Task III.C.1.c	The velocity of contaminant movement in groundwater	Section 4.1; Section 4.2.11; Section 4.2.12
Task III.C.1.d	The horizontal and vertical concentration profiles of any 40 CFR Part 264 Appendix IX constituents and radiochemical constituents in the groundwater plume(s)	Section 3.2; Appendix 3-A
Task III.C.1.e	An evaluation of factors influencing the plume movement	Section 3.1, Section 3.2, Section 4.1, Section 4.2.12
Task III.C.1.f	An extrapolation of future plume movement	Section 4.1, Section 4.2.12

* LANL, 1995.

- Potential sources of contaminants: contaminant character, inventory, and locations
- Release mechanisms that introduce contaminants to the environment
- Contaminant transport mechanisms from the location of the release to groundwater
- Transport of contaminants through the groundwater system: direction and velocity of groundwater and of contaminants

Monitoring data needs were identified for each component of the groundwater system: alluvial, intermediate perched groundwater in the vadose zone, and regional aquifer and the connections between the components. Figure 1-2 shows the overall hydrogeologic conceptual model. In wet canyons, where surface water is present, the water infiltrates the alluvium in the canyon bottoms and forms alluvial groundwater. Dry canyons and mesas do not have alluvial groundwater. Alluvial groundwater flows down the canyon until it reaches an area where infiltration is enhanced by thin or absent Bandelier Tuff, highly fractured rock below the alluvium, or anthropogenic alterations (e.g. sediment traps). In areas with enhanced infiltration, alluvial groundwater percolates through the vadose zone and collects in relatively more permeable units, if there are any present beneath the canyon, e.g. fractured basalt. Alluvial groundwater and perched intermediate groundwater continue to percolate through the deeper vadose zone until they reach the regional

aquifer. The interconnected nature of the hydrogeologic system may allow anthropogenic constituents that are present in surface water to be transported into alluvial groundwater, the vadose zone and to the regional aquifer.

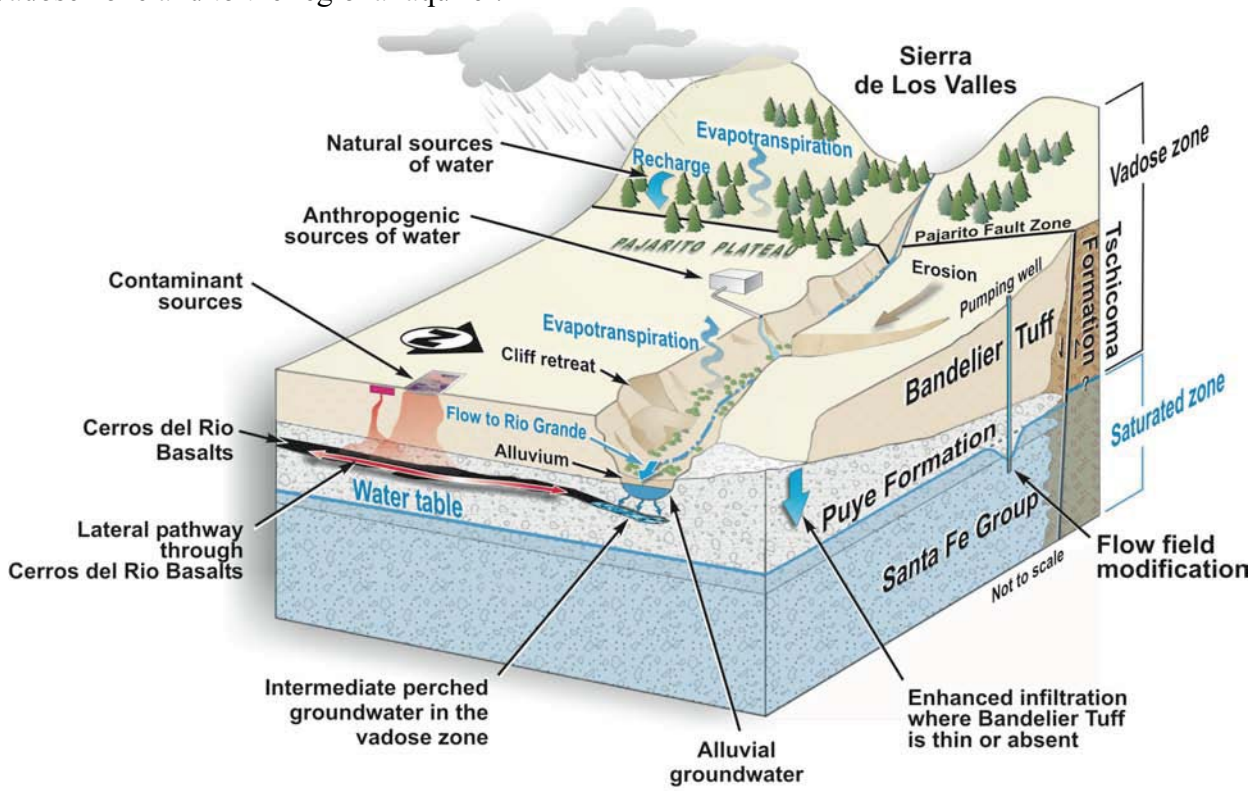

Figure 1-2. Groundwater components at LANL.

The data collection articulated in the Hydrogeologic Workplan considered elements of risk assessment, e.g. sources, release mechanisms, and transport, because these same elements are important in establishing a monitoring network capable of detecting releases. Thus, the data collected under the auspices of the Hydrogeologic Workplan are considered adequate to support risk assessment, but are not intended to serve as a risk assessment. Characterizing the source terms and release mechanisms or other chemical phenomena is the subject of ongoing investigations and information from those investigations was used in developing the Hydrogeologic Workplan (LANL 1998). Characterizing the alluvial component of the hydrologic system was undertaken in conjunction with investigating source terms and the results of the alluvial investigations are reported here (Section 2.4) because of the importance of alluvial groundwater in the hydrogeologic system. The primary focus of the Hydrogeologic Workplan (LANL 1998) activities was on the deeper groundwater components and to understand the movement of contaminants through the vadose zone and in the regional aquifer.

Since 1998, twenty-five regional aquifer wells and six intermediate-zone wells have been completed for hydrogeologic characterization (Table 1-2). The locations of the hydrogeologic characterization wells are shown on Figure 1-3. Well completion fact sheets (Appendix 1-B) and well completion reports document the drilling, well construction, well completion, testing, and

sampling for each characterization well. A description and analysis of the characterization sampling for many wells are documented in geochemistry reports.

1.3. Topical Organization

The most basic control on the movement of water and contaminants through the system is the rocks through which the water moves. The conceptual model of the site is built from surface and subsurface geologic data (Appendix 2-A). Section 2.1 describes the regional geologic setting as a context for understanding the stratigraphic framework of the Pajarito Plateau presented in Section 2.2. Cross sections that illustrate the relationship between the stratigraphic units are critical for understanding how groundwater flows (Section 2.3).

The hydrologic properties of stratigraphic units in the vadose zone and regional aquifer are described in Section 2.4. This section quantifies the properties of the hydrologic units and explains the sources of data, including the uncertainties in the properties. The hydrologic properties and processes are combined to create conceptual models of the alluvial, vadose zone, and regional aquifer components in Sections 2.5, 2.6 and 2.7, respectively.

The natural groundwater geochemistry of the Pajarito Plateau is important to understand in order to identify and quantify contaminants added to the system. The background groundwater chemistry is integrated with geochemical processes to provide the comprehensive geochemical model described in Section 3.1. Overprinted on the natural water chemistry are the contaminants potentially released by LANL activities. Section 3.2 synthesizes the contaminant distribution data with respect to hydrologic processes and explores the contaminant transport implications.

Numerical modeling is an analytical tool that can be used to integrate and synthesize the sometimes widely-spaced point hydrogeologic field data and that predicts how the hydrologic system will behave at different times and under different conditions in the future. However, before models can be used for prediction, they must adequately reproduce the current conditions. The vadose zone and regional aquifer models that have been developed adequately reproduce current conditions beneath the Pajarito Plateau are described in Sections 4.1 and 4.2. These sections include the underlying assumptions, hydrologic processes, calibration, and predictions for flow and transport.

Section 5 summarizes the information presented in Sections 2, 3 and 4 and highlights how the refined understanding of the hydrogeologic systems can be applied to evaluating the adequacy of the existing the monitoring system and, if necessary, the design of an enhanced monitoring network.

Table 1-2.
Los Alamos National Laboratory Hydrogeologic Characterization Wells

Well	Location	Date Completed	Primary Drilling Methods	Type of Drilling Fluid Used	Total Depth (ft bgs*)	Number of Screens[1]	Reference
R-1	Mortandad Canyon	November 2003	Conventional-circulation fluid-assisted air-rotary methods with casing advance to 90 ft followed by conventional-circulation fluid-assisted air-rotary drilling in an open hole to[2] TD at 1165 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1165	1–R	Kleinfelder, 2004e
R-2	Pueblo Canyon	October 2003	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to 403 ft followed by conventional-circulation mud rotary drilling to TD at 943 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD in the upper part and municipal water mixed with bentonite, soda ash, PAC-L in the lower part	943	1–R	Kleinfelder, 2004b
R-4	Pueblo Canyon	October 2003	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to 266 ft followed by conventional-circulation mud rotary drilling to TD at 844 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD in the upper part and municipal water mixed with bentonite, soda ash, PAC-L in the lower part	844	1–R	Kleinfelder, 2004a
R-5	Pueblo Canyon	June 2001	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 870 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 902 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	902	2–I 2–R	LANL, 2003a
R-6	Los Alamos Canyon	December 2004	Conventional-circulation air-rotary and fluid-assisted air-rotary drilling methods in an open hole to 945 ft followed by conventional-circulation mud rotary drilling in a cased hole (casing set to 815 ft depth) to TD at 1303 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD in the upper part and municipal water mixed with bentonite (Max-Gel and Quik-Gel), N-seal, Drispac, and soda ash in the lower part	1303	1–R	Well completion report unavailable
R-7	Los Alamos Canyon	February 2001	Reverse-circulation fluid-assisted air-rotary methods with casing advance to 290 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1097 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1097	2–I 1–R	Stone et al. 2002
R-8	Los Alamos Canyon	February 2002	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 809 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 880 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	880	2–R	LANL, 2003b

Table 1-2.
Los Alamos National Laboratory Hydrogeologic Characterization Wells (continued)

Well	Location	Date Completed	Primary Drilling Methods	Type of Drilling Fluid Used	Total Depth (ft bgs*)	Number of Screens[1]	Reference
R-9	Los Alamos Canyon	October 1999	A combination of reverse-circulation air-rotary methods in open hole to 175 ft, coring to 419 ft, and with casing advance and reverse-circulation air-rotary methods TD at 771 ft.	Air in upper part of the borehole and air with municipal water mixed with Quik-FOAM, EZ-MUD in the lower part	771	1–R	Broxton et al. 2001a
R-11	Sandia Canyon	August 2004	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 927 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	927	1–R	Kleinfelder, 2004c
R-12	Sandia Canyon	January 2000	A combination of reverse- circulation air-rotary methods in open hole and with casing advance to 710 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 886 ft.	Air and municipal water in the upper part and air with municipal water mixed with TORKEASE, Quik-FOAM, EZ-MUD in the lower part	886	2–I 1–R	Broxton et al. 2001
R-13	Mortandad Canyon	September 2001	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to TD at 1133 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1133	1–R	LANL 2003c
R-14	Mortandad Canyon	July 2002	Reverse-circulation fluid-assisted air-rotary methods in open hole to 1225 ft with hole cased to 1050 ft; conventional-circulation mud rotary drilling in open hole from 1225-1285 ft; reverse-circulation fluid-assisted air-rotary methods with casing advance from 1285 ft to TD at 1327 ft.	Air and municipal water mixed with EZ-MUD in the upper part and municipal water mixed with soda ash, bentonite, LIQUI-TROL, in the lower part	1327	2–R	LANL, 2003d
R-15	Mortandad Canyon	February 2000	Reverse-circulation fluid-assisted air-rotary methods with casing advance to TD at 1107 ft.	Air and municipal water mixed with TORKEASE, Quik-FOAM, EZ-MUD	1107	1–R	Longmire et al. 2000
R-16	White Rock Overlook	August 2002	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 729 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to 867 ft. Hole completed using conventional-circulation mud rotary methods from 867 ft to TD at 1287 ft.	Air and municipal water mixed Quick-gel, liqui-trol, Quick-FOAM, and soda ash in the upper part and municipal water mixed Quick-gel, EZ-MUD, liqui-trol, magma-fiber, n-seal in the lower part	1287	4–R	LANL, 2003e
R-18	Mesa above Pajarito Canyon	December 2004	Conventional-circulation fluid-assisted air-rotary drilling methods in an open hole to TD at 1440 ft.	Air and municipal water mixed with Quik-FOAM and EZ-MUD	1440	1–R	Well completion report unavailable

Table 1-2.
Los Alamos National Laboratory Hydrogeologic Characterization Wells (continued)

Well	Location	Date Completed	Primary Drilling Methods	Type of Drilling Fluid Used	Total Depth (ft bgs*)	Number of Screens[1]	Reference
R-19	Mesa above Potrillo Canyon	April 2000	Reverse-circulation fluid-assisted air-rotary methods with casing advance to 227 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1902 ft.	Air and municipal water mixed with TORKEASE, Quik-FOAM, EZ-MUD	1902	2–I 5–R	Broxton et al. 2001d
CdV-R-15-3	Cañon de Valle	September 2000	Reverse-circulation fluid-assisted air-rotary methods with casing advance to 722 ft; install casing; complete hole by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1722 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD plus polymers	1722	3–I 3–R	Kopp et al. 2002
CdV-R-37-2	Cañon de Valle	October 2001	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 825 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1664 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1664	1–I 3–R	Kopp et al. 2003
R-20	Pajarito Canyon	January 2003	Conventional-circulation mud rotary drilling to TD at 1365 ft.	Municipal water mixed Quick-gel, liqui-trol, Quik-FOAM, soda ash, PAC-L, n-seal (mineral fiber)	1365	3–R	LANL, 2003f
R-21	Cañada del Buey	January 2003	Conventional-circulation air-rotary drilling in an open hole to 237 ft followed by conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 995 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	995	1–R	Kleinfelder, 2003f
R-22	Mesa above Pajarito Canyon	December 2000	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 1345 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1489 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1489	5–R	Ball et al. 2002
R-23	Pajarito Canyon	January 2003	A combination of conventional mud-rotary drilling, reverse-circulation fluid-assisted air-rotary drilling in open hole, and reverse-circulation fluid-assisted air-rotary drilling with casing advance to TD of 935 ft.	Municipal water mixed with bentonite, Quick-gel, liqui-trol, Quik-FOAM, soda ash, magna-fiber, PAC-L, n-seal and air with municipal water mixed with Quick-gel, liqui-trol, Quik-FOAM, and soda ash	935	1–R	LANL, 2003g
R-25	Mesa above Cañon de Valle	February 1999	Reverse-circulation fluid-assisted air-rotary drilling with casing advance to TD of 1942 ft.	Air and municipal water mixed with TORKEASE, Quik-FOAM, EZ-MUD	1942	4–I 5–R	Broxton et al. 2001e

Table 1-2.
Los Alamos National Laboratory Hydrogeologic Characterization Wells (continued)

Well	Location	Date Completed	Primary Drilling Methods	Type of Drilling Fluid Used	Total Depth (ft bgs*)	Number of Screens[1]	Reference
R-26	Cañon de Valle	October 2003	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to 1000 ft; casing installed to 1000 ft; borehole completed by conventional-circulation mud-rotary drilling in an open hole to TD at 1490.5 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1490.5	1–I 1–R	Kleinfelder, 2004f
R-28	Mortandad Canyon	December 2003	Conventional-circulation fluid-assisted air-rotary methods with casing advance to 80 ft followed by conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1005 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1005	1–R	Kleinfelder, 2004d
R-31	Ancho Canyon	March 2000	A combination of reverse- circulation fluid-assisted air-rotary methods in open hole and with casing advance to 787 ft followed by reverse- circulation fluid-assisted air-rotary methods with casing advance to TD at 1103 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1103	1–I 4–R	Vaniman et al. 2002
R-32	Pajarito Canyon	January 2003	Reverse-circulation fluid-assisted air-rotary drilling in open hole to 908; install casing; complete hole by conventional-circulation mud rotary drilling in an open hole to TD at 1008 ft.	Air and municipal water mixed with Quick-gel, liqui-trol, Quik-FOAM, and soda ash in the upper part and municipal water mixed with Quick-gel, liqui-trol, EZ-MUD, magma-fiber, PAC-L, n-seal in the lower part	1008	3–R	LANL, 2003h
R-33	Ten Site Canyon	October 2004	Conventional-circulation air-rotary and fluid-assisted air-rotary drilling methods in an open hole to 1030 ft followed by reverse-circulation fluid-assisted air-rotary drilling methods in an open hole to TD at 1140 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1140	1–R	Completion report not available
R-34	Cedro Canyon	August 2004	Conventional-circulation air-rotary and fluid-assisted air-rotary drilling methods in an open hole to TD at 1065 ft.	Air and municipal water mixed with Quik-FOAM and EZ-MUD	1065	1–R	Completion report not available
MCOB T-4.4	Mortandad Canyon	June 2001	Reverse-circulation fluid-assisted air-rotary drilling using casing advance to 130 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 767 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	767	1–I	Broxton et al. 2002

Table 1-2.
Los Alamos National Laboratory Hydrogeologic Characterization Wells (continued)

Well	Location	Date Completed	Primary Drilling Methods	Type of Drilling Fluid Used	Total Depth (ft bgs*)	Number of Screens[1]	Reference
MCOB T-8.5	Mortandad Canyon	June 2001	Reverse-circulation fluid-assisted air-rotary drilling using casing advance to 130 ft followed by reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 740 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	740	—	Broxton et al. 2002
R-6i	Los Alamos Canyon	December 2004	Conventional-circulation air-rotary and fluid-assisted air-rotary drilling in an open hole to TD at 660 ft.	Air and municipal water mixed with Quik-FOAM	660	1–I	Completion report not available
R-9i	Los Alamos Canyon	March 2000	Reverse-circulation fluid-assisted air-rotary drilling in an open hole to TD at 322 ft.	Air and municipal water mixed with EZ-MUD	322	2–I	Broxton et al. 2001c
CdV-16-1(i)	Cañon de Valle	November 2003	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 683 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	683	1–I	Completion report not available
CdV-16-2(i)	Cañon de Valle	December 2003	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1063 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1063	2–I	Completion report not available
CdV-16-3(i)	Cañon de Valle	January 2004	Conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 1405 ft.	Air and municipal water mixed with Quik-FOAM, EZ-MUD	1405	—	Completion report not available

* bgs = below ground surface
[1] R = screen(s) in regional groundwater; I = screen(s) in intermediate-depth (perched) groundwater
[2] TD = total depth

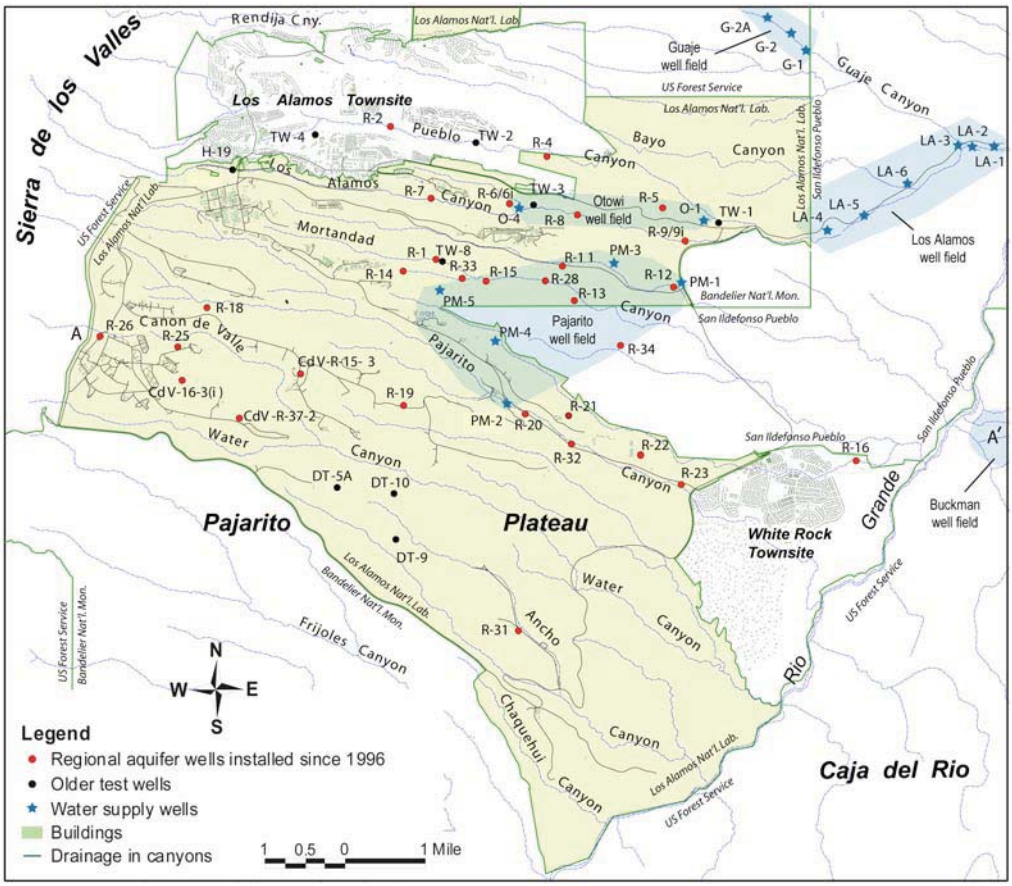

Figure 1-3. Locations of the Hydrogeologic Workplan characterization wells.

2.0 HYDROGEOLOGY

Groundwater occurs in three settings beneath the Pajarito Plateau: alluvium, intermediate perched saturated zones, and the regional aquifer. The major source of recharge to the regional aquifer is precipitation within the Sierra de los Valles. However, alluvial groundwater on the Pajarito Plateau is a source of recharge to underlying intermediate perched saturated zones and to the regional aquifer.

This section describes the conceptual understanding of the hydrogeology beneath the Pajarito Plateau. The conceptual models of the hydrogeologic system described here are based on empirical observations combined with knowledge of geologic and hydrologic processes. These conceptual models are the foundation of the numerical models described in Section 4. First, the geologic conceptual model is described to provide an understanding of the geologic units that are present. Second, the connection between geology and hydrology is discussed because the geology is the first-order control on the Pajarito Plateau hydrology. Finally, the conceptual models for the alluvial groundwater, perched intermediate groundwater, and the regional aquifer are described.

2.1 Geologic Conceptual Model

The geologic conceptual model for the LANL site is developed from (1) past studies of site and regional geology that predate implementation of the Hydrogeologic Workplan, including over 50 years of mapping, drilling, and regional geophysical studies; (2) borehole data collected specifically for the Hydrogeologic Workplan; and (3) integration of results from current Hydrogeologic Workplan studies with other studies in the region, particularly those that are brought together by the Española Basin Technical Advisory Group. Table 2-1 provides a summary of the types of information used to develop the geologic conceptual model and Appendix 2-A contains a detailed description of the geologic types of data used to develop the conceptual model.

There are localized subsurface geologic data associated with drilling boreholes and regional geologic data, surface and subsurface, which are obtained by aerial surveys and work done by others on a regional scale. The localized subsurface geologic data are obtained from:

- Cuttings and core
- Borehole geophysical data
- Borehole video logs
- Drilling rates and character

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Table 2-1.
Summary of Geologic Data

Data Type	Purpose	Data Collection	Data Records	Archives
Lithologic Information from Cuttings	Direct measurements of the top and bottom and character of the hydrogeologic units at each borehole. Correlations of rock units among boreholes are key components of the site-wide 3-D geologic model for the plateau.	Approximately 500 to 700 ml of bulk drill cuttings were collected every 5 ft, as conditions permitted, to the total depth (TD) of each boring. Cuttings were visually examined and a small subset of core and cuttings was selected for additional characterization: X-ray diffraction for mineralogy, X-ray fluorescence for rock chemistry, thin-section petrography, and $^{40}Ar/^{39}Ar$ age dating.	Lithologic logs summarize rock lithologies, alteration features, and stratigraphic contacts from visual examination and interpretations of borehole geophysical logs.	Core and cuttings are currently archived at the ENV Division Sample Management Facility located at Technical Area 3, building 03-0271-101. All borehole materials are stored in core boxes labeled with the well name, box number, and footage range for the box.
Lithologic Information from Core	Core was collected to fulfill a number of characterization objectives, including: • geology of perched saturated zones and aquitards • hydrologic and chemical analyses of vadose-zone samples (e.g. moisture, anions) • hydraulic properties of selected hydrogeologic units.	Core was collected from dedicated core holes and from selected intervals in some regional aquifer boreholes.	Same as for cuttings above.	Same as for cuttings above

Table 2-1.
Summary of Geologic Data (continued)

Data Type	Purpose	Data Collection	Data Records	Archives
Drilling Information	Observations about drilling characteristics by the drillers and on-site geologists contributed to understanding the hydrogeology of the boreholes.	Major lithologic and stratigraphic contacts were commonly marked by significant changes in drill penetration rates. Drilling rates are primarily affected the competency of the rocks being penetrated. Hard rock units have slow drilling rates, whereas less-competent rocks were drilled more rapidly. Important information about water-bearing strata was obtained when drillers noted changes in the drilling fluids circulating through the borehole.	These observational data were recorded in field logs, and they provided supplemental information that aided the interpretation of hydrogeologic data from other sources such as cuttings and geophysical logs.	N/A
Borehole Geophysical Data	Determine the geologic and hydrologic characteristics of the vadose zone, perched saturated zones, and regional aquifer. Preliminary logs were used by contractor, DOE, and LANL personnel to help select well screen locations and to evaluate borehole conditions prior to well construction.	*LANL*: caliper, spontaneous potential, single-point resistance and induction, and natural gamma radiation logs. *Contractor:* wire-line logging service was contracted to obtain a more extensive suite of borehole geophysical logs once the borehole reached total depth	Preliminary results of geophysical logs were generated in the logging truck at the time the geophysical services were performed. Contractor reprocessed the field measurements to correct them and to combine the logs into a single presentation enabling integrated interpretation.	Results of contractor geophysical logging and analysis are summarized in an interpretive report that is included in each well completion report.

Table 2-1.
Summary of Geologic Data (continued)

Data Type	Purpose	Data Collection	Data Records	Archives
Borehole Video Logs	To obtain lithologic information and to help determine stratigraphic contacts; visual examination of borehole walls for evidence of perched saturation; document water levels in the boreholes; document the as-built condition of installed well components; assess the effectiveness of well development techniques; to assess problematic borehole conditions and to guide fishing operations for tools and equipment lost downhole.	Borehole video was used in each borehole or completed well. The videos were viewed by geologists to assess geologic conditions. Often used in conjunction with geophysical logs to determine the locations of perched zones in some boreholes and the presence and nature of fractures.	Video logs were collected during installation of workplan wells.	N/A
Regional Airborne Surveys	Focus groundwater investigations by defining the conductivity structure beneath the plateau. Gravity data were used to help define regional structure beneath the Pajarito Plateau.	A total of 762 line kilometers of MegaTEM® time domain EM data and magnetic data were collected (80% of LANL area). Flight lines spaced at 105 m within the laboratory boundaries, and at 210 m in buffer zones. Lines oriented N20E, with tie lines about 2000-meter spacing.	Maps of Residual Magnetic Intensity (RMI), apparent conductance and conductivity depth slices at various depths, multiparameter profiles with conductivity-depth-transform (CDT) sections for flight lines and digital archives of line and grid data.	All of the processing assumed a "layered-earth" model, and inversions were: single points/multiple depths (1-D), multiple depths along individual flight lines (2-D), or a constant depth on multiple flight lines (2-D). The results of all three models, for each flight line are available as Adobe PDF files.

Note: N/A = not applicable

Geologic data derived from regional-scale studies were obtained from multiple sources, including:

- Surface geophysical data were used to help constrain the site-wide geologic model (Appendix 2-A). These data include regional gravity data, airborne electromagnetic data, high resolution resistivity, and magnetotellurics. Gravity data were used to help define regional structure beneath the Pajarito Plateau. Airborne electromagnetic data, high resolution resistivity, and magnetotelluric data were used to focus groundwater investigations by defining the conductivity structure beneath the plateau
- Numerous local and regional mapping projects and geological studies have provided important information supporting development of geologic conceptual models and digital realizations of these models.
- Española Basin workshops were hosted annually by the Española Basin Technical Advisory Group and sponsored by the U.S. Geological Survey, the New Mexico Bureau of Geology and Mineral Resources, Los Alamos National Laboratory, and the city of Santa Fe.
- The Seismic Hazards program at LANL was an important source of information about faults and fractures in the vicinity of the Laboratory.
- Students and their advisors from the graduate programs from the University of New Mexico and New Mexico State University, New Mexico Institute of Mining and Technology, and the University of Texas have provided additional hydrogeologic information for the Jemez volcanic field, the Espanola Basin, and the Puye Formation.

2.1.1 Goals of the Geologic Model

- Define the geologic setting of the groundwater system beneath the Pajarito Plateau
- Relate lithologic properties of rocks to groundwater flow characteristics and rock/water interactions
- Provide a benchmark for comparing new data to predicted geology
- Improve selection of new well sites based on iterative evaluation of hydrogeologic information
- Provide a framework for numerical flow and transport models of the vadose and saturated zones

2.1.2 Site-Wide Geology

The discussion of site-wide geology presented here is condensed from a summary by Broxton and Vaniman (2005). More detailed, fully referenced information is available in that publication. The deep characterization wells drilled in the time period from 1997 to 2004 have provided the foundation for constructing the geologic framework surfaces presented in this section.

2.1.2.1 Regional Setting

The Pajarito Plateau lies at the volcanically and seismically active boundary between the Colorado Plateau and the Rio Grande Rift in north-central New Mexico (Figure 2-1). The Rio Grande rift is a major geologic feature that consists of north-trending, fault-bounded basins

extending from central Colorado to northern Mexico. The local area of subsidence, termed the Española Basin, lies between two larger basins—the Albuquerque Basin to the south and San Luis Basin to the north (Kelley, 1978). The Española Basin is about 70 km (44 mi) long and 60 km (37 mi) wide. The plateau overlies the deepest part of the west-tilted Española Basin adjacent to the highlands of the Jemez volcanic field. Geologic units consist of Miocene and Pliocene basin-fill deposits and interfingering volcanic rocks from the Jemez and Cerros del Rio volcanic fields. Miocene and Pliocene sedimentary and volcanic rocks are covered by Pleistocene ash-flow tuffs making up the Pajarito Plateau.

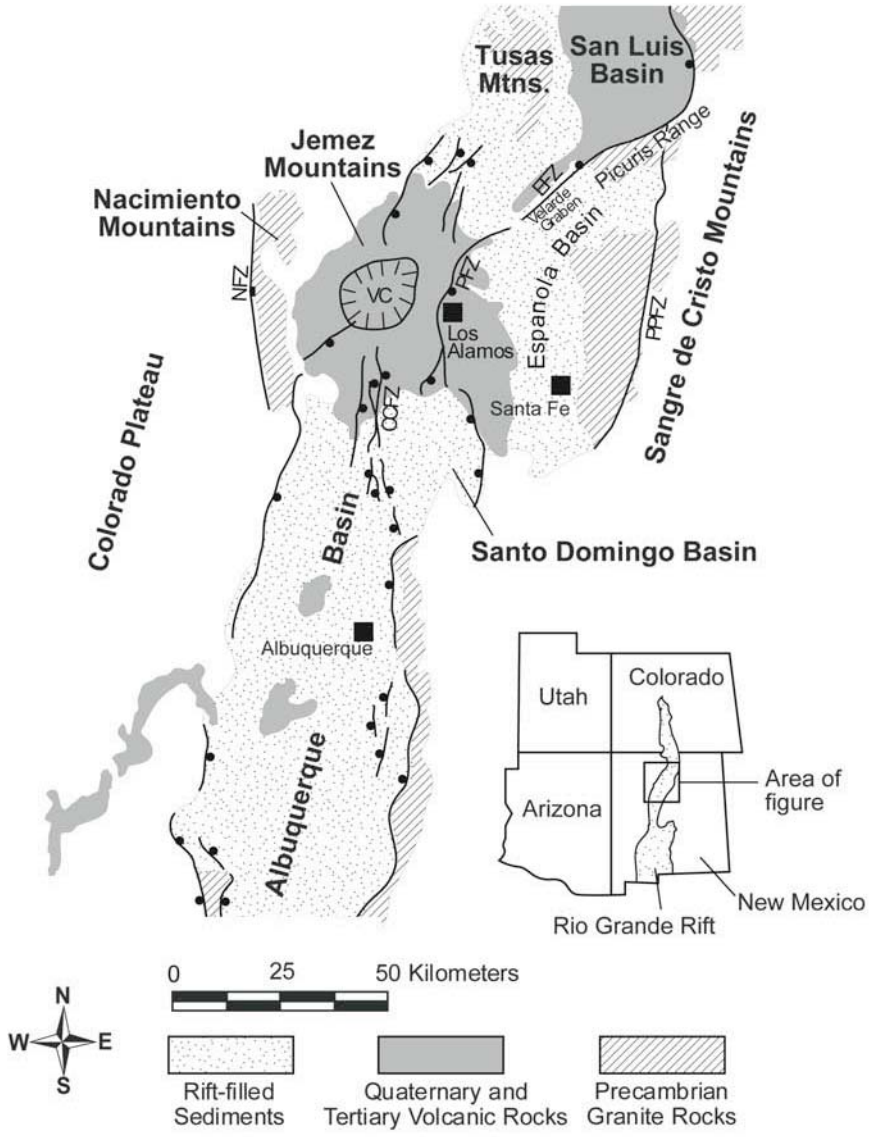


Figure 2-1. Locations of major structural and geologic elements near LANL. Major fault systems are shown with ball on downthrown side. VC is the Valles Caldera complex; NFZ is the Nacimiento fault zone; CCFZ is the Cañada del Cochiti fault zone; PFZ is the Pajarito fault zone; and PPFZ is the Picuris-Pecos fault zone.

The western structural margin of the Española Basin is partly covered by rocks of the Jemez volcanic field, but probably includes a broad zone of north-trending faults such as the Cañada de Cochiti fault zone (Figure 2-1) that cut older volcanic units in the south-central part of the volcanic field (Gardner and Goff, 1984). The present active western boundary of the Española Basin is the Pajarito fault zone, a narrow band of north- and northeast-trending normal faults that delineate the western margin of the Pajarito Plateau. Neogene displacement along the Pajarito fault zone is dominantly down to the east with episodic faulting indicated by progressively larger offsets in older rock units.

Gravity data (Biehler et al., 1991; Ferguson et al., 1995) indicates the deepest part of the Española Basin coincides with three deep, intrabasinal grabens arrayed along the Pajarito and Embudo fault systems. From north to south, these subbasins include the Velarde graben (Manley, 1979, 1984), a north-northeast trending basin beneath Santa Clara pueblo, and a north-trending basin near Los Alamos. The Pajarito fault zone forms the western boundary of the Los Alamos subbasin (Biehler et al., 1991; Ferguson et al., 1995; Smith, 2004). Gravity data suggest that the eastern boundary is bounded by buried faults that lie east of the southern projections of the Rendija Canyon and Guaje Mountain (Ferguson et al., 1995), but the location and size of faults in this area are not well known.

The basement of the Española Basin is an eroded terrane of Eocene-Precambrian aged rocks uplifted during the Laramide mountain-building episode (orogeny, approximately 65 million years ago (m.y.a.). One of these uplifted areas, the Pajarito uplift, is bounded on the east by the Picuris-Pecos fault in the Sangre de Cristo Range and on the west by the Pajarito fault (Cather, 2004; Smith, 2004). At the time of Laramide uplift, the Pajarito fault was a westward-verging reverse fault, but it was reactivated as a down-to-the-east normal fault during Neogene (within the last 24 m.y.) subsidence of the Española Basin.

2.1.2.2. Structural Geology of the Pajarito Plateau

The Pajarito fault zone and its associated structures are the most prominent tectonic features of the LANL site (Figure 2-2). The fault, which forms a 120-m (400-ft) high escarpment on the western margin of the plateau, has the surface expression of a large, north-trending, faulted monocline. Along strike the fault varies from a simple normal fault to broad zones of small faults, faulted monoclines, and unfaulted monoclines. These varied styles of deformation are all considered expressions of deep-seated normal faulting. The amount of fault displacement for older rock units is not known because thick deposits of Bandelier Tuff cover critical relations. Stratigraphic separation on the Tshirege Member of the Bandelier Tuff (1.22 Ma) ranges between 80 and 120 m (260 to 400 ft) along the segment of the fault west of LANL (Gardner et al., 1999). Holocene movements (within the last 10,000 years) and historic seismicity indicate this fault system is still active.

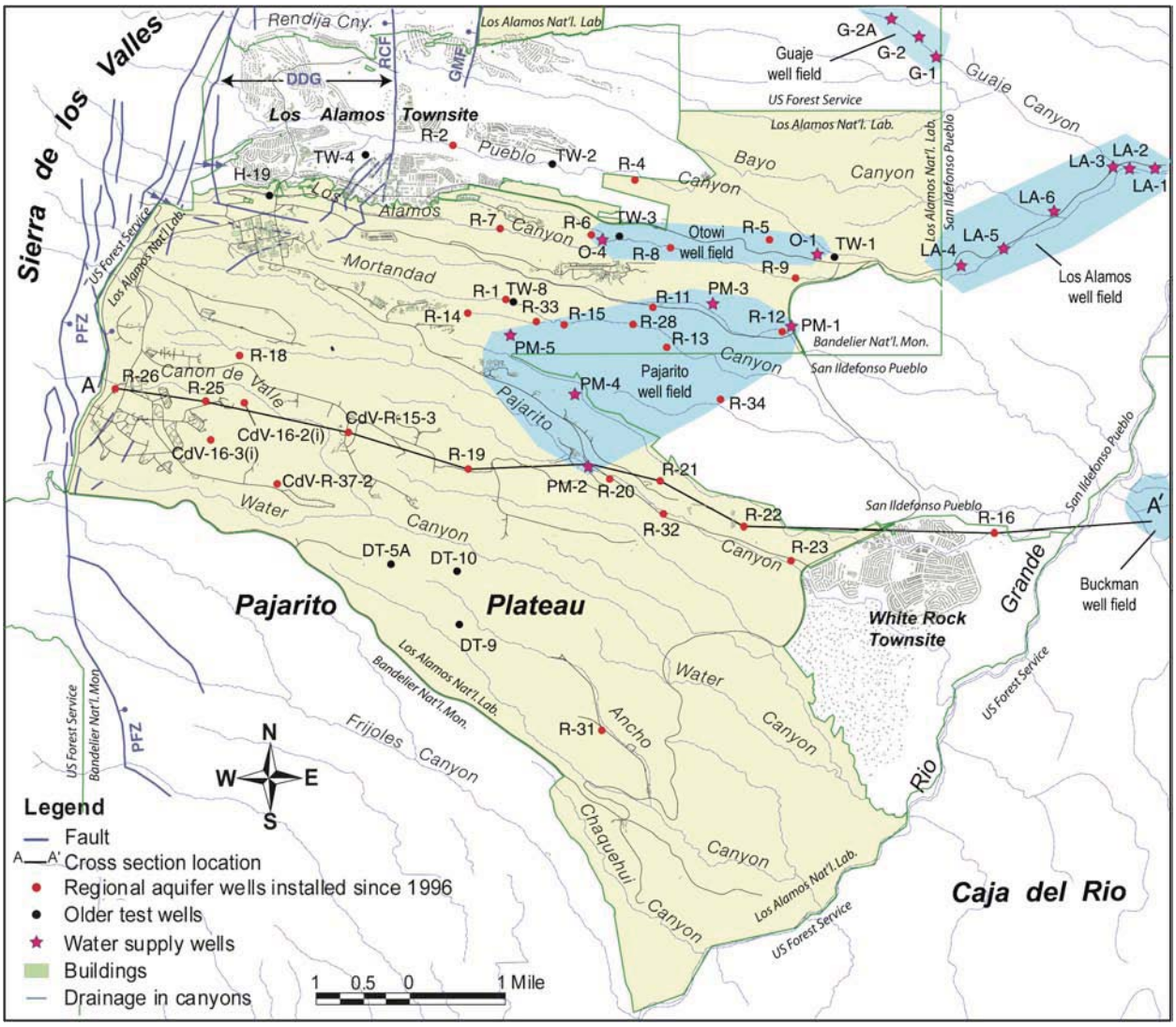


Figure 2-2. Location map of the central Pajarito Plateau.

Yellow-shaded area is the Los Alamos National Laboratory. Also shown are the municipalities of Los Alamos and White Rock. East- and southeast-trending canyons are incised into the plateau. Water supply wells are shown as blue stars and the water-supply well fields are indicated in blue shading; additional wells of Guaje well field extend north of this map. The Buckman well field provides water to Santa Fe. Water supply wells LA-1 through LA-6 are no longer used for municipal water production. New regional aquifer wells installed since 1998 are shown as red dots. Older test wells are shown as black dots. Line A-A' shows the location of the cross-section in Figure 2-5. Main elements of the Pajarito fault zone are shown in blue. PFZ is the main trace of the Pajarito fault zone; RCF is the Rendija Canyon fault; GMF is the Guaje Mountain fault; and DDG is the Diamond Drive graben. Faults modified from Gardner et al. (2001) and Lewis et al. (2002).

Other major faults on the Pajarito Plateau include the Rendija Canyon and Guaje Mountain faults. The Rendija Canyon fault, located in the northern part of the plateau, is a north-trending normal fault with down-to-the-west displacement. The Rendija Canyon fault dies out as a simple normal fault on the north side of LANL. Southward across LANL it is replaced by a broad arc of small-displacement faults that trend in a southwesterly direction towards the main trace of the Pajarito fault. The Guaje Mountain fault lies east of and is generally parallel to the Rendija Canyon fault. It is also a north-trending normal fault with down-to-the-west displacement. Surface traces of the Guaje Mountain fault die out north of LANL.

Additional faults are probably buried beneath the cover of Bandelier Tuff on the Pajarito Plateau. Where exposed along the east side of the basin, Santa Fe Group rocks are cut by numerous north-trending normal faults. Similar fault densities and orientations are probably present in the basin-fill sediments beneath the Pajarito Plateau. Unfortunately, existing well data are of limited use in defining these structures because of the complex depositional patterns and interfingering relations of Pre-Bandelier rock units beneath the plateau.

2.1.2.3 Volcanic Setting of the Pajarito Plateau

The Pajarito Plateau overlaps two volcanic fields whose activities were coeval with rifting. The plateau is bounded on the west by the Jemez volcanic field, a nearly circular volcanic field 72 km (45 mi) in diameter that includes the Valles caldera (Figure 2-1). The plateau is bounded on the southeast by the smaller Cerros del Rio volcanic field. The Jemez volcanic field was an important source of sediments during basin subsidence and the basin-fill sediments interfinger laterally with rocks of both volcanic fields.

Cerros del Rio Volcanic Field

The Cerros del Rio volcanic field is mainly exposed as the Caja del Rio basalt plateau on the east side of the Rio Grande. The surface of the basalt plateau ranges in elevation from 6000 to 7396 ft. The exposed part of the volcanic field extends about 26 mi in a north-south direction and is up to 12 mi wide. The volcanic field extends an additional 7 mi to the west beneath the Pajarito Plateau, where Bandelier Tuff covers it. The exposed portion of the volcanic field is made up of about a dozen volcanoes and >70 vents of cinder cones, plugs, and tuff rings. Basalts and related intermediate-composition lavas are the predominant rock types, and most were erupted between 2.3 and 2.8 Ma. The Rio Grande cuts a south-southwesterly course through the northwestern part of the basalt plateau, forming White Rock Canyon (Broxton and Vaniman 2005).

Jemez Volcanic Field

The Jemez volcanic field lies at the intersection of the northeast-trending Jemez lineament, a major crustal structure of Precambrian ancestry, and north-trending faults of the Rio Grande Rift. Volcanism over the last 14 million years (m.y.) built up the Jemez Mountains, while contemporaneous tectonic rifting resulted in subsidence of the Española Basin, the area extending from the Valles caldera to the western margin of the Sangre de Cristo Mountains. The Jemez volcanic highlands were a major source of Miocene and Pliocene volcaniclastic sediments that were deposited as alluvial fans in the western part of the Española Basin. Eastward, these volcaniclastic deposits interfinger with arkosic basin-fill sands and gravels derived predominantly from Precambrian–cored uplifts on the east side of the Española Basin.

The Jemez volcanic field began to develop between ~14 and 10 Ma with the eruption of predominantly basaltic and rhyolitic rocks of the Keres Group. Major rock units of the Keres Group include:

- **~14.5 to 7.6 Ma:** Basalts that were erupted predominantly in the southern and northeastern parts of the volcanic field.
- **~12.4 to 8.8 Ma:** The Canovas Canyon Rhyolite of the Keres Group, made up of rhyolite domes and associated pyroclastic deposits that were erupted from vents aligned along faults of the Cañada de Cochiti fault zone.
- **~10.6 to 7.1 Ma:** 1000 km^3 of andesite and subordinate basalt and rhyodacite that were erupted as part of the Paliza Canyon Formation.
- **7.1 to 6.0 Ma:** High-silica rhyolite plugs, domes, and tuffs of the Bearhead Rhyolite, including thick tuffaceous deposits of the Peralta Canyon Member, that were erupted from along faults of the Cañada de Cochiti fault zone.

The period from 6 to 7 Ma also coincided with a transition to predominantly dacitic volcanism throughout the volcanic field (Gardner et al., 1986). Porphyritc dacitic lavas of the Tschicoma Formation of the Polvadera Group were erupted primarily between 5 and 3 Ma (Goff and Gardner, 2004; G. WoldeGabriel, personal communication) from large, overlapping dome complexes typified by the extensive exposures of this formation in the highlands of the Sierra de los Valles west of the Pajarito fault zone.

Volcanism in the Jemez volcanic field reached a climax with eruption of the Bandelier Tuff from the Toledo and Valles calderas. The Bandelier Tuff has two members, each consisting of a basal pumice fall overlain by a petrologically related succession of ash-flow tuffs. Eruption of the two members was accompanied in each case by caldera collapse. The Otowi Member (1.61 Ma) was erupted from an earlier caldera that was nearly coincident with, and was largely destroyed by, the younger Valles caldera. The Valles caldera formed during the eruption of the Tshirege Member (1.22 Ma). About 300 km^3 of high-silica rhyolite magma was erupted for each of the two Bandelier Tuff members. Deposits of Bandelier Tuff form radially distributed flat-topped tuff plateaus that dip away from the central volcanic highlands. The Pajarito Plateau at LANL is made up of Bandelier Tuff that flowed more than 21 km across the western Española Basin.

An interval of about 400,000 years separated the eruptions of the two Bandelier Tuff members. During this interval, domes of Cerro Toledo Rhyolite were emplaced northeast and southeast of the earlier Toledo caldera. Tephras from these domes were deposited as ash and pumice falls over the Sierra de los Valles and Pajarito Plateau. The Cerro Toledo interval is a mixture of reworked Cerro Toledo Rhyolite tephras and Tschicoma dacite sediments eroded from the Sierra de los Valles.

2.2 Stratigraphic Framework of the Pajarito Plateau

A generalized diagram showing the stratigraphic sequence of rock units of the Pajarito Plateau is shown in Figure 2-3. Rock units are described below from oldest to youngest. The stratigraphy, lithology, and geochronology of the Santa Fe Group beneath the Pajarito Plateau are known primarily through drillhole data because Bandelier Tuff covers these older rock units. Based on

exposures near the Rio Grande and new drillhole data, the Santa Fe Group beneath the Pajarito Plateau is believed to include, in ascending order, the Tesuque Formation, older fanglomerate deposits of the Jemez volcanic field, the Totavi Lentil and older river gravels, pumice-rich volcaniclastic rocks, and the Puye Formation. Recent mapping of basin sediments north and east of Los Alamos suggests that the Tesuque Formation, as used in this report, may include rocks of the Chamita Formation (Koning et al., 2005). The older fanglomerate and pumice-rich volcaniclastic rocks are new units that are given provisional informal names. These units are generally similar to the Puye and Cochiti Formations, but are older than rocks normally assigned to them. Redefining the Puye and Cochiti Formations is beyond the scope of this report, and the older fanglomerates and pumice-rich volcaniclastic rocks are treated as informal units until they can be incorporated into the new stratigraphic framework being developed for the Española Basin (see discussion in Smith, 2004). In the vicinity of the Pajarito Plateau, Santa Fe Group deposits interfinger with or are overlain by volcanic rocks of the Jemez and Cerros del Rio volcanic fields. Rock units older than the Santa Fe Group (e.g., early Tertiary and older rocks) are not described here because they underlie the Laboratory at considerable depth and have not been penetrated by deep drillholes. These prebasin rock units are described in papers by Biehler et al. (1991), Cather (1992 and 2004), Ferguson et al. (1995), and Smith (2004).

The total thickness of the Santa Fe Group in the eastern and northern part of the Española Basin is as much as 1450 m (4800 ft) (Galusha and Blick, 1971). The Yates La Mesa no. 2 exploration well penetrated 1200 m (3966 ft) of Tesuque Formation in the south-central part of the basin (Meyer and Smith, 2004). However, the thickest Santa Fe Group deposits are believed to occur in the western Española Basin beneath the Pajarito Plateau (Kelly, 1978; Biehler et al., 1991; Ferguson et al., 1995; Smith, 2004). The thickness of these deposits is not well known because the deepest wells on the plateau (e.g., PM-5 with a depth 950 m; 3110 ft) do not fully penetrate the basin-fill sediments. Biehler et al. (1991) estimate that the Santa Fe Group in the central basin might be as much as 2000 m (6650 ft) thick based on gravity data. Cross sections by Kelly (1978) and Koning and Maldonado (2001) show up to 2750 to 3300 m (9000 to 10000 ft) of Santa Fe Group deposits in the central and western parts of the basin. Drillhole data and outcrops indicate that Santa Fe Group deposits are considerably thinner (<500 m; <1640 ft) west of the Pajarito fault (Goff and Gardner, 2004).

This section includes structure contour maps (contoured elevations at the top or bottom of a hydrogeologic unit) and isopach maps (contoured maps showing the unit thickness). These maps, which are prepared by interpolation between points of one-dimensional drillhole data, provide information on the extent of a unit beneath the site and the relative contribution of each unit to the hydrostratigraphy at any given point. Isopach and structure-contour figures representing key hydrostratigraphic units include:

- Cerro Toledo interval (Figure 2-4),
- Otowi Member ash flows (Figure 2-5),
- Guaje Pumice Bed at the base of the Otowi Member (Figure 2-6),
- Cerros del Rio lavas (Figures 2-7 and 2-8),
- Pumiceous volcaniclastic rocks (Figure 2-9).

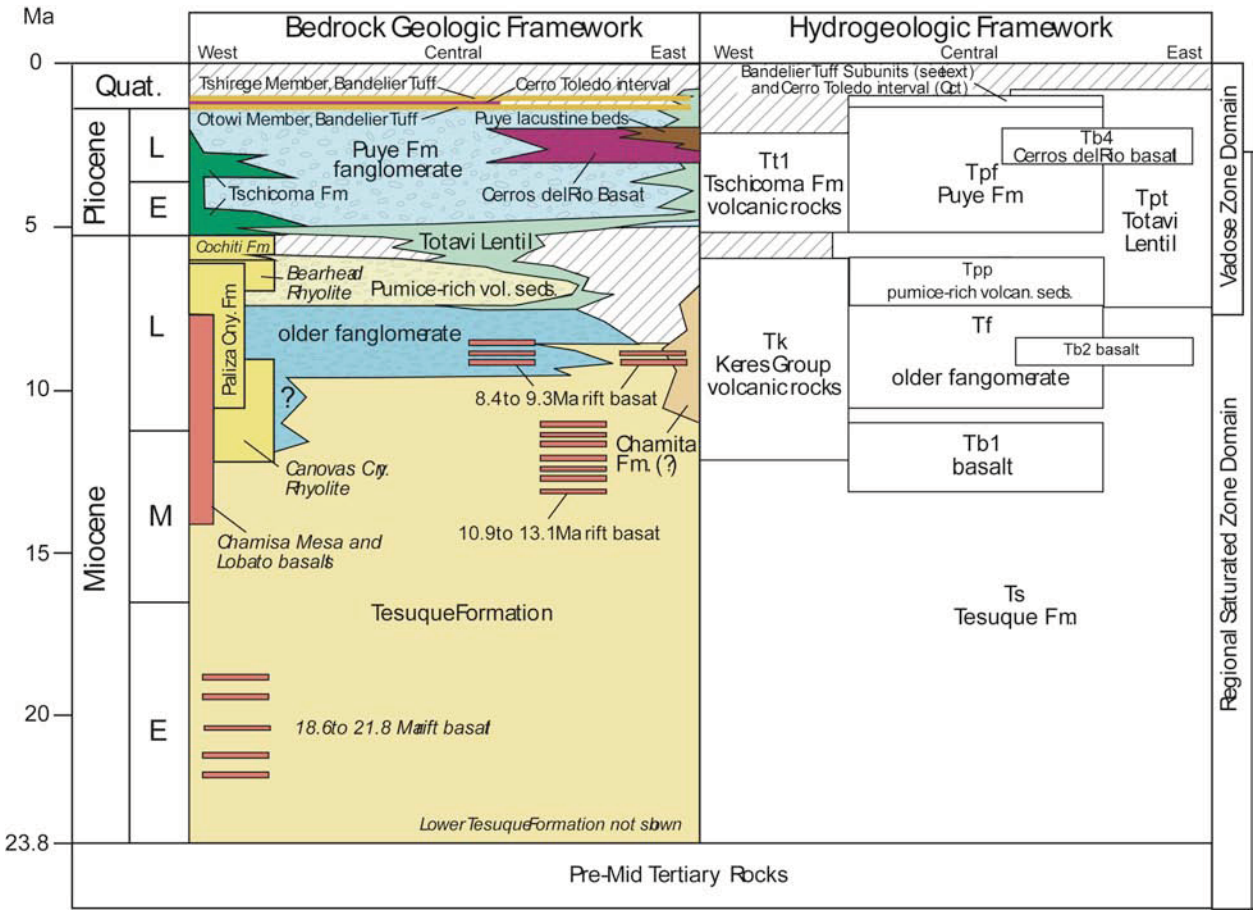


Figure 2-3. Pajarito Plateau stratigraphy and hydrogeologic units as used in this report. The bedrock geologic framework shows the stratigraphy of the plateau and the adjacent Sierra de los Valles. Units with italicized names are not exposed or penetrated by boreholes in the immediate vicinity of the plateau, but they are coeval units of the Jemez volcanic field that may be important source rocks for plateau deposits. The hydrogeologic framework shows units that are defined for site-wide numerical modeling (Broxton and Vaniman, 2005).

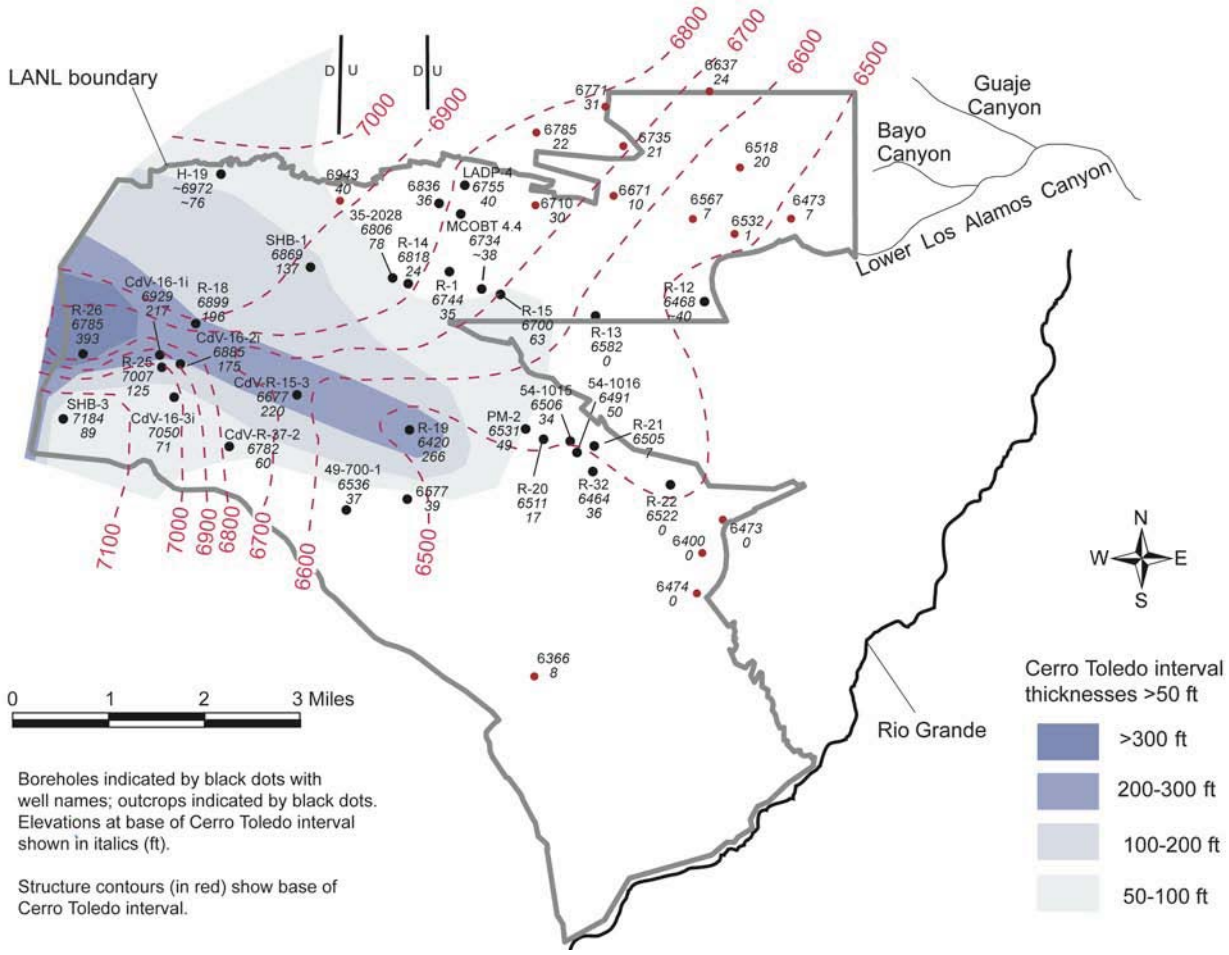


Figure 2-4. Structure contour and isopach map for the Cerro Toledo interval. Structure contours for base of unit indicate that Cerro Toledo filled a broad southeast-trending paleovalley incised into the Otowi Member (see isopach map for Otowi Member in Figure 2-5). The thickest Cerro Toledo deposits coincide with the axis of the paleovalley.

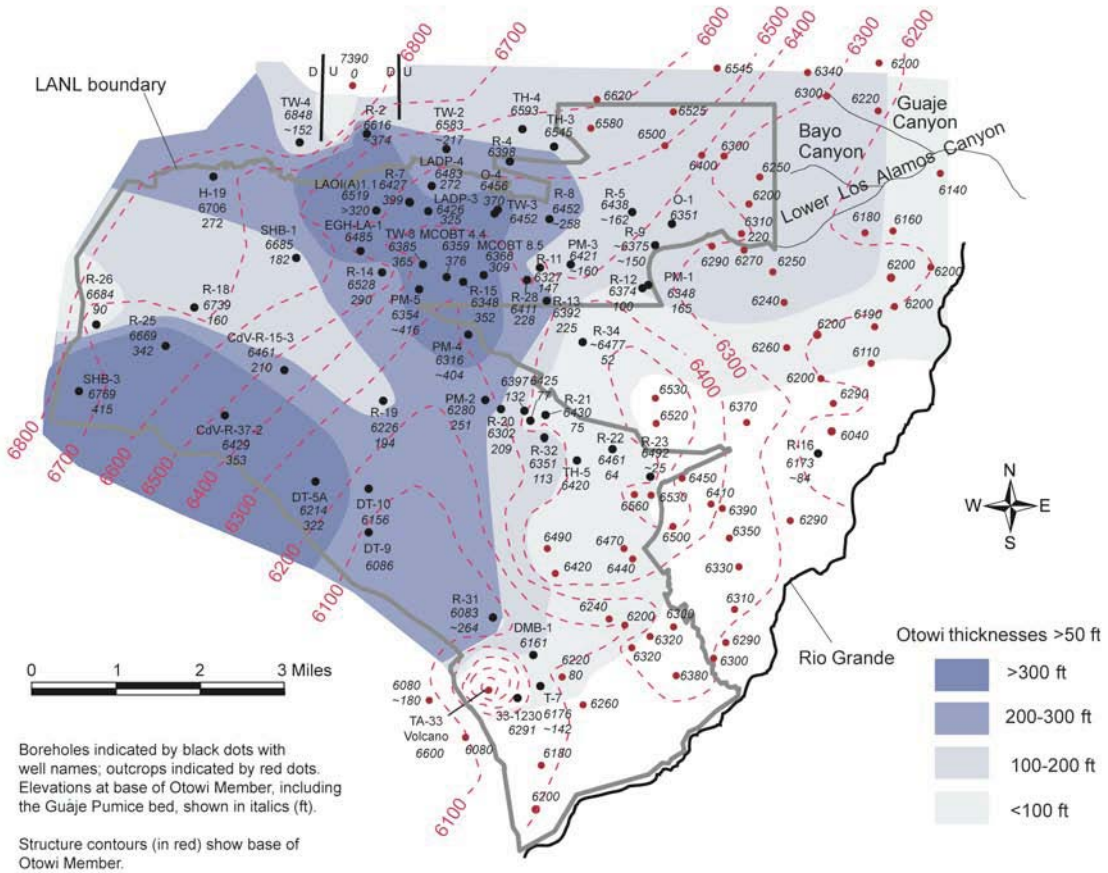


Figure 2-5. Structure contour and isopach map for the Otowi Member of the Bandelier Tuff. Structure contours are for base of Guaje Pumice Bed and show the paleotopography prior to eruption of the Otowi Member. Otowi ash-flow tuffs filled a broad north-trending paleovalley bounded by the Sierra de los Valles highlands on the west and the Cerros del Rio basaltic highland on the east. The variable thickness of the Otowi Member on the western side of the plateau represents deep erosion of these poorly consolidated nonwelded tuffs prior to eruption of the Tshirege Member.

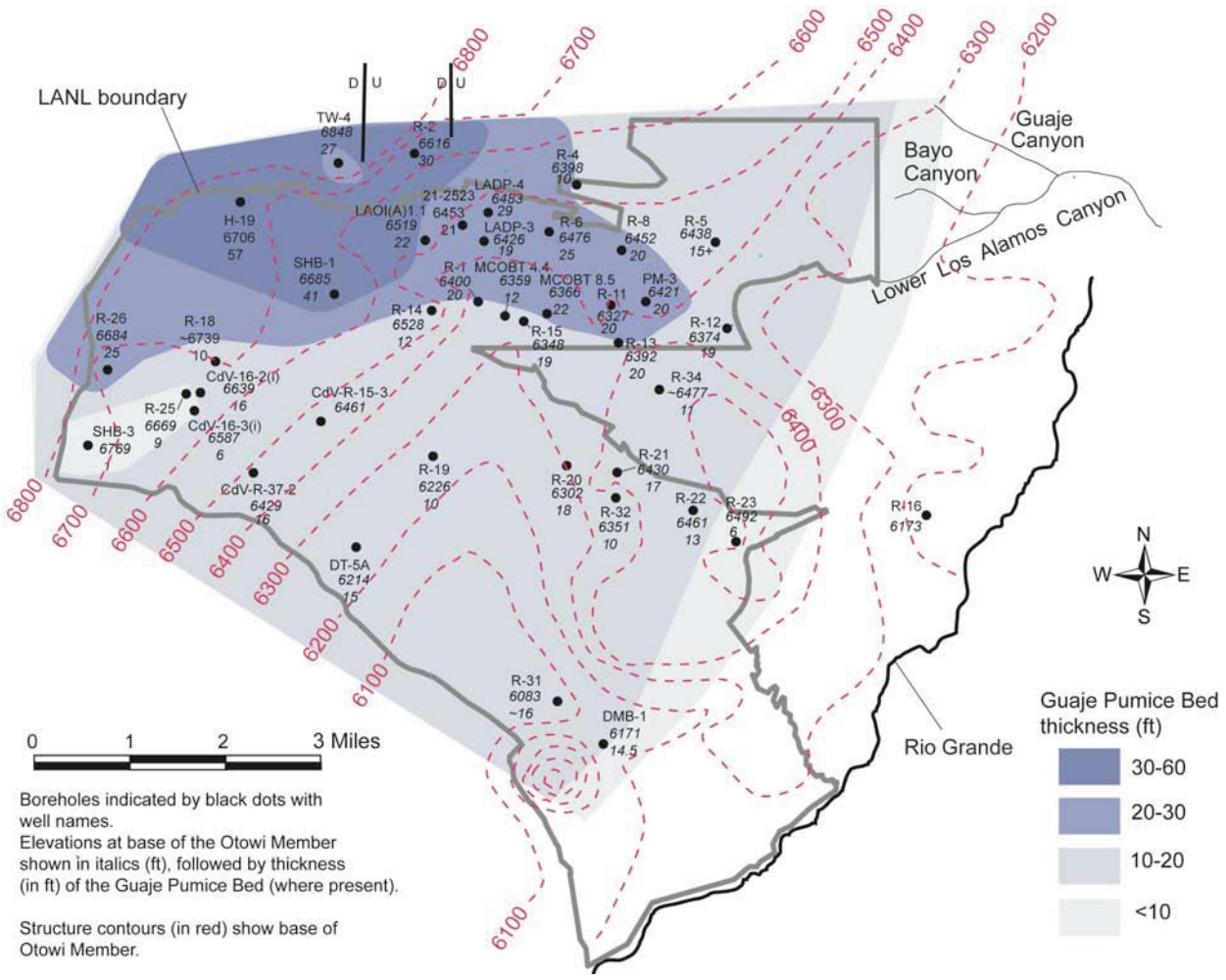


Figure 2-6. Isopach and structure contour map of the Guaje Pumice Bed.

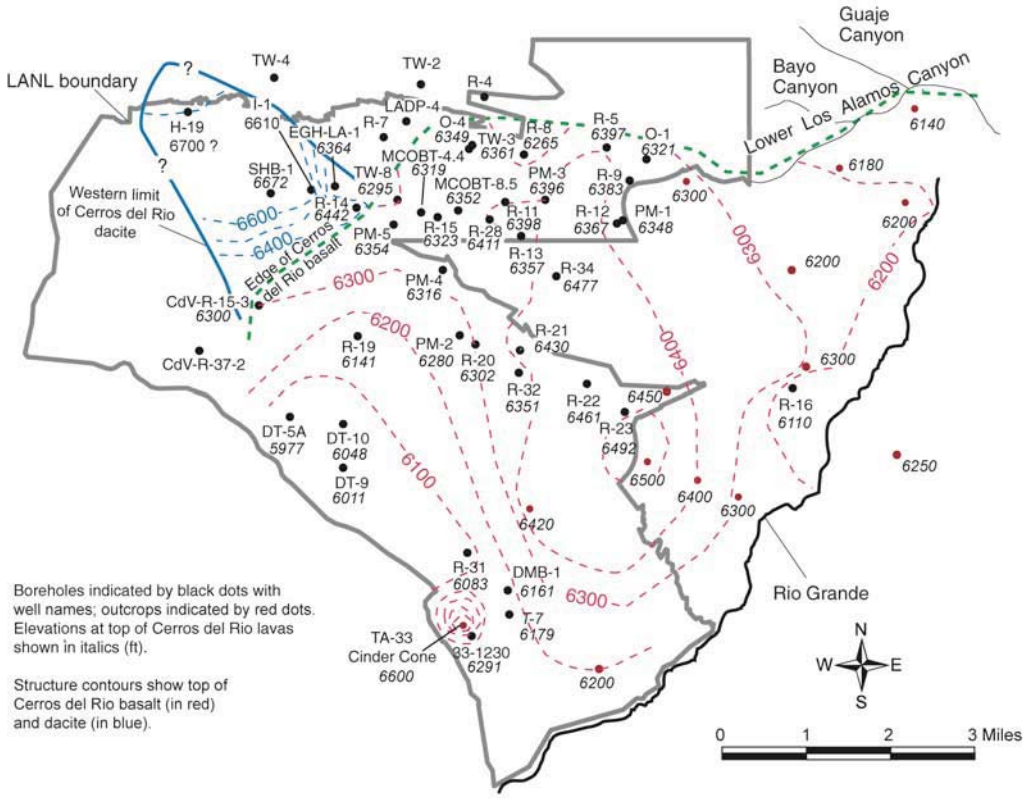


Figure 2-7. Structure contour for the top of Cerros del Rio basalt and western dacite on the Pajarito Plateau. Green dashed line indicates the northern and western extent of the Cerros del Rio volcanic field. Blue line indicates western extent of dacitic lavas that were contemporaneous with the basalts. Top of Cerros del Rio basalts formed broad north-trending highland on east side of plateau. This highland is now covered by Bandelier Tuff.

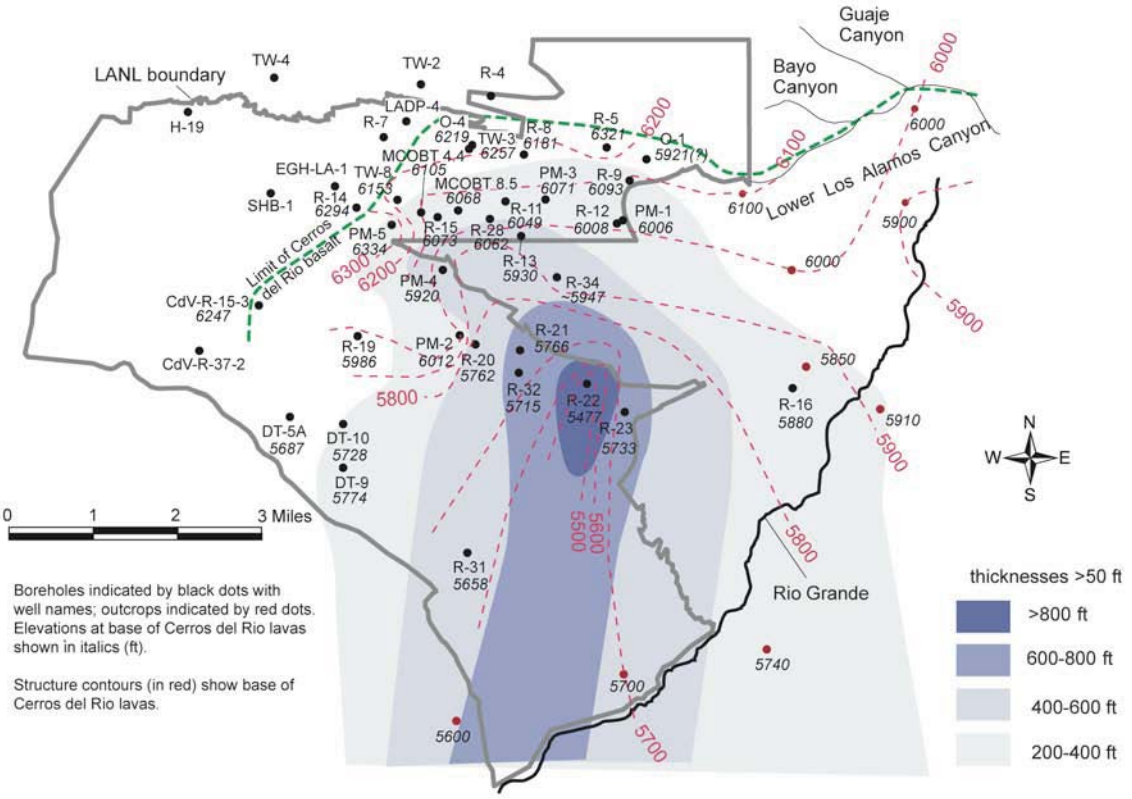


Figure 2-8. Structure contour for the base of Cerros del Rio basalt with isopachs showing the cumulative thickness of flows. Green dashed line indicates the northern and western boundary of the Cerros del Rio volcanic field. The maximum thickness of basalt corresponds with structural-contour lows, suggesting that the basalts accumulated in topographic basins.

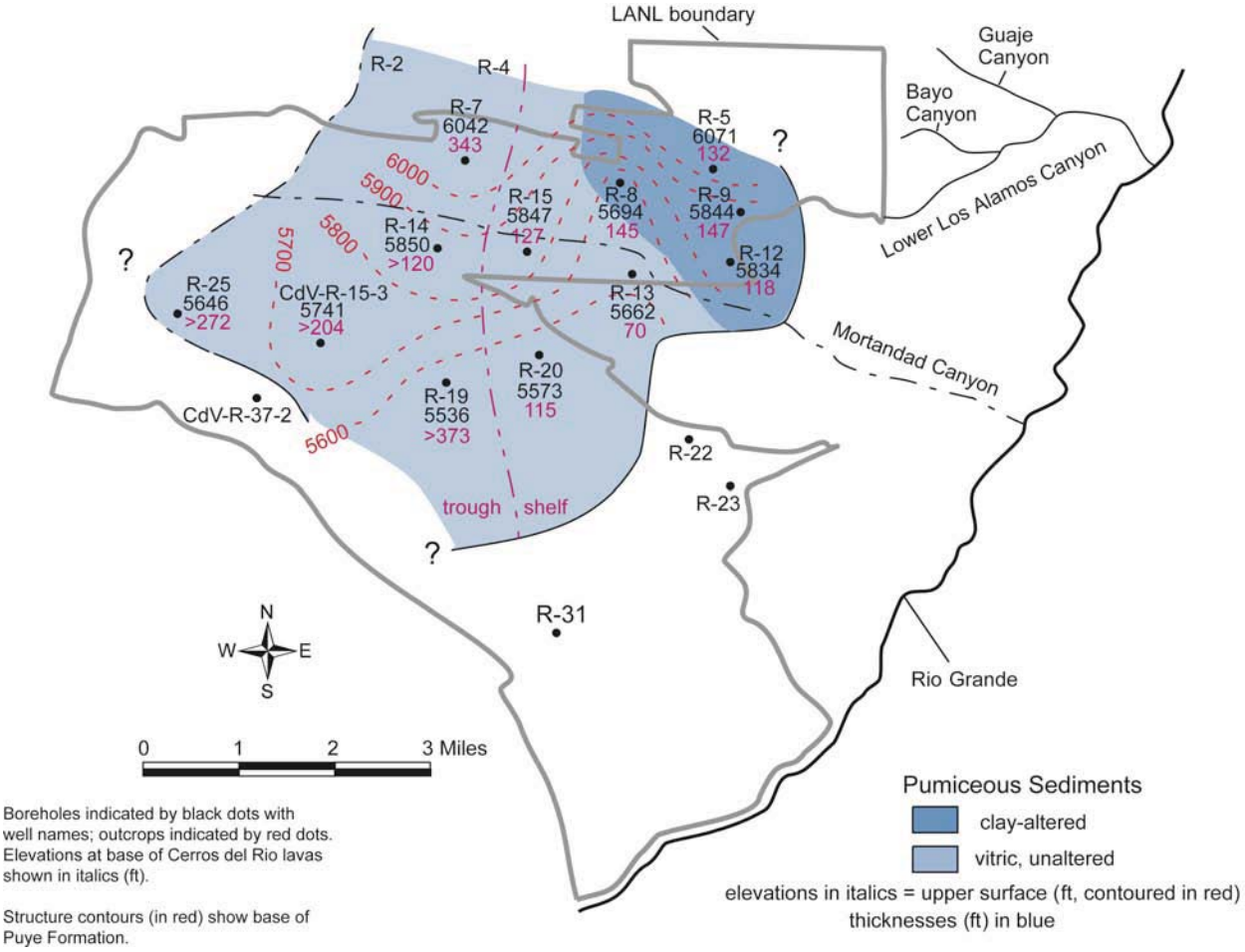


Figure 2-9. Topography at the upper surface of the pumiceous deposits underlying Puye Formation fanglomerates, with pumiceous deposit thicknesses (ft) indicated in blue. Color shading is used to distinguish vitric unaltered pumiceous deposits from those that are clay-altered.

Each of these figures is based on the interpretations of cuttings, geophysical logs, and in some cases borehole video data to determine the elevations of the upper and lower stratigraphic contacts for individual stratigraphic units. Isopach maps for shallow units that crop out in canyon walls, such as the Cerro Toledo interval and the Otowi Member, are corrected for the effects of the modern canyon incision. Each point on the figure represents either a borehole (with borehole name listed) or an outcrop location (without a borehole label). The data points list the elevation of the basal contact in ft above sea level (asl) and the unit thickness in ft. Dashed red contours are hand-generated and indicate an interpretation of the topology of the geologic contact; increasingly darker shades of blue indicate increasing unit thickness above this topologic surface.

2.2.1 Tesuque Formation

The Miocene Tesuque Formation is partially penetrated by wells in the eastern part of the Pajarito Plateau where it makes up a significant portion of the aquifer for local communities and LANL (Purtymun, 1995). It is primarily made up of thick fluvial deposits consisting of partly lithified, arkosic sediments derived from Precambrian granite, pegmatite, and sparse sedimentary rocks of the Sangre de Cristo Range and from Tertiary intermediate to felsic volcanic rocks from northern New Mexico and possibly southern Colorado (Cavazza, 1989). Individual beds are generally less than 3 m (10 ft) thick and consist of massive to planar- and cross-bedded light pink-to-buff siltstone and sandstone, with minor lenses of pebbly conglomerate. Exposures near the Rio Grande (Koning and Maldonado, 2001) indicate that the Tesuque Formation beneath the plateau probably consists primarily of the Pojoaque Member. In well PM-5, a 110-m (360-ft) thick series of basalt flows within the Tesuque Formation yielded a $^{40}Ar/^{39}Ar$ date of 11.39 ± 0.40 Ma (WoldeGabriel et al., 2001).

Based on Formation Microimager (FMI) logs for well R-16, bedding in the Tesuque Formation on the east side of the plateau dips predominantly towards the west-northwest (LANL, 2003). The mean dip is 11° but dips tend to be greater in the lower part of the well (median dip 14° below 1170 ft) than in the upper part (median dip 9°). Tesuque beds just east of the Rio Grande dip westward mainly at angles of 3° to 10° (Koning and Maldonado, 2001).

2.2.2 Miocene Basalts

Miocene basalts are intercalated with Santa Fe Group deposits in the east-central part of the Pajarito Plateau. WoldeGabriel et al. (1996) divided these basalts into two age groups based on $^{40}Ar/^{39}Ar$ dates. The older group ranges in age from 10.9 to 13.1 Ma and is largely found in the vicinity of Guaje Canyon. The younger group ranges in age from 8.4 to 9.3 Ma and is found over a wide area that extends from Bayo Canyon on the north to Ancho Canyon on the south and from PM-1 on the east to PM-5 to the west.

2.2.3 Older Fanglomerate

The informal term “older fanglomerates” refers to a thick sequence of late Miocene fan deposits that were shed from the Jemez volcanic field into the western Española Basin. These deposits, which are found only in deep boreholes, are important for the development of high-yield,

low-draw-down municipal and industrial water supply wells on the Pajarito Plateau (Purtymun, 1995). Purtymun (1995) called these deposits the "Chaquehui Formation" and assigned them a post-Chamita and pre-Puye age. From borehole observations, the Chaquehui Formation consisted of up to 1500 ft of gravels, cobbles, and boulders derived from the Jemez volcanic field and volcanic, metamorphic, and sedimentary rocks derived from highlands to the north and east. However, the Miocene deposits identified as Chaquehui Formation in deep wells are more appropriately called "older fanglomerates" because recent stratigraphic studies indicate the Chaquehui Formation type section consists of younger (late Pliocene) phreatomagmatic deposits (Heiken et al., 1996).

The older fanglomerates are widespread beneath the Pajarito Plateau, based on borehole observations. These deposits are mostly made up of volcanic detritus derived from Keres Group rocks and possibly from early Tschicoma Formation centers. They are characterized by dark, lithic sandstones and gravel and cobble deposits dominated by fresh to silicified, subangular to rounded andesite, latite, and porphyritic dacite. Subordinate clasts (<10%) include subangular to rounded rhyolite and basalt, and rounded quartzite. Rounded granite and angular chert clasts are generally rare (<1%) (Broxton and Vaniman 2005).

Precambrian quartzite, granite, and chert clasts are persistent, but in low abundance in the older fanglomerates. The source of Precambrian clasts may be Santa Fe Group rocks that were exposed within the Jemez volcanic field at the time of Keres volcanism. Stratigraphic relationships described by Gardner and Goff (1996) indicate that Santa Fe Group deposition interfingered with Keres volcanism in the caldera area. Additionally, rounded quartzite and granitic gneiss pebbles are found in lag gravels on the resurgent dome of the Valles caldera where they presumably weathered out of Santa Fe Group rocks in megabreccia blocks that slumped into caldera during caldera collapse (Goff et al., 2003).

The maximum thickness of older fanglomerate penetrated by wells is 1650 ft in well Otowi-4. However, thicknesses could be greater to the west where drillholes did not fully penetrate the unit. The westward thickening wedge of volcaniclastic sedimentary deposits corresponds to the zone of thick, highly productive aquifer rocks that extend northeastward across the central plateau as described by Purtymun (1995). The western boundary of this thick sequence of sediments is poorly defined, but recent drilling results suggest that these rocks probably extend to the Pajarito fault zone. The older volcaniclastic deposits abruptly thin eastward between east-west pairs of wells such as R-23/R-22 and Otowi-1/Otowi-4. The transition zone generally corresponds to the eastern boundary of the gravity low beneath the Pajarito Plateau described by Ferguson et al. (1995).

2.2.4 Totavi Lentil

The Totavi Lentil is made up of river-channel sands and gravels that crop out along the Puye escarpment, in lower Los Alamos and Guaje Canyons, and along White Rock Canyon. These rocks are also penetrated by a number of wells on the Pajarito Plateau. These axial-channel deposits were named the Totavi Lentil of the Puye Formation for a type section in Los Alamos Canyon (Griggs, 1964). Griggs recognized their importance as ancestral Rio Grande deposits,

and he used them to delineate the base of the Puye Formation with which they are conformable in outcrops.

The Totavi Lentil is a poorly consolidated conglomerate containing well-rounded cobbles and gravels of Precambrian quartzite, granite, and pegmatite with subrounded to subangular cobbles and boulders of silicic to intermediate and rarer basaltic volcanic rocks. Precambrian clasts typically make up >80% of the clasts in the deposits. Though commonly subordinate in abundance, clasts of volcanic rocks from the Jemez volcanic field make up to 50% of the deposit in some interbedded horizons. Lenses of loose, well sorted, fine to coarse sands containing abundant quartz and microcline are intercalated with the conglomerate. Totavi deposits are generally ~50 ft thick near the Rio Grande and thicken to the northwest (Griggs, 1964). An unusually thick sequence of quartzite-rich conglomerate (>323 ft) was penetrated in well R-31, located in Ancho Canyon. A number of wells (e.g. R-5, R-9, R-12, R-32) did not encounter the Totavi Lentil, indicating that these channel conglomerates may form lenticular deposits of limited lateral extent.

Based on new well data, it is evident that ancient river deposits in the Pajarito Plateau area are coeval with variety of stratigraphic units that span a longer time interval than previously recognized. River gravels occur beneath the pumice-rich volcaniclastic rocks (described below) in wells R-13, R-15, R-20, R-33, R-34, PM-1, PM-2, and PM-5. These river gravel deposits are generally 10- to 30-m (30- to 100-ft) thick and include abundant well-rounded gravels of quartzite, angular to subangular basalt, andesite, and dacite, and minor metavolcanics. Granitic clasts are rare to absent. Radiometric ages indicate the overlying pumice-rich volcaniclastic rocks are late Miocene in age. In well H-19, river gravels 3-m (10-ft) thick occur as rounded quartzite pebbles between two Tschicoma lava flows (Griggs, 1955, 1964). The quartzite-dominated clast compositions suggest these gravels were derived from the Tusas Mountains and were transported southward by the ancestral Rio Chama, with tributaries draining the Jemez volcanic field. A late Miocene age for the early riverine deposits is consistent with geologic interpretations that through-going rivers were established in the Española Basin prior to about 6.96 Ma (Smith et al., 2001; Smith, 2004).

2.2.5 Pumice-Rich Volcaniclastic Rocks

The pumice-rich volcaniclastic rocks (pumiceous deposits) are characterized by well-bedded horizons of light-colored, reworked, tephra-rich sedimentary deposits and subordinate primary ash- and pumice-fall deposits. These rocks consist mainly of tuffaceous sandstones and contain a few beds of lava-rich gravels. The underlying older fanglomerate and overlying Puye Formation contain higher percentages of gravel and cobble beds. In a number of wells, pumice-rich volcaniclastic rocks are separated from the older fanglomerate by the Totavi Lentil (axial deposits of the ancestral Rio Grande).

The pumice-rich deposits typically contain 10 to 30% subangular to rounded, rhyolitic lapilli mixed with 70 to 90% ash and lithic sands. Gravels contain porphyritic dacite, rhyolite, and lesser andesite and basalt. Some intervals contain as much as 90% subangular to angular pumice lapilli that represent primary fall deposits or reworked deposits that underwent minimal transport. In most areas, pumice lapilli are vitric and show little effect from submergence within

the regional saturated zone except for oxidation on clast surfaces and minor clay development in vesicles.

However, these deposits are diagenetically altered where most of the volcanic glass is replaced by smectite in the northeastern portion of the Laboratory, an area defined by wells R-5, R-8, R-9, and R-12. Shadings of blue in Figure 2-9 distinguish vitric unaltered pumiceous deposits (pale blue) from those that are heavily clay-altered and retain little or no glass (dark blue). The formation of clay in this area is locally accompanied by abundant calcite and variable amounts of zeolite alteration. Because of the extent of alteration, the lack of preservation of glass, and the loss of many petrographic clues for individual pumice bed correlation, it is difficult to determine whether the heavily altered pumices are related to the unaltered pumice or represent an earlier pumice unit and an earlier alteration event.

Most lapilli in the pumice-rich volcaniclastic rocks are aphyric or contain sparse phenocrysts of quartz, sanidine, and plagioclase, but the presence of some biotite-, hornblende-, and pyroxene-phyric varieties indicates that multiple volcanic sources supplied tephra to these deposits. Seven recent $^{40}Ar/^{39}Ar$ feldspar ages between 6.8 and 7.5 Ma were obtained from crystal-poor pumice falls in six wells that penetrate into this unit. The younger ages overlap the 6.01 to 7.1 Ma range of ages reported for the Bearhead Rhyolite (Justet, 1996; Smith, 2001) and the older ages are slightly older. Additional work is taking place to investigate the relation between the pumice-rich volcaniclastic rocks and Keres Group silicic volcanism with the goal of assigning the pumiceous sediments to either the Puye or Cochiti Formations or delineating them as a separate formation.

The pumice-rich volcaniclastic rocks thin northeastward across the central part of the plateau and are absent north of Pueblo Canyon. Borehole geophysical logs indicate that these deposits dip 5° to 15°, primarily towards the southwest and west. Figure 2-9 illustrates structure contours and thickness of pumiceous deposits that occur over a broad region beneath the central portion of the Laboratory where multiple pumice beds have been encountered. Observations from boreholes suggest that the structure of these pumiceous deposits is complex, including both primary and reworked pumiceous units intermixed with fanglomerates. Nevertheless, the pumiceous unit is predictably encountered in the area shown in Figure 2-9. Drilling experience shows that this unit is highly transmissive, providing a difficult drilling horizon where injected fluids are likely to be lost. Hydrologic testing shows that the pumiceous deposits have relatively high transmissivity (Section 2.3.4.2).

In Figure 2-9 the structure contours represent the top, rather than the bottom of the pumiceous deposits. This is done because the bottom of this unit is poorly constrained in R-series drillholes to the south and west, where this unit was seldom penetrated. The structure contours at the top of the pumiceous unit show that it slopes to the south and shows evidence of incision of a broad south-trending paleocanyon, filled by Puye fanglomerate, in the central portion of the Laboratory. This broad canyon is somewhat similar to that seen at the base of the Bandelier Tuff (Figure 2-6) and at the base of the Cerros del Rio volcanic rocks (Figure 2-8), suggesting that broadly south-trending canyons have been a common feature for over 5 m.y. prior to the eruption of the Bandelier Tuff. The present west-northwest/east-southeast drainages on the plateau may be a relatively recent drainage pattern that developed on the thick east-sloping tuff ash flows emplaced after 1.6 Ma.

2.2.6 Tschicoma Formation

The Tschicoma Formation of the Polvadera Group consists of thick, predominantly dacite to low-silica rhyolite lava flows erupted from large overlapping dome complexes. Major peaks in the Sierra de los Valles, including Cerro Grande, Pajarito Mountain, Caballo Mountain, and Tschicoma Mountain, are compositionally distinct lava domes that represent separate volcanic source areas for detritus that was shed to form the Puye fanglomerates. Low-silica rhyolite erupted from a deeply eroded dome complex in the upper Rendija Canyon and Guaje Mountain area yielded three ages between 4.95 and 5.32 Ma. Dacites of the Cerro Grande, Pajarito Mountain, and Caballo Mountain centers have closely overlapping ages of 2.91 Ma to 3.34 Ma (Broxton and Vaniman, 2005).

Outcrops of the Tschicoma Formation in the Sierra de los Valles are primarily gray to purplish-gray lavas characterized by pronounced jointing and flow foliation. The interflow zones between flow units are commonly marked by blocky breccias. Flow interiors consist of dense, massive rock that is commonly devitrified to form a microcrystalline groundmass, giving the rocks a stony appearance. Chilled volcanic glass is sometimes preserved in flow tops and bottoms. Fragmental deposits of ash and lava debris occur in the distal parts of the formation.

The Tschicoma Formation is at least 2,500 ft thick in the Sierra de los Valles, but has a variable thickness due to the lenticular shapes of its lava flows. The Tschicoma Formation thins eastward under the western Pajarito Plateau where it interfingers with the Puye Formation. The Tschicoma Formation was encountered in wells TW-4, H-19, CDV-16-3(i) and CDV-R-37-2 in the western part of the Pajarito Plateau, but is absent in boreholes to the east, with the possible exception of thick dacite lava in boreholes EGH-LA-1, SHB-1, and I-1. These lavas may be assigned to the Tschicoma but their source and distribution is presently unknown.

2.2.7 Puye Formation

The Puye Formation is a large apron of overlapping alluvial and pyroclastic fans that were shed eastward from the Jemez volcanic field into the western Española Basin (Griggs, 1964; Turbeville et al., 1989). The Puye Formation unconformably overlies rocks of the Santa Fe Group (Tesuque Formation), and the Otowi Member of the Bandelier Tuff unconformably overlies it. Turbeville et al. (1989) estimated its areal distribution at 200 mi^2 and its volume at ~3.6 mi^3. Because its primary source area was volcanic domes in the Sierra de los Valles, the Puye Formation overlaps and post-dates the Tschicoma Formation in age. The Puye Formation is subdivided into fanglomerate and lacustrine facies.

The fanglomerate facies, the dominant unit of the Puye Formation, is a heterogeneous assemblage of clast- to matrix-supported conglomerates, and of gravels and lithic-rich sandstones. Clasts in the coarsest deposits consist of subangular to subrounded cobbles and boulders of latite, dacite, rhyolite, and tuff in a poorly sorted matrix of ash, silts, and sands. Consolidated mudflow deposits are common throughout the unit, and tend to be cliff-forming. At least 25 ash beds of dacitic to rhyolitic composition are interbedded with the conglomerates and gravels (Turbeville et al., 1989).

The lacustrine facies includes lake and riverine deposits in the upper part of the Puye Formation. These deposits are characterized by lacustrine fine sand, silt, and clay up to 30 ft thick. Basaltic ash beds (maar deposits) up to 10 ft thick are locally present above or below the lacustrine deposits. The lacustrine facies includes some well-rounded riverine gravels of Precambrian quartzite and gneiss that fill channels cut into the underlying fanglomerates. The lacustrine facies crops out in lower Los Alamos Canyon and extends both northward and southward in discontinuous outcrops for several miles. Apparently, their extent is limited to the eastern side of the plateau because they are found only in wells R-9, R-12, and R-16. Because of their spatial and temporal association with palagonitic basalt flows and maar deposits, these lacustrine deposits probably represent periods of damming and diversion of the Rio Grande caused by the eruptions of lavas within the Cerros del Rio volcanic field.

The Puye Formation reaches a maximum thickness of >1000 ft in well R-25 on the western side of the Laboratory but thins to 50 ft in areas north of the Pajarito Plateau. In the central and eastern portions of LANL, it is about 600 ft thick and the upper Puye is interbedded with basaltic lavas of the Cerros del Rio volcanic field.

2.2.8 Basaltic Rocks of the Cerros del Rio Volcanic Field

Cerros del Rio basalts typically form thick sequences of stacked lava flows separated by interflow breccia, scoria, sediment, and ash. These rocks are mostly basalts and basaltic andesites, but subordinate dacite is present within thick basalt stacks in the east and central plateau (e.g. Ball et al., 2002) or is found as isolated flows on the western side of the volcanic field. Cerros del Rio lavas were erupted from vents located both east and west of the Rio Grande (Smith et al., 1970; Aubele, 1978; Kelley, 1978).

In major-element composition the dacitic components are very similar to partially contemporaneous dacitic lavas that occur within the highlands of the Tschicoma Formation to the west. However, dacites are less abundant than basalts within the Cerros del Rio and these thin dacitic lavas have relatively few of the common hydrous minerals (amphibole and biotite) that characterize most of the Tschicoma lavas. These distinctions are important because they strongly affect the hydrogeologic character of the lavas. Lavas of the Cerros del Rio lie within suites of relatively thin (a few tens of feet), largely basaltic lava flows with laterally extensive flow-boundary rubble zones that provide pathways for flow. Lavas of the Tschicoma Formation are far more massive, up to hundreds of feet thick, and are generally poorly transmissive (Griggs, 1964).

Individual flows typically range in thickness from about 3 ft to more than 100 ft. The internal structures of flows show some similarities to those described for the Columbia River Basalt Group in Washington, Oregon, and Idaho and for Snake River basalts in Idaho (Swanson et al., 1979; Whiteman et al., 1994; Faybishenko et al., 2000). In ascending order, the flows are characterized by: (1) a flow base characterized by vesicular basalt with clinker and scoria, (2) a colonnade zone made up of vertical, large-diameter columns bound by cooling joints, (3) a thin zone of complexly-overlapping fractures, and (4) a flow top of vesicular basalt with scoria and clinker. In addition to highly porous clinker zones associated with flow tops and bottoms, interflow zones include cinder deposits and sedimentary deposits. Interflow cinder deposits are

fairly common, and their thickness is highly variable (0 to 100 ft), depending on proximity to source vents. The thickest cinder deposits are as much as 300 ft thick on or near source vents (e.g. R-34). Interflow sedimentary deposits are generally thin (<20 ft) where present and consist mostly of reworked basaltic rocks. In the eastern part of the plateau, where the basalts interacted with surface water, flow bases commonly include porous, pillow-palagonite complexes.

The basaltic rocks of the Cerros del Rio volcanic field include buried remnants of maar volcanoes in White Rock Canyon. The aprons of fragmental debris surrounding these buried craters consist of thin layers of basaltic ash and sediments. The maar deposits resulted from steam explosions that occurred where basalt erupted through an aquifer or standing body of water. Thin maar deposits were identified at the base of the Cerros del Rio basalt in R-9 and R-12.

The distribution, form, and thickness of the Cerros del Rio volcanic field beneath the plateau are illustrated in Figure 2-7, which shows the topography at the top of the Cerros del Rio and Figure 2-8, which shows structure contours (red dashed lines) at the base of the Cerros del Rio. In Figure 2-8 shadings of purple represent the variation in thickness of the total Cerros del Rio deposits that lie between the two contoured surfaces in these figures.

Figure 2-7 shows that the upper surface of the Cerros del Rio is irregular, with a broad highland that extends from north to south under the east-central portion of the Laboratory. This highland is largely buried beneath the Bandelier Tuff, but remnants of the eastern slope extending from the highland are exposed beneath the town of White Rock. The highland represents distributed volcanic centers that produced most of the basaltic and dacitic lavas that underlie the Laboratory. Direct evidence of these eruptive centers is found in thick cinder deposits that were encountered in drillholes R-22 and especially R-34, and a low cinder-covered volcanic center exposed just south of R-23 in TA-36. These cinder deposits are extremely porous and generally provide highly transmissive media, but they are localized around volcanic centers so that enhanced groundwater flow is likely to extend for less than one mile, based on the extent of the TA-33 cinder cone (Figure 2-7).

Figure 2-8 shows the topography at the base of the Cerros del Rio volcanic series and the exceptional thickening of these deposits beneath R-22 and (probably) extending along a paleocanyon extending to the south. The extent of this deep trough to the north and south is not well defined by current drillhole locations. Based on the absence of Totavi-like deposits within this channel at R-22 and the lack of evidence to the northeast in the canyon walls of lower Los Alamos Canyon, it is likely that the head of the canyon rose steeply to the northwest and drained the Sierra de los Valles. This thick keel of lavas and intercalated rubble zones occurs largely beneath the regional aquifer water table and hosts an important part of the regional aquifer beneath the southeast portion of the Laboratory. It is possible that this feature could affect the flow direction and head distributions at depth.

2.2.9 Bandelier Tuff

The Laboratory facilities are located almost entirely on mesa and canyon outcrops of Bandelier Tuff. The Bandelier Tuff consists of ash flows and minor airfall pyroclastic deposits with ages of

1.61 Ma for the Otowi Member and 1.22 Ma for the Tshirege Member (Izett and Obradovich, 1994). The two Bandelier Tuff members are separated by the Cerro Toledo interval, which is a stratified sequence of volcaniclastic sediments and tephra of mixed provenance. Although it occurs between the ash-flow members of the Bandelier Tuff, the Cerro Toledo interval is not considered part of the Bandelier Tuff, a usage consistent with the original definition by Bailey et al. (1969).

2.2.9.1 Otowi Member, Bandelier Tuff

The Otowi Member crops out in several canyons but is best exposed in Los Alamos Canyon and in canyons to the north. It consists of moderately consolidated, porous, nonwelded ash-flow tuffs that form colluvium-covered slopes along the base of canyon walls. The Otowi ash-flow tuffs are vitric and contain light gray-to-orange pumice supported in a white to tan ashy matrix of glass shards, broken pumice, crystals, and rock fragments. The Otowi Member is made up of multiple ash flows, but individual ash-flow deposits cannot be traced in the subsurface using core and cuttings from widely spaced boreholes. The base of the member is called the Guaje Pumice Bed (Figure 2-6), and is discussed below. In some drillholes, a shift in borehole gamma measurements in the central part of the unit provides a useful datum for correlations between drillholes. The nonwelded ash-flow tuffs of the Otowi Member collectively form a relatively homogenous rock unit throughout the plateau. Transport through this hydrogeologic unit appears to occur primarily by matrix flow, although open fractures may contribute to transport locally (e.g., R-25). Although made up of multiple flow units, the combined Otowi ash flows are massive, and borehole geophysical logs show only minor variations in density and porosity.

The present maximum thickness of Otowi Member occurs in two areas in the western part of the plateau where the deposits are about 350 to 400 ft thick. Otowi deposits are only <100 to 300 ft thick between these two areas. The thin deposits are overlain by unusually thick Cerro Toledo sediments that apparently accumulated in a broad east-southeast-trending drainage incised into the top of the Otowi Member. On the eastern side of the plateau, the Otowi Member is 0 to 100 ft thick. Thinning of the deposits eastward reflects both the general thinning of the Otowi Member away from its caldera source and thinning of the ash-flow tuffs over the Cerros del Rio highland on the east side of the plateau. Structure contours indicate that Otowi ash-flow tuffs filled a broad south-draining paleovalley west of the Cerros del Rio basaltic highland.

Figure 2-5 shows structure contours (red dashed lines) at the base of the Otowi Member of the Bandelier Tuff and color shading in purple that represents relative overall thickness of the unit. The Otowi Member thickens from the central portion of the Laboratory toward the west, with the exception of a paleocanyon that is aligned with and filled by the thick Cerro Toledo deposits shown in Figure 2-5. To the east, south of PM-1 where Otowi deposits ramp up onto the Cerros del Rio basaltic volcanic centers with little or no Puye sediment cover, the Otowi deposits are thinner than to the northeast where they are underlain mostly by eastward-sloping Puye fans. In the south-central portion of the Laboratory the Otowi deposits fill a broad south-trending valley formed by low terrain between Puye fans sloping down from the west and Cerros del Rio highlands to the east, such as the TA-33 volcano.

The Guaje Pumice Bed occurs at the base of the Otowi Member and is an extensive marker horizon in outcrop and wells. The Guaje Pumice Bed contains layers of sorted pumice fragments

whose mean size varies between 2 and 4 cm. It has an average thickness of ~15 ft over much of the plateau, but thickens considerably to the northwest (Figure 2-6). Geophysical logs show that the Guaje Pumice Bed has a higher porosity than overlying Otowi ash-flow tuffs and underlying Puye Formation. The Guaje Pumice Bed appears consistently as a zone of higher porosity and elevated moisture content in CMR geophysical logs. Because of this property the Guaje Pumice Bed can provide a relatively thin (a few feet to a few tens of feet) but laterally continuous horizon capable of local saturation.

Figure 2-6 uses color shading to represent the thickness of the Guaje Pumice Bed. Because the Guaje Pumice Bed formed as a pumice fall rather than an ash flow, the tendency to thin away from the source (the Valles caldera) is much less pronounced except for the area underlying the northwestern corner of the Laboratory. The distribution of pumice fall deposits is more strongly influenced by prevailing wind direction at the time of eruption, compared with the largely internal energy sources that distribute ash flows. A general lack of incision and weathering at the top of the Guaje Pumice Bed indicates that little time elapsed before it was buried by magmatically related ash flows of the Otowi Member. Locally, however, the Guaje Pumice is unusually thin compared to surrounding areas and may have been partially eroded before or during the passage of the earliest Otowi ash flows. In the eastern portion of the Laboratory the Guaje Pumice Bed is seldom more than a few feet thick and is locally absent.

2.2.9.2 Tephra and Volcaniclastic Sediments of the Cerro Toledo Interval

The Cerro Toledo interval crops out in Los Alamos Canyon and in canyons to the north, and it occurs in many of the wells on the plateau. It unconformably overlies the deeply eroded Otowi Member and its thickness is highly variable (3 to 390 ft). Figure 2-4 shows structure contours at the base of the Cerro Toledo interval and a colored representation of relative overall thickness of the unit. Structure contours for the base of the Cerro Toledo indicate that this unit fills a broad southeast-draining valley fed by one or more canyons exiting the Sierra de los Valles. The thickest Cerro Toledo deposits coincide with the axis of this paleovalley.

The predominant rock type in the Cerro Toledo interval is rhyolitic tuffaceous sandstone and tephra. These deposits contain abundant crystal-poor ash and pumice, and clasts of vitric to devitrified rhyolite lava and minor obsidian. They represent the reworked equivalents of Cerro Toledo Rhyolite tephra erupted from the Cerro Toledo and Rabbit Mountain dome complexes located northeast and southeast of the Valles caldera, respectively. Primary pumice-and ash-falls are interbedded with these sedimentary deposits in most locations.

Clast-supported gravel, cobble, and boulder deposits of porphyritic Tschicoma dacite derived from the Tschicoma Formation are also interbedded with the tuffaceous rocks. In some deposits, the dacitic detritus is volumetrically more important than the tuffaceous detritus. These coarse dacitic deposits commonly define the axial portions of channels incised into the underlying Otowi Member.

In the western part of the plateau, the Cerro Toledo interval contains a large component of crystal-rich tuffaceous detritus. These tuffaceous sediments represent reworked Otowi tuff that accumulated in drainages incised into the Otowi Member prior to emplacement of the Tshirege

Member. These reworked Otowi deposits are interbedded with other volcaniclastic deposits derived from Cerro Toledo and Tschicoma sources.

Data from boreholes R-19, CdV-R-15-3, CdV-16-1(i), R-18, and R-26 revised the conceptual model for the Cerro Toledo interval, which was a general thinning from Cerro Toledo age volcanic sources in the caldera to the northwest of the Laboratory to distal deposits toward the east-southeast (Broxton and Vaniman, 2005). These boreholes, however, showed that the thickening is not uniform and the Cerro Toledo sediments fill a deep and broad east-southeast draining paleocanyon in the middle western portion of the Laboratory. This paleocanyon is incised into the top of the Otowi ash flows; the overlying base of the Tshirege Member of the Bandelier Tuff and the underlying base of the Otowi Member (Figure 2-5) show no such canyon development. The structure contours that show the base of the Cerro Toledo interval in Figure 2-4 show the topology of the canyon eroded into the top of the Otowi ash flows. The exact width and the orientation of this canyon, whether it is one canyon or several, and where this canyon connected to paleodrainages toward the Rio Grande to the east are relatively unconstrained points that allow a certain amount of latitude in the way that Figure 2-4 is constructed.

2.2.9.3 Tshirege Member, Bandelier Tuff

The Tshirege Member is the upper member of the Bandelier Tuff and is the most widely exposed bedrock unit of the Pajarito Plateau. It is a multiple-flow, ash-and-pumice sheet that forms the prominent cliffs throughout the plateau. It also underlies canyon floors in all but the middle and lower reaches of Los Alamos Canyon and in canyons to the north. The Tshirege Member is generally over 200 ft thick in the north-central part of LANL and over 600 ft thick near the southern edge of LANL.

The Tshirege Member differs from the Otowi Member most notably in its generally greater degree of welding compaction. Time breaks between the successive emplacements of ash-flow units caused the tuff to cool as several distinct cooling units. For this reason the Tshirege Member is a compound cooling unit, consisting of at least four cooling subunits that display variable physical properties vertically and horizontally. These variations in physical properties reflect zonal patterns of varying degrees of compaction, welding, and glass crystallization. The welding and crystallization zones in the Tshirege Member produce vertical variations in properties such as density, porosity, hardness, composition, color, and surface weathering patterns. The degree of welding in each of the cooling units generally decreases from west to east, reflecting higher emplacement temperatures and thicker deposits closer to the Valles caldera.

The Tsankawi Pumice Bed forms the base of the Tshirege Member. Where exposed, it is commonly 2 to 3 feet in thickness. This pumice-fall deposit contains sorted pumice lapilli (diameters reaching about 2.5 in) in a crystal-rich matrix. Several thin ash beds are interbedded with the pumice-fall deposits.

Because the thick Tshirege ash flow tuffs make up a significant portion of the upper vadose zone, brief descriptions are provided below for the major subunits of the member, from bottom to top:

- **Qbt 1g** is the lowermost subunit above the Tsankawi Pumice Bed. It consists of porous, nonwelded, and poorly sorted ash-flow tuffs. The "g" in this designation stands for "glass" because none of the glass in ash shards and pumices shows crystallization by devitrification or vapor phase alteration. The tuffs of Qbt 1g are nonwelded and have an open, porous structure.
- **Qbt 1v** forms alternating cliff-like and sloping outcrops composed of porous, nonwelded, but crystalline tuffs. The "v" stands for vapor-phase crystallization that together with crystallization of glass in shards and pumices (devitrification) transformed the rock matrix into microcrystalline aggregates of silica polymorphs and sanidine. The tuffs of Qbt 1v are generally nonwelded to slightly welded, and have an open, porous structure.
- **Qbt 2** forms a distinctive, medium brown, vertical cliff that stands out in marked contrast to the slope-forming, lighter colored tuffs above and below. A series of laminated and cross-bedded deposits commonly mark its base in the eastern part of the Laboratory. In the central and western part of the Laboratory, the boundary between Qbt 2 and Qbt 1v is gradational and the distinction between the two units is somewhat arbitrary. Qbt 2 is typically the most strongly welded tuff in the Tshirege Member. Vapor-phase crystallization of flattened shards and pumices is extensive in this subunit.
- **Qbt 3** is a nonwelded to partly welded, vapor-phase altered tuff that forms the cap rock of mesas in the central part of the Pajarito Plateau. Qbt 3 becomes moderately to densely welded in the western part of the plateau.
- **Qbt 4** is a complex unit consisting of nonwelded to densely welded ash-flow tuffs and thin intercalated surge deposits. Devitrification and vapor-phase alteration are typical in this unit, but thin zones of vitric ash-flow tuff occur locally. The occurrence of Qbt 4 is limited to the western part of the Pajarito Plateau.

2.2.10 Alluvium and Colluvium

Holocene and late Pleistocene canyon-floor alluvium consists of stratified, lenticular deposits of unconsolidated fluvial sands, gravels, and cobbles (Reneau et al., 1996). Smaller canyons whose headwaters are located on the plateau contain detritus exclusively of Bandelier Tuff. Larger canyon systems that head in the Sierra de los Valles contain Bandelier detritus mixed with dacite detritus derived from the Tschicoma Formation. Active and inactive channels and floodplains form complex, cross-cutting deposits. These fluvial sediments interfinger laterally with colluvium derived from canyon walls. In Pueblo Canyon alluvium is about 11 ft thick on the west side of the plateau and about 18 ft thick near the confluence with Los Alamos Canyon. Mortandad Canyon has 1 to 2 ft of alluvium near its headwaters and more than 100 ft of alluvium (plus colluvium) near the eastern LANL boundary.

Alluvium of probable early Pleistocene age overlies Bandelier Tuff on mesas throughout the plateau (Reneau and McDonald, 1996). The alluvial deposits form fairly continuous deposits on the western side of the plateau, but only remnants of these deposits are preserved further east. These alluvial deposits are primarily made up of coarse dacitic detritus from the Sierra de los Valles, but some locations also contain Valles Rhyolite (Cerro del Medio and El Cajete) fall deposits or their reworked equivalents. These deposits record the locations post-Tshirege alluvial fans and streams that predate incision of canyons on the plateau (Reneau and McDonald, 1996).

Colluvium consists of slope or cliff detritus shed gravitationally into canyons. In most instances only large blocks of colluvium can be distinguished from locally derived alluvium, where the colluvial blocks are identified with material in adjacent cliffs. Colluvial blocks are commonly overlain by alluvium, as in the wider reaches along Mortandad Canyon where blocks of upper devitrifed units of the Tshirege Member, often several feet in diameter, are found beneath alluvial sands and gravels in drillhole MCOBT-8.5.

2.3 Geologic Conceptual Model Cross-Sections

The geologic conceptual model is based on the accumulated geologic, geophysical, and hydrogeologic data described in Section 2.1. Regional and local data sources are used to constrain possible visualizations of the thickness and extent of major hydrogeologic units beneath the Laboratory. Of all data sources, the principal sources for building the subsurface components of the geologic conceptual model are obtained through the R-hole drilling program conducted under the Hydrogeologic Workplan. These data are supplemented by drilling data collected from boreholes that were drilled for other purposes. Because samples and geophysical logs from earlier boreholes are largely unavailable, and earlier wells were not drilled with the goal of obtaining a sitewide hydrogeologic model, the R-series wells provide the best available dataset for subsurface geology at the Laboratory. The various types of stratigraphic data from R-series wells and from other boreholes used to support the geologic conceptual model are summarized in Appendix 2-A.

2.3.1 Geology at the Water Table

The distribution of bedrock units at the top of regional saturation is shown in Figure 2-10. Regional groundwater enters the Pajarito Plateau by underflow through the rocks that underlie the Sierra de los Valles (Griggs, 1964; Purtymun, 1984). This underflow is supplemented by recharge from drainages that cross the plateau (Kwicklis et al., 2005). Hydrogeologic conditions beneath the Sierra de los Valles west of the Pajarito fault zone are largely unknown because there are no deep wells in this area. Groundwater probably flows through Tschicoma lavas and underlying geologic units at depth, based on stratigraphic cross-sections (see Section 2.3.2). The geologic units beneath the Tschicoma Formation are poorly constrained but probably consist of Keres Group volcanic rocks, Santa Fe Group sediments, Eocene sedimentary rocks, Paleozoic and Mesozoic sedimentary rocks, and Precambrian crystalline rocks (Smith et al., 1970; Goff and Gardner, 2004; Smith, 2004). In the western part of the plateau, in the vicinity of Pueblo and Water Canyons, the water table is straddled by two lobes of down-faulted Tschicoma lavas that extend up to 3 km (2 mi) east of the Pajarito fault zone. Based on the physical characteristics of the rocks, groundwater flow through dacite most likely occurs as fracture flow in the lava interiors and as porous flow in interflow zones and interbedded clastic deposits.

In the central part of the plateau, the regional water table occurs within basin-fill deposits that become progressively older to the east. These basin-fill deposits consist of the Puye Formation, pumice-rich volcaniclastic rocks, older fanglomerates, and the Tesuque Formation (Figure 2-10). The most productive municipal supply wells on the plateau occur in this area where long well

screens (500 m [1600 ft]) span the Puye Formation, pumiceous deposits, Totavi deposits, older fanglomerates, and Tesuque sedimentary rocks and basalts.

Basalt straddles the water table in two areas. The most extensive is located in the south-central part of the plateau where as much as 195 ft of saturated Pliocene Cerros del Rio basalt occurs at the top of the regional zone of saturation in well DT-10 and 290 ft occurs in well R-22 (Figure 2-10). A smaller region of older Miocene basalts straddles the water table in a north-trending zone extending between wells R-12 to R-5. The southern extent of this zone is poorly constrained.

The Tesuque Formation is the primary rock unit making up the regional aquifer in the eastern part of the plateau and in the Buckman well field east of the Rio Grande (Figure 2-10). Miocene basalts are interbedded with the Tesuque Formation beneath parts of the plateau, but are absent in wells drilled to depths of 300 to 575 m (1000 to 1900 ft) in the Buckman well field (Shomaker, 1974). Most of the production from municipal supply wells in Guaje Canyon and in lower Los Alamos Canyon comes from the Tesuque Formation.

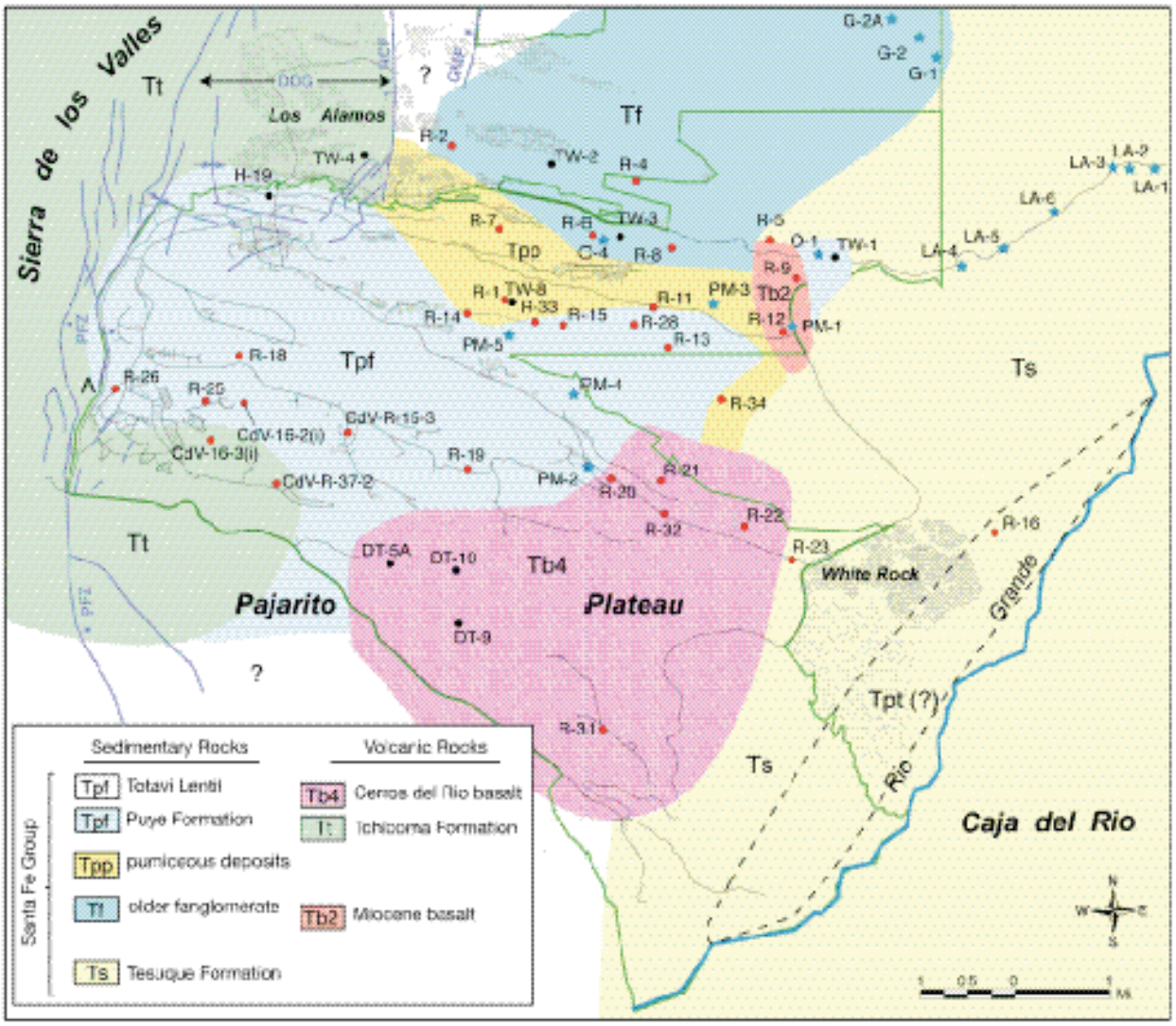


Figure 2-10. Map showing distribution of geologic units at the top of the regional saturated zone beneath the Pajarito Plateau. The wells that provided geologic control for this map are indicated by dots using the same color schemes as Figure 2-2. The LANL boundary is shown by the green outline, and the Pajarito fault zone is shown in blue. The map portrays the dominant rock unit in the upper 50 ft of the regional saturated zone.

2.3.2 Representative Cross-Sections

The full three-dimensional implementation of the geologic model is discussed in Section 4.1. The 3D model is tested against conceptual cross-sections that incorporate time-stratigraphic constraints, structural considerations, and correlations and limitations that take into account source regions and settings beyond the boundaries of the 3D model. The development of a manageable 3D model is time-intensive and requires treatment of geologic units on a large scale, where some details must necessarily be incorporated into larger units or ignored. Conceptual cross-sections help to test ideas concerning site geology, present details that may not be manageable in the 3D model, and provide a means of rapid testing of new borehole data against existing concepts.

Figure 2-11 shows alignments for eight conceptual geologic cross-sections that cover the Laboratory area. Included are four conceptual cross-sections for principal drainages:

- Los Alamos Canyon (Figure 2-12),
- Mortandad Canyon (Figure 2-13),
- Pajarito Canyon (Figure 2-14), and
- Water Canyon (Figure 2-15).

In addition, four cross-sections of approximately southwest-northeast alignment cross the grain of drainage at the Laboratory from western to eastern portions of the site (Figures 2-16, 2-17, 2-18, 2-19). Each geologic section is presented here at a vertical exaggeration of 10:1 in order to permit appropriate labeling and allow a level of detail that would not be possible at true vertical scale. Each geologic section is described separately below.

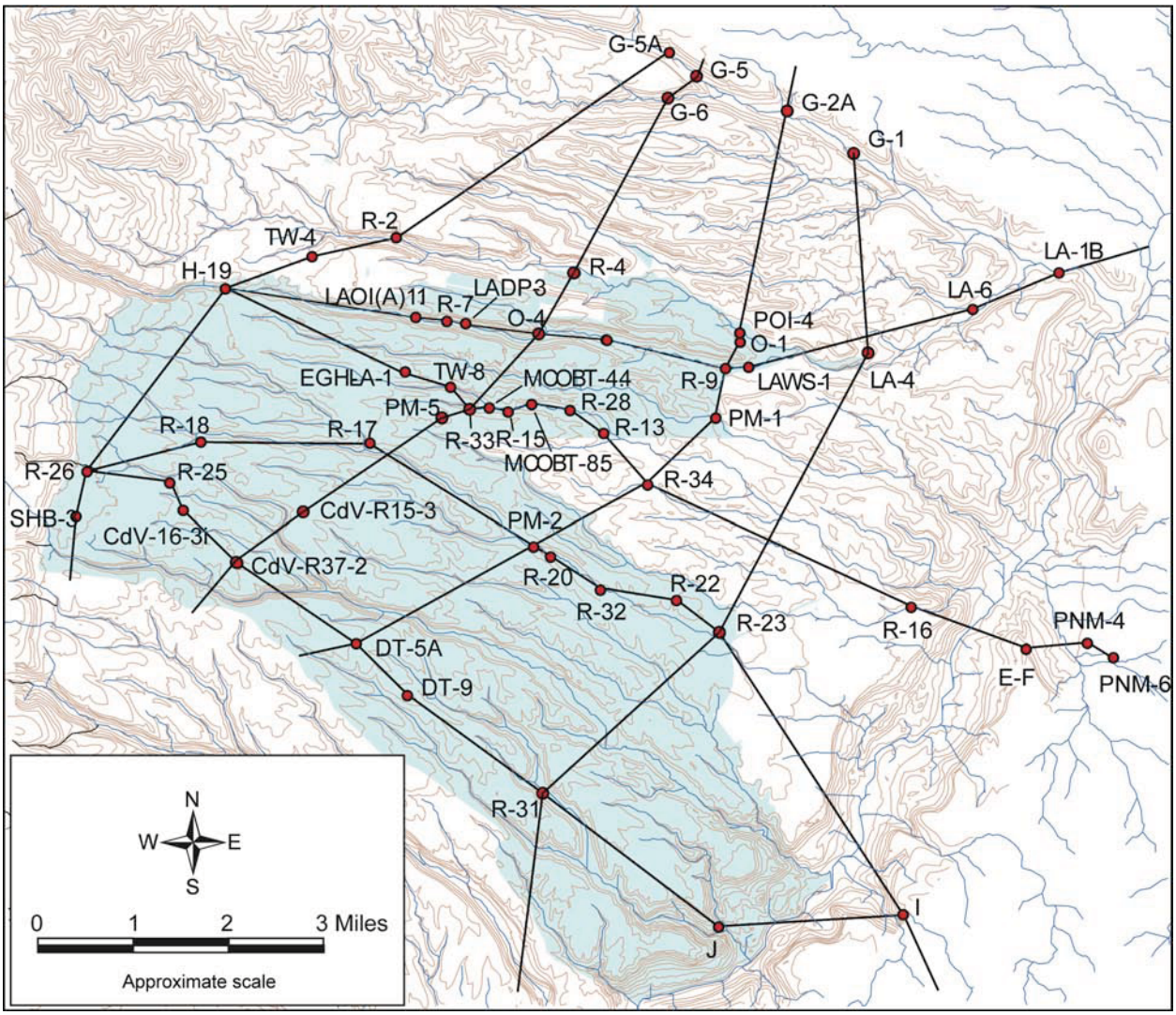


Figure 2-11. Lines of cross-section for Figures 2-12 through 2-19.

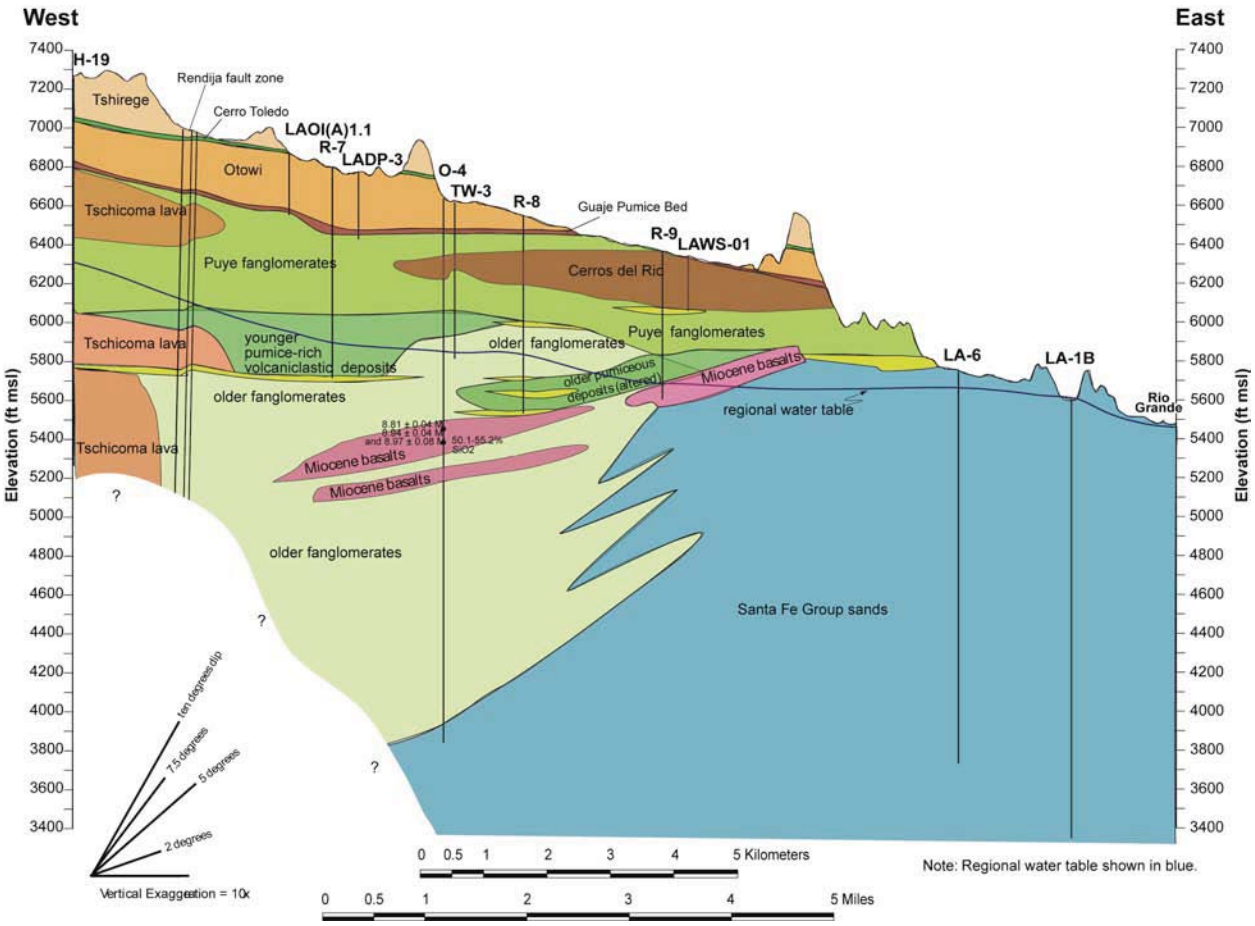


Figure 2-12. Conceptual cross-section for Los Alamos Canyon. Blue line is regional water table.

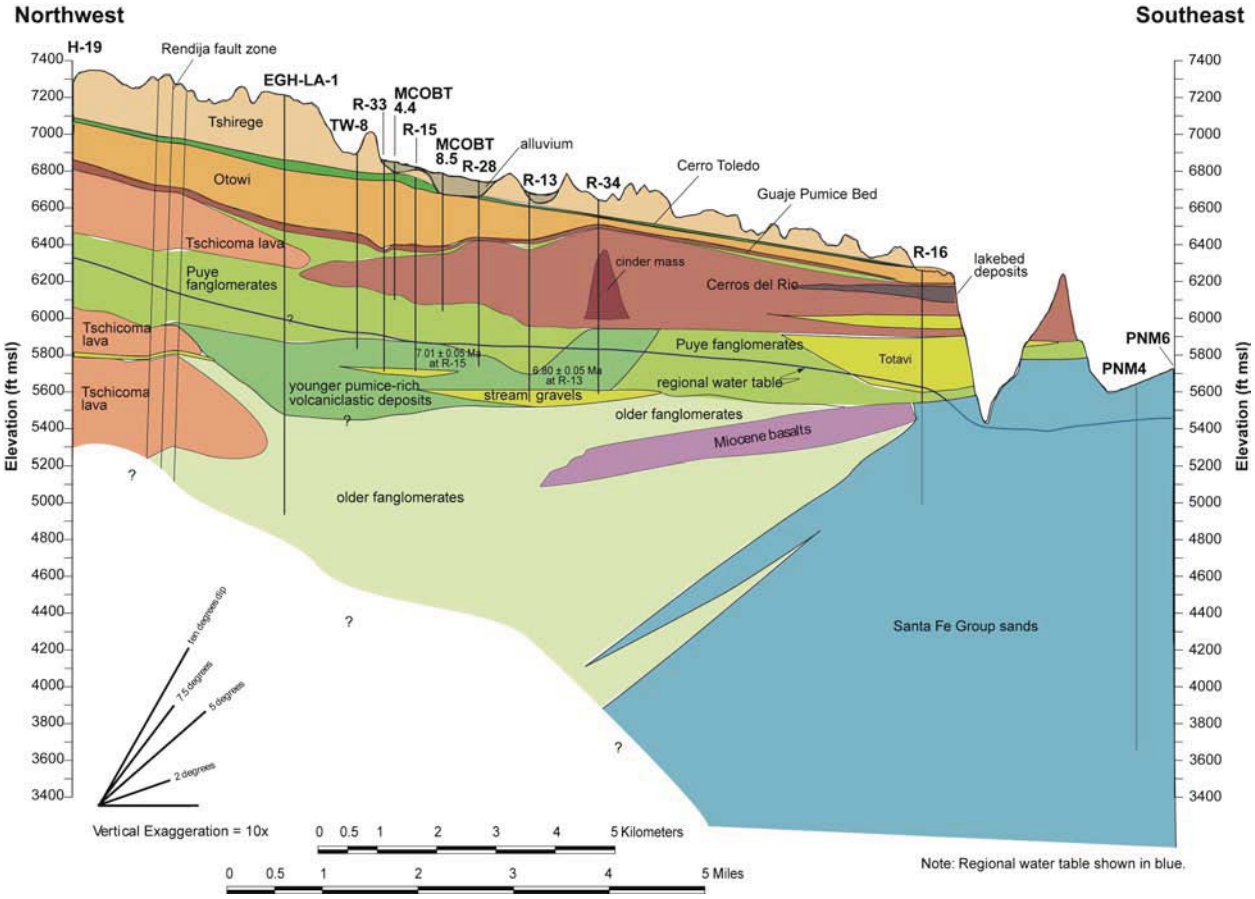


Figure 2-13. Conceptual cross-section for Mortandad Canyon. Regional water table is shown in blue.

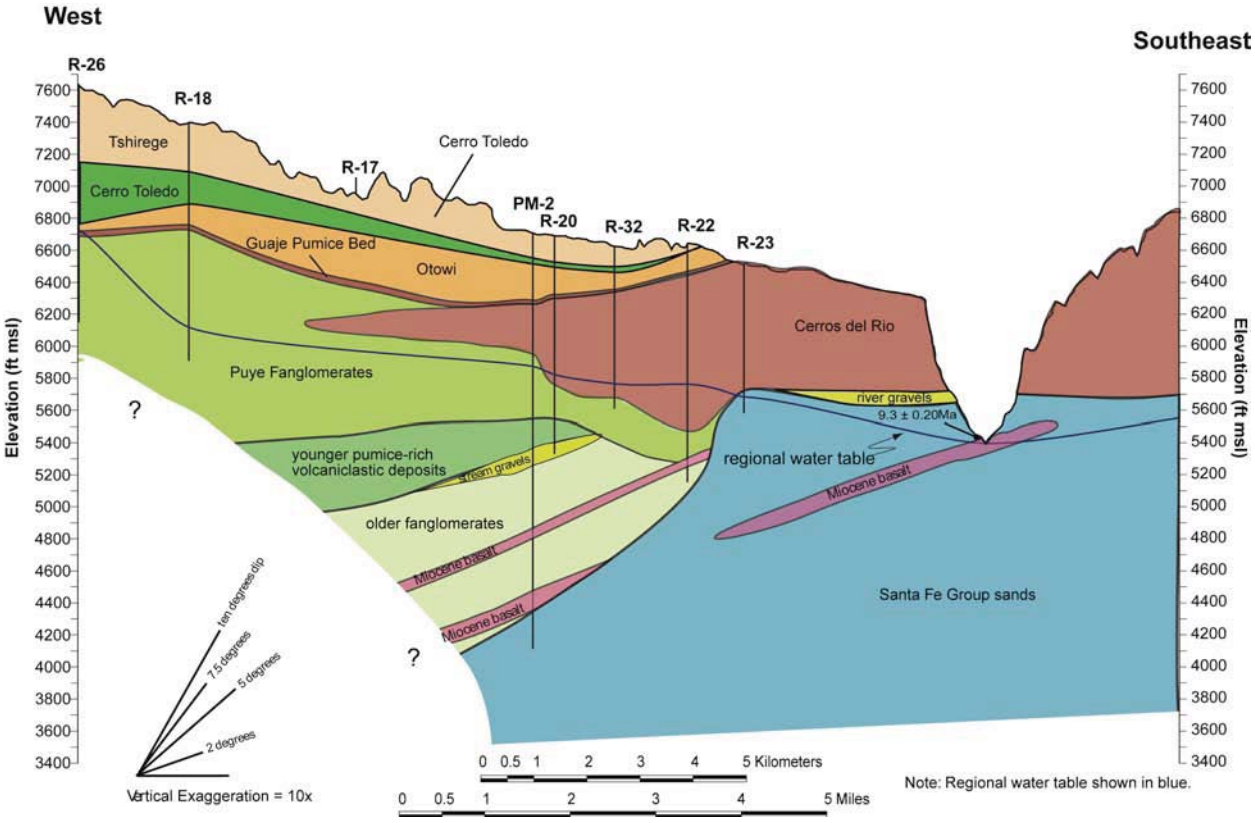


Figure 2-14. Conceptual cross-section for Pajarito Canyon. Water table is shown in blue.

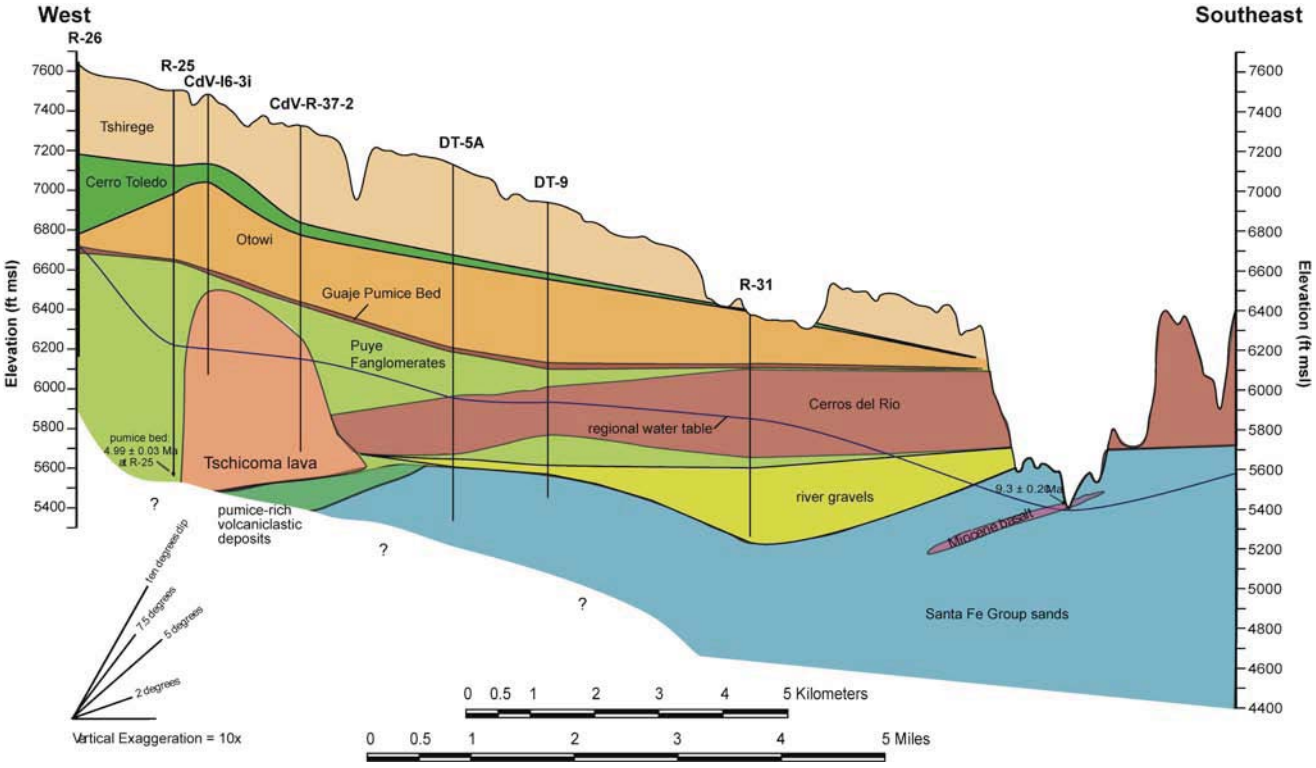


Figure 2-15. Conceptual cross-section for Water Canyon. Water table is shown in blue.

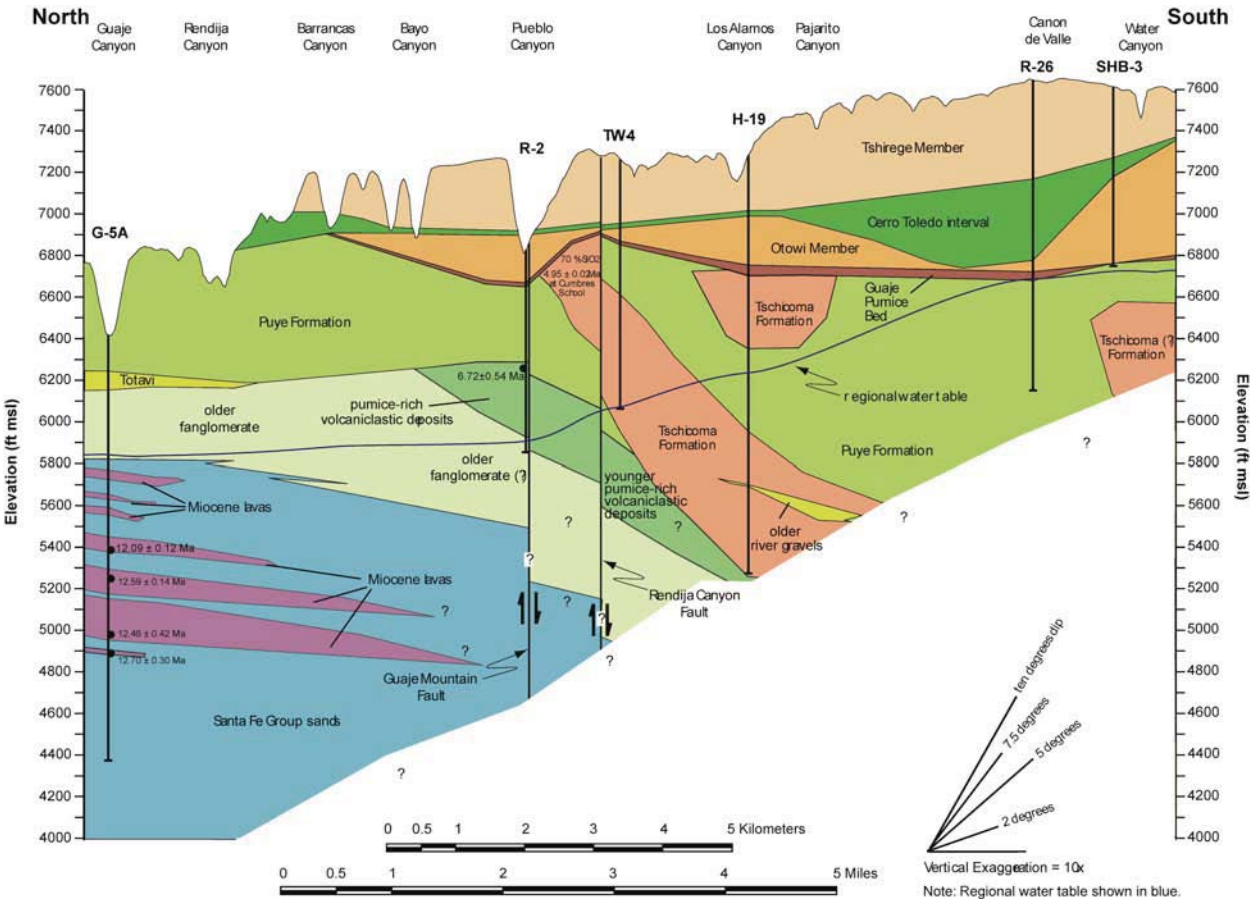


Figure 2-16. Conceptual north-south cross-section for the western portion of the Laboratory.

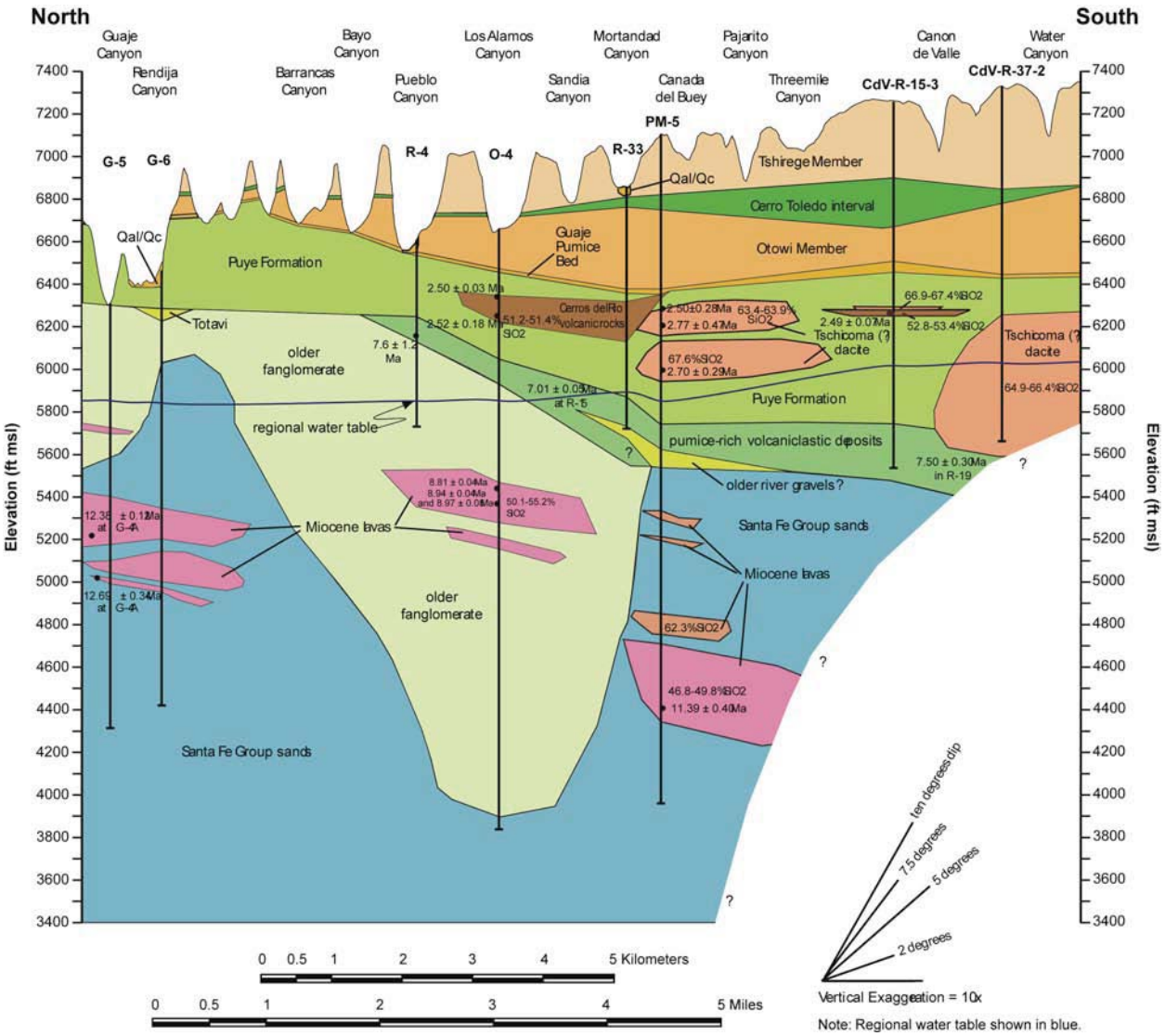


Figure 2-17. Conceptual southwest-northeast cross-section from TA-16 through the west-central portion of the Laboratory.

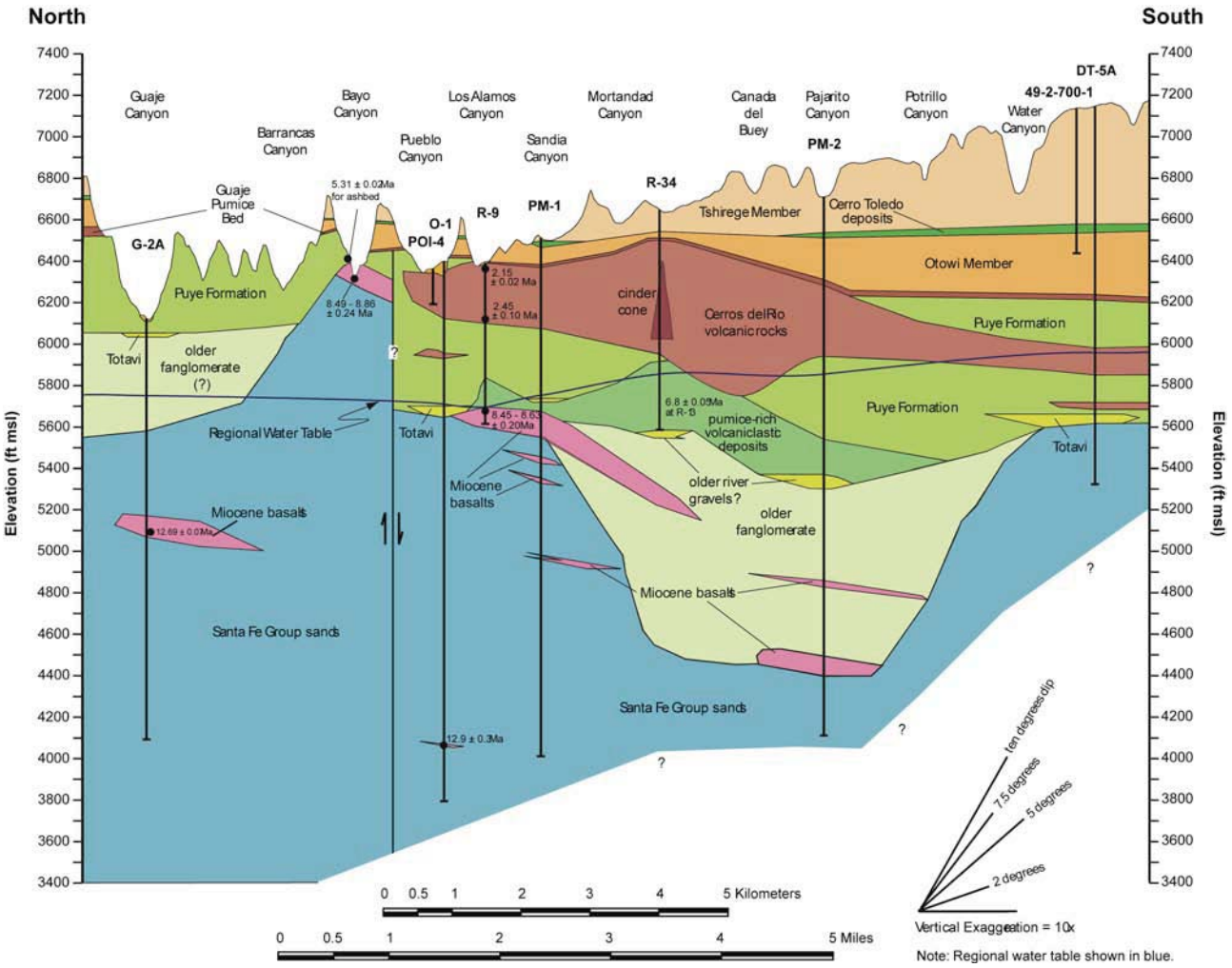


Figure 2-18. Conceptual southwest-northeast cross-section from TA-49 through the central portion of the Laboratory.

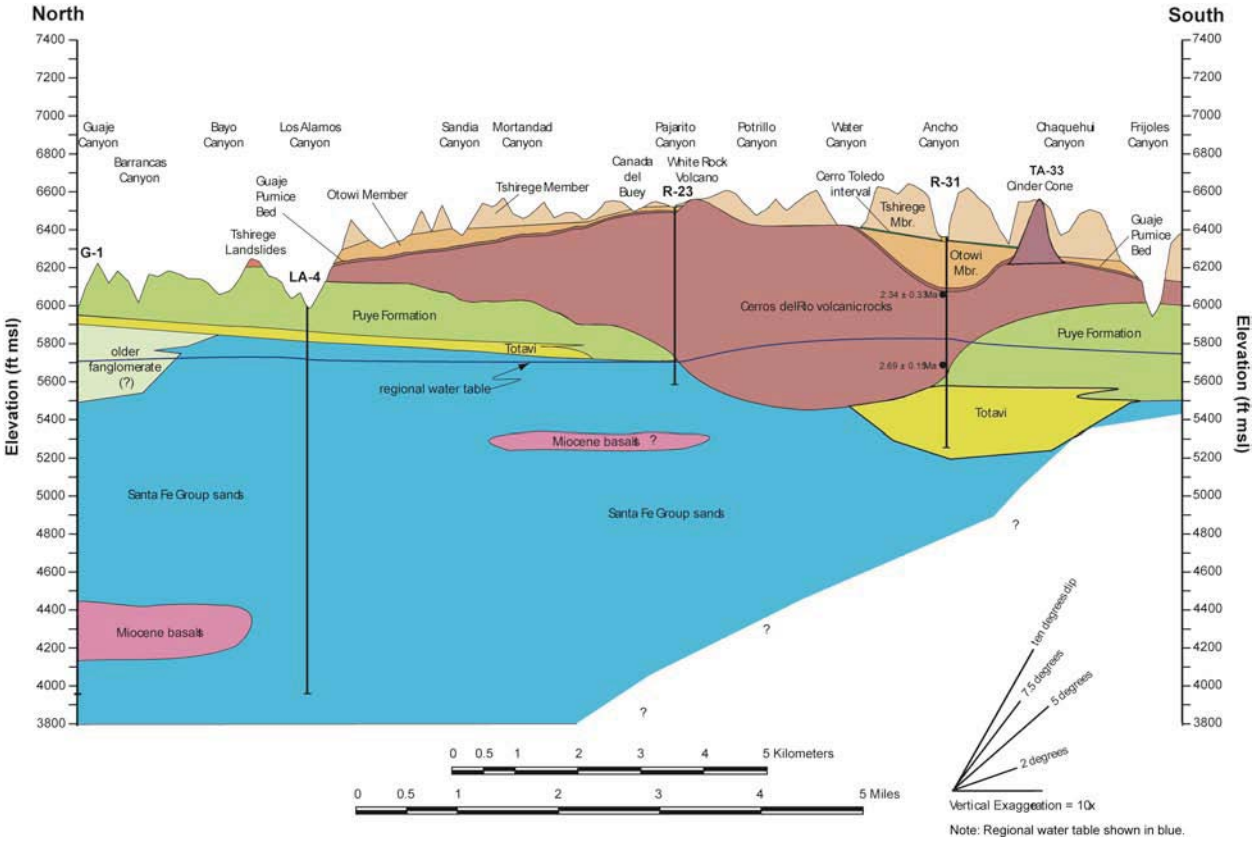


Figure 2-19. Conceptual north-south cross-section through the eastern portion of the Laboratory.

2.3.2.1 Los Alamos Canyon Cross-Section

Figure 2-12 shows a cross-section based on boreholes along the length of Los Alamos Canyon, from H-19 to the Rio Grande. At the western margin of this section, thick Tschicoma lava flows are shown extending almost to the Rendija fault zone or slightly beyond. The lack of dacitic lavas in R-7 suggests that the lavas do not extend this far to the east; however, lithologic homogeneity of dacitic lithologies in thick Puye fanglomerate sequences at R-7 may indicate that the dominant lava sources are not far away. From the opposite direction, Cerros del Rio lavas extend from exposures in lower Los Alamos Canyon to O-4 but not to R-7. The "lava gap" at R-7 provides a section of more homogeneous lithology (Bandelier, Puye, and pumice-rich volcaniclastic rocks) from canyon bottom to regional water table without interference from low-porosity dacitic or basaltic lava flow.

Pumice-rich volcaniclastic rocks at R-7 occur in a series of primary or reworked pumice beds intercalated with fanglomerates. In this cross-section these are referred to as "younger pumiceous deposits" to distinguish them from heavily clay-altered and possibly older pumice deposits observed at greater depth in O-4, R-8, and in R-9. In reality these may be unaltered and altered variants of a single unit and the distinction shown here may be abandoned if future studies provide a link between these deposits. The lenses and thin layers labeled as "river gravels" refer to well-rounded gravels that contain at least 10% Precambrian lithologies (quartzite, with and without granite and schists, etc.). As noted in Section 2.2.4, relationships between these gravels and the Totavi are uncertain.

Dips on hydrostratigraphic units in this cross section vary with age; the youngest units dip to the east and older units dip to the west. This variation in dip reflects in part the progressive drop in structural elevation along the Pajarito fault zone, just west of H-19. Younger contributions of Tschicoma lavas, steep fanglomerate slopes shed from these fans, and proximally thick Bandelier ash flows provide the east-dipping masses at higher stratigraphic levels.

2.3.2.2 Mortandad Canyon Cross-Section

Figure 2-13 shows a cross-section beginning at borehole H-19, dropping into Mortandad Canyon at TW-8 and extending along Mortandad Canyon, then to R-16 and across the Rio Grande to well PNM6 in the Buckman well field. This cross section begins in the west where Tschicoma dacitic lavas were found in drillhole H-19, but here the uppermost lavas are extended to borehole EGH-LA-1. The implied relationship between dacitic lavas in these two drillholes is speculative because there are no samples from H-19 to test similarity. If there is continuity of dacitic lavas between H-19 and EGH-LA-1 to the west as shown, then there is likely little or no "lava gap" between Tschicoma dacites and Cerros del Rio basalts as seen in the vicinity of R-7 in Figure 2-12.

The top of the pumiceous deposits, beneath Puye fanglomerates, is well defined in boreholes from TW-8 to R-13. The data from EGH-LA-1 and R-34 are largely inferred due to poor sample returns in these drillholes. There is also a lack of information to indicate whether or not there is a series of clay-altered and possibly older pumiceous deposits, as shown in Figure 2-12, on top of the Miocene basalts shown here. As in the previous cross-section for Los Alamos Canyon, dips on most units vary from easterly in upper horizons to westerly in lower horizons. The evidence for westerly dips in Santa Fe Group sands for this section is based largely on extrapolation from

the FMI dips recorded in drillhole R-16 (see Table 1-A-1). The pumice-rich volcaniclastic deposits dip 5-7° to the southwest at R-1 and R-33 and 6 ° to the southeast at R-28.

The south-trending paleocanyon at the base of the Bandelier Tuff is more evident in this section than in the more northerly section along Los Alamos Canyon (Figure 2-12). In Figure 2-13 the axis of the paleocanyon is clearly transected in the vicinity of drillholes R-33 to MCOBT-8.5. Evidence for a comparable canyon, offset to the east, may be seen in the depth to pumiceous deposits at R-13, but the paucity of deep cuttings from R-34 make this interpretation somewhat speculative. Evidence for the cinder mass within the Cerros del Rio at R-34 however is very good, and it is likely that a buried basaltic vent source is close to the R-34 drill site, although the distance and direction to the vent are not constrained.

2.3.2.3 Pajarito Canyon Cross-Section

Figure 2-14 shows a cross-section beginning at borehole R-26, extending to the location of well R-18 and planned well R-17, then along Pajarito Canyon to well R-23 and across the Rio Grande to a measured section on the eastern canyon wall (Dethier, 1997). In this cross section the deep erosion into the Otowi ash flows and filling of this eroded canyon by Cerro Toledo deposits is evident (compare with Figures 2-4 and 2-5). As in the Mortandad Canyon cross section, the broad south-trending valley filled by Bandelier Tuff is visible west of PM-2, although placement of the valley axis will depend on observations yet to be obtained from future drillhole R-17.

The deepest point filled by Cerros del Rio lavas in this section is at R-22. This point is the principal evidence for the south-trending paleocanyon seen in Figure 2-8, although the exact trend and the head of the canyon are poorly constrained by current borehole data. The west-dipping Miocene basalts are suggested by dips seen in other drillholes to the north, in outcrop along White Rock Canyon (Dethier, 1997), and by suggested correlations between Miocene basaltic lavas in PM-2 and R-22 and between PM-2 and basalt outcrops in White Rock Canyon. At R-20, FMI logs show that the pumice-rich volcaniclastic deposits dip about 5° to the southwest.

2.3.2.4 Water Canyon Cross-Section

The cross-section shown in Figure 2-15 runs approximately parallel to the southern boundary of the Laboratory, from borehole R-26 to two measured sections on the western and eastern walls of White Rock Canyon (Dethier, 1997). Here the axis of the paleocanyon at the base of the Bandelier Tuff is less evident because the eastern wall of that paleocanyon is essentially flat, from borehole DT-9 to White Rock Canyon. An older and more prominent paleocanyon is shown in the vicinity of borehole R-31, filled by accumulation of largely Precambrian sands and gravels marking a previous channel of the ancestral Rio Grande. The depth of this paleochannel is poorly known because borehole R-31 was unable to penetrate completely through the gravel deposit.

Boreholes CdV-16-3(i) and CdV-R-37-2 were both completed within thick sequences of Tschicoma Formation dacitic lavas. These lavas do not occur in borehole R-25; moreover, lavas encountered in boreholes DT-5A and DT-9 are poorly characterized but are believed to be flows within the Cerros del Rio volcanic field that are likely younger than these thick dacitic lavas, although no samples of these lavas are available for dating. Completion of planned drillhole

R-27 within Water Canyon north of DT-5A will address this question by providing samples of these lavas. Specifically, the well will provide additional information about the composition of lavas in the vicinity of TA-49 and their possible relationship with the lavas encountered in CdV-16-3(i) and CdV-R-37-2. In this cross-section the dacitic lavas in CdV-16-3i and CdV-R-37-2 are shown as being limited in lateral extent. The flow base for these lavas is speculated to be at the top of the older fanglomerates, but actual stratigraphic relations are unknown at this time.

2.3.2.5 Western Boundary Cross-Section

Figure 2-16 shows a cross-section from south of borehole SHB-3 extending up along the western boundary of the Laboratory, northeast to borehole G-5A in Guaje Canyon. This section shows in cross-section the depth and width of the paleocanyon cut into the Otowi Member and filled by deposits of the Cerro Toledo interval in the vicinity of borehole R-26. To the north the Otowi Member has been eroded away and the sediments of the Cerro Toledo interval are deposited on fanglomerates of the Puye Formation. Fanglomerates of the Puye Formation are considerably thicker beneath the Laboratory than to the north. The pumice-rich volcaniclastic and older fanglomerate are believed to occur beneath the western part of LANL but their presence is speculative because boreholes do not fully penetrate the thick Puye Formation in that area. The correlation of dacitic lavas in TW-4 and H-19 is based on lithologic descriptions of phenocryst minerals, but the lack of available cuttings from these boreholes means that this correlation cannot be tested.

2.3.2.6 West-Central Cross-Section

Figure 2-17 shows a cross-section from south of borehole CdV-R-37-2 and extending northeast across the Laboratory to borehole G-5 in Guaje Canyon. In this section the chemical composition of the lavas (wt% SiO_2) and available radiometric ages are shown to indicate how the lavas can be used as a guide in stratigraphic interpretation. In general, the ages of lavas assigned to the Cerros del Rio volcanic field or to the older Miocene sequences correlate with stratigraphic depth. The Tschicoma intermediate-composition lavas at the margins of the Laboratory, as in borehole CdV-R-37-2, have not been fully penetrated by any boreholes and the nature of their basal contacts is not known.

As in Figure 2-15, the pumiceous deposits and the underlying river gravels (Totavi) are shown with a southern component of dip, consistent with FMI dip information described earlier. The river gravels can be extended as a continuous unit between boreholes R-33 and PM-5. However, another interpretation would be as unconnected river channels at different elevations, as seen in the east-central cross-section to the east (Figure 2-18).

The cross-section suggests that there is considerable incision into the top pf the Santa Fe Group sands prior to deposition of the older fanglomerate in the vicinity of O-4. This interpretation is supported by the presence of younger Miocene basalts at O-4 that occur at the same structural levels as older Miocene basalts beneath Guaje Canyon. The orientation of possible paleovalleys incised into Santa Fe Group sands cannot be determined because most boreholes in the central and western part of the plateau are not deep enough to penetrate the base of the older fanglomerates. Relations described by Griggs (1964) for wells in the Guaje Canyon areas suggest that some uppermost Santa Fe Group sands interfinger with the older fanglomerate.

2.3.2.7 East-Central Cross-Section

Figure 2-18 shows a cross-section from southwest of borehole DT-5A extending northeast across the Laboratory to drillhole G-2A in Guaje Canyon. This section crosses a high point in the Cerros del Rio volcanic field at borehole R-34. As in the western-boundary and west-central cross-sections (Figures 2-16 and 2-17) the stratigraphy beneath the Bandelier Tuff at the southern Laboratory boundary is speculative. If the lavas penetrated by borehole DT-5A are attributed to the Cerros del Rio (see Figure 2-8) rather than the Tschicoma Formation, the distinction from Cerros del Rio volcanic rocks shown as a contact here may unnecessary. The lack of samples for analysis from borehole DT-5A allows either interpretation, but this problem should be resolved when borehole R-27 is completed in Water Canyon north of DT-5A.

Petrographic and radiometric data from lavas outcropping in Bayo Canyon and comparable data from lavas in borehole R-9 suggest an offset of several hundred feet down to the south, interpreted in this cross section as a normal fault between Bayo and Pueblo canyons, covered by and not offsetting the Bandelier Tuff. Other explanations are possible but fault offset is supported by observed offset of exposures in Bayo Canyon. The number and distribution of faults beneath the Laboratory remains largely unknown, but continuity in many younger units, particularly the Bandelier Tuff and Cerros del Rio volcanic rocks, limits the amount of significant fault offset in the central and eastern Laboratory area to units older than about 3 Ma. As in Figure 2-17, the cross section shows a paleovally incised into the top of Santa Fe Group sands filled by older fanglomerate. These relationships are based on descriptions of the pre-Puye rock units described in the lithologic logs for PM-1, PM-2, and DT-5A, and they cannot be verified because drill cuttings for these wells are not available.

2.3.2.8 Eastern Cross-Section

Figure 2-19 shows a cross-section from south of borehole R-31 extending northeast and then north across the eastern portion of the Laboratory to drillhole G-1 in Guaje Canyon. This figure illustrates the thinning and local absence of the Otowi Member of the Bandelier Tuff over highlands of Cerros del Rio volcanic rocks. The very thick sequence of Cerros del Rio volcanic rocks between boreholes R-23 and R-31 has a total depth that is poorly constrained but likely to have filled a paleocanyon (see Figure 2-8). Continuity of Totavi river gravels from north to south is shown as disrupted in the vicinity of this paleocanyon, for such gravels are missing in several boreholes near this feature. At greater depth the stratigraphic sequence is dominated by Santa Fe Group sands, based on evidence from boreholes in lower Los Alamos Canyon (e.g., LA-4), boreholes to the east (R-16), and exposures mapped in White Rock Canyon (Dethier, 1997).

2.4 Hydrologic Properties

The geologic units of the Pajarito Plateau are organized into more generalized hydrogeologic units that form the framework for flow and transport numerical models (Section 4). Hydrogeologic units are subdivided based on lithologic characteristics believed to result in different hydrologic properties. A comparison of geologic and hydrologic frameworks for the plateau region is provided in Figure 2-3.

2.4.1 Vadose Zone Hydrologic Properties

The vadose zone, the region between the ground surface and the regional aquifer, consists of variably saturated rocks, and locally saturated zones. The hydrologic properties controlling the flow of water from the surface to the regional aquifer are the saturated hydraulic conductivity (ksat) and the unsaturated hydraulic properties. As explained in basic hydrology texts and in references related to the vadose zone beneath the Pajarito Plateau such as Rogers and Gallaher (1995), when rocks are not completely saturated, the moisture retention curve defines the relationship between the volumetric water content of a soil or rock and its capillary pressure (sometimes referred to as the matric suction or matric potential). As the pores fill with water, capillary forces result in the small-diameter pores filling first, and at progressively larger water contents, the larger pores fill. The resistance to flow is much lower for the large-diameter pores, so that the unsaturated hydraulic conductivity increases as a strong function of the water content, reaching a maximum when the medium is saturated. Under unsaturated conditions, the local water content and matric potential are controlled by the percolation flux; the local values of these variables modulate themselves in response to changes in the local percolation rate, in order that fluid may pass through the rock under gravity-driven or capillary-flow conditions. For unsaturated conditions flux and water content are related and flow is in response to a gradient that is composed of capillary and gravitational terms.

Although most contaminants of concern associated with past LANL operations travel in the liquid phase, gas-phase transport is an important mechanism for radon and also for various volatile organic chemicals present in the subsurface. Furthermore, vadose zone observations used to estimate permeability at larger scales tend to be pneumatic, that is, based on the response of gas-phase pressures to changes in the air pressure exerted at the surface. When treating vapor transport, the permeability to the gas phase is the relevant property. Although in principle the permeability of the medium should be independent of the fluid (air or water), the role of fractures and issues of scale dependence come into play. Given that open fractures are most likely to be air-filled under ambient conditions, fractures dominate the behavior for gas-phase contaminant transport and the interpretation of pneumatic data.

To quantify the scale dependence of permeability of the Bandelier Tuff and to demonstrate the role of fractures, permeability estimates across all scales from laboratory samples to the scale of a mesa have been compiled. For the Laboratory scale, the geometric mean values of saturated hydraulic conductivity reported by Rogers and Gallaher (1995) are used, and water properties at standard conditions are used to convert conductivities to permeabilities. Parameter estimates for larger scales include gas-phase permeability estimates from Neeper (2002) for the tuff, and hydraulic conductivity measurements for the basalts from Stauffer and Stone (2005). In that study, Neeper (2002) presents field-scale results of pneumatic testing using straddle packers, and larger scale estimates based on the interpretation of the pressure responses to barometric cycles. The packer tests are termed “intermediate scale,” and the estimates based on response to barometric cycles are called the “large scale.”

Figure 2-20 compares the permeability estimates for the three scales. The laboratory scale values represent matrix permeability and discount the role of fractures, as unfractured samples were typically tested. Permeability values are at least one order of magnitude smaller than the

Intermediate-scale estimates. The large-scale values are similar to the intermediate scale, except in certain highly fractured regions, where even higher estimates of permeability are made. The most striking difference with scale is for the Cerros del Rio basalt, where core samples represent competent, low-permeability rock, whereas the field scale is dominated by large, open fractures or cavities that transmit air with virtually no resistance. Field observations in the basalts indicate that pressure changes at the surface are transmitted rapidly to depth (Neeper, 2002).

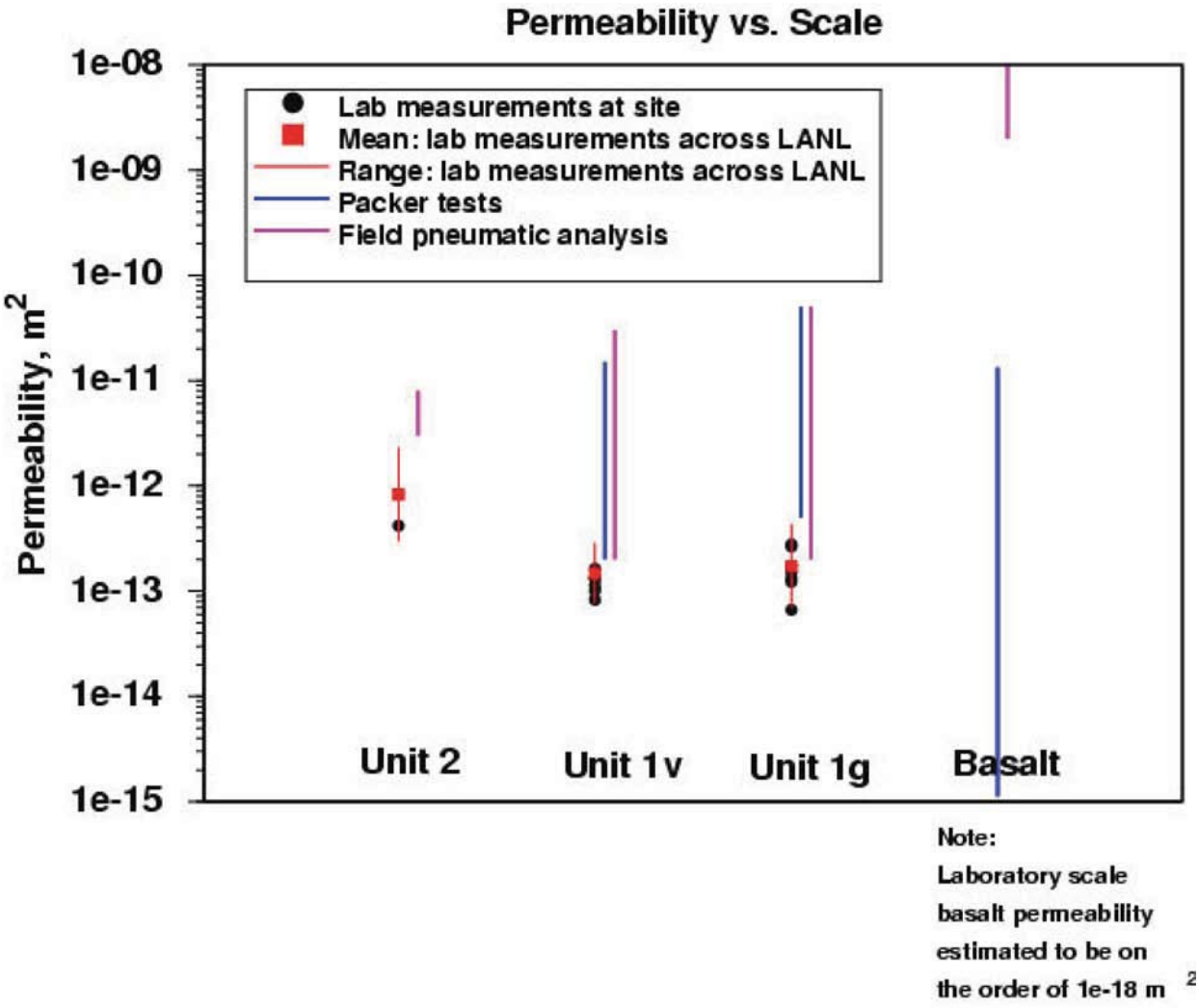


Figure 2-20. Permeability as a function of measurement scale for Bandelier Tuff (units 1g, 1v, and 2) and basalts.

These results illustrate the role of measurement scale and rock type on estimating the effective permeability of the rocks in the vadose zone. Clearly, fractures, faults, or other large-scale features exert control on the properties of the rock as scale increases. In this comparison, we have mixed the results of water and air flow observations to examine the role of scale. While it is apparent that the role of fractures in transmitting air through the vadose zone must be considered, the question of water flow and the role of fractures must also be considered. Robinson et al. (2005) provide field evidence and numerical model results that suggest that the Bandelier Tuff transmits water through the porous and permeable matrix even for cases in which water is injected at very high percolation rates. Furthermore, the hydrologic properties measured in samples collected from boreholes suffice to describe the percolation of water through the Bandelier Tuff under unsaturated conditions. That study concluded that as long as the percolation rate is lower than the local saturated hydraulic conductivity, water initially present in fractures is imbibed into the rock matrix. Therefore, rock properties of the matrix are most important, except perhaps near the surface where high-fracture-density zones may coincide with regions of high local infiltration rate. Matrix flow is an important simplification that makes vadose-zone characterization in individual canyons a more tractable problem.

In contrast to the Bandelier Tuff, the basaltic rocks clearly exhibit rapid flow through fractures and other fast pathways, and the permeability of the rock matrix is essentially irrelevant to the rates of water percolation (Stauffer and Stone, 2005). The difference is the orders of magnitude lower matrix permeabilities of these rocks, compared to the Bandelier Tuff.

2.4.2 Regional Aquifer Hydrologic Properties

Aquifer properties that are relevant to issues of groundwater quality and quantity are hydraulic conductivity, specific yield (unconfined aquifer) or storativity (confined aquifer), and effective porosity. This subsection summarizes all available information, both recent data collected in R-wells and older estimates from water supply wells. No new information on storage properties of the rocks has been collected in R-wells; this discussion, therefore, will rely entirely on older data.

There are inherent uncertainties associated with any particular estimate of aquifer properties, and there are two particularly important issues to consider when assessing these estimates. First, at the field-scale, these are quantities that are virtually impossible to measure directly. They can only be measured indirectly, via measuring the response of the aquifer to stress, then applying a theoretical model to that response. In a particularly complex aquifer such as the one beneath the Pajarito Plateau, the models used to interpret aquifer tests are necessarily much simpler than the actual aquifer and this will affect the accuracy of the test interpretation. Second, in a complex aquifer, hydraulic conductivity will vary substantially depending on the scale over which it is measured. Tests conducted in wells with long screens (such as water supply wells) and/or tests conducted over long time periods will sample large portions of the aquifer and the results will be average properties of the aquifer, including possible structural features such as faults. Short-term tests and/or tests in wells with short screens will sample small-scale features. The results from such tests will tend to show much greater variability than those in the first category. Only field-scale test results are considered here, since these are most pertinent to field-scale flow and transport in the regional aquifer. Borehole geophysics and bench-scale test approaches to

estimating hydraulic conductivity are not summarized here, although borehole geophysics-based estimates of effective porosity are discussed.

2.4.2.1 Expected Lithologic Controls on Regional Aquifer Hydrologic Properties

The two major types of aquifer rocks beneath the Pajario Plateau are sedimentary and volcanic rocks. The hydrologic properties of sedimentary and volcanic rocks can be very different and they are discussed separately.

Sedimentary units include the Puye Formation, pumice-rich volcaniclastic rocks, Totavi Lentil, older fanglomerate, Santa Fe Group sands, and sedimentary deposits between basalt flows. Based on outcrop and borehole observations, all these units are expected to be highly heterogeneous and strongly anisotropic, with a much higher conductivity parallel to sedimentary beds than perpendicular to these beds. Figure 2-21 shows photographs of the Puye Formation and the Santa Fe Group showing the typical nature of bedding. Figure 2-22 shows an outcrop of the Totavi Lentil, a unit found at the base of the Puye in some locations, containing cobble beds with abundant quartzite.

The Puye Formation is heterogeneous, containing a variety of sedimentary lithologies. Based on previous studies by Waresback et al. (1984) and Turbeville (1991) significant heterogeneity is expected to occur at scales from kilometers to meters (laterally) and meters to centimeters (vertically).

Due to lack of drill core, it is generally not possible to identify the depositional environments penetrated by R-wells within the Puye. Cuttings and borehole geophysics were used to distinguish between Puye fanglomerate (dacite detritius and sparse to absent pumice fragments), pumice-rich volcaniclastic rocks (abundant pumiceous fragments), Totavi Lentil (rounded clasts of abundant quartzite and other Precambrian lithologies), and older fanglomerate (volcanic detritus and sparse quartzite). The pumic-rich volcaniclastic rocks are expected to have a relatively high porosity, given the abundance of fairly coarse vitric pumice fragments. This high porosity *may* translate to high permeability. In some areas the pumiceous rocks are extensively clay-altered and permeability may be greatly reduced. The Totavi Lentil, an ancestral Rio-Grande alluvial deposit, is possibly the most transmissive of the sedimentary units due to the abundance of unconsolidated sands and gravels (see Figure 2-22). Fine-grained sediments, which may have low permeability, are also present in this unit.

Purtymun (1995) identified a thick zone of highly productive aquifer rocks that extends northeastward across the central plateau. Recent revisions to the plateau stratigraphy (Section 2.1) suggest that this zone includes older fanglomerate deposits, pumiceous volcaniclastic rocks, and lower portions of the Puye Formation. As will be shown below, both high and low permeability rocks are present within this zone.



Figure 2-21. (a) Outcrop of the Puye Formation, Rendija Canyon (north of LANL); (b) Outcrop of the Santa Fe Group, lower Los Alamos Canyon (east of LANL); (c) Outcrop of the Santa Fe Group, near Española (provided by Gary Smith, UNM Dept. of Earth and Planetary Sciences).



Figure 2-22. Outcrop of Totavi Lentil along SR 304 (D. Vaniman in foreground).

In heterogeneous units like these sedimentary deposits, it is particularly important to determine the lateral continuity of the high-permeability facies such as coarse stream channel deposits. However, it has not been possible to correlate individual beds in the Puye Formation because channel and overbank deposits in alluvial fan settings form complex, cross-cutting deposits, many of which are channelized or of limited lateral extent. Because of similar source rocks, clast compositions fail to provide distinct criteria for discriminating individual beds, particularly for boreholes spaced as far apart as the R-wells.

The storage properties of these rocks are expected to be within the normal range for sedimentary aquifers: specific yield (Sy) between 0.01 and 0.3 and storativity (S) between 5.E-3 and 5E-5. Likewise, effective porosity values are expected to be in the normal range for sedimentary rocks from 0.1 to 0.3 (Freeze and Cherry, 1979).

Volcanic rocks on the Pajarito Plateau include intermediate-composition lavas of the Tschicoma Formation and basalts (Cerros del Rio, Bayo Canyon, and Miocene basalts within the Santa Fe Group). These volcanic rocks consist of stacked lava flows separated by interflow zones. Figure 2-23 shows an example of Cerros del Rio basalt. Flow interiors are made up of dense impermeable rock that is variably fractured. The interflow zones contain highly porous breccias, clinker, cinder deposits, and sedimentary deposits. Groundwater flow in lava interiors is controlled by fractures, with hydraulic conductivity determined by aperture dimensions, fracture density, interconnectivity, and the presence or absence of fracture-filling minerals. Porous flow is expected to dominate groundwater flow in the interflow zones. Both nonfractured flow interiors and clay-filled fractured zones are expected to have very low permeability; zones with significant, connected open fractures, lava tubes, and interflow zones are expected to have higher permeability and low porosity, a combination of properties which can lead to very fast travel times (Stauffer and Stone, 2005).

The lava interiors presumably have very low effective porosity (<<0.1) and negligible storativity. Highly fractured zones and interflow zones may have larger porosity and storativity values, comparable to values expected for sedimentary rocks. Moderately fractured zones may have low effective porosity (10^{-3}–10^{-4}). Table 2-2 summarizes qualitative expectations of aquifer properties based on lithology and on the available data, augmented by field-scale testing, model calibration, and head gradients.

Fault zones. There are several faults on the plateau, including the Pajarito fault zone and the Rendija Canyon and Guaje Canyon faults (Figure 2-2). These are primarily oriented north-south, with local deviations. There are numerous north-south trending faults in the Santa Fe Group within the larger Española Basin; these types of faults are presumably present beneath the plateau, but they are covered by younger rocks. In general, faults can be conduits to flow (if open) or barriers to flow (if cemented or clay-filled). Field hydrologic evidence has been interpreted based on both of these occurrences. For example, Griggs and Hem (1964) postulated the presence of a fault acting as a flow barrier based on pumping tests in the Guaje Canyon wells. By contrast, Purtymun (1977) and Blake et al. (1995) observed evidence of faults acting as conduits for upward flow of deep thermal waters in the Santa Fe Group, based on geochemical and thermal evidence in lower Los Alamos Canyon wells and San Ildefonso wells. More recently, Keating et al. (2003), suggested that the large-scale effective permeability of the

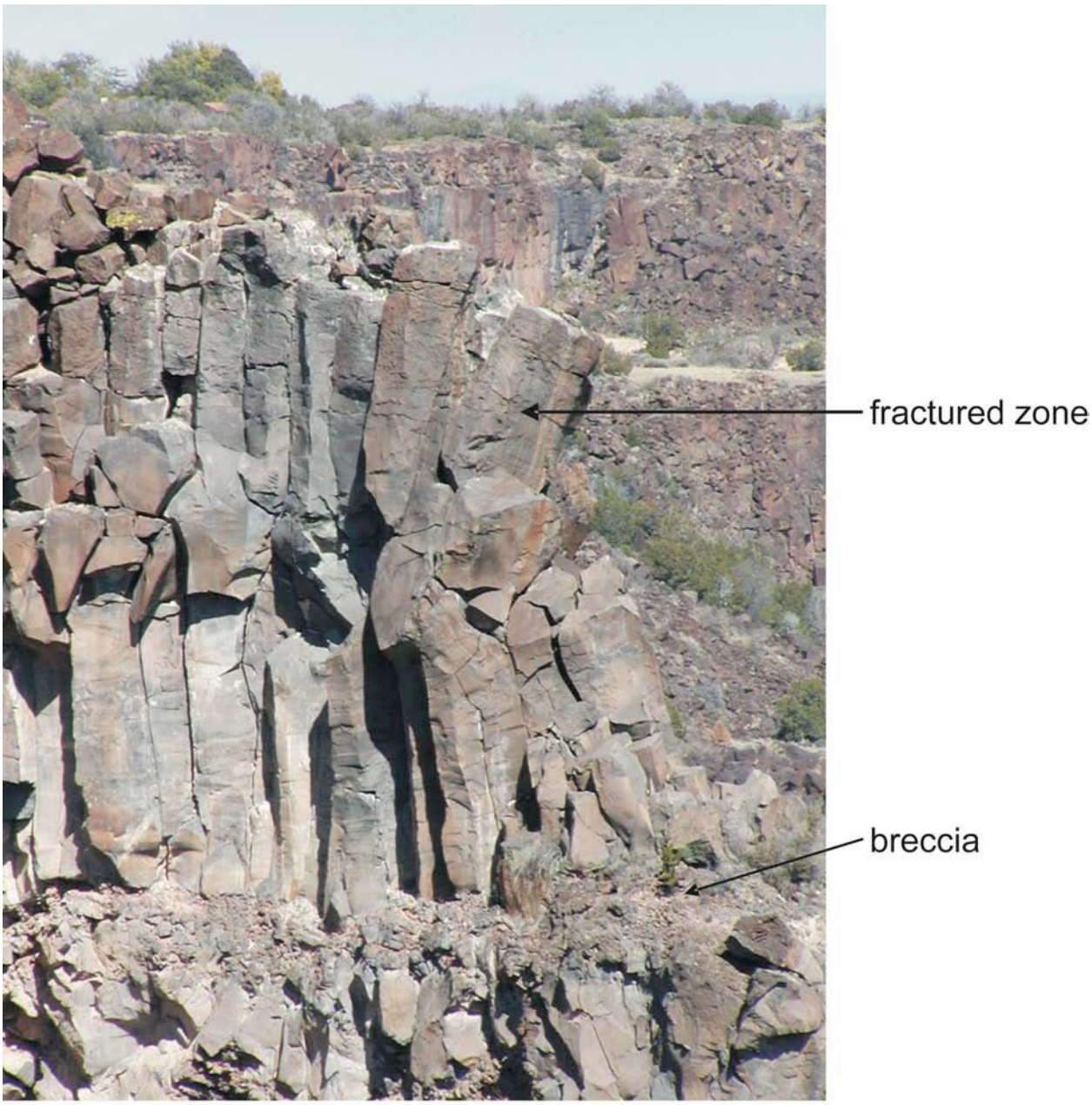


Figure 2-23. Outcrop of Cerros del Rio basalt at White Rock Overlook (east of LANL).

Table 2-2.
Inferred Properties of Hydrostratigraphic Units, Based on Field-Scale Testing, Model Calibration, and Head Gradients

Stratigraphic Unit	Sub-Unit	Description	Hydraulic Conductivity	Effective Porosity	Storage
Puye	Fanglomerate	Stream channel, overbank, colluvium, and lahar deposits	Extremely variable(0.007–45 m/day), both the highest and lowest K estimates on the plateau occur within this unit	0.07–0.2	No data
	Pumiceous	Ash and pumice-rich layers, both air fall and reworked	Extremely variable (0.3–6 m/day)	0.15–0 .2	No data
Lava flows (Tb1, Tb2, Tb4, Tt)	Massive	Pore space (vesicles) is not connected	<0.15 m/day	No data	No data
	Fractured	In flow interiors, fractures tend to be vertical; near flow tops and bottoms, many fracture orientations are observed, including sub-horizontal	1–9 m/day	No data	No data
	Breccia zones	Highly fractured rock, either open or clay-filled	No data	No data	No data
Santa Fe Group	Sandy	Alluvial fan deposits (stream channel, colluvium, overbank)	Relatively uniform (0.3 m/day); faults may decrease large scale effective K	No data	Log10 [m_{-1}] ~ –3.8 to–4.8
	Fanglomerate	Stream channel, overbank, and colluvium,	Variable (0.1–5.3 m/day), no evidence of very high permeability	No data	Log10 [m_{-1}] ~ –5.5

Pajarito fault zone is lower than surrounding rocks, based on observations of large horizontal gradients and model interpretations of these gradients. They also concluded that the large-scale effective permeability of the Santa Fe Group is lower than that indicated by individual pump test results (summarized below). These results indicate that faults in the Santa Fe Group, which tend to be north-south trending (transverse to the hydraulic gradient), may act as flow barriers in the direction perpendicular to their orientation, lowering the large-scale effective permeability of the aquifer.

2.4.2.2 Contact between Units

Depths to contacts between the major geologic units are generally well established, but their physical characteristics must be inferred from cuttings and geophysical logs. Outcrop data provide additional information about these contacts. Intra-formational and between-unit sedimentary contacts are generally conformable but are frequently disrupted by facies transitions and channel incisions. Individual beds can be traced laterally over the scale of meters to hundreds of meters. Major erosional unconformities between principal units, such as the Puye and Tesuque Formations, probably occur beneath the Pajarito Plateau, but the nature and orientations of features such as paleocanyons are unknown. Features such as clay-rich soils occur internally within some units like the Puye Formation, but do not appear to be important along intraformational contacts.

The contacts between coarse-grained units, such as the Puye Formation or the older fanglomerate, and fine-grained sediments of the Tesuque Formation may have hydrologic significance because of the juxtaposition of fundamentally different lithologies. Where exposed in the eastern part of the plateau, the contact between Puye rocks and Tesuque strata is a slight angular unconformity. Hydraulic gradients are generally easterly/southeasterly on the plateau (Figure 2-24). Within the Puye Formation, this driving force is parallel to the east-dipping beds. In contrast, within the Tesuque Formation, beds tilt to the west. This anisotropic condition will result in larger flow resistance and possible local deviations in flow direction within the Tesuque rocks.

The contact between the older fanglomerate and the Tesuque Formation may also be hydrologically important. In Guaje Canyon, thick sequences of older fanglomerate interfinger laterally for several kilometers with the Tesuque Formation (see Griggs, 1964 for discussion of these relations). The effect of these interfingering relations on groundwater flow is not known but could include changes in potentiometric surface gradients and partial confinement of groundwater in older fanglomerate enclosed by less permeable Tesuque strata. In Los Alamos and Pueblo Canyons, lateral infingering between the older fanglomerate and the Tesuque Formation appears to be more abrupt. The lithologic difference between the older fanglomerate in Otowi-4 and the Tesuque Formation in Otowi-1 is striking, and the lateral hydraulic conductivity should decrease eastward. The presence of altered Miocene basalts in the Tesuque Formation in wells R-9 and R-12 should also contribute to a decrease in hydraulic conductivity eastward.

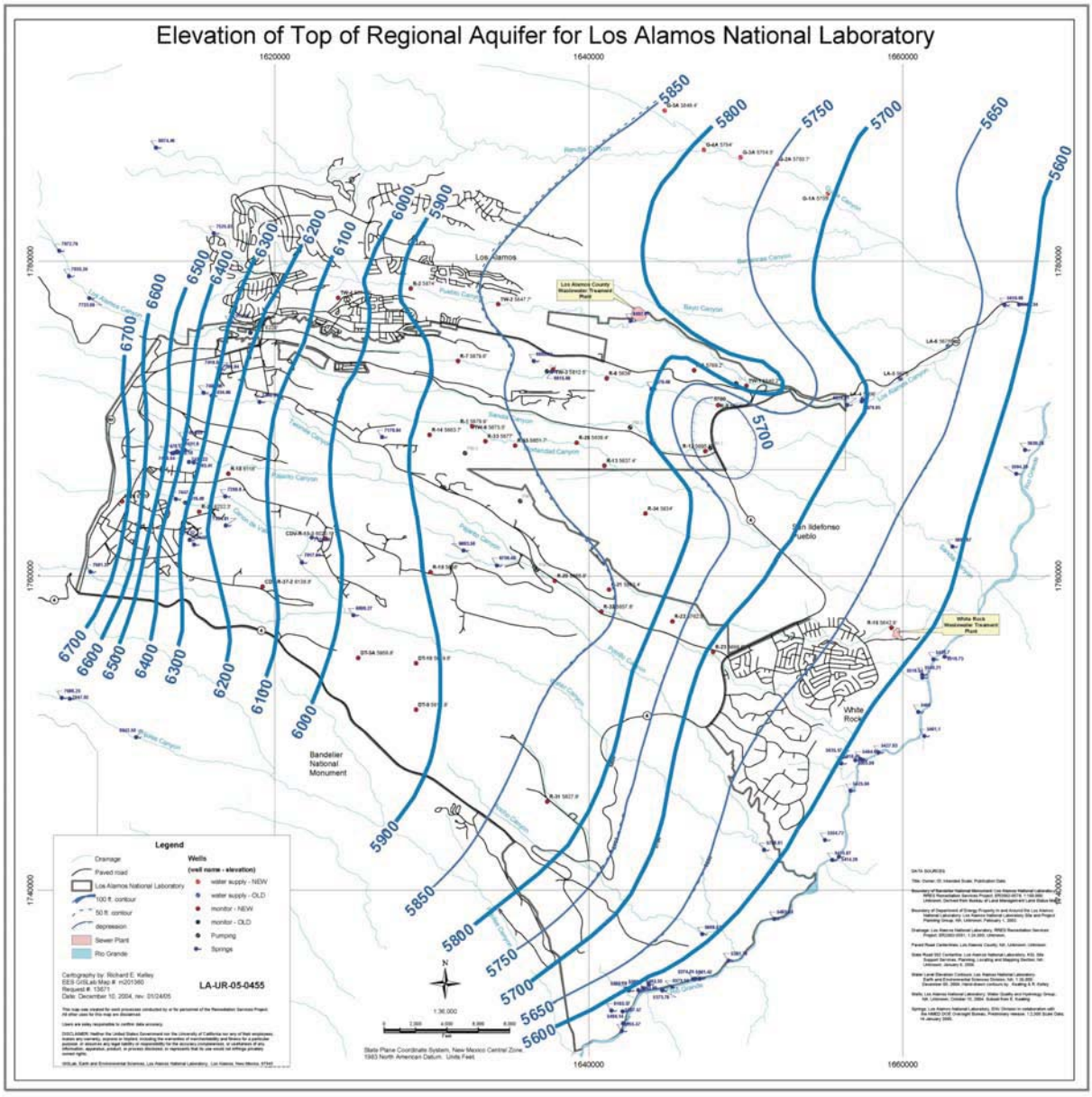


Figure 2-24. Regional aquifer water table map.

We note again that the sedimentary rocks themselves are highly stratified, and so contrasts between layers within these rocks may be as hydrologically significant (or more so) than the contacts between major geologic units described above. Contacts within volcanic units can have significant hydrologic impact. The contacts between lava flows are generally represented by interflow zones that can be very transmissive or, if clay-filled, barriers to flow. One example of a low-permeability, clay-filled interflow zone was that encountered in screen 2 of R-9i. This zone appears to act as a confining bed; water levels rose significantly in the borehole after the well penetrated this zone. Contacts between sedimentary and volcanic rocks can be structurally complex, as in the inferred paleovalley in the eastern part of the plateau that is filled by Cerros

del Rio basalt (Section 2.2.8; Figure 2-8). Groundwater flow from west to east may be more tortuous and possibly diverted when encountering such large-scale structures.

2.4.2.3 Regional Aquifer Hydraulic Conductivity

Inferences based on field-scale testing. Over the last 40 years, hydraulic conductivity has been measured using pump tests and straddle-packer injection tests in 61 locations within the Pajarito Plateau; some locations have been measured multiple times. Table 2-3 presents a compilation of these test results (86 in all). For those wells tested multiple times, or for which multiple interpretations of a single test are available, we selected one representative value for the discussion and analyses below (these are indicated with an asterisk in Table 2-3). All these tests are within the regional aquifer, with the exception of a perched zone in R-9i that is included because it represents a test of saturated basalt. If the screened interval for a test contained at least 50% of a single stratigraphic unit, the test was categorized as representing that unit. Some wells (all the PM wells, for example) are screened across too many rock units and are labeled as "mixed" in Table 2-3.

Figure 2-25 shows a histogram of the 61 hydraulic conductivity values, which range from 0.007 m/day (R-26, screen 2) to 45 m/day (R-28). The geometric mean of these estimates is 0.6 m/day, and the distribution appears to be lognormal, although we ascribe no special significance to this fact, other than to point out that it is a convenient distribution for modeling purposes. Based on the distribution, the standard deviation of the lognormal distribution is 0.76 in units of ln(m/d).

Figure 2-26 illustrates the spatial variation in hydraulic conductivity on the plateau. There are two areas with relatively high hydraulic conductivity ($K > 3$ m/day): the north-central aquifer beneath LANL (TW-2, R-4, TW-3, R-11, R-28, and R-13) and the south-central aquifer beneath LANL (R-19, screen 6, DT-10, DT-9). The location of these zones overlaps the zone of high-yield wells identified by Purtymun (1984). However, based on new geologic data and interpretations, the rocks making up this zone consist of a variety of sedimentary and volcanic units in addition to those attributed to the "Chaquehui Formation" by Purtymun. Also, it is clear that lower conductivity zones also exist within Purtymun's proposed northeast-trending high-production trough, indicating that it is a heterogeneous portion of the aquifer, with locally high and low permeability zones.

Table 2-3.
Estimates of Hydraulic Conductivity from Well Tests on the Pajarito Plateau

Well	Source	Method	m/day	ft/day	Unit	Screen		Comments
						Top	Bottom	
DT-10	Purtymun (1995)	Pump test	4.53	14.87	Tb4	472	475	Tf, Tpt, and Tpf also
R-22-2	McLin and Stone (2004)	Injection	0.01	0.04	Tb4	289	301	Could be a breccia zone
R-31-3	McLin and Stone(2004)	Injection	0.15	0.48	Tb4	203	206	0
R-9i-1	McLin and Stone (2004)	Injection	2.16	7.10	Tb4	331	429	Fractured
R-9i-2	McLin and Stone (2004)	Injection	0.03	0.11	Tb4	82	85	Massive
G-3A	Shomaker (1999)	Pump test	0.45	1.48	Tb1	180	604	
G-5A	Shomaker (1999)	Pump test	0.23	0.75	Tb1	228	604	
R-22-4	McLin and Stone (2004)	Injection	0.16	0.54	Tb1	420	422	Fractured basalt with alteration
CDV-R-15-3-5	Well completion report	Injection	0.08	0.25	Tpf	411	413	0
R-13	McLin and Stone (2004)	Pump test	5.36	17.60	Tpf	292	311	Straddles Tpf/Tpp contact
R-22-3	McLin and Stone (2004)	Injection	0.10	0.32	Tpf	388	390	High glass to clay ratio
R-26-2	Shafer (personal communication)	Pump test	0.00	.002	Tpf	433	440	
R-28	Kleinfelder (2004)	Pump test	45.42	149.00	Tpf	285	292	Tpf according to cuttings, Tpp/Tpf mixture according to geophysics
R-32-3	McLin and Stone (2004)		0.37	1.20	Tpf			
R-11	Kleinfelder (2004)	Pump test	35.51	116.50	Tpp	261	268	Assigned by Broxton and Vaniman
R-19-7	McLin and Stone (2004)	Injection	6.71	22.00	Tpp	558	561	0
R-19-6	McLin and Stone (2004)	Injection	5.67	18.60	Tpp	526	529	0
R-1	Kleinfelder (2004)	Pump test	1.19	3.90	Tpp	314	322	Assigned by Broxton and Vaniman

Table 2-3.
Estimates of Hydraulic Conductivity from Well Tests on the Pajarito Plateau (continued)

Well	Source	Method	m/day	ft/day	Unit	Screen		Comments
						Top	Bottom	
R-34	Shafer (personal communication)	Pump test	1.07	3.5	Tpp	269	276	
TW-8	Purtymun (1995)	Pump test	1.02	3.35	Tpp	290	325	0
R-15	McLin (2004)	Pump test	0.67	2.20	Tpp	292	311	Small portion is Tpf
R-14-2	McLin and Stone(2004)	Injection	0.30	1.00	Tpp	390	404	0
CDV-R-15-3-6	Well completion report	Injection	0.03	0.10	Tpp	499	501	0
R-4	Kleinfelder (2004)	Pump test	5.30	17.40	Tf	242	249	0
O-4*	Purtymun (1995)	Pump test	1.23	4.02	Tf	340	791	Basalt and Tsf, as well
O-4	Stoker et al. (1992)	Pump test	2.18	7.15	Tf	340	791	
O-4	Purtymun et al. (1995)	Pump test	2.88	9.46	Tf	340	791	
G-6	Purtymun (1995)	Pump test	0.27	0.90	Tf	213	460	And basalt and a little Tsf
R-2	Kleinfelder (2004)	Pump test	0.09	0.31	Tf	277	284	Very fine grained with fine-scale bedding
R-22-5	McLin and Stone (2004)	Injection	0.08	0.27	Tf	441	443	High glass to clay ratio
G-1*	Purtymun (1995)	Pump test	0.29	0.94	Tsf	86	604	Also Tf and basalt
G-1	Griggs (1964)	Pump test	0.40	1.31	Tsf	86	604	
G-1	Griggs (1964)	Pump test	0.55	1.79	Tsf	86	604	
G-1A	Purtymun (1995)	Pump test	0.37	1.22	Tsf	83	461	Significant Tf?
G-2*	Purtymun (1995)	Pump test	0.37	1.22	Tsf	86	597	Significant Tf?
G-2	Griggs (1964)	Pump test	0.05	0.16	Tsf	86	597	
G-2	Griggs (1964)	Pump test	0.54	1.78	Tsf	86	597	
G-2A	Shomaker (1999)	Pump test	0.21	0.70	Tsf	172	431	0
G-3*	Griggs (1964)	Pump test	0.27	0.90	Tsf	134	544	Also Tf and basalt
G-3	Purtymun (1995)	Pump test	0.22	0.71	Tsf	134	544	
G-4*	Purtymun (1995)	Pump test	0.46	1.51	Tsf	130	587	Also Tf and basalt

Table 2-3.
Estimates of Hydraulic Conductivity from Well Tests on the Pajarito Plateau (continued)

Well	Source	Method	m/day	ft/day	Unit	Screen		Comments
						Top	Bottom	
G-4	Griggs (1964)	Pump test	0.63	2.05	Tsf	130	587	
G-4	Griggs (1964)	Pump test	0.91	3.00	Tsf	130	587	
G-4A	Shomaker (1999)	Pump test	0.36	1.17	Tsf	200	604	0
G-5*	Purtymun (1995)	Pump test	0.36	1.17	Tsf	141	558	0
G-5	Griggs (1964)	Pump test	0.50	1.65	Tsf	141	558	
G-5	Griggs (1964)	Pump test	0.72	2.35	Tsf	141	558	
LA-1B	Purtymun (1995)	Pump test	0.38	1.25	Tsf	99	516	0
LA-3*	Theis and Conover (1962)	Pump test	0.16	0.51	Tsf	32	264	0
LA-3	Theis and Conover (1962)	Pump test	0.08	0.25	Tsf	32	264	
LA-3	Purtymun (1995)	Pump test	0.13	0.44	Tsf	32	264	
LA-3	Theis and Conover (1962)	Pump test	0.14	0.46	Tsf	32	264	
LA-3	Theis and Conover (1962)	Pump test	0.22	0.72	Tsf	32	264	
LA-2	Purtymun (1995)	Pump test	0.14	0.47	Tsf	32	264	
LA-2*	Purtymun et al. (1995)	Pump test	0.20	0.66	Tsf	32	264	
LA-2	Purtymun et al. (1995)	Pump test	0.36	1.17	Tsf	32	264	
LA-4	Purtymun (1995)	Pump test	0.23	0.76	Tsf	230	599	0
LA-5*	Theis and Conover (1962)	Pump test	0.20	0.67	Tsf	134	530	0
LA-5	Purtymun (1995)	Pump test	0.12	0.40	Tsf	134	530	
LA-6*	Purtymun, (1977)	Pump test	0.29	0.96	Tsf	128	542	0
LA-6	Purtymun (1977)	Pump test	0.22	0.73	Tsf	128	542	
LA-6	Purtymun (1995)	Pump test	0.37	1.22	Tsf	128	542	

Table 2-3.
Estimates of Hydraulic Conductivity from Well Tests on the Pajarito Plateau (continued)

Well	Source	Method	m/day	ft/day	Unit	Screen		Comments
						Top	Bottom	
O-1*	Purtymun (1995)	Pump test	0.19	0.63	Tsf	310	755	Thin basalt
O-1	Purtymun et al. (1993)	Pump test	0.25	0.81	Tsf	310	755	
R-16-2	McLin (2005; personal communication)	Pump test	0.49	1.6	Tsf	187	187	
R-16-3	McLin (2005; personal communication)	Pump test	0.61	2.0	Tsf	306	314	
R-16-4	McLin (2005; personal communication)	Pump test	0.49	1.6	Tsf	367	392	
TW-2	Purtymun (1995)	Pump test	9.84	32.29	Tpt	234	251	0
TW-3	Purtymun (1995)	Pump test	4.90	16.08	Tpt	245	248	0
R-31-4	McLin and Stone (2004)	Injection	3.38	11.10	Tpt	252	255	0
R-31-5	McLin and Stone (2004)	Injection	2.53	8.30	Tpt	307	310	0
TW-1	Purtymun (1995)	Pump test	0.16	0.54	Tpt	193	196	0
R-32-1	McLin and Stone (2004)	Injection	1.28	4.20	Tpt			
CDV-R-37-4	Well completion report	Injection	3.46	11.36	Tt	472	475	0
CDV-R-37-3	Well completion report	Injection	2.14	7.01	Tt	472	475	0
TW-4	Purtymun (1995)	Pump test	0.78	2.55	Tt	364	367	0
PM-1	Purtymun (1995)	Pump test	1.26	4.15	Mixed	288	756	
PM-2	Purtymun (1995)	Pump test	1.14	3.75	Mixed	306	695	
PM-3	Purtymun (1995)	Pump test	7.31	23.99	Mixed	291	772	
PM-4	Purtymun (1995)	Pump test	0.98	3.22	Mixed	384	870	
PM-5	Purtymun (1995)	Pump test	0.22	0.71	Mixed	439	936	
DT-5A	Purtymun (1995)	Pump test	0.69	2.28	Mixed	357	555	
DT-9	Purtymun (1995)	Pump test	4.98	16.35	Mixed	317	457	

An asterisk (*) after a well number indicates inclusion in statistical summaries.

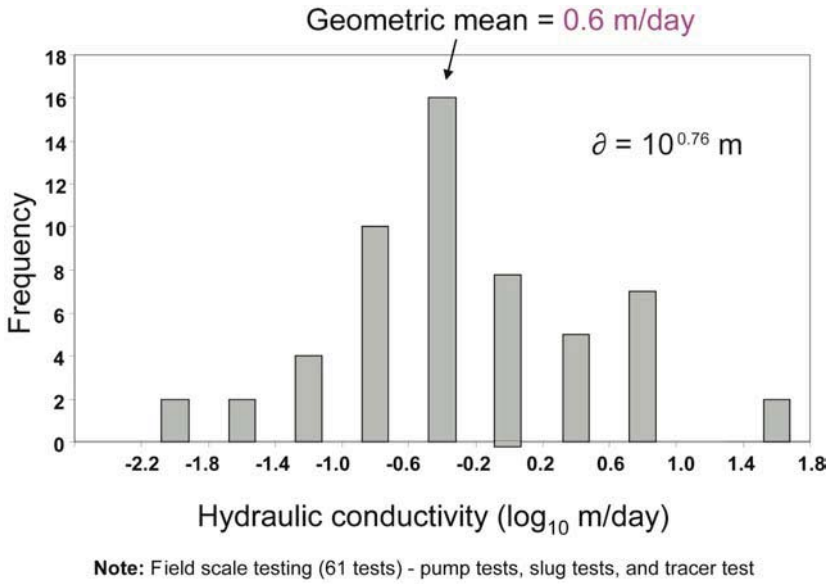


Figure 2-25. Distribution of hydraulic conductivity estimates, derived from tests of 59 wells on the plateau; N = 59; geometric mean = 0.6 m/day.

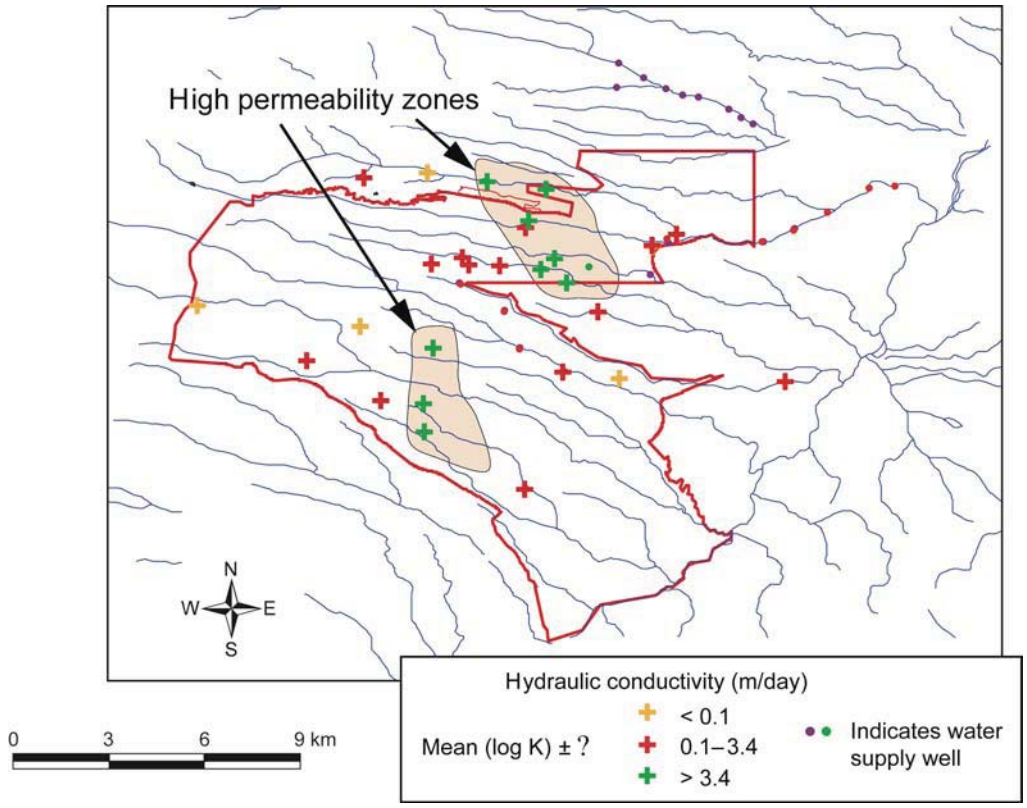


Figure 2-26. Hydraulic conductivity estimates in the regional aquifer. If multiple screens have been tested at a single location, the uppermost result is shown. Red line is the outline of the Laboratory.

In several wells there are multiple estimates of hydraulic conductivity at different depths (R-22, CDV-R-15-3, CDV-R-37-2, R-16, R-31, R-19, R-9i); in these cases we show the uppermost screen result in Figure 2-26. Only two of these wells, R-9i and R-31, show significant difference in hydraulic conductivity with depth. R-31, screen 3 (uppermost regional aquifer screen), completed in basalt, is very poorly conductive. The two lower screens, 4 and 5, completed in the Totavi Lentil, are very conductive. For this reason, they are shown in Figure 2-26 as connected to the southern high permeability zone. Both screens in R-9i are completed in basalt. The upper conductive screen is located in an interval that includes highly fractured basalt and an interflow zone, and the lower nonconductive screen is located within clay-filled interflow breccia at the base of the basalt sequence. The other wells (R-22, CDV-R-15-3, CDV-R-37-2, and R-19) show consistent results in all screens. This is particularly interesting in the case of R-22 and CDV-R-15-3, where the screens are located in a variety of rock units.

The hydraulic conductivity values for major rock units of the regional aquifer are shown in Figure 2-27 and summarized in Table 2-4. Cerros del Rio basalt, Puye Formation, pumiceous volcaniclastic rocks, Totavi Lentil, older fanglomerate, and Santa Fe Group sands are clearly heterogeneous. The Santa Fe Group sandy unit (Tesuque Formation) appears to be more uniform, although many of the wells representing this unit have very long screens (>300 m), which would tend to smooth the effect of small-scale heterogeneity. Nonetheless, the short screens within Tesuque sands tested at R-16 gave results similar to those obtained from wells with long screens.

The variation within the Cerros del Rio basalt may be related to whether the tested interval contains abundant open fractures (as reported at R-9i, screen 1) or is a clay-filled interflow zone (reported at R-9i, screen 2). All three tests within the Tschicoma Formation represent interflow zones and/or breccia and show relatively high permeability. Both outcrop and borehole observations suggest that much of the Tschicoma Formation is, in fact, massive and so these tests of breccia zones may not be representative of the larger aquifer unit. Some of the low permeability measurements in the Cerros del Rio basalt may represent clay-filled fractures in flow interiors or clay-filled interflow breccia zones.

A number of factors could explain the variability of hydraulic conductivities within the Puye, the Totavi, and the Santa Fe Group fanglomerate, including different degrees of alteration (clay content) and intraformational depositional facies (e.g., stream channel versus overbank deposits). Depositional facies are characterized by different grain sizes and degrees of sorting, but bedding characteristics and rock fabric are needed to evaluate the depositional setting. Bedding and rock fabric cannot be identified from drill cuttings, however borehole geophysical tools such as FMI logs can provide information that may be relevant (Table 2-5). In some cases, depositional environments inferred from FMI logs (Table 2-5) appear to be related to measured hydraulic conductivities. For example, the coarse-grained, poorly sorted gravels and cobbles in CdV-R-15-3, screens 5 and 6, are consistent with deposits expected in proximal alluvial fan deposits. The K values measured here (0.08 and 0.03 m/day, respectively) are lower than most on the plateau. The four highest conductivity zones in Tpf or Tpp, measured in R-28, R-11, R-4, and R-13, are associated with well-bedded sands and gravels with sparse cobbles located in the medial portion of the Puye alluvial fans. Fractures are visible in the screened intervals of the R-11 and R-13 wells.

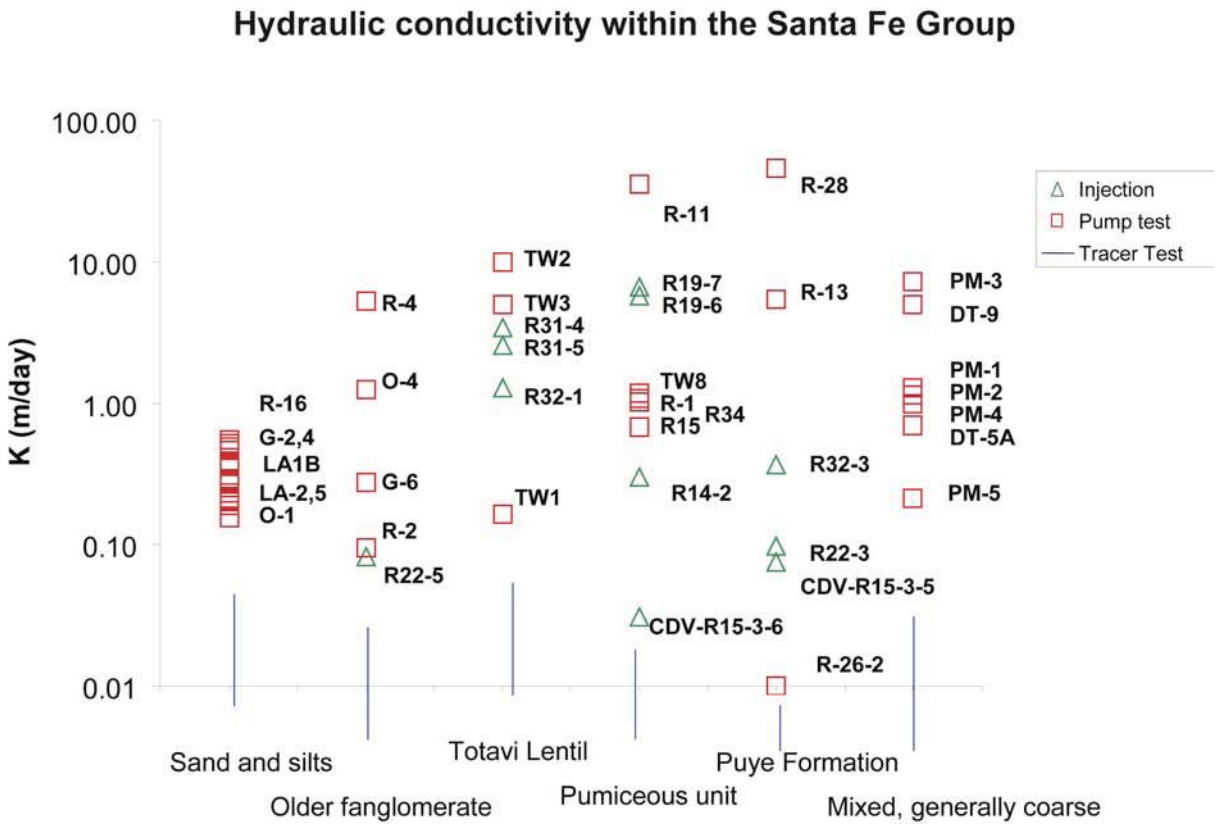


Figure 2-27-a. Hydraulic conductivity within the Santa Fe Group. (See Table 2-3 for a list of wells.)

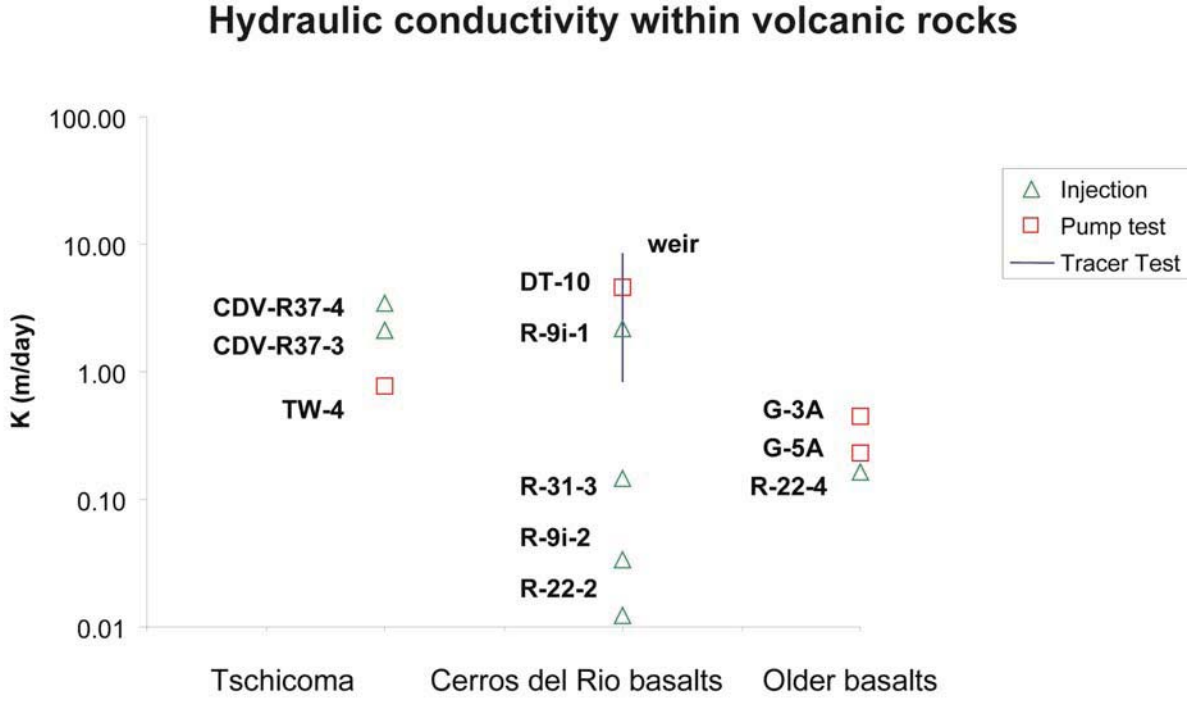


Figure 2-27-b. Variation of hydraulic conductivity in volcanic rocks of the Pajarito Plateau.

Table 2-4.
Summary Table of Hydraulic Conductivity for Each Hydrostratigraphic Unit

Unit		Number of Wells	m/day	Max m/day	Geometric Mean
Cerros del Rio		5	<0.1	4.5	0.2
	Older	3	0.2	0.6	0.3
Puye	fanglomerate	6	.007	45	0.4
	pumiceous	9	0.3	36	1.3
Totavi		5	0.2	9.8	2.1
Santa Fe Group	Fanglomerate	5	0.1	5.3	0.4
	Sandy	18	0.2	0.5	0.3
	(off plateau data)*	15	<0.1	4.4	0.1
Tschicoma		3	0.2	9.8	0.9

Source: Daniel B. Stephens (1994)
Note: An asterisk (*) means reported in the literature by numerous workers.

There are exceptions to these trends, however. For example, screen 3 of R-32 is also completed in the medial portion of Puye Formation alluvial fans, but has lower conductivities than the wells listed above. The screened interval in R-28 does not show evidence of fractures, yet it has a higher conductivity than does R-11, which is screened across an interval containing several fractures.

The possible influence of alteration can be examined by comparing the percentage of clay present in a hydrostratigraphic unit to the spatial variation in permeability. As shown in Figure 2-28a, there is a tendency for the Puye Formation and pumice-rich volcaniclastic rocks to be more altered in the southeastern portion of the plateau, which may explain the low K values estimated for R-22, screen 3 and R-32, screen 3. However, low clay content is not necessarily associated with higher conductivity. R-26, screen 2 in the western part of the plateau has low clay content and a low K value. Presumably a combination of facies distributions and post-depositional alteration are contributing to the complex patterns evident in Figure 2-26. Data on which to base these results are somewhat limited, and additional data collection could shed light on this issue.

There is no readily apparent correlation between alteration trends in the pumiceous unit (Figure 2-28b) and hydraulic conductivity. In fact, the lowest K values reported for this unit (CDV-R-15-3, screen 6, and R-14, screen 2) are both in regions of lowest clay content. With the limited data available, it appears that alteration within the pumiceous unit is not the only factor controlling hydraulic conductivity.

Table 2-5.
Summary of Formation Micro-Image (FMI) Data Derived from Borehole Geophysics

Drillhole	K m/day	Unit	Texture	Bed thickness	Orientation	Fractures	Effective porosity	Comments
R-26	0.002	Tpf	Very coarse, crude bedding, boulders 2 ft tall	Most are 5–10 ft (some are 0.5 ft)	10–40°	nd	2–0%	Similar to outcrops in upper Guaje, vertical k should be large, probably is colluvium (like at the bottom of a fault scarp)
CDV-R15-3-5	nd	nd	Discrete packages of coarse and fine layers, 1520% is boulder beds, rest is sand and gravels, perhaps thin clay beds, overlapping channel deposits and some overbank	1–5 ft (sand beds are 1 ft)	nd	nd	nd	Coarse layers are comparable to R-26
CDV-R15-3-6	nd	nd	Coarser than screen 5, mostly discrete sand bodies (above screen in sandpack are gravel and coarse sands)	0.5–5 ft	nd	nd	nd	Similar to outcrops in upper Rendija Canyon
R-13	17.6	Tpf (upper half of screen)	Sand and gravel beds, a few cobbley lenses	1 ft–3 ft	nd	One 8' vertical, another dipping, intersecting 2 ft of screen	>60%	Medial fan
	nd	Tpp (upper half of screen)	Fine bedding, intercolated in coarser beds of gravels and cobbles	2-6 in.	nd	nd	nd	
R-11	116.5	Tpp	No fine-grained beds, very stratified	0.5 ft (up to 3 ft)	<10°	Fractures visible (one 2 ft long)	5–10%	
R-28	149	Tpf	Very similar to R-11, very stratified, perhaps can correlate beds	nd	5–10° (S and E)	None visible	15–60%	

Table 2-5.
Summary of Formation Micro-Image (FMI) Data Derived from Borehole Geophysics (continued)

Drillhole	K m/day	Unit	Texture	Bed thickness	Orientation	Fractures	Effective porosity	Comments
R-4	17.4	Tf	Mostly sands and gravels, very sparse cobbles, very stratified	Few tenths up to 1 ft	5–0° (30° max)	nd		
R-2	0.31	Tf	Coarser, 15% cobbles, the rest is sand and gravels	Most are 1–2 ft (range 0.5–3 ft)	Many dips are to the west	nd	5–10%	
R-16-2	1.6	Tsf	Sands and silts, a little gravel (10% or less)	0.1–1.5 ft	2–10° variable direction	nd	nd	
R-16-3	1.8	Tsf	Sands and silts, sand beds are massive (2' thick)	nd	10–5° dip, strongly westerly	nd	nd	
R-16-4	1.7	Tsf	Fine laminar bedding, silts sands, perhaps some cross-bedding	0.1 ft or less (max of 0.5 ft)	10–0° (to the west)	nd	nd	
R-34	3.5	Tpp	Fairly coarse, gravels with some cobble beds, lesser amount of sand	Mostly 3 ft (0.5 to 4 ft)	Not many data, 5–10°	Most commonly 35% (10–60)	nd	Pumice looks mostly reworked, possibly one fall bed

Note: nd = no data

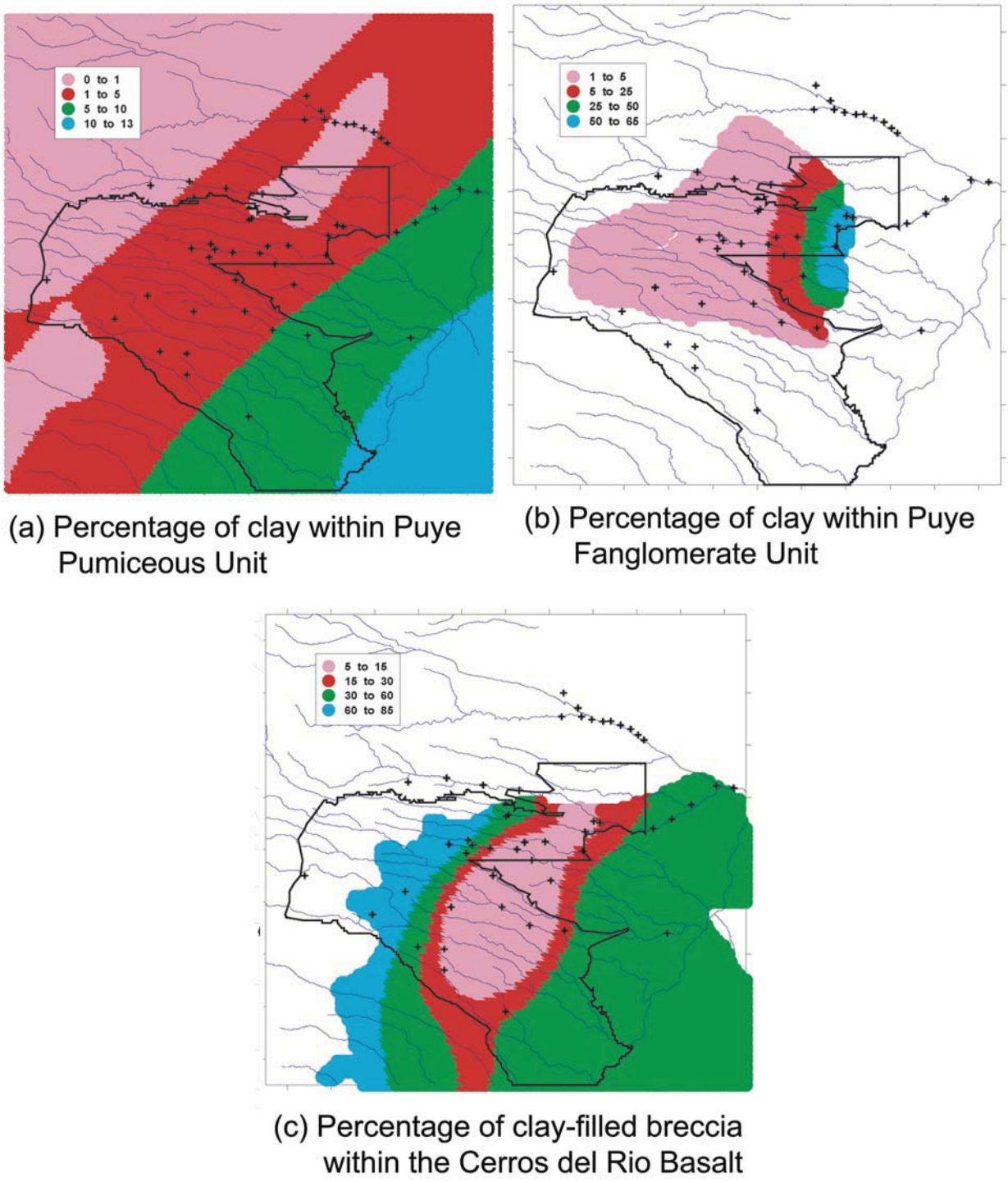


Figure 2-28. Comparison of the percentage of clay present in a hydrostratigraphic unit to the spatial variation in permeability: (a) percentage of clay within the Puye pumiceous unit; (b) percentage of clay within Puye fanglomerate unit; (c) percentage of clay-filled breccia within the Cerros del Rio basalt.
Note: + = well locations

The percent of clay-filled breccia within the Cerros del Rio basalts (Figure 2-28c) is relatively high to the southeast and this factor may explain the low K value estimated for R-22, screen 2 and R-31, screen 3. These areas coincide with the topographically-highest part of the Cerros del Rio basalts on the Pajarito Plateau, and they probably are proximal volcanic vent areas. The low values for K and high degrees of alteration here, both within the basalts and within the Puye, suggest that hydrothermal alteration may have affected the rocks in this area.

Despite the evident variability in most of the rock types, the average properties of the rocks derived from our limited data sets show a few distinctions. The geometric mean hydraulic conductivity of the pumice-rich unit and Totavi Lentil appear to be significantly greater than the other rock types (Table 2-4). At large scales, this trend may be important for flow and transport calculations. At small scales, however, the variability evident in both these rock types will be very important to consider. Local flow directions in the vicinity of release locations and water supply wells are likely to depend strongly on these small-scale differences in hydrologic properties.

Inferences based on hydraulic gradients. Head gradients will tend to be larger in low permeability rocks, and so head data can be used, at least in a qualitative way, to infer information about permeability. Other controls on head gradients, such a recharge and pumping, complicate this approach. It is evident from the water table map (Figure 2-24) that there is large spatial variation in head gradients at the top of the aquifer. If these variations were entirely or mostly due to variations in permeability, we might conclude that rocks and structures on the western portion of the plateau (Tschicoma Formation, Pajarito Fault zone) have relatively low permeability. However, mountain-front recharge creates hydrologic conditions that lead to larger gradients, even if the rocks were homogeneous. In addition, there is an increase in permeability towards the center of the plateau (older fanglomerate, pumiceous rocks, Puye Formation and Cerros del Rio basalts). The gradient is relatively steep in the vicinity of R-22, where hydraulic testing indicates very low permeability (locally) in the Cerros del Rio basalts.

2.4.2.4 Anisotropy

As mentioned above, bedding within the Santa Fe Group and the Puye Formation is likely to cause higher permeability parallel to beds than perpendicular to beds. Large vertical head gradients measured in R wells are evidence of anisotropy; persistent vertical gradients are presumably caused by intermittent low-permeability strata that provide resistance to vertical flow. The beds within the Puye Formation range from centimeters to meters in thickness. Most are very low angle, dipping to the east. In contrast, beds within the pumiceous volcaniclastic rocks tend to dip to the southwest (R-20, R-2, R-7, R-19, and R-33). Beds within the Santa Fe Group exposed on the eastern margin of the plateau dip approximately 2–5° to the west (Golombek et al. 1983). Data from R-16 suggest that shallow layers are very low-angle, but deeper layers dip as much as 14° to the west. Hydrologic modeling and pump test analysis suggests that vertical permeability is 100 to 1000 times lower than horizontal permeability in the Santa Fe Group silts and sands (Hearne, 1985; McAda and Wasiolek, 1988; Keating et al., 2003).

If the north-south trending fault zones on the plateau tend to be barriers to flow, this would cause horizontal anisotropy, with north-south permeability higher than east-west permeability. Multiple-well pump tests on the plateau could be used to test this hypothesis.

2.4.2.5 Porosity

Tracer tests, which provide the most valuable information about effective porosity, have not been conducted in the saturated zone at this site. The only available data come from interpretations of borehole geophysical logs, using the combined magnetic resonance (CMR) tool. Using only data from the Puye Formation and the pumice-rich volcaniclastic rocks within the saturated zone, estimates of total porosity based on geophysical logs from R-7, R-19, and CDV-R-15-3 have been compiled. Figure 2-29 shows the distribution of these estimates, with data collected at 0.5 ft intervals. Table 2-6 summarizes the data. The mean effective porosity for these units as estimated from these logs (0.01–0.2) are somewhat low for sedimentary rocks (0.1–0.3, from Freeze and Cherry 1979). There is some indication that these values relate to hydraulic conductivity. For example, CDV-R-15, which has a high proportion of very low effective porosity measurements, also has a relatively low hydraulic conductivity (0.03–0.08 m/day; Table 2-6). R-19 has higher mean effective porosities and higher K values (5.7–6.7 m/day). However, there are significant differences in effective porosities between screens 5 and 6 in CDV-R-15 that do not correlate with differences in hydraulic conductivity.

Table 2-6.
Summary of Effective Porosity Estimates based on Borehole Geophysics

Well	Mean Effective Porosity	N	Formation	Hydraulic Conductivity (m/day)
CDV-R-15[a]	0.07	744	Tpf, Tpp	-
CDV-R-15-4	0.06	87	Tpf	-
CDV-R-15-5	0.01	13	Tpf	0.08
CDV-R-15-6	0.16	15	Tpp	0.03
R19[a]	0.1	1466	Tpf, Tpp	-
R19-6	0.2	14	Tpp	5.7
R19-7	0.2	15	Tpp	6.7
R7[a]	0.09	293	Tpf, Tpp	-

[a] all depths within Puye Formation
Note: - = no data
Note: For comparison, hydraulic conductivity values derived from in situ testing (Table 2-3) are also shown.

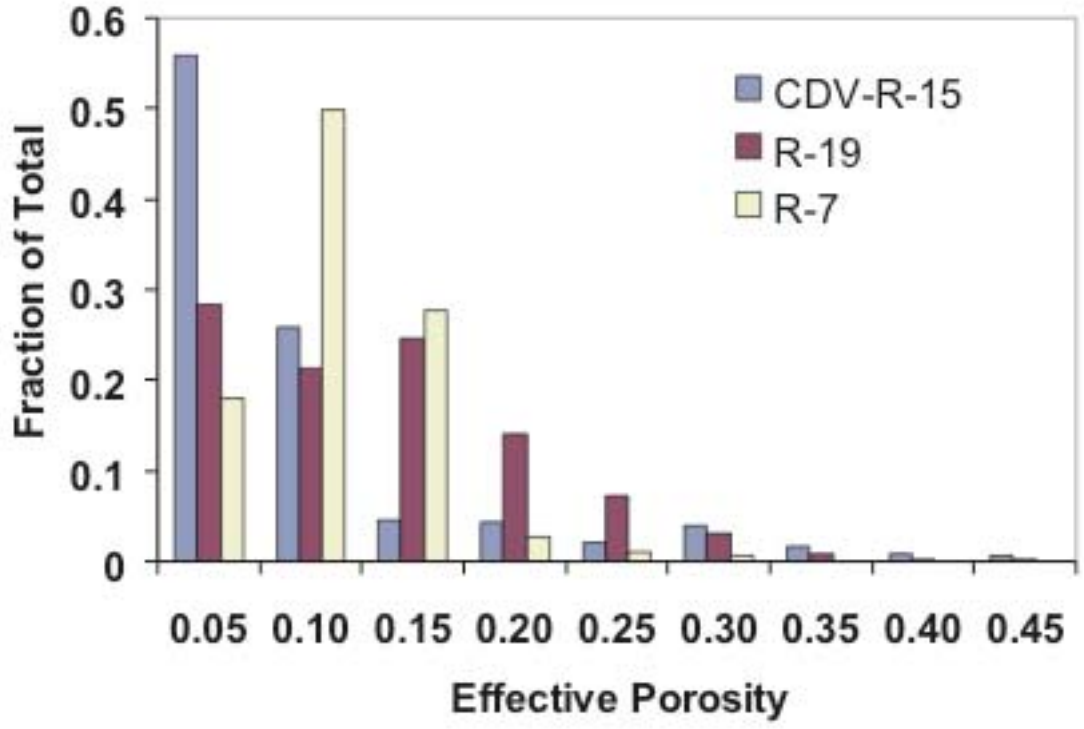


Figure 2-29. Distribution of effective porosity measured within the Puye Formation beneath the regional aquifer water table.

2.4.2.6 Storage Properties

Storage properties of rocks will depend on whether the aquifer is unconfined or confined; delineating these two conditions beneath the plateau has been difficult. There are a number of interpretations in the literature about the degree and extent of confined conditions on the Parjarito Plateau. Based on limited data, Cushman (1965) concluded that the aquifer is under water table conditions beneath the plateau, with the exception of the vicinity of the Rio Grande where water table conditions exist in shallow layers and confined conditions exist at depth. Purtymun (1974) suggested that water table conditions exist on the western margin of the plateau and artesian conditions exist along the eastern edge and along the Rio Grande. Recent drilling has confirmed the existence of water table conditions at many locations beneath the plateau. Pump test results for water supply wells, drilled to depths up to 2000 ft below the water table on the plateau, suggest that the deeper portions of the aquifer behave as either:

- "Leaky confined" in the Los Alamos well field, specific storage $S_s \sim 10^{-4.8}$/m (Theis and Conover, 1962); and in O-4, $S_s \sim 10^{-5.5}$/m (Purtymun et al., 1995a and 1995b) or
- Unconfined in O-1, $S_s \sim 10^{-3.8}$/m (Purtymun et al., 1990, Purtymun and McLin, 1990).

In the LA wellfield, Theis and Conover (1962) expanded on the "leaky confined" interpretation by stating that there are, in fact, several aquifers and several semiconfining beds in this well field. Just to the southeast, along the Rio Grande, the aquifer has been called "partially confined" (Balleau Groundwater, 1995).

Drilling activities conducted during the Hydrogeologic Workplan have shown that in most R-wells, at all screens, the aquifer is unconfined. Heads tend to decrease with depth (see Figure 2-45, Section 2.7.7). In the shallowest portion of the aquifer (the upper 150 m), specific yield is presumably dominated by effective porosity (see Table 2-6 for estimates in the Puye Formation). Specific yield is likely to be very low for basalts. No new information is available for the deeper, leaky-confined portions of the aquifer.

2.4.3 Summary of Hydrologic Properties

Pump test data (Table 2-3, Figures 2-26 and 2-27) illustrate the heterogeneity of the aquifer, with K values ranging from 0.007 to 45 m/day The geometric mean hydraulic conductivity is 0.6 m/day; the larger-scale effective permeability may be lower due to large-scale structures and/or untested, low-permeability portions of the aquifer, based on the lower permeability values obtained in regional aquifer model calibrations (Section 4.2). Table 2-2 presents a summary of inferred properties of each of the lithologies present in the regional aquifer.

Heterogeneity tends to be particularly significant in the Puye Formation, pumiceous volcaniclastic rocks, Totavi Lentil, and older fanglomerate. The wide variety of depositional environments within the Puye Formation are consistent with this observation. However, it is difficult to go beyond this general statement to develop a predictive relationship between facies and hydrologic properties. On average, the permeabilities of the Puye Formation, pumiceous volcaniclastic rocks, Totavi Lentil, and older fanglomerate are similar and ranges of permeability overlap one another.

As shown in Figure 2-26, there appear to be two zones near the top of the aquifer that are particularly conductive (>3 m/day). These zones are not correlated with hydrostratigraphy, suggesting that structure or alteration may be the controlling factor. No high permeability zones occur east of R-13. Large-scale trends in alteration (Figure 2-28) do not explain the location of these zones; although alteration may be an important factor in the location of a low-conductivity zone in the southeast (R-31 and R-22).

The older fanglomerate unit is also heterogeneous, consistent with its probable depositional history. The Tesuque sandy unit appears to be less heterogeneous, due to the dominance of relatively well-sorted sand and silt layers (Section 2.2.1). Discrepancies between pump test data and model-calibrated values suggest the possibility that large-scale structures such as north-south trending faults may lower the large-scale effective permeability of this unit.

Permeabilities of volcanic rocks appear to be bimodal, presumably a function of whether the groundwater is associated with fractures in flow interiors or is found in interflow zones between lavas. The amount of clay filling pore space in these settings can also affect permeability. Permeabilities of the fractured Tschicoma and Cerros del Rio lava flows are of the order of 1 to 9 m/day; permeability of poorly fractured flow interiors or clay-filled fractured units is much lower (<0.15 m/day). Limited data on Bayo Canyon basalts suggest an intermediate permeability.

Based on the depositional environment (Figure 2-21) of the Puye Formation and the Santa Fe Group, strong anisotropy (horizontal K >> vertical K) is predicted. This is confirmed by modeling studies, pump test analyses, and by the presence of large vertical gradients in many R-wells. The ratio of horizontal to vertical K may be as large as 1000 (see Section 2.4.2.3). If north-south trending low-permeability faults exist within these units (as modeling results suggest; Keating et al., 2003), this would tend to cause horizontal anisotropy.

Although porosity data are limited, geophysical logs indicate that the effective porosity of the sedimentary rocks is relatively low (0.07–0.2). Small-scale data from these geophysical logs need to be augmented by interwell tracer tests to obtain larger scale, transport-related porosity values that can be used in numerical models and transport-velocity estimates.

2.4.4 Uncertainties in the Relationship between Geologic and Hydrogeologic Units

This section describes uncertainties and sources of error in defining the relationships between hydrogeologic properties and lithology. Three of the uncertainties described here are large scale, in that they reflect the reliability of stratigraphic assignments. The large-scale uncertainties are:

- Extent and hydrogeologic nature of the Cerros del Rio unit
- Unassigned pumiceous sediments of uncertain age
- Totavi variants (see Section 2.4.4.3 below)

The remaining two uncertainties are small scale, in that they address uncertainties in the composition within a single stratigraphic unit or of a single property. The small-scale uncertainties are:

- Disposition of Santa Fe Group sediments
- Spatial variation in permeability within sedimentary rocks

2.4.4.1 Extent and Nature of the Cerros del Rio Hydrogeologic Unit

The Cerros del Rio hydrogeologic unit straddles the top of regional saturation across much of the southeastern portion of the LANL site (Figure 2-10). The thickness of the unit has proved difficult to predict in critical areas (e.g., drillhole R-22 within TA-54) because multiple flows from different source areas accumulated as stacked sequences in topographically low areas. The nature of the volcanic deposits is highly variable and has led to difficult drilling, as at R-34 where the drill site appears to have been located above a buried cinder cone with no surface expression and unknown shape and lateral extent (Figure 2-14). Data from the basalt field in the Snake River Plain indicate that permeability in basaltic volcanic sequences can vary by 10 orders of magnitude from the laboratory to the field scale, and the flow field can be strongly anisotropic (Whelan and Reed, 1997). Drilling experience in this unit at LANL shows that air permeability can be very high; open boreholes generally "breathe" with diurnal barometric variation as soon as they penetrate into the Cerros del Rio deposits. All of these features indicate significant importance of the Cerros del Rio in flow and transport. At present the 3-D geologic model allows for estimation of relative percent of flow interior, open breccia, and clay-filled breccia for each borehole, but such distributed percentages may not be sufficient for adequate hydrogeologic characterization where stochastic flow simulation may require knowledge of volcanic stratigraphy (Whelan and Reed, 1997). In addition, a conceptual model describing the characteristic length scales of the basalt subunits would also be required.

2.4.4.2 Unassigned Pumice-Rich Volcaniclastic Rocks

The extent of clay alteration in pumiceous sediments can be a critical hydrogeologic parameter, for the unaltered deposits are highly transmissive whereas local zones of extensive clay alteration transform the pumice-rich intervals into aquitards. Extensive pumiceous sediments (Figure 2-9) are widely distributed beneath Puye fanglomerates in the central portion of the LANL site. This unit is not known in outcrop and was not anticipated when drilling for the Hydrogeologic Workplan began. Radiometric dates of 6.8 and 7.5 Ma from pumice in this unit suggest a possible relationship with Peralta Tuff to the south, but petrographic variation and stratigraphic occurrence indicate that multiple volcanic sources supplied tephra to these deposits. The pumiceous sediments in R-9 and R-12 are completely altered to smectite, whereas other occurrences have little clay and are essentially unaltered. It is uncertain whether the altered and unaltered pumice units are related. This uncertainty can have considerable impact on how the pumiceous deposits are represented in cross-section for the conceptual geologic model (see Figure 2-12) and in 3-D for the numerical geologic model, as well as having an impact on flow and transport properties.

2.4.4.3 Totavi Variants

The Totavi may be an important transmissive unit at the site, providing a significant flowpath where laterally contiguous, making the treatment of this unit in the 3-D numerical geologic model particularly important. The axial deposits left by paleochannels of the Rio Grande are well defined in outcrop by their high abundance of Precambrian lithologies derived from northern sources. Dethier (1997) provides extensive data for these deposits exposed along the eastern margin of the LANL site; his definition of the Totavi notes that it contains "generally >80%

quartzite and other resistant lithologies from northern New Mexico, but clasts from the southern Sangre de Cristo range are common locally." The high quartzite abundance is distinctive. Previous conceptual models of the LANL site geology have extended these axial gravels in a continuous unit beneath the site as a horizon underlying Puye fanglomerates. More recent drilling has provided evidence of many stream gravels at varied stratigraphic levels, most with a smaller abundance of Precambrian stream gravels (generally <25% Precambrian gravel) and with more gravels from volcaniclastic sources. Furthermore, new radiometric dates on pumice-rich volcaniclastic rocks indicate that underlying river gravels are considerably older than the Totavi deposits exposed on the east side of the plateau. The construction of a Totavi unit is thus problematic, with some areas where the stream gravels are moderately extensive and other areas with isolated channels (e.g., cross-sections in Figures 2-12 and 2-13). Therefore, the representation of the Totavi unit within the geologic framework model is illustrative.

2.4.4.4 Disposition of Santa Fe Group Sediments

The impact of distinguishing different lithologies of Santa Fe Group sediments can be of hydrogeologic significance in defining the extent of more productive gravels and in construction of hydrogeologic unit boundaries. The Santa Fe Group sediments exposed in outcrop along the eastern margin of the LANL site consist of sands and lesser stream gravels, commonly with some amount of carbonate cement, that are derived predominantly from plutonic and metamorphic Precambrian sources. The 1997 conceptual geologic model for the site projected extensive amounts of Santa Fe Group sediments beneath the site that were predicted to be encountered by most drillholes deeper than ~1000–1500 ft. Furthermore, the central and most hydrologically productive zone was interpreted as consisting of deposits of equivalent age that contained more abundant volcaniclastic material. More recent drillholes have found that this deeper volcaniclastic material is predominantly of Jemez-derived lithologies and is distinct from the generally arkosic deposits of the Tesuque Formation. Recent work in the Española Basin suggests that "lithosomes" of the Santa Fe Group grade laterally and interfinger, as fault displacements episodically dropped the western margin of the basin. However, the downdropping western margin of the basin, which is beneath the LANL site, may also have been the locus of past flow for major drainages. At this time it is uncertain whether the lithologic variations in these older sediments beneath the site reflect interfingered facies of similar age or unconformable, younger channel deposits in paleocanyons cut into the older Santa Fe Group sands. Resolution of this uncertainty could confirm or rule out the existence of long-distance, high-permeability pathways in the regional aquifer.

2.4.4.5 Spatial Variation in Permeability within Sedimentary Rocks

With the exception of the relatively uniform sandy sub-unit of the Santa Fe Group, variability within hydrostratigraphic units tends to be much larger than variability between hydrostratigraphic units. To understand intra-unit variability, using limited data the possible role of texture (Table 2-5) and alteration (Figure 2-28) have been examined and no consistent relationships were found. There does not appear to be a method to deterministically interpolate the spatial variation in permeability within these sedimentary rocks, given the available data. It is possible that a larger dataset and better information about sedimentary facies (if cores were available, for example) would allow a better understanding of the mechanisms controlling hydraulic conductivity. Even so, local variation may be sufficiently great that accurately

interpolating point data (tests at wells) within a deterministic 3-D framework model from known point estimates may not be feasible.

For the purposes of modeling flow and transport through sedimentary rocks in the saturated zone, it may be more appropriate to use a probabilistic approach based on the statistical properties of the hydraulic conductivity dataset rather than a deterministic approach based on defined geometries of hydrostratigraphic units (Section 4.2.10). Another promising method may be to use head data directly to infer heterogeneities in the aquifer (Doherty et al., 1994).

Although the data suggest there are no large differences in permeability between the volcanic and sedimentary rocks, differences in porosity and storage characteristics are likely to be large. For this reason, it is important to delineate the extent of the volcanic rocks in a 3-D framework model of the site for the purposes of flow and transport modeling.

Available porosity data are very limited; more data could be derived from existing borehole geophysical logs and perhaps a geostatistical model of porosity could be built from those logs.

2.4.4.6 Influence of Structure on Groundwater Flow

The influence of structures on groundwater flow is uncertain, but the evidence suggests that structure plays a role in groundwater flow beneath the Pajarito Plateau. First, the large head gradients across the Pajarito fault zone indicate that the faults exert control on flow. Associated modeling results described in Section 4.2.10 suggest that the Pajarito fault zone and north-south trending faults in the Santa Fe Group may act as flow barriers at large scales. Zones of high permeability in the center portion of the plateau (Figure 2-26), which cross hydrostratigraphic boundaries, suggest that perhaps large-scale features such as faults play an important role here.

Further interdisciplinary work combining geophysics, geochemistry, hydrology, and geology investigations would be required to better understand the processes controlling variability in aquifer properties at this site. Given the large heterogeneities in flow and transport properties and the complexities of the hydrogeologic formations, it is unlikely that transport models can ever be based purely on a deterministic hydrogeologic framework. Rather, models should be based on a blend of deterministic (e.g., 3-D hydrogeologic framework models) and geostatistical approaches.

2.5 Alluvial Groundwater Conceptual Model

The alluvial groundwater conceptual model is based on data collected during investigations of alluvial groundwater systems at LANL that have been conducted to meet various objectives not specific to the Hydrogeologic Workplan (Appendix 1-A). Most of the early investigations were driven by alluvial groundwater contamination concerns in canyons with persistent alluvial saturation along significant segments of the canyon, and most of the early investigations were conducted in Mortandad Canyon. Examples of these studies include those conducted by Purtymun (1974), Purtymun et al. (1983), and Stoker et al. (1992). Many of these investigations were conducted in collaboration with the United States Geological Survey. Additional investigations conducted in the mid-1990s measured alluvial aquifer properties (Koening and Guevara, 1992) and calculated bulk groundwater flow velocity (Gallaher, 1995). Purtymun

(1995) contains a significant body of additional information and references pertaining to alluvial groundwater investigations conducted at the Laboratory up to the mid-1990s.

2.5.1 Physical Setting

Average annual precipitation across the Pajarito Plateau ranges from over 0.5 m along the western boundary near the Jemez Mountains to less than 0.36 m to the east at the Rio Grande (Bowen, 1990). Most precipitation occurs either as winter/spring snow or as summer "monsoonal" rains. As a result, most infiltration occurs episodically during spring snowmelts or during the intense summer thunderstorm season.

Surface-water flow in the canyons is generally ephemeral or intermittent, although a few canyons have short stretches with perennial surface flow. Anthropogenic discharges from water treatment outfalls can be a significant source of water in some canyons. Infiltration of these surface sources forms near-surface perched alluvial groundwater systems in many of the canyons (Stone et al., 2001). These alluvial groundwaters are not sufficiently extensive for domestic use. Nevertheless, these waters are an important component of the subsurface hydrologic system. In addition, laboratory contaminants introduced into the canyons can affect shallow groundwaters. Therefore, alluvial groundwaters provide pathways for contamination to migrate to significant lateral distances and potentially to greater depths.

The deposits that comprise alluvial groundwater aquifers are confined to the bottoms of canyons and are composed of axial fluvial deposits interbedded with deposits of alluvial fans, colluvium, and rock fall from adjacent mesa slopes. For watersheds that head on the Pajarito Plateau (e.g., Mortandad and Sandia Canyons), the source of sediment is primarily Bandelier Tuff and, to a much lesser extent, other formations such as the Cerro Toledo interval. Tschicoma dacite and Bandelier Tuff are primary sources of sediment for watersheds that head in the Sierra de los Valles. Canyons that have Bandelier Tuff as the primary source of sediment tend to have predominantly sand-sized alluvial fill with some interbedded coarser-grained side-slope deposits, including colluvium, whereas canyons that head in the Sierra de los Valles have alluvial fill that contains a wide range of grain sizes including dacitic boulders and gravels. Available data indicate that the thickness of alluvium and colluvium in the canyons ranges from a few feet up to approximately 100 feet.

2.5.2 Hydrology

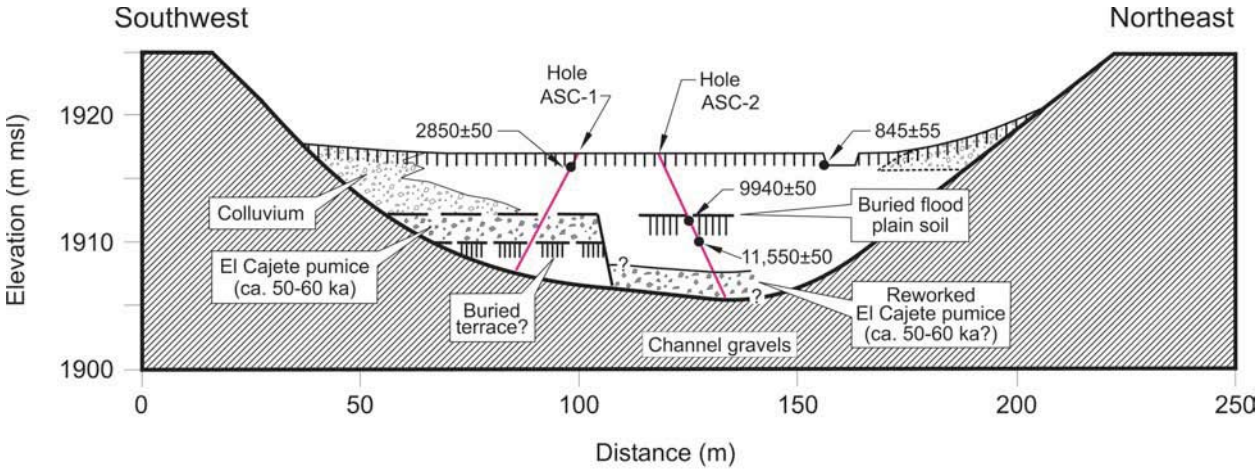
The presence and extent of saturation within the canyons is dependent on a number of variables including source(s) of water, volume and persistence of water sources, the magnitude and location of infiltration of groundwater from the alluvial system to underlying bedrock units (i.e., loss to underlying vadose zone), and evapotranspiration.

These controls on variability of saturation are difficult to quantify, but are based largely on observations made during drilling for installation of alluvial monitoring wells and piezometers in several canyons, including, Los Alamos and Mortandad Canyons, and Cañon de Valle. Adjacent boreholes commonly show different saturated conditions and sometimes a borehole with substantial saturation will be adjacent to one or more boreholes with no or minimal saturation.

This phenomenon is likely related to juxtaposition of facies with highly variable hydrologic properties, such as porosity, permeability, or hydrologic conductivity (Figure 2-30; Reneau and McDonald, 1996).

2.5.2.1 Alluvial Recharge

Recharge to alluvial groundwater systems on the Pajarito Plateau occurs via infiltration from three primary sources: storm-water runoff, anthropogenic effluents, and snowmelt. Each of these recharge sources produces a characteristic groundwater response. The conceptual model for alluvial system recharge on the Pajarito Plateau is based on continuous stream flow, precipitation, and water-level data collected within the Los Alamos and Pueblo Canyon watersheds (including DP Canyon). Three example plots (Figures 2-31, 2-32, and 2-33) show the relations of precipitation, stream flow, and groundwater hydrographs for several representative alluvial monitoring wells in Los Alamos and Pueblo Canyons. The precipitation data shown in the plots are values of average daily precipitation estimated using Theissen weighted averages of precipitation measured within and near the watershed (Dunne and Leopold, 1978). This approach is described in greater detail in LANL (2004) and in Reneau and Kuyumjian (2005). These examples are believed to be representative of canyons across the plateau.



Note: The numbers shown at the dots are radiocarbon dates in years before the present.
Source: Reneau and McDonald (1996).

Figure 2-30. Schematic cross section of complex stratigraphy within the alluvial package in Ancho Canyon.

Examples of recharge via infiltration of storm water are shown in Figure 2-31. The water-level record for monitoring well LAO-0.3 in Los Alamos Canyon is plotted against precipitation data and the stream flow record at gaging stations E025, E030, and E042. The water-level data show generally rapid rises in response to summer and fall precipitation events and associated storm water runoff. Good examples are the large precipitation events in mid-August 2001 and late June 2002. These water-level rises occur instantaneously and generally correlate well with the stream flow record, indicating infiltration into the streambed during floods. The duration of the recessional limb varies between events. Several small but distinct increases in the water-level recorded during late spring and summer months are not related to precipitation events, but rather are related to draining of the Los Alamos Reservoir for dredging and maintenance following the Cerro Grande fire. Storm-water runoff can be generated from precipitation in upland portions of watersheds, directly onto the plateau, or on impervious surfaces in developed areas within the Laboratory or in the Los Alamos townsite.

Effluent-supported recharge results in more sustained and consistent water levels, as shown in Figure 2-32. Groundwater levels observed in monitoring well PAO-4 are dominated by infiltration of effluent discharged from the Bayo wastewater treatment plant (WWTP) to the stream channel in Pueblo Canyon (Figure 2-2). The variation in water-level elevations down canyon of the WWTP is controlled primarily by seasonal rerouting of effluent for "downstream" uses such as watering at the Los Alamos County golf course. Other examples of canyon reaches with similar effluent-supported recharge include effluent/upper Mortandad Canyon (TA-50 outfall) and upper Sandia Canyon (power-plant outfall). These sources represent relatively consistent sources of recharge to alluvial groundwater creating stable alluvial groundwater levels. During dry periods in drier canyons that have little natural runoff, anthropogenic sources provide the majority of groundwater recharge.

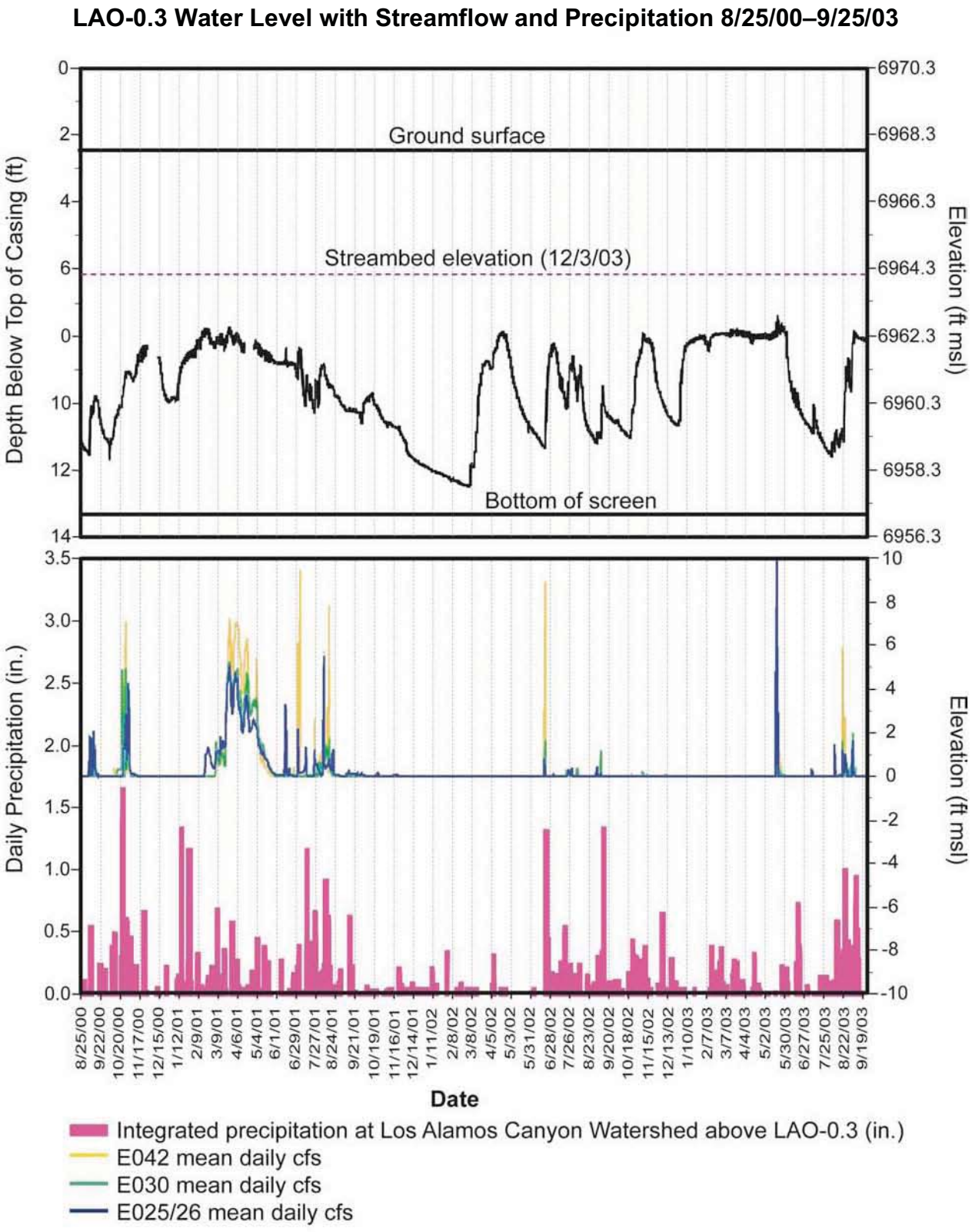


Figure 2-31. LAO-0.3 water level with streamflow and precipitation.

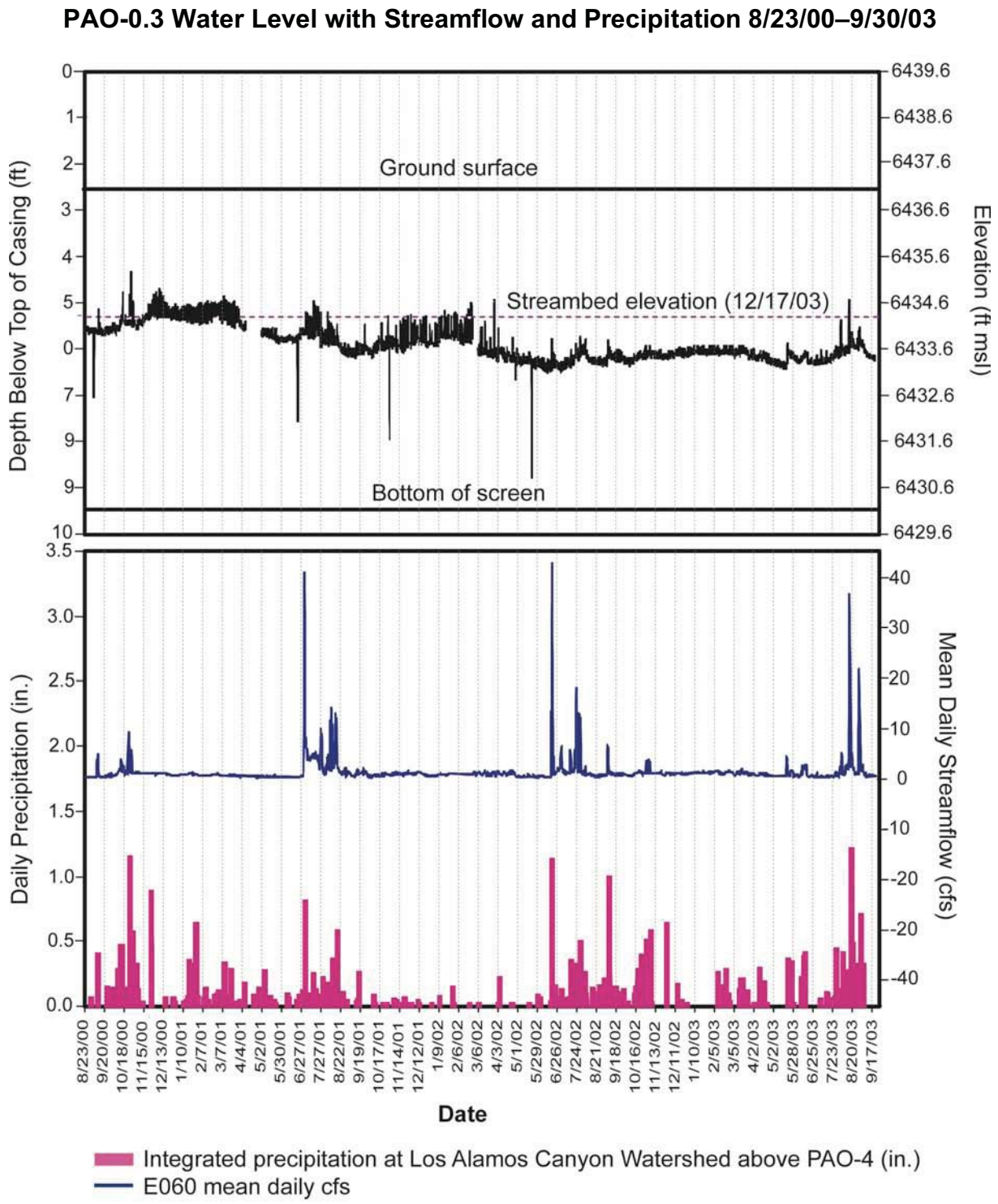


Figure 2-32. PAO-4 water level with streamflow and precipitation.

Recharge also occurs in response to winter/spring snowmelt. Figure 2-31 shows rising alluvial groundwater levels during the late winter to early spring of each of the years represented on the plot. All three winter/spring periods show alluvial-groundwater-level responses prior to initiation of sustained streamflow at even the most up-canyon gaging station, E025. The winter and spring

of 2000–2001 alluvial-groundwater-level shows a substantial response to snowmelt runoff from an appreciable winter snowpack. The alluvial-groundwater-level response occurs over one month prior to initiation of stream flow at E025. The conceptual model for this type of response is that recharge within the alluvium is associated with early-season snowmelt that infiltrates into alluvium in the upper canyon and creates an underflow recharge front that advances down canyon. Once the aquifer saturation has reached capacity (i.e., the elevation of the adjacent stream channel), stream flow is initiated, suggesting that stream flow during these periods represents discharge from the aquifer to the channel.

Figure 2-33 shows groundwater-level data from four alluvial groundwater monitoring wells in Los Alamos Canyon. Initiation of the alluvial-groundwater-level rise in the winter/spring of 2001 at each well occurs prior to the onset of sustained surface water flow. This suggests that the persistent baseflow conditions associated with snowmelt infiltration may actually be sustained largely from discharge of groundwater to the channel. Long-duration snowmelt runoff is most significant in watersheds with upland drainage basin areas, although watersheds that drain developed areas with pavement and storm-drain systems can provide short-duration, pulsed snowmelt runoff associated with melt from individual events.

The down-canyon extent of alluvial groundwater saturation varies significantly from year to year and seasonally. During dry years, and especially during years with limited spring snowmelt runoff, saturation may not extend far from the upland sources of snowmelt recharge.

Gray (1997; 2000) and LANL (2004) investigated alluvial groundwater in Los Alamos Canyon, creating a numerical model that calculated infiltration of alluvial groundwater to the underlying vadose zone. Results indicate that the alluvial groundwater infiltrates into the underlying vadose zone at variable rates along the length of the canyon with a higher rate of loss estimated for a portion of the canyon coincident with the projected trace of the Guaje Mountain fault (mapped to the north but not evident in the walls of Los Alamos Canyon). Nested piezometer data from Los Alamos Canyon (LANL 2004) corroborate modeling results indicating greater infiltration rates in the vicinity of the projected Guaje Mountain fault. The variability in infiltration rates is interpreted to be caused by either loss into permeable units underlying the alluvium or loss within zones of relatively greater fracture size or density.

In addition to the watershed-scale investigation of alluvial groundwater responses to various recharge sources, site-specific alluvial groundwater investigations have been conducted in DP Canyon and in Cañon de Valle. A potassium bromide tracer study was conducted in DP Canyon in 2003 to investigate alluvial groundwater travel times, surface water/groundwater exchange, hydrologic linkage from reach DP-2 to DP Spring, and to measure vertical hydraulic gradients and seepage velocity into the underlying Bandelier Tuff. The primary conclusions regarding alluvial recharge from this study were that surface water/groundwater exchange is an important recharge mechanism and that groundwater flow is transient, primarily controlled by episodic recharge from townsite runoff. For a detailed description of these findings, see LANL (2004) and LANL (2003a).

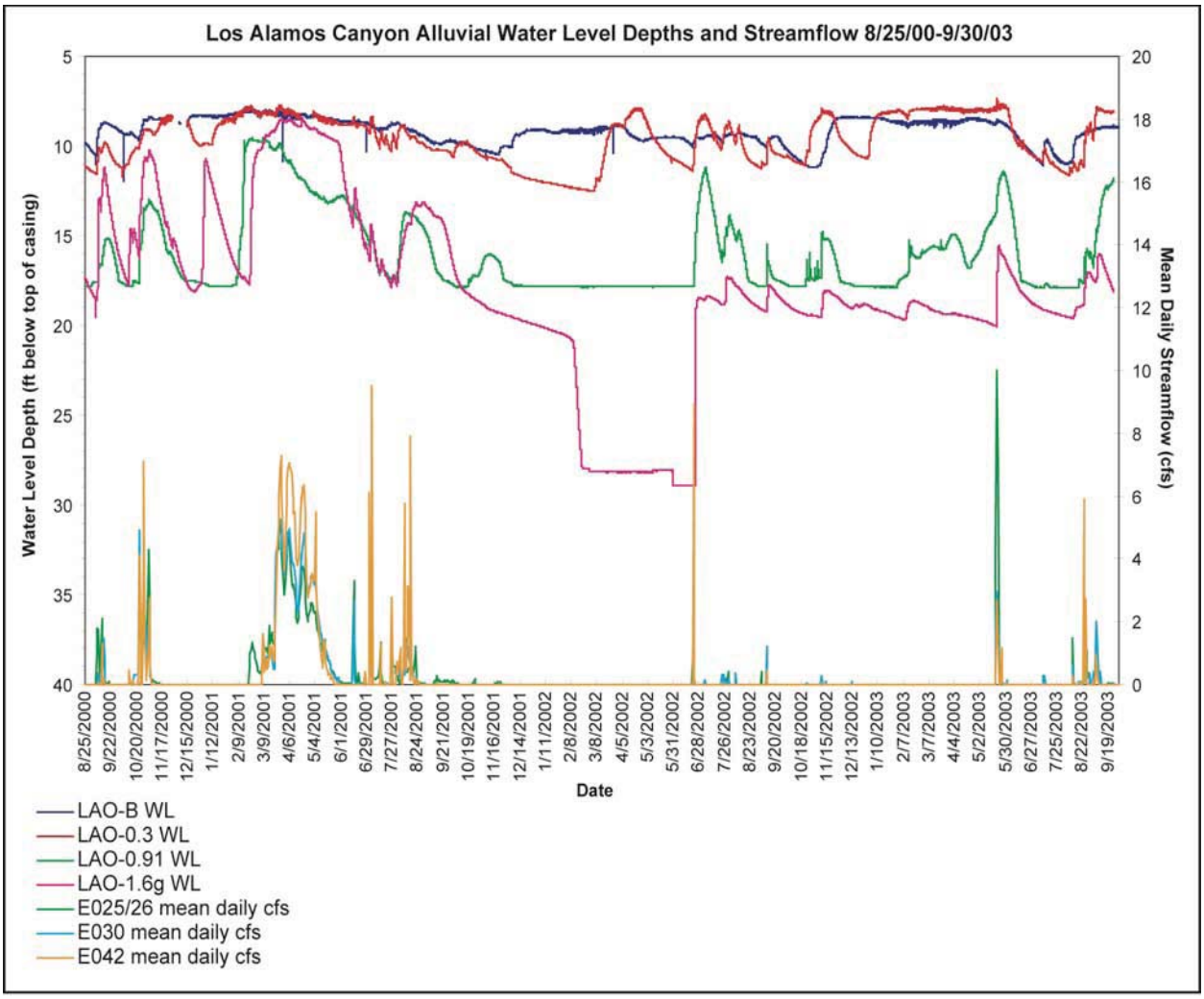


Figure 2-33. Los Alamos Canyon alluvial water level depths and stream flows.

To quantify infiltration, Kwicklis et al. (2005) developed a map of average annual "net infiltration" in the Los Alamos area, based on physical features such as elevation, vegetation, surface geology and stream flow (Figure 2-34). They define net infiltration as that water remaining after accounting for evapotranspiration in the shallow subsurface (i.e., the root zone). They estimate the highest net infiltration rates in canyons, especially those that head in the mountains, with magnitudes of up to a few hundred millimeters per year caused by channelized runoff. In contrast, much lower net infiltration rates occur across mesas and in the smaller canyons that head on the plateau (see Section 4.1 for a site-wide numerical model employing these concepts).

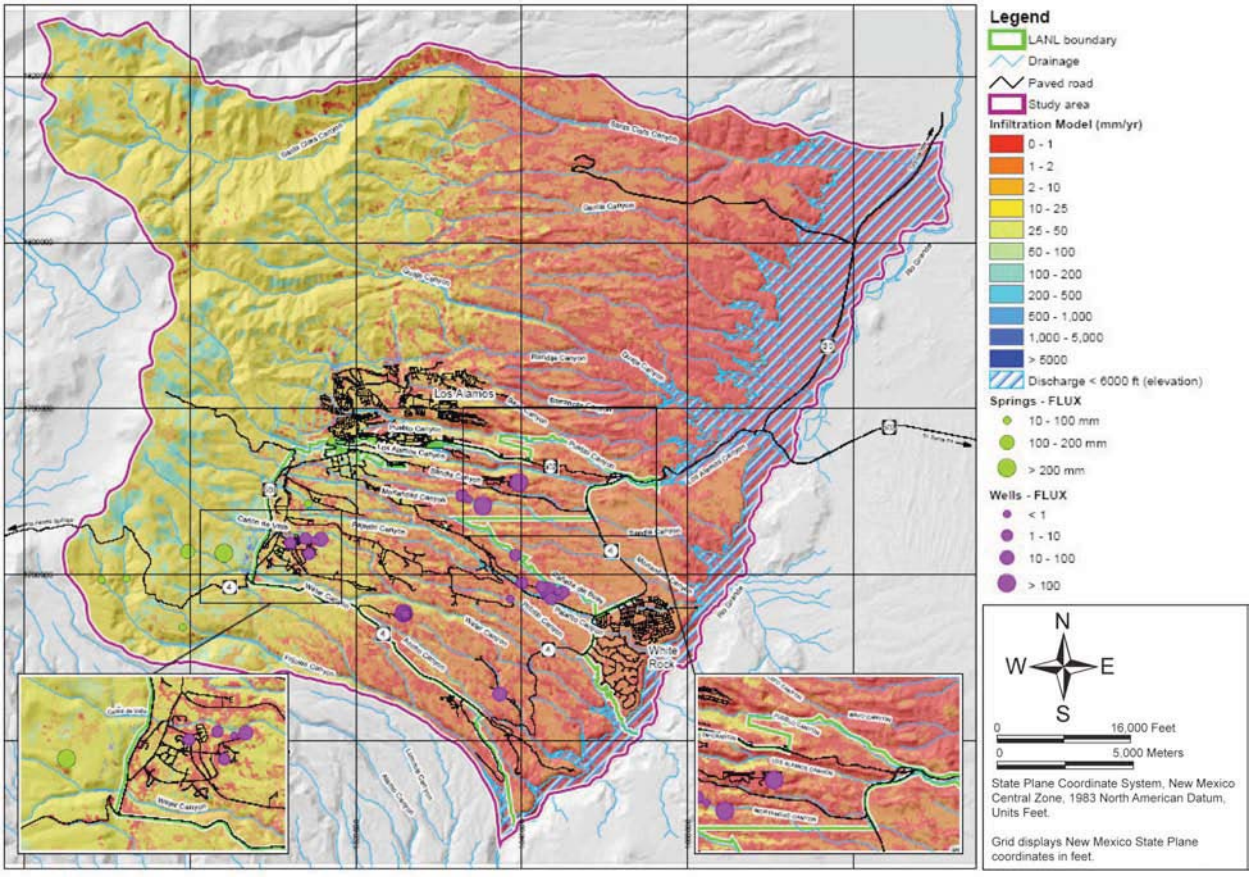


Figure 2-34. Estimated infiltration on the Pajarito Plateau (reproduced from Kwicklis et al., 2005).

2.5.2.2 Alluvial Aquifer Properties

Observations of alluvial groundwater were initially focused on understanding the distribution of contaminants. Purtymun (1974) performed one of the first quantitative investigations where groundwater velocities were calculated from a tritium release in Mortandad Canyon. The release from the TA-50 outfall was a planned event staged to discharge wastewater containing elevated tritium. Groundwater velocities calculated from travel time of the tritium centroid showed values ranging from 20 meters/day in the upper canyon, where alluvium is thin and the alluvial aquifer volume is small, to approximately 2 meters/day in the lower canyon where the canyon widens and alluvium thickens to approximately 30 meters (Table 2-7). These observations indicate that alluvial groundwater flow can be highly variable along the length of a canyon. Other factors influencing system-scale groundwater velocity include aquifer sediment textures, stratigraphic complexity, and hydraulic gradient.

Gallaher (1995) calculated Darcy velocity (Table 2-7) from mean saturated hydraulic conductivities (Table 2-8) and water table gradients in Los Alamos Canyon. Using the results from slug tests conducted by Koening and Guevara (1992), Gallaher estimated the rate of groundwater movement in alluvium at 0.75 meters/day. Additional saturated conductivity values for Los Alamos and Mortandad Canyons are presented in Table 2-8. Slightly lower hydraulic

conductivities in middle Mortandad Canyon may be due to an overall fining of the alluvial material in that portion of the canyon.

Gray (1997, 2000) measured aquifer parameters, calculated a hydrologic budget and performed numerical modeling of groundwater flow in Los Alamos Canyon. Hydraulic conductivity measurements from these studies are included in Table 2-9.

2.5.2.3 Cerro Grande Fire Effects

The May 2000 Cerro Grande fire produced significant hydrologic changes in the watersheds west of the Laboratory (BAER 2000). Loss of vegetation and forest litter, development of ash covers, and extreme hydrophobic soil conditions, primarily in the upland portions of watersheds, greatly reduced the capacity for infiltration and storage of precipitation. Rapid surface-water runoff in the first two summer monsoon seasons following the fire contained high ash content with a complex mixture of inorganic and organic compounds. Calcium, magnesium, silica, potassium, sodium, and carbonate were among the constituents concentrated in the ash (Longmire et al., 2002).

A detailed water-level and water-quality record was obtained from Los Alamos and Pueblo Canyons using dedicated multiparameter pressure transducers installed in a series of alluvial monitoring wells. Hydrologic system effects were manifested as rapid water-level response to numerous post-fire floods and possibly also earlier-than-typical onset of a snowmelt runoff response. Reduced or eliminated forest canopy is thought to have allowed winter snow to melt shortly after individual precipitation events and early in the spring. There were stormwater related excursions in water-quality parameters, including increases in pH in the alluvial groundwater and elevated concentrations of several constituents in alluvial groundwater due to infiltration of ash-rich storm water. A detailed discussion is presented in Chapter 7 and Appendix B of the Los Alamos and Pueblo Canyons Investigation Report (LANL, 2004). It is not known how long such perturbations will persist, although the effects of the fire are expected to progressively decrease over time as the upper watershed recovers.

2.6 Vadose Zone Conceptual Model

The vadose zone is the section of soil and rock material between the alluvial groundwater or the ground surface (where alluvial groundwater is not present) and the regional aquifer water table. Beneath the Pajarito Plateau, the thickness of the vadose zone ranges from about 600 feet to over 1,200 feet. Intermediate-depth perched groundwaters are present within the vadose zone. Specific intermediate perched zones that occur beneath major canyons and in the western portion of the Laboratory are described in Section 2.7.

Table 2-7.
Groundwater Velocities in Alluvial Aquifers on the Pajarito Plateau

Measure Locations	Source	Distance between Measurement Points (m)	GW Velocity (m/d)	Test Type
Upper Los Alamos Canyon	A	Approximately 7000	0.75	Calculated from (mean K_s[A]), average gradient of stream channel (0.027), and an estimated porosity of 0.3.
Mortandad Canyon				
MCO-5 to MCO-6	B	393	^{3}H 16 Cl 25	Tritium (^{3}H) and chloride (Cl) TA-50 discharge tracer test
MCO-6 to MCO-7	B	320	^{3}H 4.2 Cl 5.1	Tritium (^{3}H) and chloride (Cl) TA-50 discharge tracer test
MCO-7 to MCO-7.5	B	290	^{3}H 4.4 Cl 5.6	Tritium (^{3}H) and chloride (Cl) TA-50 discharge tracer test
MCO-7.5 to MCO-8	B	185	^{3}H 1.7 Cl 2.3	Tritium (^{3}H) and chloride (Cl) TA-50 discharge tracer test

Note: Calculated groundwater velocity using mean saturated hydraulic conductivity from LAO-C, LAO-1, LAO-2, LAO-3, LAO-3A, LAO-4, LAO-4.5A, LAO-4.5C, LAO-5.

A Gallaher (1995)

B Purtymun (1974)

Table 2-8.
Saturated Hydraulic Conductivity Values for Alluvial Groundwater on the Pajarito Plateau

Well/Piezometer	Location	Mean Ksat (cm/sec)	Test Type
Los Alamos Canyon			
Piezometer	LAP-1-#1a	4.67E-04	Rising head slug test; Bouwer-Rice solution
Piezometer	LAP-1-#2a	1.32E-03	Rising/falling head slug test; Bouwer-Rice (1976)
Piezometer	LAP-1-#3a	2.71E-03	Rising/falling head slug test; Bouwer-Rice (1976)
Piezometer	LAP-1.5-#1a	2.62E-03	Rising/falling head slug test; Bouwer-Rice (1976)
Piezometer	LAP-1.5-#2a	4.43E-03	Rising/falling head slug test; Bouwer-Rice (1976)
Piezometer	LAP-1.5-#3a	9.42E-03	Rising/falling head slug test; Bouwer-Rice (1976)
Piezometer	LAP-3a	3.10E-03	Rising/falling head slug test; Bouwer-Rice (1976)
Piezometer	LAP-3.5-#1a	2.660E-03	Rising/falling head slug test; Bouwer-Rice (1976)
Piezometer	LAP-3.5-#2a	1.27E-03	Rising/falling head slug test; Bouwer-Rice (1976)
Piezometer	LAP-3.5-#3a	2.82E-05	Rising/falling head slug test; Bouwer-Rice (1976)
Piezometer	LAP-4-#1a	2.58E-05	Rising/falling head slug test; Bouwer-Rice (1976)
Piezometer	LAP-4-#2a	2.20E-05	Rising/falling head slug test; Bouwer-Rice (1976)
observation well	LAO-Bb	7.01E-03	slug tests; Bouwer-Rice (1976)
observation well	LAO-Cc	1.16E-03	slug tests; Bouwer-Rice (1976)
observation well	LAO-0.3b	1.25E-02	slug tests; Bouwer-Rice (1976)
observation well	LAO-0.6b	7.58E-03	slug tests; Bouwer-Rice (1976)
observation well	LAO-0.91b	3.56E-02	slug tests; Bouwer-Rice (1976)
observation well	LAO-1c	1.58E-02	slug tests; Bouwer-Rice (1976)
observation well	LAO-1.6(g)b	4.82E-03	slug tests; Bouwer-Rice (1976)
observation well	LAO-2c	1.01E-02	slug tests; Bouwer-Rice (1976)
observation well	LAO-3c	1.34E-02	slug tests; Bouwer-Rice (1976)
observation well	LAO-3ac	1.22E-02	slug tests; Bouwer-Rice (1976)

Table 2-8.
Saturated Hydraulic Conductivity Values for Alluvial Groundwater on the Pajarito Plateau (continued)

Well/Piezometer	Location	Mean Ksat (cm/sec)	Test Type
observation well	LAO-4c	2.41E-02	slug tests; (1976)
observation well	LAO-4.5b	2.55E-03	slug tests; (1976)
observation well	LAO-4.5ac	2.33E-03	slug tests; (1976)
observation well	LAO-4.5cc	2.77E-03	slug tests; (1976)
observation well	LAO-5c	3.35E-03	slug tests; (1976)
Mortandad Canyon			
observation well	MCO-3c	3.72E-02	slug tests; (1976)
observation well	MCO-4c	7.13E-04	slug tests; (1976)
observation well	MCO-4Cc	3.47E-04	slug tests; (1976)
observation well	MCO-4.9c	2.88E-05	slug tests; (1976)
observation well	MCO-5c	5.41E-05	slug tests; (1976)
observation well	MCO-6c	7.08E-04	slug tests; (1976)
observation well	MCO-7.5c	9.63E-04	slug tests; (1976)
observation well	MCO-7Ac	1.06E-04	slug tests; (1976)
observation well	MCO-7c	5.11E-04	slug tests; (1976)
observation well	MT-3c	2.93E-05	slug tests; (1976)

a Results have been published in the Los Alamos and Pueblo Canyons Investigation Report (LANL, 2004b).
b Results from 1998 slug tests (Los Alamos and Pueblo Canyons Investigation Report (LANL, 2004b).
c Results from 1995 slug tests.

2.6.1 Climate and Infiltration

Arid and semi-arid regions often exhibit thick vadose zones. Infiltration is often focused in topographic lows or beneath surface water bodies, rather than being diffuse, as is common in wetter climes (e.g. Sanford, 2002). The average annual potential evapotranspiration (PET) rates far exceed precipitation rates. Under these conditions, infiltration events that propagate beneath the root zone are sporadic and occur only when the short-term infiltration rate exceeds the ET rate, such as during snowmelt or after large rainstorms. Consequently, the rates for deeper infiltration are difficult to quantify through traditional water balance studies because this component of the water-balance can be orders of magnitude smaller than the other components (Devries and Simmers, 2002; Scanlon et al., 2002; Sophocleous, 2002; Sanford, 2002; Flint et al., 2002). These generalities apply to the near-surface hydrology of the Pajarito Plateau, which has a semiarid climate.

The infiltration rate estimates from canyon bottom alluvium and mesa top sites developed by Kwicklis et al. (2005) (Figure 2-34) can be tested for consistency against the estimated infiltration rates inferred from moisture content profiles. In Section 4.1.3.2, a set of numerical models for wells LADP-3 and LADP-4 in Los Alamos Canyon are presented showing that moisture profiles reflect the conceptual model of high infiltration in canyons and low infiltration in mesas. That analysis also shows that the uncertainties associated with such estimates are quite high (in the range of a factor of 3). However, by combining moisture content, tracer or contaminant profiles, and water budget information, a more constrained estimate can be achieved. One of the purposes of the vadose zone numerical models being developed is to provide the additional constraints afforded by the use of multiple, independent data sets (Robinson et al. 2005a).

2.6.2 General Description of Conceptual Models

Conceptual models for vadose zone flow and transport on the Pajarito Plateau are based on observations from a variety of data sources, including both mesa-top and canyon sites under both natural conditions and disturbed conditions resulting from Laboratory operations. The key conceptual-model elements describe percolation of water through both fractured and relatively unfractured volcanic tuffs, buried sedimentary formations, and basalts. The types of data incorporated into the development of the conceptual models include water content and pore-water chemical compositions from borehole samples for naturally occurring tracers, introduced tracers, and Laboratory contaminants.

The conceptual models differentiate the rate of percolation by their location and surface hydrologic setting, including wet and dry canyons, and wet, dry, and disturbed mesas. Perched water is often found beneath wetter canyons, either associated with near-surface alluvial systems or at intermediate depths, along low-permeability interfaces such as buried soils and unfractured or clay-filled horizons of basalt flows. Alluvial groundwater is discussed in Section 2.4, while perched water is addressed in Section 2.6. The generalized view of the role of wet and dry canyons on vadose zone flow and transport is quantified in the numerical model section of this report (Section 4).

2.6.2.1 Mesas

Dry finger mesas constitute most of the mesa area on the plateau. The hydrologic conditions on the surface and within these dry mesas lead to slow unsaturated flow and transport. The mesas shed precipitation as surface runoff to the surrounding canyons such that most deep infiltration occurs episodically following snowmelt (Section 2.4.2.1). Much of the water that does enter the soil zone is lost through evapotranspiration (ET). As a result, annual net infiltration rates for dry mesas are less than ten mm/yr and are more often estimated to be on the order of one mm/yr or less (Kwicklis et al., 2005). Since the dry mesas are generally comprised of nonwelded to moderately welded tuffs with low water content, flow is likely to be matrix dominated. Wetter mesas, supporting ponderosa forest above densely welded and fractured tuff in the western portion of the plateau, may provide fracture flow to a few meters to tens of meters depth but evidence of fracture infiltration usually diminishes at the depth of the first nonwelded horizon. For most of the LANL site, travel times for contaminants migrating through mesas to the regional aquifer are expected to be several hundred to thousands of years (Newman, 1996; Newman et al., 1997b; Birdsell et al., 2000; and Section 4.1.1 of this report).

The topographic relief of these steep-sided mesas influences their internal hydrologic conditions as well. High solar radiation, strong winds, and fluctuations in barometric pressure cause temperature and pressure gradients between the surface of the mesa and its interior. These gradients enhance air circulation through the mesas, which is thought to enhance deep evaporation (Neeper 2002; Neeper and Gilkeson, 1996; Newman, 1996; and Newman et al., 1997b). This additional drying in the mesa-top units further slows downward water flow and transport of dissolved species. However, these same conditions enhance vapor transport of volatile species (Stauffer et al., 2005).

Anthropogenic discharges and surface disturbances due to laboratory operations can drive infiltration rates higher in usually dry mesas. In some cases, multiple disturbances of mesa sites through liquid waste disposal, asphalt covers, and/or devegetation have caused mesa infiltration rates to temporarily increase to near wet canyon levels (representative values are given in Section 4.1). Even with elevated infiltration, at most sites flow remains matrix dominated. Fracture flow has occurred in a few instances beneath long-term liquid disposal sites with ponded conditions. However, fracture flow ceases once liquid disposals stop. Infiltration rates are expected to return to low, near-background levels when the surface and vegetation return to natural conditions.

An exception to the general concepts just discussed occurs for mesas along the mountain front of the plateau. Due to their higher elevation, these mesas receive higher precipitation and higher infiltration than the drier mesas in the central and eastern portions of the plateau (Birdsell et al., 2005). Mountain-front areas also have units of the Tshirege Member that are more strongly welded, yielding rocks with more fracturing and lower matrix permeabilities. Under these conditions, infiltrating water travels laterally through fractures and other fast pathways, often issuing at springs that feed the canyons in this area. These near-surface processes can be thought of as sources for deeper vadose zone transport from canyon bottoms, although the possibility of deeper vertical migration from the mesa source without first entering the canyon is also possible.

2.6.2.2 Canyons

This section summarizes the hydrologic conditions present in canyons characterized as either wet or dry. Several features characterize naturally wet canyons on the Pajarito Plateau. Their headwaters are in the mountains, they have large catchment areas (13 to 26 km^2), surface flow occurs frequently, and alluvial groundwater systems exist in the canyon floors. In some cases, anthropogenic sources can elevate flows sufficiently in smaller dry canyons that head on the plateau so that they act as wet canyons. In addition, springs issuing from the sides of mesas are a water source in the mountain front canyons; these springs are a characteristic of wet canyons in the western portion of the plateau. Often, deeper, intermediate perched zones are associated with wet canyons. The geometry of wet canyons promotes hydrologic conditions that yield relatively fast, unsaturated flow and transport.

Wet canyons such as Los Alamos Canyon receive large runoff volumes, either through channeling of precipitation or through wastewater discharges. This runoff, in turn, creates surface-water flow along canyon bottoms, which subsequently infiltrates to form near-surface, alluvial water bodies (Section 2.4.2.1). Lateral flow and transport through surface water and in the alluvial systems are rapid with respect to other subsurface hydrologic processes on the plateau. Rates of lateral transport are even higher during surface flow events, which occur more frequently in the larger wet watersheds than in other areas of the plateau. Sorbing species transport slowly in alluvial waters and more commonly migrate down the canyon floor by sediment transport (LANL, 2004; Lopes and Dionne, 1998; Solomons and Forstner, 1984; and Watters et al., 1983).

It has been suggested that trace quantities of strongly sorbing contaminants can travel via colloid-facilitated transport in the alluvial groundwater (Penrose et al. 1990), although this interpretation of the data from Mortandad Canyon has been called into question (Marty et al., 1997). Since some of the wet canyons that cross Laboratory land have received liquid-waste discharges from outfalls, the alluvial systems act as line sources for both water and contaminants to the deeper vadose zone beneath such canyons (Birdsell et al., 2005). The term “line source” denotes that infiltration is likely at any location along the region defined by the alluvial groundwater; there are probably preferential zones of enhanced infiltration at certain locations that will yield larger than average travel velocities through the deeper vadose zone. The net percolation rates beneath the alluvial systems of wet canyons to the underlying unsaturated zone are expected to be among the highest across the plateau, approaching meters per year (100 - 1000 mm/yr) (Kwicklis et al., 2005).

In addition, the vadose-zone thickness decreases with increasing distance down canyon, due to thinning of the Bandelier Tuff (Section 2.2.9). This is especially true for the deep wet canyons because their canyon bottom elevations are 45 to 60 m lower than smaller canyon systems on the plateau. Contaminants transported down canyon via surface flow or through the alluvial groundwater system often percolate through a geologic column consisting primarily of basalt and fanglomerate with little or no overlying tuff. Downward percolation is believed to be more rapid in the basalt than through moderately welded tuff (Section 2.2.8). Thus, these wet canyons have thinner vadose zones and a smaller portion of the flow path with matrix-dominated flow.

These stratigraphic factors, compounded by the relatively high deep-percolation rate in wet canyons, likely yield the fastest vadose-zone travel times for contaminants from the land surface of the plateau to the regional aquifer. Transport to the regional aquifer beneath wet canyons is predicted to be on the order of decades to hundreds of years (see Section 4.1 for details).

In contrast to wet canyons, dry canyons such as Potrillo Canyon and Cañada del Buey head on the plateau, have smaller catchment areas (less than 13 square km), experience infrequent surface flows, and have limited or no saturated alluvial systems in their floors. If anthropogenic sources are present, they are small volume sources. These hydrologic factors yield little lateral near-surface contaminant migration and slower unsaturated flow and transport from the surface to the regional aquifer. For example, because surface and alluvial waters are less common, contaminants remain close to their original source locations. Pathways through the vadose zone tend to be longer in the shallow dry canyons that have thicker sections of nonwelded to moderately welded tuff than the deeper-cut wet canyons. Net infiltration beneath dry canyons is much slower, with rates generally believed to be less than tens of millimeters per year and commonly on the order of 1 mm/yr. Finally, transport times to the aquifer beneath dry canyons are expected to be much longer than travel times from the bottom of wet canyons.

2.6.3 Vadose Zone Flow and Transport Mechanisms

Given the description in the previous section of surface and near-surface hydrologic conditions, the next step is to consider the flow and transport mechanisms for water that infiltrates into the subsurface. Most of the plateau is covered with nonwelded to moderately welded Tshirege and Otowi Member ash-flow tuffs (Section 2.2.9). Unsaturated flow and transport through these nonwelded to moderately welded tuffs is thought to occur predominantly through the porous matrix. These units are quite porous, with typical porosities of 40 to 50%, moderate saturated hydraulic conductivities (e.g., 10^{-4} cm/sec), and water contents that are generally far below saturated conditions (2 to 25%) (Abrahams et al., 1961; Rogers et al., 1996a; Birdsell et al., 2000; Springer, 2005).

Although the tuff units are often fractured, flow is expected to be matrix dominated unless conditions approach full saturation due to the presence of a high-flow-rate, constant water source (Soll and Birdsell, 1998), such as beneath liquid-waste disposal pits or outfalls. This result is a consequence of the difference in capillary pressure behavior in a porous matrix versus within a fracture. Even if water is injected into a fracture, capillary forces tend to pull water into the rock matrix over a relatively short flow distance. This concept has been established for a wide variety of fracture and matrix hydrologic properties (e.g., Nitao and Buscheck, 1991; Robinson and Bussod, 2000; Soll and Birdsell, 1998; Robinson et al., 2005a, 2005b).

Field observations and analyses support the matrix-flow hypothesis. Robinson et al. (2005b) modeled a vadose-zone, wellbore injection test that was performed in the Tshirege Member of the Bandelier Tuff (Section 2.2.9.3) and reported by Purtymun et al. (1989). Their analysis examined different numerical representations for the fractured porous medium, including a discrete fracture model, a matrix-dominated continuum model, and a dual-permeability representation. Figure 2-35 shows the field-measured moisture profiles at different times during the injection. Water diffused laterally downward, and upward in a relatively uniform fashion,

rather than percolating rapidly through a fracture network. The agreement between the matrix-dominated model and the observations was acceptable, both qualitatively and quantitatively (Robinson et al. 2005b). They estimated an equivalent infiltration rate during the injection phase of about 2.7×10^4 mm/yr, which is greater than any estimates of infiltration across the plateau. They concluded that if matrix-dominated flow is observed at the high effective infiltration rate of this injection test, then it is even more likely to be the case under natural conditions on the plateau.

As discussed in Section 2.6.2.1, this general picture that applies in the eastern portion of the Pajarito Plateau must be modified for areas near the mountain front on the western edge, where some of the Tshirege units of the Bandelier Tuff have densely welded intervals as a result of being closer to the volcanic source (Section 2.2.9.3). These more welded units are less porous, with porosities ranging from 17 to 40%, and have low saturated hydraulic conductivities (e.g., 10^{-6} to 10^{-9} cm/sec) (LANL, 2003b). They are also more fractured and can support fracture flow and transport when sufficient water is present. A bromide tracer test and high explosives contaminant distributions suggest that both fracture and matrix-dominated flow can occur near the mountain front depending on the degree of welding (or matrix conductivity) of the tuff (LANL, 1998b; LANL, 2003b). Therefore, the location and degree of welding of the tuff units affects the degree to which fracture flow will be sustained.

In contrast to the behavior of the Bandelier Tuff units, much of the vadose zone flow through the basalt units is almost certainly fracture dominated (flow-base rubble and scoria may also be highly permeable, but these are stratified components of generally limited vertical extent). Under ponded conditions, rapid flow through fractured basalt has been observed (Stauffer and Stone, 2005). The Laboratory fielded an experiment on the upstream side of a low-head weir located in Los Alamos Canyon (Stone and Newell, 2002). Figure 2-36 is a schematic of the field experimental setup. The objective of the experiment was to monitor flow and bromide tracer transport through fractured basalt under typical unsaturated and periodically ponded conditions using three observation boreholes. Following three ponding events, the bromide tracer advanced quickly downward to a depth of several tens of meters in 10 to 14 days after the first ponding event (Stauffer and Stone, 2005). These observations confirm that fracture flow and transport occurs through basalts under ponded conditions. Model calibration of the bromide transport yields an effective fracture porosity in the range of 10^{-2} to 10^{-3} and saturated hydraulic conductivity in the range of 10^{-2} to 10^{-3} cm/sec (Stauffer and Stone, 2005). In fact, the data and simulations both indicate that the bromide continued to advance through the fractured system even after the all the ponded water had infiltrated.

However, under drier conditions no direct observations have been made of vadose-zone flow and transport in these deeper locations. For this reason, the conceptual model for unsaturated flow and transport through basalts is still evolving.

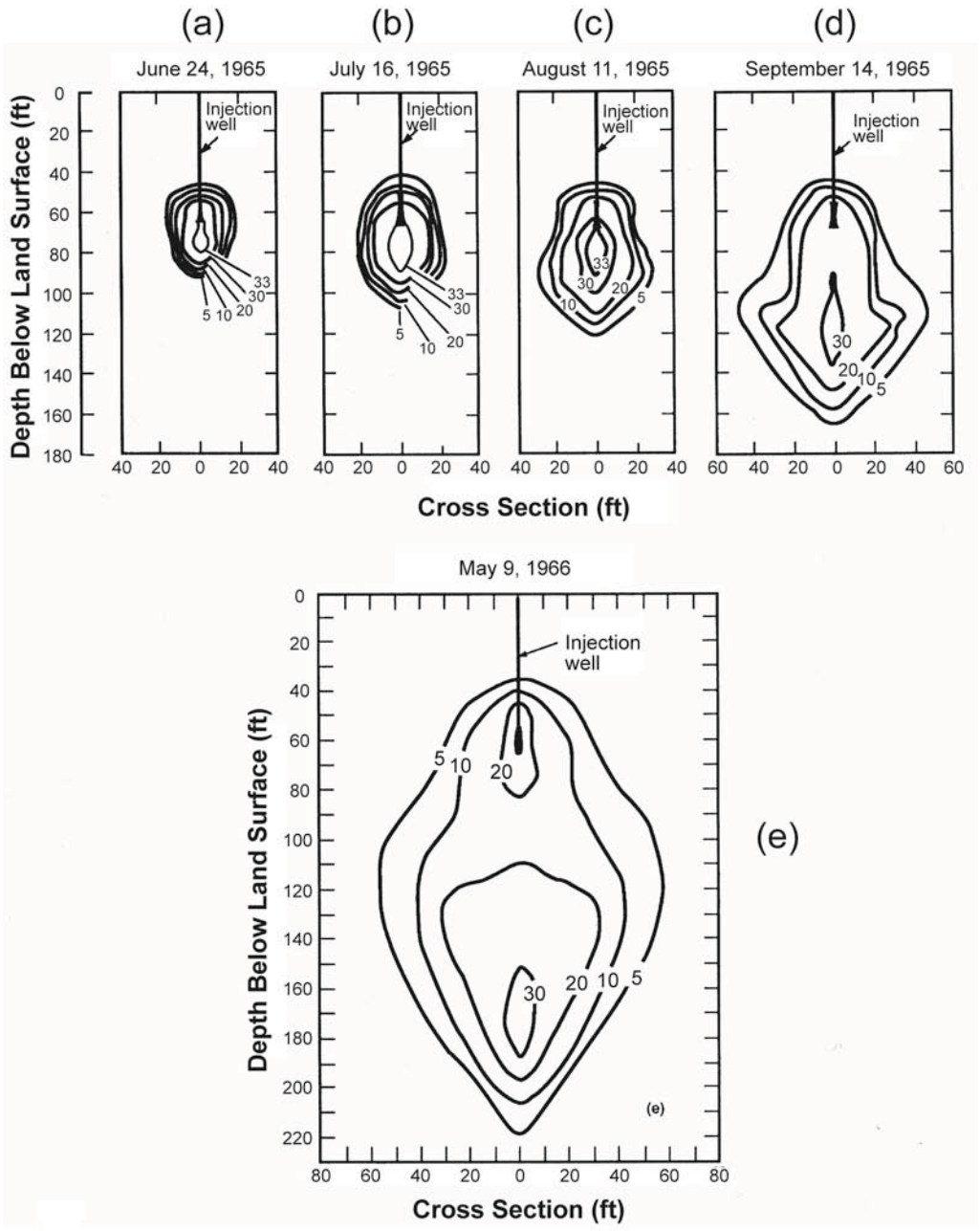
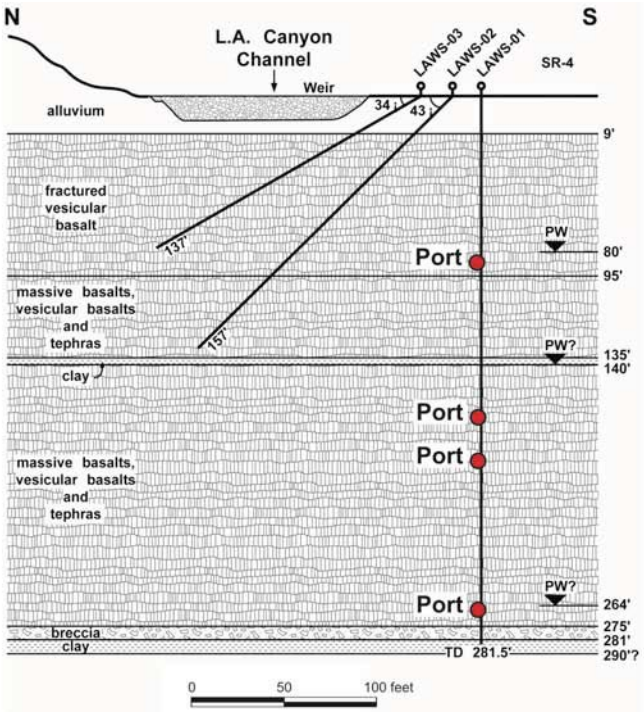


Figure 2-35. Contours of water content constructed from the neutron log data during and after the wellbore injection test: (a) Day 7 after injection; (b) Day 29; (c) Day 55; (d) Day 89 (end of injection phase); (e) Day 327 (post-injection phase). From Purtymun et al. (1989).



(a)



(b)

Figure 2-36. Low head weir monitoring well setup; (a) schematic; (b) north-south photograph.

2.6.4 Alternative Hypotheses

Although the basic processes outlined in the preceding sections are supported by the available data and observations and form the best current conceptual model, alternative hypotheses are possible and cannot be completely ruled out by the available information. This section briefly discusses the potential alternative conceptual model of fracture flow. In addition, alternative conceptual models for the mechanisms of flow within perched water zones are described in Section 2.7.

Fracture flow through the Bandelier Tuff is a conceptual model that is often proposed, in contrast to the conceptual model of matrix-dominated flow and transport discussed earlier. Although the available information is consistent with matrix flow, it is possible that in certain situations, fracture flow is important, including the examples related to mountain front processes described earlier. Despite the fact that water input into fractures tends to imbibe into the rock matrix, the observations presented earlier may capture the flow behavior of most, but not all of the water flow. It is possible that preferential flow paths through Bandelier Tuff fractures allow a small portion of the infiltrating fluid to travel to significant depths, even though most water imbibes into the matrix. Alternatively, unstable fingering flow through heterogeneous matrix rock could also lead to preferential downward flow. Regarding the TA-50 water injection test, it is possible that a small amount of fast-moving water could have escaped detection and traveled to greater depths via these mechanisms. The implication of this uncertainty is that small quantities of contamination could potentially be observed at some point in the future at greater depths than

"expected." If this occurs, then we will need to assess whether a relatively small, fast-moving fraction of a released contaminant, combined with a center of mass that travels much more slowly, poses a significant threat to groundwater.

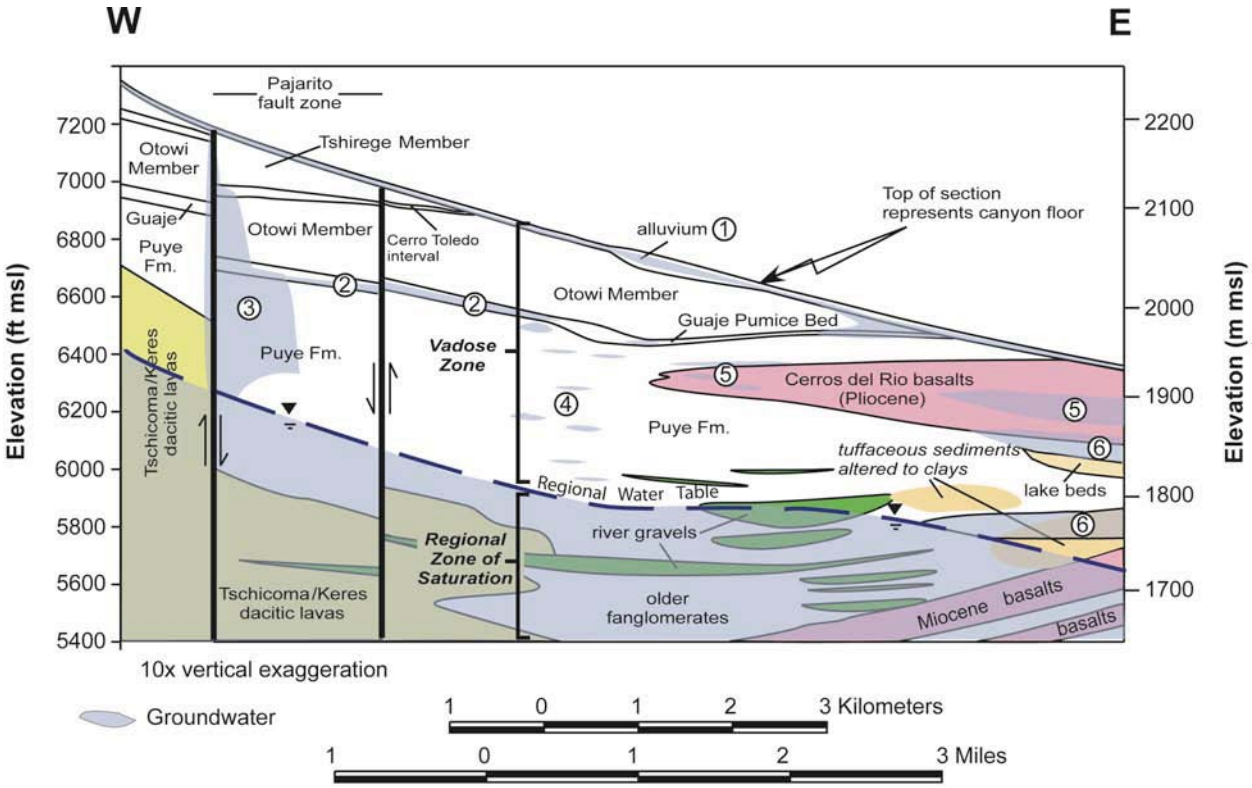
2.7 Perched Water

A common feature of vadose zone flow systems is the presence of perched water. Perching can occur for a number of reasons, including capillary barriers and low-permeability barriers coupled with complex stratigraphic structures in the subsurface (e.g., Bagtzoglou, 2003a, 2003b). Beneath the Pajarito Plateau, perched waters may be important components of subsurface pathways that facilitate movement of contaminated fluids from the ground surface to the water table of the regional aquifer. These perched groundwater bodies are generally too small for use as municipal water supplies. Nonetheless, they are of interest because (1) they represent natural groundwater resources that are protected under State law, (2) their chemical and isotopic characteristics help constrain groundwater transport rates through the vadose zone, (3) their presence may divert, slow, or stop the vertical migration of groundwater through the vadose zone, or they may indicate the presence of a fast subsurface pathway, depending on the characteristics of the perched zone, and (4) they can be used as vadose zone monitoring points that provide early warning of contaminants approaching the regional aquifer.

Characterization of these groundwater bodies is challenging because of the thickness of the vadose zone, the heterogenous nature of bedrock geologic units that serve as host rocks and perching horizons, and the depths of groundwater occurrences. Despite these limitations, substantial new information has been gathered about intermediate perched zones on the plateau. This section summarizes information about the location, depth to water, saturated thickness, and geologic setting of perched water occurrences beneath the Pajarito Plateau. This summary includes data from historical investigations and much new information collected as part of the Hydrogeologic Workplan characterization program.

2.7.1 Perched Water Occurrence

The different modes of groundwater occurrence beneath the Pajarito Plateau are shown conceptually in Figure 2-37. Contaminant distributions in groundwater strongly suggest that groundwater of the plateau alluvial systems is in communication with intermediate perched and regional aquifer groundwater to varying degrees. The focus of this section is the intermediate perched groundwater; a description of the alluvial groundwater is presented in Section 2.5, and the regional aquifer is described in Section 2.8.



1. Canyon-floor alluvial groundwater—most commonly found in large, wet watersheds with significant snow and storm run off or in smaller watersheds that receive liquid effluent from wastewater treatment plants. Saturated thickness and down-canyon extent varies seasonally.
2. Perched ground water is associated with the Guaje Pumice Bed in Los Alamos Canyon. This perched water body has a lateral extent of up to 3.7 mi Guaje Pumice Bed has a high moisture content but is not fully saturated in most other locations.
3. Cañon de Valle area in the southwest part of LANL. This is the largest perched zone identified on the plateau. A deep-sounding surface-based magnetotelluric survey suggest that this perched zone is discontinuous laterally, occurring as vertical pipe-like groundwater bodies. One interpretation of this zone is that it represents groundwater record(s) formed in response to local recharge beneath a wet cany9on floor. Recharge may be enhanced across the Pajarito fault zone where shallow, densely-welded tuffs rocks are highly fractured.
4. Small zones of perched water formed above stratigraphic traps in Puye fanglomerate. these perched zones tend to be more numerous beneath large wet canyons and less frequent beneath dry mesa tops.
5. Perched groundwater associated with Cerros del Rio basalt. Saturation occurs in fractured basalt flows and in interflow breccias and sediments.
6. Perched zones form in response to local geologic conditions on the eastern side of the plateau. These include perched zones within clay-altered tuffaceous sediments and above lake deposits.

Figure 2-37. Conceptual model of groundwater occurrences beneath the Pajarito Plateau.

Identification of perched groundwater systems beneath the Pajarito Plateau comes mostly from direct observation of saturation in boreholes, wells, or piezometers or from borehole geophysics. Additional information is provided by surface-based electrical geophysics, although these types of investigations are generally limited by their relatively shallow depths of investigation and poor vertical resolution. Identification of larger perched groundwater bodies in boreholes is generally reliable, but use of drilling fluids, which is necessary in most boreholes, may mask smaller or relatively unproductive zones. Defining the lateral extent of saturation is more problematical because of the costs associated with installing deep wells. One geophysical method, a deep-sounding surface-based magnetotelluric survey, has been conducted in the Cañon de Valle/Water Canyon area. The survey results suggest that perched groundwater is

discontinuous laterally, occurring instead as vertical, finger-like groundwater bodies. These geophysical interpretations are currently being tested by additional drilling. Despite these limitations, substantial new information has been gathered about deep perched zones on the plateau during the Hydrogeologic Workplan investigations.

This section briefly summarizes the observed occurrences of perched water. Appendix 2-B contains a comprehensive description of the 33 occurrences of perched groundwater detected in boreholes across the Pajarito Plateau. Perched groundwater is widely distributed across the northern and central part of the plateau (Figure 2-38) with depth to water ranging from 36 to 272 m (118 to 894 ft). The principal occurrences of perched groundwater occur in (1) the large, relatively wet Los Alamos and Pueblo Canyon watersheds, (2) the smaller watersheds of Sandia and Mortandad Canyons that receive significant volumes of treated effluent from LANL operations, and (3) in the Cañon de Valle area in the southwestern part of LANL. Perched water is most often found in Puye fanglomerates (Section 2.2.7), the Cerros del Rio basalt (Section 2.2.8), and in units of the Bandelier Tuff (Section 2.2.9) (Figure 2-38). There are few reported occurrences of perched water in the southern part of LANL, but few deep boreholes are located there and additional perched zones are likely beneath the large wet watersheds of Pajarito and Water Canyons.

2.7.2 Interpretation of Perched Water Observations

General conclusions about the nature of perched groundwater beneath the Pajarito Plateau are based on the observations summarized above. The conclusions pertain to surface hydrologic conditions necessary to support perched groundwater, geologic and hydrostratigraphic controls on perched water occurrence, the lateral and vertical extent of perched zones, and alternative hypotheses about the role of perched zones in contaminant transport.

2.7.2.1 Surface Water Conditions for Perched Water

A requirement for deep perched water to exist is a surface water source (natural or anthropogenic) that supplies water to alluvial systems. The alluvial groundwater systems act as storage for groundwater entering underlying bedrock units at high infiltration rates (Section 2.5). This interpretation is supported by the observation of perched groundwater in wet canyons. In addition, ponding associated with anthropogenic sources is another possible water source that could lead to subsurface perched water.

A special situation also exists in the western portion of the Laboratory, in the mountain-front mesa area at TA-16. In contrast to the dry mesas prevalent further east, these mesas receive greater precipitation (e.g., 500 mm/yr) and increased runoff and infiltration. The wet, mountain-front mesas contain numerous perennial and ephemeral springs. Such springs are rare in the dry mesas of the eastern part of the plateau, except where the regional groundwater aquifer discharges along the Rio Grande.

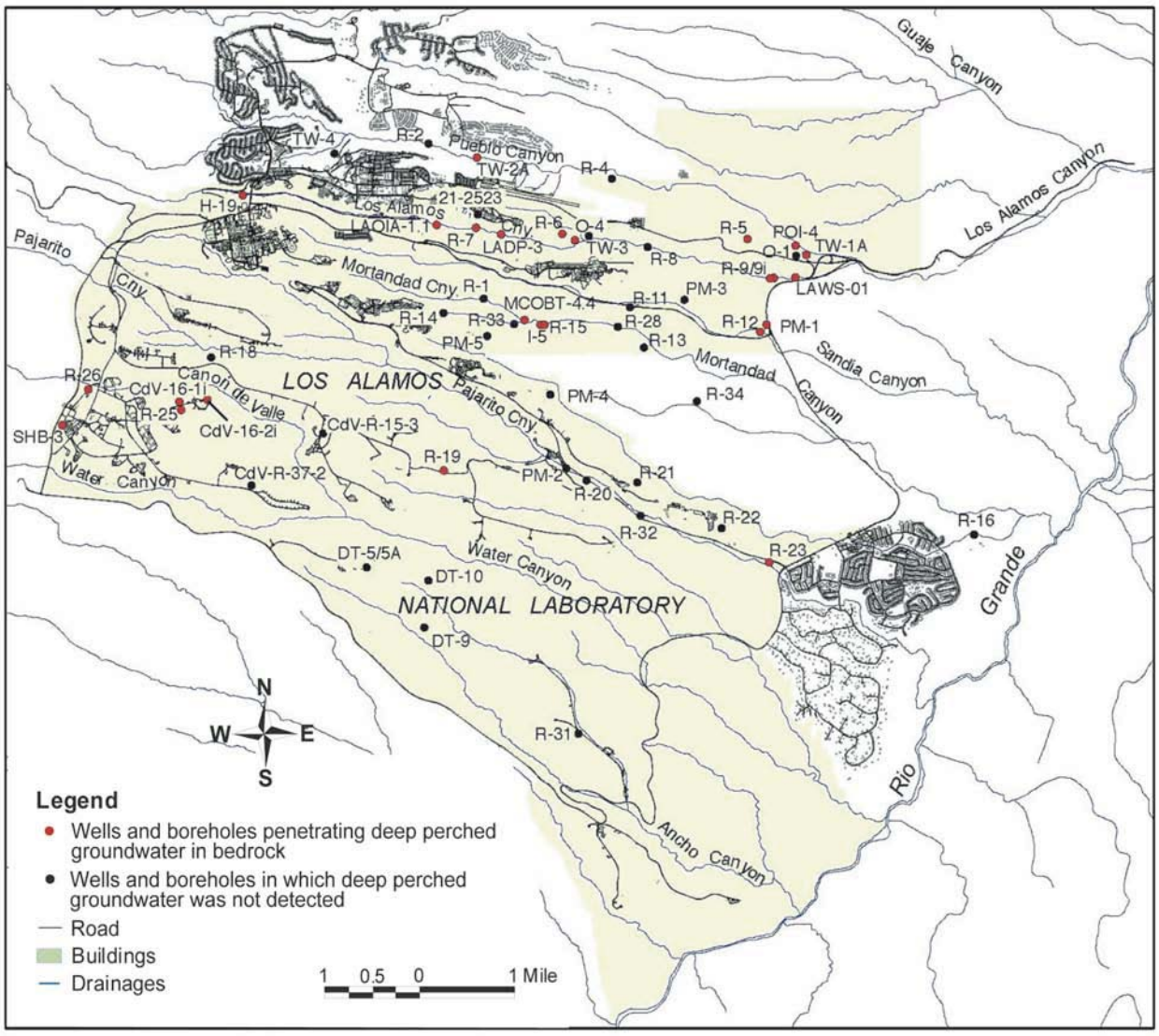


Figure 2-38. Locations of wells and boreholes that have penetrated perched groundwater systems in bedrock.
Note: The area shown in yellow is LANL.

2.7.2.2 Geologic and Hydrostratigraphic Controls on Perched Water Occurrence

Deep perched groundwater occurs most frequently in the Puye Formation (Section 2.2.7) and Cerros del Rio basalt (Section 2.2.8), but some of the thickest and/or most laterally extensive zones involve units of the Bandelier Tuff (Section 2.2.9). Perching horizons include a wide variety of layered geologic lithologies including

- Unfractured basalt flows
- Clay-rich interflow zones in basalt
- Buried soils and other fine-grained deposits in fanglomerate,

- Clay-altered tuffaceous sediments
- Lake deposits.

Therefore, in addition to high local infiltration rates, low-permeability barriers to downward vertical flow appear to be required to induce perched groundwater (Robinson et al., 2005b). In contrast, there have been no observations of perched groundwater caused by a capillary barrier effect, despite the presence of layered stratigraphy with units of contrasting unsaturated flow properties.

An alternative hypothesis is that the deepest perched water occurrences are a manifestation of complex groundwater flow within the phreatic zone at the top of the regional aquifer. Localized heterogeneities, such as the clay-rich alteration zones in the Puye Formation at well R-9, combined with high recharge, may give rise to a complex flow structure that includes mounding, interconnected saturated zones, and locally confined conditions (Robinson et al., 2005b). However, the complexity of the alteration and the depth of these groundwater zones make detailed characterization prohibitively expensive. Hydrologic testing of the regional aquifer could be conducted to discriminate between alternatives.

With respect to the western portion of the Laboratory, Duffy (2004) discusses the importance of mountain-front processes and hydrologic conditions in semiarid landscapes and suggests that the mountain block and mountain-front areas are the dominant recharge zones in semiarid landscapes. An important hydrostratigraphic feature in this area is that the upper tuff units along the mountain front are often moderately to strongly welded because of close proximity to the caldera source. Welding results in increased fracturing during cooling, and because the mountain-front mesas lie within the Pajarito fault zone, additional fracturing and minor faulting of the tuff units has resulted. The welded tuffs create a hydraulic condition where matrix hydraulic conductivities are low (e.g., 10^{-7} to 10^{-9} cm/sec), but fracture densities are relatively high. Thus, there is a possibility for significant fracture flow. Fracturing appears to control locations of springs along the mountain-front mesas and fracture flow is suggested by water content and contaminant distributions in the tuff proximal to outfalls and wastewater lagoons (LANL, 2003b).

2.7.2.3 Subsurface Extent of Zones of Saturation

Observed saturated thicknesses of perched zones vary from 1 to 128 m (3 to 421 ft). The lateral extent of saturation in these zones is less well understood because costs associated with installing deep wells are high. However, perched groundwater generally is more likely to be present beneath wet canyons, based on observations of both occurrences and nearby absences of perched groundwater in adjacent wells. The extent that perched groundwater flows along dipping geologic strata into areas beneath adjacent mesas is not fully known. However, the few paired canyon/mesa wells such as R-7 and 21-2523 in Los Alamos Canyon and R-22 and R-23 in Pajarito Canyon suggest that perched zones are much less common beneath dry mesas.

2.7.2.4 Flow Conditions Upstream and Within Intermediate Perched Groundwater Zones

The presence of mobile (nonsorbing) anthropogenic chemicals in some perched groundwater zones indicates a connection with surface and alluvial groundwater (e.g., Robinson et al., 2005

and references therein). The travel time of groundwater moving from the surface to perched groundwater systems is on the order of several decades, based on the age of facilities that are potential sources of contaminants. Within the perched zones themselves, the topography of the perching horizon, the bedding features, and the orientation of interconnected fracture systems probably control local groundwater flow velocity. However, direct evidence such as single-well or multiple-well hydrologic and tracer testing, is not available. Therefore, the following discussion is based on reasonable hydrologic principles rather than direct measurements.

Flow conditions can, in principle, be categorized with the following two end-member conceptual models for flow within a perched water zone:

- *Low-velocity, virtually stagnant water resting in a perching horizon within a local structural or stratigraphic depression.* Water percolates very slowly out the bottom of this zone, or spills over the sides of the depression. This configuration views perching horizons as barriers that slow the downward percolation of water. In several wells, intermediate saturated zones thought to represent perched groundwater were screened but failed to produce significant water (Robinson et al., 2005). These occurrences may represent cases where zones of limited extent were substantially drained when the perching horizon was penetrated during drilling. Once the stagnant water is depleted in an initial round of sampling, there is insufficient recharge to keep the zone saturated.
- *High-velocity, laterally migrating fluid that travels on top of the perching horizon.* This conceptualization suggests that once groundwater reaches a perched zone, it rapidly percolates laterally along high-permeability pathways until the perching horizon pinches out or is breached by high-permeability features such as fractures or lateral changes in lithology. In this scenario, water could move in stairstep fashion from one perching horizon to another. There are no confirmed instances of large-scale, lateral vadose zone pathways beneath the Pajarito Plateau at depths greater than the alluvial groundwater. The case of lateral flow through the wet, mountain-front mesas at TA-16 suggests that this possibility exists at greater depths. Although we categorize the TA-16 observations as shallow for the purposes of this discussion because they discharge via springs in the local canyons, it could be argued that deep pathways with flow geometries similar to those of the mountain-front mesa or today's alluvial groundwater zones are evidence for the possibility of deeper fast pathways elsewhere.

Tracer experiments in alluvial and mountain-front mesa perched zones have been used to measure transport velocities. However, fluid velocity in the deeper perched groundwater zones is unknown due to the lack of direct measurements. The two end-member conceptual models, relatively stagnant fluid in a local subsurface depression, or lateral diversion in the hydrologic unit overlying the perching horizon, cannot be ruled out with existing data. Hydrologic, tracer, or remote geophysical techniques would be required to shed light on this question. Given the complexity and cost of such field campaigns, they should be performed only if model sensitivity analyses indicate that sorting out this issue is important to study impacts, or if remediation of a perched zone is to be conducted.

2.8 Regional Aquifer Conceptual Model

This section summarizes the current understanding of flow and transport in the regional aquifer beneath the plateau. This work builds on results obtained from earlier hydrologic studies in the region (Griggs and Hem, 1964; Purtymun, 1984; Purtymun and Johansen, 1974; Rogers et al., 1996b). The previous literature is supplemented with interpretations of new data collected by the LANL Groundwater Protection Program. These new data, combined with previous studies, provide the foundation for the flow and transport model development presented in Section 4.2

2.8.1 Regional Hydrologic Setting

This section briefly summarizes the regional hydrologic setting before focusing on the regional aquifer beneath the Pajarito Plateau (Section 2.7.2), which is the subject of this report. The Española Basin (see Figure 2-39) is one of a series of basins located within the Rio Grade Rift zone, a tectonic feature that extends from northern Colorado to the south into Mexico. Elevations within the basin range from more than 3,800 m along peaks in the surrounding mountain ranges to about 1,700 m at the basin surface water outlet. Vegetation is predominantly ponderosa pine forest at higher elevations and piñon pine/ juniper at lower elevations (Spiegel and Baldwin 1963).

The Española Basin and surrounding areas receive annual total precipitation ranging from 18 to 86 cm/yr. Precipitation is strongly elevation dependent (Spiegel and Baldwin 1963). The largest streams in the basin are the Rio Grande and Rio Chama. Median monthly flow, calculated using USGS average monthly flow data for the past 80 years, is 26.0 m^3/s along the Rio Grande (at Otowi Bridge) and 10.0 m^3/s along the Rio Chama (at Chamita) (U.S. Geological Survey, 2001). Numerous tributaries enter these rivers; many of these are ephemeral and many are ungaged. The Rio Grande and the lower reaches of many tributaries comprise the regional groundwater discharge zone.

In most parts of the basin, the water table is 0–60 m below ground surface; but on the Pajarito Plateau the water table is much deeper (up to 350 m below the surface). Throughout much of the basin, the water table appears to intersect the surface at the Rio Grande (Purtymun, 1984). Perched waters exist on the Pajarito Plateau (Robinson et al., 2005) where the unsaturated zone is much thicker than in other parts of the basin (Section 2.7). Contours of predevelopment water level data (Purtymun et al., 1995a, 1995b; U.S. Geological Survey, 1997) indicate that hydraulic gradients are generally towards the Rio Grande (Figure 2-40).

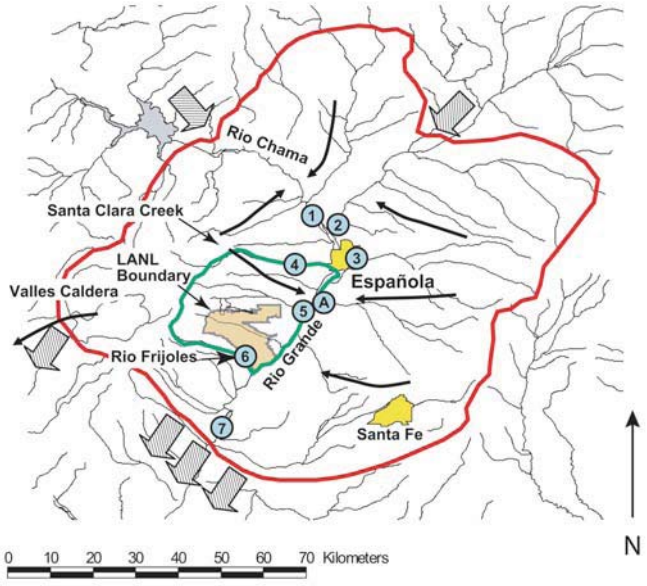


Figure 2-39. The Española Basin and vicinity, with basin-scale numerical model outline shown in red, site-scale model outline shown in green. Black arrows are generalized groundwater flow directions, based on regional water level data (Keating et al., 2003). The striped arrows indicate groundwater flow between the Española Basin and adjacent basins. Circled numbers refer to USGS stream gages: (1) Rio Chama at Chamita; (2) Rio Grande at San Juan; (3) Santa Cruz River; (4) Santa Clara Creek; (5) Rio Grande at Otowi; (6) Rio Frijoles; (7) Rio Grande at Cochiti. Circled "A" indicates the mouth of the Pojoaque Creek.

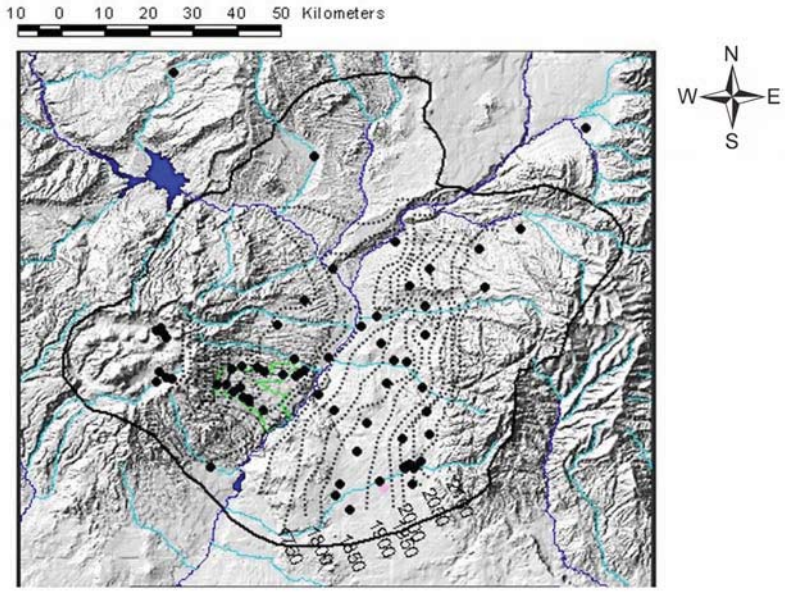


Figure 2-40. Approximation to present-day water table elevations (m).
Note: Some older head data are used to improve the spatial distribution.

The regional aquifer is a major source of drinking water and agricultural water supply for northern New Mexico. The largest cities in the basin are Santa Fe, Española, and Los Alamos; these all rely primarily on groundwater for municipal supply. In addition to discharges to water supply wells, the aquifer discharges to the Rio Grande, the lower reaches of its tributaries, and to numerous springs. There are additional withdrawals for municipal and agricultural supply. Recharge is thought to occur primarily in the higher elevations—estimates based on water budget and chloride mass balance methods range from 7–26% of total precipitation (Anderholm, 1994; Wasiolek, 1995). Little or no recharge occurs at lower elevations other than along stream channels due to low precipitation rates and high evapotranspiration demand (Anderholm, 1994).

The aquifer is predominantly composed of Santa Fe Group rocks, which are weakly consolidated basin-fill sediments reaching over 3,000 m in thickness near the basin axis (Cordell 1979). Groundwater also occurs in older crystalline rocks along the eastern and northern basin margin and in younger volcanic lavas and volcaniclastic sedimentary rocks in the vicinity of the Pajarito Plateau to the west (Purtymun and Johansen, 1974; Coon and Kelly, 1984; Daniel B. Stephens & Associates, 1994).

2.8.2 Hydrology Beneath the Pajarito Plateau

Groundwater beneath the Pajarito Plateau is part of a regional aquifer which extends throughout the Española Basin (an area roughly 6000 km^2; Figure 2-39). This aquifer is the primary source of water for the Laboratory, the communities of Santa Fe, Española, Los Alamos, and numerous pueblos. Four water supply wellfields exist on the plateau (Figure 2-41); one additional wellfield that supplies the city of Santa Fe (Buckman) sits just to the east of the Rio Grande, close to the plateau. As is the case for many aquifers in the semiarid southwest, there is concern that current withdrawal rates may not be sustainable over long periods of time and current drought conditions might have significant impacts on both surface water and groundwater quantity and quality.

Of more direct relevance to the Hydrogeologic Workplan studies are concerns about water quality, due to a variety of anthropogenic contaminants. Beneath the Pajarito Plateau, there is contamination from various LANL sources in shallow groundwaters in some locations (primarily alluvial aquifers). Some of the LANL-derived contamination has been observed in the regional aquifer at trace concentrations much below the EPA drinking water standards (see Section 3 for a complete discussion of this point). The regional aquifer is the groundwater zone most directly accessible to humans through municipal water-supply wells or springs issuing to the Rio Grande. Therefore, a solid foundation of understanding of the hydrogeologic conditions and controls on flow and transport in the regional aquifer must be obtained in order to make risk-based decisions, to design the required groundwater monitoring network, or to design treatment and remediation systems.

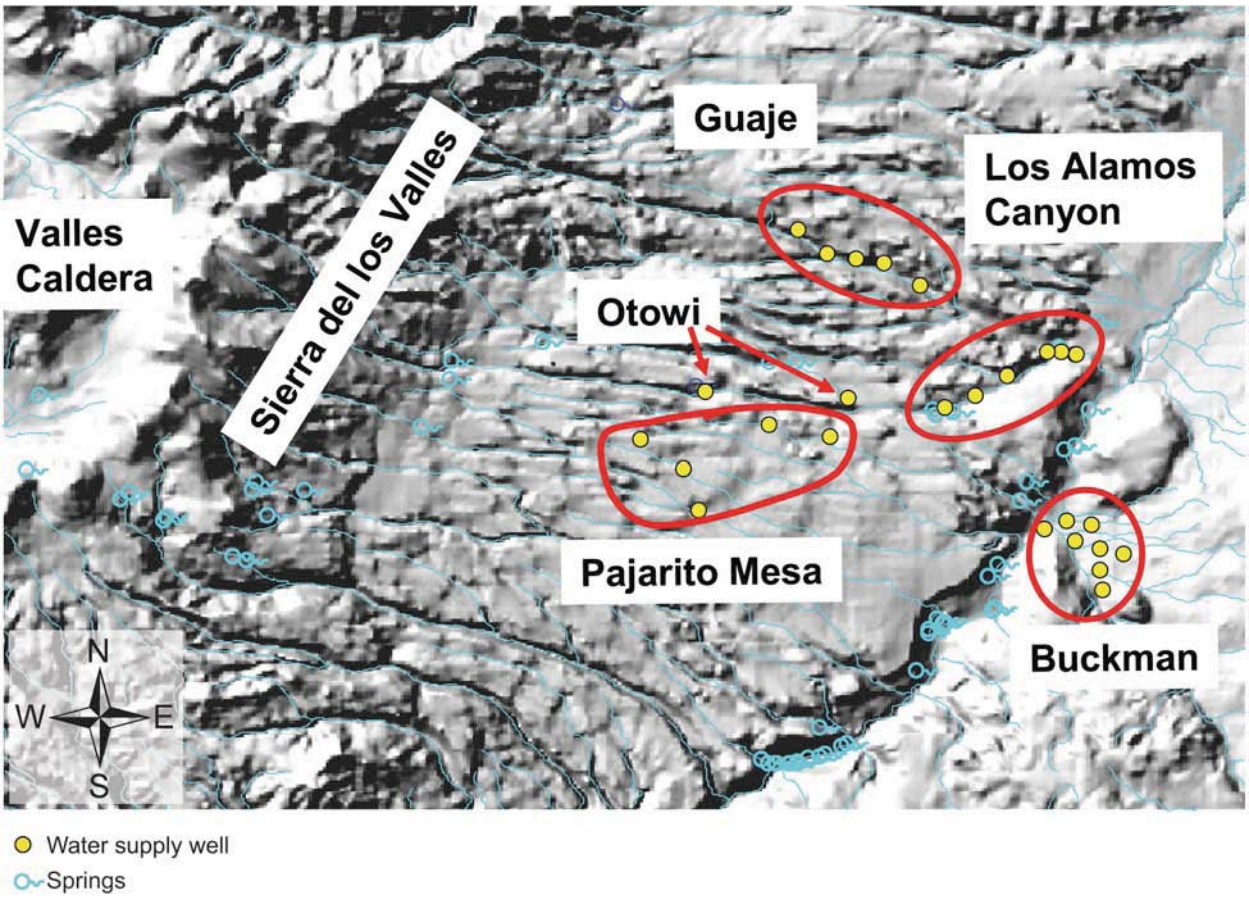


Figure 2-41. The Pajarito Plateau, with major wellfields indicated by enclosures in red.

2.8.3 Water Budget

The water budget for the regional aquifer defines the sources and sinks of water to and from the Española Basin and, on a smaller scale, under the Pajarito Plateau. This section summarizes the state of knowledge and addresses uncertainties in the quantities and spatial distribution of recharge, discharge, and interbasin flow.

2.8.3.1 Recharge

As the water source term, recharge to the regional aquifer provides the driving force for fluid movement through the system. Furthermore, water recharging on the Pajarito Plateau on LANL property can carry with it liquid-borne contamination. This subsection addresses both basin-scale and local recharge, addressing the spatial distribution and quantity of recharge.

2.8.3.1.1 Recharge Distribution

Various theories have been proposed regarding the locations of recharge zones for this aquifer. Griggs (1964) suggested that most of the recharge occurred in the Sierra del los Valles and along stream channels in the western edge of the Pajarito Plateau (Figure 2-41). Purtymun and Johansen (1974) proposed that the major portion of the recharge occurs in the Valles Caldera, with smaller amounts recharging through stream channels in the Sierra del los Valles. However, Blake et al., (1995) argued that recharge could not originate in the Valles Caldera, since the

chemistry of geothermal waters in the western Valles Caldera is clearly distinct from the groundwaters on the Pajarito Plateau (Blake et al., 1995; Goff and Sayer, 1980). These authors also proposed, on the basis of stable isotope values in groundwaters beneath the plateau, that recharge areas for the aquifer beneath the plateau were either to the north and/or to the east (Sangre de Cristo Mountains) and not to the west. They hypothesized that the two flow systems are separated by the Pajarito fault acting as a flow barrier (Blake et al., 1995).

In contrast, other lines of evidence indicate that the majority of recharge to the basin aquifer occurs in the mountains along the basin margin where precipitation rates are relatively high. This has been shown using water-budget and chloride-mass balance analyses in the eastern portion of the basin (Anderholm, 1994; Wasiolek, 1995). In the course of the Hydrogeologic Workplan studies, inverse modeling using head and streamflow data (Keating et al., 2003) demonstrated that the elevation above which significant recharge occurs at the basin-scale is very well constrained (2195m ± 177m). Modeling results such as this are to some extent a function of the model conceptualization and structure, and therefore do not provide a precise indication of the recharge elevation. Nevertheless, the modeling result agrees with the conclusion on the elevation above which recharge occurs, as determined from those other lines of evidence.

Isotope geochemical information can also be brought to bear on the question of recharge distribution. Distributions of δD and $\delta^{18}O$ ratios are consistent with the conclusion that the mountain front recharge supplies most of the groundwater beneath the Pajarito Plateau (Longmire, 2002a; Longmire, 2002b; Longmire, 2002c; Longmire, 2002d; Longmire, 2002; Longmire and Goff, 2002). Lighter or more negative δD and $\delta^{18}O$ ratios indicate both a cooler climate for precipitation and/or a higher elevation of recharge (Clark and Fritz, 1997). Heavier or less negative δD and $\delta^{18}O$ ratios are representative of a warmer climate for precipitation and/or recharge that occurs at lower elevations. Groundwater samples collected within the Sierra de los Valles have lighter δD and $\delta^{18}O$ ratios relative to those collected beneath the Pajarito Plateau and along the Rio Grande. Precipitation of meteoric water at higher elevations, for example near the Sierra de los Valles, is characterized by cooler temperatures relative to other waters found at lower elevations on the Pajarito Plateau. Long-term temperatures (paleotemperatures) and seasonal variations in temperature also influence $\delta^{18}O$ and δD values because of enrichment or depletion of oxygen-18 and deuterium (Clark and Fritz, 1997).

A plot of δD versus $\delta^{18}O$ (average values) for numerous groundwater samples collected from wells R-9, R-12, R-15, R-19, R-25, R-26, CdV-R-37-2, and CdV-R15-3 and springs within the Valles caldera and Sierra de los Valles is shown in Section 3.1.1.1. In this figure, the Jemez Mountains meteoric line (upper) ($\delta D = 8\delta^{18}O + 12$) (Vuataz et al., 1986) and the mean worldwide meteoric water line (lower) (($D = 8\delta^{18}O + 10$) (Clark and Fritz, 1997) are denoted by JMML and MWL, respectively. Analytical uncertainties of $\delta^{18}O$ and δD are ± 0.1 and ± 1‰ (per mil), respectively. Results of stable isotope analyses for the R wells and springs indicate a meteoric source in which the samples plot close to both the JMML and MWL (Section 3.1.1.1). The distribution of isotopic ratios suggests that evaporation of groundwater has not taken place to a significant extent prior to recharge.

The Sierra de los Valles is the likely recharge source for wells R-25, R-26, CdV-R-15-3, CdV-R-37-2 because the Sierra de los Valles springs have similar $\delta^{18}O$ and δD ratios (Blake et al. 1995).

The less negative stable $\delta^{18}O$ and δD values (relative to well R-25) in wells R-9, R-12, R-15, and R-19 are consistent with additional recharge at lower elevations (Section 3.1.1.1). This interpretation is consistent with the concept of local recharge on the plateau as the source for water at shallow depths in the regional aquifer beneath the Laboratory.

Although analyses such as these can be useful in identifying the elevation of recharge, Keating et al. (2005) point out that uncertainties due to variability in isotopic composition of precipitation and potential differences in precipitation and infiltration elevations complicate the use of these isotopic tracers. For example, stable isotope ratios may actually be tracing the *timing* of recharge for very old waters (Phillips et al., 1986), as opposed to the location. Very low $\delta^{18}O$ values (< -14), significantly lower than average modern precipitation signatures at all elevations in the basin, have been measured in groundwaters near the Rio Grande (Anderholm, 1994; Blake et al., 1995). These ratios are indicative of paleorecharge during a cooler climate (Phillips et al., 1986) and were interpreted by Anderholm (1994) and Newman (1996) to indicate recharge during the Pleistocene (with age in order of 8,000 – 17,000 years). These age estimates are consistent with ^{14}C observations suggesting a component of old fluid (Rogers et al., 1996b). Note however that some of these same waters also clearly contain a component of young water, as indicated in Section 3.1.1.3.

A quantitative assessment of the spatial distribution of recharge on the Plateau was recently published by Kwicklis et al. (2005). The goal of the study was to provide a summary of the current state of knowledge on amount and spatial distribution of infiltration. The study was intended to provide quantitative estimates for use in other studies, as well as to provide a baseline that can be tested and improved upon as more data are collected. The study uses streamflow gain and loss data along canyon bottoms from the Pajarito Plateau, along with point infiltration estimates based on moisture content profiles interpreted using the Richards equation, the chloride mass-balance method, transport rates of tritium in canyons on the Plateau, and numerical modeling. The infiltration rates estimated with these techniques were extrapolated to uncharacterized parts of the study area using maps of environmental variables that are correlated with infiltration (such as topography, vegetation cover, and surficial geology and structure) and spatial algorithms implemented with GIS software that use the mapped variables.

The map of estimated infiltration is presented in Figure 2-34. The large-scale characteristics of these estimates are in line with the discussion presented above. Infiltration rates throughout most of the plateau are generally less than 2 mm/yr, whereas infiltration rates in the mixed conifer-dominated areas of the Sierra de los Valles are typically greater than 25 mm/yr and, in the aspen-dominated areas, greater than 200 mm/yr. Thus, at lower elevations, recharge occurs primarily along arroyos and canyons, and infiltration rates are estimated to be low on mesas except near the mountain front (Anderholm, 1994; Birdsell et al., 2005). Despite the low flux, the total quantity of infiltration associated with the mesas is small but not negligible, due to the large area associated with these parts of the plateau.

The Kwicklis et al. (2005) study estimates that of the total infiltration of about 8600 acre-ft/yr (336 kg/sec), about 23% of the infiltration occurs from canyon bottoms on the plateau at lower elevations. This canyon-bottom infiltration includes about 14% of the total from streams that flow at least partly within LANL boundaries. The inserts in Figure 2-34 indicate regions for

which localized, high-infiltration zones are expected to exist on the plateau. Focused infiltration is expected in the faulted regions associated with the Pajarito fault zone within Cañon de Valle and Water Canyon (see lower left insert in Figure 2-34). Local infiltration at rates up to 1000 mm/yr is estimated. For the insert showing the confluence of Los Alamos and Pueblo Canyons (lower right), rates of 1500–2000 mm/yr are estimated in this region. These high values are a consequence of infiltration directly onto Puye fanglomerates or fractured basalts. In other canyons with similar characteristics, such as Pajarito Canyon, similarly high local infiltration values are expected.

Although relatively small volumetrically compared to mountain recharge to the west, aquifer recharge occurring locally on the plateau is important to the assessment of flow paths of potentially contaminated water. Tritium data confirm that relatively young water is present in the aquifer (Rogers et al., 1996b), indicating fast pathways through the vadose zone beneath LANL. Quantitative estimation of recharge using ^{3}H data is complicated by the sometimes confounding influences of bomb-pulse atmospheric ^{3}H and locally derived ^{3}H related to on-site LANL activities. Elevated ^{3}H in regional aquifer samples has been observed at O-1, TW-1, TW-3, TW-8, LA-1A and LA-2 (Rogers et al., 1996b), as well as in several wells drilled during the more recent characterization drilling program (see Section 3.3).

Kwicklis et al. (2005) used vadose zone occurrences of ^{3}H to estimate the time-dependent transport velocities, from which they derived infiltration rates to the regional aquifer. They found that in Mortandad Canyon, infiltration rates are as high as 2000 mm/yr occur during periods of large volumes of effluent discharge. This infiltration rate has apparently decreased to 100-200 mm/yr once effluent discharge flow rates were reduced. These observations and analysis confirm that local recharge in canyons is an important component of the recharge distribution for the plateau.

2.8.3.1.2 Total Recharge

Estimates of total recharge provide important constraints on flow and transport models of the regional aquifer by tying model calibrations to measured or estimated water balance components. Therefore, various techniques and data sets have been examined to estimate total recharge. Griggs (1964) estimated the total recharge to the aquifer beneath the Plateau to be between 168 and 216 kg/s. McLin et al. (1996) estimated an upper bound of 192 kg/s, based on recovery of water levels in supply wells rested for a period of several months to several years. Using a variety of methods and considering a larger area, the Kwicklis et al. (2005) study discussed above estimates total average annual recharge to the Pajarito Plateau of 336 kg/sec.

A number of researchers have used baseflow gain to the Rio Grande to estimate total aquifer discharge, from beneath both the plateau and the eastern basin. These estimates presumably approximate the total aquifer recharge before significant pumping began. However, total gain must be combined with an estimate of the proportion of the gain that originates beneath the plateau. Long-term average aquifer discharge between the Otowi Bridge gage and the now-submerged Cochiti gage, a reach which bounds the southern portion of the plateau, was estimated by Spiegel and Baldwin (1963) to be 710 kg/sec and more recently by the U.S. Department of Justice to be 400 kg/sec (U.S. Department of Justice and New Mexico State Engineer Office, 1996). The former estimate is significantly higher because the authors did not

include years of record that indicated the reach to be losing, which was attributed to measurement error. Keating et al. (2005) present an analysis of data from this reach as well as the reach immediately to the north (Española to Otowi), which bounds the northern portion of the plateau. This analysis estimates the total gain to the Rio Grande adjacent to the Pajarito Plateau (Santa Clara Creek to Rio Frijoles) to be approximately 911 kg/sec (+/– 30%). The modeling study of Hearne (1985) assumes 316 kg/sec recharge to the Pajarito Plateau; McAda and Wasiolek (1988) assume 291 kg/sec lateral inflow from the Jemez Mountains.

Aquifer modeling studies can also shed light on the recharge quantities and distribution. Keating et al. (2003) performed basin-scale inverse modeling as part of the Hydrogeologic Workplan, using both streamflow data and transient head data. That study indicated that approximately 253 kg/sec of the gain to the river along this reach originated on the Pajarito Plateau and the Sierra de los Valles. This analysis probably underestimated total recharge on the plateau, in part because the basin model was calibrated to a lower estimate of aquifer discharge north of Otowi Bridge than is indicated by the streamflow analysis subsequently performed by Keating et al. (2005). Part of the reason for the differences between these various estimates of total recharge is that several of the smaller estimates (McLin et al., 1996; Speigel and Baldwin, 1963; and Griggs 1964) emphasized the southern portion of the plateau (including LANL) which, according to the streamflow analysis in Keating et al. (2005), is discharging less water than the northern portion of the plateau.

In summary, although these various estimates span a range and reflect some uncertainty, they are extremely valuable as bounding values for flow and transport modeling in that they constrain the total quantity of water flowing through the aquifer beneath the Pajarito Plateau.

2.8.3.2 Discharge

Data constraining quantity of discharge for the regional aquifer were discussed in Section 2.8.3.1 in the context of estimating recharge. Regarding discharge locations, many authors have identified the Rio Grande as the principal discharge point for the regional aquifer (Cushman, 1965; Griggs and Hem, 1964; Hearne, 1985; McAda and Wasiolek, 1988; Purtymun and Johansen, 1974; Theis and Conover, 1962). Previous reports have cited a variety of evidence to support this, including:

- Streamflow gain along the Rio Grande (Balleau Groundwater, 1995; Purtymun and Johansen, 1974; Spiegel and Baldwin, 1963)
- Measured vertical upward gradients in the vicinity of the Rio Grande (Cushman, 1965; Griggs and Hem, 1964)
- The presence of flowing wells (McAda and Wasiolek, 1988; McLin et al., 1996; Spiegel and Baldwin, 1963)
- Springs along the river (McLin et al., 1996).

Discharge to the river may occur as lateral flow, upward flow, or as flow from springs in White Rock Canyon. Purtymun (1966) suggested that all the springs, which collectively flow approximately 85 kg/sec, discharge water from the upper surface of the main aquifer. Stone (1996) suggested that many of these springs may be discharging perched aquifers rather than the regional aquifer; unfortunately it is difficult to test these alternative hypotheses, although stable

isotopes may provide some discrimination. It has been emphasized that although discontinuous, low-permeability beds produce confining conditions in the aquifer locally near the Rio Grande and elsewhere in the basin, flow is able to cross the low permeability beds in some locations as water discharges to the river (Hearne, 1985; Spiegel and Baldwin, 1963).

The degree of connection between the aquifer and the Rio Grande has been investigated by Balleau Groundwater (1995), who drilled 16 wells in the alluvial aquifer of the Rio Grande near the Buckman wellfield and conducted pumping tests. They found that head in the alluvium is generally 0.1 to 0.2 feet higher than the Rio Grande, indicating discharge from the alluvium to the Rio Grande. Head in the regional aquifer below the alluvium, at a depth of 59 feet, is about 2.8 feet higher than the Rio Grande. From pumping tests, they concluded that the hydrogeologic system at the site behaves as a layered water-table system in hydraulic contact with the river with delayed yield from pore-water storage and an adjacent river boundary source.

2.8.3.3 Interbasin Flow

Overall groundwater fluxes between the regional aquifer beneath the plateau and the basin and flow between the Española Basin and adjoining basins are not well constrained. It is possible that virtually all the groundwater flowing beneath the Pajarito Plateau flows easterly/southeasterly and discharges to the Rio Grande, and that interbasin flow to the south is small. An alternative possibility, that deep flow discharges instead to the basins to the south, is difficult to confirm or refute because of the lack of hydraulic data collected at discrete intervals at great depths within the aquifer. This could have a large impact on flow conditions at and near the site and thus will be the subject of future study.

The Española Basin is separated from the Albuquerque and Santo Domingo basins to the south by a structural high, a prong of older sedimentary rocks, and several major fault zones (Golombek et al., 1983). The Santa Fe Group aquifer thins significantly at this boundary (Shomaker, 1974). If these structures impede flow to the south, this might enhance both regional aquifer and interflow discharge to the surface. We have not evaluated the possible interflow component to streamflow gain in the southern portion of the basin; if it were significant our estimate of groundwater discharge would be erroneously high.

Numerical models of groundwater flow in the basin have generally predicted the interflow component of flow to the south to be small. The model of Hearne (1985) has no groundwater flow to the south by assumption; the McAda and Wasiolek (1988) and Keating et al. (2003) models allow interflow, but the models predict much larger discharge within the basin (to the Rio Grande) than to basins to the south. For example, Keating et al. (2003) estimated southerly flow from the Pajarito Plateau aquifer to the south to be approximately 9 kg/sec. Uncertainty analysis showed a possible range of values + 34 kg/sec or – 62 kg/sec. All of these values are relatively small compared to the total flow to the Rio Grande.

Regarding basin boundaries to the north and west, fluxes entering the region beneath the plateau were estimated by Keating et al. (2003), using basin-scale head and streamflow data and inverse modeling analysis. They estimated that flow into the plateau from the north was very small or zero, with a relatively large degree of certainty. Inflow from the west (Valles caldera) and outflow to the south is more uncertain, and could be as low as zero or as high as 94 or 34 kg/s,

respectively. These fluxes are relatively small compared to estimates of total recharge for the plateau.

These modeling results, when combined with recharge and streamflow estimates, result in a self-consistent mass balance on water moving through the aquifer. Given the uncertainties in the individual flow estimates and the inherent difficulty of defining the appropriate structural features for a large-scale model, it is possible that other conceptualizations would provide equally valid representations of the available information. For example, it is possible that a conceptualization in which more water flows from the Española Basin to the adjoining Albuquerque Basin, rather than discharging at the Rio Grande, would prove valid. Elements of such a model conceptualization are (1) less flow restriction to the south; (2) more restricted flow from the deeper, confined aquifer to the Rio; and (3) southerly flow of a fraction of the deeper aquifer from the Sierra de los Valles and the Sangre de Cristo Mountains to the south. Of course, such a conceptualization would also need to be consistent with the available water budget information. The point here is that alternate conceptualizations such as this cannot be unequivocally ruled out and thus should be considered in future numerical models developed for the plateau and the basin.

2.8.4 Aquifer Hydrologic Properties

This subsection briefly summarizes the hydrologic properties of the regional aquifer rocks. A more detailed treatment of this critical topic, including statistical and spatial distributions of hydraulic conductivities measured in aquifer tests, is presented in Section 2.4. The aquifer beneath the plateau consists of the fractured crystalline rocks of the Tschicoma Formation, Cerros del Rio basalts, and older basalt flows, as well as the sedimentary rocks of the Puye Formation and the Santa Fe Group. These units are described in detail in Section 2.1, as well as by Broxton and Vaniman (2005). Both the Santa Fe Group and the Puye Formation are alluvial fan deposits with alternating beds of high and low permeability, with north-south trending faults associated with basin-scale rifting (Kelley, 1978).

Permeability estimates for the Santa Fe Group are primarily derived from pumping tests in water supply wells screened over large intervals; estimates range from 10^{-11} to $10^{-12.8}$ m^2 (Griggs and Hem, 1964; Purtymun, 1995; Purtymun et al., 1995a; Theis and Conover, 1962). Testing of monitoring wells, with relatively short screens completed within the Puye Formation, has shown very large variability (10^{-11} to $10^{-13.5}$ m^2). The basalt flows beneath the plateau include massive, fractured lava units, breccia zones, and inter-flow zones with significant clay content. Permeability within the Cerros del Rio basalts ranges from $10^{-11.2}$ to $10^{-13.8}$ m^2 (Nylander et al., 2002). Testing at R-28 shows the upper bound of permeability to be between $10^{-10.5}$ and $10^{-10.2}$ m^2 (Kleinfelder, 2004b).

Several estimates of specific storage (Ss) have been derived from various pumping tests: $10^{-4.8}$ /m in the Los Alamos Canyon wellfield (Theis and Conover, 1962); $10^{-5.5}$/m and $10^{-3.8}$/m in the Otowi wellfield (Purtymun et al., 1990; Purtymun et al., 1995b). These relatively low values are indicative of confined or leaky-confined conditions at the depth that these observations were made. This point is expanded upon in the next subsection, along with more recent estimates of specific storage based on a pumping test conducted as part of the Hydrogeologic Workplan.

2.8.5 Anisotropy and Scale Dependence

Both the Santa Fe Group and the Puye Formation are, at least locally, strongly anisotropic. Pumping tests have confirmed that permeability normal to bedding is much lower than permeability parallel to bedding, both on the Pajarito Plateau (McLin et al., 2005; Purtymun et al., 1990; Purtymun et al., 1995b; Stoker et al., 1989) and elsewhere in the basin (Hearne, 1980). Estimates of anisotropy (ratio of vertical to horizontal hydraulic conductivity) vary from 0.00005 (Hearne (1980), pumping test analysis) to 0.04 (Hearne (1980), hydraulic gradient analysis), to 0.01 (McAda and Wasiolek, 1998).

Effective permeability and anisotropy at large spatial scales are difficult to estimate. Many authors have noted the lack of spatial continuity of low or high permeability beds with the Santa Fe Group (Hearne, 1980; Spiegel and Baldwin, 1963; Theis and Conover, 1962) and the difficulty of correlating geophysical or lithologic logs between even closely spaced wells (Cushman, 1965; Shomaker, 1974). Hearne (1980) notes that because of limited spatial continuity in low or high permeability rocks, under a regional pressure gradient vertical flow will occur through circuitous routes and thus effective anisotropy may be less pronounced at large spatial scales than that measured at small scales during pumping tests.

Large-scale, multiple-observation-well aquifer pumping tests are invaluable to examine scale effects and to estimate the impacts of water supply well pumping on pressure gradients in the aquifer. As part of the characterization program, a 25-day aquifer test was conducted at municipal water supply well PM-2 from February 3–28, 2003 (McLin, 2005). The pumping phase was conducted at a constant discharge rate of 1,249 gpm, followed immediately by a 25-day recovery period. Surrounding observation wells were used to record both drawdown and recovery in response to pumping at PM-2. The PM-2 well draws water from a continuous louvered screen between 1,004 and 2,280 ft below ground surface (bgs). Prior to the start of the test, production wells in the vicinity were completely shut down so that hydrostatic conditions in the regional aquifer could recover and a static baseline could be established. Except for the test pumping at PM-2, all of the surrounding water supply wells remained off throughout the test period. Continuous water-level responses to pumping at PM-2 were recorded by transducers that were placed in municipal wells PM-2, PM-4, and PM-5 and in characterization wells R-20 (three separate screens) and R-32 (three separate screens). Periodic responses to pumping were also recorded in characterization wells R-15 (one screen), R-21 (one screen), and R-22 (five separate screens); however, no significant drawdown values were recorded in these latter wells.

Figure 2-42 (from McLin, 2005) shows a layout of PM-2 and nearby monitoring locations during the test. Individual drawdown and recovery water levels in responsive wells demonstrate that the regional aquifer surrounding PM-2 is vertically anisotropic with pronounced resistance to vertical propagation of drawdown at shallower depths. Hydraulically, the aquifer behaves like a semiconfined aquifer at depth with leaky units located above (and perhaps below) a highly conductive layer that averages about 850 ft in thickness. Drawdown in this highly permeable unit was recorded more than 8,800 ft away in well PM-5, while drawdown only 1,225 ft away at the R-20 multiple-screened well was directly related to individual screen depth (Figure 2-43a, from McLin, 2005); the shallowest screen at R-20 showed little drawdown, while the deepest screen

showed a dramatic response to pumping at PM-2. Similar but more subdued behavior was also recorded 4,457 feet away in the R-32 multiple screened well (Figure 2-43b). In contrast, no recordable drawdown was recorded 8,900 feet away in the R-22 multiple screened well, suggesting that an idealized radius of influence for pressure responses due to pumping at PM-2 was at least 8,800 feet after 25 days of continuous pumping. The idealized radius of influence shown in Figure 2-42 is schematic, based on the available data and is not meant to imply that the pressure response spreads uniformly in all directions.

A schematic diagram proposed by McLin (2005) to interpret the aquifer-pumping test and to estimate hydrologic parameters is reproduced in Figure 2-44. Clearly, this aquifer configuration is highly idealized, in that a single, well-defined semi-confining layer has not been identified, and layered heterogeneities certainly exist within the zone depicted as the deeper aquifer (for example, see the geologic cross section of Figure 3 in McLin, 2005). Nevertheless, using this idealized aquifer configuration, McLin (2005) estimated hydraulic conductivity at the scale of this test to be about 5.0 ft/day (based on an assumed aquifer thickness of 850 ft), with a storage coefficient ranging from about 0.00032 to 0.002. Finally, the observations of muted drawdown at observation points near the water table (significantly above the pumping elevation) suggest that the horizontal-to-vertical anisotropy ratio of hydraulic conductivities is highly variable: McLin (2005) suggests that the ratio of vertical to horizontal hydraulic conductivity may be on the order of 0.01 in some locations within the regional aquifer.

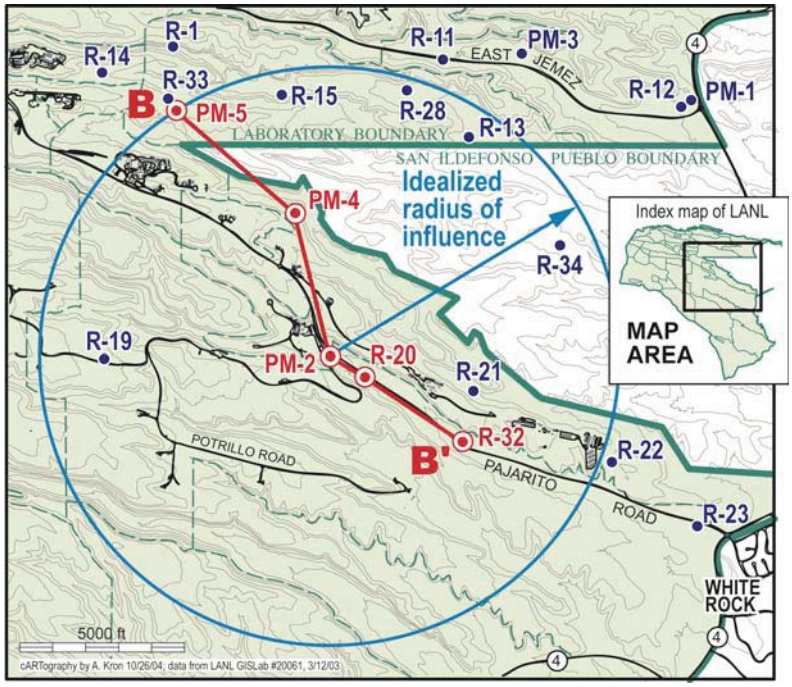


Figure 2-42. Idealized radius of influence of PM-2 on surrounding wells (McLin, 2005).

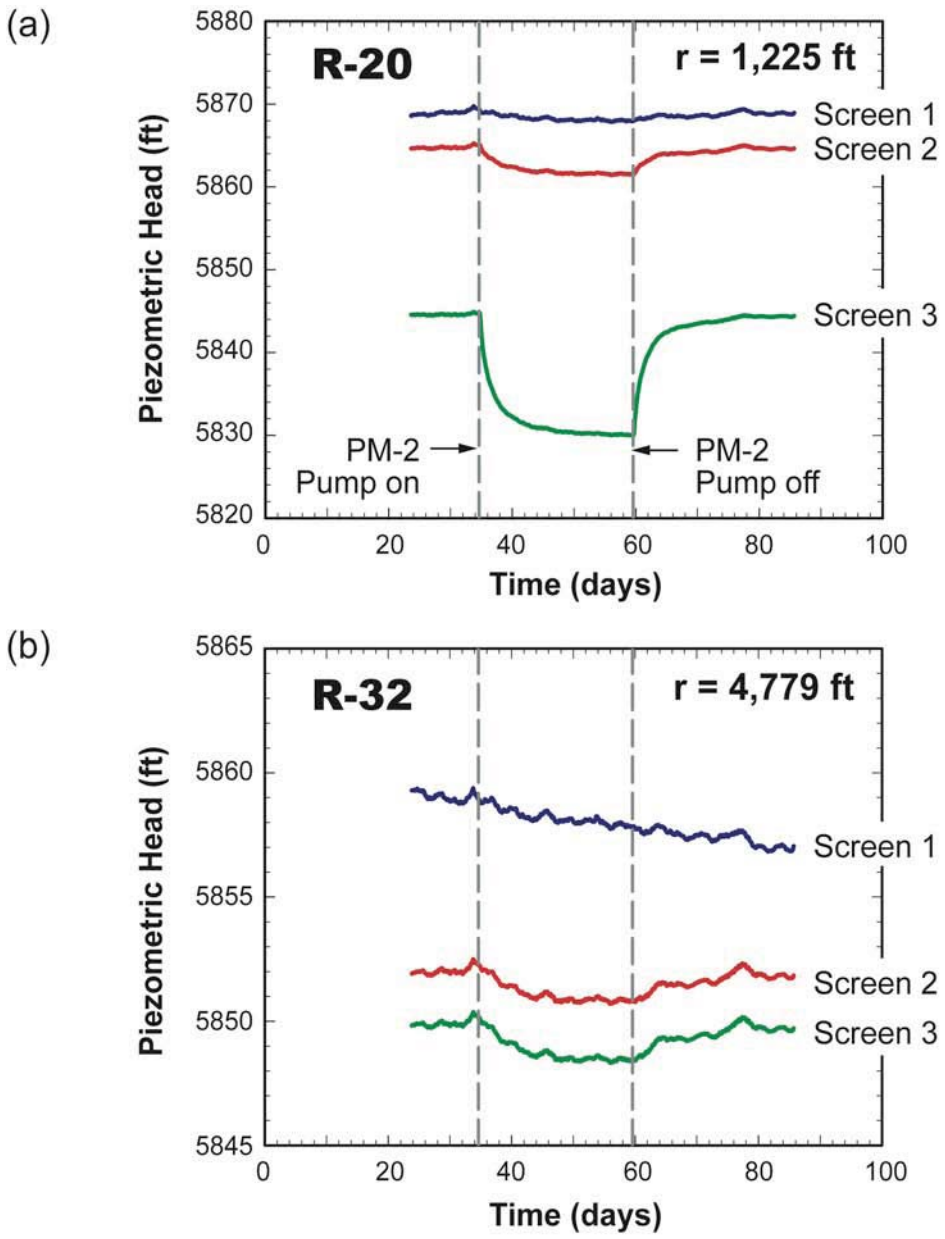


Figure 2-43. Drawdown at wells R-20 (a) and R-32 (b) in response to pumping at PM-2 (McLin, 2005).

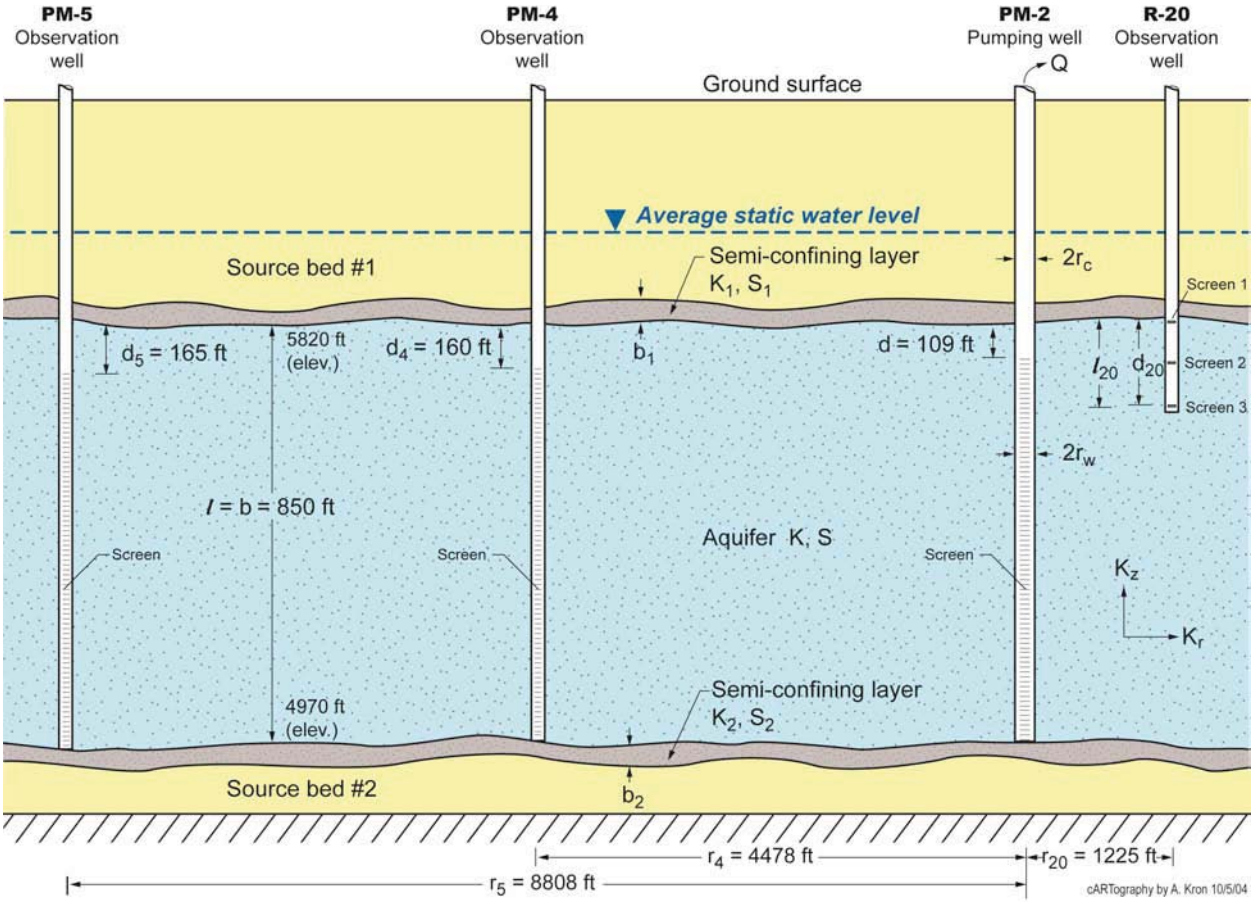


Figure 2-44. Idealized representation of the aquifer near PM-2 during the pumping test. A shallow system that includes the water table is separated from a deeper system by a semiconfining layer of low permeability (McLin, 2005).

The analysis of McLin (2005) suggested an aquifer that behaves as a confined system at early stages in the test, transitioning to a behavior characteristic of leaky-confined aquifer behavior when the long-term drawdown behavior is interpreted. Although the behavior of the pumping test has the signature of a leaky-confined aquifer, with a temporal stabilization of drawdown relative to a confined aquifer, other aquifer flow mechanisms can give rise to similar behavior. For example, either leakage from low-permeability aquitards within a confined aquifer or interception of the cone of depression with a recharge boundary is an alternative explanation. The pumping test illustrated the importance of conducting tests of long enough duration to discern the large-scale behavior of the aquifer at progressively larger scales. Additional tests at other municipal water supply wells are planned to probe the hydrodynamic conditions of the aquifer at different locations. By combining the results of several such tests, we should be able to sort out the various flow mechanisms, thereby uncovering a more detailed picture of flow paths and mechanisms in the aquifer.

2.8.6 Hydraulic Heads and Flow Directions

The principal reason for studying the regional aquifer in the Hydrogeologic Workplan activities is to determine the direction and rate of movement of water and contaminants. Historically, easterly/southeasterly flow directions in the regional aquifer have been proposed, based on data available to Purtymun and Johansen (1974) and Rogers et al. (1996b). Data collected as part of the Hydrogeologic Workplan confirm this result with a much larger number of wells than were available to earlier studies, particularly wells completed with short screens near the water table.

2.8.6.1 Water Level Map

The potentiometric surface for the regional aquifer is shown in Figure 2-24 (from LANL, 2005). Data used to construct this map are given in Table 2-10 for wells under water table conditions. In addition, data from wells under leaky-confined conditions in lower Los Alamos Canyon were included to augment the spatial coverage of the data because observations at the water table are not available at that location. The analysis of the data used to construct this and other maps of water levels and trends with time is discussed in detail in LANL (2005). The lateral component of gradients along the top of the aquifer beneath the plateau varies over one order of magnitude, from a low of 0.0026 (TW-3 to R-5) to a high of 0.04 (CDV-R-37 to CDV-R-15). Even higher gradients are evident west of R-25 (0.162; R-26 to R-25).

A simple conceptual model for these trends is that gradients are high to the west where significant recharge is occurring and gradients are low in the central plateau where lower recharge rates are occurring and higher permeability rocks are present (Purtymun, 1995). The general easterly-southeasterly flow direction suggested by these gradients is consistent with radiocarbon ages of water from deep wells beneath the Pajarito Plateau, which increase from west to east. Age estimates for groundwaters beneath the plateau range between about one to six thousand years, increasing to several tens of thousands of years near the Rio Grande (Rogers et al., 1996b). However, as will be discussed below, interpretation of these data is complicated by the fact that the flow patterns within the aquifer are complex, and mixing of fluids of different ages is likely. The presence of anthropogenic tritium in the regional aquifer demonstrates that mixed waters of vastly different ages are present in the aquifer.

2.8.6.2 Shallow and Deep Flow Paths

The nature of the measured head gradients suggests that flow in the shallow portion of the aquifer (less than 150 m) below the upper surface of the saturated zone is primarily easterly-southeasterly. The tendency for aquifer rocks to be strongly anisotropic will cause water to move in large part horizontally, despite the strong driving force of vertical head gradients. As described in the previous subsection, the degree to which the uppermost phreatic zone and the deeper, leaky-confined aquifer are hydrologically connected is not known with certainty. Nevertheless, hydrologic testing indicates that there is considerable resistance to vertical flow relative to horizontal flow; this phenomenon is likely to be widespread throughout the aquifer, but the magnitude of the anisotropy ratio at small scales probably varies considerably across the plateau. One interesting observation is that the amount of recharge estimated by Kwicklis et al. (2005) to occur in canyon bottoms on the plateau (77 kg/sec) is close to the total discharge from the springs of 85 kg/sec estimated by Purtymun (1966). This observation is consistent with a

compartmentalized aquifer with plateau recharge traveling laterally in the phreatic zone, partially isolated from deeper groundwater flow.

In general, the direction of flow in deeper portions of the aquifer (at depths greater than the deepest water supply wells) is unknown because of sparse data, and is likely to be different under pumping conditions than under pre-development conditions. Purtymun (1995) suggested that heads at deeper intervals of the aquifer also have a westerly gradient. It is conceivable that the predominant flow direction under natural gradient conditions could be different from what is found at shallower depths, but data to constrain the direction are insufficient. The conceptual model for the nature of flow discharging to the Rio Grande or flowing to the Albuquerque Basin to the south will likely influence the predicted flow direction deeper in the aquifer. A model with significant flow to the Albuquerque Basin (described in Section 2.8.3.3 as an alternate conceptual model) would lead to more southerly flow paths in the deep aquifer.

2.8.6.3 Influence of Water Supply Well Pumping

Despite evidence for compartmentalized flow with significant flow resistance between the shallower and deeper zones, it is likely that some downward movement of water and contaminants does occur due to pumping of water supply wells at depth. Occurrences of tritium and perchlorate in well O-1 show that flow paths between the shallow and deep aquifer water can exist during production. However, the extent of vertical transport is undoubtedly a function of the local permeability structure between the water table and the pumping interval in the water supply well, which may vary spatially across the plateau. Finally, pumping-induced upward movement of deeper water has been observed in the Los Alamos Canyon wellfield (Gallaher et al., 2004; Purtymun, 1977).

Although our understanding of the impact of water production on aquifer storage and discharge to the Rio Grande is incomplete, there is a clear trend of decreasing water levels over the time period of production from major wellfields on the plateau. Pumping rates increased from near zero in 1945 to 183 kg/sec in 1971 and have been relatively stable since then (171 kg/sec in 2001) (Koch et al., 2004); although year-to-year variability in pumping rates at individual wells has been large. Figure 2-45 (from LANL, 2005) shows the rate of water level decline in ft/yr estimated from long-term monitoring of water levels in wells on the plateau. Details of this map, constructed using a combination of test wells with a long (greater than 10 year) record and more recent characterization wells, are described in LANL (2005). The main features of the map are an area of high water-level decline rate (over 1 ft/yr) along Pueblo Canyon, which lies at the northern edge of data coverage, and an elongated zone of high decline rate (up to 0.8 ft/yr) that runs north to south, just east of and including PM-5, PM-4, and PM-2. This zone then extends east along Pajarito Canyon to R-23.

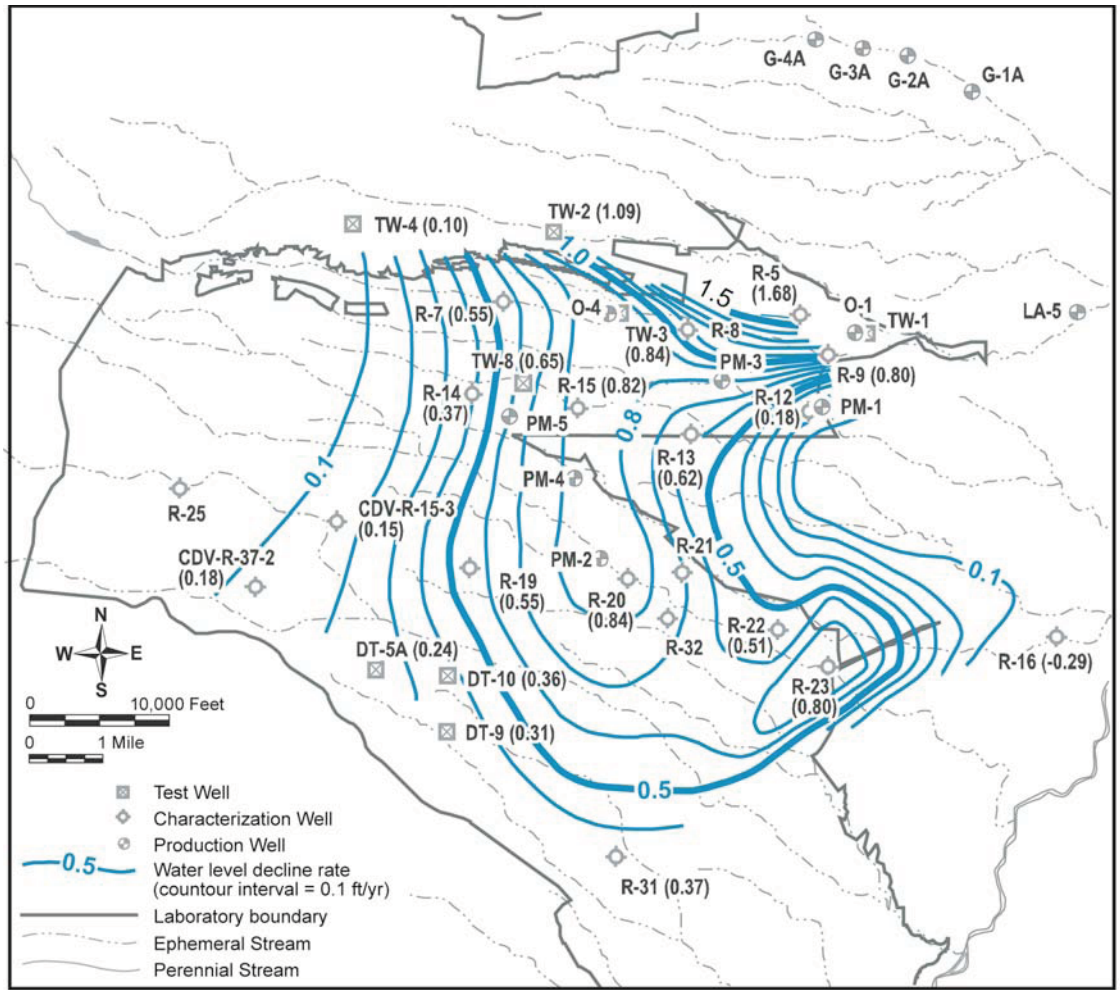


Figure 2-45. Annual water level decline due to municipal water supply well pumping (from LANL, 2005).

In the Los Alamos Canyon wellfield, after substantial water level declines when pumping initiated in the late 1940s, water levels rose and fell in response to inter-annual pumping variability. When the wells were retired in the late 1980s to early 1990s, water levels rapidly increased. Similarly, water levels in the Guaje wellfield decreased initially in response to pumping in the early 1950s and then stabilized until the 1970s; this was interpreted by Koch et al. (2004) to suggest that the aquifer had reached equilibrium. Water levels began to decline gradually again in the 1990s, perhaps due to pumping in nearby wellfields. Pumping in the Pajarito Mesa (PM) wellfield has produced less water level decline than pumping in the Guaje or Los Alamos Canyon wellfields, despite heavy usage. Nevertheless, water levels in PM-1 and PM-3, which have been pumped more consistently than other PM wells, have shown a long, steady decline. Test wells, which are much shallower than water supply wells, have also shown long, steady, declining water levels; before 1970 declines were very small (~1 m); since 1970 declines have increased to a total of ~5 m.

The impact of production on storage in the aquifer was estimated by Rogers et al. (1996b). They calculated storage depletion by estimating the volume of the combined cones of depression observed in all the wellfields on the plateau, assuming drainage under water table conditions, and by assuming uniform aquifer properties (porosity = 0.1). They concluded that the total storage loss has been approximately equal to total production in the time period 1949 – 1993, and thus perhaps that there has been no significant net recharge to the wellfields during this period. In contrast, McLin et al. (1996) suggested that significant recharge has occurred, since water levels have recovered in wells that were allowed to rest a period of several months or several years. Flow modeling is one approach to estimate the proportion of storage loss that has been replaced by recharge. Simulations suggest that flow beneath the Rio Grande (west to east) has been induced by production at the Buckman wellfield. Calculations show that this flux may have increased from zero (pre-1980) to approximately 45 kg/s at present, or ~20% of the total annual production at Buckman (Keating et al. 2003).

2.8.7 Aquifer Hydrodynamics

The hydrodynamics in various portions of the aquifer beneath the plateau is critical to determining the potential pathways of contaminant transport. There have been numerous theories proposed in the literature on the degree and extent of confined conditions of the plateau. This is not too surprising considering the extremely complex geologic structure of the plateau and the inherent limitations of short-term pumping tests. Based on limited data, Cushman (1965) concluded that the aquifer is under water-table conditions beneath the plateau, with the exception of the vicinity of the Rio Grande, where water-table conditions exist in shallow layers and confined conditions exist at depth. Purtymun (1974) suggested that water-table conditions exist on the western margin of the plateau and artesian conditions exist along the eastern edge and along the Rio Grande.

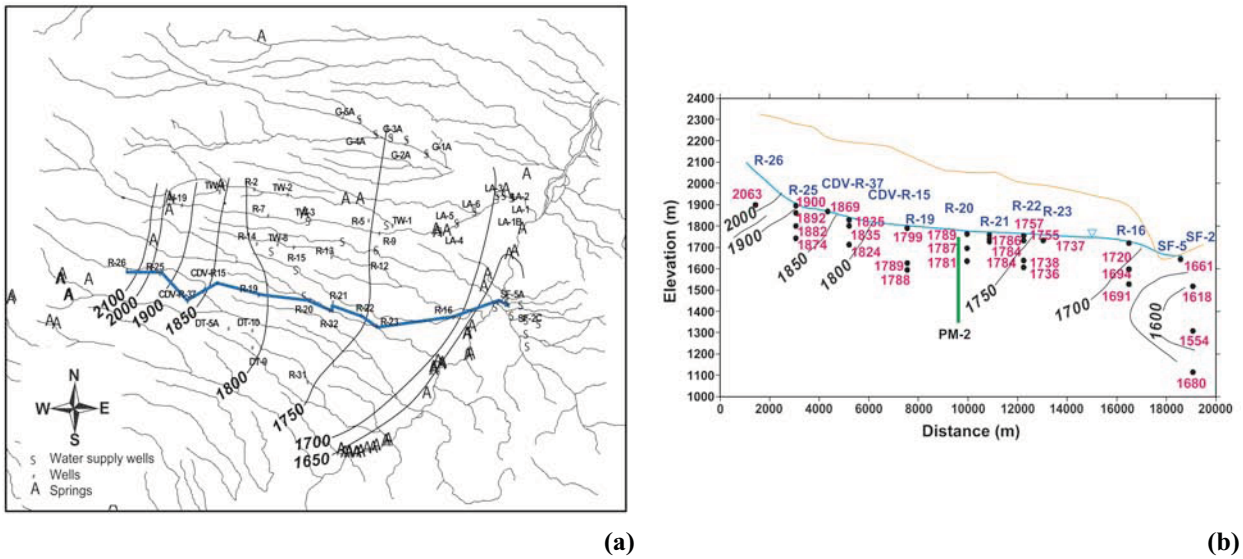
Drilling associated with the characterization program has confirmed existence of water-table conditions at many locations beneath the plateau. Table 2-10 shows the water levels in wells (or, for wells with multiple screens, in the uppermost screen below the water table) used to construct the water table map discussed in Section 2.8.6. Clearly, the characterization program has revealed the presence of unconfined conditions locally over most regions of the plateau, with the exception of locations near the Rio Grande, where confined conditions are generally observed.

Table 2-10.
Water-Level Data Used to Create the Revised Piezometric Water-Level Contours for the Top of the Regional Aquifer

Well Name-Screen Zone	Water Elevation (ft)	Data Vintage		Well Name-Screen Zone	Water Elevation (ft)	Data Vintage
CDV-R15-3-4	6020.1	2004		R-14-1	5883.7	2005
CDV-R-37-2-2	6138.8	2004		R-15	5851.7	2005
DT-10	5919.8	2003		R-16-2	5642.9	2004
DT-5A	5958.8	2003		R-18	6118.0	2004
DT-9	5917.9	2002		R-19-3	5888.0	2005
G-1A	5705.0	2001		R-20-1	5865.9	2003
G-2A	5750.7	2001		R-21	5853.4	2004
G-3A	5704.5	2001		R-22-1	5762.9	2004
G-4A	5784.0	2001		R-23	5696.6	2004
G-5A	5848.4	2001		R-25-5	6232.3	2004
H-19	6228.0	1949		R-26-1	7034.8	2003
LA-4	5706.0	1987		R-28	5839.4	2005
LA-5	5673.0	1987		R-31-3	5827.9	2002
LA-6	5678.0	1995		R-32-1	5857.8	2005
R-1	5879.9	2005		R-33	5877.0	2004
R-2	5874.0	2004		R-34	5834.0	2004
R-5-3	5769.2	2004		TW-1	5840.2	2003
R-7-3	5879.6	2004		TW-2	5847.7	2000
R-8	5836.0	2004		TW-3	5812.5	1999
R-9	5691.0	2004		TW-4	6071.5	2003
R-12-3	5695.9	2004		TW-8	5875.5	2003
R-13	5837.4	2005				

Source: LANL (2005) and references therein

Significant new information on the relationship of the shallow and deeper regional aquifer hydrodynamics has also been obtained. Potentiometric measurements at several new multiple-screened wells have revealed that decreasing head with depth is a pervasive feature of the aquifer. Head data (in meters) along a vertical cross-section in the southern portion of the plateau, where there are several wells with multiple completions, are presented in Figure 2-46. Decreasing head with depth has been observed in wells in the western portion of the Laboratory (see Figure 2-47 for well CdV-R-15-3) away from pumping well influence, but in a region where increased recharge is expected; near the Rio Grande (see Figure 2-48 for well R-16); in the central portion of the Laboratory (R-19, Figure 2-49); and in locations expected to be more strongly influenced by water supply well pumping (R-20, Figure 2-50). One counter example, well R-31 (Figure 2-51) located in the southern portion of the Laboratory away from municipal water supply wells and the region of expected high recharge, shows a very small (note the expanded scale of the y-axis compared to the other plots) decrease in head with screen depth between screens 2 and 3, but head increases with depth in the lower two screens 4 and 5.



(a) (b)

Figure 2-46. (a) Map view showing the location of a cross-section of the plateau. (b) Head data from a vertical cross-section across the southern portion.

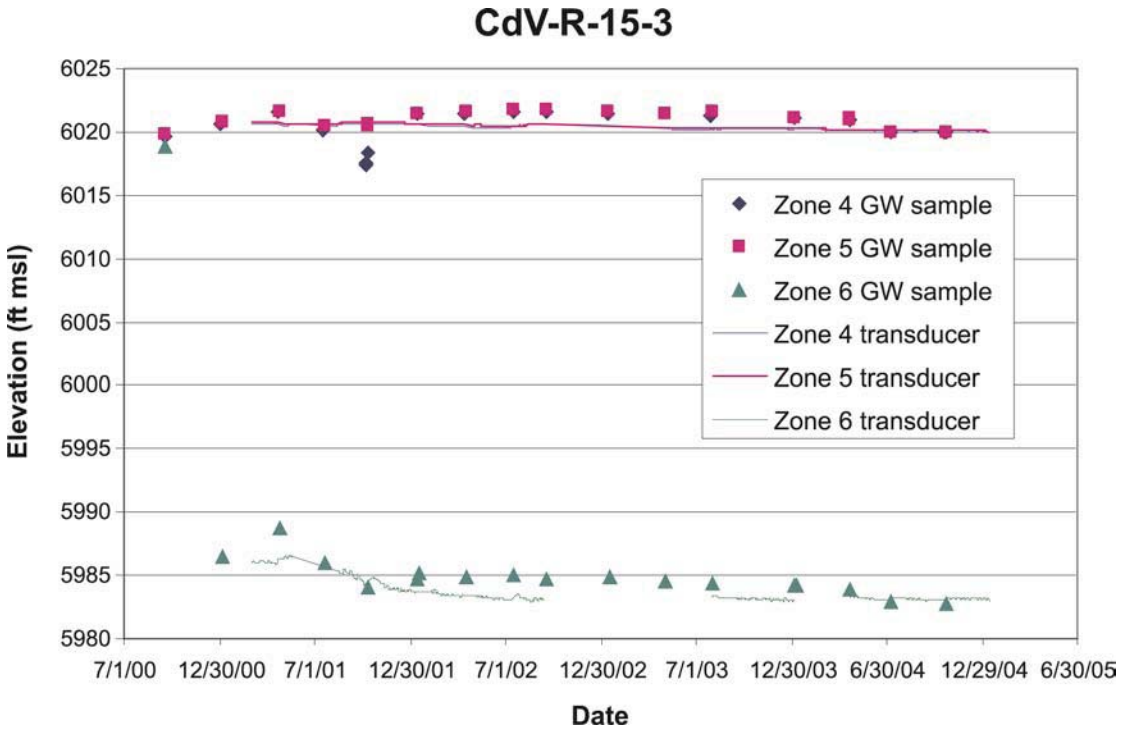


Figure 2-47. Piezometric water levels in different screens in well CdV-R-15-3.

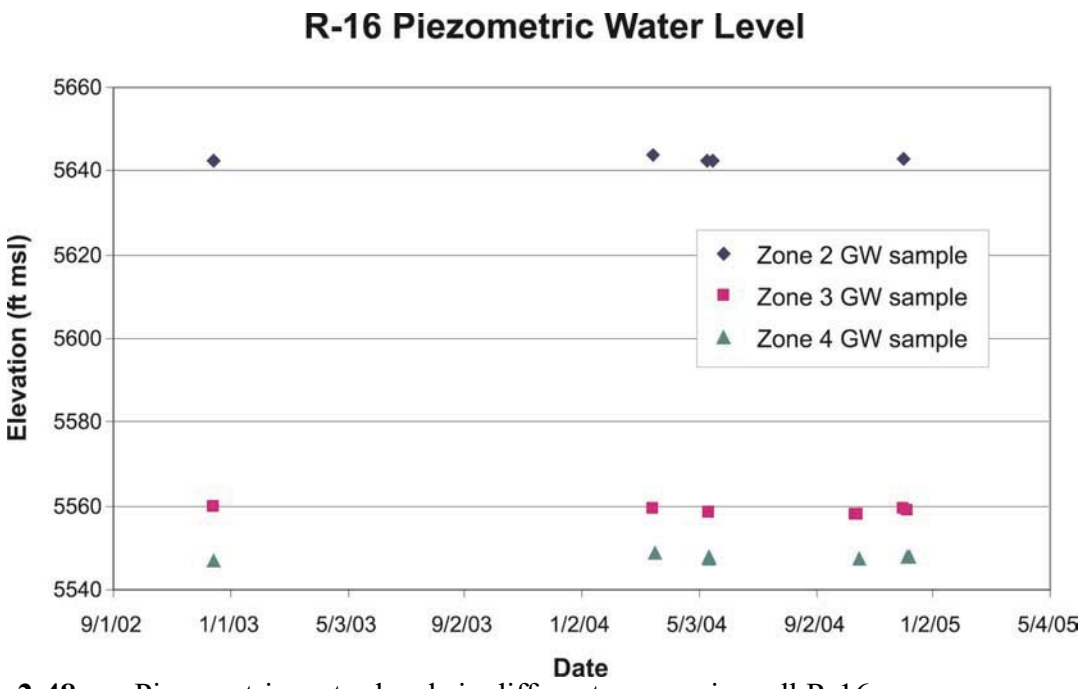


Figure 2-48. Piezometric water levels in different screens in well R-16.

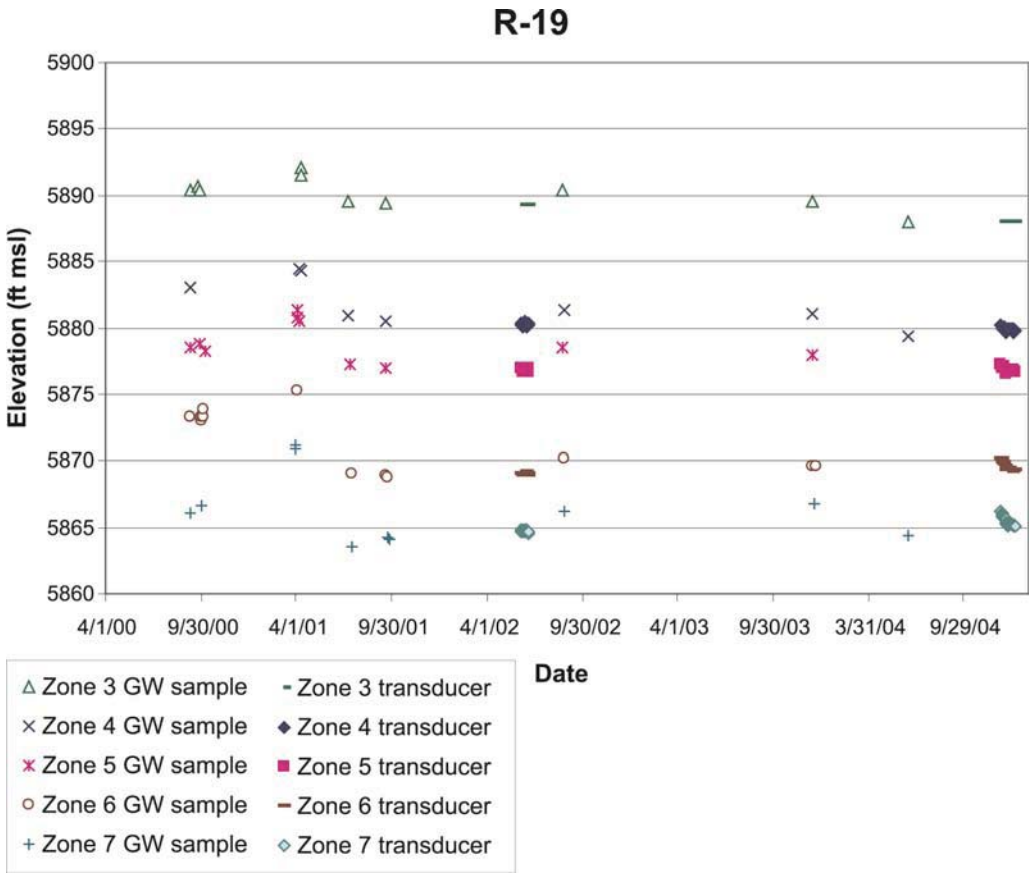


Figure 2-49. Piezometric water levels in different screens in well R-19.

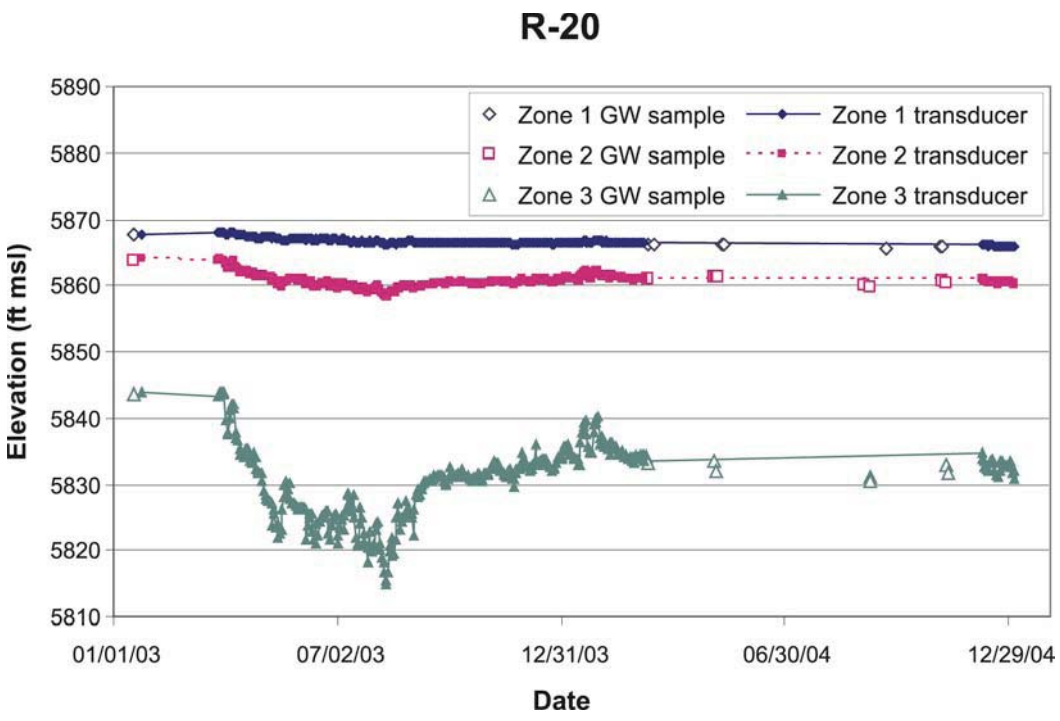


Figure 2-50. Piezometric water levels in different screens in well R-20.

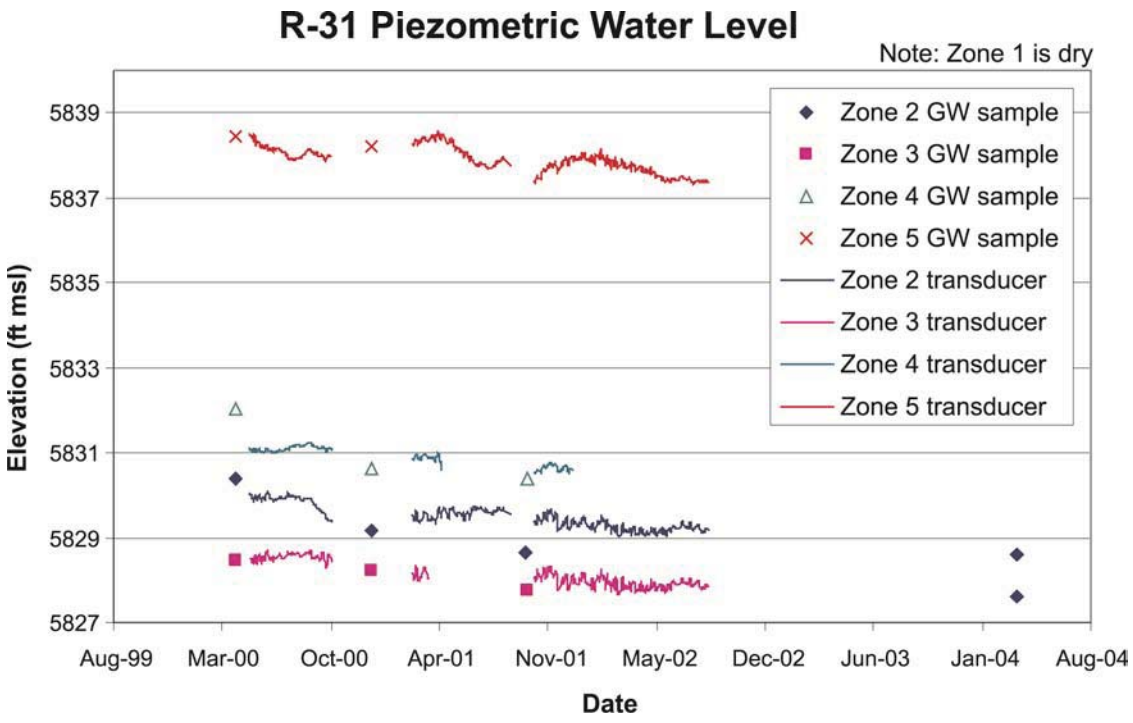


Figure 2-51. Piezometric water levels in different screens in well R-31.

There are several hydrologic mechanisms that can give rise to the observed data. First, note that in a region with a sloping water table, with recharge at high elevation and discharge at lower elevations, the theoretical result for a uniform medium is lower heads with depth, except close to the discharge zone. This explanation alone is consistent with the uppermost screens of R-31. At greater depths in R-31, the higher heads are perhaps due to a zone that is hydrologically separated from the upper zone, with higher head due to recharge to the west and deep, confined flow beneath the plateau. The reasons for the larger downward head drops in well CdV-R-15-3 (as well as other wells in the vicinity, such as R-25) are uncertain, but are probably due to a combination of high local and mountain front recharge, combined with an extremely complex hydrostratigraphic and structural condition in which poorly connected, compartmentalized flow zones are encountered with depth. The wells in the vicinity of water supply wells on the plateau are clearly influenced by water extraction. It is possible that relatively small head differences with depth before water withdrawal have grown substantially because of pumping. Although data on shallow and deep head declines due to long-term pumping are sparse, it is likely that drawdown at the elevation of pumping is highest, and a more muted drawdown exists at the water table. Finally, for R-16, the lower head with depth is probably caused by pumping at the Buckman wellfield.

The critical element that appears to be necessary to explain the observations from both pumping tests and information from multiple-screened wells is the presence of different hydrodynamic conditions at depth than are present at the top of the regional aquifer. The observations (unconfined conditions and a muted response to pumping at depth) suggest a phreatic zone under water-table conditions that is weakly connected hydrologically to a deeper zone that behaves as a leaky-confined aquifer.

The nature of the aquifer heterogeneities giving rise to this compartmentalized system remains an open question. Two conceptual models appear to be possible. One is that the strongly anisotropic characteristic of the aquifer, which limits vertical movement of groundwater at virtually all depths within the Puye Formation and Santa Fe Group, produces the observed trends with depth. Cushman (1965) noted that this aquifer characteristic can cause an unconfined aquifer to appear confined in a short-term pumping test. This explanation is consistent with the observation of McLin (2005) described in Section 2.8.5 of a hydrograph that transitions from confined to leaky-confined behavior at later times. This conceptual model is implemented in the numerical models of McAda and Wasiolek (1988) and Hearne (1980). The McAda and Wasiolek (1988) model places the majority of water supply wells in the basin within the upper 600-ft-thick unconfined layer of the model.

Another conceptual model is that a laterally extensive low permeability zone exists within the aquifer separating the shallow phreatic zone from a deeper confined aquifer. This is the conceptualization depicted in Figure 2-44. A single, laterally extensive zone of low permeability has not yet been identified in boreholes on the plateau. This fact, combined with observations indicating vertical resistance at all elevations in basalts, the Puye Formation, and the Santa Fe Group, strongly favor the former conceptual model. Either model would be expected to give rise to lateral transport of contaminants reaching the water table, especially at locations relatively unaffected by municipal water well pumping. The anisotropic model would allow for vertical

contaminant pathways to water supply wells in locations where continuous high-permeability pathways are present.

2.8.8 Velocities and Travel Times

Transport velocities and travel times through the regional aquifer are poorly understood, because of the lack of tracer tests and in-situ measurements of effective porosity. Data concerning the spatial distribution of anthropogenic contaminants in the regional aquifer have been difficult to use to constrain regional aquifer travel times because of the exceptionally thick and complex vadose zone, which makes it impossible to define the location and timing of contaminant entry to the regional aquifer. Transport over significant distances in the alluvial aquifers is known to occur, and complex vadose zone lateral pathways are also possible, though they have not been directly observed, except for the shallow subsurface pathways identified in the mountain front portion of the plateau (See Section 2.6.2.1). Despite these limitations, we note that no evidence of larger-scale migration of contaminant plumes has been observed, although the presence of anthropogenic chemicals at low levels in springs discharging to the Rio Grande at White Rock Canyon has been suggested by some to be due to regional aquifer transport (Section 3.2). Lack of evidence of migrating plumes may indicate that they travel too slowly to be observed over the relatively short period of study, or that sampling locations are not present in the right locations in sufficient density to track a migrating plume.

In principle, isotopic data can constrain possible transport velocities. These data clearly demonstrate that some waters beneath the plateau and discharging to the Rio Grande are thousands of years old, similar to ages of groundwaters measured in the Albuquerque Basin to the south (Plummer et al., 2004). Tritium data, described in Section 2.8.3, clearly demonstrate that young waters are present as well. These young and old waters may co-mingle at numerous locations within the aquifer including the discharge zone at the Rio Grande.

Therefore, there is no single answer to the question: How old is the groundwater? Mixing between older and younger waters is the norm for the waters sampled from the regional aquifer. Figure 2-52 illustrates that in many instances, both younger and older components are present. Tritium measurements at wells tapping the top of the regional aquifer near Los Alamos Canyon and Mortandad Canyon (among others), as well as isolated observations that include some of the springs discharging at White Rock Canyon, indicate a component of the water is young (less than 60 years old). Reconciling these observations with age estimates of several thousand years based on C-14 requires a model in which fluids of vastly different ages mix, yielding disparate age estimates from the different groundwater tracers.

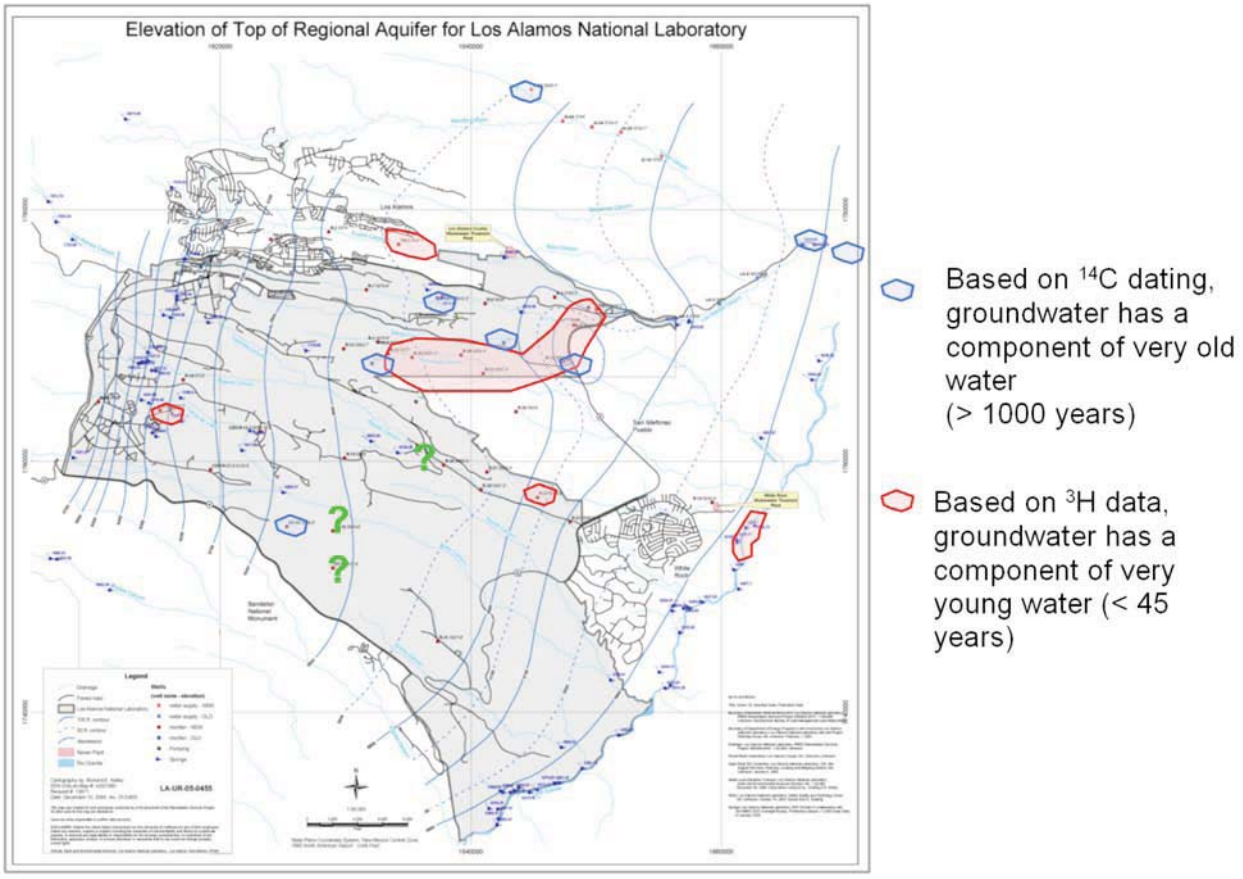


Figure 2-52. Diagram of the locations of "young" and "old" water at different locations. The figure shows that waters with different apparent ages, based on different geochemical indicators, can co-exist at the same location.

The model prediction of transport velocity and ultimate point of discharge of a contaminant in the regional aquifer is intimately tied to, even controlled by, the conceptual model used to develop the numerical model. If the picture emerging from the data described above of a compartmentalized aquifer is valid, then contaminants would travel laterally in the phreatic zone and arrive at springs discharging at the Rio Grande. These flow paths would be predominantly within the Puye Formation and the Cerros del Rio basalts, the geologic units commonly present at the water table of the regional aquifer (Figure 2-10). Travel times through these rocks might be expected to be relatively short. For example, taking the hydraulic conductivity of 1 m/d, a gradient of 0.02, and a porosity of 0.1, the computed velocity of a contaminant moving with the water (with no adsorption to the rock) is about 70 m/yr. Travel times on the order of 100 years would therefore be predicted to the springs from the most easterly zones of contaminated waters in the alluvial aquifers on LANL property.

The role of supply-well pumping in altering these directions and points of discharge is a function of the conceptual model and the water usage scenario chosen for examination. Section 4.2.12. presents a capture zone analysis suggesting that contaminants reaching the regional aquifer beneath canyons on the plateau will be largely captured by the PM wells. Anisotropic conditions in the regional aquifer that tend to keep transport pathways shallow are overcome by induced

downward gradients, and contaminants are drawn to the depths of the screens of the water supply wells, where they are captured. Implicit in these results is the conceptualization of discrete pathways leading to downward transport, perhaps through tortuous "windows" of high-permeability rock in between discontinuous low-permeability layers. A more continuous low-permeability zone between the contaminant residing at the water table and the water supply well would create two disconnected zones at the scale of a contaminant plume. Under this scenario, contaminants would be isolated to the phreatic zone and travel to a down-gradient supply well or the Rio Grande, despite pumping near the contaminant source.

Another important consideration is that steady-state capture-zone results require the assumption of constant pumping for a long enough time for a water particle to arrive at the well. This water usage scenario maximizes the induced downward gradient, exaggerating the downward gradients and leading to flow paths in which capture by the water supply wells is favored over lateral transport at shallow depths. If transport velocities are low enough, water supply wells are likely to be taken out of service before this theoretical arrival at the well would occur. In this case, the actual transport problem is inherently transient, and predictions are intimately tied to the actual water withdrawal scenario. In summary, these complexities render the predictions model- and scenario-dependent. Interpretations based on such models must keep this fact in mind. In the future, a broader range of water-usage scenarios and transient capture zone analyses should be used to fully explore these alternatives.

3.0 GROUNDWATER GEOCHEMISTRY, CONTAMINANT DISTRIBUTIONS, AND IMPLICATIONS FOR FLOW AND TRANSPORT

It is important to understand geochemical processes and the natural water quality beneath the Pajarito Plateau, so that anthropogenic perturbations to the natural system can be identified and quantified. The natural geochemistry of groundwater is the result of physiochemical interactions between air, water, soil, biota, and aquifer material. Geochemical processes are influenced by several factors, including the composition of the groundwater, groundwater temperature, microbial populations, the mineralogical composition of the aquifer material(s), and the length of time the water is in contact with aquifer material(s). Section 3.1 describes the conceptual model of geochemical processes and reactions for the Pajarito Plateau and surrounding area. It also describes the "background" water chemistry, that is, the water chemistry not affected by Laboratory activities.

Imprinted on the natural variations in chemistry is the presence of contaminants historically released since the early 1940s when Laboratory operations commenced. While most of the contaminants are at concentrations largely below regulatory standards, they demonstrate the presence of pathways for groundwater flow and contaminant transport from the surface to deeper groundwater. The impacts to groundwater at the Laboratory have occurred mainly where effluent discharges have caused increased infiltration of water. The depth to which chemical constituents move in the subsurface is determined partly by their chemical behavior: non-reactive constituents move readily with groundwater, while reactive or adsorbing constituents move a shorter distance.

In most cases where effluent sources have been eliminated, groundwater concentrations of non-reactive discharged contaminants have decreased far below past levels (e.g., RDX, nitrate, tritium, and perchlorate) in alluvial groundwater. These mobile contaminants readily move through the subsurface and are detected within perched intermediate zones and at the regional water table beneath several canyons, including Pueblo Canyon, Los Alamos Canyon, Sandia Canyon, Mortandad Canyon, and Cañon de Valle (HE in Cañon de Valle is an exception to this). In the case of reactive or adsorbing chemicals, the concentrations remain elevated significantly above background levels after elimination of discharges or other contaminant source terms (e.g., excavation and removal of contaminated sediments). These include constituents such as strontium-90 and the actinides (americium-241, plutonium-238, and plutonium-239,-240). A discussion of observed contaminant distributions within alluvial and perched intermediate zones and the regional aquifer is provided in Section 3.2. Many of the characterization wells and their chemical data are not included because characterization sampling conducted as part of the Hydrogeologic Workplan is not complete.

3.1 Geochemical Conceptual Model

A geochemical conceptual model that describes the geochemical environment beneath the Pajarito Plateau combines knowledge of geochemical processes with observations of water chemistry at sampling locations and mineralogy of aquifer materials. The components that contribute to the geochemical conceptual model include

- natural chemical compositions of groundwater,

- residence time,
- reactive minerals controlling groundwater composition and solute mobility,
- adsorption and precipitation reactions,
- redox conditions controlling solubility, and
- chemical speciation.

The following subsections discuss these conceptual model components and describe the observations and data that are the basis of each component.

3.1.1 Natural Chemical Composition of Groundwater

Groundwater occurs in three hydrostratigraphic settings beneath the Pajarito Plateau, which include the alluvium, perched intermediate zones (Bandelier Tuff, Cerros del Rio basalt, and the Puye Formation), and the regional aquifer (Puye Formation, Cerros del Rio basalt, older basalts, and the Santa Fe Group). As a result of geochemical processes, the natural composition of groundwater in the three hydrostratigraphic settings varies along flow paths from recharge areas in the Sierra de los Valles, west of the Laboratory, to the discharge areas along the Rio Grande to the east. Recharge also occurs along canyon reaches that contain saturated alluvium.

A hydrochemical investigation was conducted from 1997 to 2000 to define the background chemical composition of groundwater beneath the Pajarito Plateau. Based on the data and information compiled, the statistical properties of natural (background) distributions of stable isotopes (δD, $\delta^{15}N$, and $\delta^{18}O$), tritium, and major and trace solutes in groundwater were established. A complete description of the background study is available in LANL (2005a).

Natural groundwater (alluvial, intermediate, and regional aquifer) ranges from calcium-sodium bicarbonate composition within the Sierra de los Valles to a sodium-calcium bicarbonate composition east and northeast of the Laboratory. Sodium bicarbonate groundwater occurs within the regional aquifer in lower Los Alamos Canyon and at several White Rock Canyon springs near Otowi Bridge (Blake et al. 1995; LANL, 2001a; LANL, 2002; LANL, 2004b). Figure 3-1 shows average background concentrations of specific conductance, major cations and anions, silica, tritium, and several trace elements including barium and uranium analyzed during six sampling rounds (LANL 2005a).

Concentrations of trace elements increase from alluvial groundwater to perched intermediate zones to the regional aquifer. They also increase from west to east within the regional aquifer due to increasing solute residence times and water/rock interactions, including recipitation/dissolution and adsorption/desorption reactions. The highest natural solute concentrations are associated with older groundwater within the regional aquifer. Concentrations of dissolved bicarbonate, sodium, calcium, and uranium increase from west to east. The following subsections discuss the evolution of natural groundwater chemistry from the recharge zone, along the flow paths, and out to the discharge zone.

3.1.1.1 Geochemistry of the Recharge Zone

Groundwater generally has the lowest total dissolved solids (TDS) in the recharge area and increases in TDS along flow paths (Figure 3-1, where TDS is approximated by specific conductance). The Sierra de los Valles provides most of the recharge to groundwater beneath the Pajarito Plateau, based on distributions of stable isotopes, including δD and $\delta^{18}O$ ratios (Figure 3-2). This interpretation was presented in Section 2.8.3.1.1. Recharge water derived from precipitation near the Sierra de los Valles contains natural tritium (19 to 71 pCi/L), which decays to less than 3 pCi/L along groundwater flow paths within non-contaminated perched intermediate zones and the regional aquifer beneath the central and eastern parts of the Laboratory (Figure 3-1).

3.1.1.2 Aqueous Geochemistry along the Flow Path

This subsection evaluates or describes solutes or dissolved species occurring along groundwater flow paths, which show variation among the three types of saturated zones. Variation in solute concentration results from the mixing of groundwaters, mineral precipitation (solute sink), mineral dissolution (solute source), and adsorption/desorption reactions. Natural groundwater quality in the regional aquifer beneath the Pajarito Plateau is excellent and, with the exception of arsenic in Guaje Canyon groundwater, does not exceed federal and state drinking water standards.

The occurrence of reactive minerals within aquifer material controls the composition of groundwater chemistry along flow pathways. Calcium, sodium, and bicarbonate are the dominant major ion solutes in natural groundwater beneath the Pajarito Plateau and surrounding areas. Bicarbonate is the dominant anion in groundwater at Los Alamos (LANL 2005a). This solute increases in background concentrations from shallow alluvial groundwater to the regional aquifer (Figure 3-3). Bicarbonate forms complexes with several trace metals, which has a direct influence on the metal's mobility or transport in the subsurface. Low concentrations of natural bicarbonate and calcium within the alluvium and perched intermediate zones within the Bandelier Tuff and the Puye Formation are insufficient to precipitate calcium carbonate (calcite) (Figure 3-4). Calcite is not typically observed within these saturated zones under natural conditions. In contrast occurrences of calcite within the Santa Fe Group basalt and sediments are reflective of higher concentrations of both calcium and bicarbonate.

Silica is the next most abundant solute found in surface water and groundwater within the Los Alamos area (Figure 3-1) because of hydrolysis reactions taking place between soluble silica volcanic glass and water. All groundwater sampled as part of the background investigation (LANL 2005) are oversaturated with respect to quartz, which is the most stable mineral of the silica phases (Lindsay 1979). Dissolved silica concentrations, however, are not controlled by quartz because this mineral is less reactive than volcanic and sedimentary glass found within the different hydrostratigraphic units. Groundwater within the three groundwater zones is calculated to be in equilibrium with silica glass. In some instances, dissolved silica can be used as a tracer to evaluate groundwater flow from the silica-rich (pumice-rich) Puye Formation to the underlying Santa Fe Group basalt encountered at wells R-9 and R-12. Groundwater flowing through the Bandelier Tuff (well LAOI(A)-1.1) and some sections of the pumiceous-rich Puye

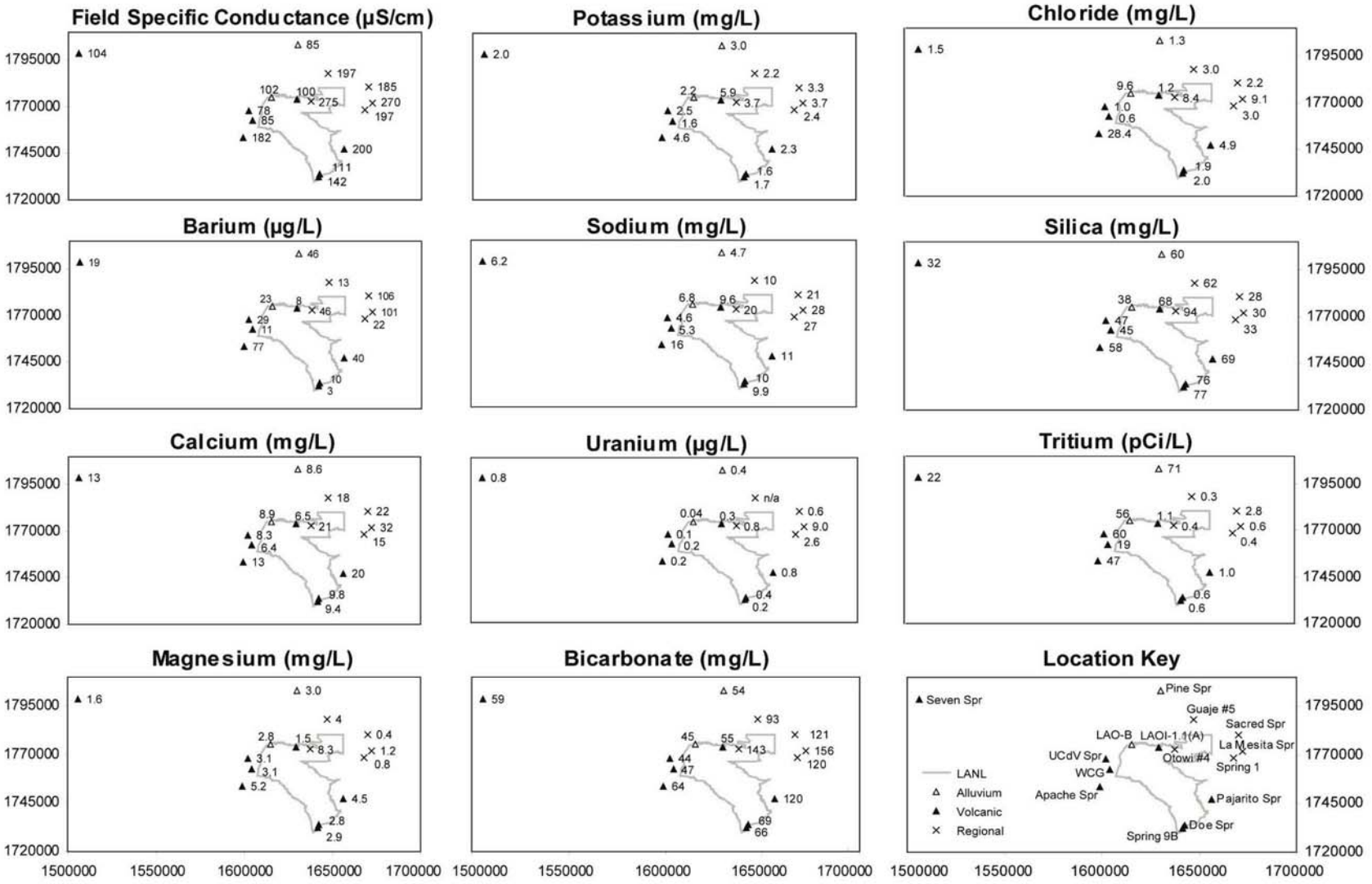


Figure 3-1. Average spatial distributions (n = 6) for key analytes in LANL background wells and springs (LANL, 2005a).

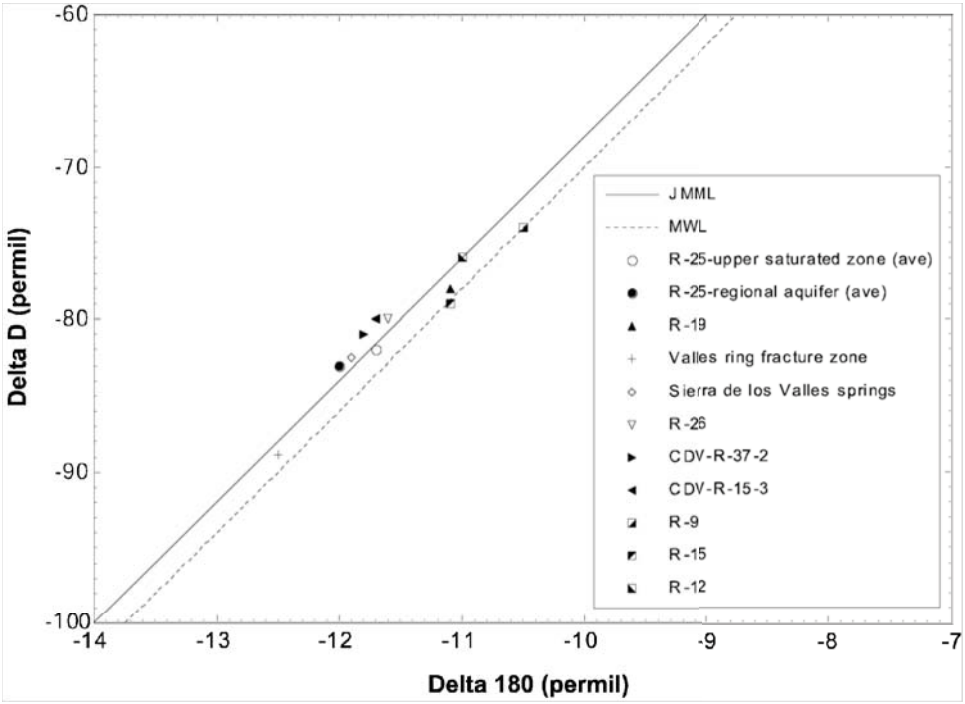


Figure 3-2. Stable isotope results for wells R-9, R-12, R-15, R-19, R-25, R-26, CdV-R-15-3, and CdV-R-37-2, and for other springs in the Jemez Mountains. (The upper line is the Jemez Mountains meteoric line and the lower is the mean worldwide meteoric line.)

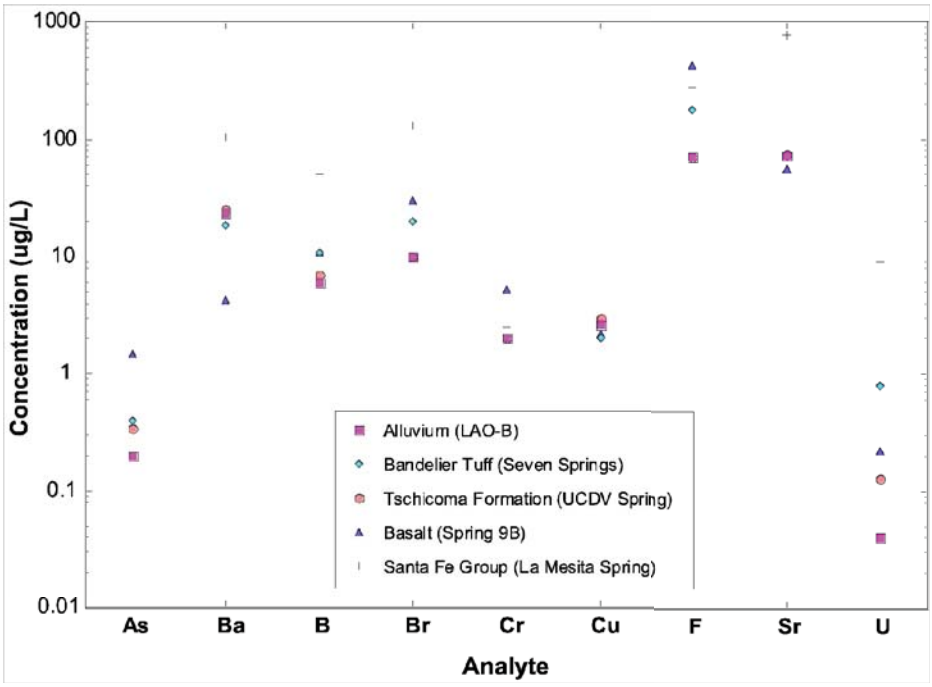


Figure 3-3. Average dissolved concentrations of selected natural trace elements in a represenative well or spring within alluvial and perched intermediate groundwater and the regional aquifer. Note: Average of six rounds.

Formation (wells R-7 and R-15) is characterized by higher dissolved silica concentrations than groundwater flowing through the Cerros del Rio basalt (well R-9i and Spring 9-B) (Figure 3-4). This contrast is attributable to the fact that the volcanic glass within the basalt is both less abundant and less reactive than the ubiquitous glass within the Otowi Member of the Bandelier Tuff and pumiceous-rich Puye Formation.

Figure 3-3 shows average dissolved concentrations of several natural trace elements within alluvial and perched intermediate groundwater and the regional aquifer. Average concentrations of natural arsenic, chromium, and fluoride were the highest within the Cerros del Rio basalt (Spring 9B). Variations in groundwater trace element concentrations depend on solute residence time, speciation, and extent of water-rock interactions. Many trace elements show considerable variations, even in young recharge water. For example, average concentrations of barium, boron, bromide, strontium, and uranium are the highest within the regional aquifer in the Santa Fe Group at La Mesita Spring. Average concentrations of dissolved natural uranium were 9.1 μg/L at La Mesita Spring, which is 300 times greater than that observed at well LAO-B in alluvium (Figure 3-3).

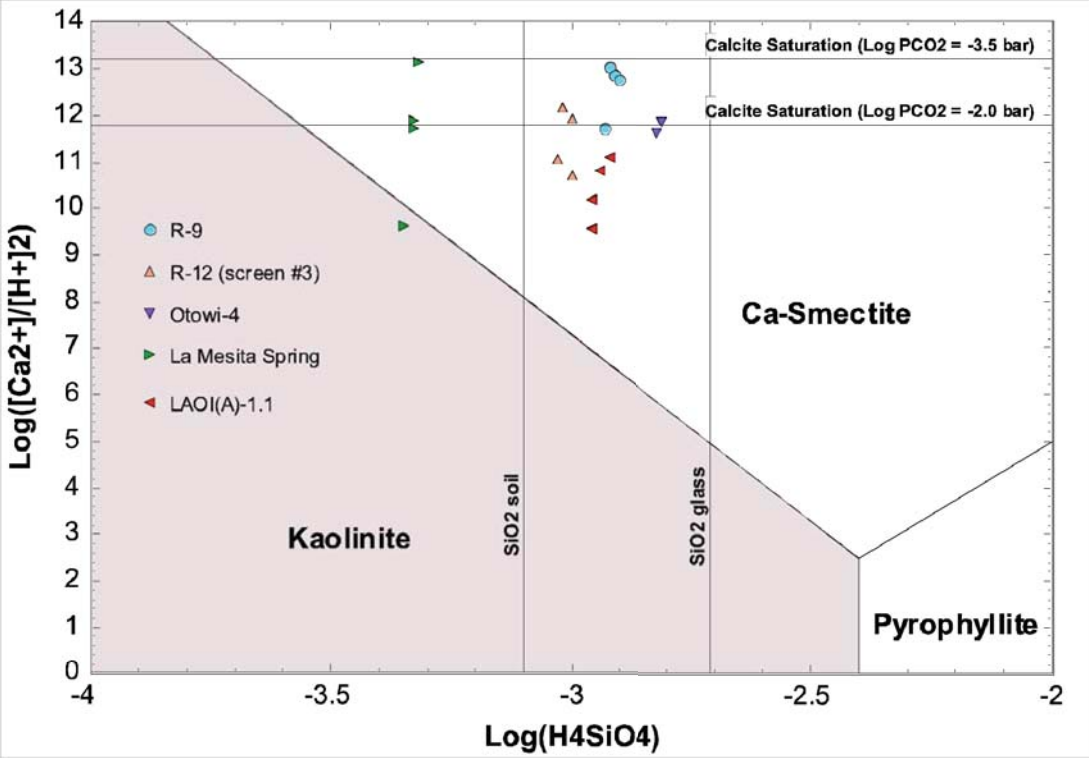


Figure 3-4. Activity diagram of log activity [H_4SiO_4] versus log activity $Ca^{2+}/[H^+]^2$ at 25°C for wells Otowi-4, R-9, R-12 (screen #3), and LAOI(A)-1.1 and La Mesita Spring.
Note: These were selected because of observed smectite in x-ray diffraction of core and cuttings.

Naturally occurring solid organic matter containing carbon, oxygen, nitrogen, and hydrogen is an important component of alluvial sediments within and surrounding the Laboratory. Dissolved organic carbon (DOC) is derived from leaching of solid organic matter and concentrations of DOC are typically less than 2 mg carbon (C)/L within perched intermediate zones and the regional aquifer. Higher concentrations of DOC (up to 20 mg C/L) are found in soil, surface water, and alluvial groundwater within the upper reaches of Los Alamos Canyon where runoff through grasslands and forests takes place. The DOC contains dissociated carboxylic acids that are stable as anions above pH 4.5 (Thurman, 1985). The anions are mobile in the groundwater. Dissolved organic carbon mainly occurs in the forms of humic and fulvic acids (Vilks and Bachinski, 1996). These acids occur as anions and can complex with calcium and magnesium, which can influence precipitation reactions involving calcite.

Leaching of ash produced from the Cerro Grande fire in May 2000 resulted in the generation of elevated concentrations of total organic carbon (TOC), consisting of both DOC and suspended organic carbon (SOC). Shortly after the Cerro Grande fire, increased concentrations of TOC were observed in surface water and alluvial groundwater within Pueblo Canyon, Los Alamos Canyon, Pajarito Canyon, and other watersheds. Since 2002, concentrations of TOC have decreased in surface water, but remain elevated in alluvial and perched-intermediate groundwater. Total organic carbon provides an excellent tracer for tracking movement of recent water (post Cerro Grande fire) in the subsurface. For example, concentrations of TOC have exceeded 300 mg C/L in perched zones within the Cerros del Rio basalt at the Los Alamos Canyon weir (Stone et al., 2004).

3.1.1.3 Geochemistry of the Discharge Zone

Groundwater chemistry within discharge zones can significantly differ from that characteristic of recharge zones. Total dissolved solids generally increase along groundwater flow paths. Specific conductance provides an indirect measurement of TDS and both parameters increase from west to east along groundwater flow paths. For example, groundwater within the Sierra de los Valles contains specific conductance values typically less than 100 μS/cm (Figure 3-1). Springs discharging within White Rock Canyon, however, have specific conductance greater than 100 μS/cm. Concentrations of sodium also increase relative to calcium and magnesium at selected White Rock Canyon springs. This change in major cation chemistry most likely results from cation exchange processes with reactive minerals along flow paths, including smectite, kaolinite, and volcanic glass (discussed in Section 3.1.3).

Groundwater within a discharge zone, at the end of groundwater flow paths, generally has the highest mineral or solute content and also represents the oldest water, provided that mixing with younger groundwater has not taken place. The main groundwater discharge zone for the Sierra de los Valles and the Sangre de Cristo Mountains occurs as springs and gaining reaches along the Rio Grande. Older groundwater within the regional aquifer tends to have higher concentrations of trace elements due to a combination of mineral dissolution and desorption processes. Many trace elements, including arsenic(III, V) and uranium(VI), form anions and tend to desorb from mineral surfaces under basic pH conditions (Langmuir, 1997). Dissolved concentrations of major cations and anions, arsenic, uranium, and other trace elements are higher in groundwater east of the Rio Grande based on water quality/geochemical data collected by the New Mexico

Environment Department (NMED) and most recently by LANL. Based on water samples brought in to the Pojoaque water fair in 2004, concentrations of natural uranium in groundwater are generally in the range from up to 0.2 ppm along the Rio Grande and eastward toward the Sangre de Cristo Mountains. In contrast, uranium concentrations in the regional aquifer beneath the Pajarito Plateau rarely exceed 0.1 ppm.

In the discharge zone, as well as along flow paths, tritium is an excellent tracer that can be used to qualitatively date or bound the age of groundwater less than 61 years old, with a few exceptions. Background springs discharging within White Rock Canyon typically have tritium concentrations less than 1 pCi/L, indicating that groundwater is greater than 61 years old. This pre-dates historic discharges associated with the Laboratory and atmospheric fallout that may provide sources of recharge. These springs are characterized by groundwater flow paths that are of variable lengths and differing groundwater residence times.

3.1.2 Residence Times

Residence times of groundwater and chemical solutes increase both with depth and from west to east across the Pajarito Plateau within each groundwater zone. Groundwater flow paths within the regional aquifer generally are from west to east based on water level measurements. Accordingly, the concentrations of natural major ions and trace elements increase with distance along flow paths.

In the Sierra de los Valles, a known recharge area west of the Laboratory, a component of groundwater is less than 61 years old, based on measurable activities of tritium observed in springs. Movement of groundwater through fractured volcanic rock within the Sierra de los Valles is rapid in most cases (Water Canyon Gallery, Apache Spring, upper Cañon de Valle Spring, and Pine Spring). With a few exceptions, most springs in the discharge zone in White Rock Canyon, however, do not contain tritium, and the age of groundwater probably ranges between 3,000 and 10,000 years and possibly even older (Rogers et al. 1996b).

The oldest groundwater residence times within the regional aquifer are on the order of several to tens of thousands of years, based on carbon-14 dating (Rogers et al, 1996b). The carbon-14 dates provide a reasonable estimate of the maximum age of groundwater within the regional aquifer, provided that mixing with more recent water or older water with lower alkalinity has not taken place. Groundwater within the regional aquifer becomes progressively older from west to east (Rogers et al, 1996b). Presence of tritium near the water table and within the regional aquifer beneath the Laboratory, however, confirms that a much younger component of groundwater is present in the regional aquifer. Small concentrations of anthropogenic tritium (less than 100 pCi/L) at some locations are suggestive of mixing of a majority of old water with a component of young water at the regional water table. Mixing ratios using chloride or bromide are needed as additional information to more precisely determine fractions of young and old groundwater.

3.1.3 Reactive Minerals Controlling Groundwater Composition and Solute Mobility

Because there are variations in pH, temperature, and major ion and trace element chemistry within shallow and deep saturated zones, different reactive minerals and amorphous solids precipitate or dissolve. In some instances, they control the major ion composition of groundwater. Some of these phases, including hydrous ferric oxide, manganese (oxy)hydroxide, smectite, calcite, and zeolites, have a high adsorptive capacity for trace elements including chromium, lead, strontium, and thorium, and radionuclides including americium-241, cesium-137, and plutonium-238, -239, -240. Reactive minerals and amorphous solids approach equilibrium with groundwater when the residence time exceeds the reaction half time (amount of time required for 50% of reactant A to form product B assuming there is no B initially present). This condition is usually met within perched intermediate zones and the regional aquifer based on observed mineralogy, because hydrous ferric oxide is present in all the groundwater zones.

Calcite and smectite are two important minerals that have been observed in core samples collected from several R wells. The stability of reactive phases, including $CaCO_3$ (calcite) and calcium smectite, can be evaluated by considering concentrations of major dissolved ions, chemical composition of minerals, and equilibrium concepts. Figure 3-4 is a log activity diagram showing the stability of several minerals including kaolinite, pyrophyllite, silica soil, silica glass, and calcium smectite. Groundwater samples collected from selected wells R-9, Otowi-4, R-12 (screen #3), and LAOI(A)-1.1 and La Mesita Spring are also plotted on the figure. Important points from this figure are as follows:

- Most groundwater is oversaturated with respect to calcium smectite, as the groundwater samples plot within that stability field.
- One sample collected from La Mesita Spring plots within the stability field for kaolinite due to a lower pH measurement.
- Groundwater is oversaturated with respect to SiO_2 soil (amorphous silica) and undersaturated with SiO_2 glass, which suggests that some of the silica could be formed from pedogenic (soil-forming) processes.
- La Mesita Spring (representative of young recharge water) is undersaturated with respect to silica soil and silica glass and has lower concentrations of silica relative to those measured in groundwater samples collected at wells R-9, Otowi-4, R-12, and LAOI(A)-1.1.

Under equilibrium conditions, calcite controls dissolved concentrations of calcium and bicarbonate within the regional aquifer. Beneath the western and central portions of the Laboratory, however, calcite is relatively rare in most of the lithologies characterized at the regional aquifer water table (Figure 2-10) except for the pre-Puye Formation Santa Fe Group sediments. These sediments have variable amounts of dispersed calcite cement (0-20 wt%). There is also a zone of post-depositional alteration centered in the northeastern portion of the Laboratory where calcite alteration is common in the Puye fanglomerate and the pumiceous sediments. Calcite precipitation is observed in Santa Fe Group sediments near the Rio Grande.

As groundwater flows through perched intermediate zones and the regional aquifer, chemical and mineralogical compositions of reactive phases, including silica glass, change over time. For example, silica glass is the most soluble component of the aquifer material (Puye Formation and unassigned pumiceous unit) and reacts with groundwater to form clay minerals, such as kaolinite and smectite. These alteration phases have been observed at wells R-5, R-8A, R-9, and R-12. Calcium-sodium smectite has been observed in core and cutting samples collected from R-9 (Broxton et al., 2001a). Smectite has also been observed in rock samples collected from Santa Fe Group sediments in lower Los Alamos Canyon (Vaniman, unpublished data). The presence of smectite enhances natural attenuation of anthropogenic metals stable as cations, including strontium and barium, because this phase increases the adsorption capacity of the aquifer material under circumneutral pH conditions (discussed in more detail in Section 3.1.4).

The saturation index (SI) is an indicator of whether a mineral is likely to precipitate or dissolve under particular groundwater conditions. The SI is defined as the $\log_{10}$(activity product/solubility product). Precipitation of reactive minerals, including calcite, occurs in groundwater under near neutral pH conditions. Figure 3-5 shows saturation indices for calcite versus calcium and bicarbonate concentrations (millimoles/liter) at selected background springs and wells. The computer program MINTEQA2 (Allison et al., 1991) was used to perform SI calculations. For a given solid phase at equilibrium, the SI is equal to 0 ± 0.05. Oversaturation (positive SI) implies precipitation, whereas undersaturation (negative SI) implies dissolution. Native alluvial and perched intermediate groundwaters are calculated to be undersaturated with respect to calcite, and dissolution of this mineral takes place. This is consistent with the absence of calcite within the natural alluvium at the Laboratory. Groundwater samples collected at wells R-9, R-12, and Otowi-4 and La Mesita Spring generally are saturated with respect to calcite, whereas LAOI(A)-1.1 is not. Activities of dissolved calcium and bicarbonate at well LAOI(A)-1.1 are not sufficient to precipitate calcite. Calcite typically is not observed in native groundwater within the alluvium and Bandelier Tuff. The regional aquifer (Santa Fe Group sediments) is slightly undersaturated, but within thermodynamic uncertainty, with respect to calcite.

3.1.4 Adsorption and Precipitation Reactions

Adsorption occurs when dissolved species interact with surfaces of aquifer material coated with hydrous ferric oxide, manganese dioxide, clay minerals, or other adsorbents. Adsorption is usually reversible with the net effect being that the transport of the absorbed species is much slower than that of the water. Hydrous ferric oxide is an important adsorbent present in different aquifer materials beneath the Pajarito Plateau. Other adsorbents of metals include smectite, calcite, manganese oxide, and solid organic carbon, which can provide additional adsorption sites on aquifer material and within the unsaturated zone. Hydrous ferric oxide has a specific surface area of 600 m^2/g, which is much higher than quartz or silica gel that have specific surface areas of 0.14 and 53 to 292 m^2/g, respectively (Langmuir, 1997). Many metals and radionuclides including barium, chromium, nickel, uranium, strontium-90, americium-241, plutonium-238, and plutonium-239, -240 typically adsorb onto hydrous ferric oxide-coated particles between pH values 5 and 8.

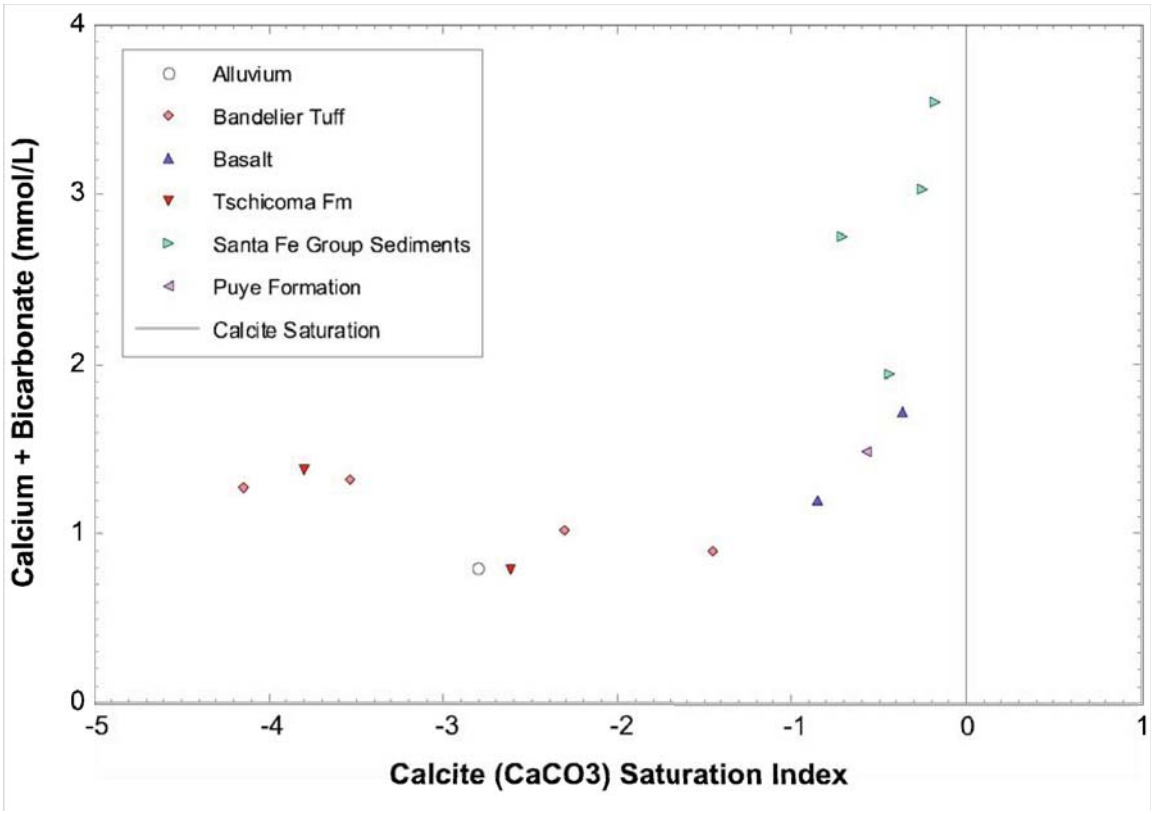


Figure 3-5. Saturation indices for calcite versus calcium and bicarbonate concentrations (millimoles/liter) at springs and wells representing different aquifer types at LANL (perched, intermediate, and regional).

Concentrations of inorganic contaminants (actinides, fission products, and trace elements) remaining within treated effluents are too small to be removed from solution through precipitation, based on results of computer simulations. Downgradient from Laboratory discharge points, adsorption processes are considered to dominate over mineral precipitation for continual removal of metals and radionuclides from alluvial groundwater. As a result, concentrations of adsorbing radionuclides and inorganic species generally decrease downgradient along the groundwater flow path. Alluvial material provides the largest reservoir for constituents from treated Laboratory effluent, including strontium-90, cesium-137, plutonium-238, plutonium-239, -240, and americium-241 because the constituents readily adsorb onto clay- and silt-sized material. For example, it is hypothesized that strontium-90 has been reversibly adsorbed on alluvial sediments by cation exchange, and the sediments provide a continuing source of this constituent to the alluvial groundwater. Eventually, strontium-90 will decay to stable zirconium-90 (via short-lived yttrium-90), reducing its remaining radioactivity by a factor of two approximately every 29 years.

Based on numerous studies reported in the literature, and supported by field observations documented in LANL Surveillance Reports (e.g. LANL, 1996a, 2000a, 2001a, 2002) and

experimental results, the relative adsorption of HE compounds, radionuclides and inorganic species decreases at circumneutral pH (6 to 8) conditions as follows:

cesium-137 (highest adsorption) = americium-241 > barium > strontium-90 > uranium > nitrate = molybdate = sulfate = chloride = perchlorate = TNT > RDX = tritium (lowest adsorption).

Cations adsorb more strongly than anions under acidic to circumneutral pH conditions because adsorbents, including hydrous ferric oxide, smectite, and silica glass, are characterized by a net-negative surface charge (Langmuir, 1997). (Oxy)anions, including molybdate, nitrate, and perchlorate, are mobile in groundwater under circumneutral to basic pH conditions due to the net-negative surface charge on the adsorbent. Neutral species including TNT, RDX, and tritium do not adsorb to any significant extent onto inorganic mineral surfaces. Characterization and surveillance data collected within Pueblo Canyon, Los Alamos Canyon, Mortandad Canyon, and Cañon de Valle support the observed mobilities of anions (chloride, molybdate, nitrate, perchlorate, sulfate, and uranium) and neutral species (RDX, TNT, and tritium). High explosive compounds undergo hydrophobic sorption with solid organic matter present in alluvial channels, including Cañon de Valle, but such material is not present in significant concentrations in the regional aquifer.

Other variables that influence adsorption processes include precipitation and dissolution of the adsorbent, adsorption capacity, and changes in aqueous chemistry. Adsorption capacities of unsaturated and saturated material may change over time due to changes in solution composition, contaminant speciation and reactive phase mineralogy. In isolated cases where effluent discharges have changed alluvial groundwater alkalinity or pH, trace elements such as strontium and barium may precipitate as $SrCO_3$, $BaCO_3$, and coprecipitate as $(Sr\text{-}Ba)SO_4$. These precipitation processes are considered to be important within the upper reaches of Cañon de Valle and Mortandad Canyon.

Cation exchange reactions typically influence major cation compositions of groundwater. This influence is especially true for older groundwater with a long residence time characteristic of the regional aquifer east of the Rio Grande. Cation exchange between divalent, magnesium and calcium and monovalent sodium results in increasing water hardness (increased calcium and magnesium) in which calcium typically dominates over magnesium as the dominant dissolved cation. Softening of water occurs when calcium and magnesium are removed from groundwater and sodium becomes the dominant cation. This water-softening process is observed northeast of the Laboratory (former lower Los Alamos wellfield) and along sections of the Rio Grande.

3.1.4.1 Adsorption and Precipitation of Uranium(VI) Species

Uranium is a naturally occurring trace element found in groundwater and it is also processed at the Laboratory. This subsection provides a summary of the aqueous chemistry and adsorptive characteristics of this actinide because of its importance to background conditions and Laboratory effluents.

Uranium is a naturally occurring actinide found essentially in all soils, sediments, rocks, surface waters, and groundwaters worldwide. Whole rock concentrations of uranium within the Bandelier Tuff, Cerros del Rio basalt, and Puye Formation range from less than 1 to over 10 mg/kg or ppm (Longmire et al. 1996a, Broxton et al. 2001a). Silica-rich rocks, including the Bandelier Tuff, contain higher concentrations of uranium than do the less siliceous rocks, including the Cerros del Rio basalt and Puye Formation.

Background concentrations of dissolved uranium within alluvium, perched intermediate zones, and the regional aquifer are generally detectable but at concentrations less than 1 μg/L in groundwater beneath the Pajarito Plateau (Longmire et al., 1996b, LANL 2005a). These naturally low concentrations of dissolved uranium are probably controlled by aqueous solubilities of minerals containing uranium. For example, zircon ($ZrSiO_4$) is a trace mineral found within the Bandelier Tuff. Concentration of uranium in a zircon crystal within a sample of the Bandelier Tuff was 1180 ppm (Stimac et al. 1996). This highly refractory mineral has an aqueous solubility of $10^{-15.4}$ M at pH 7. Uranium does not significantly leach out of this mineral at circumneutral pH values (6 to 9) based on its low aqueous solubility. Some uranium concentrated within the Bandelier Tuff is associated with volcanic glass, which has an aqueous solubility of $10^{-2.71}$ M at pH 7. Consequently, there is higher occurrence of uranium in groundwater within the Bandelier Tuff because it is more susceptible to leaching from glass due to its higher aqueous solubility. The rate of uranium leaching from glass, however, is slow, as indicated by the low dissolved concentrations of uranium (<0.5μg/L) measured in perched groundwater within the Bandelier Tuff (well LAOI(A)-1.1).

The uranyl (UO_2^{2+}) cation is analogous to other divalent metal species that significantly adsorb onto hydrous ferric oxide under acidic pH conditions. Increasing concentrations of hydrous ferric oxide result in increasing the adsorption capacity of uranium(VI) complexes because more binding sites are present. Concentrations of hydrous ferric oxide vary between alluvial groundwater, perched intermediate zones, and the regional aquifer. This variation is dependent on chemical weathering of primary iron-rich minerals and iron-rich volcanic glass. Iron-rich glass and minerals within the Cerros del Rio basalt enhance precipitation of increasing amounts of hydrous ferric oxide compared to the Bandelier Tuff, which contains iron-depleted glass and smaller amounts of iron-bearing minerals.

The computer program MINTEQA2 (Allison et al., 1991) was used to model adsorption (surface complexation) of uranium(VI) onto hydrous ferric oxide for perched intermediate groundwater characterized at well R-9. The double layer model (DLM) was selected for the simulation because it takes into account adsorbent characteristics (specific surface area, charge density, and adsorbent concentration) and aqueous chemistry parameters (pH, ionic strength, and solution composition).

Figure 3-6 shows both calculated distributions of adsorbed uranium(VI) complexes onto hydrous ferric oxide and dissolved complexes as a function of pH. Results of the calculation suggest that maximum adsorption takes place at pH 5.5 and decreasing adsorption occurs with increasing pH, which is due to the formation of uranyl carbonate complexes. Uranyl dicarbonate and uranyl tricarbonate complexes do not significantly adsorb onto negatively charged surface sites present

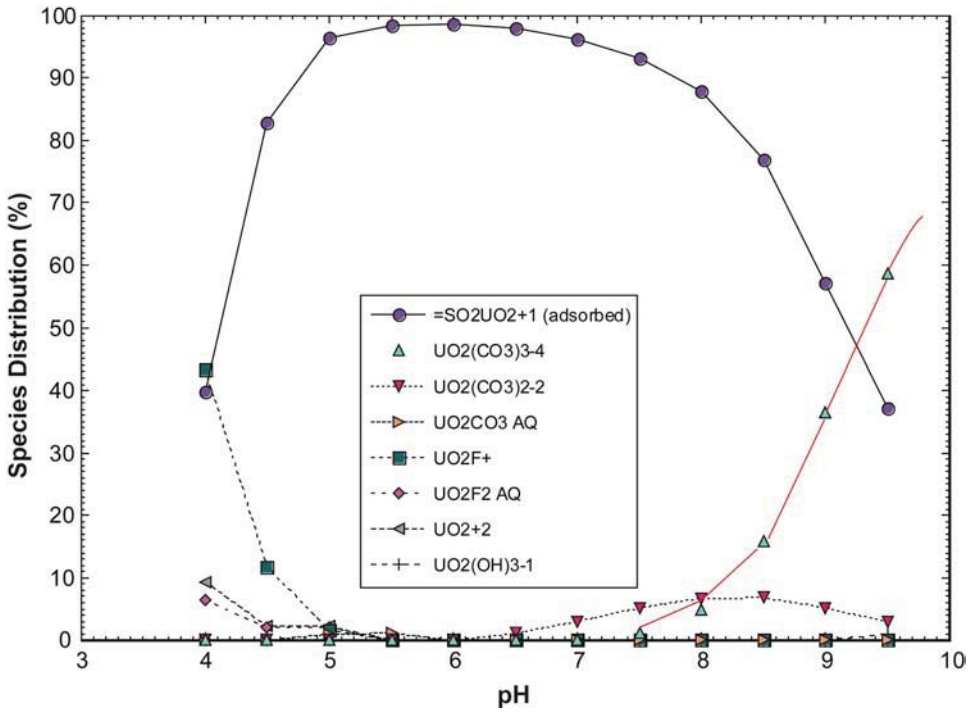


Figure 3-6. Calculated distributions of adsorbed and dissolved uranyl species for well R-9 (275 ft perched zone) (HFO concentration = 1.46 g/L and total dissolved uranyl [UO_2^{2+}] = 0.054 ppm, 25°C). Calculation was made for R-9 because uranium was measured in groundwater whithin the Cerros del Rio basalt.

on hydrous ferric oxide. There is a sharp rise in uranium(VI) adsorption onto hydrous ferric oxide between pH values of 4.0 and 5.0 (Figure 3-6), where uranyl cation species dominate.

Other divalent cations compete with uranyl species in both natural and contaminated groundwater. Calcium (Ca^{2+}) strongly competes with UO_2^{2+} for adsorption sites present on hydrous ferric oxide, based on experimental results, including DLM intrinsic stability constants provided by Langmuir (1997). Concentrations of dissolved calcium are much higher (in the mg/L range) than dissolved uranium (less than 1 μg/L), which allows for more calcium binding onto hydrous ferric oxide.

Similar competition between calcium and the uranyl cation may take place with clay minerals. This has relevance to groundwater chemistry east of the Rio Grande that is characterized by higher concentrations of calcium and uranium compared to groundwater beneath the Pajarito Plateau. This exchange reaction results in concentrations of natural uranium within the regional aquifer ranging from 0.5 μg/L (Los Alamos) to over 1800 μg/L (west of Nambé).

Exchange reactions between calcium and sodium are of importance based on inverse relationships between dissolved calcium, sodium, and uranium. Figure 3-7 shows calcium/sodium ratios (milliequivalents/L) versus uranium concentrations for 127 groundwater samples collected at Pojoaque, New Mexico during June 2004. The highest concentrations of uranium in groundwater occur at lower calcium/sodium ratios. This relationship suggests that

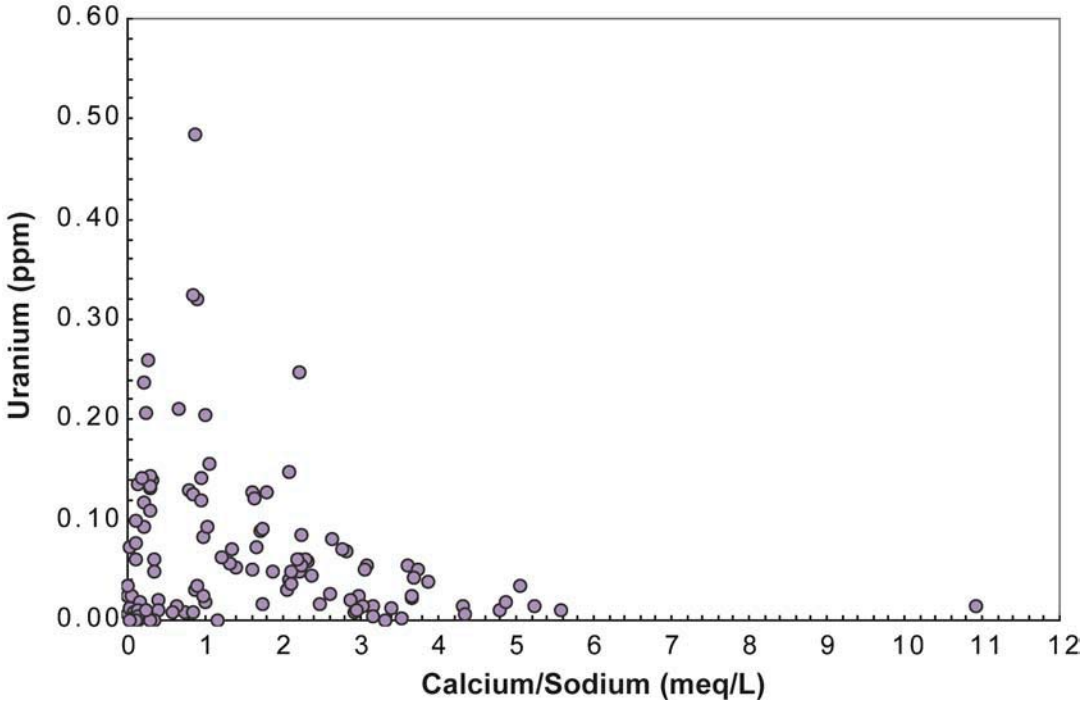


Figure 3-7. Calcium/sodium (meq/L) versus uranium concentrations, Pojoaque water fair, June 2004.

calcium is removed from groundwater, whereas uranium is added to groundwater through cation exchange. Alternatively, the relationship between uranium and sodium/calcium rations could be due to bulk compositional effects rather than cation exchange. In some groundwater samples, calcium is removed to a greater extent than sodium.

Precipitation reactions serve as a sink for removing uranium from solution. There are numerous uranium (VI) minerals that are naturally occurring and are found in aquifers (ore deposits) within sedimentary and igneous rocks. Several uranyl silicate minerals including $(UO_2)_2SiO_4 \cdot 2H_2O$ (soddyite) and $Ca(UO_2)_2(Si_2O_5)_3 \cdot 5H_2O$ (haiweeite) are potentially important within silica-rich groundwater beneath the Pajarito Plateau. Figure 3-8 shows a plot of saturation indices for several reactive minerals including silica solids, carbonate minerals, soddyite, and haiweeite for several groundwater sampling stations including Spring 2B, alluvial well LAO-B, perched intermediate groundwater (well LAOI(A)-1.1), and regional aquifer groundwater (wells Otowi-4, TW-3, R-9, and TW-1). The computer program MINTEQA2 (Allison et al., 1991) was used to perform the saturation calculations.

Temperature, pH, redox potential, and dissolved activities of calcium, uranium(VI), bicarbonate, and silicic acid influence the precipitation/dissolution of soddyite and haiweeite. As bicarbonate concentrations increase, dissolved uranium(VI) reacts to form complexes, which decreases the amount of uranyl cation (UO_2^{2+}) available for precipitation of soddyite and haiweeite. This is counter balanced, however, by increasing concentrations of dissolved calcium that enhances precipitation of haiweeite at Otowi-4, R-9, TW-1, and Spring 2B (Figure 3-8). This assessment is

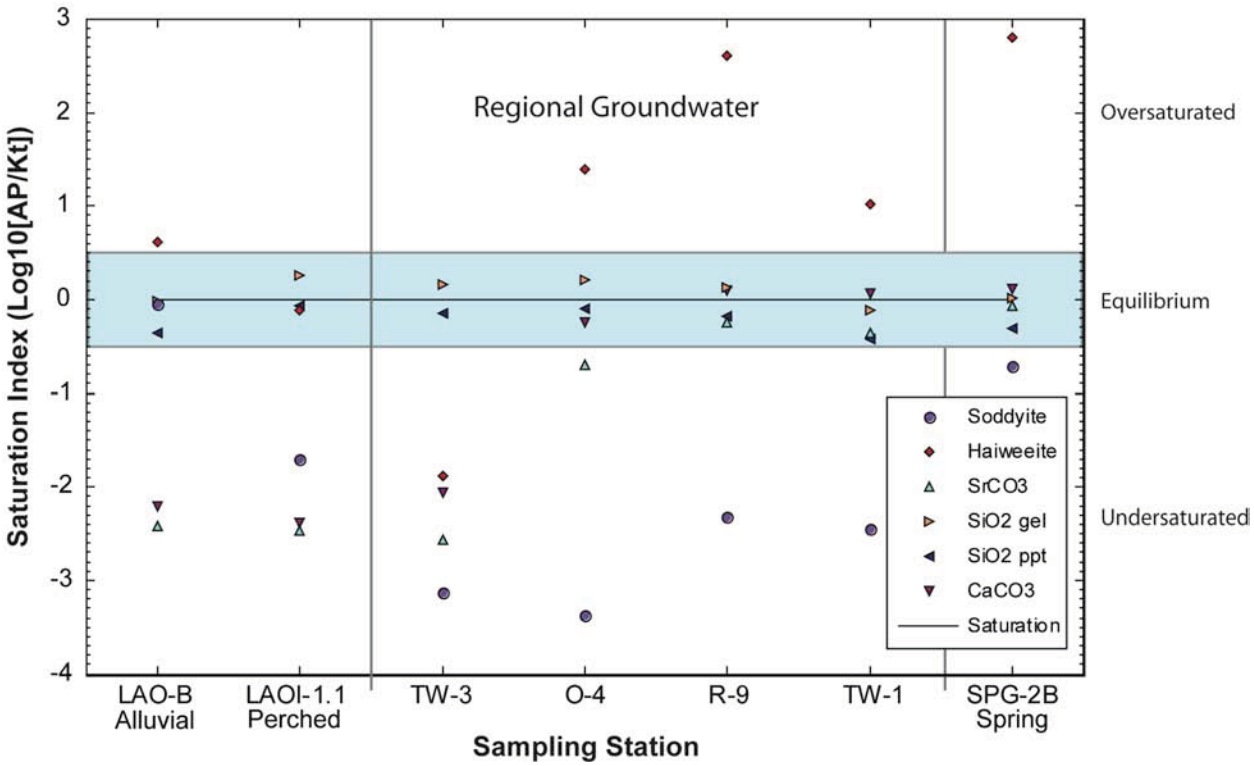


Figure 3-8. Saturation indices for several solid phases in alluvial (LAO-B) and perched intermediate groundwater (LAOI(A)-1.1) and the regional aquifer (Otowi-4, TW-3, R-9 and TW-1) within Los Alamos Canyon, Pueblo Canyon, and Spring 2B. The computer program MINTEQA2 was used to perform the calculations. Note: These wells were selected because they show hyrochemical snapshot of the three aquifer types within the Los Alamos Canyon and a spring.

based on geochemical calculations and the overall oxidizing conditions characteristic of natural groundwater beneath the Pajarito Plateau.

While it is useful to perform saturation index calculations to evaluate mineral equilibrium, most of the deep groundwaters are not in equilibrium with respect to either soddyite or haiweeite. Based on results of the calculations presented, adsorption processes involving uranium(VI) appear to control dissolved concentrations of this actinide in groundwater beneath the Pajarito Plateau.

3.1.5 Redox Conditions

This subsection presents a brief discussion on oxidation-reduction concepts with application to groundwater chemistry characterized during this investigation. Contaminants associated with treated Laboratory effluents that are stable in more than one oxidation state include plutonium(III, IV, V, and VI), uranium(IV and VI), technetium(IV and VII), iron(II and III), and chromium(III and VI). Other contaminants that can undergo reduction include perchlorate,

molybdate, nitrate, RDX, and TNT. A group of contaminants that is stable in one oxidation state under the geochemical conditions that prevail in groundwater includes americium(III)-241, cesium(I)-137, strontium(II)-90, barium(II), boron(III), and tritium(I). Adsorption and precipitation reactions involving redox-sensitive contaminants are directly influenced by oxidation and reduction reactions. Under oxidizing conditions, species including uranium(VI), sulfate, nitrate, and perchlorate form soluble anions that are mobile in groundwater. Under reducing conditions, however, these species either precipitate from solution (uranium and sulfide minerals), transform (perchlorate) and/or adsorb onto aquifer materials (nitrogen-ammonium).

Oxidation-reduction (redox) reactions are very important in groundwater systems for controlling distributions of trace elements and are quite often mediated by a wide variety of microbes. Redox conditions for groundwater most often cannot be quantified with a single redox couple and oxidation-reduction potential (ORP) (Langmuir, 1997) because numerous couples are present and they differ with respect to kinetic reaction rates (Figure 3-9). Some couples are electrochemically reversible, including the iron(III)/iron(II) and hydrous ferric oxide/iron(II) pairs. However, most pairs are not reversible under normal groundwater conditions in the absence of microbes, including: dissolved oxygen/water, nitrogen (V)/nitrogen(0), nitrogen(V)/nitrogen(III), uranium(VI)/uranium(IV), sulfur(VI)/sulfur(-II), and carbon(IV)/carbon(0, -IV). General trends in redox chemistry, however, can be inferred based on distribution and concentration of redox-sensitive solutes such as iron and manganese, mineralogy of aquifer material, presence or absence of dissolved oxygen, knowledge of microbial populations, and presence of electron donors (reducing agents, reductants), and electron acceptors (oxidizing agents, oxidants).

Under natural or baseline conditions, groundwater under the Pajarito Plateau within perched intermediate zones and the regional aquifer is oxidizing. This is also generally true for alluvial groundwater, although DOC may enhance localized reducing conditions within wetlands occupying some canyon reaches. Naturally occurring and measurable concentrations of dissolved oxygen (DO) (1 to 9 ppm), sulfate (>2 ppm), and nitrate (typically 0.5 ppm) are characteristic of oxidizing conditions. Low concentrations of dissolved iron (<0.5 ppm) and manganese (<0.05 ppm) are also characteristic of oxidizing conditions. Under reducing conditions, concentrations of reduced forms of carbon (methane, hydrocarbons, carbohydrates), nitrogen (ammonium), and sulfur (hydrogen sulfide) would exceed concentrations of the oxidized forms. Iron and manganese reduction would also be observed under reducing conditions. Reducing conditions do not occur in normal groundwater beneath the Pajarito Plateau although they have been encountered in several R wells as a highly localized consequence of residual drilling fluids, as described by Longmire and Goff (2002) and Longmire (2002a, 2002b, 2002d, and 2002e) and Bitner et al. (2004) in detail.

3.1.6 Uranium Speciation

Chemical speciation has a direct control on mineral precipitation and adsorption processes. Special attention is given to uranium in this report because this actinide occurs naturally in groundwater and has also been processed at the Laboratory. Large variations in natural uranium concentrations are observed beneath the Pajarito Plateau and to the east in the Rio Grande Valley.

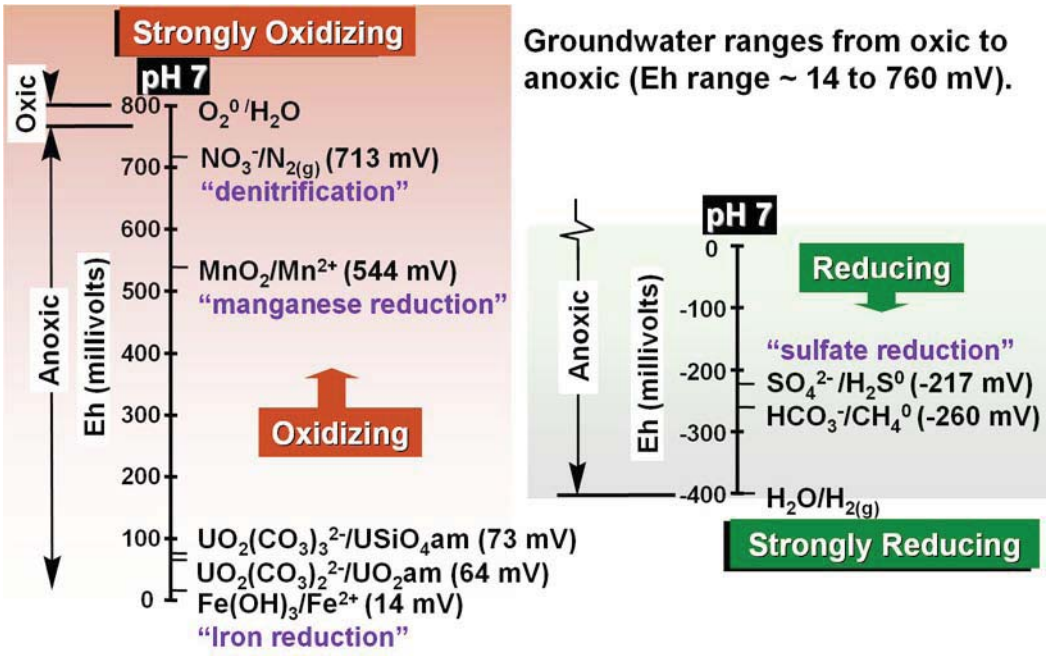


Figure 3-9. Selected oxidation-reduction couples in water at pH 7 and 25°C for the Pajarito Plateau and surrounding areas.

As uranium leaches from minerals and glass, it is stable as uranium(VI) under oxidizing conditions characteristic of aquifer systems beneath the Pajarito Plateau. Uranium(VI) forms strong complexes with bicarbonate and carbonate including $UO_2CO_3^0$, $UO_2(CO_3)_2^{2-}$, and $UO_2(CO_3)_3^{4-}$ (Langmuir 1997) above pH 6.

Figure 3-10 shows calculated distribution of uranium(VI) at Spring 9B discharging from the Cerros del Rio basalt east of the Laboratory. Dissolved concentrations of uranium are typically less than 0.2 µg/L at Spring 9B (LANL 1996a, 2000a, 2001a, 2002).The computer program MINTEQA2 (Allison et al., 1991) was used for the speciation calculations of Spring 9B. The aqueous complex, $UO_2(CO_3)_3^{4-}$ dominates above pH 8.4, whereas $UO_2(CO_3)_2^{2-}$ dominates between pH values of 6.6 and 8.4 at Spring 9B (Figure 3-10). Dissolved uranyl carbonate ($UO_2CO_3^0$) dominates between pH values of 5.0 and 6.6. Spectroscopic evidence has shown that $Ca_2UO_2(CO_3)_3^0$ significantly influences uranium(VI) speciation between pH values of 6 to 10 in calcium-rich uranium-mining waters (Bernhard et al., 2001). This complex may have relevance to groundwater east of the Rio Grande characterized by high calcium and carbonate alkalinity.

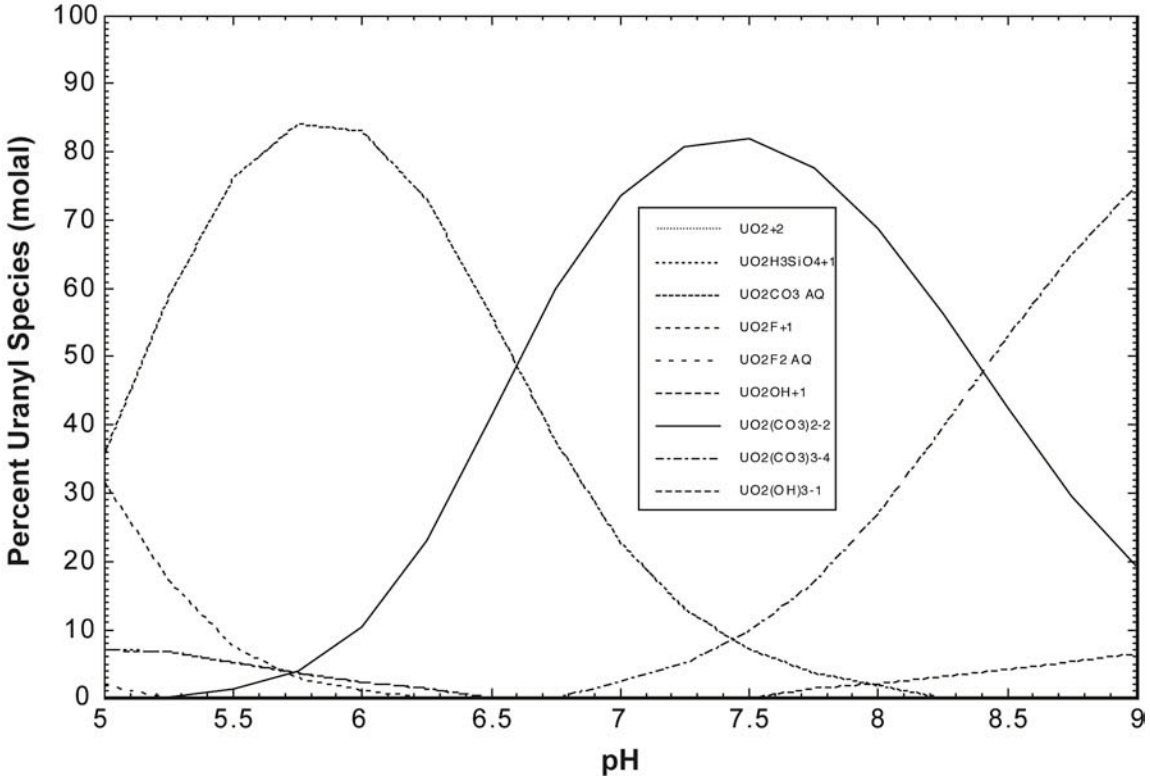


Figure 3-10. Results of speciation calculations for Spring 9B in White Rock Canyon using the computer program MINTEQA2. Log U(VI) = -9.26 molal (m), log F = -4.69 m, log H_4SiO_4 = -2.92 m, and log CO_3^{2-} = -3.07 m at 20.5°C.

Figure 3-11 shows total alkalinity versus uranium concentrations for 127 groundwater samples collected within the Rio Grande Valley near Pojoaque, New Mexico, contrasted with samples from the Pajarito Plateau. Formation of uranyl carbonate complexes has a direct control on the solubility of uranium(VI), leading to dissolved concentrations of uranium much greater than 10 µg/L observed in the Rio Grande Valley.

Uranium(IV) is stable in strongly reducing groundwater containing dissolved sulfide and reduced forms of DOC (Langmuir 1997). Calculations show that uranium(IV) in the form of $U(OH)_4^0$ is stable under reducing conditions below an Eh of –225 millivolts (mV) at pH 7, 25°C, and $10^{-3.0}$ M (61 mg/L) bicarbonate. Formation of uranium(IV) complexes is very unlikely to occur because natural groundwater at Los Alamos, New Mexico is oxidizing and uranium(VI) species are stable. However, in groundwater near Pojoaque uranium(IV) is inferred to be stable in the presence of hydrous ferric oxide reduction.

3.1.7 Summary of Geochemical Conceptual Model

It is important to understand geochemical processes and the natural water quality beneath the Pajarito Plateau, so that anthropogenic perturbations to the natural system can be identified and quantified. While the contaminants are at concentrations largely below regulatory standards or

risk levels, they demonstrate the presence of pathways for groundwater flow and contaminant transport from the surface to deeper groundwater.

Natural groundwater (alluvial, intermediate, and regional aquifer) ranges from calcium-sodium bicarbonate composition within the Sierra de los Valles to a sodium-calcium bicarbonate composition east and northeast of the Laboratory. The Sierra de los Valles provides most of the recharge to groundwater beneath the Pajarito Plateau and groundwater in the recharge area has the lowest TDS of the overall flow system.

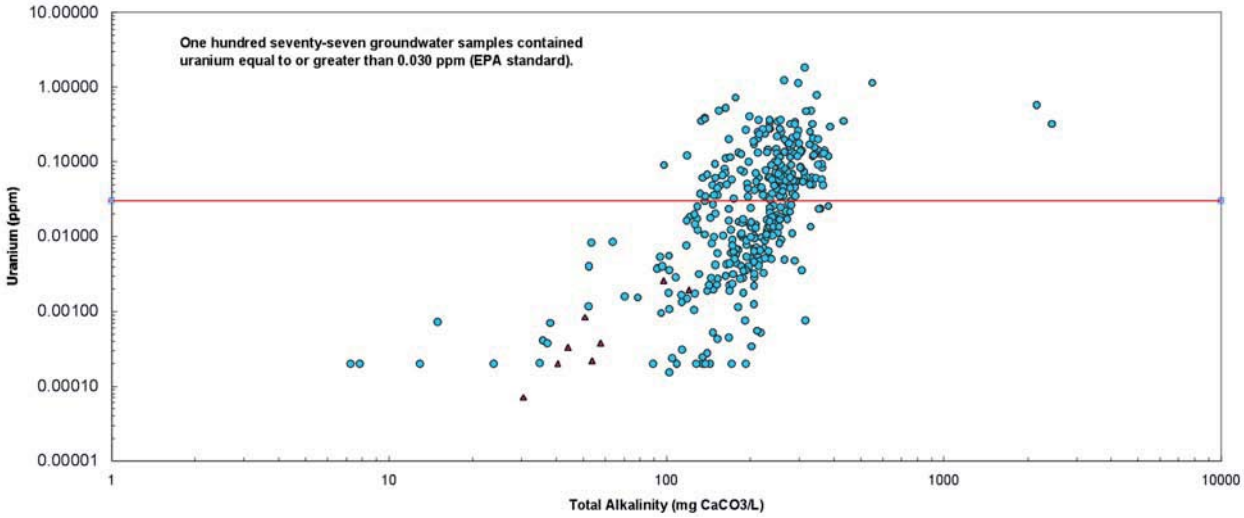


Figure 3-11. Total alkalinity (as carbonate) versus uranium concentrations in groundwater samples collected from the Rio Grande Valley and the Pajarito Plateau. Red triangles are from Pajarito Plateau and blue dots are from the Rio Grande Valley.

Along flow paths variation in solute concentration results from mixing of groundwaters, mineral precipitation (solute sink), mineral dissolution (solute source), and adsorption/desorption reactions. Calcium, sodium, and bicarbonate are the dominant major ion solutes in natural groundwater beneath the Pajarito Plateau and surrounding areas. Silica is the second most abundant solute found in surface water and groundwater within the Los Alamos area because of hydrolysis reactions taking place between soluble silica volcanic glass and water. Variations in groundwater trace element concentrations depend on solute residence time, speciation, and extent of water-rock interactions.

All of the mobile chemicals measured in perched intermediate zones and in the regional aquifer are stable as anions (perchlorate, nitrate, sulfate, chloride, uranium) or as neutral species (RDX, TNT, HMX, boron). Contaminants stable as cations (barium, americium-241, plutonium(V)-238, -239, -240, strontium-90, cesium-137) have migrated within alluvial groundwater and are infrequently detected in deeper groundwater.

Groundwater within a discharge zone, at the end of groundwater flow paths, generally has the highest mineral or solute content and also represents the oldest water. Residence times of groundwater and chemical solutes increase both with depth and from west to east across the Pajarito Plateau within each groundwater zone. The oldest groundwater residence times within the regional aquifer are on the order of several thousand to tens of thousands of years, based on carbon-14 dating and on flow and transport models.

Geochemical processes that affect the groundwater chemistry include the following:

- ***Precipitation/Dissolution***: Different reactive minerals and amorphous solids precipitate or dissolve and can control the major ion composition of groundwater. As groundwater flows through perched intermediate zones and the regional aquifer, chemical and mineralogical compositions of reactive phases including silica glass change over time. For example, silica glass is the most soluble component of the aquifer material reacting with groundwater to form clay minerals, including kaolinite and smectite. Precipitation reactions serve as a sink for removing uranium from solution.
- ***Adsorption:*** Dissolved species interact with surfaces of aquifer material coated with hydrous ferric oxide, manganese dioxide, clay minerals, or other adsorbents, often resulting in the release of adsorbed species via replacement reactions. Hydrous ferric oxide is an important adsorbent present in different aquifer materials beneath the Pajarito Plateau. Other common adsorbents of metals include smectite, calcite, manganese oxide, and solid organic carbon. Downgradient from Laboratory discharge points, adsorption processes are considered to dominate over mineral precipitation for continual removal of metals and radionuclides from alluvial groundwater. Adsorption processes involving uranium(VI) appear to control dissolved concentrations of this actinide in groundwater beneath the Pajarito Plateau.
- ***Redox Conditions***: Under natural or baseline conditions, groundwater under the Pajarito Plateau within alluvial, perched intermediate zones, and the regional aquifer is oxidizing. Adsorption and precipitation reactions involving redox-sensitive contaminants are directly influenced by oxidation and reduction reactions. Under oxidizing conditions, species including uranium(VI), sulfate, nitrate, and perchlorate form soluble anions that are semimobile in groundwater. Uranium(VI) partly adsorbes onto ferric oxyhydroxide and is semimobile in groundwater between a pH range of 7 to 8.5, typically observed in groundwaters of the Pajarito Plateau. Under reducing conditions, however, these species either precipitate from solution (uranium and sulfide minerals), transform (perchlorate) and/or adsorb onto aquifer materials (nitrogen-ammonium).
- ***Chemical Speciation***: has a direct control on mineral precipitation and adsorption processes. Formation of uranium(IV) complexes is very unlikely to occur because natural groundwater at Los Alamos, New Mexico is oxidizing and uranium(VI) species are stable.

3.2 Contaminant Distributions and Transport

This section describes the sources, presence, and trends through time of chemical constituents in groundwater originating from anthropogenic (principally LANL) sources. The movement rates and distribution of these chemical constituents give an indication of groundwater flow paths and flow mechanisms over time. Appendix 3-A provides a description and map of each canyon, arranged by watershed, because this framework highlights the connection between surface liquid discharge sources and their effects on shallow and deeper groundwater chemistries.

In this section anthropogenic chemical constituents found in groundwater are divided into two classes: contaminants and other anthropogenic chemical constituents. Contaminants in groundwater are chemicals found at concentrations near or exceeding either regulatory standards or, where no standards exist, exceeding EPA screening levels of either hazard index (HI) of 1 or excess cancer risk of 10^{-5}. For chemicals with no standards, the EPA Region VI tap water screening levels were used (http://www.epa.gov/earth1r6/6pd/rcra_c/pdn/screen.htm). For cancer-causing substances, the Region VI tap water screening levels are at a risk level of 10^{-6}, therefore, 10 times these values were used to screen for a risk level of 10^{-5}. A hazard index value of 1 or less indicates that no (noncancer) adverse human health effects are expected to occur.

Anthropogenic chemical constituents other than contaminants are found at lower concentrations, although some of these constituents may have been contaminants (that is, at higher concentrations) in the past.

Table 3-1 summarizes the anthropogenic constituent observations in alluvial, intermediate, and regional aquifer groundwater. Information on Table 3-1 indicates that most canyons with anthropogenic constituents in alluvial groundwater also have anthropogenic constituents in the intermediate (if present) and the regional aquifer. The water quality impacts of effluent releases on alluvial groundwater extend to perched groundwater at depths of a few hundred feet beneath these canyons. The contaminated perched groundwater bodies are separated from the regional aquifer by hundreds of feet of dry rock, and in these wet canyons recharge from the shallow perched groundwater occurs in a time frame of decades. Nevertheless, the magnitude of water quality impacts on the regional aquifer are quite low.

Table 3-1.
Summary of Factors Influencing Contaminant Distributions in Groundwater at Los Alamos National Laboratory

Canyon	Presence of Contaminant Sources	Water Inputs		Hydrogeologic Controls			Observed Contaminants in Groundwater		
		Natural	Anthropogenic	Enhanced Infiltration	Potential Lateral Pathways	Flow Field Modification	Alluvial	Intermediate	Regional Aquifer
Guaje	Minor dry sources	Low	None	Puye Formation exposed in canyon bottom	None	Near Guaje wellfield	None	No intermediate groundwater	None
Bayo	Previous sources removed; little present source	Low	Low	None, basalts not present in vadose zone	None, basalts not present in vadose zone		No alluvial groundwater present	No intermediate groundwater present	None
Pueblo (including Acid Canyon)	Multiple, liquid sources	Low	High, POTW effluent-supported stream	Yes, associated with faults	No, basalts not present in vadose zone	O-1 located in Pueblo Canyon	Nitrate, boron, tritium (past); Strontium-90	Tritium (TW-2A); nitrate (TW-1A)	Perchlorate (O-1), tritium (O-1, R-4), nitrate (TW-1, O-1, R-4)
Los Alamos (including DP)	Multiple liquid sources	Moderate	High, effluent discharges	Yes, Cerros del Rio basalt exposed in canyon bottom at R-9	Yes, Cerros del Rio basalt present in vadose zone	O-4 located in Los Alamos Canyon	Strontium-90; molybde-num, tritium, plutonium-239, -240, -248	Tritium (LADP-3, R-9i,R-6i); nitrate (R-6i)	Tritium (TW-3, R-9, R-6)
Sandia	Multiple liquid sources	Low	High, effluent discharges	Yes, Cerro Toledo Member exposed in canyon bottom near PM-1	Yes, Cerros del Rios basalts within shallow vadose zone	PM-1 and PM-3 located in Sandia Canyon	Alluvial groundwater not present	Tritium (R-12, R-7), nitrate (R-12)	Tritium (R-12, R-11), nitrate (R-12, R-11)

Table 3-1.
Summary of Factors Influencing Contaminant Distributions in Groundwater at Los Alamos National Laboratory (continued)

Canyon	Presence of Contaminant Sources	Water Inputs		Hydrogeologic Controls			Observed Contaminants in Groundwater		
		Natural	Anthropogenic	Enhanced Infiltration	Potential Lateral Pathways	Flow Field Modification	Alluvial	Intermediate	Regional Aquifer
Mortandad	Multiple liquid sources	Low	High, effluent discharges	Thick pockets of alluvium; sediment ponds	Extensive Cerros del Rio basalt in vadose zone	Within PM wellfield	Americium-241, plutonium-238, plutonium-239, -240, strontium-90, tritium, nitrate, perchlorate, fluoride	Tritium (MCOBT-4.4, R-15), nitrate (MCOBT-4.4), perchlorate (MCOBT-4.4, R-15)	Tritium (R-15, R-28), nitrate (R-15, R-28), perchlorate (R-15)
Canada del Buey	Major dry sources; minor liquid sources	None	None on LANL property; effluent from White Rock POTW	No, canyon bottom underlain by Bandelier Tuff	Extensive Cerros del Rio basalt close to surface	Within PM wellfield	Gross alpha, gross beta	No intermediate perched groundwater is present	None
Pajarito Canyon	Major dry sources	High	Moderate	Yes, Cerros del Rio basalt exposed at the surface from west of R-23 to Rio Grande	Yes, extensive Cerros del Rio basalt	Yes, within PM wellfield	Metals, radio-nuclides, HE, VOCs and anions	HE (springs)	None
Water	Multiple dry and liquid sources in upper part of canyon	High	High	Yes, Cerros del Rio basalt exposed in lower part of canyon	Yes, extensive Cerros del Rio basalts in lower canyon	None	HE, barium		

Table 3-1.
Summary of Factors Influencing Contaminant Distributions in Groundwater at Los Alamos National Laboratory (continued)

Canyon	Presence of Contaminant Sources	Water Inputs		Hydrogeologic Controls			Observed Contaminants in Groundwater		
		Natural	Anthropogenic	Enhanced Infiltration	Potential Lateral Pathways	Flow Field Modification	Alluvial	Intermediate	Regional Aquifer
Cañon de Valle	Multiple dry and liquid sources in upper part of canyon	High	High	No, underlain by thick Bandelier Tuff	Yes, Cerro Toledo interval in vadose zone	None	Barium, HE, perchlorate	HE, barium,	Tritium (R-25), HE(?) (R-25)
Potrillo/ Fence	Minor dry sources	Low	None	No, underlain by Bandelier Tuff	Yes, extensive Cerros del Rio basalt in vadose zone	None	No, alluvial groundwater not present	No, intermediate perched groundwater not present	None
Ancho	Minor dry and liquid sources	Low in upper portion; moderate in lower portion	Minor, septic systems	No, underlain by Bandelier Tuff	No	None	None	No, intermediate perched groundwater is not expected	HE(?) (Ancho Spring)
Chaquehui	Minor dry and liquid sources	Low in upper portion; moderate in lower portion	Low	Yes, basalts exposed at surface in canyon	Yes, extensive Cerros del Rio basalts present in vadose zone	None	No, alluvial groundwater not present	No, perched intermediate groundwater not expected	
Frijoles	No LANL sources	High	None	Yes, basalts exposed in canyon bottom	Yes, basalts in vadose zone	None	No data	No data	
White Rock	No LANL sources	High	Low	Yes, basalts exposed in canyon bottom	Yes, basalts in vadose zone	None	No alluvial groundwater present	No intermediate groundwater is present	Tritium, nitrate (Springs 1, 3, 3A, 4, 5);

Table 3-1.
Summary of Factors Influencing Contaminant Distributions in Groundwater at Los Alamos National Laboratory (continued)

Canyon	Presence of Contaminant Sources	Water Inputs		Hydrogeologic Controls			Observed Contaminants in Groundwater		
		Natural	Anthropogenic	Enhanced Infiltration	Potential Lateral Pathways	Flow Field Modification	Alluvial	Intermediate	Regional Aquifer
									perchlorate, uranium (Spring 2B)

3.2.1 Contaminant and Constituent Sources

Table 3-1 indicates the factors that have primary influence on distribution of anthropogenic constituents in groundwater. The first factor is the presence of upgradient sources of these constituents. The sources affecting groundwater at the Laboratory are mainly liquid effluents rather than solid waste disposal or other activities. Since the 1940s, liquid effluent disposal by the Laboratory has degraded water quality in the shallow perched groundwater that underlies a few canyons (Figure 3-12). Drainages that received significant radioactive effluent discharges are Mortandad Canyon and Pueblo Canyon from its tributary Acid Canyon, and Los Alamos Canyon from its tributary DP Canyon. Rogers (2001) and Emelity (1996) summarize radioactive effluent discharge history at the Laboratory. Water Canyon, its tributary Cañon de Valle, and Pajarito Canyon have received effluents produced by HE processing and experimentation (Glatzmaier 1993, Martin 1993, LANL, 1998a). Over the years, Los Alamos County has operated three sanitary treatment plants in Pueblo Canyon (LANL, 1981). Only the Bayo plant is currently operating. The Laboratory has also operated numerous sanitary wastewater treatment plants, as shown in Figure 3-12.

Solid waste disposal has less potential to affect groundwater. Most solid waste disposal sites are located on mesa tops where there is little natural or artificial percolation to carry anthropogenic constituents to groundwater. Canyons that have little or no source of anthropogenic constituents (Guaje, Bayo, Potrillo, Fence, Ancho, Chaquehui, and Frijoles) have no anthropogenic constituents in groundwater (Table 3-1). Canyons that had small volume liquid sources or major dry sources are Cañada del Buey and Pajarito Canyon (Table 3-1).

3.2.2 Water Inputs

The second factor influencing anthropogenic constituent distribution in groundwater shown on Table 3-1 is water input, either natural or anthropogenic. The amount of water in a canyon system is a determining factor for transporting anthropogenic constituents. In most cases where Laboratory anthropogenic constituents are found at depth, the setting is one of the following:

- canyons where natural water input is high (Pajarito Canyon, Water Canyon, and Cañon de Valle);
- canyons where anthropogenic water input is high (Pueblo, Los Alamos, Sandia, Mortandad Canyons); or
- mesa-top sites where large amounts of liquid effluent have been discharged (such as retention ponds or outfalls) (mesa tops bounded by Cañon de Valle and Water Canyon).

The presence of water, either natural or from the discharge of effluents to canyons or mesa-top locations in the Laboratory's semiarid setting initiates or increases downward percolation of water. Even under unsaturated flow conditions, this percolation may move significant volumes of water to the regional aquifer within a few decades.

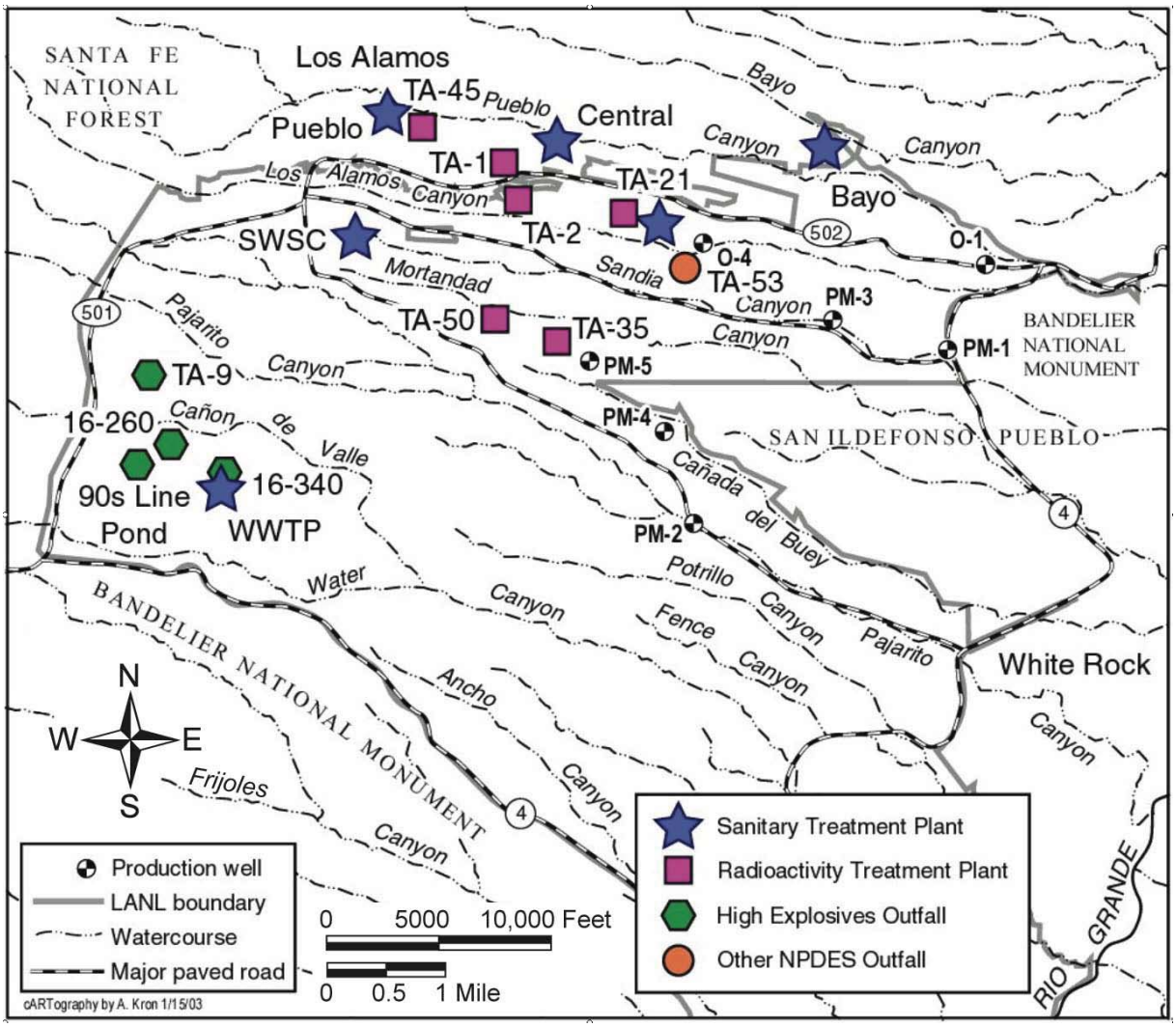


Figure 3-12. Major liquid release sources that have potentially affected groundwater at Los Alamos National Laboratory. Most of these sources are now inactive.

3.2.3 Hydrogeologic Controls

The third factor that contributes to anthropogenic constituent distribution consists of hydrogeologic controls on groundwater pathways and travel rates (Table 3-1). The controls considered most important in influencing contaminant distribution and transport are infiltration at the surface and transport of contaminants in alluvial groundwater, pathways in the vadose zone and transport through intermediate perched groundwater, and flow field modification in the regional aquifer.

The movement of groundwater contaminants is best seen through the distribution of conservative (that is, non-reactive) chemical species. Under most conditions, compounds like RDX, tritium, perchlorate, and nitrate move readily with the groundwater. In many settings, chemical reactions do not retard the movement of these compounds or decrease their concentrations, although the

activity of tritium does decrease due to radioactive decay. For some compounds or constituents (uranium, strontium-90, barium, some HE compounds, and solvents) movement is slowed or their concentrations are decreased by adsorption or cation exchange, precipitation or dissolution, chemical reactions like oxidation/reduction, or radioactive decay. Other constituents (americium-241, plutonium, and cesium-137) are nearly immobile because they are strongly adsorbed onto sediment particles.

3.2.3.1 Infiltration Rate and Transport in Alluvial Groundwater

The first hydrogeologic control, infiltration rate, affects the movement of anthropogenic constituents from the surface to groundwater. As described in Section 2.5.3, undisturbed Bandelier Tuff has a very low infiltration rate. Areas that have other geologic units (particularly basalt units) exposed in the canyon bottom have higher, or enhanced, infiltration rates. Anthropogenic alterations can also enhance infiltration, for example sediment ponds in Mortandad Canyon and ponds in the Cañon de Valle watershed.

The alluvial groundwater present in several canyons has a small volume relative to the annual volume of runoff or effluents, does not extend beyond the LANL boundary, and is generally completely refreshed by recharge on a time scale of about a year (Section 2.4.1). This rapid turnover of groundwater volume means that, rather than increasing over time, the groundwater concentrations of conservative compounds are controlled by concentrations in recharge sources such as effluent. The principal compounds that accumulate or persist in alluvial groundwater are those, such as strontium-90, that are not highly mobile. Strontium-90 has accumulated mainly in the canyon floor sediments, from which it slowly but continually leaches into the groundwater due to cation exchange, maintaining a nearly steady concentration. In some cases, such as RDV in Cañon de Valle, mobile contaminants also persist, possibly due to their continuing presence in water source regions.

A study by Purtymun et al. (1977) documented this rapid turnover of groundwater and solutes in Mortandad Canyon. Purtymun showed that the mass of various solutes in Mortandad Canyon alluvial groundwater was a fraction of the total solute mass that had been discharged into the canyon over the history of effluent releases. To a first approximation, the entire body of alluvial groundwater in Mortandad Canyon is chemically well mixed, and variations in concentrations of specific sources propagate throughout the groundwater system in times of about a year. Concentrations are at times higher for wells nearest to the outfall, partly because of variable mixing of effluent with ground and surface water. Concentrations appear to decrease downstream from the outfall due to mixing and the occasional higher values in upstream wells. While concentrations vary between wells, overall concentrations of the constituents are generally similar throughout the alluvial groundwater body at a given time.

Rather than a contaminant plume existing within the alluvial groundwater, a relatively small volume of groundwater (with a volume of about 20,000 cubic meters) is completely replenished annually by recharge water (with a volume of about 90,000 to 160,000 cubic meters) which includes the discharges from RLWTF at TA-50. Purtymun et al. (1977) attributed the losses of water to evapotranspiration and infiltration into the underlying tuff. The composition of the alluvial groundwater is a combination of input from the TA-50 facility and other sources such as

runoff and other Laboratory discharges. The groundwater composition nearest the TA-50 discharge point shows short term (weekly or daily) variations related to the TA-50 outfall, but over the longer term (annually), these variations are spread throughout the alluvial groundwater body.

Data for conservative constituents (tritium, nitrate) in alluvial groundwater support the conceptual model that this groundwater has a short residence time and conservative contaminants do not accumulate in alluvial groundwater. The time trend pattern for these contaminants shows a high level when they were being released, followed by a sharp decline in concentration to nearly nondetectable levels when the source is eliminated. Past values of tritium and nitrate in alluvial groundwater in DP, Los Alamos, Pueblo, and Mortandad Canyons exceeded the 20,000 pCi/L MCL (Rogers 1998). Such high values do not occur today in these locations because of improvement in effluent quality, and also possibly because of deeper infiltration of older effluents.

In Pueblo Canyon, tritium activity in alluvial groundwater was 15,000 pCi/L in the early 1970s, nearly a decade after effluent discharges ceased; today it is barely detectable (Figure 3-13). Similarly, alluvial groundwater tritium values in DP and Los Alamos Canyons exceeded 300,000 pCi/L in the late 1960s, but have been barely detectable for the past decade (Figure 3-14). TA-21 effluent caused tritium levels in surface water and alluvial groundwater in and downstream of DP Canyon to reach values up to 5,000,000 pCi/L, or 250 times the MCL (Figure 3-14, Figure 3-15). The tritium levels decreased greatly after discharges ceased. In Los Alamos Canyon above the mouth of DP Canyon, the Omega West Reactor cooling line leaked water containing tritium from 1956 to 1993. As a result of this leak, tritium activity in alluvial groundwater remained at values around 10,000 pCi/L or half of the MCL. Once the leak was discovered and shut off, tritium levels in Los Alamos Canyon water returned to background. In Mortandad Canyon alluvial groundwater tritium activities often exceeded 300,000 pCi/L and even reached 2,000,000 pCi/L, but have fallen below the MCL since the RLWTF adopted effluent limits in 2001 (Figure 3-15, Figure 3-16). At the end of 2000, the RLWTF adopted a voluntary goal of having tritium activity in its effluent below 20,000 pCi/L, and tritium activity in the effluent dropped below that in 2001 and was 10,400 pCi/L in 2003. Tritium activity in alluvial groundwater downgradient of the facility has dropped correspondingly, with a maximum value of 8,770 pCi/L in 2003.

Nitrate levels in Pueblo Canyon surface water and groundwater follow a strong downward trend similar to those for tritium. Nitrate has been discharged from Laboratory radioactive liquid waste effluents and Los Alamos County sanitary wastewater effluent (Figure 3-17, Figure 3-18). The highest values were found in surface water in the 1950s and 1960s, related to both types of sources. With decommissioning of the radioactive outfall in 1964 and moving the sanitary discharge downstream to the Bayo treatment plant, less water and less nitrate have been present in the upper portion of the drainage in recent years. Nitrate in discharges into DP Canyon from TA-21 caused surface water and alluvial groundwater concentrations to exceed 100 mg/L (nitrate as nitrogen), or 10 times the MCL, until discharges ceased in 1986 (Figure 3-18, Figure 3-19). Nitrate concentrations have returned to background since discharges ended. In Mortandad Canyon nitrate (as N) concentrations in alluvial groundwater have generally mirrored the concentration in RLWTF effluent (Figure 3-18, Figure 3-20). The nitrate concentration in the

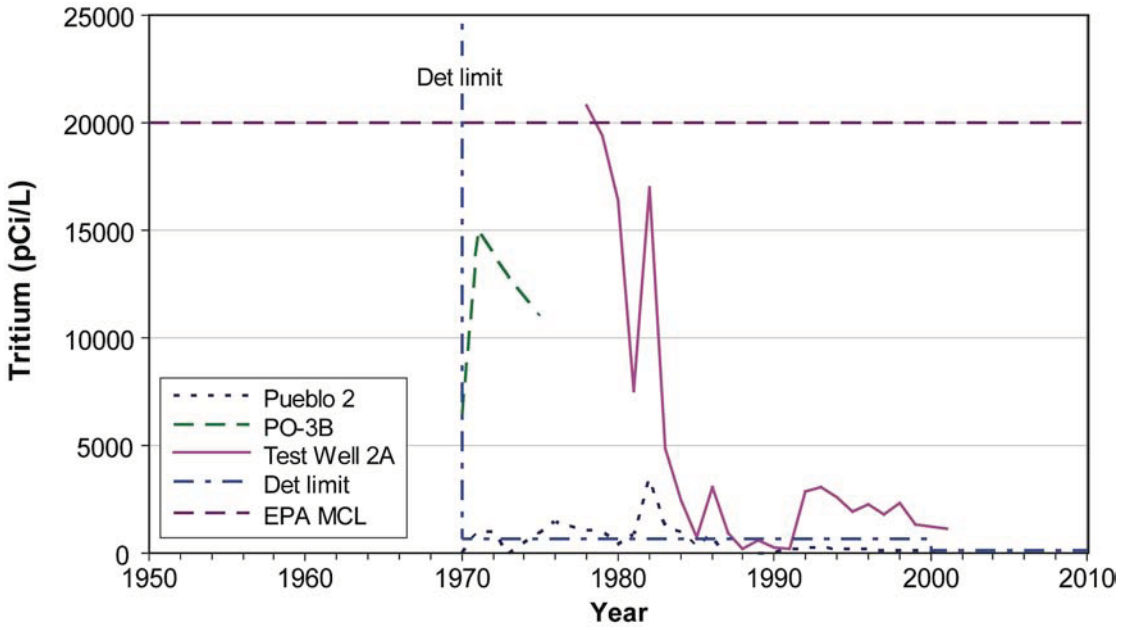


Figure 3-13. Tritium histories in Pueblo Canyon surface water and alluvial and intermediate groundwater zones. Data are annual averages of all results including nondetects; note that detection limits have varied greatly through time.

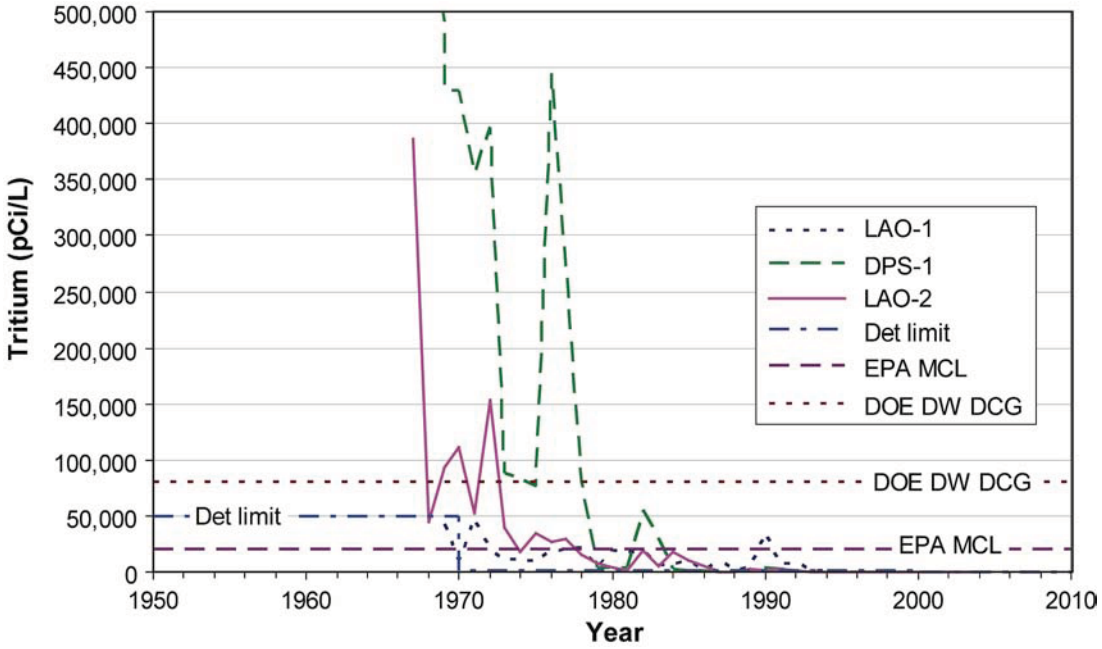


Figure 3-14. Tritium histories in DP and Los Alamos Canyon surface water and alluvial groundwater. Data are annual averages of all results including nondetects; note that detection limits have varied greatly through time.

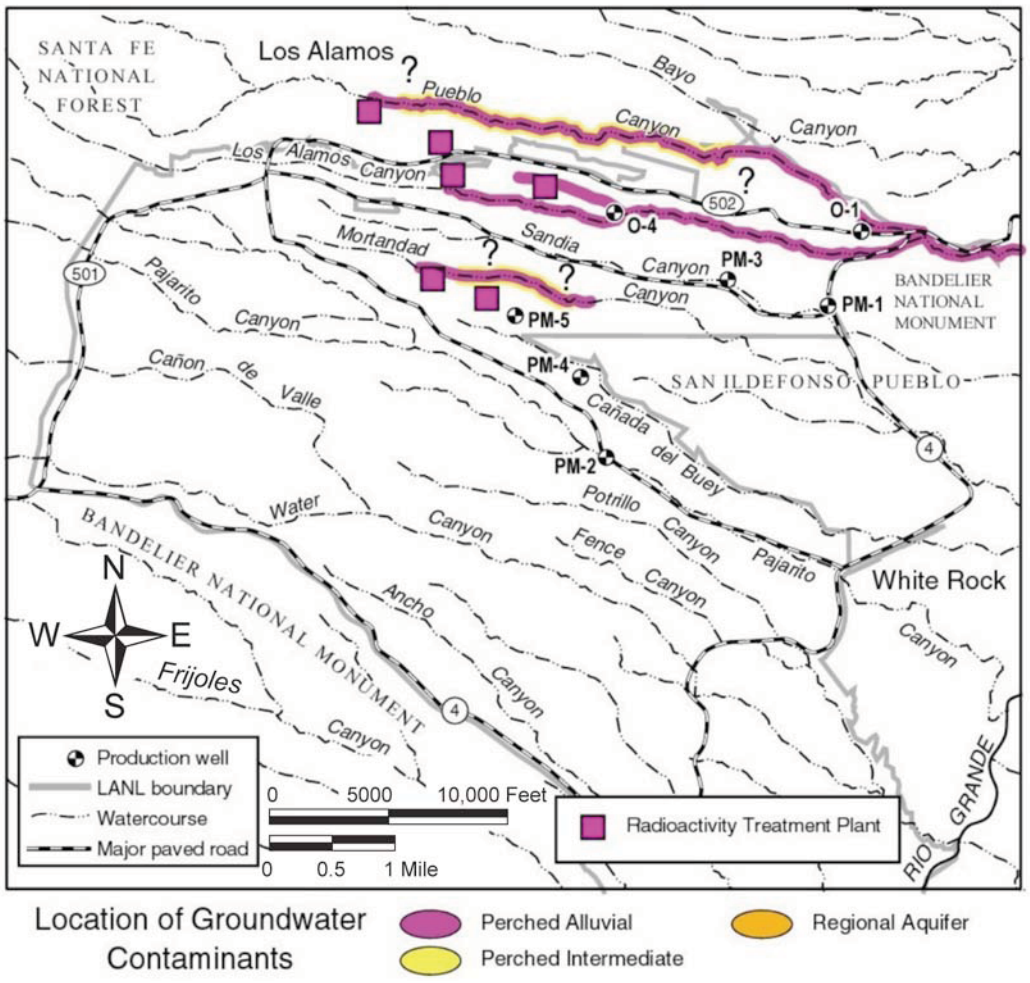


Figure 3-15. Location of inferred past extent of groundwater contamination by tritium above the 20,000 pCi/L EPA MCL. No groundwater tritium exceeded this value in 2003. Different colors indicate the affected groundwater zones. The extent of intermediate groundwater and regional aquifer contamination is based on a limited number of wells; question marks on the maps indicate where contaminant extent is inferred, not necessarily substantiated.

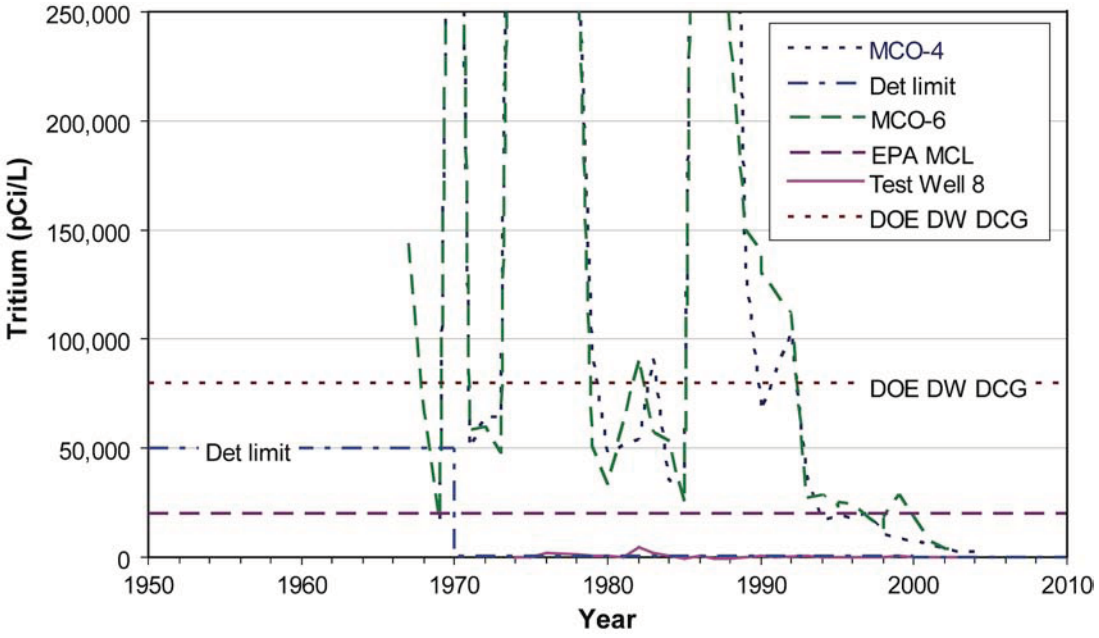


Figure 3-16. Tritium histories in Mortandad Canyon alluvial groundwater and the regional aquifer. Data are annual averages of all results including nondetects; note that detection limits have varied greatly through time.

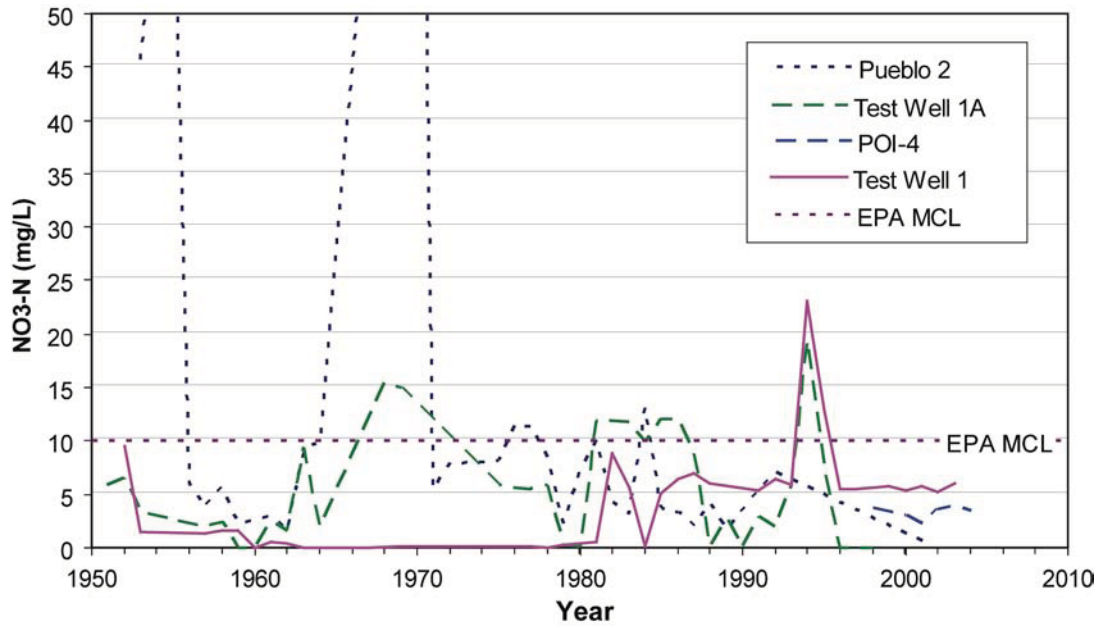


Figure 3-17. Nitrate histories in Pueblo Canyon surface water, alluvial and intermediate groundwater zones, and the regional aquifer. Data are annual averages of all results.

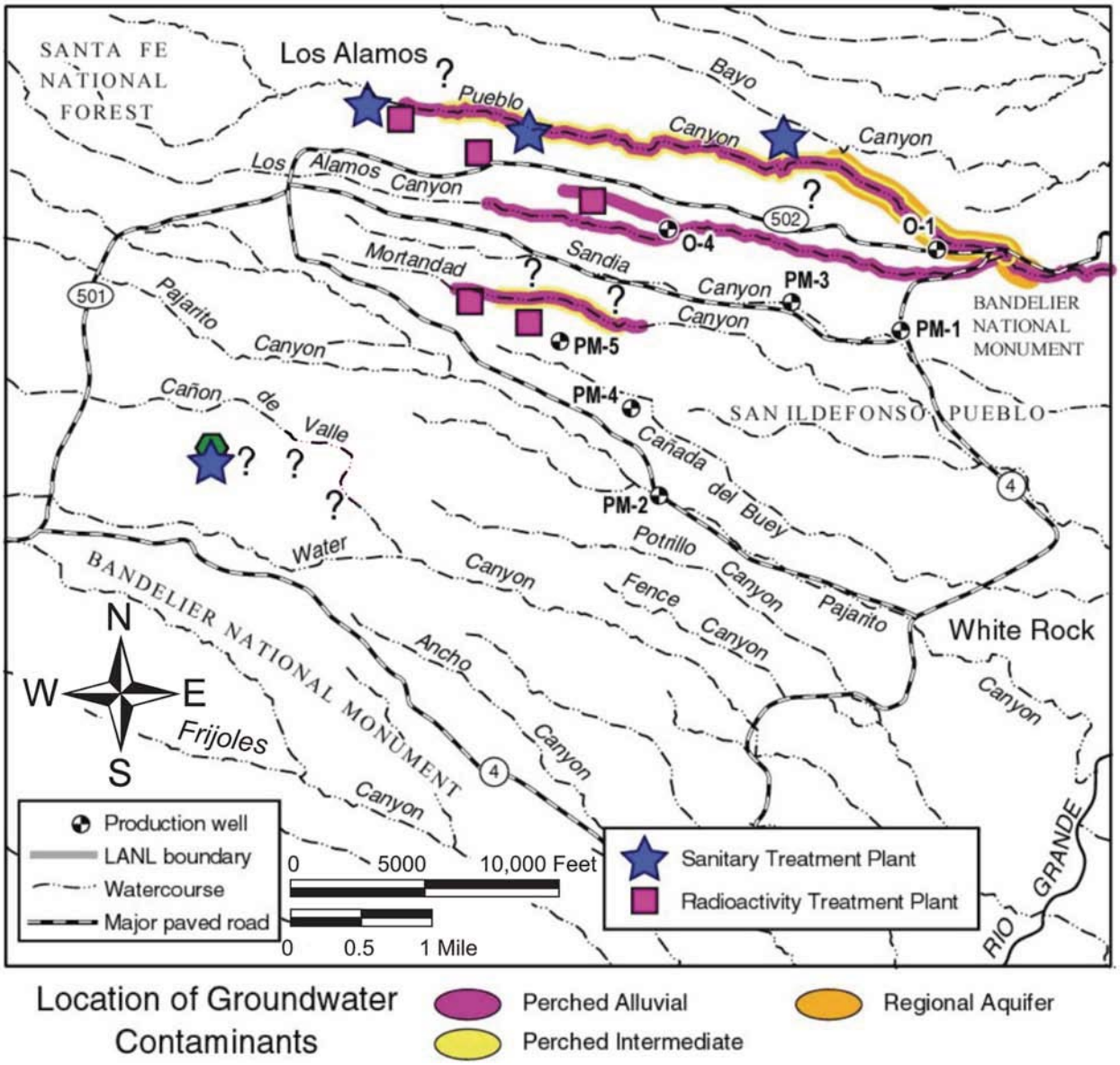


Figure 3-18. Location of inferred past extent of groundwater contamination by nitrate (as nitrogen) above the 10 mg/L EPA MCL. Only intermediate perched groundwater in Mortandad Canyon exceeded this level in recent years. Different colors indicate the affected groundwater zones. Along canyons, the extent of alluvial groundwater contamination lateral to the canyon is not to scale: contamination is confined to the alluvium within the canyon bottom and is narrow at the map scale. The extent of intermediate groundwater and regional aquifer contamination is based on a limited number of wells; question marks on the maps indicate where contaminant extent is inferred, not necessarily substantiated.

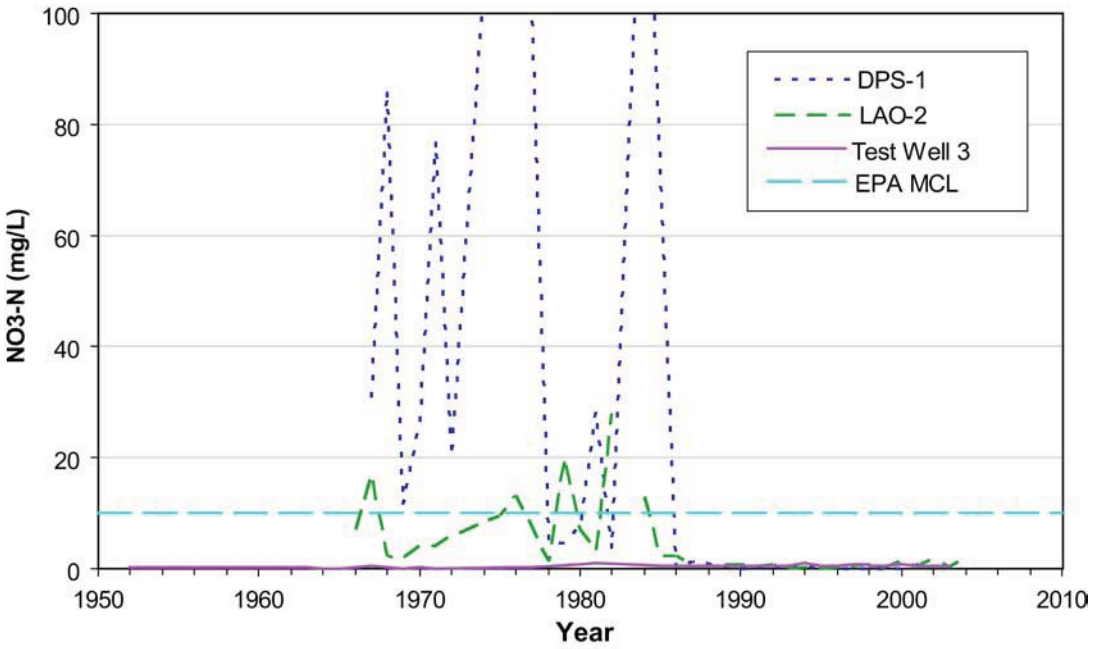


Figure 3-19. Nitrate histories in DP and Los Alamos Canyon surface water, alluvial groundwater, and the regional aquifer. Data are annual averages of all results.

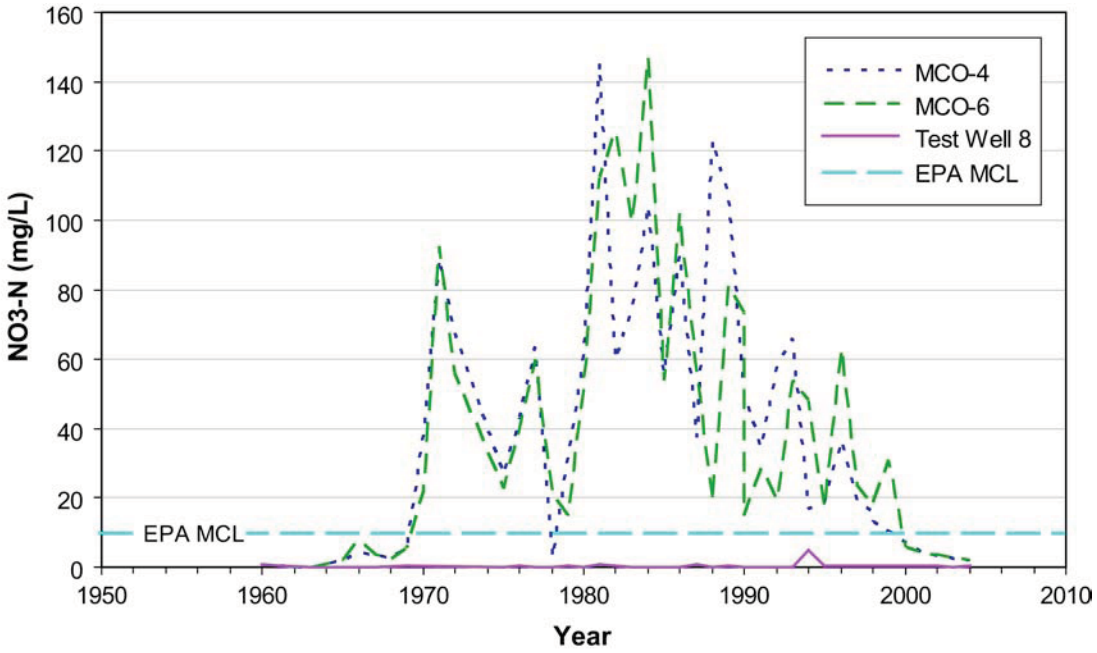


Figure 3-20. Nitrate histories in Mortandad Canyon alluvial groundwater and the regional aquifer. Data are annual averages of all results.

effluent decreased in 1999 due to improved treatment in the RLWTF, and alluvial groundwater concentrations have fallen below the New Mexico Groundwater Standard of 10 mg/L as a result.

The distribution of perchlorate indicates where effluent releases have occurred in canyons (Figure 3-21). Perchlorate history in Mortandad Canyon shows the rapid decrease in perchlorate after the source was eliminated (Figure 3-22). The perchlorate concentration in the effluent decreased in 2002 due to improved treatment in the RLWTF, and alluvial groundwater concentrations have fallen significantly as a result.

Data for adsorbing constituents (strontium-90, plutonium-239, -240) support the conceptual model of contaminant adsorption onto alluvial sediments. The adsorbing contaminants decline in concentration when the source is cut off, followed by maintenance of a fairly constant low concentration in the groundwater due to cation exchange. The highest measured strontium-90 activity was about 500 pCi/L in Acid Canyon surface water in 1960. With no present source, levels have dropped dramatically and strontium-90 is now seen only at low activities, below 1 pCi/L in alluvial groundwater (Figure 3-23).

In Los Alamos Canyon is strontium-90 contamination in surface water and alluvial groundwater derived from reactor sources at TA-2 and effluent discharges from TA-21 (Figure 3-24). The strontium-90 activity in DP Canyon surface water reached 28,600 pCi/L. There is no present source, and activities dropped greatly after discharges ceased. However, strontium-90 persists in alluvial groundwater at levels above the EPA MCL of 8 pCi/L due to the large inventory in alluvial sediment, which moves to the groundwater by cation exchange (Figure 3-24). Effects of Manhattan Project releases in upper Los Alamos Canyon cause plutonium-239, -240 activity in alluvial groundwater to remain at about 25% of the DOE 4 mrem drinking water derived concentration guide (DCG) of 1.2 pCi/L (Figure 3-25). Discharges from TA-21 resulted in plutonium-239, -240 activity in surface water much above the DOE 4 mrem DCG, even exceeding the 100 mrem DCG of 30 pCi/L in the late 1960s. Plutonium activity decreased substantially with the end of discharges in 1986, but is still occasionally detected in surface water and alluvial groundwater below the former outfall. In Mortandad Canyon the discharge from the RLWTF creates a localized area of alluvial groundwater where strontium-90 persists at levels above the 8-pCi/L EPA drinking-water MCL (Figure 3-26). The radionuclides plutonium-238; plutonium-239, -240; and americium-241 are also present above the 4-mrem DOE DCG for drinking water (Figure 3-27).

3.2.3.2 Vadose Zone Pathways and Transport in Intermediate Groundwater

A hydrogeologic control on movement of anthropogenic constituents through the vadose zone is the presence of geologic units that can act as pathways. In general, these are units that are conducive to perching groundwater and forming intermediate perched groundwater. The water quality impacts from effluent releases extend in a few cases to intermediate perched groundwater at depths of a few hundred feet beneath these canyons. Because the contaminated alluvial groundwater bodies are separated from the intermediate perched groundwater by hundreds of feet of dry rock, pathways within the vadose zone are likely present in those canyons.

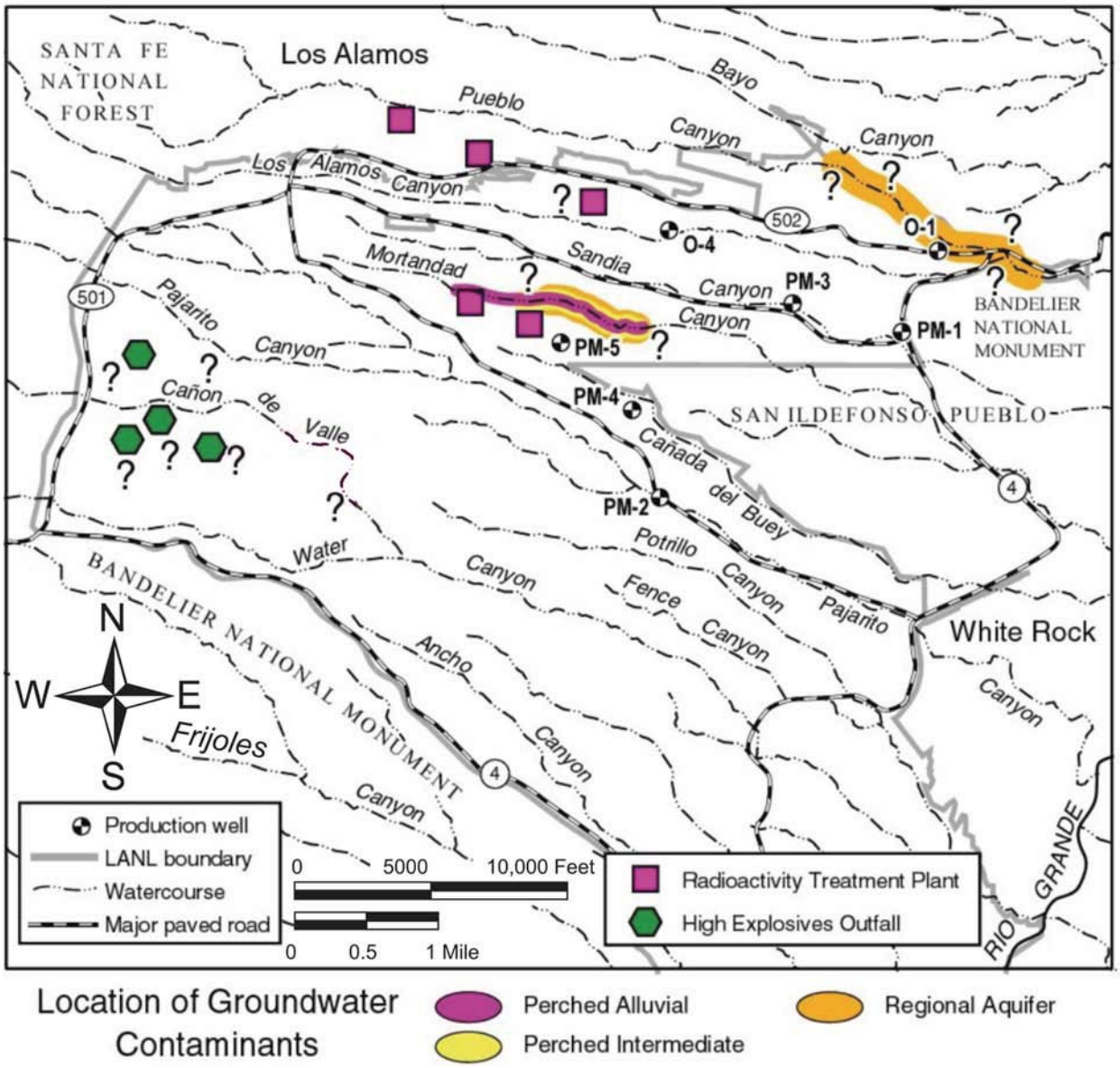


Figure 3-21. Location of groundwater contamination by perchlorate above the 3.7 ppb EPA Region VI risk level. Different colors indicate the affected groundwater zones. The extent of intermediate groundwater and regional aquifer contamination is based on a limited number of wells: question marks on the maps indicate where contaminant extent is inferred, not necessarily substantiated.

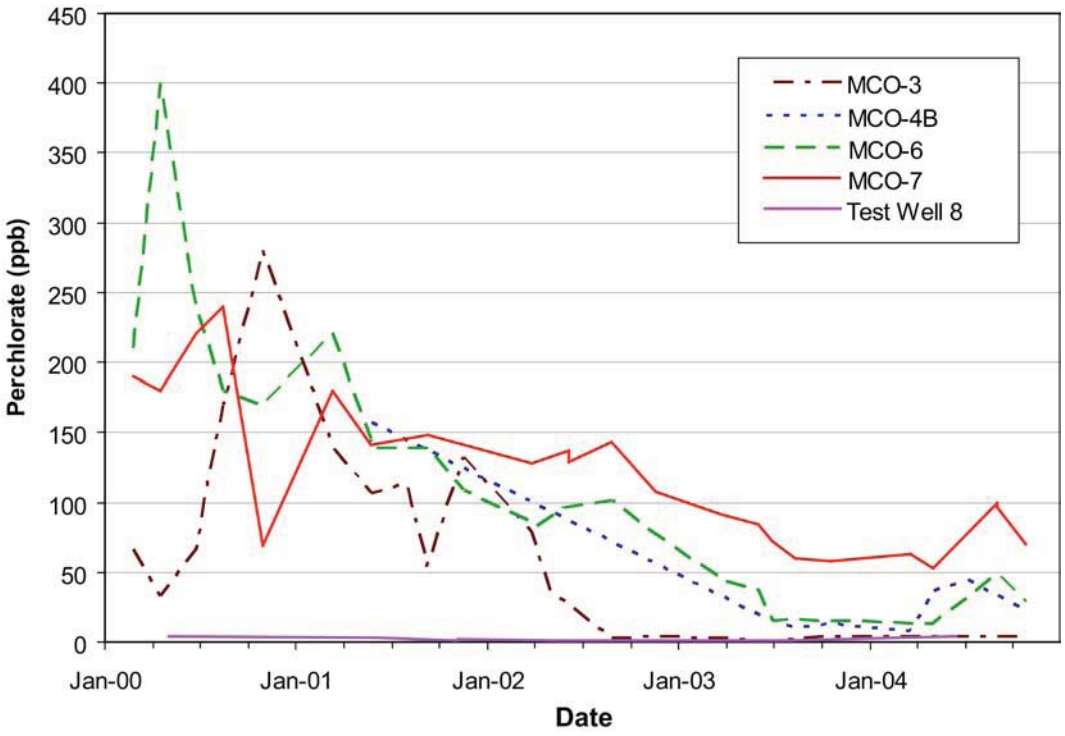


Figure 3-22. Perchlorate histories in Mortandad Canyon alluvial groundwater. All data points are shown.

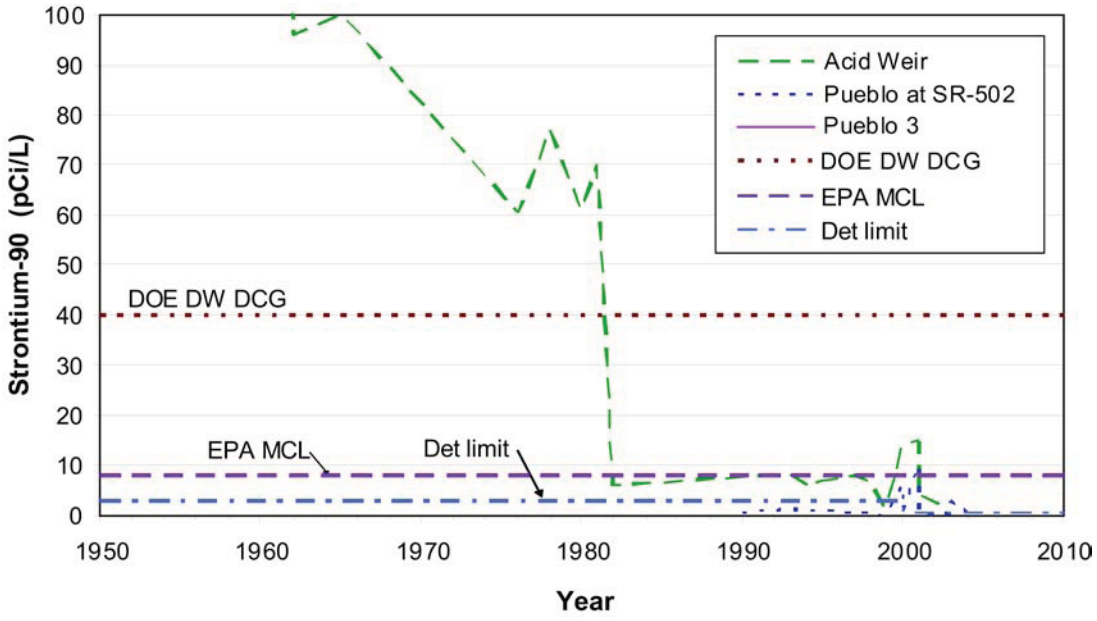


Figure 3-23. Strontium-90 histories in Acid and Pueblo Canyon surface water. The surface water data incorporate the longest record of strontium-90 and the highest values in these canyons; few strontium-90 detections have occurred in groundwater in these canyons. Data are annual averages of all results including nondetects; note that detection limits have varied greatly through time.

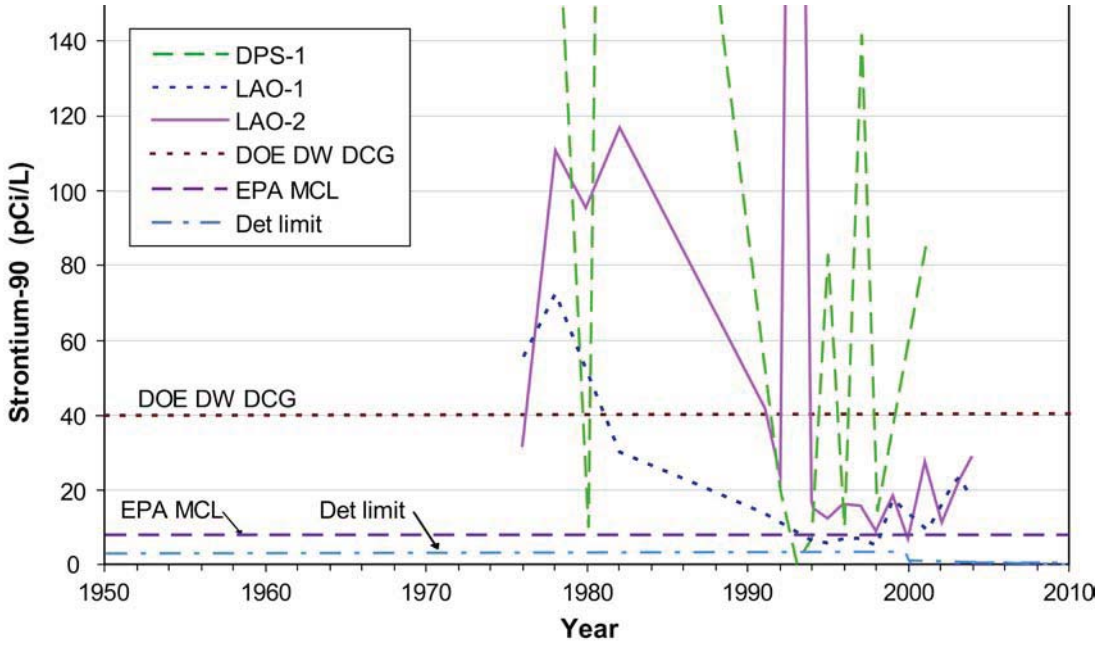


Figure 3-24. Strontium-90 histories in DP and Los Alamos Canyon surface water and alluvial groundwater. Data are annual averages of all results including nondetects; note that detection limits have varied greatly through time.

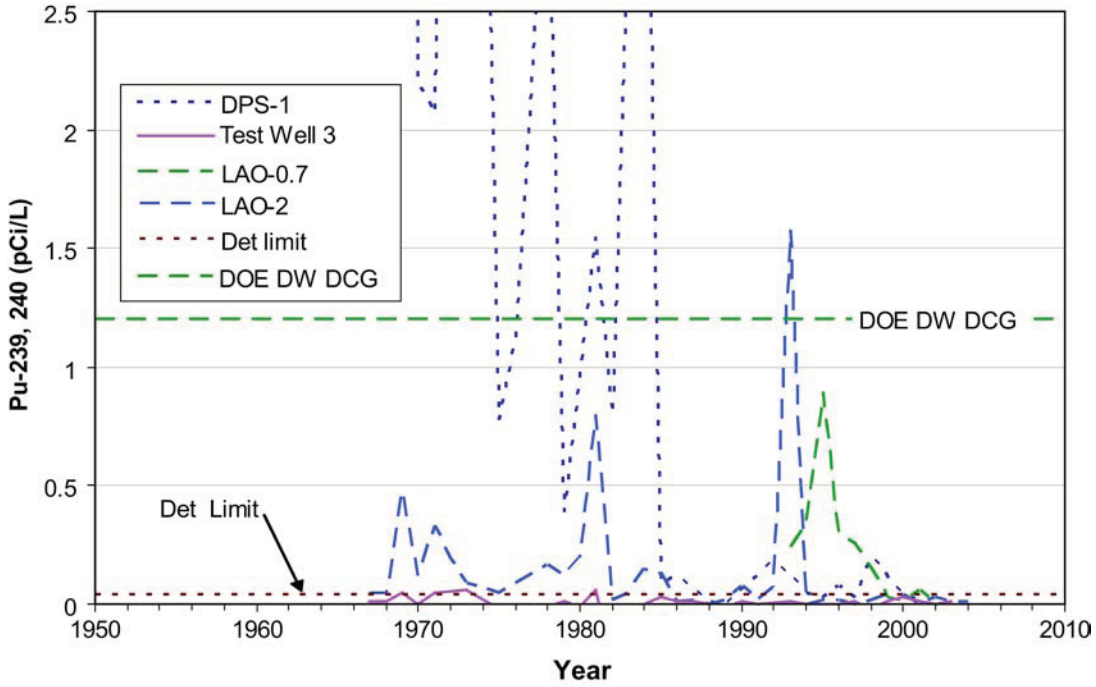


Figure 3-25. Plutonium-239, -240 histories in DP and Los Alamos Canyon surface water, alluvial groundwater, and the regional aquifer. Data are annual averages of all results including nondetects; note that detection limits have varied greatly through time.

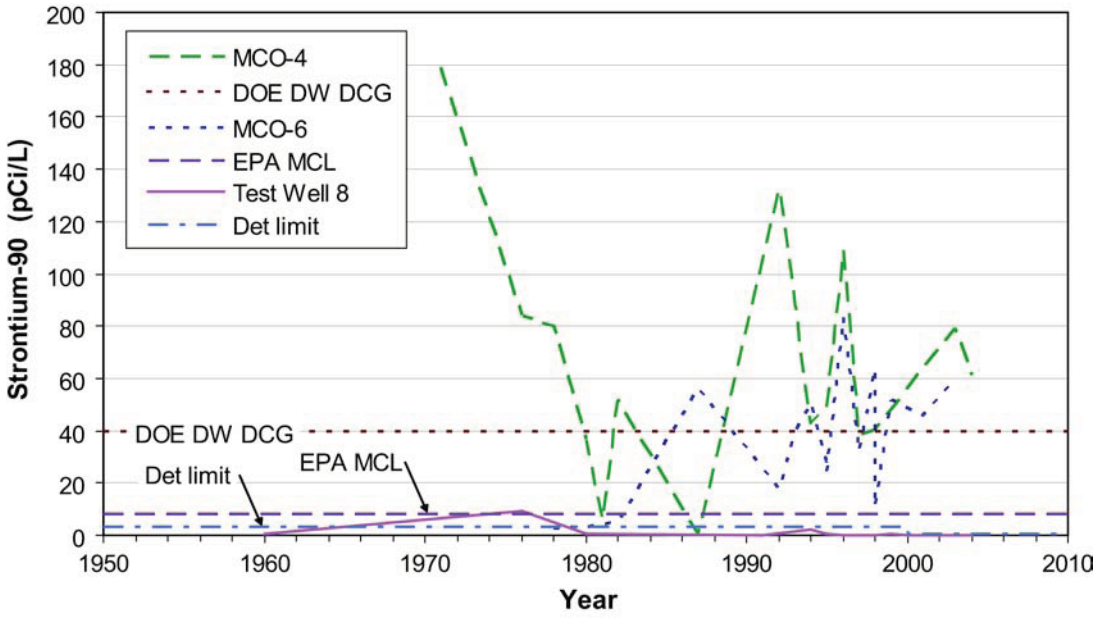


Figure 3-26. Strontium-90 histories in Mortandad Canyon alluvial groundwater and the regional aquifer. Data are annual averages of all results including nondetects; note that detection limits have varied greatly through time.

In Mortandad Canyon, Purtymun et al. (1977) estimated that, on average, about 15% of the surface water and shallow alluvial groundwater was lost to evapotranspiration. Because surface water or alluvial groundwater rarely flows beyond the Laboratory boundary, the remaining 85% of the water that enters the canyon must be lost by infiltration into the underlying tuff. Core profiles (Longmire 2001a) indicate a significant inventory of perchlorate and nitrate within the 400 ft of unsaturated Bandelier Tuff underlying the canyon floor.

Concentrations of contaminants such as nitrate, perchlorate, and tritium in Mortandad Canyon intermediate perched groundwater lie between current and past values in the alluvial groundwater. This banded range of observed concentrations suggests that the alluvial groundwater is a significant source of recharge to the intermediate groundwater; that this recharge requires on the order of decades; and that the solutes in the infiltrating water may be diluted by uncontaminated water already in the vadose zone or in the intermediate perched zone.

Low-level tritium data in intermediate perched groundwater support the conceptual model that alluvial groundwater affected by effluent discharges is a principal source of recharge and contaminants for the intermediate perched groundwater (Figure 3-28). The highest values are found where effluent discharges have occurred, but are much lower than values observed in alluvial groundwater. The lower values may be due to mixing of recharge with other groundwater sources as well as radioactive decay due to recharge time of decades. Higher-than-background tritium values occur in

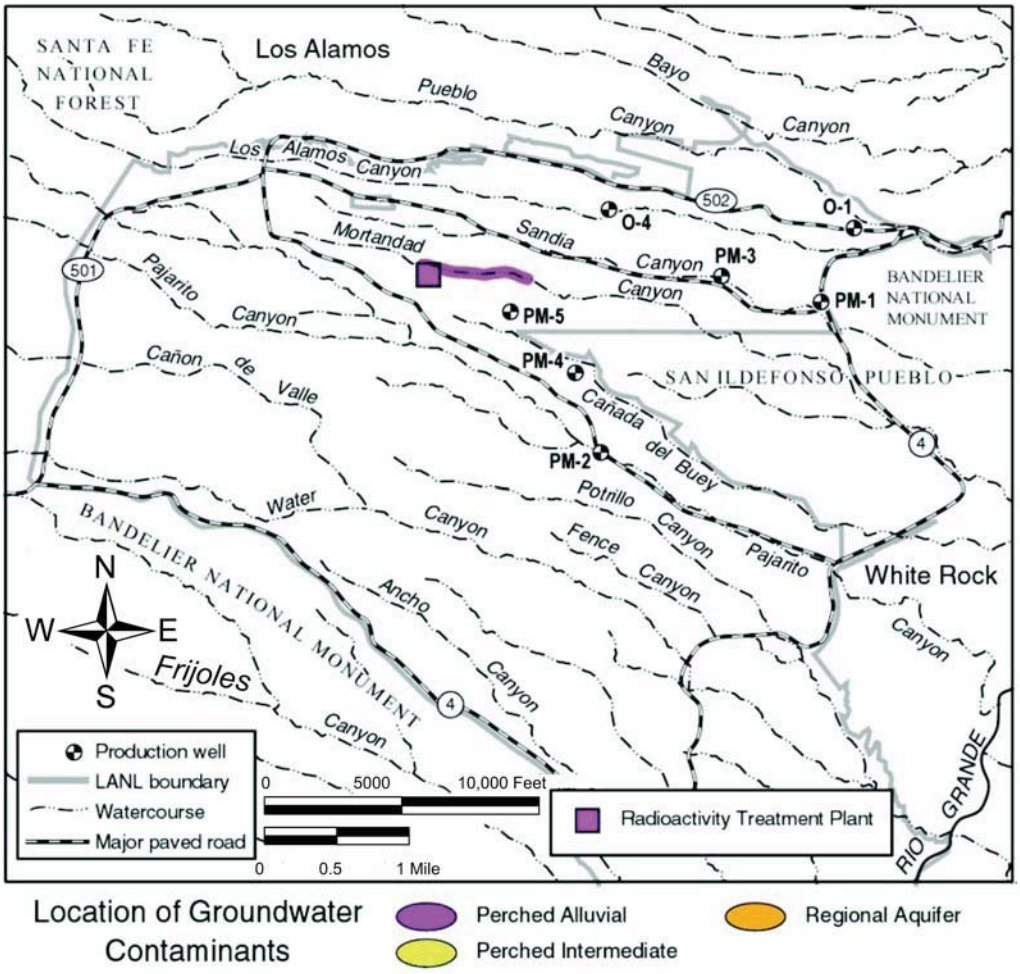


Figure 3-27. Location of groundwater contamination by plutonium-238; plutonium-239, -240; and americium-241 above the 4-mrem DOE DCG for drinking water. The 2003 maximum values in Mortandad Canyon alluvial groundwater for plutonium-238; plutonium-239, -240; and americium-241 were 1.4, 1.3, and 1.4 times the 4-mrem limit, respectively. Different colors indicate the affected groundwater zones.

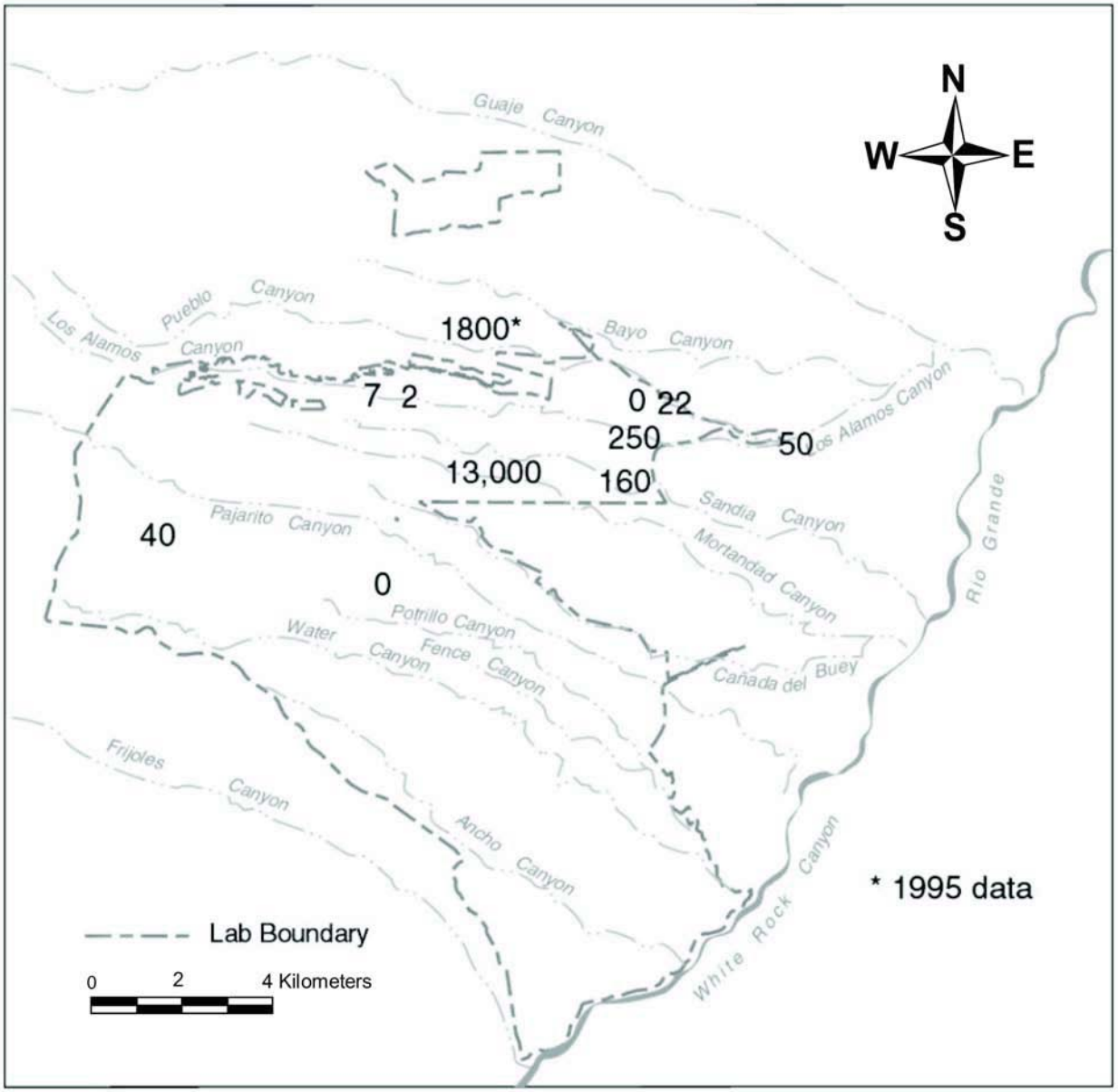


Figure 3-28. Low-detection-limit tritium data from wells and springs sampling intermediate perched groundwater. Data are mainly from 2002 to 2004 and do not include borehole data. The highest values occur where effluent discharges have occurred.

- R-25 near the 260 outfall and other discharges in TA-16,
- below the former TA-45 discharge in Pueblo Canyon,
- downstream from the Omega West reactor site and TA-21 discharges in Los Alamos Canyon, and
- below the sanitary effluent discharge site in Sandia Canyon, and the RLWTF in Mortandad Canyon.

Tritium time-series data also support a conceptual model that groundwater in the intermediate perched zones may have short residence times. Following cessation on effluent discharge from TA-45 into Acid Canyon in 1964, tritium in the intermediate perched zone sampled by TW-2A fell rapidly during the 1980s (Figure 3-13). Analysis of water samples from TW-2A show that this perched zone continues to contain elevated activities of tritium (2,228 pCi/L). This suggests that tritium associated with the former TA-45 treatment plant has infiltrated the canyon floor and migrated vertically, at least to the depth of the intermediate perched zone at TW-2A. Elsewhere in intermediate perched groundwater tritium has been detected mainly at trace levels (Figure 3-13). Although these incomplete data sets begin 15 years after discharges ceased, they support the conceptual model of short groundwater residence time.

In LADP-3 in Los Alamos Canyon, tritium activities fell rapidly over the decade after the Omega West reactor cooling line leak was stopped. Tritium was initially found in LADP-3 at 5500 pCi/L (Broxton et al. 1995) but activity has declined greatly since then, related to cessation of the Omega West reactor cooling line leak in 1993. Tritium in the two intermediate perched zones at R-9i was about 233 pCi/L at 180 ft and 110 pCi/L at 275 ft.

3.2.3.3 Flow Field Modification and Transport in Regional Aquifer Groundwater

Relatively little contamination reaches the regional aquifer from the alluvial groundwater bodies, and water quality impacts on the regional aquifer, though present, are low. The last hydrogeologic control, flow field modification, is considered important in controlling anthropogenic constituent distribution in the regional aquifer. Anthropogenic constituents that enter the regional aquifer near pumping wells are predicted to have much travel times than those outside the influence of pumping (Section 4).

The distribution of tritium in the regional aquifer supports the conceptual model that surface effluent discharges are the source of Laboratory contaminants at depth (Figure 3-29). The map shows low-level tritium values from 2002-2004 and includes springs and wells.

In most cases, the highest regional aquifer tritium values are found near where effluent discharges have occurred, but are much lower than values observed in overlying alluvial or intermediate perched groundwater. The lower regional aquifer values may be due to dilution of recharge by other groundwater sources as well as radioactive decay due to recharge times of decades. The locations of the highest values in Figure 3-29 are near the recharge sources described in Appendix 3-A, with two additional locations that have high tritium values. One is at R-22 near MDA G, which may be due to past tritium disposal at that site. The second is at

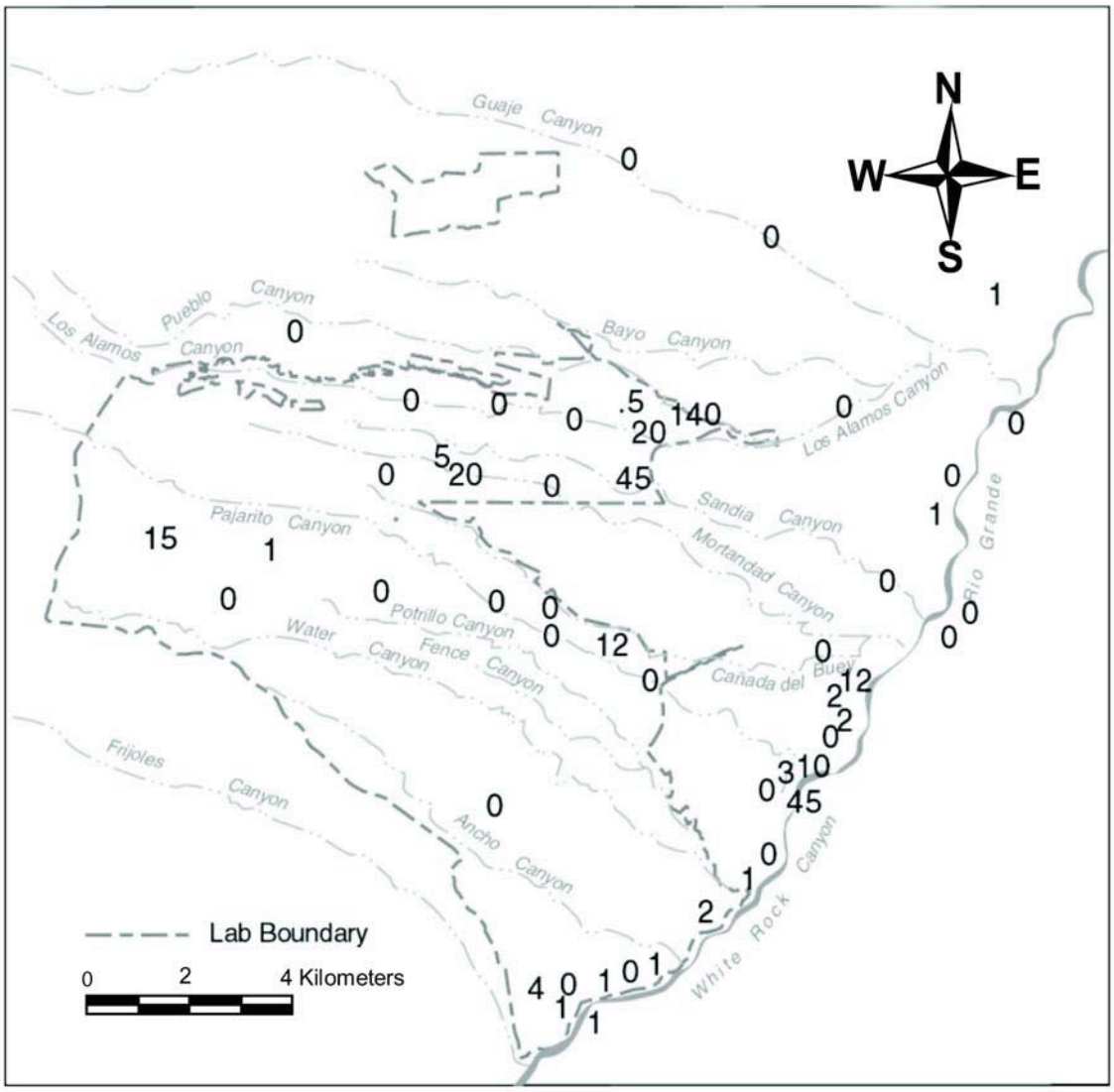


Figure 3-29. Low-detection-limit tritium data from wells and springs sampling the regional aquifer. Data are from 2002 to 2004 and do not include borehole data. The highest values occur where effluent discharges have occurred.

Spring 4B. The values, in the range of 45 pCi/L, are similar to data from rainfall and the Rio Grande and may be due to a component of surface water in the spring sample (LANL 2004b).

3.2.4 Off-Site Transport

Anthropogenic constituents that reach the regional aquifer will be transported along flow paths that will extend either to pumping wells or to the Rio Grande, the discharge area for the regional aquifer in the Española Basin (Section 2). The travel times along the natural flow paths are quite long (tens of thousands of years), but can be shorter for flow paths leading to pumping wells (Section 4).

As discussed in Section 3.2.1, the most mobile contaminants would be the first to appear in any of the regional aquifer discharge points. Appendix 3-A contains descriptions of canyons and the constituents that have been detected in the regional aquifer. Highly mobile groundwater contaminants including chloride, nitrate, perchlorate, and tritium have migrated into the regional aquifer near LANL. Monitoring data suggest that these constituents may also be discharging in some White Rock Canyon springs. Nitrate, chloride, and sulfate have increased gradually during the past 20 years in Spring 3 and Spring 3A (Figure 3-30). Tritium values in the springs are either in the range of regional aquifer values (less than 3 pCi/L) or up to 45 pCi/L, which could indicate either Laboratory impact or a component of precipitation (tritium in precipitation is 30–450 pCi/L). Perchlorate measured at low levels in some springs appears to be naturally occurring because it is within the range of regional background levels.

Four alternative pathways have been articulated to explain the presence of anthropogenic constituents in White Rock Canyon springs. One potential source is effluent discharged from the county's sewage treatment plants. McQuillan et al. (2004) noted that Los Alamos County water supply well Otowi-1 produces water with above-background nitrate, and detectable perchlorate and tritium, as do some of the springs. The calcium-bicarbonate groundwater at Spring 2B is chemically similar to that in regional aquifer well TW-1 in lower Pueblo Canyon. Although the Spring 2B major ion chemistry is consistent with the upgradient geochemical data from TW-1 in lower Pueblo Canyon, TW-1 is located approximately 4 miles away from Spring 2B. The White Rock Sewage Treatment Plant is very close to the springs. Both TW-1 and Spring 2B are located near (separate) municipal sewage discharges and the common sewage signature could yield similar water chemistries at both sites. Nitrate and chloride are common contaminants associated with sewage effluent.

McQuillan et al. (2004) suggest rapid transport in the regional aquifer from Pueblo Canyon to White Rock Canyon. Contaminants released in Acid Canyon, after having reached the regional aquifer, traveled rapidly through the regional aquifer in an easterly, then southerly path line starting at about Otowi-1 and TW-1, discharging in several springs along White Rock Canyon. However, these flow paths are inconsistent with the gradients in the regional aquifer, based on the latest potentiometric data. This pathway also requires rapid transport through the regional aquifer, contrary to evidence (carbon-14 data) that suggests slow transport through the regional aquifer (Sections 2.7.7 and 4). Water from lower Pueblo Canyon would need to travel many miles through the regional aquifer to Spring 2B with minimal mixing or dispersion in order to account for the observed concentrations.

One further geochemical argument, which suggests that water in Spring 2B does not originate near O-1 and TW-1 in Pueblo Canyon, is the high uranium concentration in Spring 2B water. Uranium concentrations in Spring 2B are sharply anomalous compared to adjacent springs. There have been no high uranium concentrations measured in regional groundwater beneath LANL or Pueblo Canyon (Gallaher et al. 2004) that are comparable to those in Spring 2B. However, high natural uranium concentrations are known to exist throughout the Pojoaque Valley, in the well field in lower LA Canyon, and in the nearby Buckman wellfield. The natural levels have been shown to vary in response to pumping in the old LA wellfield, and delayed impacts may appear in Springs 1 and 2.

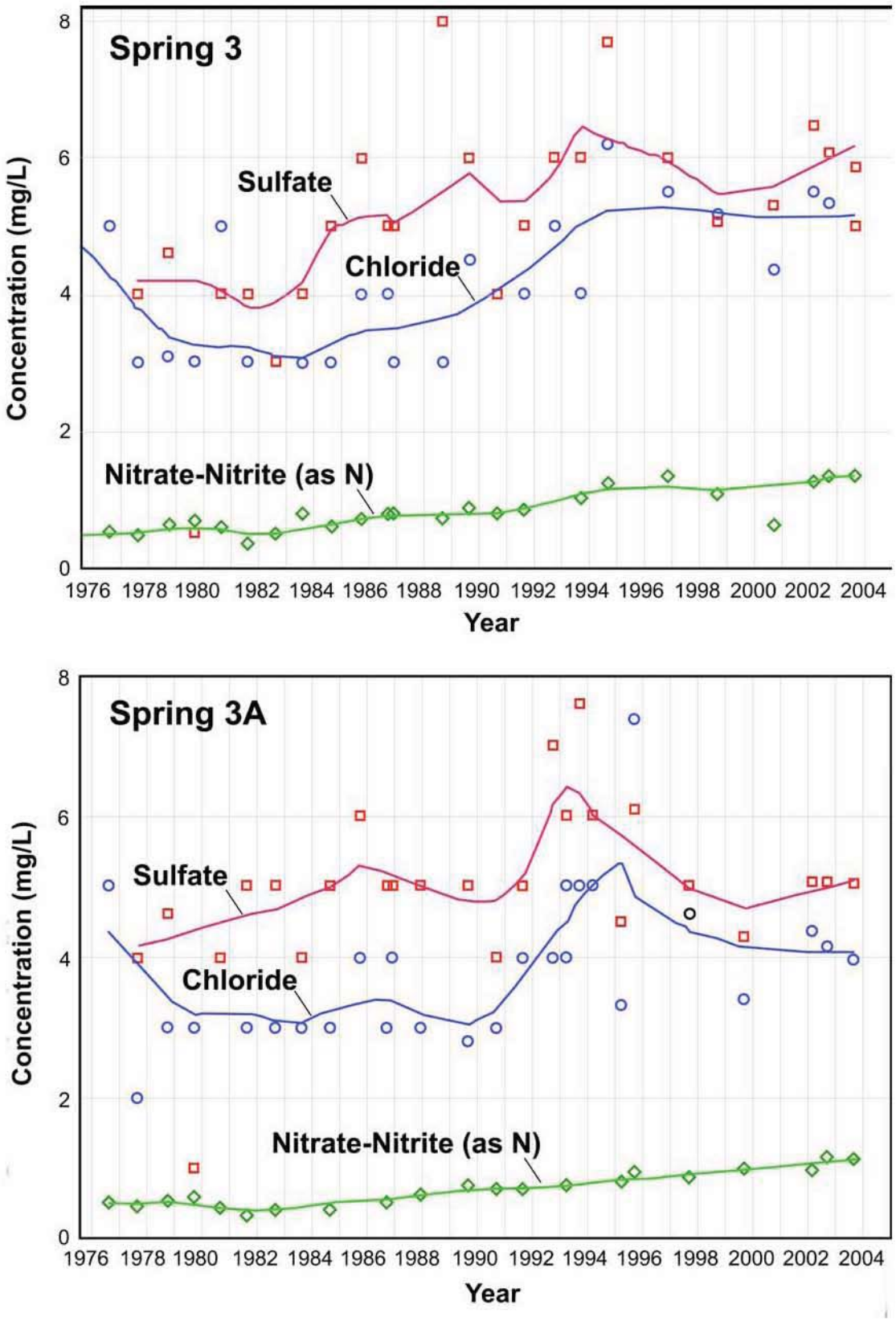


Figure 3-30. Anion concentrations in Springs 3 and 3A. Solid lines are best fit smooths to the data using loess methods (Cleveland 1979).

A second hypothesized pathway is a local source for contaminants present in the springs. Spring 2B chemistry is consistent with effluent from the White Rock Sewage Treatment Plant (located on the White Rock Canyon rim above Spring 2B). The decades-long increases in nitrate and chloride concentrations in Springs 3 and 3A suggest a sustained source such as an effluent discharge. Surface flows from the plant pass near these springs.

The third potential pathway is near-surface transport of contaminants to the White Rock Canyon springs. LANL contaminants are hypothesized as being transported in surface water and/or shallow groundwater along Pajarito Canyon from TA-9 to White Rock, followed by infiltration near the springs and a relatively short transit through the vadose zone to the regional aquifer. Such fast, shallow paths are more plausible and consistent with available information than fast transport through the regional aquifer. The major ion chemistry in the springs near Pajarito Canyon is generally consistent with that of groundwater along this flow path. Some fast regional aquifer transport would still need to occur for the contaminants to reach the springs.

The fourth possible pathway is transport via alluvial groundwater and fractural basalt. This pathway involves Laboratory contaminants reaching the springs via shallow and deep pathways in which transport is dominated by movement through fractural basalts. Fast transport through the basalts is more plausible than fast transport in the regional aquifer within the Puye Formation or the Santa Fe Group. The basalt-dominated pathway would likely be fast through the vadose zone as well. Drilling to date has not located any major contamination zones in basalt, but such zones could be isolated and difficult to encounter.

If any of the hypothesized alternative fast pathways invoked to explain the possible presence of LANL-derived constituents in springs exist, groundwater beneath LANL may travel more rapidly to downstream wells or springs than previously recognized, but the overall water quality changes would be anticipated to be relatively minor. Faster travel in the regional aquifer likely would result in less natural attenuation (for example, adsorption, radioactive decay, mixing) of any LANL-derived contamination. The monitoring history to date, however, has revealed minor impacts on the regional aquifer beneath the Laboratory. Continued LANL-wide groundwater monitoring is the most effective mechanism for identifying potential off-site transport of contaminants. See Appendix 3-D for discussion of other alternative conceptual transport models.

3.2.5 Summary of Contaminant Distribution and Transport

The impacts to groundwater at the Laboratory have occurred mainly where effluent discharges have increased local infiltration rates and volumes. The depth to which chemical constituents move in the subsurface is determined partly by their chemical behavior: non-reactive constituents move readily with groundwater, while reactive or adsorbing constituents move a shorter distance.

In most cases where effluent sources have been eliminated, groundwater concentrations of non-reactive discharged contaminants have decreased far below past levels (e.g., RDX, nitrate, tritium, and perchlorate) in alluvial groundwater. These mobile contaminants readily move through the subsurface and are detected within perched intermediate zones and at the regional water table beneath several canyons, including Pueblo Canyon, Los Alamos Canyon, Sandia

Canyon, Mortandad Canyon, and Cañon de Valle. In the case of reactive or adsorbing chemicals, the concentrations may remain elevated above background levels for long periods of time after elimination of discharges or other contaminant source terms (e.g., excavation and removal of contaminated sediments). These include constituents such as strontium-90 and the actinides (americium-241, plutonium-238, and plutonium-239, -240).

4.0 NUMERICAL MODELS

The conceptual models of the hydrogeologic system beneath the Pajarito Plateau, as well as the supporting data and information, were described in Sections 2 and 3. Numerical modeling is an analytical tool that can be used to integrate and synthesize the sometimes widely spaced point hydrogeologic field data and that allows prediction of how the hydrologic system will behave at different times and under different conditions in the future. However, before models can be used for prediction, they must be shown to adequately reproduce current conditions. A caveat is that different model representations (assumptions, boundary conditions, structural features, dimensionality) can in many cases provide equally good fits to available data. This fact, sometimes called equifinality in the hydrologic literature, implies that different model representations may result in significantly different model predictions. In this section we have selected representative model structures that are most consistent with the available information, while acknowledging that conceptual uncertainties also exist. This section describes the site-scale vadose zone and regional aquifer models that have been developed, including the underlying assumptions, hydrologic processes, calibration, and predictions for flow and transport.

4.1 Site-Wide Vadose Zone Flow and Transport Model

Hydrologic modeling of the vadose zone has been conducted to understand the key factors influencing the transport of contaminants from the ground surface to the regional aquifer, and to quantify uncertainties. The main goal of the site-wide vadose zone flow and transport model is to identify regions at the Laboratory where deep migration of contaminants is most likely. These analyses have been useful for guiding and prioritizing site characterization activities and can be used to support risk and performance assessments.

The following summary describes the underlying assumptions and hydrologic processes, and presents numerical modeling predictions of the travel times from the ground surface to the top of the regional aquifer across the Pajarito Plateau. Simulation of travel time of traced water is a necessary first step in predicting the velocities and concentrations of contaminants through the vadose zone. For a modeling analysis that includes predictions of tritium concentrations, see the presentation of a numerical model for Los Alamos Canyon in Section 4.1.3.2.

4.1.1 Model Development

Transport of water and dissolved chemicals through the vadose zone beneath the Pajarito Plateau has been the subject of numerous laboratory and field investigations and numerical model development efforts. The characterization and modeling of vadose zone systems requires knowledge of the water supply, percolation rates and the hydrologic properties of rocks and soils under unsaturated conditions. Such an understanding, at a basic level, has been acquired for the Bandelier Tuff underlying much of the Pajarito Plateau. In the past, that knowledge has been used to develop geometrically complex numerical models to investigate in detail the influence of dipping stratigraphy, rugged topography, and manmade alterations to the natural system (see Section 4.1.3 for examples).

Due to the complexity and computational demands of vadose zone models, they typically cover only a small portion of the Laboratory property, and thereby provide only a local picture of the vadose zone system. This section describes a site-wide model for performing first-order analysis of travel time through the vadose zone across the entire Pajarito Plateau. By foregoing some of the complexities in favor of a simpler representation of the flow physics, this model can be extended to include all locations of interest on the LANL property.

The following subsections present the modeling inputs, assumptions, and methodology in more detail.

4.1.1.1 Flow and Transport Processes

Despite the potential complexities associated with vadose zone systems, many basic processes are amenable to characterization and numerical simulation. In the Bandelier Tuff, when the percolation rate is lower than the saturated hydraulic conductivity K_{sat} of the matrix rock, the fluid saturation in the partially water-filled pores modulates itself in order to transmit the fluid under unit-gradient conditions associated with gravity-driven flow. Section 2.6.3 included data suggesting that under most conditions, water percolates through the Bandelier Tuff matrix, and the role of fractures is minor, except for the uppermost units of the Tshirege Member, present only in the westernmost portion of the Laboratory. In these locations, units with very low hydraulic conductivity induce lateral flow, probably through fractures. This phenomenon leads to shallow zones of saturation in which water travels laterally and issues at springs in Cañon de Valle and Water Canyon, from which it flows vertically downward through the rest of the Bandelier Tuff in matrix flow. In contrast, flow through the basaltic and dacitic rocks is assumed to be controlled by fractures. The practical consequence of these conceptual models for travel times will be established in the numerical modeling results. Finally, flow through the Puye Formation is probably also matrix-dominated, although the hydrogeology is complicated and the possibility of channelized, heterogeneous flow must be considered.

In spite of the inherently three-dimensional nature of flow in the vadose zone, an appropriate approximation for estimating travel time is to assume one-dimensional downward percolation of water and migration of contaminants. Intermediate perched groundwater observed in several wells across the Plateau indicates the possibility of lateral diversion (see Section 2.7), but the influence of such groundwater on vadose zone travel time can be assessed in a bounding manner, as is illustrated in Section 4.1.2.3.

4.1.1.2 Infiltration Rate

As the upper fluid flow boundary condition, infiltration is one of the most important inputs for a vadose-zone model. Infiltration is known to depend, often in a complex way, on the local surface hydrologic conditions, topography, microclimatic conditions, evapotranspirative (ET) conditions (including vegetation type), and the presence or absence of impermeable layers such as thin clay layers within and at the base of the alluvium. The water that escapes ET and surface runoff is assumed to percolate through the remainder of the vadose zone to the regional aquifer, carrying with it any aqueous chemicals such as contaminants or dissolved minerals. The percolation rate below the zone of evapotranspiration is the direct input to the vadose zone numerical models. Although this rate undoubtedly changes with time due to storm transients, seasonal variations, and climatic variability, it is assumed that such effects are buffered by the hydrologic processes

that redistribute water in the surface water, alluvial groundwater, and unsaturated rocks of the vadose zone, so that an equivalent constant percolation rate can be assigned. The infiltration rate is also spatially variable at scales ranging from the width of fractured zones to the length of individual canyons.

The methodology for estimating infiltration rates across the Pajarito Plateau is to classify canyons or portions of canyons with a numerical designator, called the Net Infiltration Index (NII). Then, for applying infiltration in the numerical model, each NII would have associated with it an infiltration rate. For the mesas, a uniform infiltration rate of 1 mm/yr was assumed. Appendix 4-A presents the development of the NII values across the Pajarito Plateau; the results are depicted in Figure 4-A-1. Table 4-1 lists, for each NII, the descriptive characteristics of each infiltration class, and the infiltration rates associated with each of the model runs.

4.1.1.3 Numerical Model Implementation

To predict travel time, the FEHM computer code (Zyvoloski et al. 1997) was used to simulate the two-phase, air-water flow problem. For the vertical stratigraphy predicted by the site geologic model, a one-dimensional grid was constructed with 10 evenly spaced numerical grid points within each layer. Hydrologic properties of each unit were assigned based on laboratory measurements and results of previous vadose-zone modeling efforts, and the percolation rate was assigned based on the infiltration map (Figure 2-34). The calculation consists of two steps: first, a steady-state one-dimensional fluid flow calculation is executed to establish the fluid water contents and water velocities through the stratigraphic column from the surface to the water table. Then, this steady-state flow model is used to compute a travel time using particle tracking. After performing the calculation at numerous locations across the Plateau, a site-wide description of vadose zone travel times is assembled in the form of travel-time maps.

To conduct these calculations, several steps of the process were automated within a GIS-based data assembly and querying system. At a given location, the one-dimensional vertical stratigraphy from the site-scale geologic model was used to generate a numerical grid for flow and transport calculations. The point distribution for the one-dimensional models consisted of a high density of points close to drainages across the Pajarito Plateau, and a coarser resolution on the mesas. Regions corresponding to the drainages, where relatively large infiltration is applied, were converted to a high-resolution grid (cell size of 128 ft) with each point located in the center of the cell. On the mesas, a coarser point distribution of 512 ft was taken. This resulted in a total of 30,577 points across the plateau at which one-dimensional transport times were calculated.

Table 4-1.
Determination of Net Infiltration Index and Net Infiltration Rates Used in the Model

Net Infiltration Index (NII)	Headwaters or Source	Surface Water	Alluvial Water	Net Infiltration Estimate (mm/yr)	
				Base Case	High Infiltration Scenario
1	Plateau	Ephemeral or Intermittent	Not Saturated	1	10
2	Mountain or Small Anthropogenic Source	Ephemeral or Intermittent	Not Saturated	10	30
2	Plateau	Ephemeral or Intermittent	Sometimes Saturated	10	30
2	Plateau	Perennial	Not Saturated	10	30
3	Plateau or Small Anthropogenic Source	Ephemeral or Intermittent	Saturated	100	300
3	Mountain	Ephemeral or Intermittent	Sometimes Saturated	100	300
4	Plateau	Perennial	Saturated	300	1000
4	Mountain or Anthropogenic Source	Ephemeral or Intermittent	Saturated	300	1000
5	Mountain or Large Anthropogenic Source	Perennial	Saturated	1000	3000

4.1.2 Model Results

Numerical modeling results are presented for a "base-case" model for canyons and mesas, after which uncertainty in infiltration rate and the impact of perched water conceptual uncertainty are studied.

4.1.2.1 Base-Case Results

A full-scale map of predicted travel times of a water molecule in the vadose zone (from ground surface to the water table of the regional aquifer) is shown in Figure 4-1. Along each canyon with NII other than 1, travel times are predicted to be less than 1000 years. Although the results in canyons are the main focus of this study, results for the mesas are described first. On mesas, the predicted travel times are variable, but for the most part are greater than 1000 years, ranging from 1000-5000 years on the eastern portions of the Laboratory to 20,000 to 30,000 years in the western region.

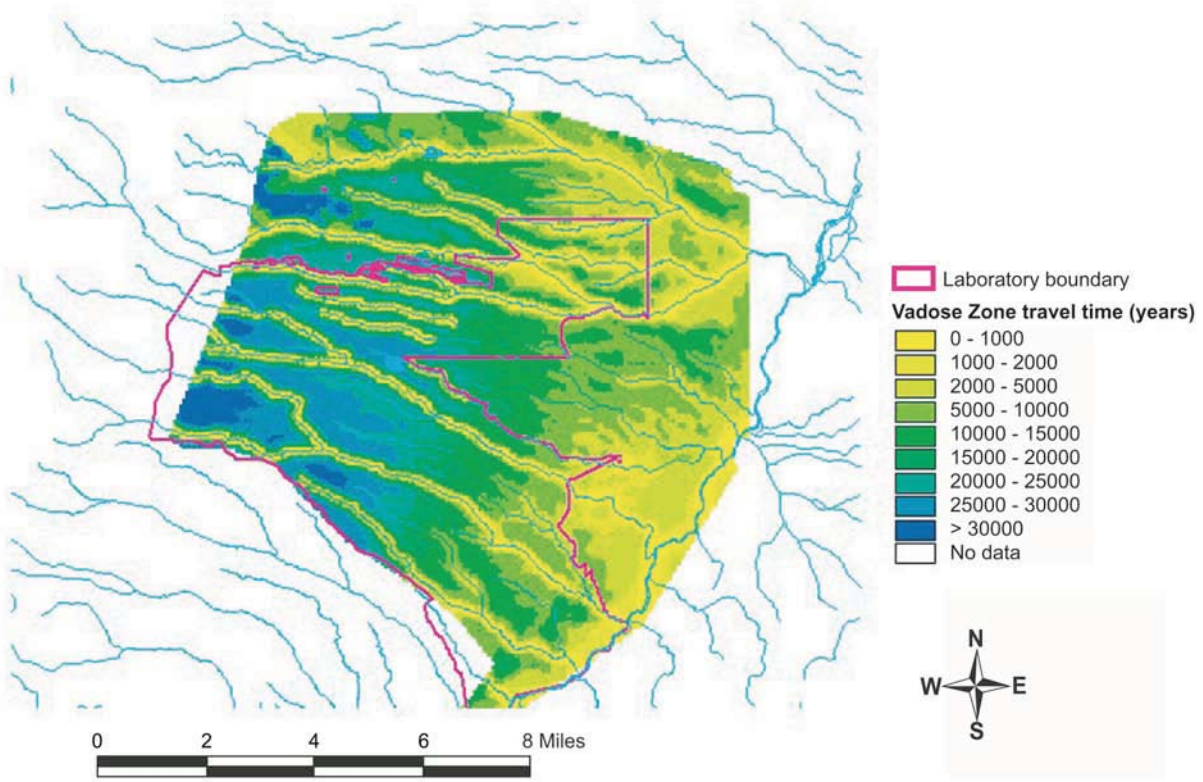


Figure 4-1. Predicted vadose zone travel times (years) to the water table: Base case, full scale of travel times.

To a first approximation, travel times from mesa tops are controlled by the thickness of the Bandelier Tuff. Because the Bandelier Tuff exhibits matrix percolation, the travel times on the mesas are controlled by slow percolation at a flux of 1 mm/yr through these units. Other units between the ground surface and the water table are the Cerros del Rio basalts, the Puye Formation, and the Tshicoma dacites. The basalts and dacites are modeled with an extremely low porosity (0.01) to capture the conceptual model feature of flow through these units controlled by fast pathways such as fractures or other heterogeneities. Therefore, most of the travel time to the water table is within the Bandelier Tuff, and the travel time map is therefore dominated by the tuff thickness.

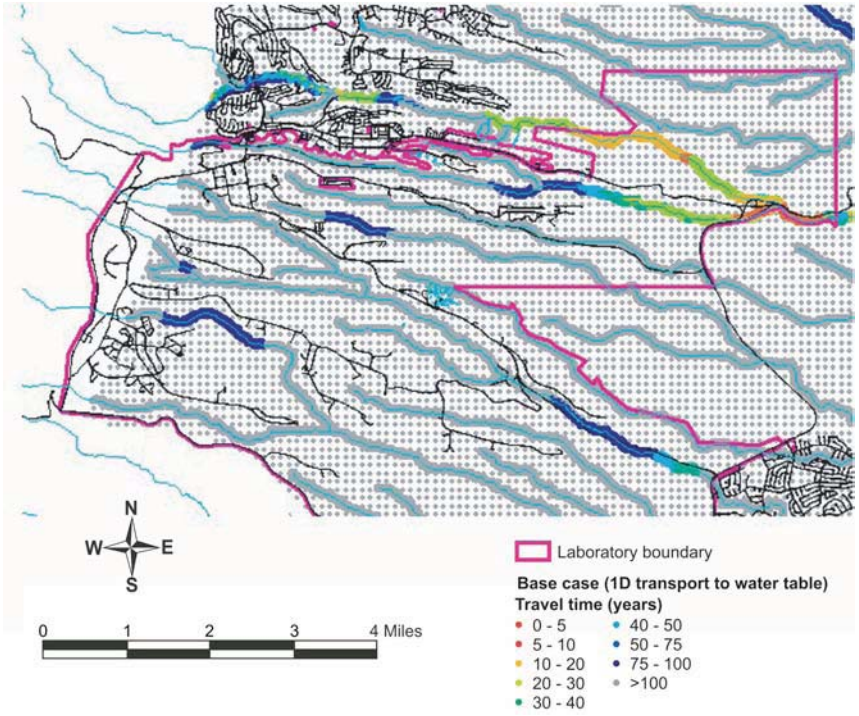
Identification of rapid travel times to the water table from canyon bottoms is important to determine if they are in locations likely to have experienced Laboratory-derived groundwater contamination. Figure 4-2a shows the base-case model result presented in Figure 4-1, except that the travel-time scale ranges from 0 to 100 years (all points with values greater than 100 years are shown in gray). The model predicts that regions of relatively rapid travel times are present in the following canyons: Pajarito Canyon near White Rock, a portion of Cañon de Valle, Mortandad Canyon at the Radioactive Liquid Waste Treatment facility, middle and lower Los Alamos Canyon, large portions of Pueblo Canyon, and Guaje Canyon.

Two factors control these results: infiltration rate and hydrostratigraphy. Generally, travel times less than 100 years are predicted in the portions of canyons with NII values of 4 or 5 (300 mm/yr and 1000 mm/yr, respectively), especially in locations where the Bandelier Tuff is thin. Clearly, canyons with high infiltration rates are locations in which travel times through the vadose zone are likely to be relatively short. In addition, Los Alamos and Pueblo Canyons have regions in the vicinity of their confluence in which the Bandelier Tuff is thin or non-existent. Water infiltrates directly onto basaltic rocks or the Puye Formation, thereby yielding rapidly downward flow through fractures or preferential flow channels. The predicted travel times are especially short (5 to 10 years) in these locations.

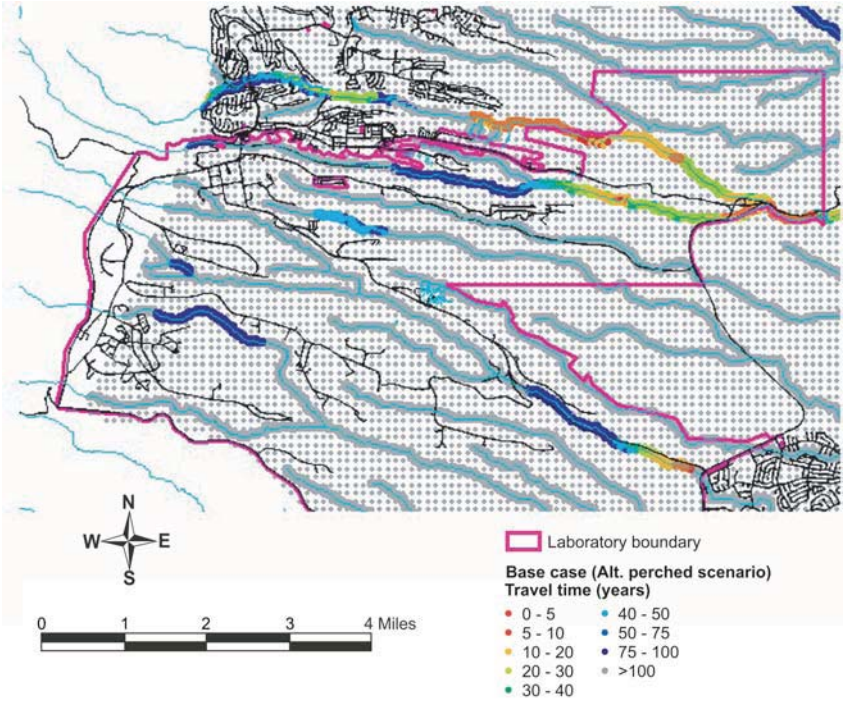
4.1.2.2 Uncertain Infiltration Rate

The infiltration rates associated with the NII are uncertain, and therefore must be varied to investigate the uncertainty in the model predictions. Figure 4-3a shows the same vadose zone travel time map as in Figure 4-2a, but for the high infiltration rate scenario (NII = 4-5). As expected, travel times are shorter at the same location in any particular canyon at the higher infiltration rate. As a result, greater stretches of canyons are predicted to exhibit travel times to the regional aquifer water table of less than 100 years. Specifically, in the high flux scenario, most of Pajarito Canyon, much longer stretches of Mortandad and Los Alamos Canyons, Cañon de Valle/Water Canyons from the west to the central portion of the Laboratory, and all of Pueblo Canyon in the vicinity of the Laboratory are predicted to have travel times that are less than 100 years.

This analysis highlights a key uncertainty in the model: the lack of precision in predicting the percolation rate from canyon bottoms. Because contaminants have been introduced into the groundwater in canyons, it is likely that the percolation rate will be one of the key uncertainties that detailed site characterization may address, possibly in conjunction with sensitivity analyses.



(a)



(b)

Figure 4-2. Predicted vadose zone travel times (years) to the water table, showing only travel times of 100 years or less. Base case percolation scenario: (a) 1-D transport to the water table; (b) alternate perched water model.

4.1.2.3 Perched Water Conceptual Uncertainty

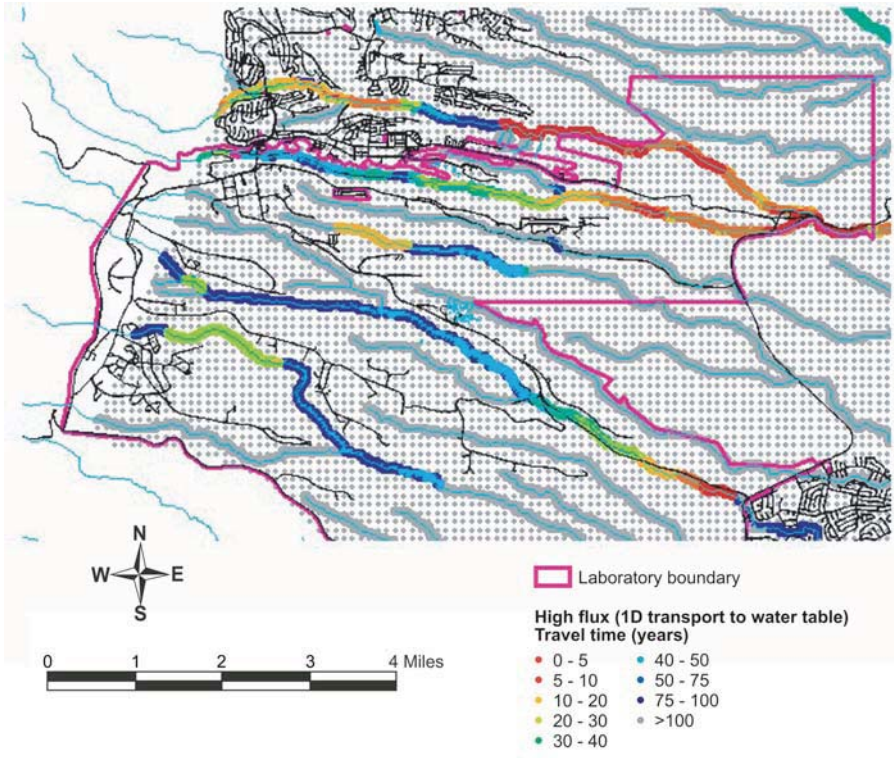
The one-dimensional, vertical transport model assumption is an approximation that may not be valid, given the presence of intermediate groundwater at various locations around the Laboratory. As presented in Section 2.7, zones of saturation have been located directly beneath canyons, where infiltration rates are highest. There is little or no evidence that connected groundwater pathways exist over large areal distances beneath mesas. Given the limitations of the data, the approach taken in the present study is to bracket the range of travel times to the water table that would be predicted assuming "end-member" conceptual models for perched water discussed in Section 2.7:

- Low velocity, virtually stagnant fluid
- High velocity, laterally migrating fluid

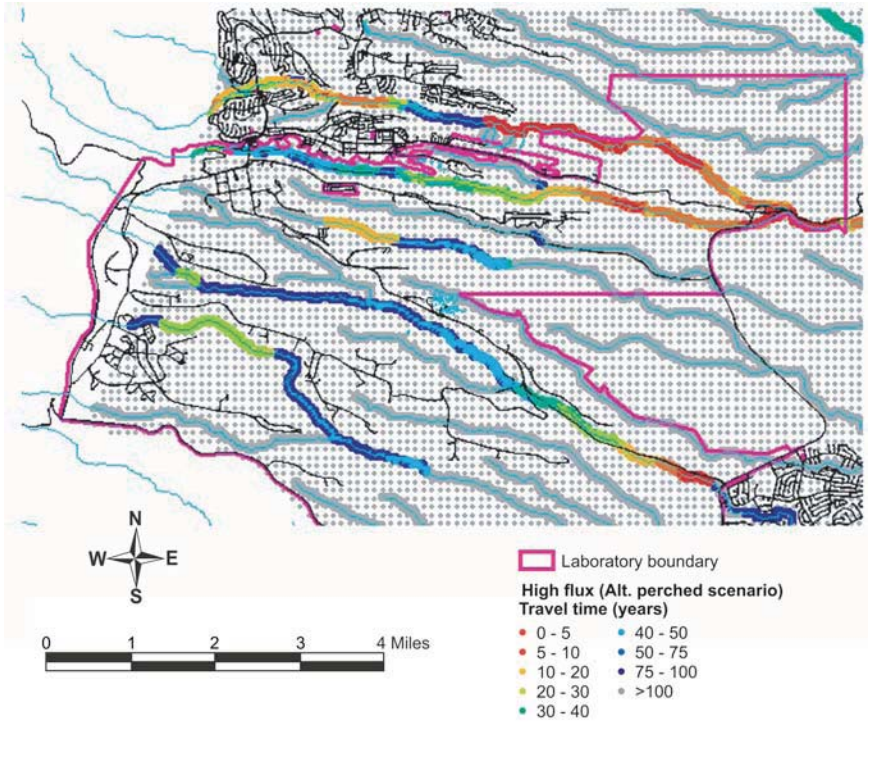
For the case of stagnant fluid, the one-dimensional pathway approach presented above is an appropriate model. For this case, the calculations already presented are representative. However, the lateral diversion model explicitly violates the one-dimensional assumption, and therefore a bounding approximation is required. In these analyses, it is assumed that the travel time from the surface to the elevation of perching is the same as was modeled previously, but the travel time from the perched water zone to the water table is minimal. This approach yields the shortest overall possible travel time, and therefore is useful for assessing the impact of this conceptual uncertainty. Note that this analysis assumes that lateral displacement of water and contaminants in perched zones is relatively small compared to lateral displacement in alluvial groundwater systems that are the source of deep percolation.

To perform these calculations, regions were identified within the canyons where intermediate groundwater has been observed, and it was assumed that the vadose zone pathway terminates at that location. This allows travel times to be bounded without explicitly modeling transport from the perching horizon to the regional aquifer. Figures 4-2b and 4-3b show the results of the travel time simulations for the alternate perched water conceptual model for each percolation scenario. Comparing these figures to their counterparts for the one-dimensional downward flow cases (Figures 4-2a and 4-3a), the differences in travel time are quite subtle. The regions with vadose zone travel times of less than 100 years remain approximately the same, and the travel times at the same location are only mildly impacted by the perched water conceptual model. For example, for the base-case infiltration scenario, travel times are shorter by about 15-20 years for the alternate perched water model, and for the high flux scenario, these differences are even smaller.

To understand this result, note that transport from the ground surface to the water table in the one-dimensional model is dominated by percolation through the matrix of the Bandelier Tuff. Therefore, terminating the transport pathway at the base of the tuff, as in the alternate perched water scenario, eliminates a relatively small portion of the total travel time to the regional aquifer. Of course, despite this insensitivity of travel time, the arrival location at the water table is potentially quite different for the two cases: this factor should be considered in specific cases of contaminant transport predictions.



(a)



(b)

Figure 4-3. Predicted vadose zone travel times (years) to the water table, showing only travel times of 100 years or less. High percolation flux scenario: (a)1-D to the water table; (b) alternate perched water model.

4.1.3 Contaminant Transport Model Predictions—Representative Canyon and Mesa Sites

This section presents an overview of modeling studies focusing on two representative LANL sites. The first example models contaminant transport from a relatively dry mesa top, while the other addresses a canyon bottom.

4.1.3.1 MDA G Model

This section highlights the model developed for the Material Disposal Area G (MDA G) performance assessment. A detailed description of the model is provided in Appendix 4-B. A performance assessment (PA) is required to site and authorize permanent disposal facilities for radioactive waste. The purpose of the PA is to demonstrate that performance metrics related to protection of human health and the environment are not likely to be exceeded for a specified period of time. Performance objectives and periods of compliance vary according to the characteristics of the radioactive waste being disposed, but groundwater protection for U.S. sites is always explicitly required for at least 1000 years. This study was designed to predict the groundwater pathway dose in support of the PA of MDA G, an active, low-level, solid radioactive waste site located at LANL, as shown in Figure 4-4 (Fig. 1 of Birdsell et al. 2000).

The three-dimensional unsaturated-zone flow and transport model captures the complex hydrogeology and topography of the site and yields radionuclide flux estimates to the regional aquifer. Within the unsaturated-zone model, the source release of radionuclides is computed for 38 waste disposal pits and four shaft fields, as shown in Figure 4-5 (Figure 3 of Birdsell et al. 2000), each contributing to the total inventory. The continued migration of radionuclides through the aquifer is calculated by using a three-dimensional model designed to maintain the temporally and spatially varying distribution of radionuclide flux from the unsaturated zone.

Due to uncertainty of model parameters, the results of these transport simulations contain intrinsic uncertainty. The greatest uncertainties associated with predicting aquifer-related doses from the site, according to Birdsell et al. (2000), are related to understanding of the mechanisms that control flow and transport within the unsaturated zone and the ability to model these mechanisms. To accommodate both parameter and conceptual model uncertainties, large parameter ranges are used to ensure that the range of calculations captures the behavior of the actual system. However, predicted doses using parameters from the most conservative ends of the uncertain ranges are still well below those that would cause concern.

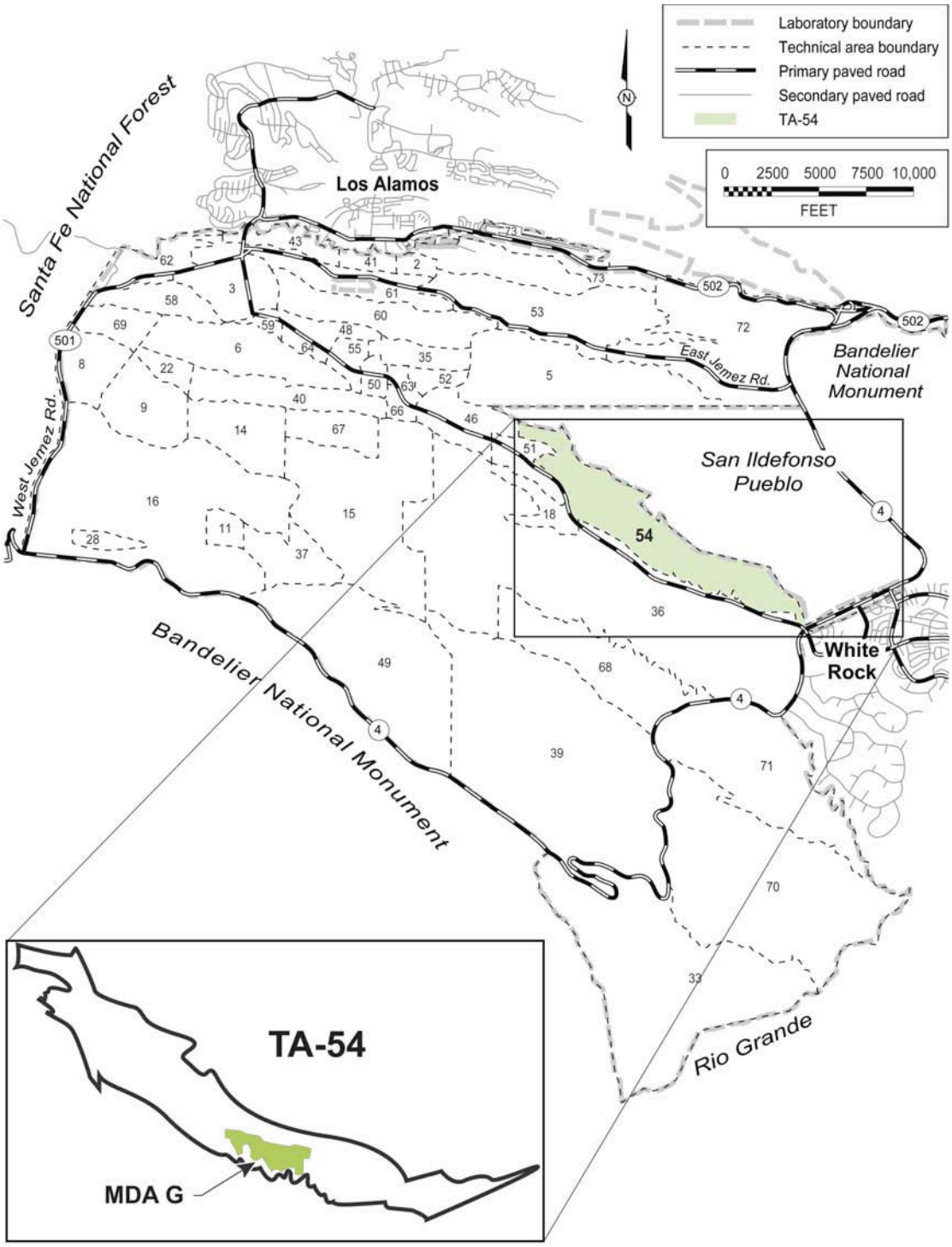


Figure 4-4. Study area for the performance assessment of MDA G, an active low-level, solid radioactive waste site located at LANL (from Birdsell et al. 2000).

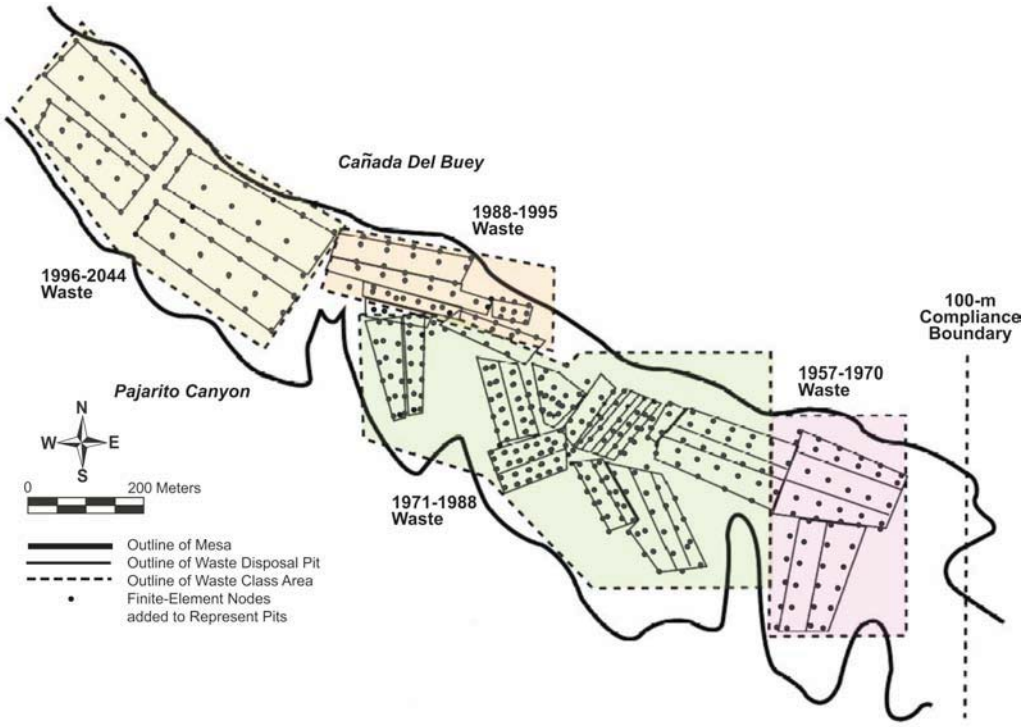


Figure 4-5. Approximate locations of the four waste classes and the 100-m compliance boundary used for the MDA G performance assessment. Also shown are the pit boundaries, internal pit nodes, and the outline of the mesa edge for the three-dimensional unsaturated-zone grid (Figure 3 of Birdsell et al. 2000).

The results recorded by Birdsell et al. (2000) indicate that the mesa-top infiltration rate has the greatest impact on the simulated migration of waste through the unsaturated zone. For the current conceptual and numerical models, it controls both the source release rate and subsequent downward solute migration. This uncertainty was bounded by considering a base-case flow field and high- and low-flow cases. A variation in mesa-top infiltration rate from 1 to 10 mm/yr (Appendix 4-B and Table 4-2) results in a range of six orders of magnitude in the 1000-year groundwater-related doses. Clearly, a good understanding of this key parameter is important to the dose assessment. However, because doses are so much less than the performance objectives, conservative yet realistic infiltration rates seem adequate for the MDA G site.

Table 4-2.
Infiltration Rates (mm/year) Used as Upper Boundary Conditions for MDA G Performance Assessment Simulations (fom Birdsell et al. 2000)

	Mesa Top	Cañada del Buey	Pajarito Canyon
1_1_20 (lowest flow case)	1	1	20
5_1_20	5	1	20
5_1_50 (base case)	5	1	50
10_1_20	5	1	20
10_5_100 (highest flow case)	10	5	100

Another source of uncertainty is related to flow in the deeper unsaturated-zone units for which few hydrologic data are available. The simulations take virtually no credit for transport times through the Cerros del Rio basalts, which make up more than 50% of the unsaturated zone. The transport results are based on the steady-flow assumption and on the use of matrix hydrologic properties for all tuff units at the site. Understanding of the response of this fractured system to transient flow events remains uncertain. Transient calculations (Birdsell et al. 1999) indicate that the steady-flow assumption is adequate because fluctuations in both saturation and contaminant flux rates dampen with depth, even when including fractures in the upper two units. Fracture infiltration studies (Soll and Birdsell 1998) lead to the conclusion that fracture flow is difficult to initiate and is short-lived in the upper two tuff units at the observed low field saturations. In addition, only Unit 2 and the uppermost portion of Unit 1v-u of the Tshirege Member, Bandelier Tuff, show evidence of significant fracturing (Krier et al. 1997), and these are excavated during disposal operations to depths where the tuff is poorly fractured. Therefore, the waste should not migrate through any highly fractured units until reaching the basalts. These observations help justify the use of the matrix hydrologic properties for the calculations.

In summary, travel times to the regional aquifer from locations on mesas are expected to be large (e.g., > 1000 yr) due to low infiltration rates and matrix-dominated flow. Calculations in this performance assessment model were deliberately conservative and therefore predicted travel times that were an order of magnitude shorter than the base case model presented in Section 4.1.2.1. Exceptions to this general conclusion are in the western portion of the Laboratory (see Section 4.1.1.1) and in locations where the natural mesa-top conditions have been disturbed by Laboratory activities.

4.1.3.2 Los Alamos Canyon Model

This section highlights the model developed for Los Alamos Canyon RCRA Facility Assessment investigations. A detailed description of the model is provided in Appendix 4-C. Los Alamos Canyon, as shown in Figure 4-6, is one of the most complex sites at the Laboratory. A number of technical areas have been or are currently located in or adjacent to the canyon, resulting in multiple release locations along the canyon. This study examined, through a synthesis of available data and the development of numerical models, fluid flow and contaminant transport in the vadose zone beneath Los Alamos Canyon. Modeling of the subsurface hydrology and transport in the vadose zone is also a challenging activity, given the wide range of infiltration rates, the presence of perched water, and the introduction of a host of contaminants of different chemical properties. Because the canyon serves as a collector of a wide range of contaminants, it was necessary to develop a model at the scale of the canyon, rather than at a smaller scale. The specific goals of the model are to

- Synthesize the available data and conceptual understanding of the vadose zone hydrology beneath Los Alamos Canyon;
- Produce a "base-case" numerical model of the subsurface vadose zone hydrology that ultimately can be used to predict contaminant migration rates and concentrations in fluids reaching the regional aquifer beneath the canyon;

- Quantify the uncertainties associated with those predictions by establishing the bounds on system behavior through a suite of possible models, all of which are consistent with the available data, but which bracket the range of possible behavior;
- Provide a simulation tool for predicting the fate and transport of contaminants in Los Alamos Canyon under different assumed hydrologic and ER stewardship scenarios; and
- Demonstrate a model development methodology that can be used in studies of other canyons on the Pajarito Plateau.

This work focuses on the hydrology beneath Los Alamos Canyon, as a first step toward developing a predictive tool that can be used to simulate contaminant migration in the canyon. Since water is the carrier fluid for the contaminants of interest, constructing a realistic flow model that captures the most important hydrologic processes of the vadose zone is an essential first step in the development of a reliable model. Although the study primarily restricts attention to flow issues, tritium transport in the vadose zone is also modeled. Tritium, in the form of tritiated water, is an excellent tracer for groundwater, and hence is included in this modeling study as a constraint on the flow model.

Figures 4-7 and 4-8 show a full three-dimensional view of fluid saturation and a series of two-dimensional vertical slices through the three-dimensional model. As expected, the figure shows wet conditions in the canyon, dry conditions in surrounding mesas. As with the two-dimensional model, this model result shows the overriding importance of the stratigraphy in controlling the water contents in the rock. The local infiltration rate also exerts a strong control on the results. Directly beneath the canyon, fluid saturation is much higher within a given stratigraphic unit than in other parts of the model domain, a reflection of the high infiltration in the canyon.

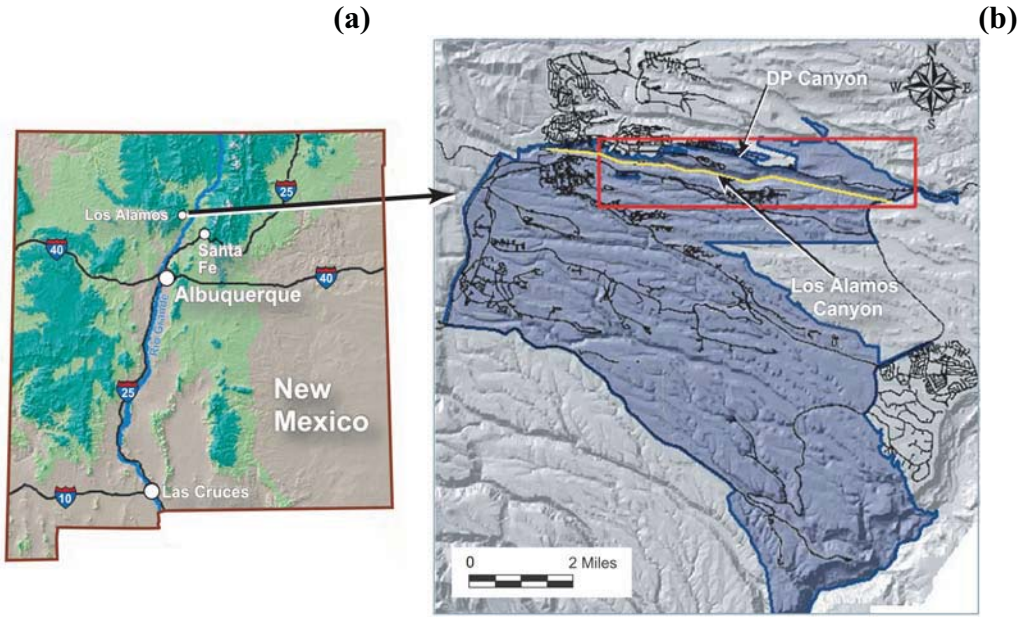


Figure 4-6. Location of Los Alamos, New Mexico (a), Los Alamos Canyon study area, and the flow and transport model domain (b). The shaded blue area is the LANL property; the red box indicates the areal extent of the three-dimensional model domain; and the yellow line is the trace of the two-dimensional model domain.

Volumetric water content is the primary measurement used to evaluate the model results because adequate data on water content are available from virtually all vadose zone characterization wells. The fits to the data are presented for three different levels of infiltration rates, i.e., the base-case infiltration map, a map with infiltration scaled down by a factor of three from the base map, and a map with infiltration scaled up by a factor of three (Figures 4-C-7 and 4-C-8). It is evident from the following comparisons that the model is able to capture the general features of data:

- The base infiltration map does an adequate job of jointly matching the water content profiles in these wells, despite the different stratigraphy and position relative to the canyon bottom.
- Good fit for LADP-4 illustrates the adequacy of the model in capturing the fluid saturations in the Tshirege Member (not present in the two-dimensional model), as well as in a region where infiltration rates are taken to be significantly lower than in Los Alamos Canyon at LADP-3.
- The need to apply significantly lower infiltration near LADP-4 is best understood by comparing the water content model and data for these two wells. The significantly wetter conditions in LADP-3 are simulated in the three-dimensional model through the setting of high infiltration in the canyon.

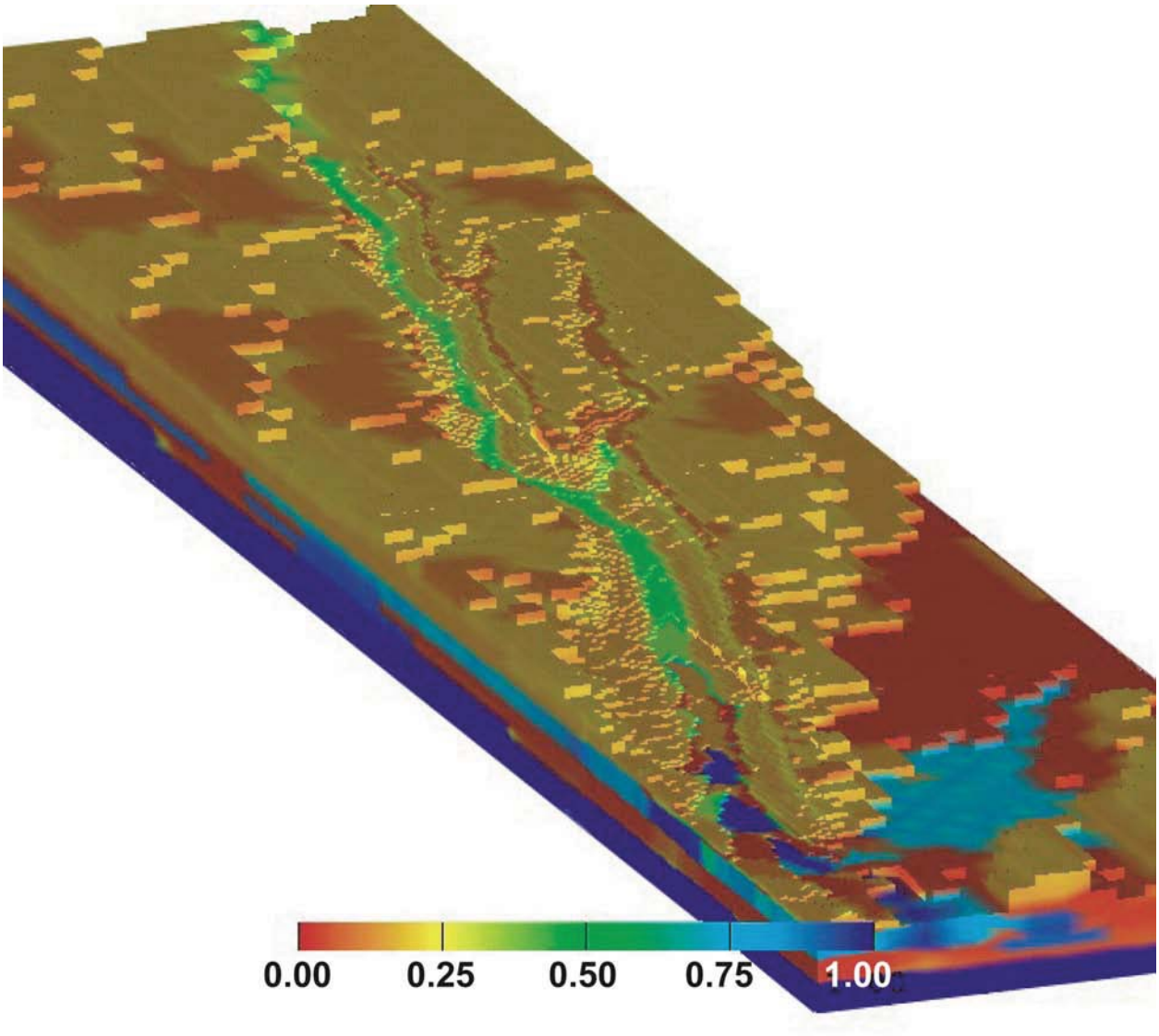


Figure 4-7. Three-dimensional flow model results, showing fluid saturation predictions (%) through the model domain (full model view).

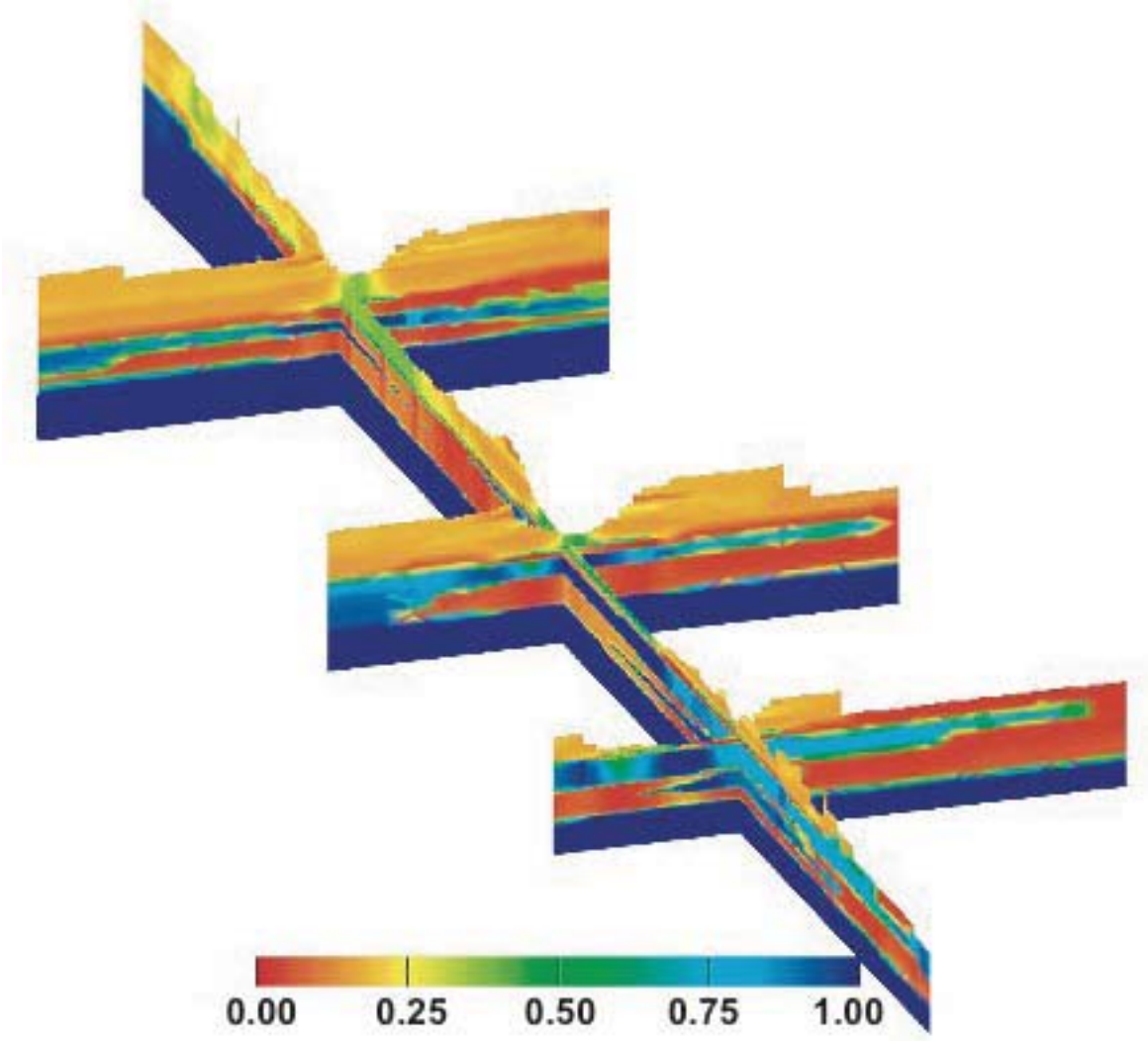


Figure 4-8. Fence diagram showing fluid saturation predictions (%) along one north-south and three east-west cross-sections.

Tritium transport model results are presented to further demonstrate the validity of the model and to explore important processes occurring in the vadose zone. Figure 4-9 is the three-dimensional model prediction of the tritium concentration of fluid reaching the water table in the year 1999. The model results are consistent with the available field data, indicating that regional aquifer fluid collected in well R-7 has undetectable levels of tritium, whereas TW-3 and R-9 show that tritium has reached the regional aquifer. Determining the ability of the model to reproduce the field data more quantitatively is difficult because of mixing of the tritium percolating from the vadose zone with regional aquifer fluid and the subsequent mixing of contaminated and clean fluid in the wellbore itself. The latter difficulty is especially acute for the water supply wells, which may draw water from hundreds of feet of screened length.

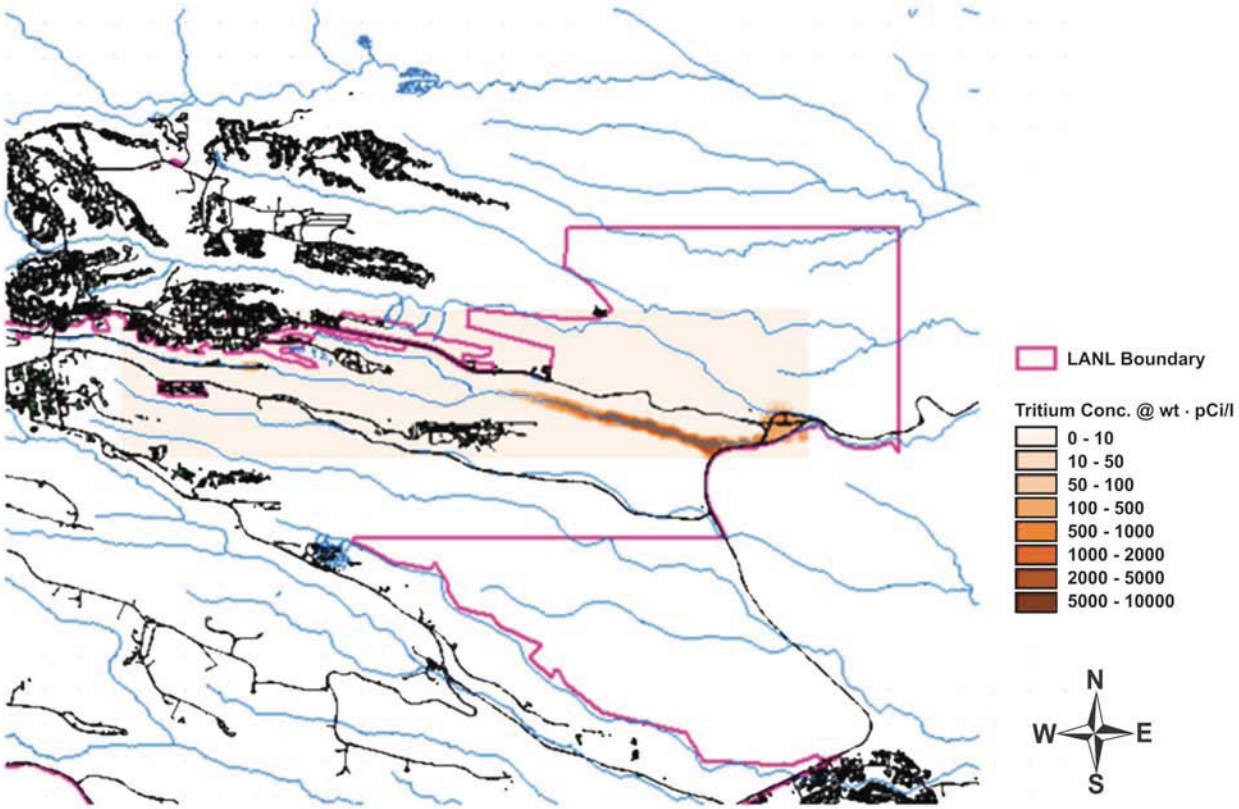


Figure 4-9. Three-dimensional model predictions of the tritium concentration of fluid reaching the water table in the year 1999. Significant, above background concentrations are predicted along the canyon at locations downstream of where the Bandelier Tuff is not present in the canyon bottom.

As a final comparison to the available data, we contrast the model results with regional aquifer water supply well O-1. However, because contaminant transport sources from Pueblo Canyon (north of Los Alamos Canyon) were not included in this model, the conclusions related to O-1 are more qualitative. For this comparison, monitoring information published in LANL (2001) is used. Contaminants tritium, perchlorate, and nitrate are all thought to be nonsorbing in this system, and thus the combined results of all three contaminants are used in this interpretation. Well O-1 has been found to contain measurable levels of perchlorate at about a 5 ppb level, nitrate levels higher than at other regional aquifer wells in the area, and consistent, above-background levels of tritium in the 30-40 pCi/L range. All observations point to both Laboratory-derived contaminants and effluent discharges from Los Alamos County. Past releases in Los Alamos and Pueblo Canyons have traversed the entire vadose zone. The present model explains these observations as a consequence of the hydrostratigraphy along the canyon, with rapid travel times at locations where the Bandelier Tuff is thin or non-existent.

Contrast these results with the transport model for MDA G presented in Section 4.1.3.1. Most important, travel times through the vadose zone are predicted to be orders of magnitude larger

for this mesa site than for transport from the bottom of a wet canyon. These travel-time results are consistent with the site-wide vadose zone results presented in Section 4.1.2. Infiltration rates, which directly impact transport velocities, are much larger in a canyon setting, in which all water in a catchment is channeled to the canyon bottom. A significant percentage of that water will escape evapotranspiration and percolate into the deep subsurface along the canyon. In contrast, a mesa top typically provides opportunity for water to run off as surface water or to be lost as evapotranspiration. Moreover, mesa sites have thick sequences of tuff with exceptionally low matrix flow rates. Therefore, percolation rates are much lower.

4.2 Numerical Models of Flow and Transport in the Regional Aquifer

The first numerical model for the regional aquifer was developed in 1998 in support of the LANL Groundwater Protection Program (LANL 1998). A number of related models have been developed since then, in support of both the Groundwater Protection Program and the Environmental Restoration Program, at a variety of spatial and temporal scales according to the requirements of the particular model application. In general, there have been three goals for these modeling studies:

- Integrate and interpret 3-D site-wide hydrologic and hydrostratigraphic data, to provide a quantitative basis for developing and testing site-wide conceptual models.
- Predict fate and transport of contaminants in the regional aquifer, in order to optimally place monitoring wells and inform risk assessment studies.
- Provide guidance in prioritization of data collection activities, highlighting the importance of those data that could most reduce numerical and conceptual model uncertainty.

As the Hydrogeologic Workplan has progressed, the data sets supporting the modeling studies have been steadily expanding. Updating the model with larger data sets has identified weaknesses in the modeling approaches and prompted changes in the methodology. This iterative process of data collection and model update and evaluation has significantly increased our understanding of the regional aquifer.

4.2.1 Previous Numerical Models

Two models have previously been developed by the USGS for the regional aquifer of the Española Basin, the aquifer system which provides drinking water to Los Alamos, Santa Fe, and Rio Arriba counties, as well as numerous pueblos. In contrast to the LANL modeling effort, these models were developed primarily to address water supply issues—particularly impacts of pumping on streamflow. The first was developed by Hearne (1985), using a computer code he wrote himself. The second was developed by McAda and Wasiolek (1988) (and later refined by Frenzel (1995), using the MODFLOW code (McDonald and Harbaugh 1988). At present, various local and state agencies continue to refine and apply both of these models to water supply issues in this basin.

In many ways, these two models are based on a similar conceptual model of the basin aquifer. Key elements of this conceptual model are as follows: (1) most inflow to the basin occurs as recharge in the mountains flanking the basin and along stream channels within the basin, and

(2) most discharge occurs to the Rio Grande and the lower reaches of its tributaries. A smaller portion of the total inflow and outflow occurs through lateral boundaries (i.e. up to 20% discharges to the Albuquerque Basin), due to structural and topographic features that limit inter-basin flow. The conceptual models of aquifer properties assume that hydraulic conductivity is strongly anisotropic, due to laterally discontinuous bedding features in the Santa Fe Group. The aquifer behaves as confined or leaky-confined, although no large-scale confining beds or low-permeability zones have been identified.

The lateral boundaries of the two models, shown in Figure 4-10, roughly coincide with the extent of basin-fill rocks in the southern portion of the basin (south of Española). Both models use specified flux boundaries to represent losing stream channels. Recharge is applied as specified flux, either at lateral boundaries (representing mountain block recharge) or along the upper model surface (representing recharge along stream channels or areal recharge). Discharge is to the Rio Grande and lower elevations of its major tributaries (specified head and head-dependent boundaries) and to the Albuquerque Basin (specified head in the case of the McAda model).

The conceptual model shared by these models is one of a complex transition from unconfined to leaky-confined conditions at depth, caused by relatively fine-scale bedding features in the rocks that provide resistance to vertical flow. Exact numerical implementation of this complexity is virtually impossible. The Hearne and Frenzel models treat the upper surface of the aquifer as a water table condition. Aquifer properties change from unconfined (top layer) to confined (lower layers); no discrete confining layer is present. Resistance to vertical flow is represented by anisotropy factors ($Kx/Kz \sim 100 – 1000$).

One significant difference between the models is the representation of large-scale heterogeneity. The Hearne model (which only includes the Santa Fe Group aquifer) treats the aquifer as homogeneous and anisotropic, with the numerical grid aligned in parallel with the dip of the beds in the Santa Fe Group. This approach allows the model to reproduce vertical upward head gradients measured in several wells in the eastern basin. The McAda and Frenzel models apply a somewhat ad hoc zonation of aquifer properties, based loosely on pump test results and the need to achieve an adequate model calibration to the data.

Appendix 4-D, Section 3, presents a comparison of inflows and outflows (steady-state, predevelopment) between the two models, as well as more recent estimates of inter-basin flow derived from USGS studies in the Albuquerque Basin.

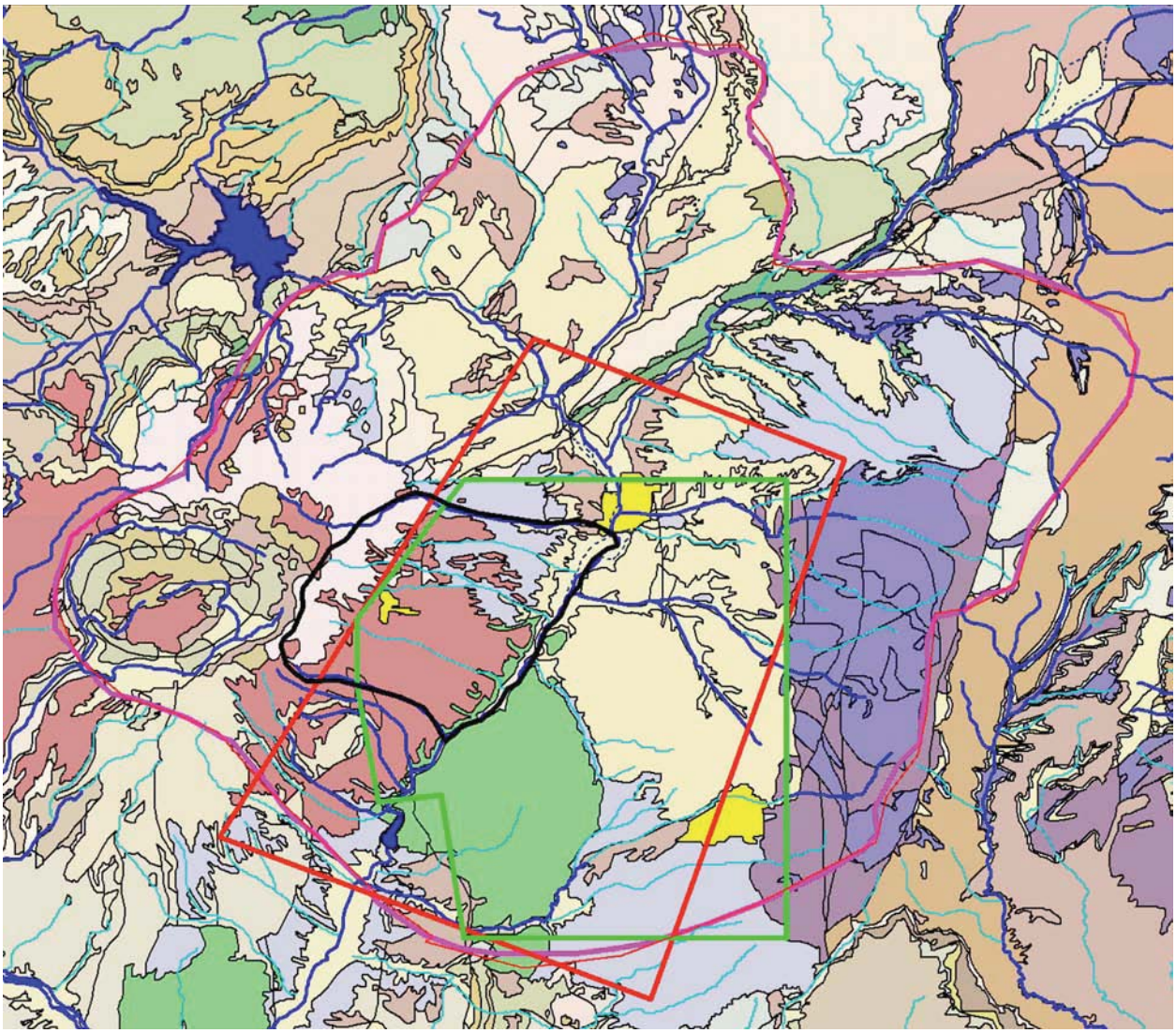


Figure 4-10. Geologic map of the Española Basin. Model outlines: green – McAda-Wasiolek model; red – Hearne model; pink – LANL basin-scale; black – LANL site-scale.

4.2.2 Overview of LANL Model Development

Unfortunately, both the USGS models of this aquifer system place a model boundary along the western edge of LANL; therefore, use of these models for the LANL site would be compromised by boundary effects (Anderson and Woessner 1992). To ensure that all model boundaries were far from the area of interest (LANL) and to incorporate the possible influences of regional flow on local conditions, a new flow model for the basin was developed. This model not only extends the western boundary farther than the existing models, to minimize boundary effects on site-scale simulations, but it also includes the major recharge areas for the basin. The inclusion of the recharge areas for the basin allows for a more comprehensive approach to estimating fluxes of water through the aquifer, as will be discussed below. The basin-scale model has been used to estimate aquifer properties, to estimate fluxes through the aquifer, to examine the possible influences of pumping in the Buckman wellfield on groundwater beneath the plateau

(and vice versa), to understand regional trends in groundwater quality, and to provide boundary conditions to small, site-scale models.

This initial basin-scale model has undergone several revisions, including increasing grid resolution in the vicinity of LANL and improving the hydrostratigraphic framework model that governs the spatial distribution of aquifer properties. In 2000, a site-scale model for the Pajarito Plateau (see Figure 4-10) was developed with much higher grid resolution than could be achieved with the basin-scale model, and was coupled to the basin-scale model (Keating et al. 2003). The site-scale model has been used to provide contaminant transport calculations, to conduct capture zone analyses, to support monitoring well siting decisions, and to estimate groundwater velocities.

Both the basin and site-scale models have been developed to address site-scale (several to tens of kilometers) issues and this has driven model development. For example, the methods of estimating aquifer properties (Section 2.8) emphasize large-scale effective properties of rocks. These properties may be different than what might be measured at very small scales, such as injection/recovery tests over small intervals in characterization wells or borehole geophysics-based estimates. These models (and model parameters) would not be appropriate for simulating the details of fine-scale (sub-kilometer) flow and transport.

Smaller-scale models have been developed. For example, a 2-D radial model was developed to evaluate the utility of using an R-well as an observation well during a pump test at O-1. In addition, a suite of 2-D and 3-D "box" models were developed to test conceptual models of flow and transport through the highly heterogeneous strata of the Puye Formation.

A principle of model development is to begin simply and gradually add complexity as needed. Even though the models, in their current form, are quite complex, they are much simpler than the aquifer itself. A major focus of the approach has been to implement numerical strategies that are flexible, so that the impacts of conceptual model uncertainty and parameter uncertainty on model predictions can be quickly assessed within a single modeling framework, without building entirely new models.

It should be emphasized that these models are for the regional aquifer only, and therefore do not include alluvial or perched groundwaters. The current versions of the models do not explicitly include springs, so pathways and travel times to springs have not been simulated.

4.2.3 Numerical Framework

All of the LANL models have employed the FEHM code (finite element heat and mass transfer) (Zyvoloski et al. 1997), publicly available software. Underlying this code is a sophisticated grid generating software, LaGrit (Trease et al. 1996) which can capture the details of complex hydrostratigraphy known to exist at this site. For conditions of saturated flow and transport (i.e. the regional aquifer), FEHM solves the same set of equations as do other more widely used codes, such as MODFLOW. The choice of this software for the LANL models was driven by the need to couple saturated zone simulations with vadose zone simulations (which use FEHM), to represent complex hydrostratigraphy, and to eventually investigate complex geochemistry and thermal effects (ongoing work). FEHM is well suited to these types of problems, since

temperature and density dependent fluid properties can be accurately accounted for. Some of the more simple simulations presented here do not utilize the specialized capabilities of FEHM and LaGrit; these simulations could easily be repeated using a code such as MODFLOW and one would expect the results to be identical (assuming grid resolution and boundary conditions were identical).

Figure 4-10 illustrates the lateral boundaries of the LANL models. In the basin model, boundaries were located such that they were far from the LANL site and coincided with either hydrologic features or structural boundaries. The northern and southern boundaries coincide with major structural transitions between the Española Basin and basins to the south and to the north, where the thickness of the Santa Fe Group aquifer declines from several thousand feet (in the center of the basin) to near zero at the basin margins (Shomaker 1974) (Cordell 1979). The basin is separated from the Albuquerque and Santo Domingo basins to the south by a structural high, a prong of older sedimentary rocks, and several major fault zones. The site-scale model boundaries coincide with a surface water divide (to the west), and surface water courses to the north (Santa Clara Creek), to the east (the Rio Grande), and to the south (Rio Frijoles).

Figure 4-11 illustrates generalized flow directions within the basin and locations of inter-basin flow along model boundaries. Stream gage locations are also indicated; these data are described more in Appendix 4-E.

The LaGrit software (Trease et al. 1996) was used to develop numerical meshes for the basin and site-scale models. A grid refinement algorithm was used that allows extra detail to be placed where needed in the mesh, such as in the vicinity of LANL. The most refined grid, the site-scale model, has a horizontal resolution of 125m × 125m and a vertical resolution of 12.5m in the shallow layers of the aquifer beneath LANL.

4.2.4 Hydrostratigraphy

In contrast to previous models of the basin aquifer, the LANL models define aquifer heterogeneity on the basis of a separate 3-D hydrostratigraphic framework model. This model was developed with surface geologic maps, published cross-sections, geophysical studies, and numerous well logs (see Section 2 and Carey et al. 1999). It is based on structure and lithology, rather than hydrologic data. The degree of detail present in the model is much greater beneath the Pajarito Plateau than for other portions of the basin. This is primarily because there are many more deep characterization wells on the plateau than elsewhere in the basin, but also because of the more complex volcanic and sedimentary stratigraphy of the plateau compared with most other portions of the basin (e.g., Buckman wellfield, entirely within Santa Fe Group sediments).

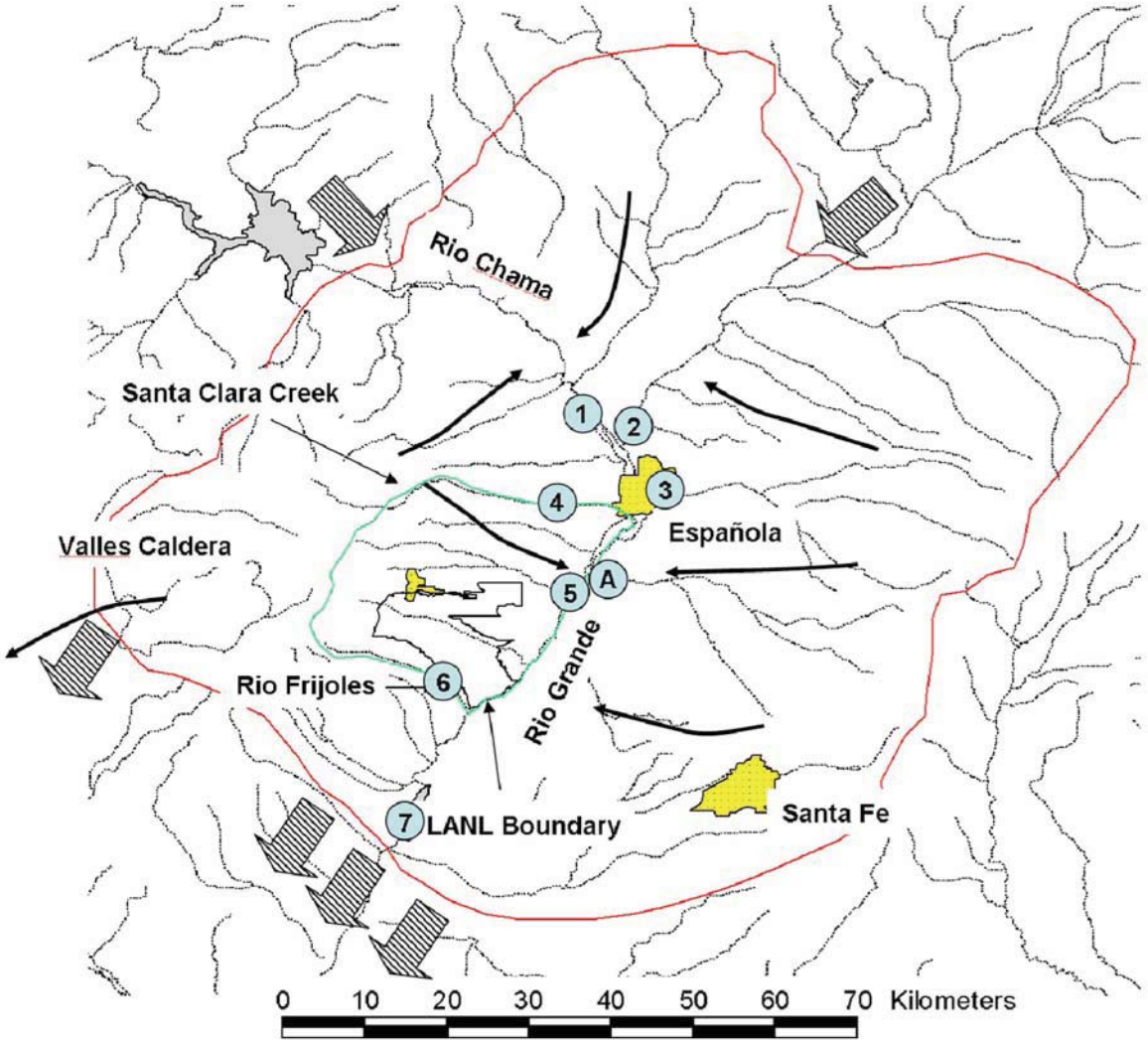


Figure 4-11. The Española Basin, with the basin-scale numerical model outline shown in red, and the site-scale model outline shown in green. Black arrows are generalized groundwater flow directions, based on regional water level data (Keating et al. 2003). Striped arrows indicate groundwater flow between this basin and adjacent basins. Circled numbers refer to USGS stream gages: (1) Rio Chama at Chamita; (2) Rio Grande at San Juan; (3) Santa Cruz River; (4) Santa Clara Creek; (5) Rio Grande at Otowi; (6) Rio Frijoles; (7) Rio Grande at Cochiti. The circled "A" indicates the mouth of Pojoaque Creek (see Appendix 4-E).

The process of overlaying the framework model on the numerical mesh for the flow and transport models has been described in Keating et al. (1999). This process assigns every node in the numerical mesh to one of the defined hydrostratigraphic units (see Appendix 4-D, Section 1). The high vertical resolution in the site-scale model is important to the representation of thin basalt flows and thin gravel beds within sedimentary units known to exist in this aquifer. The current model (September 2004) does not contain the latest update to the 3-D site-wide geologic model, which will include additional mapping from 2003 through 2005, drilling, and characterization data.

4.2.5 Boundary Conditions

The upper boundary of the model domain represents the top of the saturated zone; these nodes are either no-flow (no recharge), specified flux (recharge), or constant head (river nodes which may either recharge or discharge to the aquifer) (see Figure 4-12). Generally, the lower boundary of the model (no-flow) is the contact between the Precambrian basement and younger rocks. An exception to this is locations where the Precambrian basement crops out (such as in the Sangre de Cristos); in these areas we sub-divide the basement into a shallow, permeable block and a lower, impermeable block.

In the current model formulation, the entire thickness of the aquifer is assigned properties consistent with leaky-confined or confined conditions ($Ss = 10^{-3.3} – 10^{-4.5}$ m^{-1}). In the current numerical framework, unconfined conditions can be approximated by assigning the shallow layers a relatively high value of specific storage. However, changes in the thickness of the aquifer due to changes in the water table elevation are ignored. This approximation is reasonable for flow simulations in the vicinity of LANL, due to the large thickness of the aquifer (>3000 m) relative to measured changes in heads with time (30–50 m over 50 years). However, transport simulations may be sensitive to this approximation and the model is currently being modified accordingly.

4.2.6 Recharge

Recharge from the unsaturated zone is represented as a specified flux boundary condition along the top of the model. The spatial distribution of recharge across the plateau and in the larger basin is complex and inherently uncertain, since recharge rates cannot be measured directly. The model uses a simple approach to represent the spatial distribution of recharge. The advantage of this approach is that it can be easily manipulated to approximate a wide variety of recharge conditions; this flexibility allows for exploration of uncertainty in model predictions due to the inherent uncertainty of any recharge estimate. The disadvantage of this approach is that it does not capture very fine-scale detail. At present, the models have assumed that recharge is constant in time.

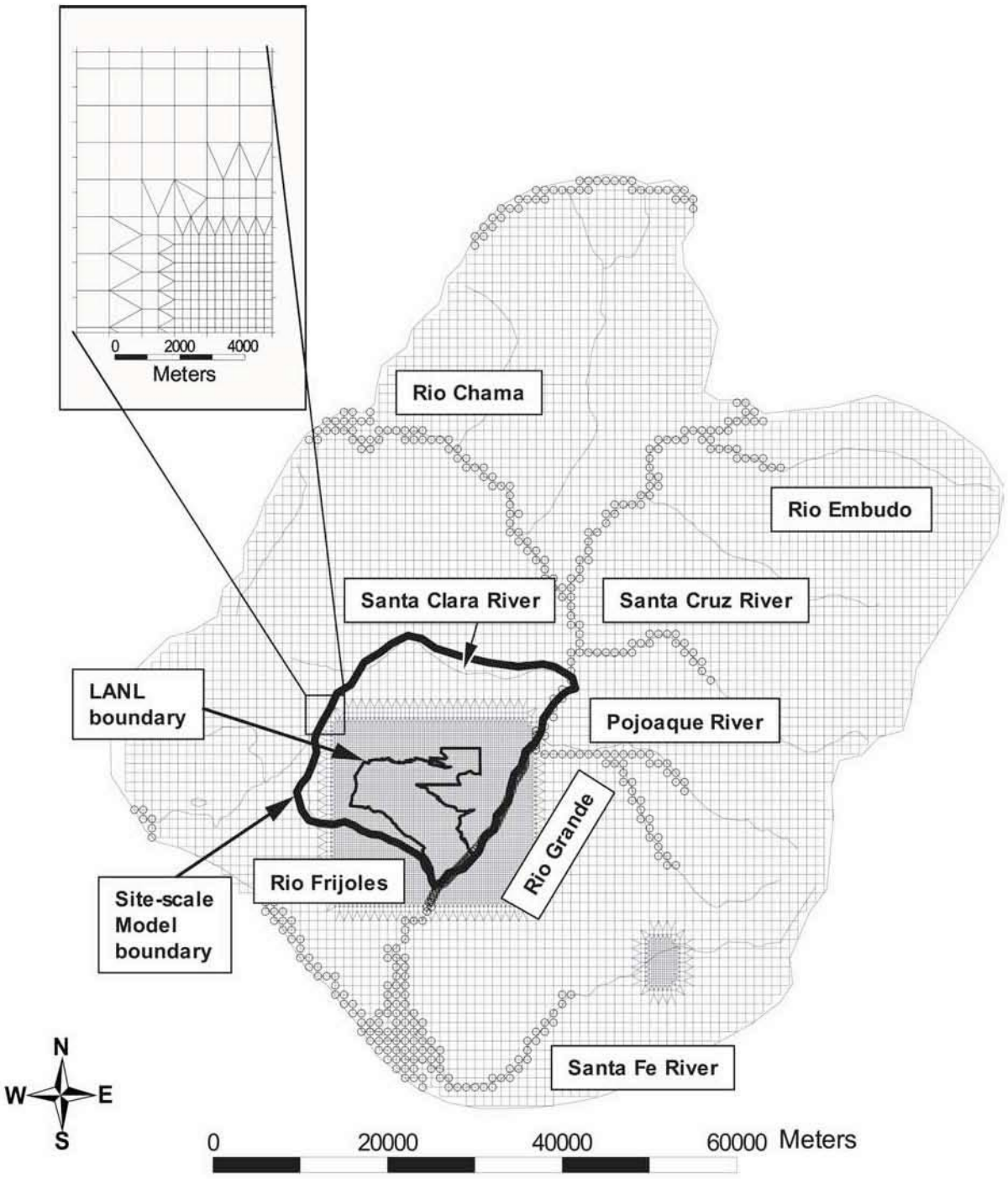


Figure 4-12. Basin model grid (plan view) with site-model boundaries indicated. The inset shows the northwest corner of the octree mesh refinement region. The circles show the locations of specified head nodes along rivers and basin margins.

There are three types of recharge accounted for in our model: areal recharge (which occurs mostly in the mountains), perennial stream channel recharge (for major streams in the basin), and ephemeral stream channel recharge (for many of the channels on the plateau). Areal recharge is determined as a function of precipitation (which is, in turn, determined by the surface elevation and long-term average precipitation trends in the basin). The details of the recharge model are presented in Appendix 4-D, Section 2. This numerical framework can be used to generate multiple possible models of recharge. Several examples are shown for the site-scale model in Figure 4-13; these different models all impart the same total flux to the aquifer. Table 4-3 shows the parameters used for these examples. For a more extensive discussion of regional and plateau recharge distributions, see Section 2.7.3.1.

4.2.7 Discharge at Rivers and Interbasin Flow

The Rio Grande, its lower tributaries, and locations where inter-basin flow occurs (upper Rio Chama, upper Rio Grande, lower Rio Grande, and Jemez River) are modeled as specified head nodes. Model-predicted fluxes at these boundaries are described in later sections. Heads at the surface are determined using digital elevation model (DEM) data for the basin. Heads at depth along the Española Basin/Albuquerque Basin are specified in accordance with estimates of the water table elevation at this boundary and are constant with depth to the Precambrian boundary. The assumption of "specified head" along the Rio Grande is an approximation suitable for flow and transport calculations far from the river. This simplification is inadequate for addressing the details of stream/aquifer interactions at the Rio Grande and is currently being addressed.

4.2.8 Lateral Boundaries of the Site-Scale Model

The locations of the lateral boundaries of the site-scale model were selected with the expectation that fluxes across the boundaries (which are uncertain) will be small relative to the total flux through this portion of the aquifer. The basin model is used to estimate these fluxes, with estimates of corresponding uncertainty (Keating et al. 2003). Fluxes across these lateral boundaries are explicitly mapped, node by node, onto site-scale model boundaries. That analysis showed that uncertainty in fluxes into the site-scale model (from the north) and out of the site-scale model (to the south) due to basin model parameter uncertainty was relatively small. In contrast, flux uncertainty across the western and eastern boundaries was relatively large. These results are described in more detail below.

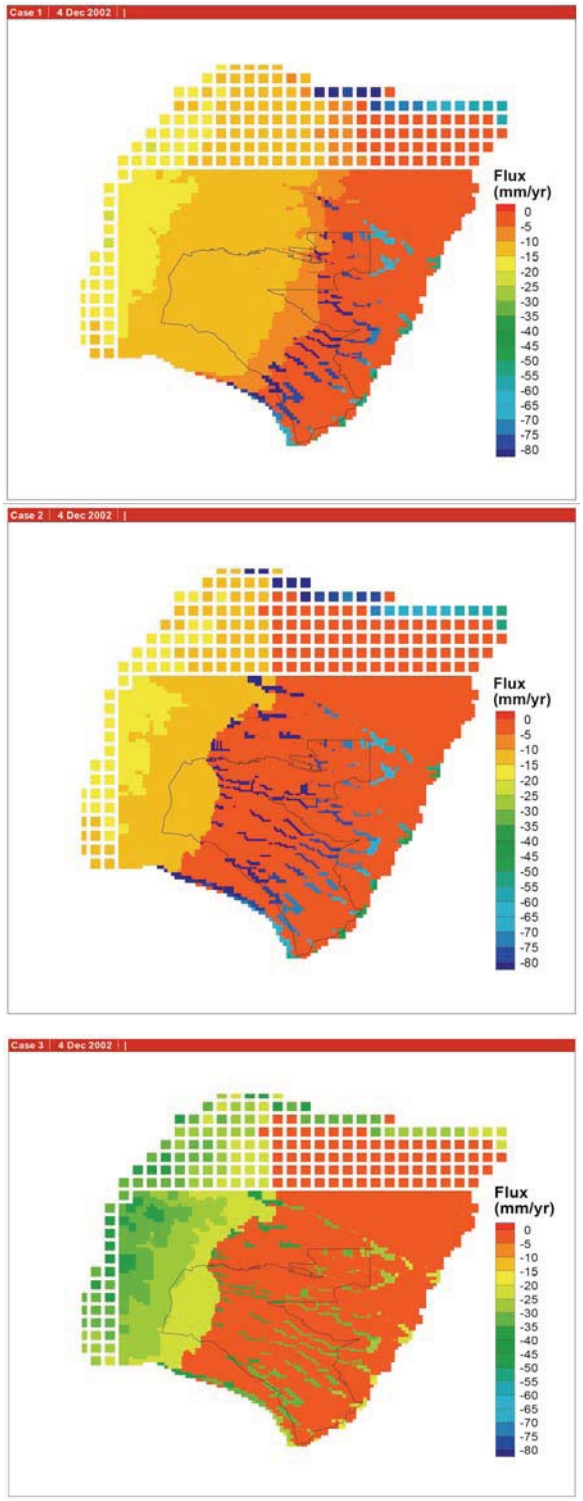


Figure 4-13. Examples of three recharge models, all imparting the same total flux. Model parameters are shown in Table 4-3.

Table 4-3.
Example Recharge Models, Shown in Figure 4-13.

	Case 1	Case 2	Case 3
Total recharge (kg/s)	200.3	200.3	200.3
Diffuse	122.3	70.6	145.2
Canyon-focused	78.0	129.7	55.1
Zmin (m)	2000	2200	2200

4.2.9 Data Used in Model Development and Testing

The datasets used in model development and testing are as follows: water level data, well construction and location data, water supply production data, hydrostratigraphy, stream channel location and elevations, hydrologic and structural boundaries for the basin, stream gage data, and selected geochemical data. The water level data, well construction and location data, water supply production data, precipitation data, stream gage data, and geochemical data are tabulated in Keating et al. (2005). Hydrologic divides (used to define model boundaries) and stream channel location and elevations were derived from USGS DEM data. Structural and geologic transitions used to define lateral basin boundaries were derived from Kelly (1978) and Shomaker (1974).

4.2.10 Flow Model Parameters

Model inputs are recharge rates, aquifer properties (permeability, specific storage), and stress (water supply production rates). Model outputs are heads and aquifer discharge (at constant head nodes along the Rio Grande, Rio Chama, and its tributaries, the Jemez River, and lateral boundaries). Other quantities such a travel times, flow directions, and well capture zones can also be derived from the model output.

As is the case in most groundwater systems, model outputs (heads and aquifer discharge) can be measured with much greater accuracy than model inputs (recharge rates and aquifer properties). This study employs the standard techniques of inverse analysis to derive model inputs (recharge rates and aquifer properties) from model outputs (heads and aquifer discharge). This is the same procedure widely used to derive aquifer properties from pump test data. The application of this method is somewhat unusual in that it acknowledges uncertainty in recharge, a complication that is usually neglected. This analysis provides information on aquifer properties and recharge, with quantified uncertainty, which can then be used to drive forward models and produce predictions.

The methodology used for inverse analysis is described in detail in Keating et al. (2000) and Keating et al. (2003). The three sets of calibration data are (1) pre-development heads (little or no impact from pumping), (2) transient heads (1946–2003), and (3) pre-development estimates of aquifer discharge to rivers. The data are listed in Keating et al. (2005). The details of the inverse analysis have changed over time, and the calibration data set has expanded as new wells have been drilled, computational resources have improved, and the hydrostratigraphic framework model has evolved. The aquifer properties derived from this process should represent larger spatial scales than those derived from short-term pump tests (days), since the transient data set

used represents a long period of time (55 years) and a widely spaced data set (several kilometers).

Table 4-4 illustrates several representative results for inverse analyses conducted using the basin- and site-scale models. See Keating et al. (2003; 2004) for details of these analyses. It is striking that the estimate for the lower Santa Fe Group is so much lower than pump tests conducted in the Los Alamos wellfield (completed entirely within the Santa Fe Group). This may be due to large-scale features, such as north-south trending faults, which would lower the effective permeability of the aquifer. Or this may be due to errors in the analysis or supporting datasets, such as a too low estimate of total recharge to the system. More detailed discussion of the hydrologic properties can be found in Section 2.8.

Figure 4-14 illustrates the degree of match between measured and simulated heads and fluxes at the basin scale, using the parameters shown in Table 4-4 (parameter set 1). Figure 4-15 shows the degree of match between measured and simulated hydrographs in the vicinity of LANL (parameter set 3). The magnitude of measured head response to 60 years of pumping (about 15 m in the central plateau, about 40 m to the east in the Los Alamos wellfield) is adequately reproduced, as is the recovery of heads in the Los Alamos wellfield after the cessation of pumping in 1975). Agreement between simulated and measured heads in water supply wells on a year-to-year basis is less accurate. Possible reasons for this, listed in detail in Keating et al. (2005) include both model errors and measurement errors. Improved fits would require explicit consideration of sub-annual variations in both water production and in measured water level responses.

4.2.11 Transport Model Methods and Parameters

The FEHM transport code employs one of two primary methods to simulate solute transport. The first is a particle-tracking methodology. This method can be used to simulate advection-only transport, which produces path lines and travel times that would be expected to represent the mean behavior of a conservative (non-reactive) solute plume. This method can also be used to simulate advective-dispersive transport, where thousands of particle paths are simulated and the number of particles present in any location represents solute concentrations. The second method is a direct solution of the advection-dispersion equation. This method can be used to simultaneously calculate the migration of multiple solutes, concentrations as a function of time and space, and a full suite of reactions with liquid, solid, and gas phases.

Table 4-4.
Regional Aquifer Model Parameters

		Basin Model		Site Model (2003)		Site Model (2004)A		Site Model (2004)B	
		Value	+/-	Value	+/-	Value	+/-	Value	+/-
Recharge									
	Zmin [m]	2195.0	177.0	2214.0	362.0	2156.1	14.0	2259.8	77.5
	Recharge volume [m^3]	3844.6	511.9	218.5	NA	253.7	NA	263.3	57.9
	α	NA	NA	NA	NA	0.1	NA	0.1	NA
	κ	NA	NA	NA	NA	0.0	NA	0.1	NA
Pemeabilities (log10[m2])									
Crystalline rocks	Deep Basement (pC)	-15.6	8.6	-15.6	305.9	-18.0	NA	-18.0	NA
	Paleozoic/Mesozoic	-15.0	3.2	-15.1	41.0	-13.7	NA	-13.7	NA
	Shallow Sangres	-12.6	0.2	na	NA	NA	NA	NA	NA
	Fractured pC	-13.1	0.6	na	NA	NA	NA	NA	NA
	Tschicoma Formation	-13.0	0.2	-13.0	5.8	-15.3	NA	-14.6	1.0
Keres Group	Tk (shallow)	NA	NA	NA	NA	-12.7	NA	-12.7	NA
	Tk (deep)	NA	NA	NA	NA	-13.7	NA	-13.7	NA
basalts	lumped	-12.2	0.2	-11.9	0.6	NA	NA	NA	NA
	Tb4	NA	NA	NA	NA	-16.1	6.5	-14.9	1.7
	Tb1	NA	NA	NA	NA	-12.1	NA	-13.5	0.4
	Tb2	NA	NA	NA	NA	-12.2	NA	-12.2	0.4
Puye Formation	(lumped)	-14.2	1.4	-14.4	2.7	NA	NA	NA	NA
	Tpt	NA	NA	NA	NA	-12.7	NA	-11.9	0.7
	Tpt-z	NA	NA	NA	NA	-12.7	NA	-17.5	3.2
	Tpp	NA	NA	NA	NA	-16.8	1.1	-11.9	0.3
	Tpf	NA	NA	NA	NA	-13.1	0.2	-12.9	0.7
	Tpf-z	NA	NA	NA	NA	-15.2	NA	-15.9	0.5
	Tpp-z	NA	NA	NA	NA	NA	NA	-11.0	71.9
Santa Fe Group	Tsf-fang[1]	-13.2	0.3	-13.4	0.4	-11.1	0.3	-19.0	75.0
	vertical	-15.5	0.9	-15.6	1.6	-11.4	NA	-18.4	0.6
	Tsf -sandy	-13.2	0.2	-13.1	0.3	-13.3	0.1	-13.4	0.1
	vertical	-15.0	0.4	-15.5	0.9	-14.2	0.1	-13.5	0.2
	East, Pojoaque	-14.1	0.4	NA	NA	NA	NA	NA	NA
	Airport	-12.6	0.8	NA	NA	NA	NA	NA	NA

Table 4-4.
Regional Aquifer Model Parameters (continued)

		Basin Model		Site Model (2003)		Site Model (2004)A		Site Model (2004)B	
		Value	+/-	Value	+/-	Value	+/-	Value	+/-
Recharge									
	North	-13.4	0.5	NA	NA	NA	NA	NA	NA
	Ojo Caliente sandstone	-13.3	0.2	NA	NA	NA	NA	NA	NA
	Peñasco embayment	-12.4	0.3	NA	NA	NA	NA	NA	NA
	deep	NA	NA	NA	NA	-16.0	NA	-16.0	NA
	Ancha formation	-12.3	0.5	NA	NA	NA	NA	NA	NA
Pajarito fault zone		-15.3	0.8	-15.3	27.1	-15.0	NA	-13.9	1.3
Specific Storage	(Ss) log10[m-1]	-3.9	0.4	-3.6	0.5	-4.3	0.1	-3.8	0.3

[1]referred to as Tsf-uv in earlier models
NA = not applicable

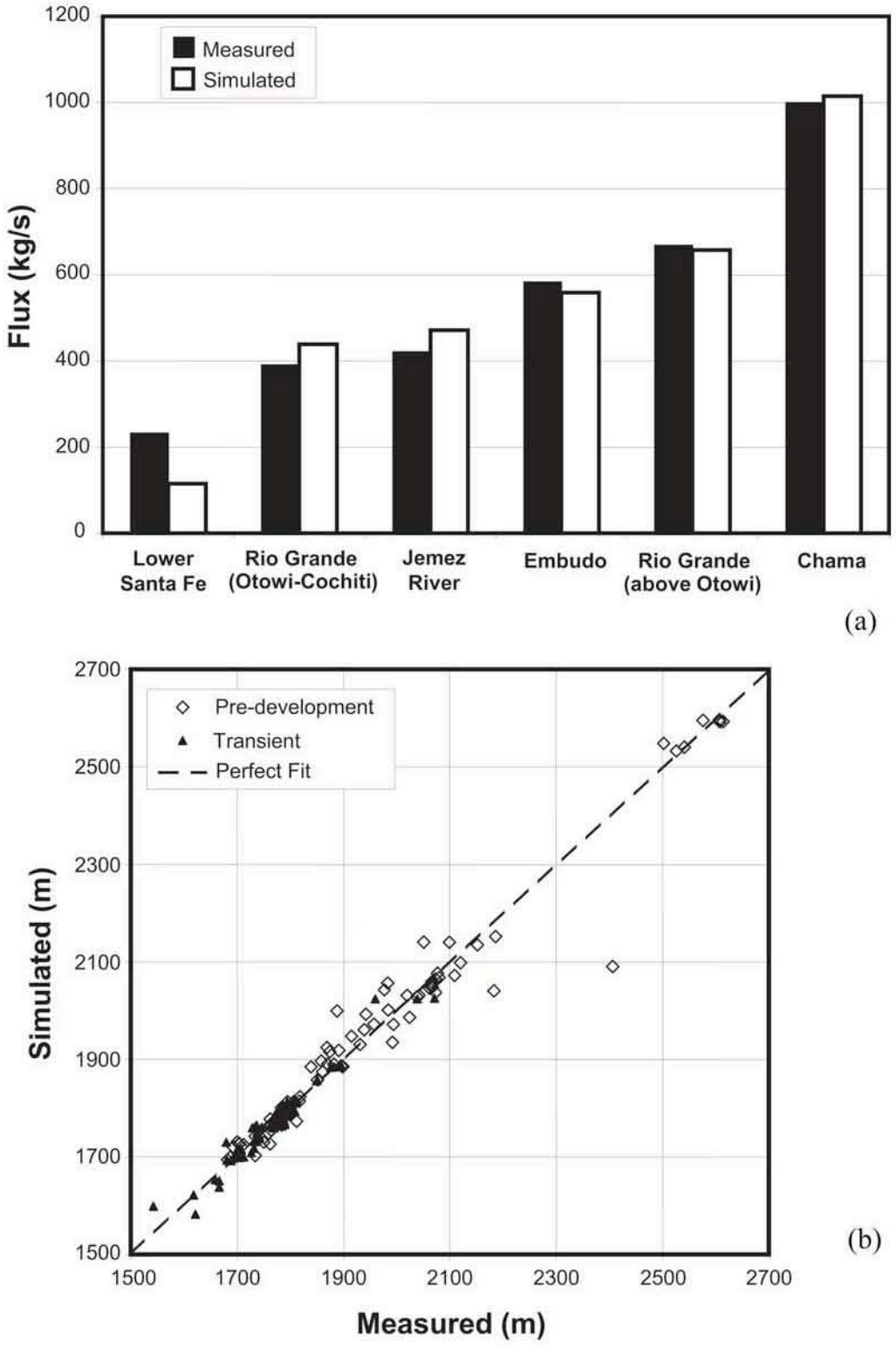


Figure 4-14. For the basin-scale model, comparison between measured and simulated (a) fluxes; (b) heads.

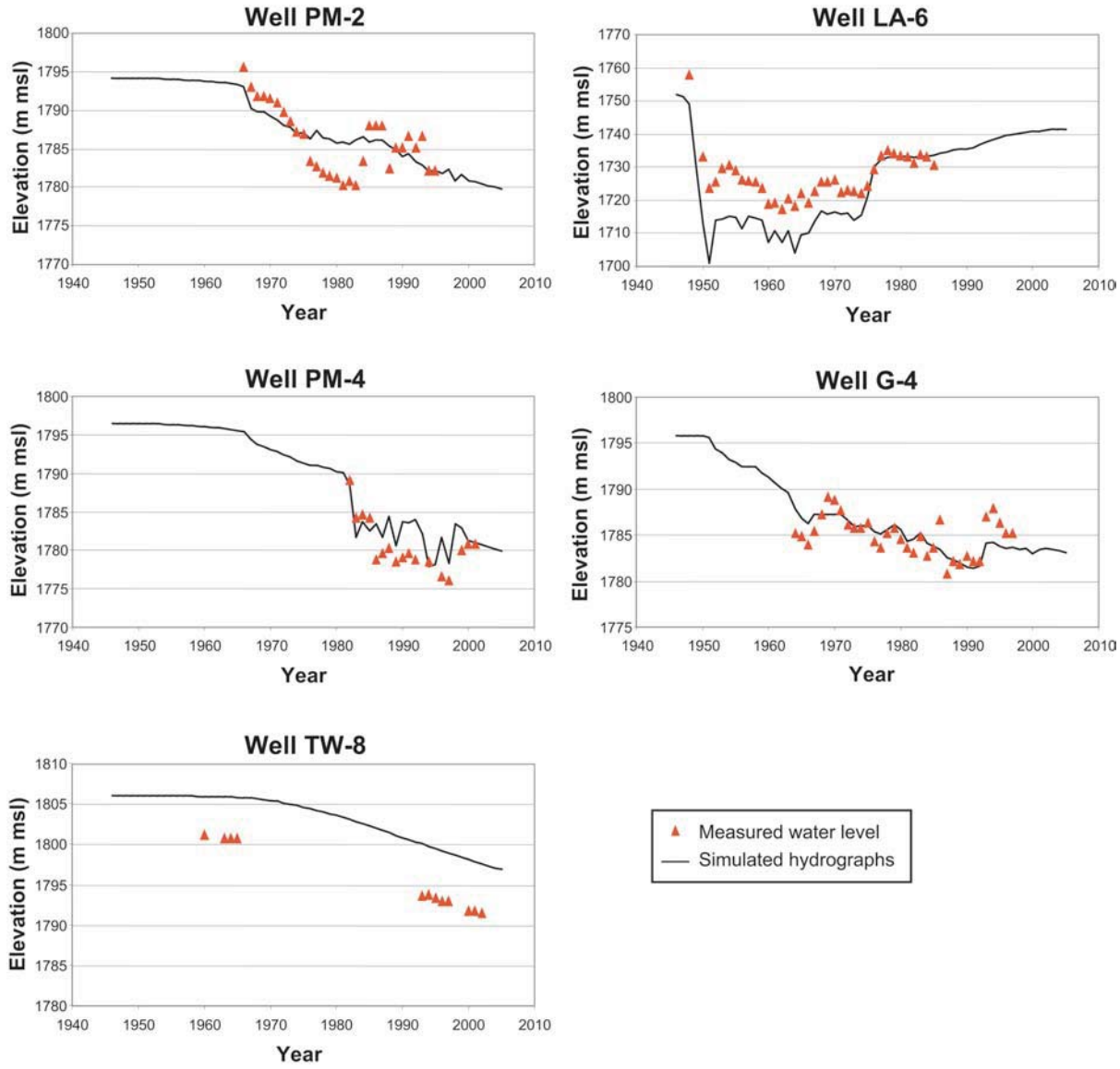


Figure 4-15. Comparison of simulated and measured hydrographs for representative wells on the plateau.

For nonreactive chemistry simulations, the particle-tracking methodology is preferable because it avoids the problem of numerical dispersion. Most of the analyses presented here use this method. One important limitation of this method is that the solution is invalid in portions of the numerical grid where elements are nonorthogonal (see Appendix 4-D, Section 1, Figure 4-D-2). However, in these calculations we restrict our analysis of particle-tracking paths to the fine-grid region at the site scale, thereby avoiding the problem.

Two critical parameters for nonreactive transport simulations are rock porosity (which is linearly proportional to travel time) and dispersivity (which controls the degree of spreading and mixing). Neither of these types of data has been collected in this aquifer at scales meaningful for site-scale transport simulations. Therefore, the model uses literature-derived values appropriate for the types of rocks present in this aquifer.

4.2.12 Model Applications

There have been three broad categories of model applications. The following subsections present brief examples of modeling studies for each category.

4.2.12.1 Category A: Integrate and interpret 3-D site-wide hydrologic and hydrostratigraphic data, to provide a more quantitative basis for testing site-wide conceptual models than was previously possible.

Many of the fundamental issues pertaining to the regional aquifer are questions that cannot be answered using data collection alone. Where are the predominant recharge areas? How much water is flowing through the aquifer? What are the large-scale hydraulic properties of the aquifer rocks? In what direction is water flowing? What is the pore water velocity of the groundwater? What effect has pumping had in the past and what effect will it have in the future? A great deal of characterization data has been collected over the past few years to address these questions, and the numerical models have been used as a framework for interpreting these data and providing at least partial answers to these questions.

1. Large scale fluxes. Keating et al. (2003) demonstrated the use of inverse and predictive analysis to examine the range of possible fluxes and recharge distributions that could explain the measured head data and stream gage data at the basin-scale. This approach acknowledges the uncertainty in aquifer properties and recharge rates, and attempts to determine to what extent quantitative estimates can be made. The aquifer property estimates that resulted from this approach, with uncertainty, are presented in Table 4-4 (parameter sets 1 and 2); the degree of agreement between measured and simulated heads and base flow gains are presented in Figure 4-14.

As shown in Figure 4-14, this analysis demonstrates that the basin-scale model provides a reasonable fit to measured head gradients and discharge to river reaches. The estimated elevation above which significant areal recharge occurs (2195 m, shown as a red line in Figure 4-16) matches almost exactly the location of the transition proposed by Wasiolek (1995). In addition, the estimated percent of precipitation that becomes recharge in the mountains (8%) falls within, although close to the low end of, the range of watershed study results (Appendix 4-E). The predicted outflow to the Albuquerque Basin of 5,801 acre feet per year (afy) is less than previous USGS studies of the Española Basin (McAda and Wasiolek 1988) and more recent studies of the Albuquerque Basin (14,300 afy) (Plummer et al. 2004). This value could be increased by increasing the percent of precipitation that becomes recharge and still be within the range of reasonable values. These results generally support the conceptual model of total basin-scale recharge and discharge fluxes (tabulated in Appendix 4-D and Appendix 4-E), as well as the generalized spatial distribution of fluxes simulated with the recharge model described in Appendix 4-D, Section 2. It also demonstrates the value, at least at large scales, of the 3-D hydrostratigraphic framework model.

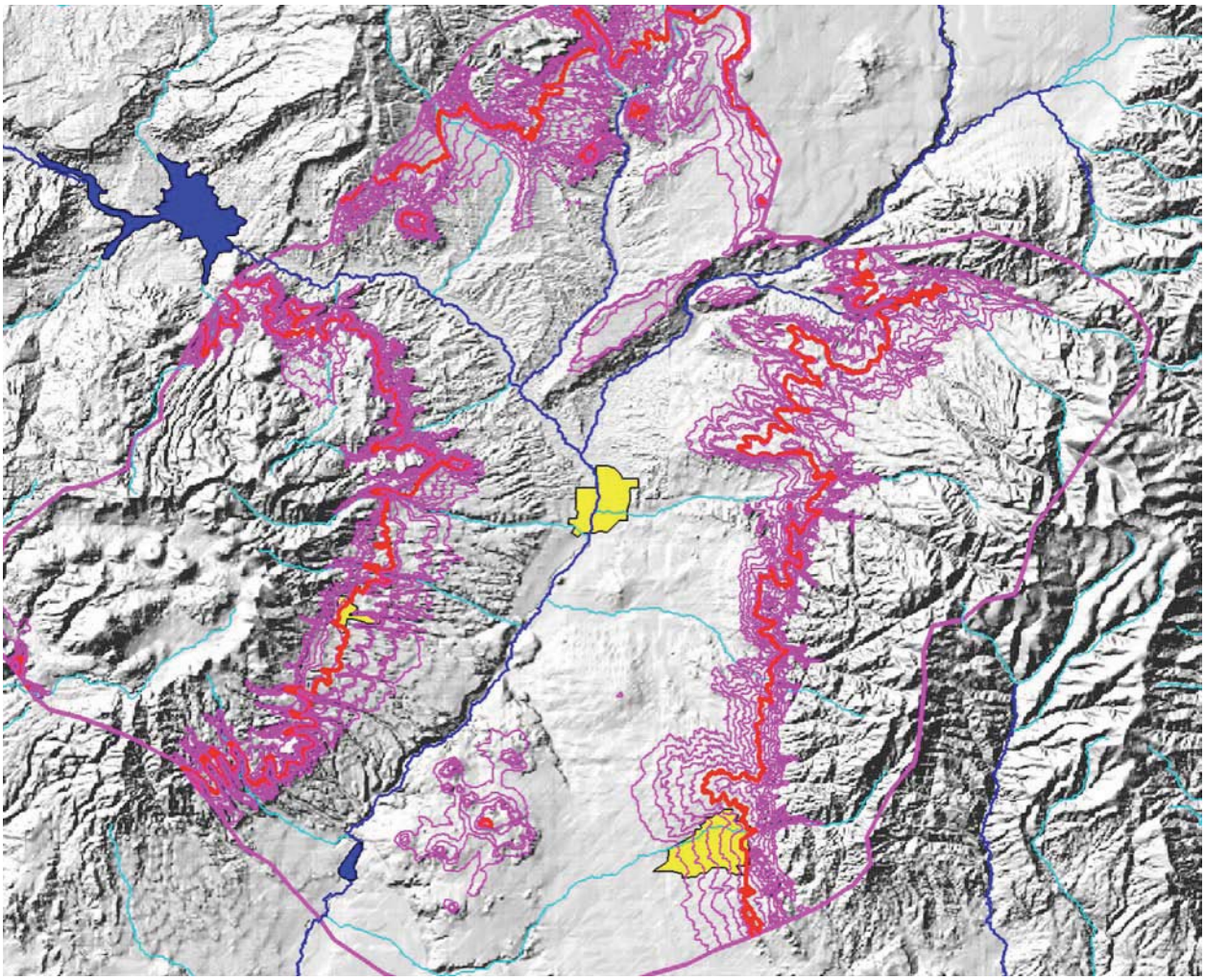


Figure 4-16. Location of predicted transition between significant areal recharge and negligible areal recharge (2195 m), and uncertainty bounds. Pink contours span the elevation uncertainty range.

The results of the basin-scale inverse analysis were used to estimate fluxes across the lateral boundaries of the site-scale model, with uncertainty. Figure 4-17 shows the results of this analysis. Fluxes perpendicular to flow (north and south) were calculated to be relatively small and showed much less uncertainty than fluxes parallel to flow (east and west). Significant flux is predicted to cross both the western and eastern boundaries; the high uncertainty of these estimates, however, means that this uncertainty should be explicitly considered when doing transport calculations that might be affected by these fluxes.

All these results depend on the streamflow analyses being reasonably accurate, the 3-D geologic model capturing the most important large-scale hydrologic features in the aquifer, and the method of inverse analysis fully exploring parameter uncertainty. This technique only explores the impact of numerical model parameter uncertainty; overall uncertainty in recharge and fluxes, which would include conceptual model errors, is undoubtedly larger.

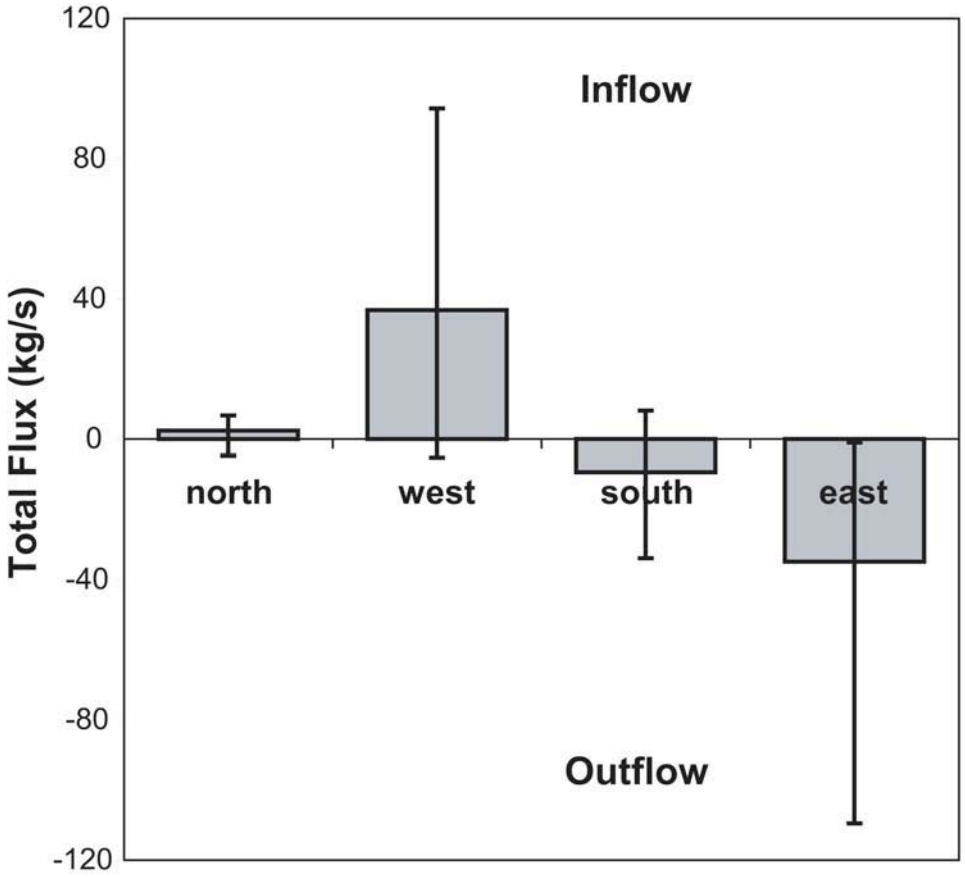


Figure 4-17. Fluxes across lateral site-model boundaries predicted by the calibrated basin model. Error bars represent the 95% nonlinear confidence intervals of estimates.

2. Small-scale fluxes, downgradient of LANL. A more recent study, Keating et al. (2004), used similar techniques to explore not only the question of uncertainty of total flux through the aquifer, but also uncertainty in fluxes through shallow portions of the aquifer immediately downgradient of LANL. This analysis is pertinent to estimates of contaminant transport away from the site. Figure 4-18 shows that parameter uncertainty in the site-scale model (including uncertainty in recharge rates and aquifer properties) contributes significantly to estimates of total recharge for the aquifer, but that the flux through the shallow portion of the aquifer immediately downgradient of the site is more certain. More detailed study of this result did highlight the large uncertainty in fluxes through a single basalt unit, however. Uncertainty in transport parameters, such as porosity, would produce a much larger impact on total velocity uncertainty; therefore, this study suggests that better measurement of fluxes and recharge would be of far less value than collecting site-specific estimates of porosity.

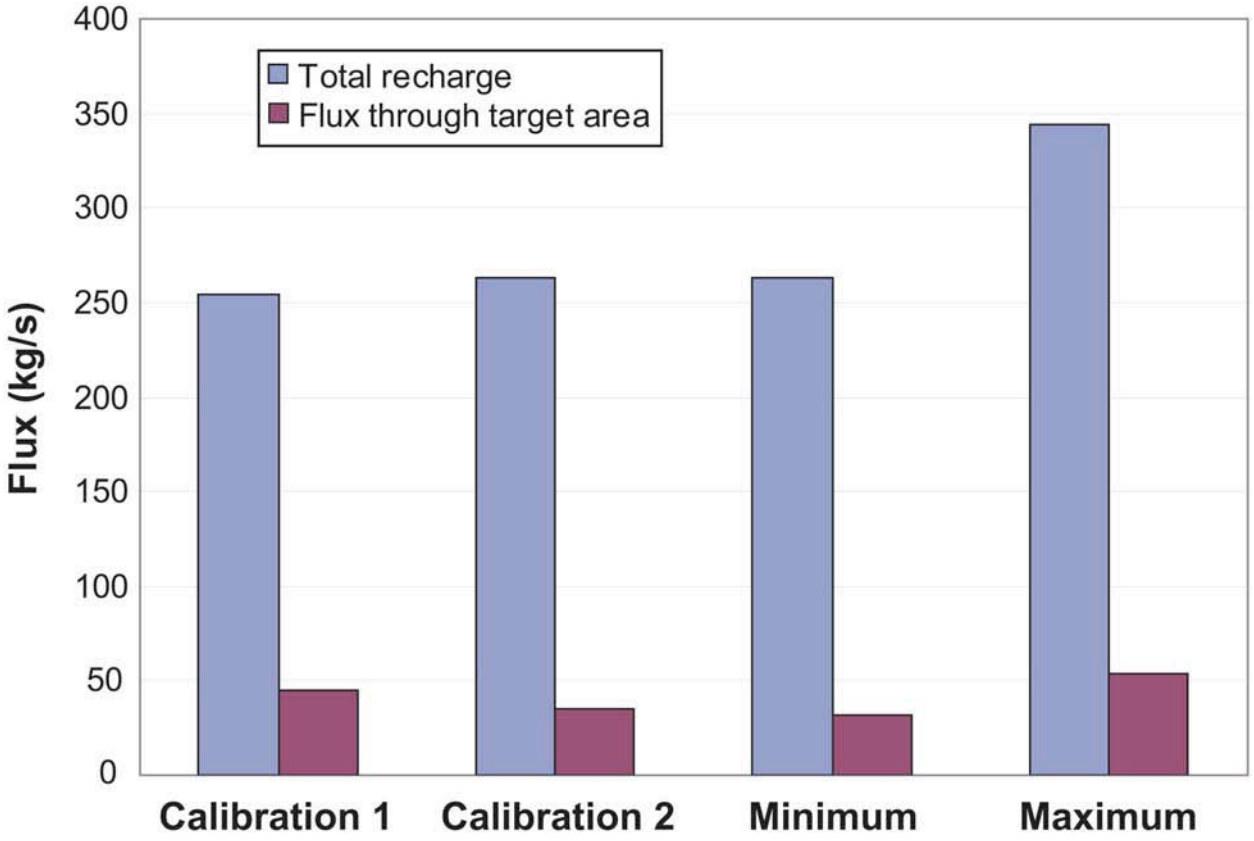


Figure 4-18. Results of predictive analysis, compared to two calibrated models. Blue bars indicate total recharge into the aquifer; red bars indicate flux through the shallow plane east of LANL.

3. Pore-water velocity. Pore-water velocities in the regional aquifer are very poorly constrained. Through modeling techniques described in this report, flow directions and fluxes can be surmised reasonably well, but velocities are very difficult to infer from hydrologic data alone. Contaminant distributions within the regional aquifer have been useful for identifying the location of fast pathways through the vadose zone, but since the exact location and timing of contaminant entry to the water table is highly uncertain, these observations do not constrain velocities in the regional aquifer. The best method for determining velocities is tracer tests.

The LANL model was used to produce a map of velocities at the water table (see Figure 4-19). These velocities are highly uncertain and are used only to illustrate a few key points. First, given the heterogeneous nature of the aquifer, groundwater velocity is likely to vary considerably over short distances. In this map, the fastest velocities are in the basalts where fracture flow (very low matrix porosity) is assumed. Second, flow on the eastern portion of LANL is predicted to be very slow. This is due to the very low permeability of the Santa Fe Group, which is prevalent at the water table east of LANL (see Table 4-4, Figure 2-10, and related discussion in Section 2.8.7).

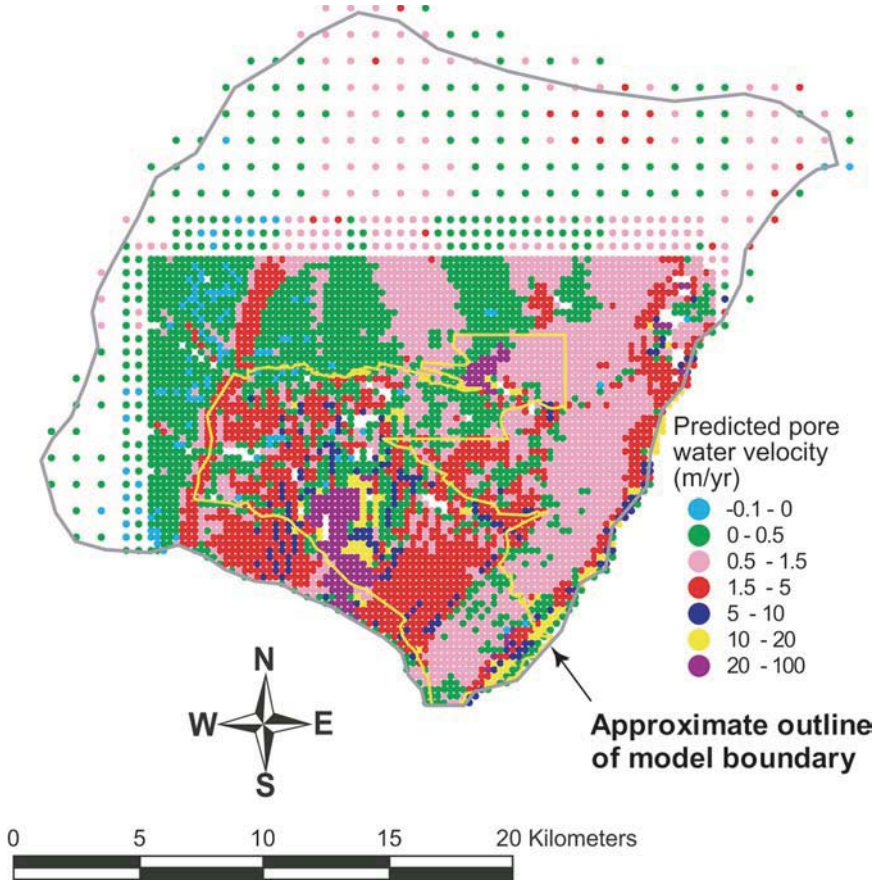


Figure 4-19. Model-predicted horizontal component of pore-water velocity at the water table, in m/yr.

The very slow velocities predicted by the model are consistent with ^{14}C data presented by Rogers et al. (1996a,b). These data are collected in both water supply wells (screened over the upper 2000 ft of the aquifer) and more shallow wells (DT5A, east side and west side artesian). Figure 4-20 shows a comparison of model predicted ^{14}C and measured ^{14}C presented by E. Kwicklis in Keating et al. (2000). One interesting aspect of this comparison is that the model underpredicts the age of the very old waters present near the Rio Grande.

In stark contrast to these predictions, Purtymun et al. (1984) produced a generalized map of pore-water velocity in the regional aquifer. His estimates assumed a uniform hydraulic gradient of 0.01 m/m, a uniform porosity of 0.1, and 1-D lateral flow. Using a 1-D version of Darcy's Law and hydraulic conductivity estimates from local pump tests, his resulting velocities ranged from 20 ft/yr (Los Alamos wellfield) to 345 ft/yr (DT wells). Assuming the high velocity estimate of 345 ft/yr, this would represent a travel time of 134 years across LANL from west to east (~9 miles). McQuillan (2003) used the chemistry data from White Rock Canyon Springs and TW-1 and an assumption of 1-D lateral flow to derive a velocity estimate of 358 ft/year (59 year travel time, ~4 miles). More recently, a report by Rice (2004), concurred with these earlier estimates.

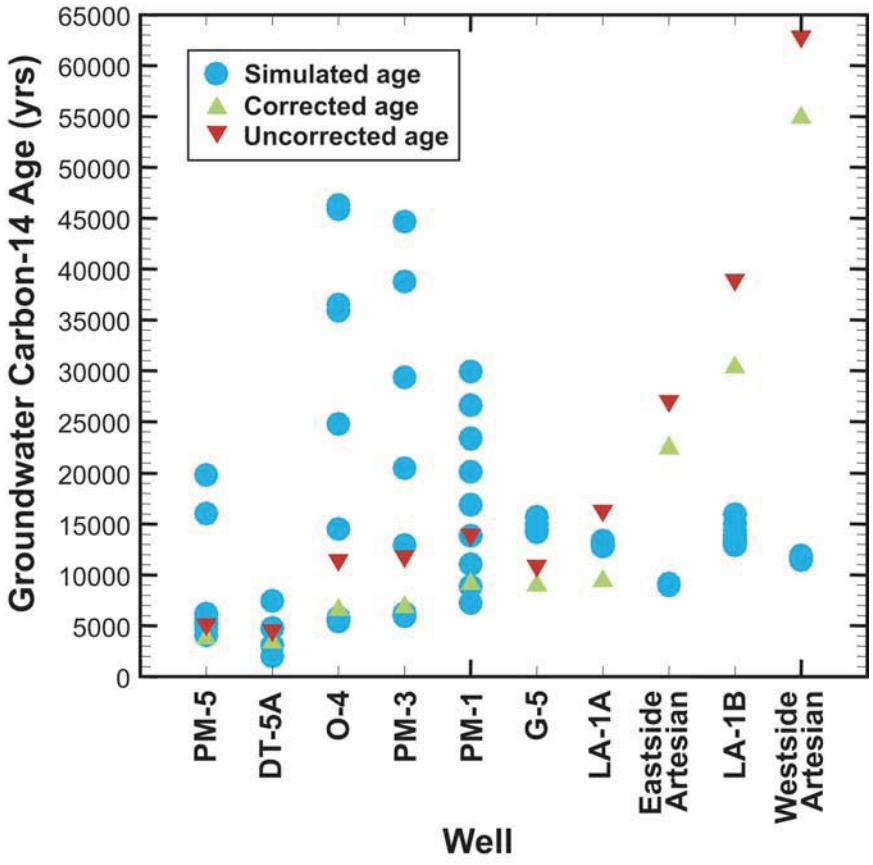


Figure 4-20. Comparison of simulated groundwater carbon-14 ages at nodes within the screened depths of wells with the corrected and uncorrected groundwater ages estimated from measured carbon-14 activities.

At present, it is impossible to compare the McQuillan and Rice calculations to the published LANL regional model predictions, because in the model (as configured for past applications) the springs are above the top of the model and therefore flow to the springs cannot be simulated. This is a subtle but very important distinction because the top of the model at present is entirely within the low-permeability Santa Fe Group in the vicinity of the Rio Grande, whereas slightly higher elevations (which include the springs) are within the more permeable units of the Puye Formation. Some springs also issue from the base of the Cerros del Rio lavas. If transport calculations to the springs are required in the future, minor adjustments to model boundaries will suffice to address this issue.

A more difficult question is that of measured hydraulic head gradients and lateral continuity of highly permeable rocks. The model honors measured gradients (in 3-D), the 3-D hydrostratigraphic framework model, and large-scale effective properties of rock units (see Table 4-4). At present, neither the measured 3-D hydraulic heads nor the permeability/hydrostratigraphy information supports the hypotheses presented by McQuillan and Rice. In such a complex aquifer, however, it is entirely possible that their hypotheses could be correct.

4. Effect of water supply well production

Capture zones. Understanding the influence of water supply production on the aquifer is important from the perspectives of both water supply and contaminant transport. From a water supply perspective, it is very important to know if the current rates of withdrawal are sustainable. From a contaminant transport perspective, an understanding of capture zones is critical to placement of a "sentry" well to protect a production well and to identification of which receptors are most at risk of contamination.

The LANL models have been used to evaluate the impact of water supply production in a number of studies. The philosophy of this approach has been to start simply and gradually add complexity only when needed. In a sense, all of these studies have illustrated the shortcomings of applying "simple" textbook methods of capture zone analysis to this site. Therefore, this is very much an ongoing study.

Using a relatively simple approach, Vesselinov et al. (2002a) calculated capture zones for the Buckman wellfield and all the Los Alamos wells. The motivation for this study was to determine if the LANL aquifer was within the capture zone for the Buckman wells, either at present or (possibly) in the future. This analysis was based on the standard "steady-state" assumption. The results, shown in Figure 4-21, demonstrated that a significant portion of the aquifer beneath LANL could eventually be captured by the Buckman wells. These results also showed the zones of influence of Los Alamos County water supply wells.

The assumptions inherent in this analysis are that current rates of production in water supply wells continue indefinitely until steady state is reached. Given the characteristics of this aquifer, this is not expected to occur for several hundred years from the present. Some wells in the Guaje field and some wells in the Pajarito field (PM-2, -4, and -5) appear to be stabilizing with respect to pumping; the assumption of steady-state may be applicable to these wells. However, given the dramatic fall of water levels in the Buckman wellfield over the past two decades, steady-state is far in the future. Given the uncertainties of water production over the next few decades (e.g. City of Santa Fe is expected to rest the Buckman field beginning in 2009, the steady-state approximation is questionable for this wellfield. It does, however, show one possibility that should be considered for planning purposes.

Vesselinov and Keating (2003) investigated the impact of dispersion and transients on capture zones analyses. Figure 4-22 shows the predicted capture zones when both dispersion (spreading of the plume) and transients (changes in source term and changes in water supply production) are included in the analysis. These authors concluded that significant errors were incurred when dispersion and/or transients were neglected in the analysis. The importance of transients (changing flow field in response to changing water production rates) highlights the importance of identifying when and where contaminants might reach the water table. For the same point of entry to the water table (for example, beneath Ten Site Canyon), a contaminant reaching the aquifer in 1960 might be captured by PM-1, whereas a contaminant reaching the aquifer in 1990 might be captured by PM-5.

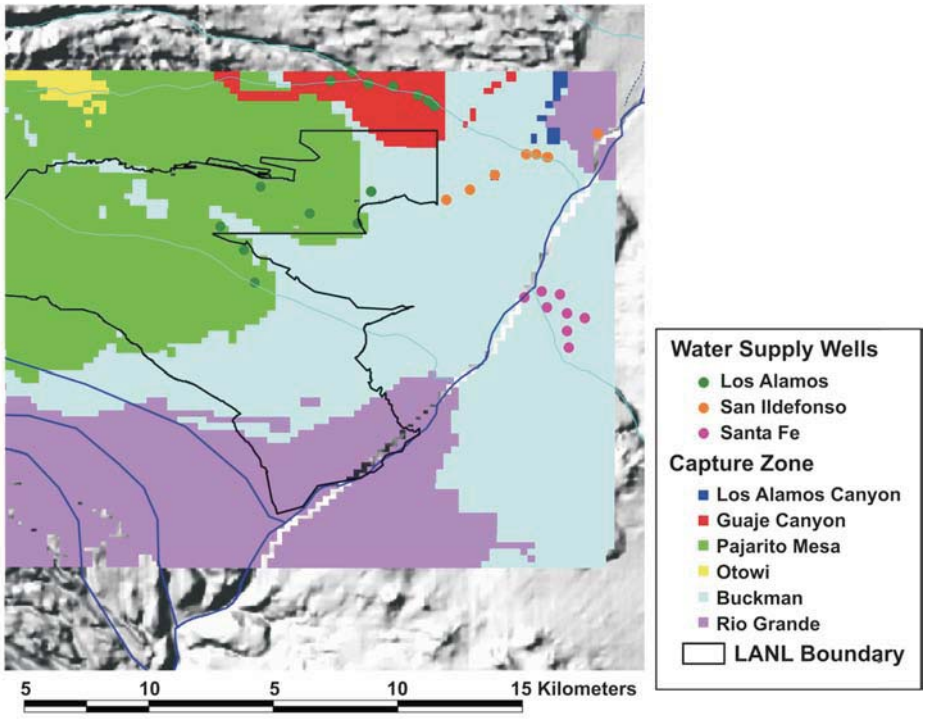


Figure 4-21. Predicted steady-state capture zones for wellfields in the vicinity of Los Alamos (from Vesselinov et al. 2002a).

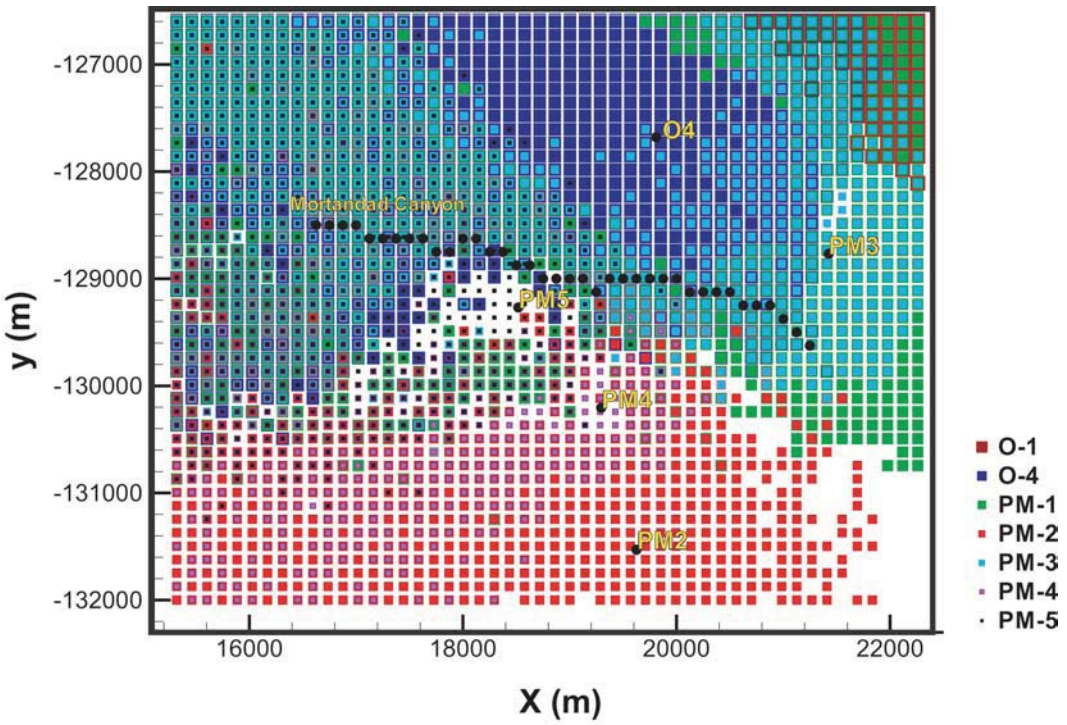


Figure 4-22. Predicted transient capture zones for wellfields in the vicinity of Los Alamos from Vesselinov and Keating (2003).

Effect on streamflow. In a basin such as the Española Basin, where surface water flow depends to a large degree on groundwater discharge, any water supply production will affect aquifer storage immediately and surface water flow eventually. When the aquifer reaches equilibrium with respect to pumping, the only continued impact will be on surface water flow. Wells drilled near the point of discharge will have a significant effect on surface water flow sooner than wells drilled far from the point of discharge.

Based on parameters shown in Table 4-4 (parameter set 3), the site-scale model was used to predict the percentage of produced water coming from storage and captured streamflow (or recharge) over the past 50 years. Figure 4-23 shows these results, demonstrating that the aquifer is still far from steady-state and that most produced water is still coming from storage.

5. Hydrostratigraphy. All of the studies listed above rely on the 3-D hydrostratigraphic framework model to define heterogeneity within the aquifer, according to the spatial distribution of approximately 15 units. Of course, with relatively sparse boreholes on the plateau there is uncertainty in the exact spatial extent of these units (Section 2.4.4). There also may be important heterogeneities within the hydrostratigraphic units as defined by the 3-D model.

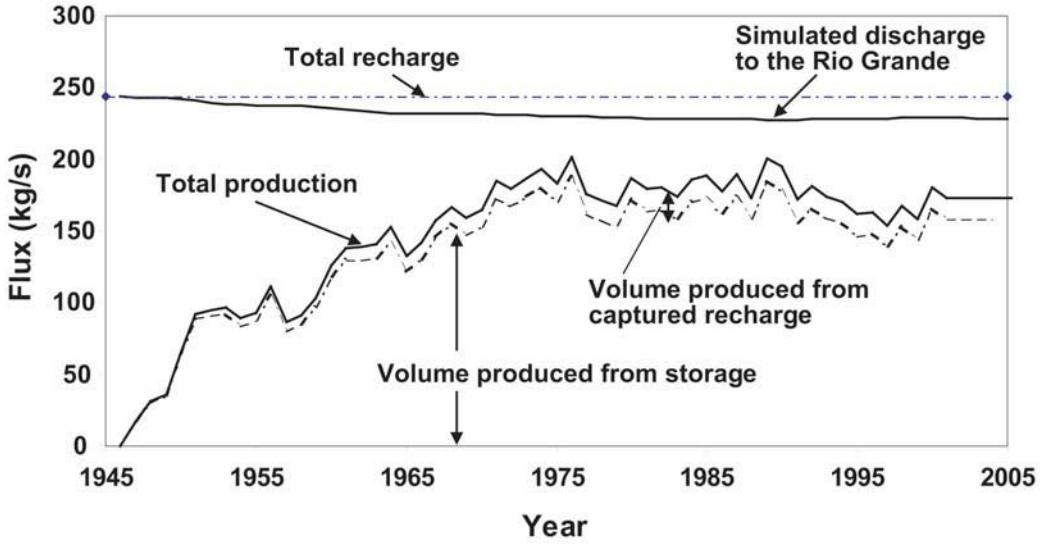


Figure 4-23. Simulated discharge to the Rio Grande, and estimated proportion of production in local wellfields that originates as storage and as captured recharge.

This study has devoted considerable effort to modeling heterogeneity within the Puye Formation at scales smaller than the 3-D hydrostratigraphic framework model. The Totavi Lentil is of particular interest, since it is characterized by beds of gravel which may be highly permeable. (Note: In situ hydraulic tests have been equivocal on this issue.) The current hydrostratigraphic framework model defines the Totavi Lentil as a continuous sheet of rock at the base of the Puye Fanglomerate; therefore model predictions that assign this unit a high permeability will be conservative (fastest travel times over long distances). Reneau and Dethier (1995) proposed a very different model of the Totavi Lentil, as a series of discontinuous north-south trending ribbons, separated from each other by terraces left behind as the Rio Grande downcut and moved westward over geologic time. Stochastic methods are appropriate for representing this type of heterogeneity, since the exact location of each of these narrow ribbons could never be known. Figure 4-24 illustrates one realization of a stochastic model of the Totavi Lentil, using Markov-chain transition probabilities based on data collected from geologic maps and measured outcrops (Carle 1996; Fogg 1989). This approach, and the data set that underlies it, are described in detail in Keating et al. (2000).

The Santa Fe Group (Tsf) has some intercalated Miocene basalts (Tb2; see cross-sections in Figures 2-12 to 2-19). To examine two extreme end-members, one might consider hypothetical cases where the deeper unit is either 100% Tsf or 100% Tb2. In 2002 a version of the framework model was created that explicitly identified zones that were uncertain, due to sparse borehole control. Figure 4-25 illustrates one such zone, which might be either a basalt or the Santa Fe Group. Figure 4-26 shows the resulting capture zone predictions, first assuming that zone is a basalt and then assuming that zone is the Santa Fe Group. By comparing the two figures, one can determine the impact of uncertainty of the hydrostratigraphy in this zone.

The Puye Fanglomerate also has beds of sand and gravel which, although of limited spatial extent, may be important in contaminant transport. Using textural descriptions from lithologic logs in R-wells, two different stochastic models of this type of heterogeneity were developed, as shown in Figures 4-27 and 4-28. Both of these methods show promise for use in future simulations.

The model calibration process itself can provide useful information about hydrostratigraphy. For example, if the conceptual model is that unit A is high permeability and unit B is low permeability, through the process of model calibration one can determine whether or not that conceptual model is consistent with large-scale head and flux data. This principle was used to test the conceptual model of a north-south trending high-permeability trough within the upper Santa Fe Group, proposed by Purtymun (1995). Carey et al. (1999) formulated this trough within the 3-D framework model as a fairly narrow feature (Figure 4-29a). Through the model calibration process, it was determined that this geometry was consistent with site-wide hydrologic data. Later, in a 2002 update of the 3-D framework model, this feature was significantly enlarged (Figure 4-29b). It was not possible to calibrate a model that assigned a high permeability to this large feature, so this model was discarded. These results suggest that the high permeability trough is likely to either be small, such as shown in Figure 4-29a, or exist as small, discontinuous patches.

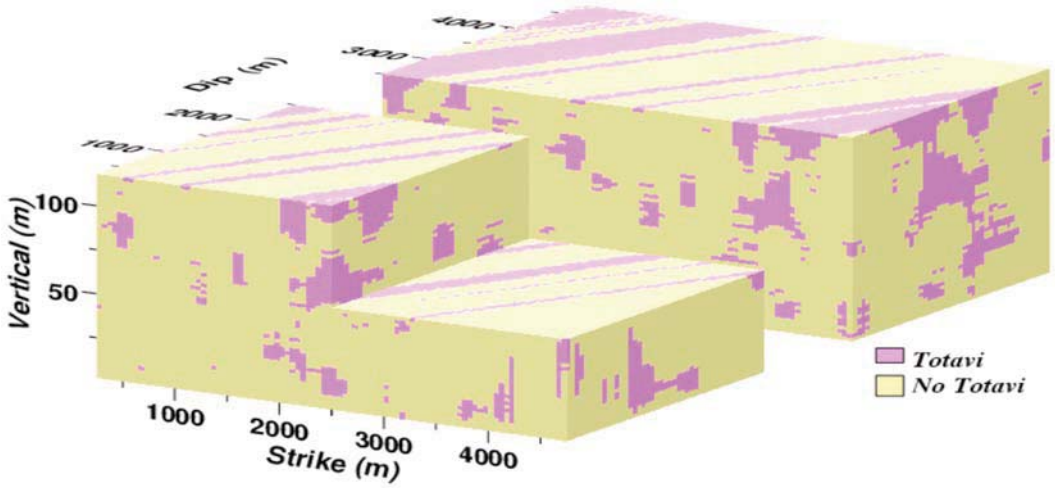


Figure 4-24. Heterogeneity within the Puye Formation; one realization of a stochastic Markov-chain model of the Totavi Lentil (dark pink). Model parameters are based on surface geologic maps and measured outcrops.

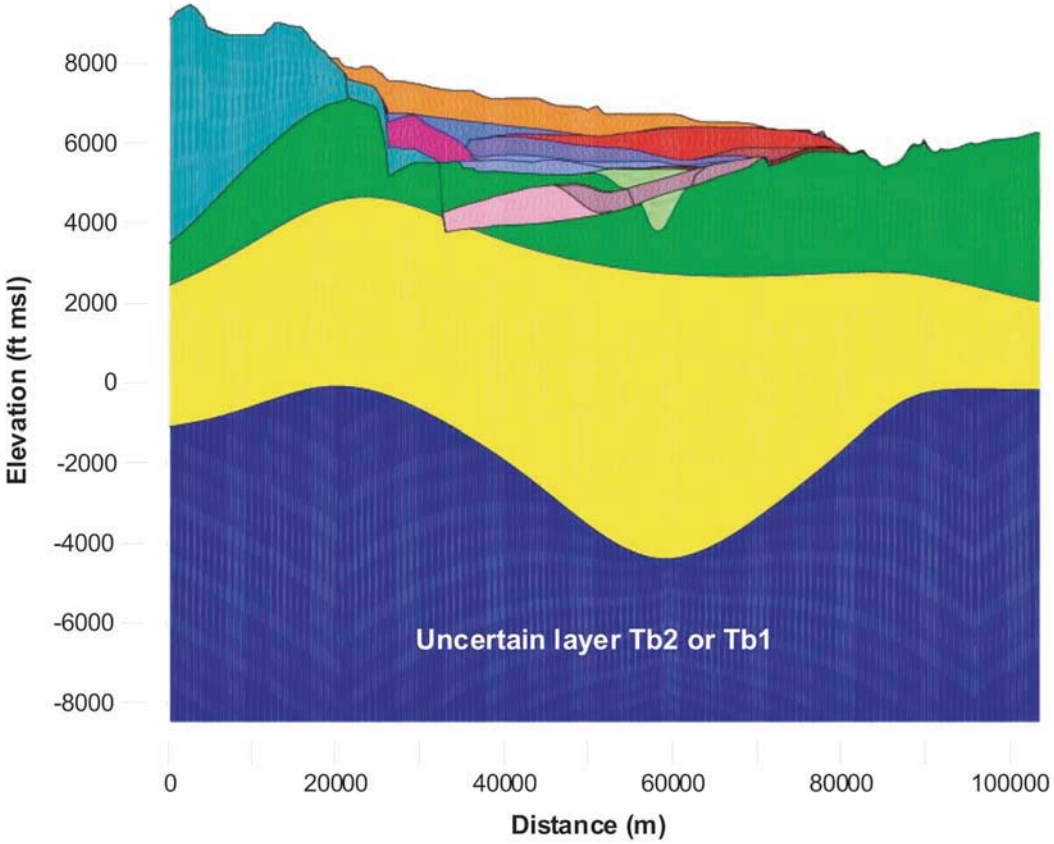


Figure 4-25. Cross section through hydrostratigraphic framework model, showing location of layer selected to perform a sensitivity analysis exploring the uncertainty in the geologic framework. The uncertain zone in pink was assumed to be either Tb2 or Santa Fe Group for the purpose of examining sensitivity.

(a) assumes uncertain layer in basalt **(b) assumes uncertain layer in Santa Fe Group**

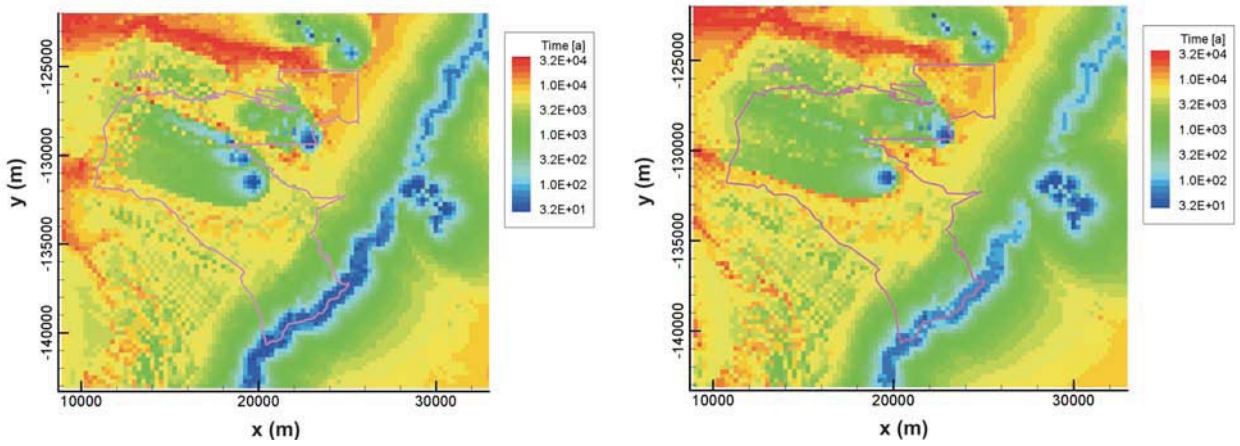


Figure 4-26. Predicted steady-state capture zones for wellfields in the vicinity of Los Alamos, using two different alternative models of hydrostratigraphy.

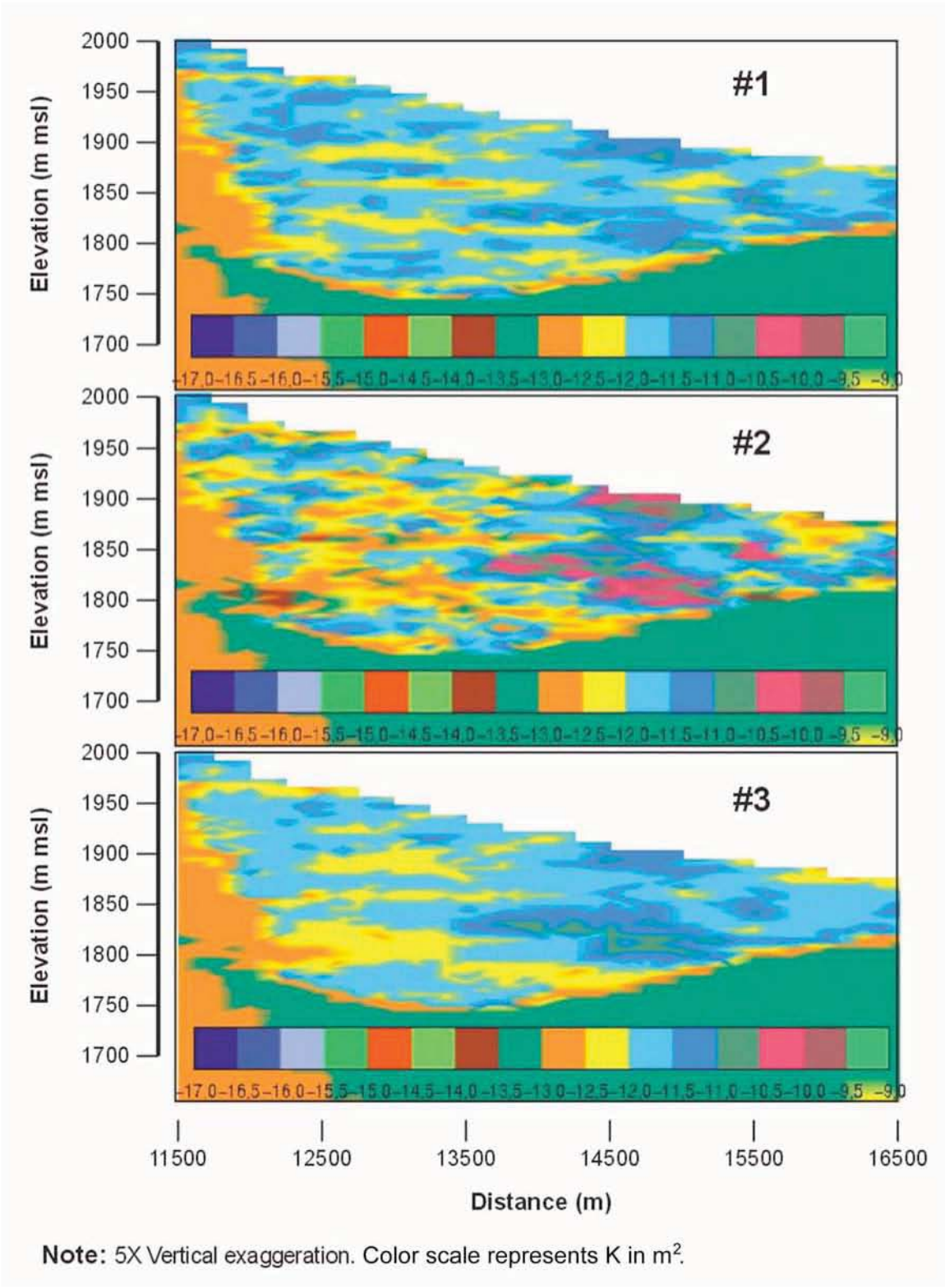
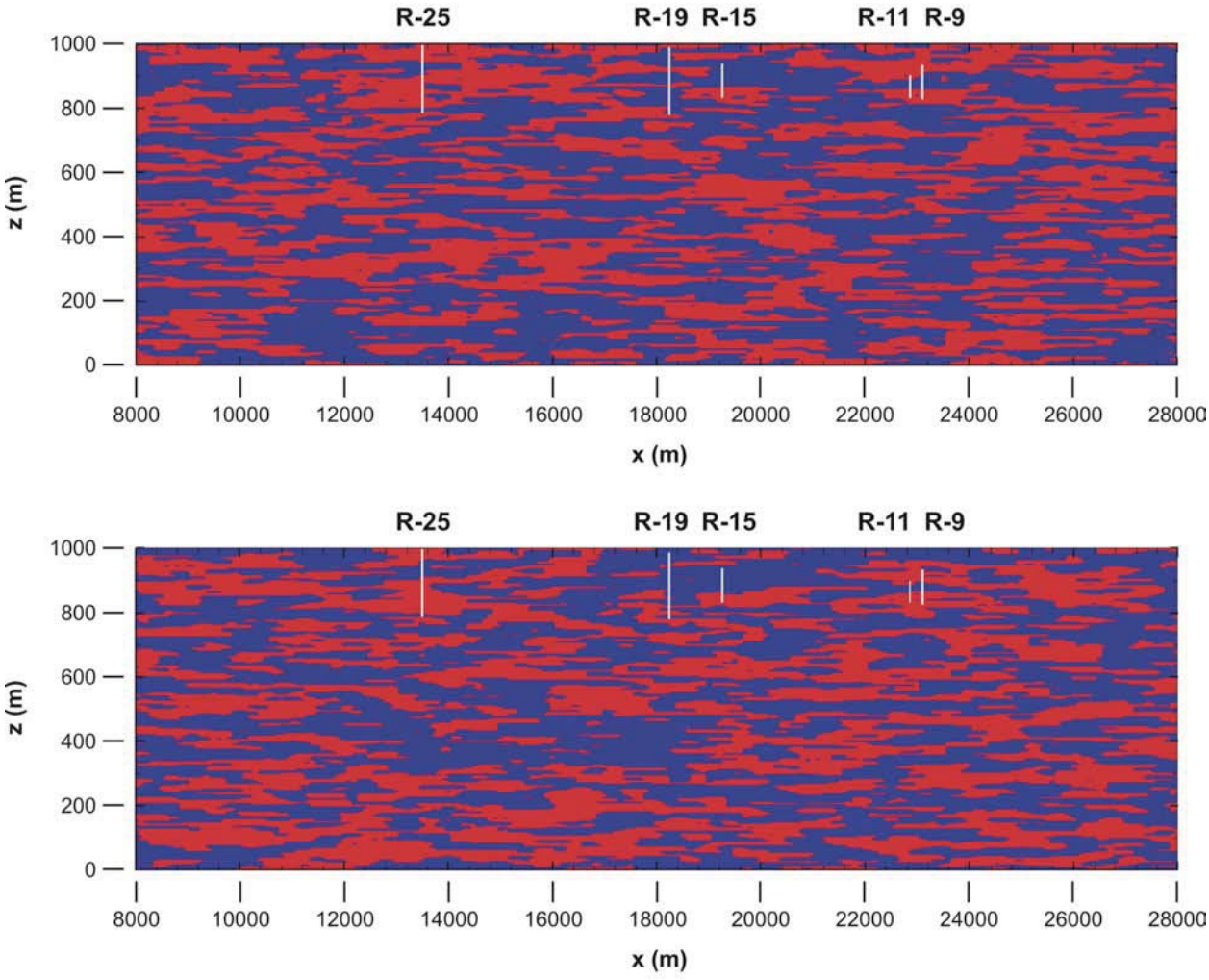


Figure 4-27. Heterogeneity within the Puye Formation; three realizations of a stochastic Gaussian model.



Notes: Examples of Markovian realizations conditioned at well data.
Coarse (blue) 55.2%, fine (red) 44.8%
Mean thickness- coarse: 23m, fine: 18m
Mean length- coarse: 1150 m, fine: 900m

Figure 4-28. Heterogeneity within the Puye Formation, fanglomerate; two realizations of a stochastic Markov-chain model. Model parameters are based on lithologic logs from R-wells.

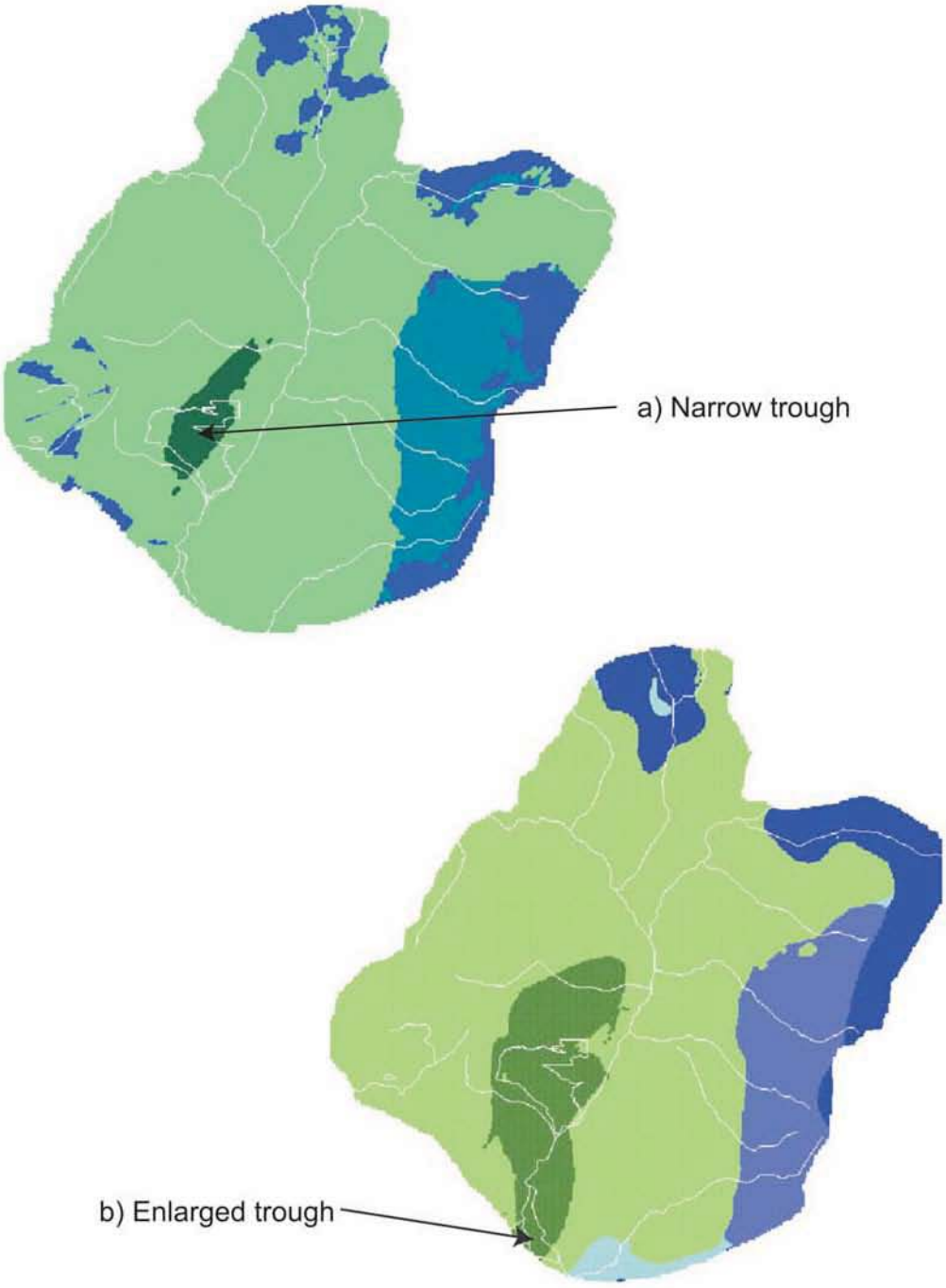


Figure 4-29. Two representations of the north-south trending trough in the upper Santa Fe Group.

4.2.12.2 Category B: Predict fate and transport of contaminants in the regional aquifer, in order to optimally place monitoring wells and inform risk assessment studies.

1. HE transport from TA-16. The first contaminant transport simulations were conducted in response to the discovery of high explosives (HEs) in the upper saturated zone at R-25. The first model predictions were based on a simple premise: that the aquifer is at steady-state (with current rates of production in water supply wells), and that the important heterogeneities were defined by the 3-D hydrogeologic framework model. HE was represented by non-reactive particles in the model, released at the water table both at TA-16 and beneath Cañon de Valle (assuming rapid downstream transport in the alluvium). Figure 4-30 illustrates these results, which show all the contamination eventually being captured by either PM-2 or PM-4. Travel is predominantly within the Puye Formation. Breakthrough curves, shown in Figure 4-31, suggested that travel times would be on the order of hundreds of years. These slow travel times are consistent with the observation that no HE has been found in monitoring wells drilled since this study, at distances relatively close to R-25. A later simulation using a transient flow field demonstrated that the steady-state analysis was sufficient for this problem.

This study was repeated in 2000 with a more realistic approach to modeling heterogeneity within the Puye Formation (see Figure 4-27). By using a stochastic approach, it was hoped to identify possible fast pathways that could significantly change our earlier result. Table 4-5 illustrates the results of this study, for ten different realizations of the Puye Formation. This result showed that given this model of heterogeneity, first arrivals of contaminants could appear at PM-4 in less than 100 years. The shorter travel times in this study are due to preferential transport through a heterogeneous medium.

None of these analyses considered the possible role of model parameter uncertainty on transport predictions. In particular, there was still concern about possible easterly-southeasterly pathways away from TA-16. Predictive analysis (Doherty et al. 1994) was used to explore the range of possible flow directions away from TA-16 that could be achieved by assigning a large number of combinations of permeability and recharge parameters, given the constraint that any model must still match measured heads and fluxes reasonably well. Figure 4-32 shows the results of this analysis, which found that only relatively small variations in flow directions were possible under variable model calibration criteria. The major caveat to this result is that it depends on the hydrostratigraphic framework model being accurate; the "true" uncertainty in flow directions is undoubtedly larger than that shown in Figure 4-32.

2. Siting a characterization well, R-13. One objective for R-13 was that it could eventually be used to monitor possible off-site migration within the regional aquifer of contaminants originating below Mortandad Canyon. Based on the similarity between ^{3}H data in alluvial and perched aquifer wells in Mortandad Canyon and in wells due east in Sandia Canyon (R-9, R-12, and O-1), a due easterly pathway had been proposed earlier. Numerical simulations, shown in Figure 4-33, suggested a slight southerly bend to flow directions due to pumping by PM-3, PM-4, and PM-5. This results in a steady-state flow field, which will tend to exaggerate the effects of pumping over what might be the effects of pumping at present. Based, in part, on these results, R-13 was sited along the LANL boundary, south of the due easterly flow path suggested by geochemical results.

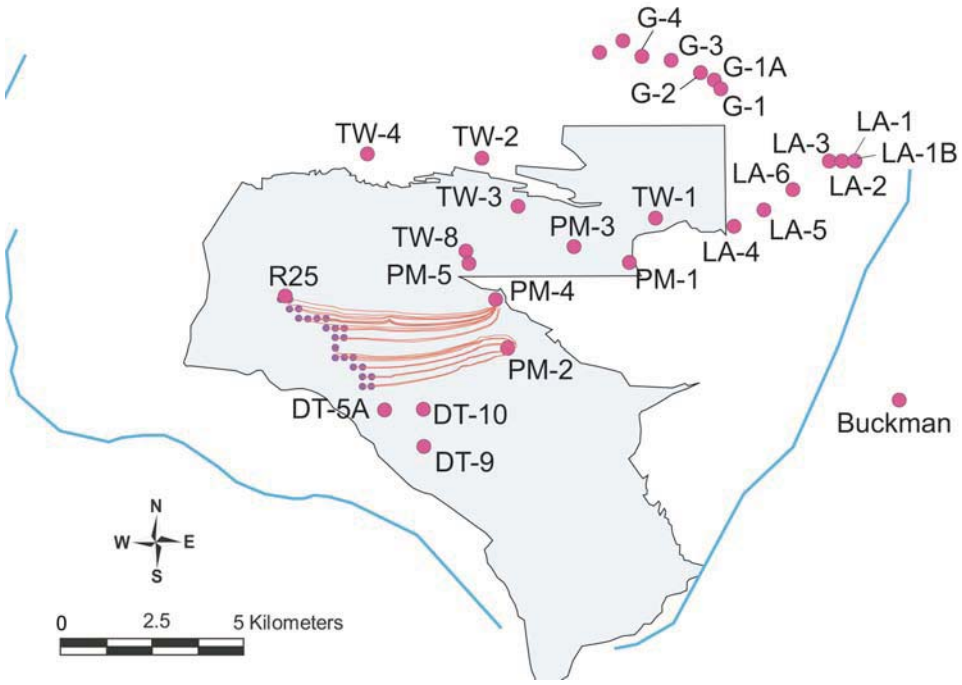
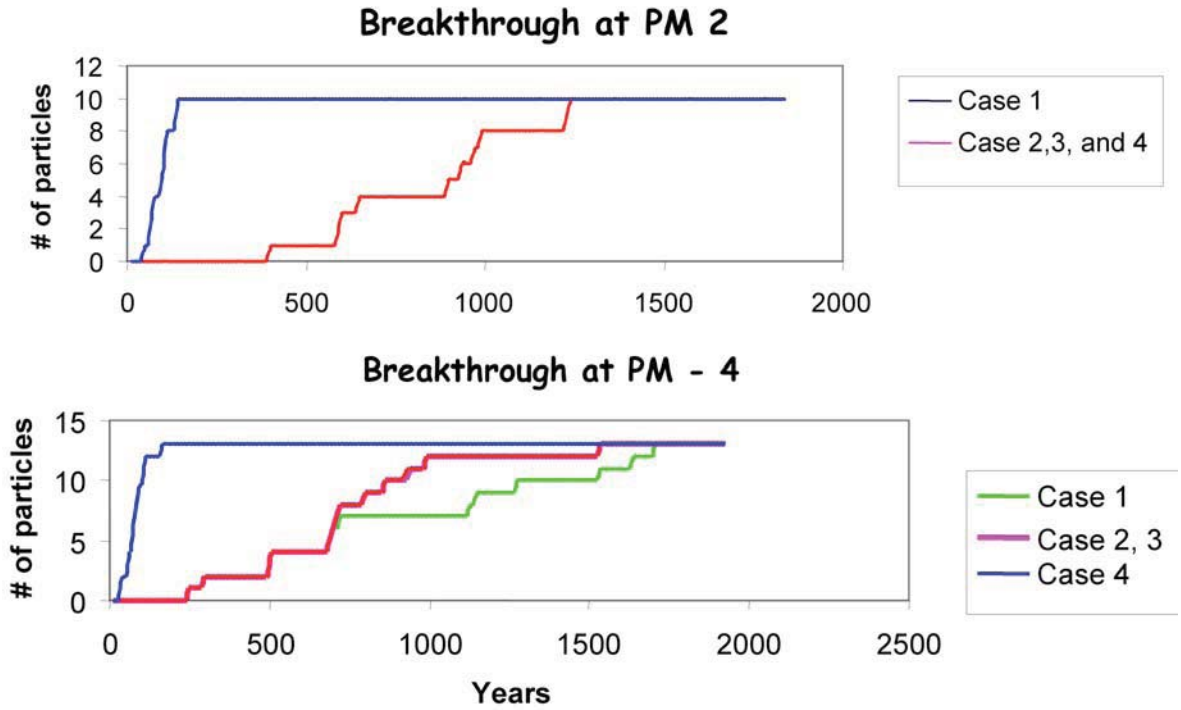


Figure 4-30. Predicted paths for particles released at TA-16 and beneath Cañon de Valle and captured at PM-4 and PM-2.



Note: Cases 1–4 represent different realizations of hydraulic conductivity.

Figure 4-31. Breakthrough curves for particles released at TA-16 and beneath Cañon de Valle at PM-4 and PM-2.

Table 4-5.
Travel Times Calculated Using Ten Different
Models of Hydraulic Conductivity within the Puye Formation

		Case 0	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
First Arrivals (yrs)	RG	420	320	390	340	340	350	360	370	650	840	920
	PM-2	N/A	250	120	110	200	NA	NA	200	NA	430	NA
	PM-4	120	100	100	90	80	100	90	100	150	180	210
Mean Arrivals (yrs)	RG	730.8	825.2	901.9	935.7	794.4	688.6	675.2	928.6	1229	1626	1569.6
	PM-2	NA	269.9	205.7	259	304.2	NA	NA	249.9	NA	430	NA
	PM-4	139.1	157.4	170.9	226.9	151.6	135.9	127.9	163.8	234	310	318.1
Standard Deviations of Arrivals	RG	201.7	254.8	312.7	379.7	226.1	211.1	213.1	247.7	345.6	478	392.6
	PM-2	NA	20	62.2	81.1	79.6	NA	NA	69.5	NA	0	NA
	PM-4	5.7	21.5	22.7	50.7	32.1	12.8	14.8	25	32.2	42.7	23.9
Percentage of Particles Captured (%)	RG	88.4	6.8	28.3	25.5	4.3	21.4	10.9	9	7	7.7	7.6
	PM-2	0	0.02	6.6	33.8	0.1	0	0	0.1	0	0.02	0
	PM-4	11.6	93.2	65.5	40.9	95.6	79.6	89.3	91	93	92.3	92.4

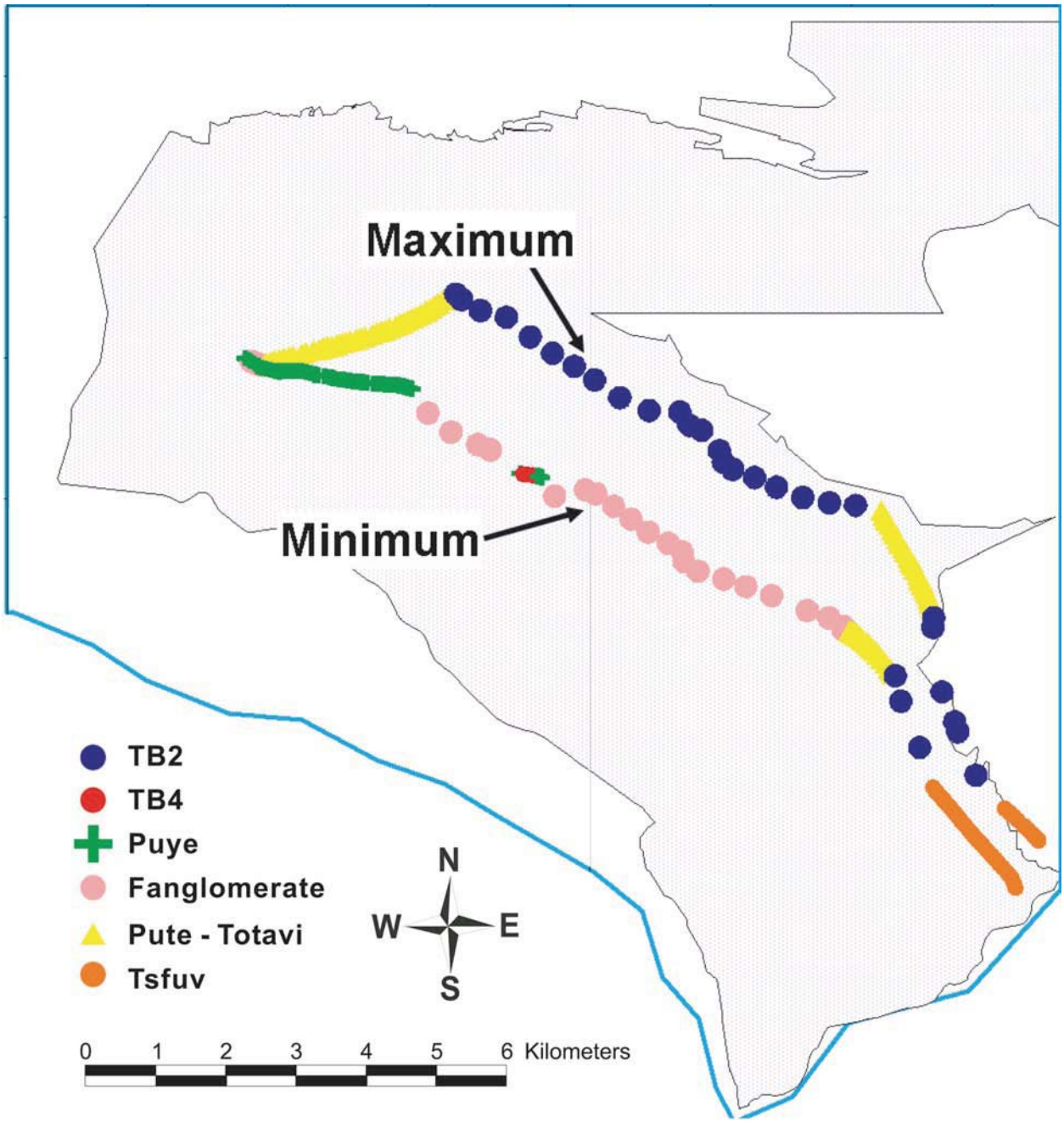


Figure 4-32. Results of predictive analysis, showing the possible range of flow directions (farthest northward and farthest southward) for sources at TA-16. Colors represent hydrostratigraphic units through which the water is flowing.

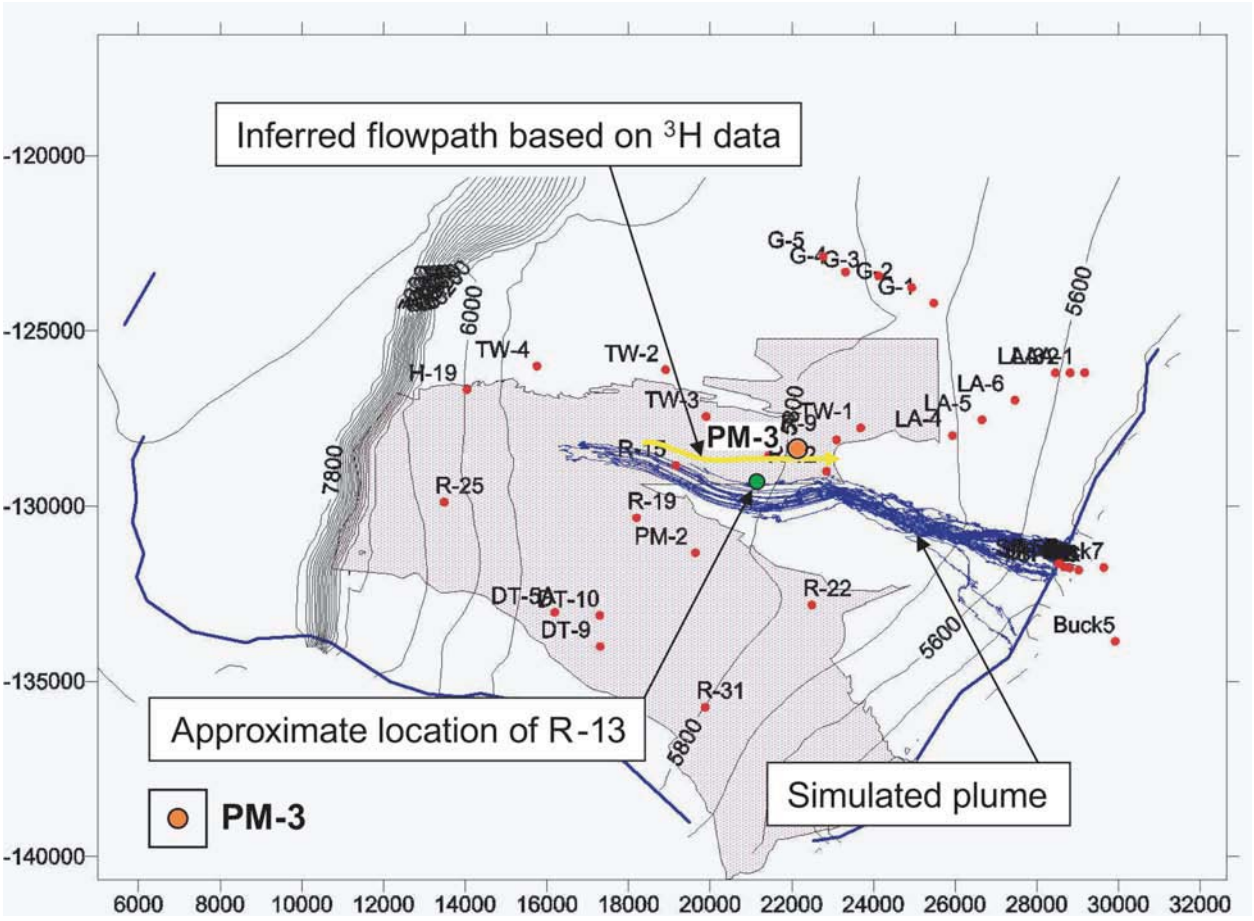


Figure 4-33. Predicted plume migration for sources released at the water table below Mortandad Canyon, based on a steady-state, with pumping, flow field.

Recent analyses of transient capture zones in the vicinity of Mortandad Canyon highlight the fact that flow directions and ultimate point of discharge change both in time and distance along the canyon. Solutes reaching the water table at early times (pre-1970s) and at easterly locations along the canyon probably moved to the east, under natural flow conditions and the pull of PM-1. Solutes reaching the water table at later times and further to the west will likely be drawn to the south. If the location and timing of contaminants reaching the water table is uncertain, the optimal monitoring network therefore will include both easterly and south-easterly monitoring locations.

3. Naturally occurring contamination. Some groundwaters in the Española Basin, including waters in the vicinity of LANL, are contaminated by naturally occurring arsenic, uranium, and flouride (McQuillan and Montes 1998; Purtymun 1977). Data collected in lower Los Alamos Canyon suggest that long-term pumping in water supply wells may increase concentrations of naturally occurring uranium (Gallaher et al. 2004).

Ongoing modeling studies, using the basin-scale model coupled with new water chemistry data collected in cooperation with Santa Fe County and the New Mexico Environment Department,

are attempting to understand the geochemical mechanisms that enhance dissolution of trace metals in aquifer rocks and the hydrologic mechanisms that may cause groundwater extraction to exacerbate the problem. Figure 4-34 illustrates an example model simulation, which simulates the spatial distribution of total dissolved solids in the basin. The prediction of a large area of high-salt water in the vicinity of Santa Fe has possible implications for water resource planning for that community, i.e., the cost of treating the high-salt water or finding alternate resources.

4.2.12.3 Category C: Provide guidance in prioritization of data collection activities, highlighting the importance of those data that could most reduce numerical and conceptual model uncertainty.

1. Reducing uncertainty in transport predictions away from TA-16. After the analysis shown in Figure 4-32 was completed, the model was used to determine how new monitoring wells might reduce the uncertainty in flow directions and travel times. Hypothetical wells were added with head data at five different locations near the particle path lines (shown in Figure 4-35) to determine the value of the head data in reducing pathway uncertainty. When the analysis was conducted, head data from R-25 were not yet available; therefore, head data at this well were not included in the analysis. Interestingly, of the five potential well locations, it was head data at R-25 that had the most benefit. The reason for this result is that information about the vertical component of the 3-D head field at R-25 helped the model determine the extent to which flowpaths are horizontal (fast) or three-dimensional (much slower).

2. Capture zone of PM-5. A similar methodology was used to determine the type of data that would be of most benefit to reducing uncertainty in the ability to predict the capture zone of PM-5 (Vesselinov et al. 2002b). A conceptual particle plume was released at a single location at the water table beneath Mortandad Canyon to simulate the transport away from the site. The calibrated model predicted that the particles traveling along the mean pathway would arrive at PM-5 (orange line, Figure 4-36). This model predicted that ~80% of the particles would arrive at PM-5. By varying recharge parameters and aquifer properties in a large number of possible combinations, within calibration constraints, a wide range of possible model predictions was generated. This analysis showed that parameter uncertainty was sufficiently great so that either 0% or 100% capture was also possible (blue and green lines, respectively, on Figure 4-36). Figure 4-37 illustrates the full plume migration in the 0% capture scenario. The analysis determined that better information on recharge rates in Mortandad Canyon would have the most benefit to reducing predictive uncertainty. The caveats to this study include the following: (1) possible recharge rates were not constrained to be within the bounds provided by existing studies of recharge, and (2) the method of modeling recharge probably overestimates the impact of local recharge on local head gradients.

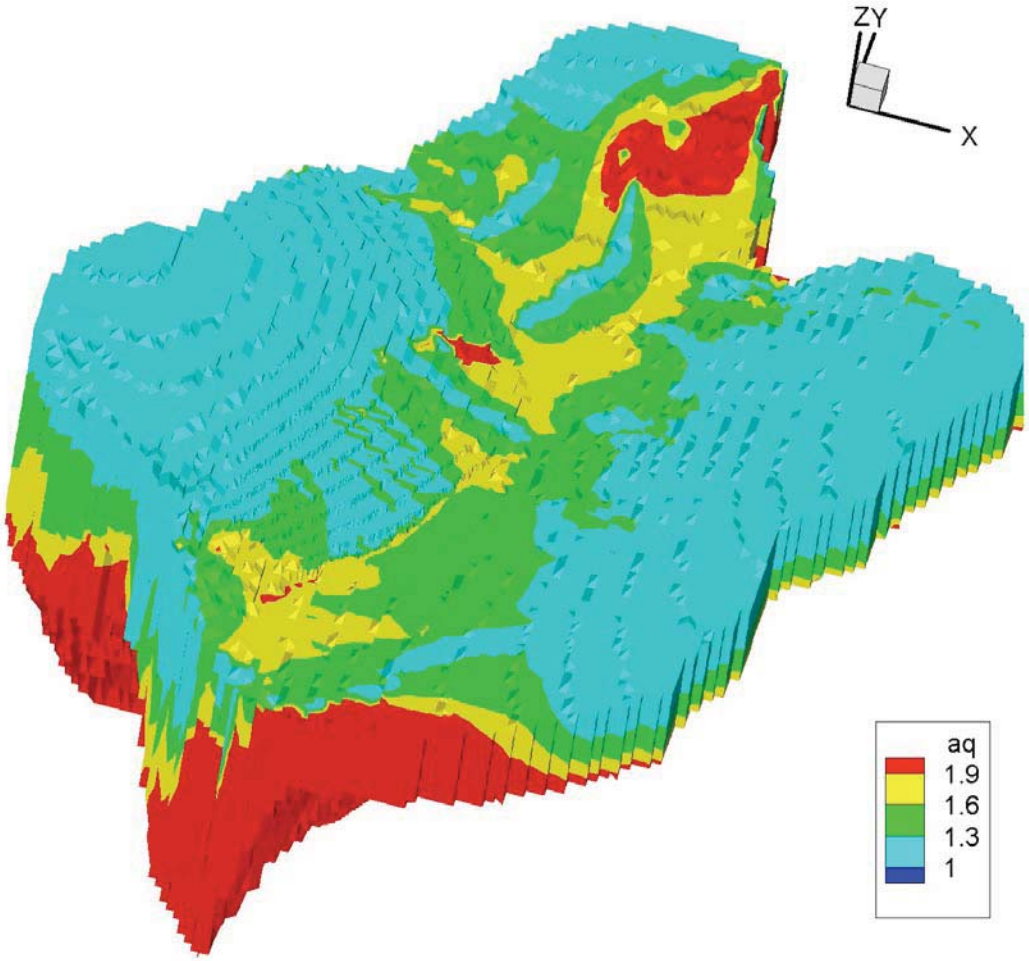


Figure 4-34. Predicted total dissolved salts in the groundwater at steady state, using a simple model of mineral dissolution. Red areas show the zones of relatively old water that are not mixing with fresh water.

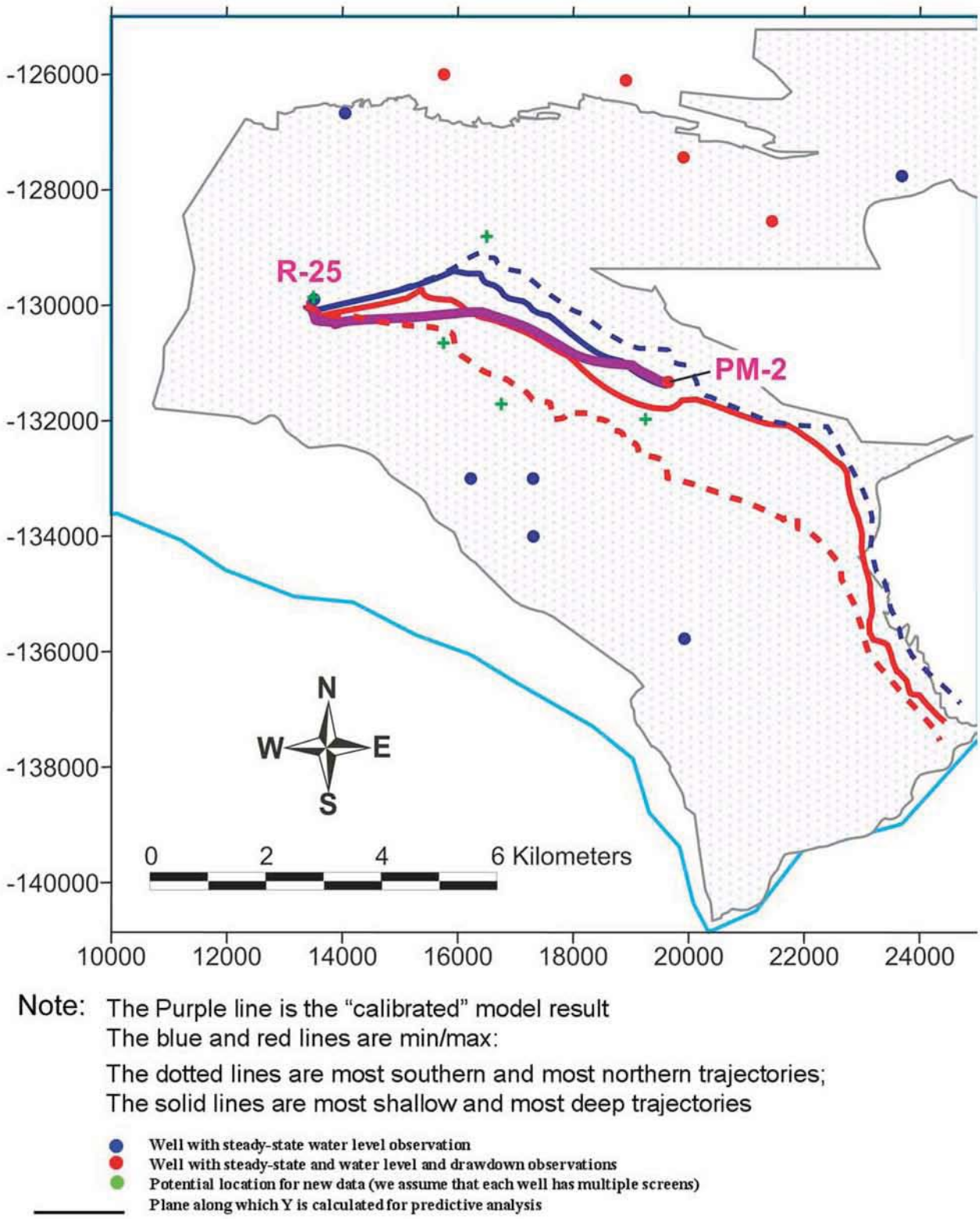


Figure 4-35. Location of hypothetical wells (green crosses) used to evaluate the potential value of head data in reducing uncertainty in flow directions. Solid and dotted lines show range of uncertainty in flow direction (north/south) and flow depth.

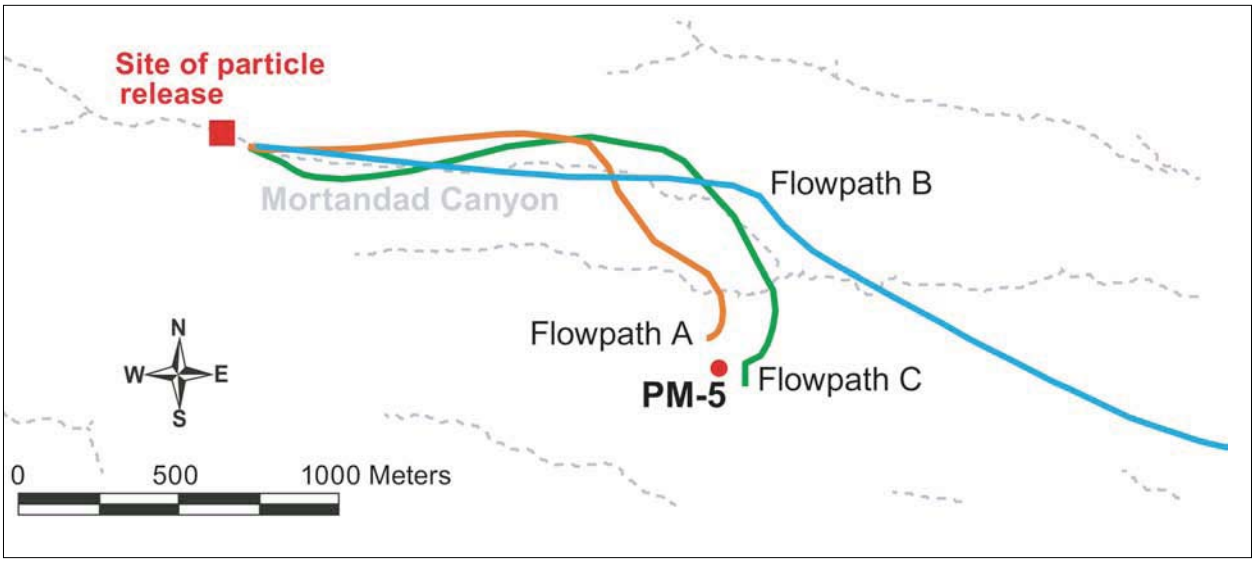


Figure 4-36. Mean flowpath for three simulations of plume migration away from Mortandad Canyon: orange-best calibrated model; green – maximum capture by PM-5; blue – minimum capture by PM-5.

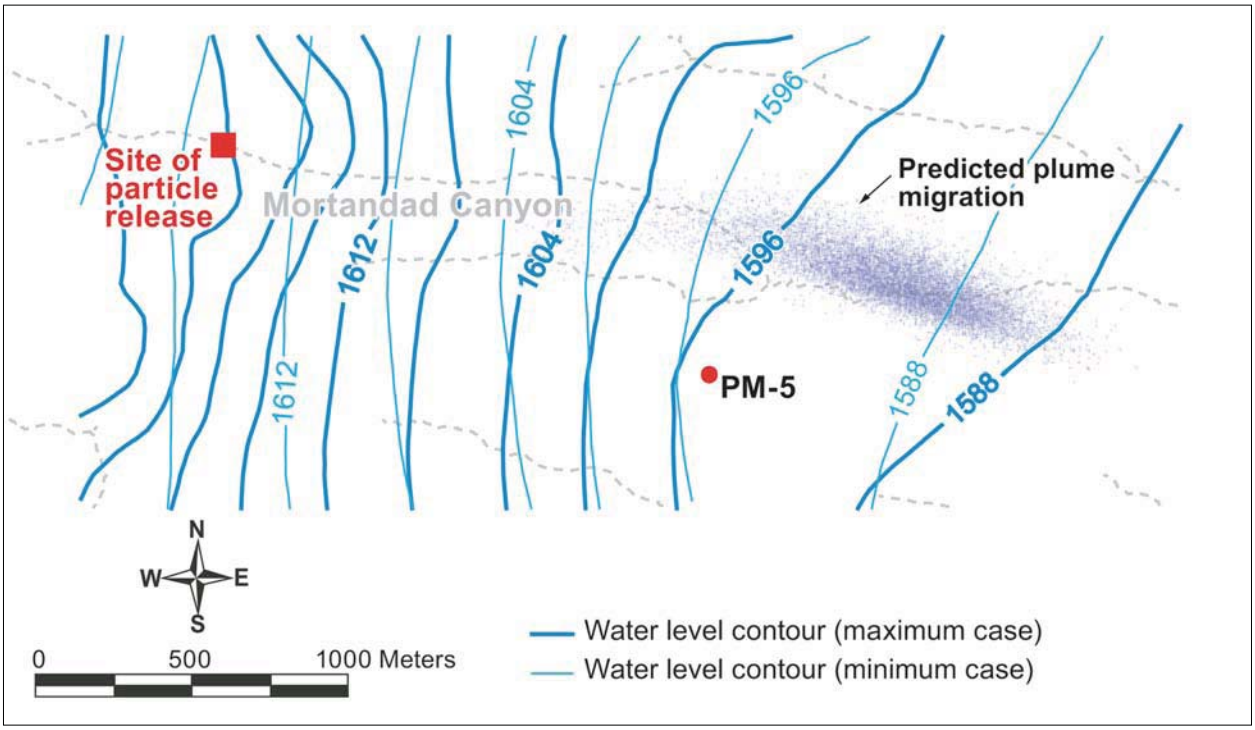


Figure 4-37. Illustration of plume migration for minimum capture by PM 5 (0%). Also shown are the two water table elevations predicted by the minimum and maximum cases.

3. Proposed pump test at O-1. The best way to characterize the hydraulic properties of the aquifer is to conduct a pump test with one or more monitoring wells. It was proposed that characterization well R-5 be drilled very close to O-1 so that a pump test could be conducted. A 2-D radial model was used, with the 3-D geologic model interpolated onto the grid to represent aquifer heterogeneity, to determine the optimal distance the characterization well should be drilled from O-1. Figure 4-38 shows the radial grid, and the predicted drawdowns as a function of distance from O-1, using a variety of model assumptions and parameters (8 cases). The range of suggested distances from the well that came from this analysis was 100–400 m. Ultimately, the well was sited at a greater distance for other purposes and no pump test was conducted. This test will be feasible when well R-3 is constructed closer to O-1.

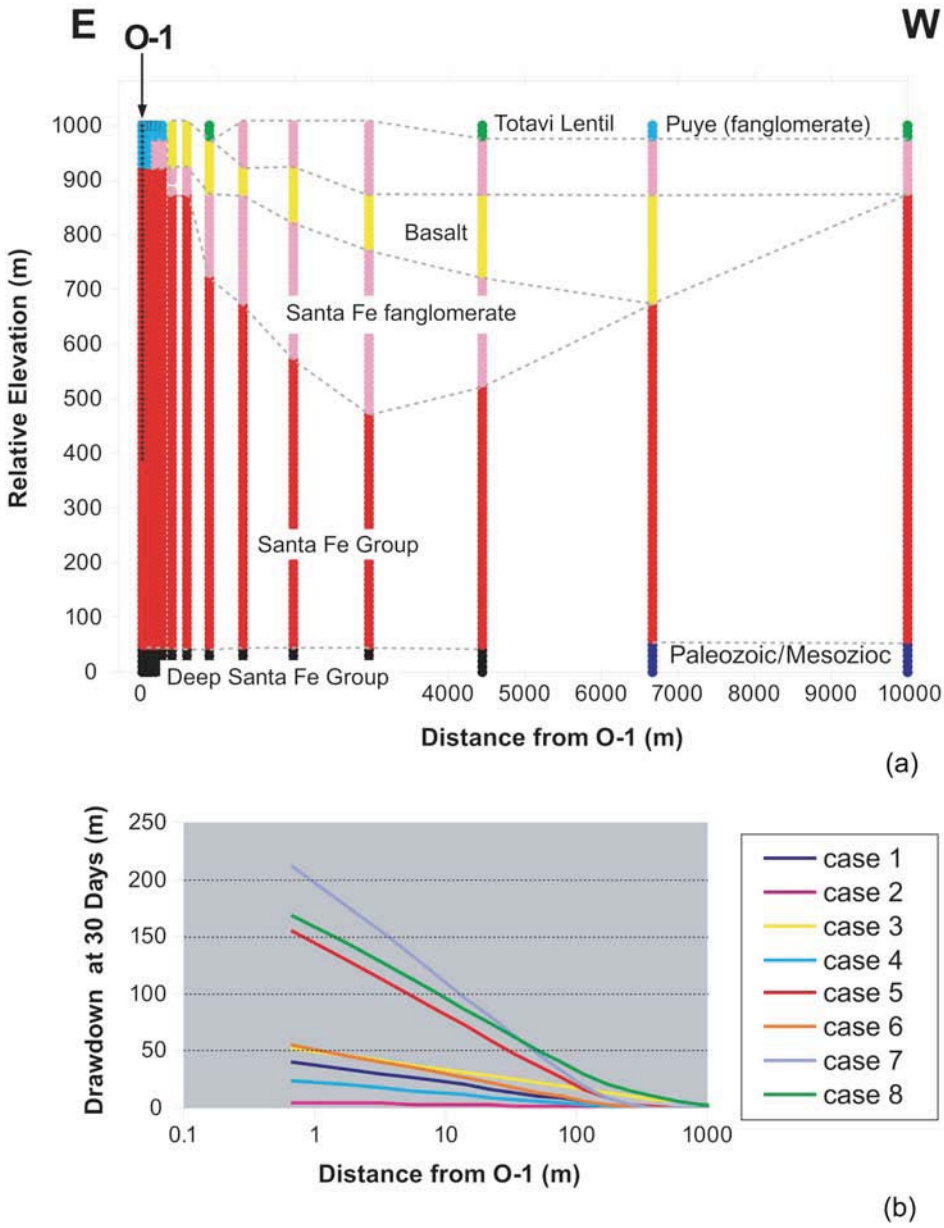


Figure 4-38. (a) Hydrostratigraphic units in the vicinity of well O-1, interpolated onto radial grid; (b) Predicted drawdowns at the top of the aquifer, for eight cases.

5.0 CONCLUSIONS

5.1 Summary

This report has described the geology, hydrology, and geochemistry of the Pajarito Plateau, based on empirical observations and modeling analyses. The purpose of this description is to provide a basis for evaluating and, and if necessary, designing an enhanced monitoring network capable of detecting contaminants. In order for a monitoring system to detect contaminants, an understanding of how contaminants reach groundwater and how contaminants move through groundwater is required. This section draws together the information present in the previous sections to establish a conceptual model of contaminant transport through the hydrogeologic system. This conceptual model is the basis for relating the work to evaluation of risk (Section 5.2) and the monitoring implications described in Section 5.3.

In overview, the contaminant transport conceptual model is one in which contaminants reach points of potential exposure in the regional aquifer only if the following conditions are met:

- Mobile contaminants have been released to the environment
- There are natural or anthropogenic water inputs to carry contaminants downward
- Vadose zone hydrogeologic controls are present, including enhanced infiltration and lateral pathways
- Flow-field modifications are present to influence transport of contaminants in the regional aquifer.

The following subsections draw together the observations and analyses that explain and support these conditions for contaminant transport.

5.1.1 Presence of Contaminants

Imprinted on the natural variations in chemistry is the presence of contaminants historically released since the early 1940s when Laboratory operations commenced. While the contaminants are at concentrations largely below regulatory standards or risk levels, they demonstrate the presence of pathways for groundwater flow and contaminant transport from the surface to deeper groundwater. The impacts to groundwater at the Laboratory have occurred mainly where effluent discharges have caused increased infiltration of water. The depth to which chemical constituents move in the subsurface is determined partly by their chemical behavior: nonreactive constituents move readily with groundwater, while reactive or adsorbing constituents move a shorter distance.

In most cases where effluent sources have been eliminated, groundwater concentrations of non-reactive discharged contaminants have decreased far below previous levels (e.g., nitrate, tritium, and perchlorate) in alluvial groundwater. These mobile contaminants move readily through the subsurface and are detected within perched intermediate zones and at the regional water table beneath several canyons, including Pueblo Canyon, Los Alamos Canyon, Sandia Canyon, Mortandad Canyon, and Cañon de Valle. In the case of reactive or adsorbing chemicals, the concentrations in the alluvial groundwater remain elevated significantly above background levels

after elimination of discharges or other contaminant source terms (e.g., excavation and removal of contaminated sediments). These include constituents such as strontium-90 and the actinides (americium-241, plutonium-238, and plutonium-239, 240) (Section 3.1.2).

Lateral flow and transport through surface water and in the alluvial systems are rapid with respect to other subsurface hydrologic processes on the plateau. Rates of lateral transport are even higher during surface flow events, which occur more frequently in the larger wet watersheds than in other areas of the plateau. Sorbing species transport slowly in alluvial waters and more commonly migrate down the canyon floor by sediment transport (LANL, 2004a; Lopes and Dionne, 1998; Solomons and Forstner, 1984; and Watters et al., 1983). Since some of the wet canyons that cross Laboratory land have received liquid-waste discharges from outfalls, the alluvial systems act as line sources for both water and contaminants to the deeper vadose zone beneath such canyons (Section 2.5.2.2).

Data for conservative (nonreactive) constituents (tritium, nitrate, perchlorate) in alluvial groundwater support the conceptual model that this groundwater has a short residence time and conservative contaminants do not accumulate in alluvial groundwater. The time-trend pattern for these contaminants shows a high level when they were being released, followed by a sharp decline in concentration to nearly nondetectable levels when the source was eliminated. Past values of tritium and nitrate in alluvial groundwater in DP, Los Alamos, Pueblo, and Mortandad Canyons exceeded the 20,000 pCi/L mean concentration level (MCL) (Rogers 1998). Because of improvement in effluent quality, values this high do not occur today in these locations (Section 3.2.3.1).

Data for adsorbing constituents (strontium-90, plutonium-239, 240) illustrate the conceptual model of contaminant adsorption onto alluvial sediments. The time- trend pattern for the adsorbing contaminants shows a decline in concentration when the source is cut off, followed by maintaining a fairly constant low concentration in the groundwater due to cation exchange. The highest measured strontium-90 activity was approximately 500 pCi/L in Acid Canyon surface water in 1960. With no present source, levels have dropped dramatically and strontium-90 is now consistently detected at low activities, below 1 pCi/L in alluvial groundwater (Section 3.2.3.1).

Data showing low levels of tritium activity in intermediate perched groundwater support the conceptual model that alluvial groundwater affected by effluent discharges is a principal source of recharge and contaminants for the intermediate perched groundwater. The highest values of tritium in intermediate perched groundwater are found where effluent discharges have occurred. Tritium time-series data also support a conceptual model that groundwater in the intermediate perched zones may have short residence time. In the absence of effluent discharge from TA-45 as a tritium source in Pueblo Canyon, tritium in the intermediate perched zone sampled by well TW-2A fell rapidly during the 1980s (Figure 3-13). This suggests that tritium associated with the former TA-45 treatment plant infiltrated the canyon floor and migrated vertically, at least to the depth of the intermediate perched zone at TW-2A, but had no continuing source when the TA-45 treatment plant was shut down (Section 3.2.3.2).

The distribution of tritium in the regional aquifer supports the conceptual model that surface effluent discharges have caused the instances where Laboratory contaminants are found at depth.

In most cases, the highest regional aquifer tritium values are found near where effluent discharges have occurred, but are much lower than values observed in overlying alluvial or intermediate perched groundwater. Elevated 3H in regional aquifer samples has been observed at wells O-1, TW-1, TW-3, TW-8, LA-1A and LA-2 (Rogers et al. 1996b), as well as in several wells drilled during the hydrogeologic characterization program (Section 2.7.3.1.1).

The fundamental condition that contaminants should have been released for groundwater contamination to occur is illustrated by the distribution of conservative (that is, nonreactive) groundwater contaminants. Generally, compounds like RDX, tritium, perchlorate, and nitrate move readily with the groundwater because chemical reactions do not retard the movement of these compounds or decrease their concentrations, although the activity of tritium does decrease due to radioactive decay. Semireactive constituents (uranium, strontium-90, barium, some HE compounds, and solvents) whose movement is slowed or their concentrations are decreased by geochemical processes and strongly reacting constituents (americium-241, plutonium, and cesium-137) that are nearly immobile are not found above background levels in intermediate perched groundwater or the regional aquifer (Section 3.2.1).

5.1.2 Water Inputs

Sufficient water input in a canyon system is a critical condition for transporting anthropogenic constituents. In most cases where Laboratory anthropogenic constituents are found at depth, the setting is either:

- Canyons where natural water input is high (Pajarito, Water, and Cañon de Valle)
- Canyons where anthropogenic water input is high (Pueblo, Los Alamos, Sandia, Mortandad)
- Mesa-top sites where large amounts of liquid effluent have been discharged (such as retention ponds or outfalls) (Cañon de Valle and Water canyons) (Section 3.2.2).

Wet canyons receive large runoff volumes, either through channeling of precipitation or through wastewater discharges. This runoff, in turn, creates surface-water flow along canyon bottoms, which subsequently infiltrates to form near-surface, alluvial water bodies (Section 2.4.2.1). The highest net infiltration rates are estimated to occur in canyons, especially those that head in the mountains, with magnitudes of up to a few hundred millimeters per year caused by channelized runoff. In contrast, much lower net infiltration rates occur across mesas and in the smaller canyons that head on the plateau (Section 2.4.2.1).

The infiltration rate estimates from canyon-bottom alluvium and mesa-top sites are consistent with the estimated infiltration rates inferred from moisture content profiles. In Section 4.1.3.2, numerical models for wells LADP-3 and LADP-4 in Los Alamos canyon are presented showing that moisture profiles reflect the conceptual model of high infiltration in canyons and low infiltration on mesas. That analysis also shows that the uncertainties associated with such estimates are quite high (in the range of a factor of 3). However, by combining moisture content, tracer or contaminant profiles, and water budget information, a more constrained estimate has been achieved (Section 2.5.1). The resulting net percolation rates beneath the alluvial systems of

wet canyons to the underlying unsaturated zone are expected to be among the highest across the plateau, approaching meters per year (100–1000 mm/yr) (Kwicklis et al. 2005) (Section 2.5.2.2).

The alluvial groundwater present in several canyons has a small volume relative to the annual volume of runoff or effluents, does not extend beyond the LANL boundary, and is generally completely refreshed by recharge on a time scale of about a year (Section 3.2.3.1). The Kwicklis et al. (2005) study shows that about 23% of the infiltration occurs from canyon bottoms on the plateau at lower elevations, including 14% of the total in streams that flow at least partly within LANL boundaries.

Although relatively small volumetrically compared to mountain recharge to the west, aquifer recharge occurring locally on the plateau is important to the assessment of flow paths of potentially contaminated water. Tritium data confirms that relatively young water is present in the aquifer (Rogers et al. 1996b), indicating fast pathways through the vadose zone beneath LANL. Kwicklis et al. (2005) used vadose zone occurrences of ^{3}H to estimate the time-dependent transport velocities from which they derived the infiltration rates to the regional aquifer. They found that, in Mortandad Canyon, infiltration rates as high as 2000 mm/yr during periods of large volumes of effluent discharge decreased to 100–200 mm/yr when effluent discharge flow rates were reduced. These observations and analyses confirm that local recharge in canyons is an important component of the recharge distribution for the plateau (Section 2.7.3.1.1).

The presence of water, either natural or from the discharge of effluents to canyons or mesa-top locations in the Laboratory's semiarid setting, initiates or increases downward percolation of water. Even under unsaturated flow conditions, this percolation may move significant volumes of water to the regional aquifer within a few decades.

5.1.3 Vadose Zone Hydrogeologic Controls

The third condition that controls the distribution of groundwater contaminants is the presence of vadose zone hydrogeologic controls. The controls considered most important in influencing contaminant distribution and transport are: near- surface circumstances that enhance infiltration, potential pathways in the vadose zone (e.g., basalts), and transport through intermediate perched groundwater.

Infiltration rate affects the movement of anthropogenic constituents from the surface to groundwater. As described in Section 2.5.3, undisturbed Bandelier Tuff has a very low infiltration rate. On mesas, the predicted travel times are variable, but for the most part are greater than 1000 years, ranging from 1000 to 5000 years on the eastern portions of the Laboratory to 20,000 to 30,000 years in the western region. Areas that have other geologic units (particularly basalt units or Puye Formation) or fractured units exposed in the canyon bottom have higher, or enhanced, infiltration rates. In addition, the vadose-zone thickness decreases with increasing distance down canyon, due to thinning of the Bandelier Tuff (Section 2.2.9). Where the Otowi Member of the Bandelier Tuff is thick, infiltration rates are quite low. However, on the eastern side of the plateau, the Otowi Member thins to 0 to 100 feet, reflecting both the general thinning of the Otowi Member away from its caldera source and thinning of the ash-flow

tuffs over the Cerros del Rio highland on the east side of the plateau (Section 2.2.9.1). The eastern portions of canyons with thinned or absent Otowi Member have enhanced infiltration. Infiltration rates of 1500 to 2000 mm/yr are estimated for the confluence of Los Alamos and Pueblo Canyons, a consequence of infiltration directly onto Puye fanglomerates or fractured basalts (Section 2.7.3.1.1.).

Enhanced infiltration is especially true for the eastern portion of deep wet canyons because their canyon bottom elevations are 45 to 60 m lower than smaller canyon systems on the plateau. Thus, the deepest canyons extend to stratigraphic horizons having higher infiltration rates because of increased fracture flow. Contaminants transported down canyon via surface flow or through the alluvial groundwater system often percolate through a geologic column consisting primarily of basalt and Puye Formation fanglomerate with little or no overlying tuff. Downward percolation is believed to be more rapid in the basalt than through moderately welded tuff (Section 2.2.8). Thus, these wet canyons have thinner vadose zones and a smaller portion of the flow path with matrix-dominated flow. Los Alamos and Pueblo Canyons have regions in the vicinity of their confluence in which the Bandelier Tuff is thin or nonexistent. Water infiltrates directly onto basaltic rocks or the Puye Formation, thereby yielding rapidly downward flow through fractures or preferential flow channels. The predicted travel times are especially short (5 to 10 years) in these locations (Section 4.1.2.1).

Other instances of enhanced infiltration include the Cañon de Valle and Water Canyon, where rates up to 1000 mm/yr are estimated for areas associated with the Pajarito fault zone. Anthropogenic alterations can also enhance infiltration, for example sediment ponds in Mortandad Canyon and ponds in Cañon de Valle.

In contrast to the Bandelier Tuff, the basaltic rocks clearly exhibit rapid flow through fractures and other fast pathways, so that the permeability of the matrix rock is essentially irrelevant to the rates of water percolation (Stauffer and Stone 2005). Fracture flow occurs because of the orders-of-magnitude lower matrix permeabilities of these rocks, compared to the Bandelier Tuff (Section 2.4.1). The upper surface of the Cerros del Rio basalt is irregular, with a broad highland that extends from north to south under the east-central portion of the Laboratory, largely buried beneath the Bandelier Tuff. The presence of the Cerros del Rio basalt in the vadose zone provides potential lateral fast pathways in the vadose zone (Section 2.2.8). These hydrogeologic factors, compounded by the relatively high deep-percolation rate in wet canyons, likely yield the fastest vadose-zone travel times for contaminants from the land surface of the plateau to the regional aquifer. Transport to the regional aquifer beneath wet canyons is predicted to be on the order of decades to hundreds of years (Section 2.5.2.2).

The water-quality impacts by effluent releases on alluvial groundwater extend in a few known cases to intermediate perched groundwater at depths of a few hundred feet beneath these canyons. Since the contaminated alluvial groundwater bodies are separated from the intermediate perched groundwater by hundreds of feet of dry rock, pathways within the vadose zone are likely present in those canyons. There are two end-member conceptual models for flow within an intermediate perched water zone:

- *Low-velocity, virtually stagnant water resting in a perching horizon within a local structural or stratigraphic depression.* Water percolates very slowly out the bottom of

this zone or spills over the sides of the depression. This configuration views perching horizons as barriers that slow the downward percolation of water. In several wells, intermediate saturated zones thought to represent perched groundwater were screened but failed to produce significant water. These occurrences may represent cases where zones of limited extent were substantially drained when the perching horizon was penetrated during drilling. Once the stagnant water is depleted in an initial round of sampling, there is insufficient recharge upstream to keep the zone saturated.

- *High-velocity, laterally migrating water that travels on top of the perching horizon.* This conceptualization suggests that once groundwater reaches a perched zone, it rapidly percolates laterally along high-permeability pathways until the perching horizon pinches out or is breached by high-permeability features, such as fractures or lateral changes in lithology. In this scenario, water could move in stair-step fashion from one perching horizon to another. There are no confirmed instances of large-scale, lateral vadose zone pathways beneath the Pajarito Plateau at depths greater than the alluvial groundwater. However, the case of lateral flow through the wet, mountain-front mesas at TA-16 suggests that this possibility does exist at greater depths. Although the TA-16 observations are categorized as shallow for the purposes of this discussion because they discharge via springs in the local canyons, it could be argued that deep pathways with flow geometries similar to those of the mountain-front mesa or today's alluvial groundwater zones are evidence for the possibility of deeper fast pathways elsewhere (Section 2.6.2.4).

The site-wide vadose zone transport model predicts that regions of relatively rapid travel times are present in the following canyons: Pajarito Canyon near White Rock, a portion of Cañon de Valle, Mortandad Canyon at the Radioactive Liquid Waste Treatment facility, middle and lower Los Alamos Canyon, large portions of Pueblo Canyon, and Guaje Canyon (Section 4.1.2.3).

Hydrogeologic controls influence movement of anthropogenic constituents through the vadose zone. The presence of geologic units that enhance infiltration, that act as pathways, or are conducive to perching groundwater and forming intermediate perched groundwater appears to be an important condition for groundwater contaminants to be transported to the regional aquifer.

5.1.4 Regional Aquifer Transport

Relatively little contamination reaches the regional aquifer from the alluvial groundwater bodies, and water quality impacts on the regional aquifer, though present, are low. Flow field modification is considered important in controlling anthropogenic constituent distribution in the regional aquifer. Anthropogenic constituents that enter the regional aquifer near pumping wells are predicted to have much shorter travel times than those outside the influence of pumping.

The LANL regional aquifer model was used to produce a map of velocities at the water table. These velocities are *highly uncertain* and are used only to illustrate a few key points. First, given the heterogeneous nature of the aquifer, groundwater velocity is likely to vary considerably over short distances. There are two areas with relatively high permeability ($K > 3$ m/day): the north-central aquifer beneath LANL (wells TW-2, R-4, TW-3, R-11, R-28, and R-13) and the south-central aquifer beneath LANL (R-19, screen 6, DT-10, DT-9) (Section 2.4.2.3).

The fastest velocities are in the basalts where fracture flow (very low porosity) is assumed. Basalt straddles the water table in two areas. The most extensive is located in the south-central part of the plateau, where as much as 195 ft of saturated Pliocene Cerros del Rio basalt occurs at the top of the regional zone of saturation in well DT-10 and 290 ft occurs in well R-22 (Figure 2-10). A smaller region of older Miocene basalts straddles the water table in a north-trending zone extending between wells R-12 to R-5.

Second, flow on the eastern portion of LANL is predicted to be *very* slow. This is due to the very low permeability of the Santa Fe Group, which is prevalent at the water table east of LANL (Section 4.2.12.1). The Tesuque Formation is the primary rock unit making up the regional aquifer in the eastern part of the plateau and in the Buckman wellfield east of the Rio Grande. Bedding within the Santa Fe Group and the Puye Formation is likely to cause higher permeability parallel to the beds than perpendicular to the beds. Large vertical head gradients measured in R wells are evidence of anisotropy. The beds within the Puye Formation range from centimeters to meters in thickness. Most are very low angle, dipping to the east. In contrast, beds within the pumiceous volcaniclastic rocks tend to dip to the southwest (R-20, R-2, R-7, R-19, and R-33). Beds within the Santa Fe Group exposed on the western margin of the plateau dip approximately 2–5° to the west (Golombek et al. 1983). Data from R-16 suggest that shallow layers are very low-angle, but deeper layers dip as much as 25° to the west. Hydrologic modeling and pump test analysis suggests that vertical permeability is 100 to 1000 times lower than horizontal permeability in the Santa Fe Group (Hearne 1985; McAda and Wasiolek 1988; Keating et al. 2003). (Section 2.4.2.3)

The regional aquifer conceptual model incorporates data from recent large-scale (30-day) pumping tests. Individual drawdown and recovery water levels in responsive wells demonstrate that the regional aquifer surrounding PM-2 is vertically anisotropic with pronounced resistance to vertical propagation of drawdown at shallower depths. Hydraulically, the aquifer behaves like a semiconfined aquifer at depth with leaky units located above (and perhaps below) a highly conductive layer (Section 2.7.5). It appears that there are water-table conditions near the water table, but leaky-confined aquifer behavior deeper down, although the degree to which the uppermost phreatic zone and the deeper, leaky-confined aquifer are hydrologically connected is unknown. The regional aquifer can be thought of as a compartmentalized aquifer with water from plateau recharge traveling laterally in the phreatic zone as the upper compartment and a lower compartment, which contains deeper groundwater flow as the leaky-confined aquifer that is isolated to some degree from the overlying compartment.

The contaminant pathways in the regional aquifer depend heavily on the strength of the hydrologic separation of the two compartments, which translates into how efficiently the pressure drawdown caused by the pumping wells propagates to the water table. Two conceptual alternatives are end members on a spectrum of potential configurations and thus capture the total potential variability.

- Weak hydraulic separation between the shallow (phreatic; water-table) and deep (leaky-confined; pumped) zones does allow pumping drawdown to reach the water table. Hydraulic gradients in the phreatic zone are affected by the pumping and contaminants

are drawn toward the wells. Contaminants are primarily predicted to arrive at water supply wells with a travel time of less than 50 years.

- Strong hydraulic separation between the shallow (phreatic; water-table) and deep (leaky-confined; pumped) zones does NOT allow the pumping drawdowns to reach the water table. Hydraulic gradients in the phreatic zone are NOT affected by the pumping. Contaminants are predicted to bypass the water supply wells and will arrive at the springs with travel time of about 200 years.

Compartmentalized flow with variably separated shallow and deep zones is supported by observations. The recent pumping tests suggest strong hydraulic separation exists, as described in the "strong separation" regional aquifer conceptual alternative. However, it is likely that some downward movement of water and contaminants does occur due to pumping of water supply wells at depth. Occurrences of tritium and perchlorate in O-1 illustrate the point that flow paths between the shallow and deep aquifer water can exist during production. This observation supports deeper pathways near water supply wells, conforming to the "weak separation" regional aquifer conceptual alternative. However, the extent of vertical transport is undoubtedly a function of the local permeability structure between the water table and the pumping interval in the water supply well, which may vary spatially across the plateau.

It is unclear whether it is important to monitoring goals to distinguish between these two alternatives. The first priority is to enable prediction of contaminant transport velocities sufficiently accurately to design an enhanced monitoring network and interpret the results. Either alternative results in lateral transport of contaminants reaching the water table, especially at locations relatively unaffected by municipal water well pumping. It is possible that the more strongly compartmentalized, two-zone aquifer conceptualization might yield more rapid contaminant transport near the water table, with transport pathways that are more lateral and less influenced by municipal water supply well pumping than the weak separation, more uniformly anisotropic case.

5.2 Relation of Hydrogeologic Workplan Results to Risk Assessment

The data, conceptual models, and numerical models resulting from work performed during implementation of the Hydrogeologic Workplan will be used, in combination with data gathered by the Environmental Restoration Program, to perform groundwater risk assessments for LANL-contaminated sites. The risk assessments will synthesize information (and uncertainty) about source term, vadose-zone flow and contaminant transport, and saturated-zone flow and contaminant transport to predict future health effects at receptor locations. They will be performed using a probabilistic approach that incorporates parameter uncertainty and variability, as well as conceptual model uncertainty. Data sets and site information gathered thus far will be used to define uncertainties in the form of parameter distributions and well-defined alternative conceptual models of groundwater flow and contaminant transport. These uncertainties will be propagated through groundwater models and then used in a risk-based decision analysis to identify and rank alternative actions to protect people from potential impacts of groundwater contamination from various release sites.

To construct the probabilistic risk assessment and associated decision analysis, several steps are employed. When using these steps we assume that we have already acquired general knowledge about the site. This assumption is, in general, valid for the main contamination issues on the plateau, based on background information gained during the Hydrogeologic Workplan and Environmental Restoration activities of the past 10 years.

1. *Define the question to be answered*. Examples of the questions might be, "What is the potential, future health risk for water users of municipal supply wells associated with historic effluent releases in canyon X? How can these risks be decreased?"
2. *Define input parameters and construct parameter distributions.* Estimates in the range of model input parameters are made based on field data, historic records and expert judgment. Example distributions might include uncertainty in contaminant masses released as a function of time in geologic and/or in hydrologic properties.
3. *Define conceptual models.* These could be related to source release, to vadose zone and groundwater flow, and to contaminant transport.
4. *Construct numerical models based on information from Steps 1 through 3*. Such models will generally include a vadose-zone and a saturated-zone model.
5. *Sample parameter sets to be used as input for a series of Monte Carlo simulations that capture the ranges of model and parameter uncertainties defined.*
6. *Run probabilistic flow and transport simulations using the numerical models and the parameter sets.*
7. *Use output from flow and transport simulations to calculate health effects or to answer other questions defined in Step 1.*
8. *Perform sensitivity analyses to determine parameters or conceptual models that produce model results indicating potential adverse health effects.*

Steps 2, 3 and 4 rely extensively on work performed for the Hydrogeologic Workplan. Predicted results are compared to field data (concentrations, heads, water content) to verify that model results are reasonable. In addition, in order to create regulator and stakeholder trust in this process and its results, stakeholder input concerning parameter distributions and conceptual models is encouraged.

Based on the sensitivity analysis described in Step 8 above, decision analysis is applied to define the optimal course(s) of action at a particular contaminated site. Such actions may include some combination of cleanup, stabilization, additional characterization, and monitoring. If additional characterization is identified as an action that can reduce risk, the sensitivity analysis yields information not only about which parameters should be better characterized, but also to what degree the uncertainty or variability in a specific parameter should be reduced. If the uncertainty were reduced to within the defined limits through characterization, then an updated risk assessment would calculate reduced risk. The decision analysis may help decrease the cost of future characterization by identifying parameters that do not need to be better characterized. Also, if experts feel that further characterization will not result in decreased uncertainty in a parameter identified in the sensitivity analysis, then that characterization effort might be rejected and an action with a higher probability of success may be pursued instead.

The generic process outlined above will be implemented on a canyon-by-canyon, or site-by-site basis in the future, using information learned from the Workplan and ER activities as a foundation. The conceptual, and for certain sites, numerical models will be formulated based on the knowledge gained and described in Sections 2 and 4 of this report. Thus, the past work becomes the springboard for future risk assessment and decision analysis activities related to groundwater at the LANL site.

5.3 Implications of Hydrogeologic Workplan Findings for Monitoring

The principal motivation for embarking on the Hydrogeologic Workplan was to provide the underlying scientific basis needed to make informed decisions regarding monitoring, remediation, or other actions to provide assurance that the groundwater beneath the Laboratory is protected. The site-wide approach taken in the investigation, both in terms of field-based characterization and modeling, has filled in many gaps in our understanding of the groundwater behavior and pathway directions and rates of migration of contaminants. Characterization wells were drilled for a range of objectives, from the collection of basic hydrogeologic information about the regional aquifer to serving as contaminant-specific and unit-specific sampling wells.

This investigation has led to a vastly improved conceptual understanding of the groundwater systems of the Pajarito Plateau: new concepts have been developed, and previous hypotheses have been confirmed or refined. Although wells have been drilled in a manner that does not preclude their being used in an enhanced monitoring network, the goal was to gather general information required to confirm or refine our conceptual models for groundwater flow and transport. Additional information may be necessary to predict contaminant transport in a particular setting: all sites are unique and require site-specific measurements to reduce uncertainties. However, armed with the improved understanding gained from the Hydrogeologic Workplan activities, we are now able to develop improved groundwater monitoring strategies or conduct more cost-effective detailed studies of individual canyons where initial studies have suggested that groundwater risk may exist.

In this section, we place the results of the findings of the Hydrogeologic Workplan into context by discussing the impact of the conceptual model elements learned in the study to the following questions: How does a particular conceptual model element impact -

- the design of an enhanced groundwater monitoring plan?
- the conduct of a detailed contaminant nature and extent study?
- the application of a remediation strategy?

5.3.1 Alluvial Groundwater

The alluvial system potentially provides a significant pathway for lateral transport at high velocity over great distances. Travel times on the order of a few years are expected in some canyons for contaminants to travel several kilometers from the release location. Tracer tests in Mortandad Canyon and contaminant migration measurements in Los Alamos and Mortandad canyons illustrate this point. A corollary is that within a few years of reducing the source term (reducing the effluent concentration, removing a solid source through remediation, etc.), concentrations of nonsorbing contaminants decrease due to flushing of the alluvial groundwater. These contaminants can enter the underlying vadose zone. Some contaminants such as Sr-90 travel much more slowly in the alluvial system due to retardation resulting from sorption. The contaminant inventory for these constituents is expected to reside mainly in the alluvial groundwater and on sediments (see Section 3).

A number of attenuation processes act to slow or impede the movement of contaminants, but ultimately the spatial extent of contamination within the canyon is limited by the distance traveled by surface and subsurface water. This distance varies seasonally with rainfall and runoff variability, and can be significantly changed from natural conditions by the input of anthropogenic water sources such as LANL effluent discharges or municipal water treatment facilities.

Alluvial groundwater is the potential source for water and contaminants to the deeper vadose zone. Percolation rates to the deeper vadose zone are temporally and spatially variable. Zones of preferential percolation exist, and it is difficult to predict their locations a priori. These zones are probably controlled by the nature of the hydrogeologic properties at the base of the alluvium, topographic conditions of the canyon, and the degree of fracturing of the underlying basement rock. For example, relatively high recharge is thought to be associated with fractures in Los Alamos Canyon near the Guaje Mountain Fault zone and in locations in the vicinity of the low-head weir, where water infiltrates directly into fractured basalts.

Implications of this conceptual model for nature-and extent studies, groundwater monitoring strategies, and remediation are:

- Long-term monitoring of the alluvial groundwater should focus on nonsorbing contaminants such as tritium, perchlorate, and aqueous HE compounds.
- To monitor changes in contaminant concentrations in response to changes in operations or after remediation, frequent samples must be taken to track progress.
- The absence of a contaminant known through historical records to have been introduced into a canyon likely means that the contaminant resides deeper in the system, and has been flushed out of the shallow system once the release was terminated.
- A relatively complete mass balance of released sorbing contaminants can be achieved by focusing on the alluvial sediments and groundwater.
- If a nonsorbing contaminant has been released for many years into a canyon, most of the inventory probably resides in strata below the alluvial system, so remediation techniques

such as permeable reactive barriers in the alluvial system will be addressing only a small fraction of the inventory.

- Sorbing contaminants are accessible to remediation technologies applied to the alluvial system. Technologies requiring a flux of contaminant, such as a permeable reactive barrier, are likely to work slowly, but may be useful, should some type of vadose zone remediation be required.
- In nature-and-extent studies for nonsorbing contaminants, zones of enhanced infiltration must be located using hydrologic studies to understand the different terms in the water budget. Surface water flow data, piezometric measurements of alluvial groundwater heads, and shallow borings that penetrate the underlying bedrock are useful to identify these zones.
- Numerical models of the surface-water/alluvial groundwater system are useful for constraining the estimates of percolation rates to the deeper vadose zone.

5.3.2 Vadose Zone

Transport velocities for nonsorbing contaminants in the deeper vadose zone (below the alluvial systems) are much larger in canyon bottoms than on mesa tops, suggesting that effluent discharges into canyons are the principle threats to the deep groundwater. Localized zones of high water flux from mesas are possible, such as in locations where the surface has been disturbed by human activities, or in faulted regions in close proximity to the Pajarito fault zone. However, most mesas show little, if any, evidence of transport of large quantities of contaminants to great depths. Numerical models of unsaturated zone transport in mesas are consistent with this observation.

Transport of contaminants from the alluvial groundwater zones to the deeper vadose zone can occur in two main rock types: Bandelier Tuff and basalts. Water percolates principally through the matrix pores in the Bandelier Tuff, but drains quickly through fractures and other open void space in the basalts. Fractures in the Tshirege Member of the Bandelier Tuff at the base of the alluvial systems probably serve as preferential pathways for downward percolation, but water quickly imbibes into the rock matrix, and matrix flow is even more likely in the more homogeneous Otowi Member. The subsurface location of contaminants in the vadose zone is controlled by the local percolation rate from the alluvial system. Although contaminants might be present in the rock pores along the entire reach of a contaminated canyon, the greatest quantities of nonsorbing contaminants will likely be present in zones of enhanced percolation. As discussed in the previous subsection, the locations of these zones are difficult to predict in the absence of detailed studies of the alluvial system.

Where Bandelier Tuff is present, travel times to the regional aquifer are controlled by the percolation flux and the total thickness of the underlying tuff units. Travel times through the tuff units probably range from a few decades to several hundred years. This means that most of the inventory of nonsorbing contaminants probably still resides in the vadose zone. In many vadose zone wells, the location of the contaminant front in the vadose zone has been located in the Bandelier Tuff. However, even where a well defined front exists, contamination is also found in deeper perched zones in the same well or in nearby wells. This suggests that a zone of higher percolation flux supplies the zone, and some lateral flow occurs. This lateral flow may be along

the canyon, but it is just as likely that the well is located nearby, but offset from the zone of highest percolation, and the lateral transport occurs a short distance perpendicular to the strike of the canyon.

Where infiltration occurs directly onto basalts, higher percolation rates are expected, along with much more rapid transport of contaminants to depth. Travel times through the basalts are expected to be a few years. Beneath the basalts and the Bandelier Tuff, the Puye Formation represents a highly heterogeneous vadose zone medium in which preferential pathways are likely. Travel times through the Puye Formation are therefore likely to be small for nonsorbing contaminants.

Sorbing contaminants are rarely detected at depths below the alluvial groundwater, even in locations where they were released coincident with nonsorbing contaminants that are found at depth. Retardation due to sorption is a key delay mechanism in the system. Detailed sampling has not been conducted in the few feet of rock immediately below the alluvial groundwater zone, but it is likely that any sorbing contaminants that have escaped the alluvial system have only migrated a very short distance into the bedrock.

Perched water is commonly found beneath naturally wet canyons or canyons with significant water input from anthropogenic sources. Generally, the perched water is not found to flow underneath the adjacent mesas, although data are somewhat limited. Perching is caused by low-permeability horizons: the downward percolation rate exceeds the saturated hydraulic conductivity of the perching horizon, and water collects or is diverted laterally. The degree of lateral flow within perched zones is uncertain. Lateral diversion will force contaminants to reach the water table at a different location than it entered the deeper vadose zone, but it is unlikely that this location will fall significantly outside the uncertainty zone defined by the alluvial groundwater zone. Travel times are not dramatically affected by the nature of flow in the perched zone. Travel times are controlled by percolation through the Bandelier Tuff, and the details of the flow path beneath these units are relatively unimportant in determining the total travel time to the regional aquifer. Finally, perching horizons provide a convenient means for monitoring the extent of transport of contaminants in the vadose zone.

Implications of this conceptual model for nature-and extent studies, groundwater monitoring strategies, and remediation are:

- Monitoring of the performance of waste sites located on mesas will probably turn up little contamination at great depth: sampling ports located in the vadose zone directly beneath the waste are probably required to detect contaminants. Given that regional aquifer monitoring to ensure the validity of this conclusion will probably be required, we should attempt to combine monitoring with characterization or other goals to maximize the utility of the well.
- Wet canyons with contaminants are the locations to focus monitoring.
- In zones where contaminants percolate directly into basalts, contamination has traversed the vadose zone, and characterization efforts should focus on the regional aquifer. Further characterization of nature and extent in the basalts of the vadose zone will not yield as

useful information in locations where contaminants have already reached the regional aquifer.

- Long-term monitoring of the intermediate groundwater should focus on nonsorbing contaminants such as tritium, perchlorate, and aqueous HE compounds.
- Sorbing contaminants can be checked on a less frequent basis because to date they have not traveled to significant depths, making the rapid breakthrough of high concentrations to the perched zones or the regional aquifer very unlikely.
- Given the range of travel times through the vadose zone, it is critical, if risk-based approaches are taken, that decision makers settle on the time period of regulatory interest. Without this definition, studies will not be appropriately focused, and misplaced characterization activities are likely to be the result.
- Although downward migration along the entire length of a wet canyon may occur, unequal percolation rates along the canyon lead to zones where greater depths of penetration of contaminated water has occurred, including all the way to the water table. Uncontaminated regional aquifer water at one location does not guarantee that the regional aquifer is clean at another location in the same canyon.
- Monitoring wells should be located near or downgradient of zones of preferential percolation determined from alluvial and vadose zone studies. In canyons posing significant risk, a higher density of shallow intermediate wells should be considered to pinpoint the preferential transport pathways than in canyons with lower risk potential.
- Given that the lateral displacement of contaminants in perched zones will not add large additional uncertainty to the location of contaminant arrivals at the water table, nor will travel times be much affected, there is no compelling reason to study in detail the nature of flow and transport in the perched zones if the regional aquifer water is ultimately of greatest interest for groundwater protection. Characterization of pathways closer to the surface is more cost effective and definitive, and should bound the lateral extent of transport above the regional aquifer.
- Contaminant inventories are likely to be small in most perched zones compared to the thick, unsaturated regions in which contaminated water is held in the matrix pores. Therefore, the perched zones are not good candidates for remediation by pump-and-treat methods because only a small fraction of the inventory will be accessed. An exception might be the large perched zone containing HE contamination at TA-16. If such a technique is attempted, better hydrologic characterization of the intermediate zones are required than we have obtained to date.
- Perched zones are targets of opportunity for acquiring contaminant concentration data, making them useful in nature and extent studies.
- Remediation of contaminants in the unsaturated rock of the vadose zone is not likely to be successful using available technologies. Water residing in matrix pores cannot be pumped, and most contaminants of interest are not volatile. Gas-phase nutrients could possibly be delivered to increase biological activity and induce bioremediation of organic contaminants, but the large spatial extent of contamination in the vadose zone probably renders such concepts impractical unless a single zone of preferential flow and transport is discovered.

5.3.3 Regional Aquifer

The regional aquifer represents the most likely groundwater accessible to humans via the municipal water supply wells and the springs that discharge at the Rio Grande in White Rock Canyon. The focus of this summary is on the elements of the conceptual model most directly connected to the migration of contaminants in the regional aquifer. Aquifer processes and measurements in the broader regional context were established in Section 2.7 and models were presented in Section 4.2.

Local recharge on the plateau on Laboratory property is a relatively small fraction of the total recharge, but is critical to understand for its implications for contamination from historical and current Laboratory operations. Some of the recharge focused along canyons contains contaminants from the Laboratory. This water potentially represents a source term for regional aquifer contamination.

To date, several observations have been made of contaminants reaching the regional aquifer. Conditions facilitating possible rapid downward migration to the regional aquifer are described in the previous subsections. High percolation rates, typically enhanced by anthropogenic water sources, and/or relatively thin or non-existent Bandelier Tuff at the surface are the conditions most likely to result in present-day regional aquifer contamination of nonsorbing constituents. Future contamination at additional locations is expected over a period of decades to centuries as more of the contaminant inventory reaches the water table.

There are no definitive observations of sorbing contaminants having reached the regional aquifer via a groundwater pathway. This fact further supports the concept of retardation due to sorption as the principal retardation mechanism for many contaminants.

Measured concentrations of nonsorbing contaminants in the regional aquifer are much lower than their concentrations in the effluent discharges or in the alluvial groundwater. This is the case even for samples collected near the top of the regional aquifer, where it might be expected that dilution due to dispersive mixing with regional aquifer water would not have taken place to as great a degree as further downgradient and at greater depth. Significant dilution of these plumes has occurred, assuming that samples are representative of the maximum concentrations and are not affected by mixing in the borehole. Borehole mixing and dilution is expected in municipal water supply wells, but is likely to be less prevalent in characterization-well samples with short screens.

Lateral flow directions in the regional aquifer are defined by the potentiometric surface constructed on the basis of new measurements in the shallow regional aquifer in characterization wells drilled during the characterization program. Flow directions are generally west to east or southeast across the plateau. Detailed gradients at scales smaller than the distance between wells are more uncertain, and might be affected by local recharge conditions and pumping of nearby water supply wells. Deeper in the aquifer, gradients and flow directions are uncertain due to lack of deep wells. Different conceptual models lead to either (1) easterly flow paths with water upwelling and discharging at the Rio Grande, or (2) more southerly flow

paths with water leaving the Española Basin via interbasin flow to the Albuquerque Basin. Data to distinguish between these two mechanisms are lacking.

Heads decrease with depth in most characterization wells on the plateau, and this condition is probably magnified by pumping of municipal water supply wells, whose screens are located well below the water table. While this condition might imply that contaminants at the water table should move downward, the hydrodynamics of the system are a function of the rock properties as well as the gradient. At some locations we find significant resistance to flow in the vertical direction, leading to compartmentalized zones that are connected only weakly to each other. Phreatic (unconfined water-table) conditions are present near the water table, whereas the aquifer exhibits behavior consistent with leaky-confined conditions at greater depths. The common observation of water-table conditions on the plateau, the depth-dependent response to pumping during multiple-well hydrologic tests, and the persistent head declines in the deeper aquifer in response to pumping are evidence of this behavior. More information is needed to determine if this is a ubiquitous feature of the aquifer.

This conceptual model means that contaminant transport pathways are not necessarily downward in the regional aquifer. In the extreme, a ubiquitous low-permeability barrier separating the phreatic zone from the deeper zone would render the downward component of the gradient meaningless: downward flow would be negligible, and contaminants hitting the regional aquifer would travel laterally along the streamlines defined by the potentiometric surface. The reality is almost certainly more complex, with thin (in the vertical), laterally discontinuous, low-permeability heterogeneities creating increasingly confined conditions with depth. In such a situation, pathways to the depths of water supply well screens are also likely.

Linear transport velocities are a function of the effective porosity of the medium as well as the groundwater flux. Porosity estimates are best made using interwell tracer tests, but these tests have not yet been conducted in the regional aquifer. Heterogeneous flow at larger scales will tend to result in lower effective porosity estimates than what is measured in cores or with borehole logging tools due to preferential flow. All else being equal, lower effective porosity leads to higher velocities and shorter travel times.

Implications of this conceptual model for nature-and extent studies, groundwater monitoring strategies, and remediation are:

- Contaminant detections in the regional aquifer are spatially variable, with detects and non-detects in the same canyon. Given that contamination has probably arrived at the regional aquifer only at a few locations, contaminant monitoring locations in the regional aquifer must be selected using an approach that integrates information of alluvial, vadose zone, and regional aquifer.
- More detailed investigations along canyons with risk-significant contamination are needed to pinpoint the spatial locations of the fastest pathways to the regional aquifer. Locations within or downgradient of these zones are good locations for contamination monitoring. The concept that the canyons are a line source of recharge is a good starting point, but more detailed information is needed to place monitoring wells.

- Contaminant detections in the regional aquifer will probably continue to be at low concentrations, and changes in time of these values will be gradual. Sampling frequency can thus be relatively long without missing important information.
- Long-term monitoring of the regional aquifer groundwater should focus on non-sorbing contaminants such as tritium, perchlorate, and aqueous HE compounds.
- Sorbing contaminants can be checked on a less frequent basis because to date they have not been detected with certainty in the regional aquifer.
- Contaminants reaching the regional aquifer most likely will travel laterally from their point of entry into the aquifer at the water table. Tortuous pathways to greater depths are also possible, with perhaps only a fraction of the contaminant taking this deeper path, and the rest continuing to travel laterally. Sampling screens in the shallowest portion of the regional aquifer are thus most likely to be well placed to detect contamination. Permeable zones within the first 100 ft or so of the regional aquifer should be the targets for monitoring locations.
- If the water discharging the regional aquifer at the springs in White Rock Canyon is principally water that recharged locally on the plateau, then continued monitoring of these springs for contamination is appropriate. Changes in concentrations are expected to be very gradual, so relatively infrequent sampling is sufficient.
- The extent of downward contaminant migration induced by water supply well pumping is uncertain, ranging from capture of the plume by the supply wells to a shallow, laterally migrating plume unaffected by pumping. Observations at O-1 prove that capture by a water supply well can occur. However, at other locations, weak or non-existent pressure responses in the shallowest screens to pumping from the deeper aquifer suggest that pathways may not exist that connect the shallow and deeper system.
- Given this variability and uncertainty, the concept of a "sentinel well," that is, a well designed to provide advanced warning of supply well contamination, will be difficult to implement. A shallow screen would miss a contaminant transport pathway in which the vertical downward migration occurs upstream of it, whereas a screen at the elevation of the producing zone might miss a vertical pathway located downstream of the monitoring well (including a situation in which the supply well itself is a pathway).
- Monitoring wells designed to be used as sentinel wells must attempt to provide coverage for both types of flow paths. Shallow screens will probably be the best sampling locations for water ultimately discharging at the Rio Grande.
- If pump-and-treat is proposed for a contaminant in the regional aquifer, the system should focus on the uppermost portion of the aquifer, where regional aquifer contaminants are known to reside. More detailed measurements of the hydrologic conditions in the shallow regional aquifer are required to better design monitoring or remediation systems.
- Pumping tests using the water supply wells to induce the pressure response are extremely informative, and should be continued as opportunities present themselves. Each pumped well provides information in the vicinity of that well, so to gain the site-wide knowledge needed, continued testing is required. The tests are not duplicative or redundant: rather, each test provides unique information.

- Tracer tests are the best way to determine the effective porosity of the medium at the field scale. This parameter is needed to convert groundwater flux estimates to a contaminant transport velocity estimate. The Puye Formation and the Cerros del Rio basalts are the most important units in which to conduct these tests, since these are the units encountered at the water table in regions where Laboratory contamination is a concern.
- The regional aquifer flow and transport model must continue to be improved by incorporating new data and concepts. Use of the model to interpret the hydrologic response of the system, to design and interpret the results of the future monitoring program, and in contaminant transport predictive studies requires that models keep up with the new data that will be collected. In the shorter term, available data sets not used in the model development to date, including the pumping tests discussed above, geochemical data, and thermal data, should be incorporated into updated versions of the model.
- For all modeling, including the regional aquifer model, continued exploration of alternative hypotheses should be continued. This statement applies for all aspects of the groundwater model, including those elements not obviously tied to questions of contaminant transport. Groundwater model development is a process in which feedbacks of changes in one portion of the system can affect model performance in unforeseen ways. A philosophy of continuous model improvement should continue to be used to enable higher fidelity predictions as improvements are made.
- Future studies should go beyond current approaches to include a data collection and modeling processes that make the greatest use of opportunities to investigate large portions of the aquifer. These opportunities may include: (1) passive monitoring of aquifer pressures in response to inputs (recharge) and withdrawals (supply well pumping) that occur as a matter of course; (2) incorporation of that information into refined versions of the regional aquifer model; and (3) increasing use of remote data that provides information on large-scale aquifer conditions and properties, including INSAR, airborne electromagnetic data, or gravity data, if initial investigations demonstrate that these techniques provide useful information.

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APPENDIX 1-A. REGULATORY FRAMEWORK

1-A-1. Hydrogeologic Workplan Background

The Hydrogeologic Workplan was intended to collect data necessary to comprehensively address DOE, federal, and state groundwater requirements. The groundwater requirements are for characterization and monitoring. The intent of the Hydrogeologic Workplan was to characterize the hydrogeologic setting to the degree necessary to evaluate the existing monitoring network and design an enhanced network, if necessary.

1-A-1.1. DOE Orders

LANL, in compliance with DOE Order 5400.1, published a Groundwater Protection Management Program Plan (GWPMP) on March 6, 1995 (LANL 1995a). A subsequent draft of the plan including revisions and dated January 31, 1996, was approved by DOE/AL on March 15, 1996 (LANL 1996a). The GWPMP provides background information on the hydrologic setting and programs in place at LANL; describes groundwater issues and solutions; and lays out business and implementation plans. The GWPMP concluded that the number and distribution of wells was insufficient to monitor the groundwater beneath LANL. The Hydrogeologic Workplan (LANL 1998) was intended in part to address the monitoring network issue by collecting data necessary to design an enhanced monitoring network.

1-A-1.2. RCRA Permit and HSWA Requirements

In 1986, the Environmental Protection Agency (EPA) authorized the State of New Mexico to operate a hazardous waste management program under the RCRA. The New Mexico Environment Department (NMED) issued a Hazardous Waste Facility Permit (Permit NMD890010515) to the Laboratory on November 8, 1989. At that time, both EPA and NMED retained administrative authority for the permit: EPA for the portions of the permit that were affected by the RCRA Hazardous and Solid Waste Amendments (HSWA) enacted in 1984, and NMED, for the parts of the permit that were unaffected by HSWA. In March 1990, the EPA issued a HSWA module to LANL's permit (known as Module VIII) and, in January of 1996, authorized NMED to act as administrative authority for that module. Thus in 1996 NMED became the sole administrative authority for the Laboratory's Hazardous Waste Facility permit.

The activities described in the Hydrogeologic Workplan support the appropriate Resource Conservation and Recovery Act (RCRA) and the New Mexico Hazardous Waste Act monitoring and corrective action decisions that have yet to be made at LANL. This investigation phase comes before and provides the basis for formal RCRA monitoring that may be warranted. The general RCRA requirements for characterization and monitoring are provided in the following sections.

1-A-1.3. RCRA Monitoring Requirements

LANL is currently in compliance with RCRA groundwater monitoring requirements. The monitoring requirements under RCRA are different for "regulated units" and for other "solid

waste management units" (SWMUs). This discussion will address both types of monitoring requirements.

RCRA Monitoring Requirements for Regulated Units

"Regulated units" are surface impoundments, waste piles, land treatment units, and landfills that received hazardous waste after July 26, 1982. The "regulated units" that remain at LANL and have not undergone clean closure (all hazardous waste residues and contamination have been removed) are

- Area G in Technical Area 54 (TA-54),
- Area H in Technical Area 54 (TA-54), and
- Area L in Technical Area 54 (TA-54).

(Note: Open Burning/Open Detonation units in the High Explosives corridor at LANL, although not considered "regulated units", once permitted may be subject to similar groundwater monitoring requirements as "regulated units" if they pose a threat to groundwater).

The monitoring requirements for regulated units are described in the RCRA regulations in sections 40 CFR 264.90 to 40 CFR 264.100. The monitoring for regulated units is divided into three structured, sequential monitoring programs: (1) a program for detection, (2) a program for compliance, and (3) a corrective action program. The requirements of these monitoring programs are summarized generally in Table 1-A-1. According to the regulations, monitoring of these units may be waived under the following conditions:

- The unit presents no potential impact to groundwater.
- The unit has been clean closed.
- The regional administrator/state director has granted a groundwater monitoring waiver.

Groundwater-monitoring waiver demonstrations for all of LANL's "regulated units" (including those that had not yet been clean-closed) were submitted to NMED in the 1980s and early 1990s. In May 1995, the NMED issued a letter to LANL indicating that there was insufficient information on the hydrogeologic setting upon which to base approval of the groundwater-monitoring waiver demonstrations, and the waiver demonstrations were denied (NMED, 1995a). By letter dated August 17, 1995 NMED required that a site-wide hydrogeologic characterization be completed that would satisfy both the RCRA "regulated units" and the HSWA module requirements. (Section III. A. 1 of the HSWA portion of the RCRA permit requires that the hydrogeologic setting be characterized) (NMED, 1995b). Thus, groundwater monitoring requirements for LANL's "regulated units" can be addressed by the completion of the site-wide hydrogeologic characterization described in the Hydrogeologic Workplan.

In response to the NMED letters, the Laboratory submitted the Hydrogeologic Workplan to NMED in 1996 and received NMED approval on May 22, 1998. The Hydrogeologic Workplan describes a 7-year characterization effort for groundwater on a Lab-wide basis with the objective of developing sufficient understanding of the hydrogeology to design an adequate detection monitoring network or to resubmit waiver demonstrations for some or all of the units.

Table 1-A-1.
RCRA Groundwater Monitoring Programs for Regulated Units

Monitoring Program	Triggered by	Purpose	Requirements	Definition	Result
Detection (40 CFR 264.98)	Required for all owners/operators of facilities that treat, store, or dispose of hazardous waste 40 CFR 264.91(4), unless exempt by waiver	Detect releases that are a threat to human health or the environment	Monitor for indicator parameters, constituents, or reaction products. Monitoring to be based on the type, quantity, and concentration of waste constituents in the unit; mobility, stability, and persistence in unsaturated zone; detectability in groundwater; and concentration in background	"Detected" defined as statistically significant evidence of contamination based on comparison of groundwater quality upgradient and unaffected by unit to groundwater that passes beneath the unit measured at the point of compliance	If "detected", institute compliance monitoring program
Compliance (40 CFR 264.99)	Whenever hazardous constituents to which the ground water protection standard applies are detected at a compliance point 40 CFR 264.91(1)	Document that a release from a unit is above a standard. Determine compliance with ground water protection standard	To determine whether regulated units are in compliance with the groundwater protection standard by monitoring constituents and their associated concentrations specified in the permit at the POC for the prescribed period. The groundwater protection standard specifies: list of constituents; concentration limits; point of compliance; period of compliance	"Exceeded" defined as statistically significant evidence of increased contamination	If ground water protection standard concentration limits are being exceeded, institute corrective action program
Corrective Action (40 CFR 264.100)	Whenever the groundwater protection standard is exceeded 40 CFR 264.91(2) & (3)	To ensure that corrective action has successfully brought regulated units into compliance with the groundwater protection standard	Requires action taken to prevent hazardous constituents from exceeding concentration limits and a groundwater monitoring program established to demonstrate effectiveness	Same as for Compliance Monitoring Program	If concentrations are being exceeded, re-evaluate corrective action

Monitoring Requirements for Solid Waste Management Units

The applicability of RCRA groundwater monitoring requirements to units not defined as "regulated units" at 40CFR264.90 (or subpart X units that pose a threat to groundwater) is described at 40 CFR 264.101. For these types of solid waste management units (SWMU), there are no specific monitoring requirements; however, preamble language suggests that repetitive monitoring may be necessary to determine the efficacy of a remedy in the event a release is determined to be a threat to human health or the environment. In addition, characterization to determine if a release to groundwater has occurred and to what extent, if any, such release threatens human health or the environment may be necessary. LANL's ENV-ERS Project conducts the investigations necessary to determine if releases have occurred and if a release represents an unacceptable risk to human health and the environment.

There is a requirement for hydrogeologic characterization at Section III.A.1 of the HSWA module of the RCRA operating permit. The work conducted under the Hydrogeologic Workplan was intended to fulfill this requirement for characterization, in addition to the requirements for "regulated units".

In summary, there are no RCRA monitoring requirements for SWMUs that are not "regulated units", unless a release requiring corrective action is identified through characterization. LANL was in the process of characterizing the hydrogeologic setting, identifying releases, determining the extent of any releases, and evaluating the risk posed by any releases through activities associated with the HWP and Module III of the HSWA module.

In 2005, NMED, DOE, and UC signed a Compliance Order on Consent (NMED 2005). The order replaces the site-wide characterization requirements of the Hydrogeologic Workplan with wells intended to investigate the nature and extent of contaminant releases from sources. The data and information gained through implementation of the Hydrogeologic Workplan are invaluable to planning and implementing the site-specific corrective action investigations required by the Order on Consent (NMED 2005).

1-A-2. Technical Objectives of the Hydrogeologic Workplan

As previously stated, the Hydrogeologic Workplan was developed in response to NMED letters requiring a better understanding of the hydrogeologic regime in order to evaluate the need for groundwater monitoring. Specifically, NMED identified four issues that needed to be resolved (NMED 1995b):

- Individual zones of saturation beneath LANL have not been adequately delineated and the "hydraulic interconnection" between these is not understood.
- The recharge area(s) for the regional and intermediate aquifers and any associated effects of fracture-fault zones with regard to contaminant transport and hydrology have not been identified.
- The groundwater flow direction(s) of the regional aquifer and intermediate aquifers, as influenced by pumping of production wells, are unknown.
- Aquifer characteristics cannot be determined without additional monitoring wells installed within specific intervals of the various aquifers beneath the facility.

In addition, the Hydrogeologic Workplan was intended to satisfy the characterization requirements in the HSWA module. Table 1-1 is a crosswalk of HSWA module requirements, how they have been addressed, and which sections of this report contain that information. The technical objectives of the Hydrogeologic Workplan were intended to be comprehensive with respect to groundwater regulatory requirements for characterization and potential future monitoring.

The questions posed by the NMED were large-scale hydrogeologic questions that were open-ended – it was unclear how much data would be required to resolve them. To address this issue, the Hydrogeologic Workplan focused the hydrogeologic investigations on information needed to understand potential contaminant transport and exposure from "aggregates": groups of potential release sites (PRS) that are geographically close and had similar waste-generating processes. The Data Quality Objective (DQO) process was employed to develop the data collection and analysis portions of the Hydrogeologic Workplan. The DQO process was developed by the Environmental Protection Agency to ensure that data collected are adequate for decision-making (EPA, 1994). The first step in applying the DQO process was developing a decision flow chart that specified the decisions for which data were necessary (Figure 1-A-1). The decision statements were in answer to the following questions:

- Are the alluvial groundwaters and uppermost subsurface waters at contaminant concentrations greater than a regulatory limit or risk level?
- Is the intermediate perched zone groundwater at contaminant concentrations greater than some regulatory limit or risk level?
- Is the regional aquifer, as affected by canyon systems, impacted by contaminant concentrations greater than some regulatory limit or risk level?
- What are the pathways for exposure to contaminants from sediments associated with alluvial groundwater and uppermost subsurface water?
- Are there sufficient source terms to cause contamination if moved along pathways to the regional aquifer within a compliance time frame?

The first three decisions are used to determine whether groundwater currently exceeds standards. The last two decisions establish whether pathways exist that may allow contamination to occur in the future. Each decision had several subordinate questions that required some data to answer. The decisions cannot be resolved until data sufficient to answer each subordinate question is available. For example, for the decision: "what are the pathways for exposure to contaminants from alluvial sediments and uppermost subsurface water?" the subordinate questions are as follows:

- Does significant recharge occur from near surface to underlying groundwater bodies?
- Do we know the hydraulic properties of the alluvium?
- What are the retardation factors of alluvial sediments?
- Do we understand groundwater movement from alluvial water to intermediate perched zones?

- Do we understand groundwater movement from intermediate perched zones to the regional aquifer?
- Are fractures and faults important contaminant transport pathways for liquids in canyons?

Although there were numerous subordinate questions and decisions, the data needed to resolve them were primarily water quality information from alluvial, intermediate, and regional aquifer groundwater, hydrologic properties, and geochemistry. Modeling tools were identified as critical to analyzing the data collected and to guide further data collection.

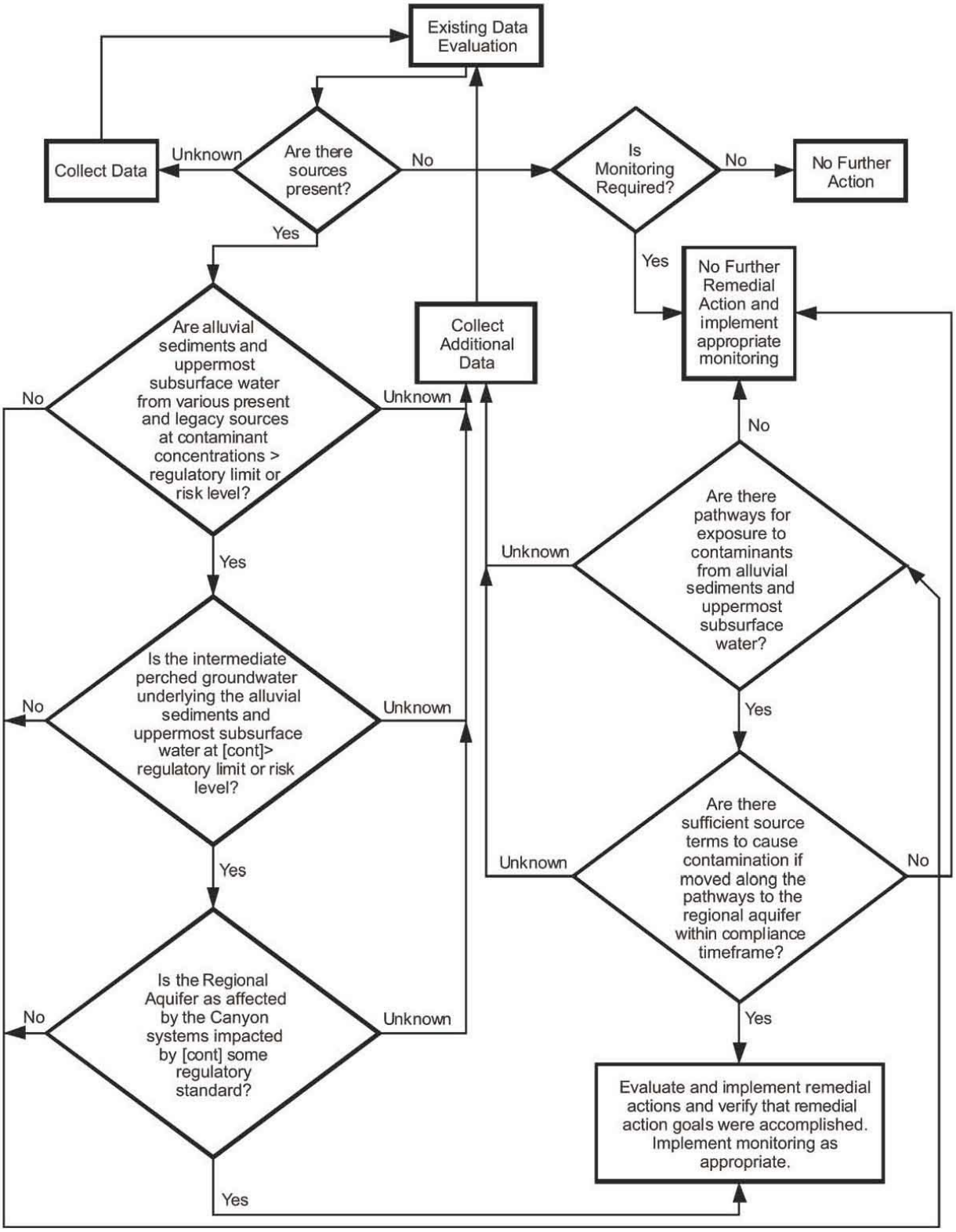

Figure 1-A-1. Flow chart used for hydrogeologic characterization decisions (LANL, 1998).

1-A-3. Hydrogeologic Workplan Data Collection Approach

The data collection approach described in the Hydrogeologic Workplan utilized an iterative approach that incorporated new information and data into the site conceptual model as it became available. This method enabled effective decision-making for aggregates to occur in the characterization process on a step-by-step basis. This approach was developed, in part, to resemble EPA's concept of the limit of the waste management area as described in the definition of the point of compliance. In this definition, it is acceptable to circumscribe several units with an imaginary line when locating the point of compliance, a vertical surface at the hydraulically downgradient limit of the waste management area at which the groundwater protection standards apply (New Mexico Annotated Code, Title 20, Chapter 4, Part 1, (20 NMAC 4.1) Subpart VI, 264.95(2)). The aggregate approach bounded similar areas in a manner that supported not only logical hydrogeologic characterization but process and regulatory application as well.

Eight aggregates were defined and data collection locations were selected to resolve the subordinate questions and decisions. In aggregates where there were existing data and known contaminant sources, wells were placed where they were most likely to encounter contaminants and to assess contaminant transport pathways. In aggregates with little existing hydrologic data and known contaminant sources, wells were located proximal and down gradient from contaminant sources. In aggregates where there were little existing data and small or no contaminant sources, wells were placed to reduce uncertainties in the hydrologic setting and to confirm the assumption of no groundwater impact.

The original Hydrogeologic Workplan proposed to characterize the hydrogeologic setting by drilling, logging, installing, and sampling wells to the regional aquifer without installing separate intermediate-depth wells. This approach was expected to provide the greatest amount of characterization data and was agreed to by NMED, as documented in a letter sent to NMED (LANL 1996b). This approach was formulated based on the following technical rationale:

- The presence of intermediate zone(s) is controlled by geologic structure and the geology across LANL is extremely variable. Understanding the geologic setting from the surface to the regional aquifer is more important in predicting flow than measurements in individual intermediate zones.
- If a well were installed at the first intermediate zone encountered, there would be a gap in the information between the upper intermediate zone and the top of the regional aquifer. Furthermore, wells installed in the first intermediate zone will not provide any information on the underlying less permeable perching layer. The characteristics of the perching layer must be understood in order to assess the impact to the regional aquifer. The perching layer stratigraphy is as important to evaluating potential pathways as the hydrologic characteristics of the saturated zone itself.
- The data collection described in the Hydrogeologic Workplan is intended to characterize the hydrogeologic setting to a sufficient degree to develop an adequate detection monitoring system or groundwater monitoring waiver, if appropriate. Wells that may be needed to monitor the intermediate zone(s) will be considered as part of the monitoring system design.

1-A-3.1 Revision to Hydrogeologic Workplan Data Collection Approach

The characterization approach was modified as the Hydrogeologic Workplan was implemented. A major drilling program change was prompted by an NMED letter (NMED 1999) with two key points: (1) water samples taken from boreholes during the drilling operation would not be adequate for regulatory decisions; and (2) perched zones did not have to be sealed off during drilling, but could be left open until the well was constructed. The practical result of these requirements was that intermediate perched zones could not be characterized by obtaining one sample during drilling. Instead, a dedicated sampling location must be installed to characterize the intermediate perched zones over time. Initially, wells that encountered intermediate perched zones were built with multiple completions. Eventually separate intermediate wells were constructed to be able to monitor the intermediate perched zones. The second point in the 1999 NMED letter, to be able to leave intermediate perched zones open, allowed the wells to be drilled faster because there was no longer a need to telescope down well casing sizes to seal off intermediate perched groundwater zones.

Another modification from the Hydrogeologic Workplan was the use of fluids in drilling. The original Hydrogeologic Workplan called for drilling with no additives in order to collect pristine samples while drilling. The earliest wells were drilled using air-rotary drilling methods with casing advance and the minimal use of fluids other than air. Because of significant problems associated with stuck casing, unstable boreholes, and lost circulation, small amounts of drilling fluids were used to improve lubricity, borehole stabilization, and cuttings circulation. Continuing drilling problems made total reliance on air-rotary drilling with casing advance impracticable for meeting drilling objectives. It became apparent that the depth of the wells and the difficult drilling environment required that more drilling techniques be added to the drilling "tool box" in order to respond to the complex hydrogeologic conditions that characterize the Pajarito Plateau. All of the drilling methods used at LANL are used in standard environmental industry practice and are described by the American Society for Testing and Materials (ASTM). Table 1-A-2 briefly describes the drilling methods used since the beginning of the drilling program.

1-A-3.2 Alluvial Groundwater Investigations

Beginning in the mid-1990s, detailed investigations were begun for the ENV-ERS Project, which is driven by the Laboratory's HSWA module to the RCRA operating permit. The first watershed investigation to be implemented was in the Los Alamos and Pueblo Canyon watershed to fulfill request for information requirements presented in the Task/Site Work Plan for Los Alamos and Pueblo Canyons, OU 1049 (LANL 1995b) and the subsequent addendum, Surface Water and Alluvial Groundwater Sampling and Analysis Plan (LANL 2002). The watershed-scale investigations conducted under the ENV-ERS Project are designed to collect data sufficient to evaluate human-health and ecological risk at a watershed scale. In accordance with existing canyons work plans, the Compliance Order on Consent, and the Federal Facility Compliance Agreement for storm water, surface water and alluvial groundwater investigations are conducted in a coupled manner in order to facilitate the development of conceptual models of the relationship between these waters.

Table 1-A-2.
Drilling Methods Used for Hydrogeologic Characterization Wells at Los Alamos National Laboratory

Drilling Method	Description	Benefits	Drawbacks
Air rotary ASTM D5782-95; D5781-95 (ASTM, 2000a; ASTM, 2000b)	A drill pipe or drill stem is coupled to a drill bit that rotates and cuts through soils, alluvium, and rock. The cuttings produced from the rotation of the drilling bit are transported to the surface by compressed air or by compressed air augmented by municipal water mixed with drilling additives. In conventional air-rotary drilling, the compressed air is forced down the borehole through the drill pipe and returns to the surface up through the annular space. In reverse air rotary, a dual tube drilling system is used and drilling fluids are forced down the outer tube and return up the center tube, where the cuttings are discharged through a cyclone velocity dissipater. The circulation of drilling fluids not only removes cuttings from the borehole but also cools the drill bit.	The air rotary drilling method, employed in an open hole, is the fastest and least expensive drilling method in the unsaturated zone. It is best suited for stable, hard rock formations with good circulation characteristics (in which there is minimal loss of fluids into the formations). Open hole drilling allows for the collection of an extensive suite of geophysical logs for the characterization of hydrogeologic properties.	Experience gained in the early part of the drilling program showed that air rotary drilling in an open hole is not always a suitable method for drilling at depths greater than 150 feet below the regional aquifer water table. The use of municipal water with drilling additives is almost always required to improve borehole stability and circulation of cuttings. Use of these drilling fluids can alter the natural properties of the rocks and it is not possible to collect pristine water samples while drilling. Generation of dust at the surface is a problem unless dust-suppression equipment is used and/or municipal water is added to the circulation fluid.
Casing advance ASTM D5876-95 (ASTM, 2000c)	Air-rotary drilling using an under reamer cutting system (rotary bits or downhole hammer) to create a hole large enough for a heavy-walled casing to slide down behind the drill bit. The casing is advanced simultaneously while drilling the hole. Compressed air or compressed air augmented by municipal water mixed with drilling additives is used to remove the cuttings from the bottom of the borehole. When the borehole has reached total depth, the well is constructed inside the heavy walled casing, as the casing is incrementally removed.	The drill casing stabilizes the borehole when drilling through poorly consolidated materials and improves circulation in highly porous or fractured rocks. The cased hole provides a stable environment for the construction of the well. There is relatively little disturbance to the borehole walls and relatively undisturbed samples of rock and water are obtained during drilling.	The heavy-wall casing frequently becomes stuck and is difficult to extract from the borehole. Casing that can not be extracted must be abandoned in the hole, possibly impacting the use of some well screens. The cost is high and drilling rates are often very slow. The use of municipal water with drilling additives is almost always required to provide lubricity between the casing and the borehole wall and to improve borehole stability and the circulation of cuttings. Use of heavy-walled casing severely limits the geophysical methods that can be used for hydrogeologic characterization.
Mud rotary ASTM D5783-95 (ASTM, 2000d)	A bit is rotated to cut through the rock while mud is the circulating fluid pumped down through the drill pipe and returned back up the borehole through the annular space. The mud-filled hole stabilizes the borehole wall and cools the drill bit. Circulation of the mud carries the cuttings up to the surface.	Rapid and effective drilling methods. Can be used to maintain borehole stability in poorly consolidated sediments of the saturated zone. Open hole drilling allows for the collection of an extensive suite of geophysical logs for the characterization of hydrogeologic properties.	Does not work well in vadose zone due to lost circulation zones in fractured basalts and in highly porous tuffs and sediments. Masks the recognition of water-bearing zones while drilling. Slow circulation of mud mixes cuttings from throughout the borehole, hampering geologic characterization. Addition of drilling muds and fluids changes the geochemical environment around the borehole. Requires extensive development to remove residual muds and drilling fluids, and to restore the aquifer's hydraulic and geochemical properties to natural conditions.

The scope of investigation in the Los Alamos/Pueblo watershed (other watershed work plans have similar scope) consisted of 4 sampling rounds collected through one year across a representative range of hydrologic conditions (e.g., higher water levels and more extensive saturation typical of spring snowmelt conditions; and low groundwater levels that commonly occur in the fall), detailed water-level measurements collected using dedicated pressure transducers, measurement of field parameters, a water balance study, and field observations on extent and persistence of surface water. These data were used to develop a conceptual model to describe the occurrence and temporal context of groundwater contamination in support of the risk assessment. The report for the Los Alamos and Pueblo Canyon investigation was submitted to the NMED in April, 2004. The Mortandad Canyon investigation is underway, and the report is scheduled for completion in 2006. Subsequent watershed-scale investigations will be completed in order of priority.

1-A-4. Independent Peer Review of the Hydrogeologic Workplan

In 1999, an External Advisory Group (EAG) was formed to provide an independent review of the implementation of LANL's Hydrogeologic Workplan. The EAG consisted of six members with diverse technical and professional backgrounds to provide a broad technical and managerial review of LANL's Hydrogeologic Workplan activities and methods. The EAG was provided semi-annual updates on the program status. The EAG provided a report of findings and observations based on the semi-annual reviews (External Advisory Group 1999a, 1999b, 2000a, 2000b, 2001a, 2001b, 2002; External Evaluation Group 1998). In response, action plans were developed that specified how the recommendations of the EAG were incorporated into the program.

In addition to the semi-annual reviews, the EAG provided technical assistance when requested. In FY99, two EAG members provided invaluable assistance in repairing the well R-25 collapsed screen #3. Numerous problems encountered in the repair process were overcome with the advice and guidance of the EAG members. The "hands on" assistance was critical in completing the characterization well.

1-A-5. Outreach Activities

The original Hydrogeologic Workplan (LANL 1998) specified a communications approach that included three quarterly meetings, one annual meeting, and an annual status report to update regulators on the characterization progress. The primary purpose of the quarterly meetings was to report on progress and findings from the previous quarter. The annual meeting was intended to provide more of a synthesis of data collected in the previous year and to allow regulators to provide their input to the planned activities for the coming year. One objective of the annual meeting was to reach a DOE, LANL, NMED consensus on the activities for the following year in time to influence budget requests. The annual report was published as a prelude to the annual meeting and provided the written synthesis of the data collected and interpreted over the year. The first annual meeting was held in March 1998 and participants were limited to representatives of the DOE, LANL, and NMED. Annual meetings were held in 1999, 2000, 2001, 2002, 2003, 2004, and the last annual meeting was held in 2005.

Extensive information has been presented and discussed with regulators and the public in several ways since the Hydrogeologic Workplan was completed in 1997 (Table 1-A-3):

- Three quarterly meetings and one annual meeting held every year (27 documented meetings) with distribution of meeting minutes to an extensive mailing list
- Annual status reports summarizing the work accomplished in the previous year
- Well completion reports
- Geochemistry reports
- Hydrologic testing reports
- Water quality data, which are available over the internet at http://wqdbworld.lanl.gov.
- Annual environmental surveillance reports, which provide the analytical results of surface water and groundwater sampling at LANL and in northern New Mexico.

Table 1-A-3.
Documents Relevant to the Hydrogeologic Workplan

Type of Document	Subject	Reference
Meeting Minutes	Annual Meeting 3/30/98	Letter, DOE/LASO file number LAAME 6BK-010
	Annual Meeting 3/29/99	Letter, LANL file number ESH-18/WQ&H: 99-0162
	Annual Meeting 3/29/00	Letter, LANL file number ESH-18/WQ&H: 00-0267
	Annual Meeting 3/20/01	Letter LANL file number ESH-18/WQ&H: 01-126
	Annual Meeting 4/10/02	Letter LANL file number RRES-DO: 02-25
	Annual Meeting 3/18/03	Letter LANL file number RES-GPP-03-053
	Annual Meeting 4/12/04	Letter LANL file number RRES-GPP-04-0023
	Quarterly Meeting 6/29/98	Letter LANL file number ESH-18/WQ&H: 98-0233
	Quarterly Meeting 10/27/98	Letter LANL file number ESH-18/WQ&H: 98-0443
	Quarterly Meeting 2/9/99	Letter LANL file number ESH-18/WQ&H: 99-0066
	Quarterly Meeting 6/23/99	Letter LANL file number ESH-18/WQ&H: 99-0275
	Quarterly Meeting 10/13/99	Letter LANL file number ESH-18/WQ&H: 99-0451)
	Quarterly Meeting 1/27/00	Letter LANL file number ESH-18/WQ&H: 00-0056
	Quarterly Meeting 6/22/00	Letter LANL file number ESH-18/WQ&H: 00-0425
	Quarterly Meeting 10/3/00	Letter LANL file number ESH-18/WQ&H: 00-0403
	Quarterly Meeting 1/30/01	Letter LANL file number ESH-18/WQ&H: 01-051
	Quarterly Meeting 6/27/01	Letter LANL file number ESH-18/WQ&H: 01-284
	Quarterly Meeting 10/16/01	Letter LANL file number ESH-18/WQ&H: 01-410
	Quarterly Meeting 1/30/02	Letter LANL file number ESH-18/WQ&H: 02-114
	Quarterly Meeting 7/24/02	Letter LANL file number RRES-GWPP: 02-03
	Quarterly Meeting 10/29/02	Letter LANL file number RES-GPP-02-021)
	Quarterly Meeting 1/22/03	Letter LANL file number RES-GPP-03-013
	Quarterly Meeting 10/27/03	Letter LANL file number RRES-GPP-03-101
	Quarterly Meeting 1/28/04	Letter LANL file number RES-GPP-04-0023
	Quarterly Meeting 7/13/04	Letter LANL file number RRES-GWPP:04-0045
	Quarterly Meeting 10/25/04	Letter LANL file number ENV-GPP:04-0051
	Quarterly Meeting 2/2/05	Letter LANL file number ENV-GPP:05-0007

Table 1-A-3.
Documents Relevant to the Hydrogeologic Workplan (continued)

Type of Document	Subject	Reference
Ground-water Annual Status Reports	Annual Report for FY97	Nylander, C.L., et al., 1998.
	Annual Report for FY98	Nylander, C.L., et al., 1999.
	Annual Report for FY99	Nylander, C.L., et al., 2000.
	Annual Report for FY00	Nylander, C.L., et al., 2001.
	Annual Report for FY01	Nylander, C.L., et al., 2002.
	Annual Report for FY02	Nylander, C.L., et al., 2003.
Well Com-pletion Reports	Well Completion Report for R-1	Kleinfelder, Well R-1, 2004c.
	Well Completion Report for R-2	Kleinfelder, Well R-2, 2004b.
	Well Completion Report for R-4	Kleinfelder, 2004a, Well R-4, 2004a.
	Well Completion Report for R-5	LANL, Well R-5, 2003a.
	Well Completion Report for R-7	Stone, W., et al., Well R-7, 2002.
	Well Completion Report for R-8	LANL, Well R-8, 2003b.
	Well Completion Report for R-9	Broxton, D.E., et al., Well R-9, 2001a.
	Well Completion Report for R-11	Kleinfelder, Well R-11, 2004c.
	Well Completion Report for R-12	Broxton, D.E., et al., Well R-12, 2001b.
	Well Completion Report for R-13	LANL, Well R-13, 2003a.
	Well Completion Report for R-14	LANL, Well R-14, 2003.
	Well Completion Report for R-15	Longmire, P., et al., Well R-15, 2000.
	Well Completion Report for R-16	LANL, Well R-16, 2003e.
	Well Completion Report for R-19	Broxton, D., et al., Well R-19, 2001d.
	Well Completion Report for CdV-R-15-3	Kopp, B., et al., Well CdV-R-15-3, 2002.
	Well Completion Report for CdV-R-37-2	Kopp, B., et al., Well CdV-R-37-2, 2003.
	Well Completion Report for R-20	LANL, Well R-20, 2003f.
	Well Completion Report for R-21	Kleinfelder, Well R-21, 2003f.
	Well Completion Report for R-22	Ball, T. et al., Well R-22, 2002.
	Well Completion Report for R-23	LANL, Well R-23, 2003g.
	Well Completion Report for R-25	Broxton, D., et al. Well R-25, 2001e.
	Well Completion Report for R-26	Kleinfelder, Well R-26, 2004f.
	Well Completion Report for R-28	Kleinfelder, Well R-28, 2004d.
	Well Completion Report for R-31	Vaniman, D., et al. Well R-31, 2002.
	Well Completion Report for R-32	LANL, Well R-32, 2003h.

Table 1-A-3.
Documents Relevant to the Hydrogeologic Workplan (continued)

Type of Document	Subject	Reference
	Well Completion Report for MCOBT-4.4	Broxton, D., et al., 2002.
	Well Completion Report for MCOBT-8.5	Broxton, D., et al., 2002.
	Well Completion Report for R-9i	Broxton, D., et al., 2001c.
	Well Completion Report for CdV-16-1(i)	(Completion report not available)
	Well Completion Report for CdV-16-2(i)	(Completion report not available)
	Well Completion Report for CdV-16-3(i)	(Completion report not available)
Geo-chemistry Reports	Geochemistry Report for R-7	Longmire, P., et al., Well R-7, 2002.
	Geochemistry Report for R-9	Longmire, P., Well R-9, 2002b.
	Geochemistry Report for R-9i	Longmire, P., Well R-9i, 2002b.
	Geochemistry Report for R-12	Longmire, P., Well R-12, 2002d.
	Geochemistry Report for R-15	Longmire, P., Well R-15, 2002a.
	Geochemistry Report for R-19	Longmire, P., Well R-19, 2002e.
	Geochemistry Report for R-22	Longmire, P., Well R-22, 2002c.
	Geochemistry Report for R-25	Longmire, P., Well R-25, 2005.
Hydro-logic Testing Reports	Hydrologic Testing Report for R-9, R-12, and R-25	Stone, W. J., Wells R-9, R-12, and R-25, 2000.
	Hydrologic Testing Report for R-9i, R-13, R-19, R-22, R-31	Stone, W.J., et al., Wells R-9i, R-13, R-19, R-22, R-31, 2003.
	Hydrologic Testing Report R-15	McLin, S.G., Well R-15, 2004.

APPENDIX 1-B. WELL COMPLETION FACT SHEETS

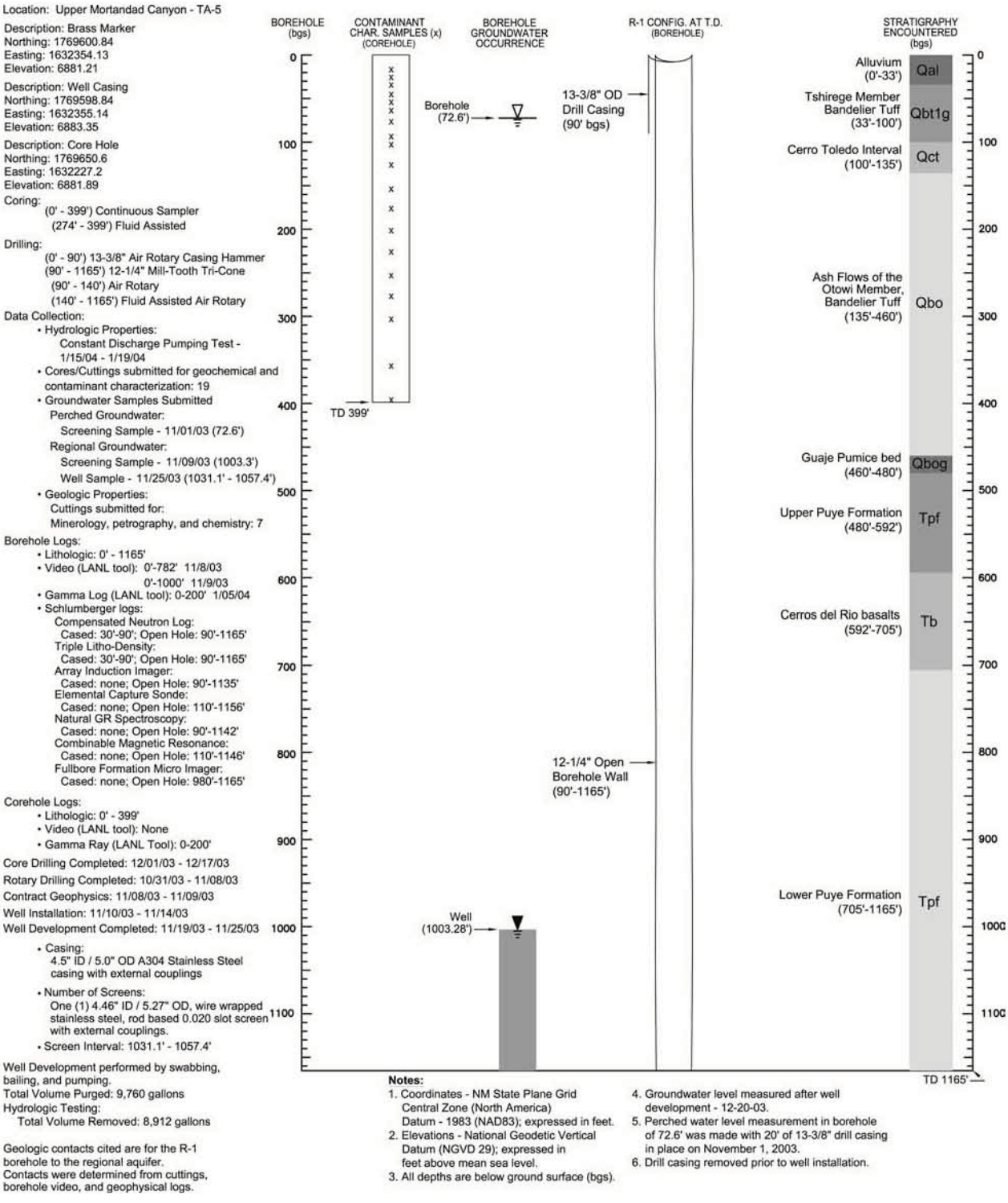

Figure 1-B-1. Completion diagram for well R-1 (Kleinfelder 2004e).

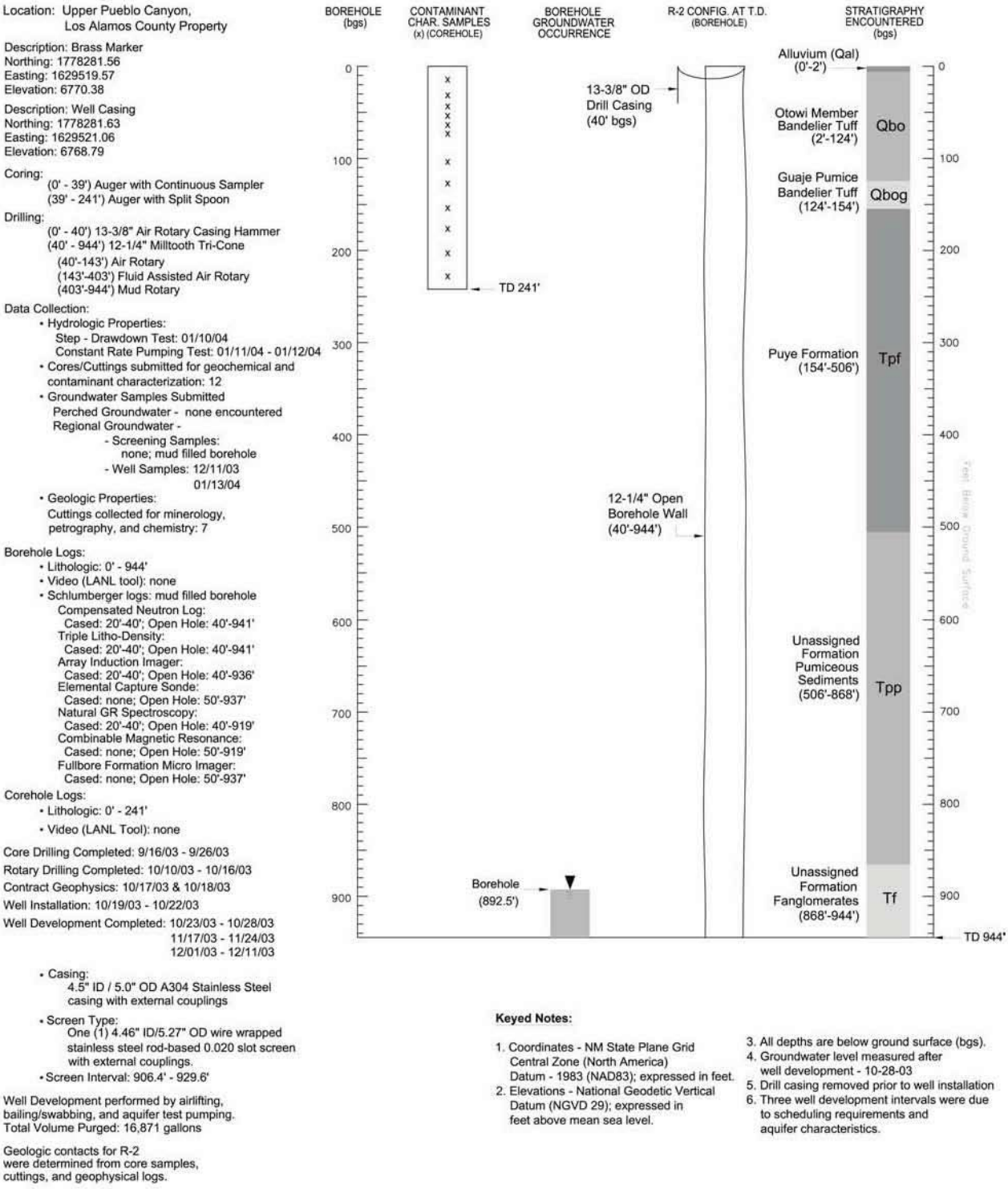

Figure 1-B-2. Completion diagram for well R-2 (Kleinfelder 2004b).

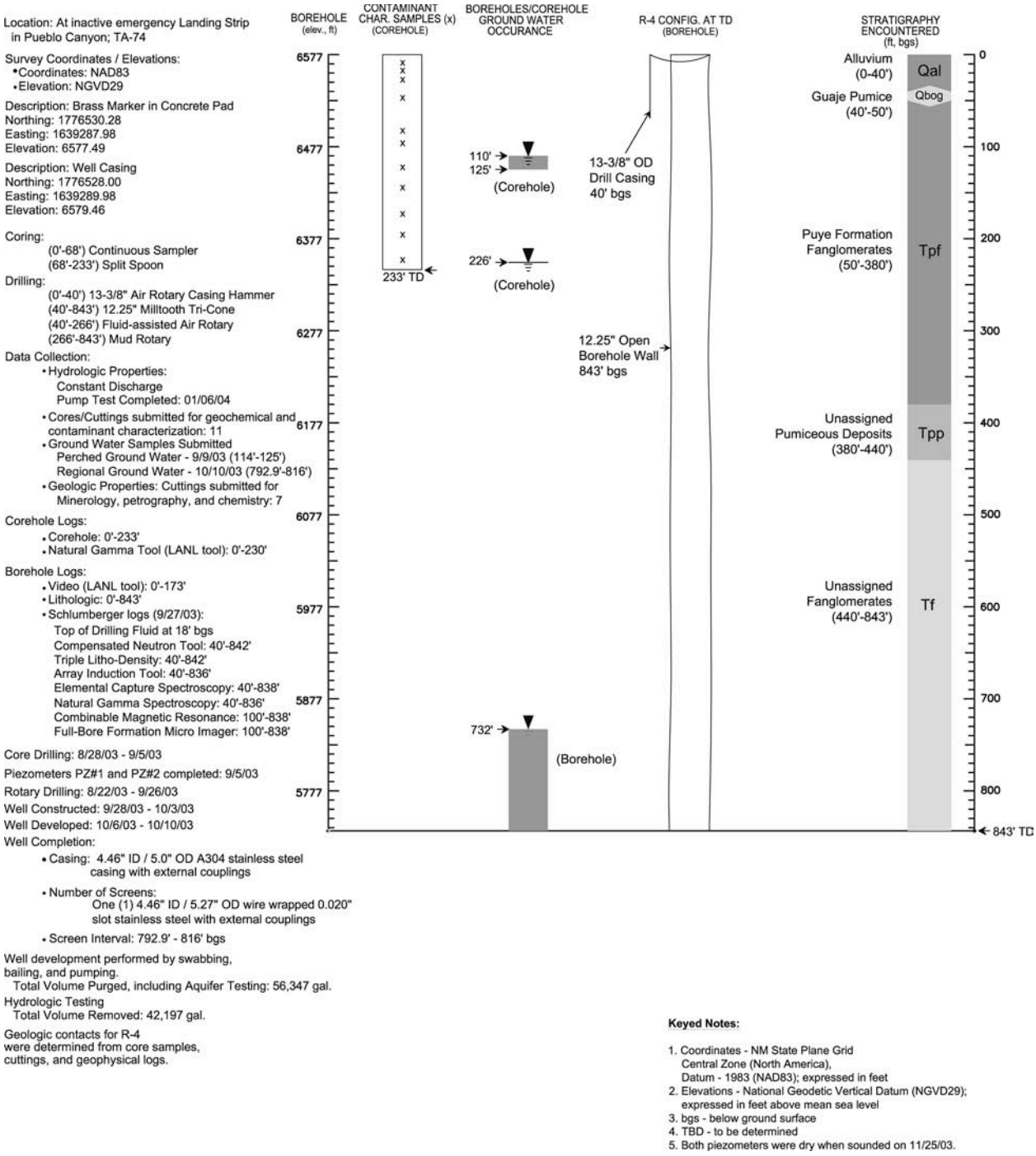

Figure 1-B-3. Completion diagram for well R-4 (Kleinfelder 2004a).

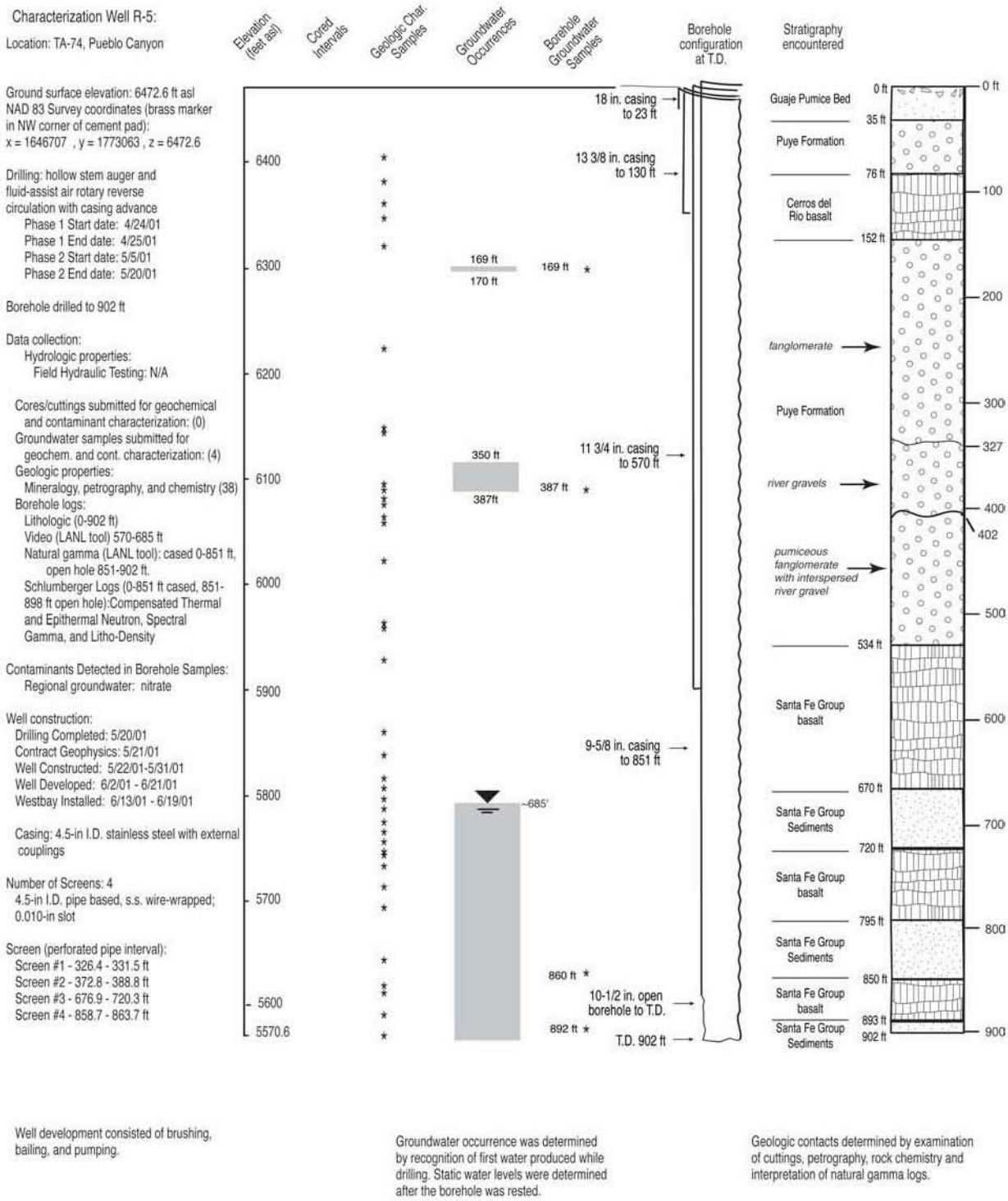

Figure 1-B-4. Completion diagram for well R-5 (LANL 2003a).

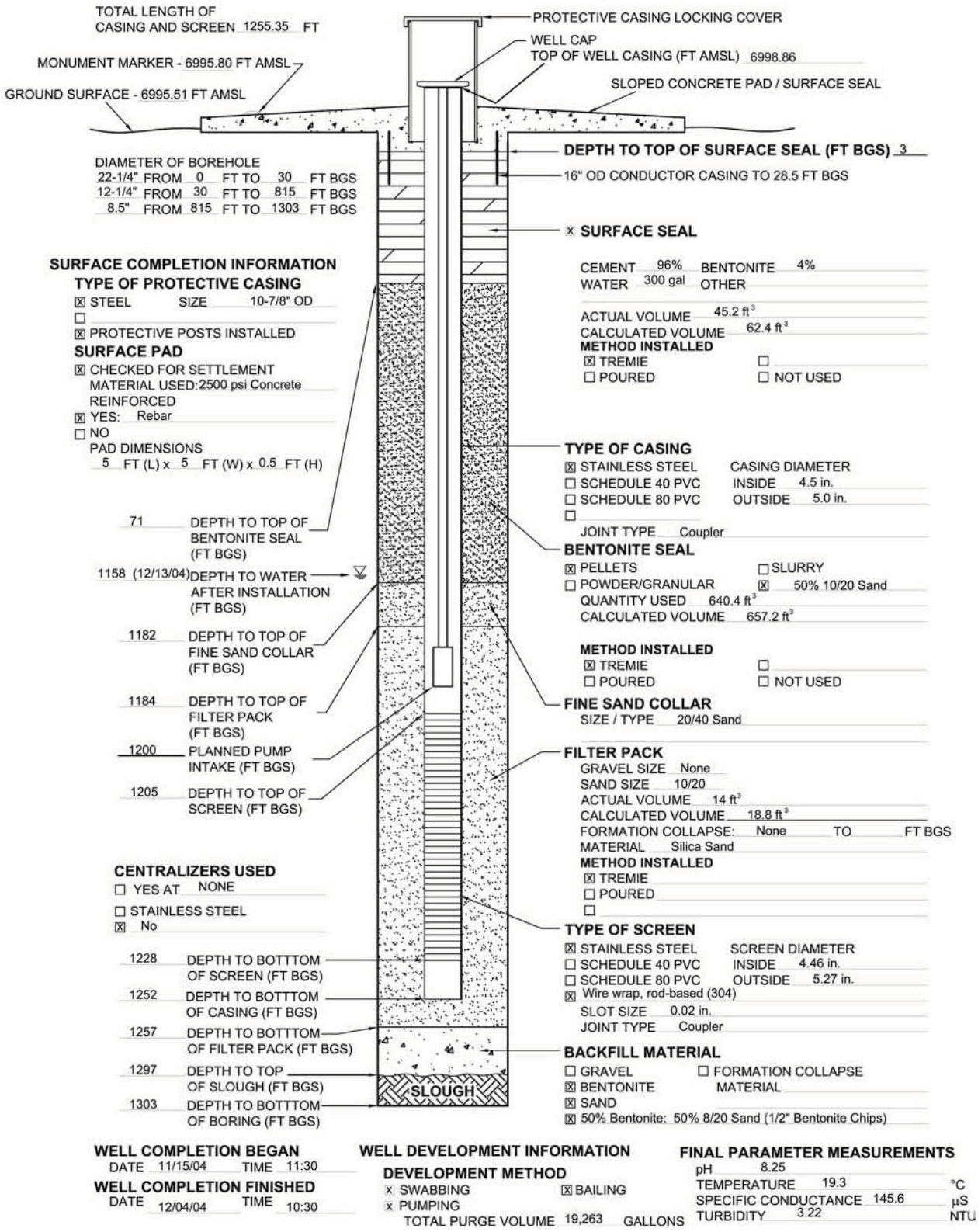

Figure 1-B-5. Completion diagram for well R-6 (Note: no report available for R-6).

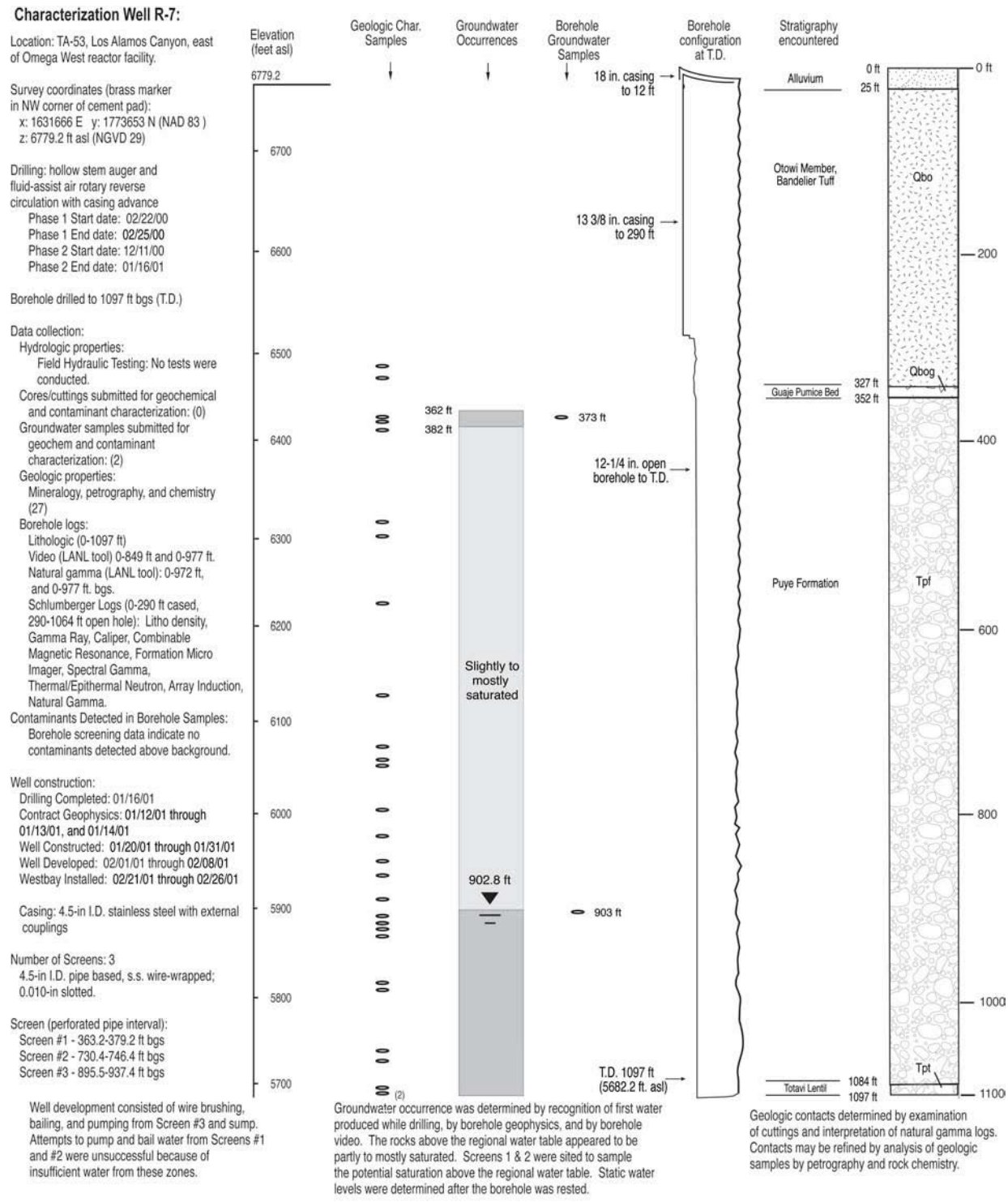

Figure 1-B-6. Completion diagram for well R-7 (Stone et al. 2002).

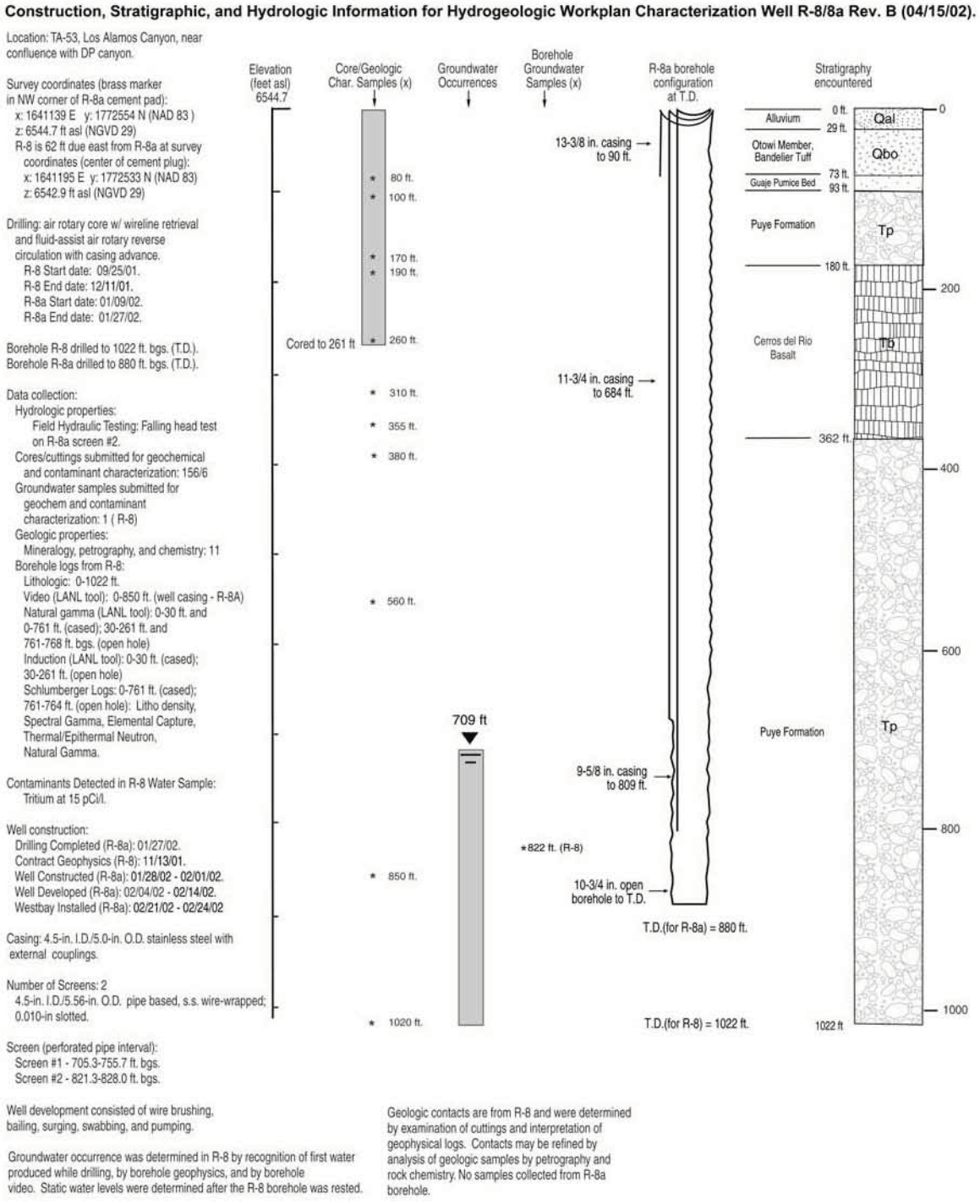

Figure 1-B-7. Completion diagram for wells R-8 and R-8a (LANL 2003b).

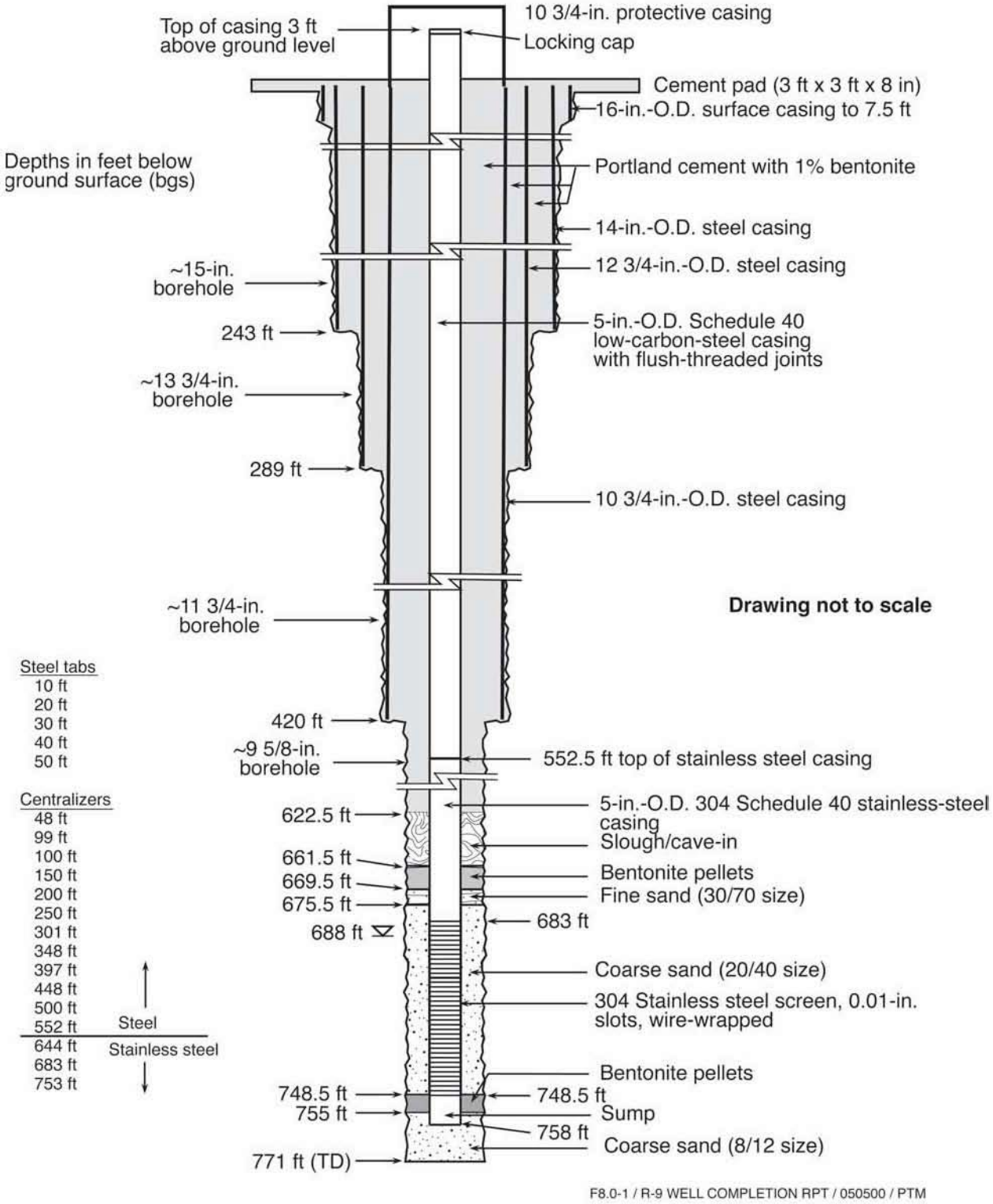

Figure 1-B-8. Completion diagram for well R-9 (Broxton et al. 2001d).

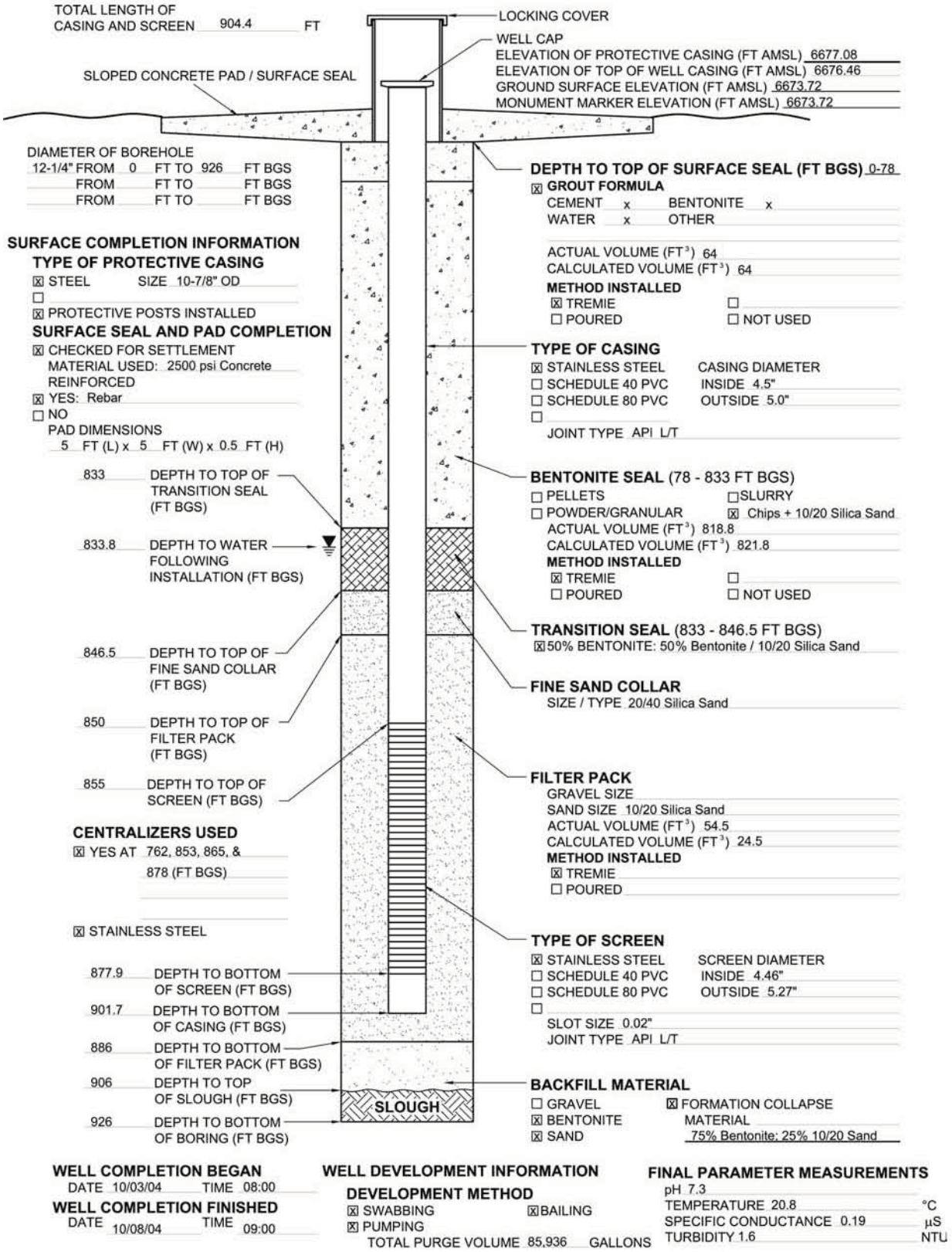

Figure 1-B-9. Completion diagram for well R-11 (Kleinfelder 2004c).

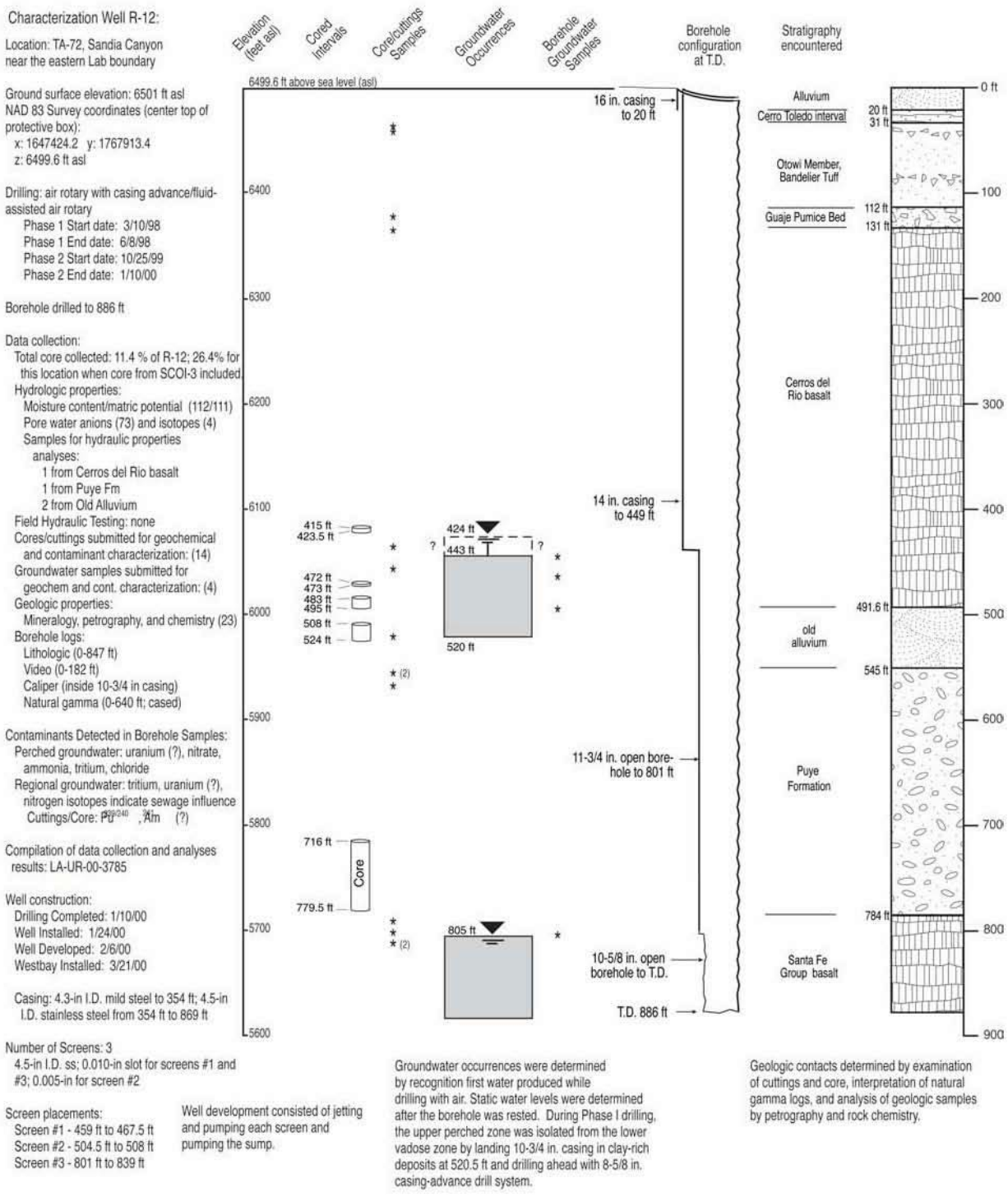

Figure 1-B-10. Completion diagram for well R-12 (Broxton et al. 2001b).

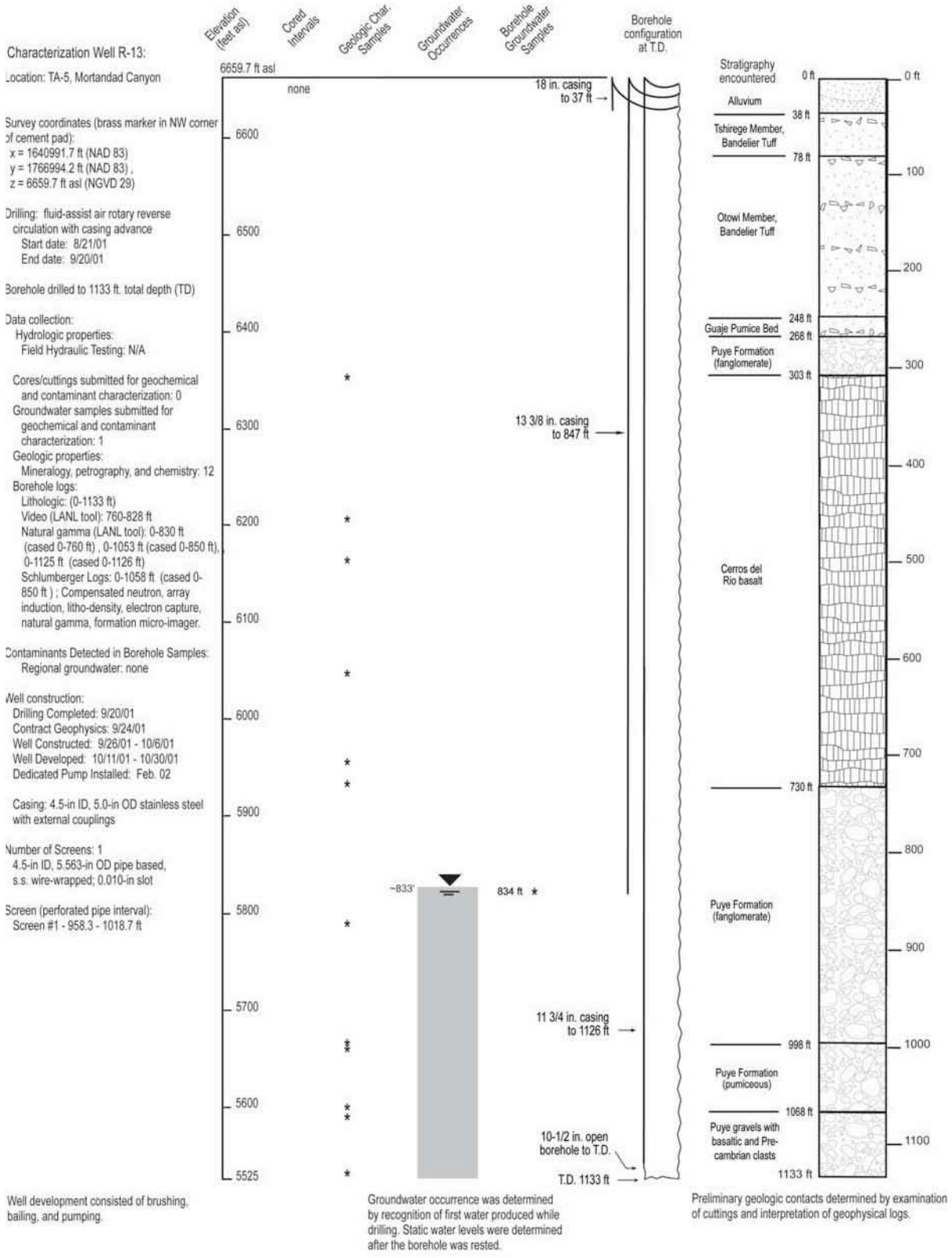

Figure 1-B-11. Completion diagram for well R-13 (LANL 2003c).

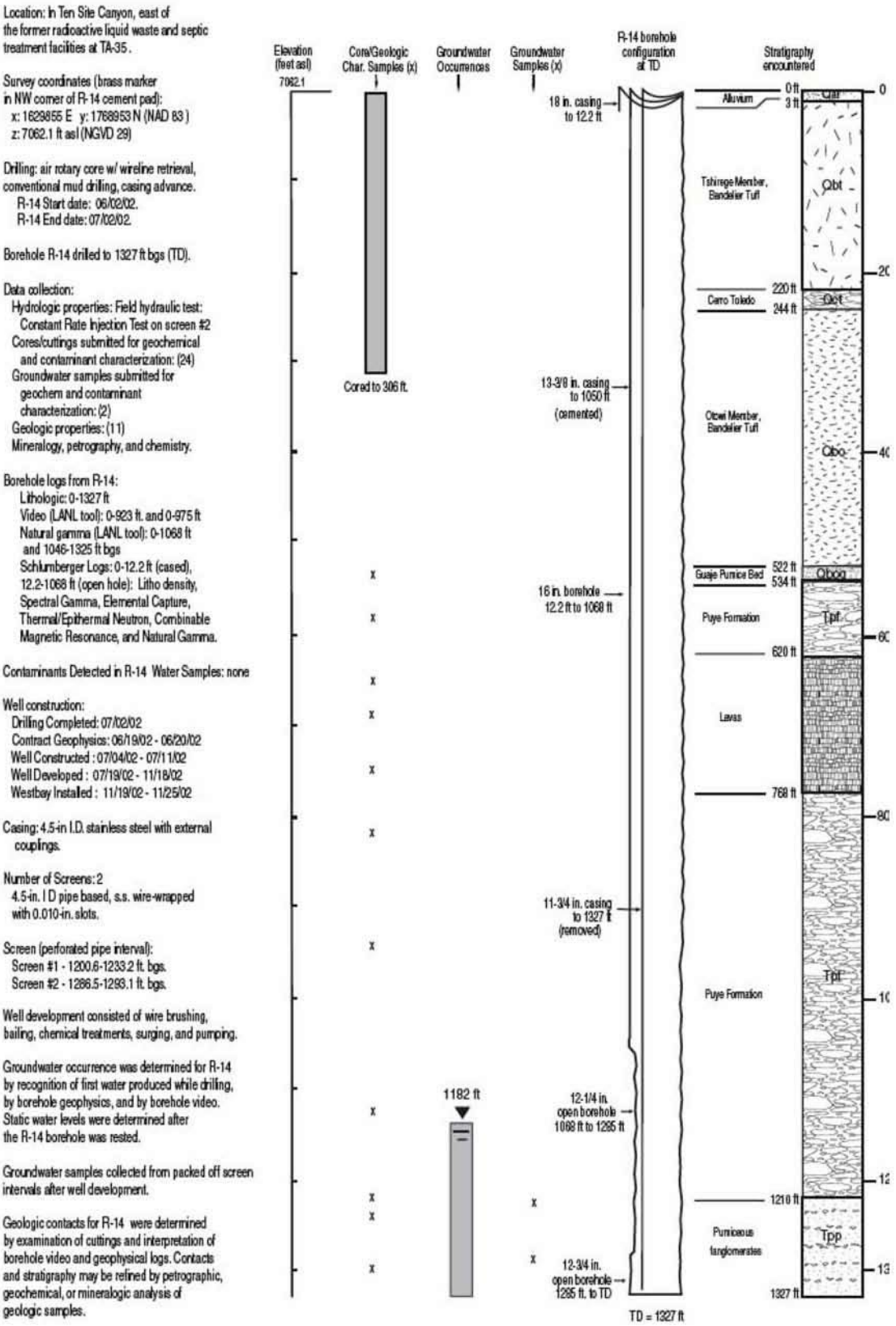

Figure 1-B-12. Completion diagram for well R-14 (LANL 2003d).

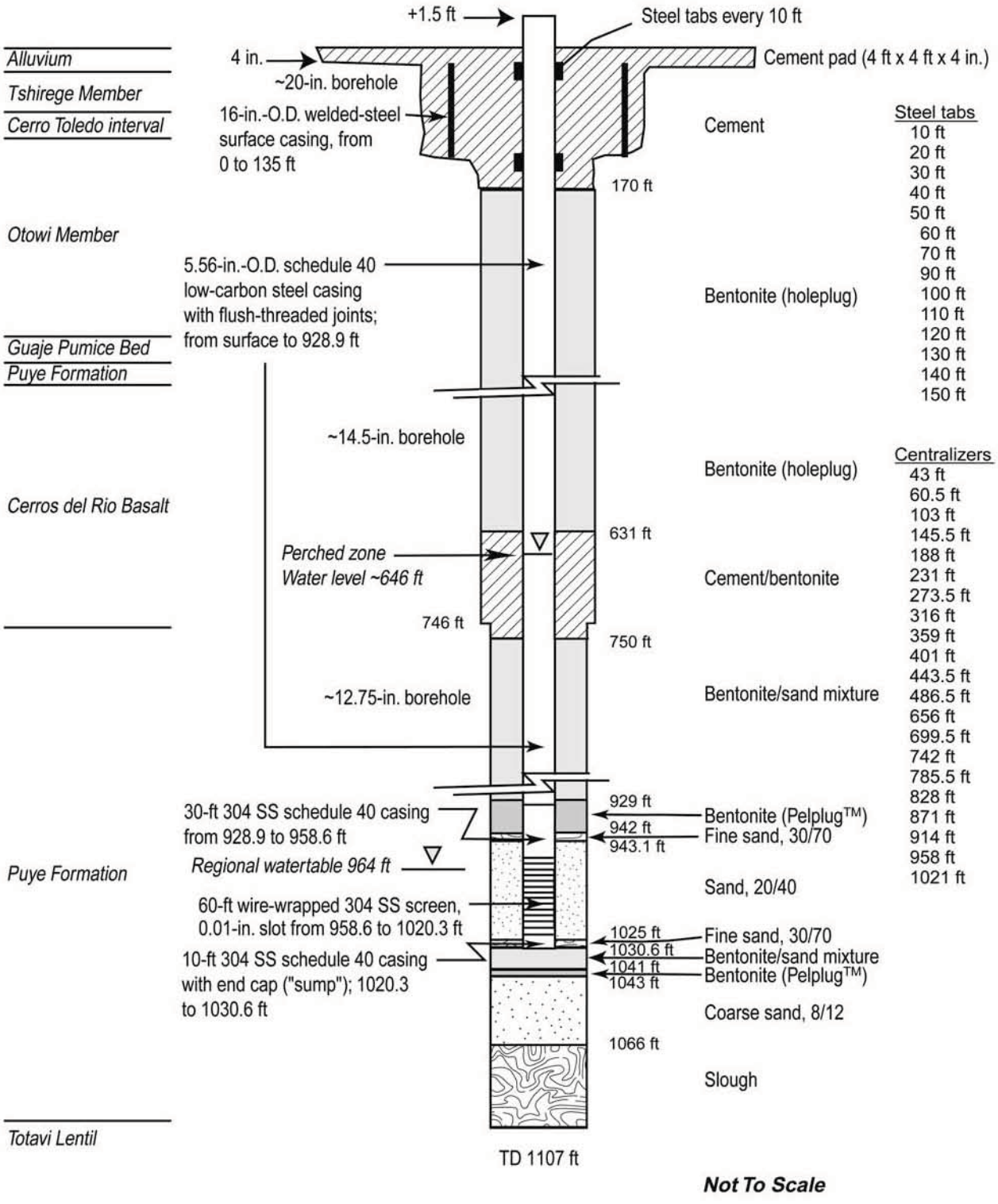

Figure 1-B-13. Completion diagram for well R-15 (Longmire et al. 2000).

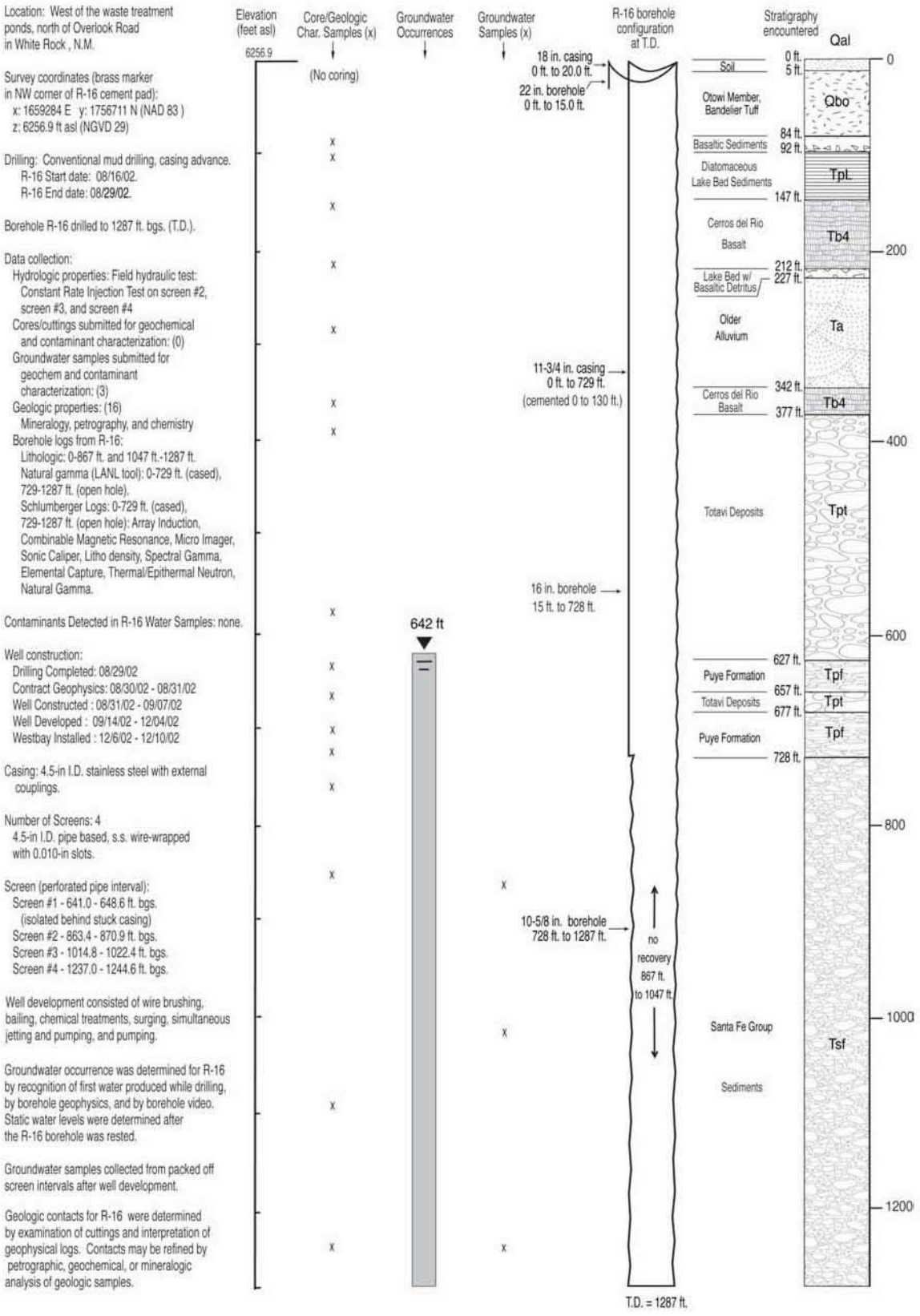

Figure 1-B-14. Completion diagram for well R-16 (LANL 2003e).

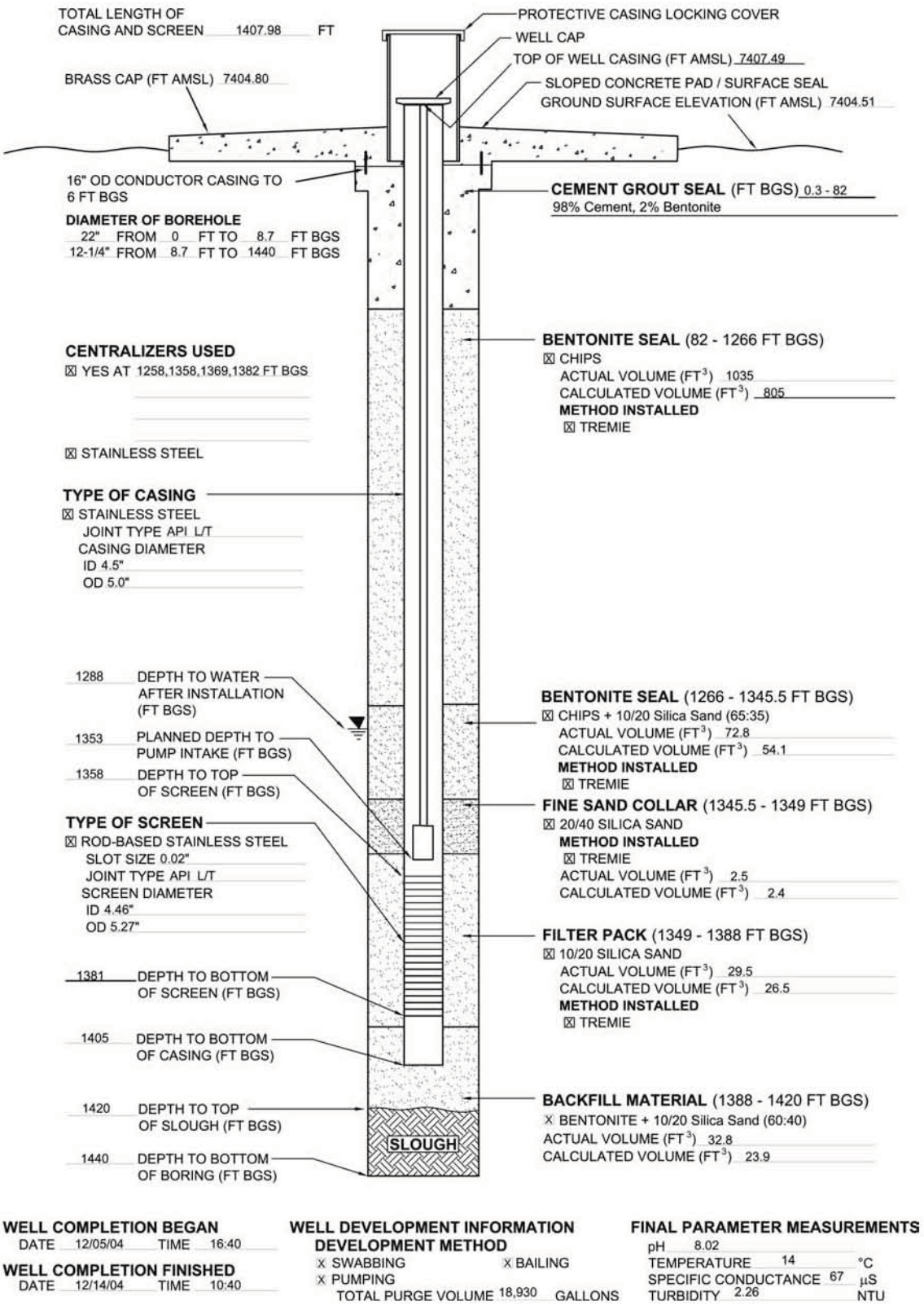

Figure 1-B-15. Completion diagram for well R-18 (Note: well completion report not available).

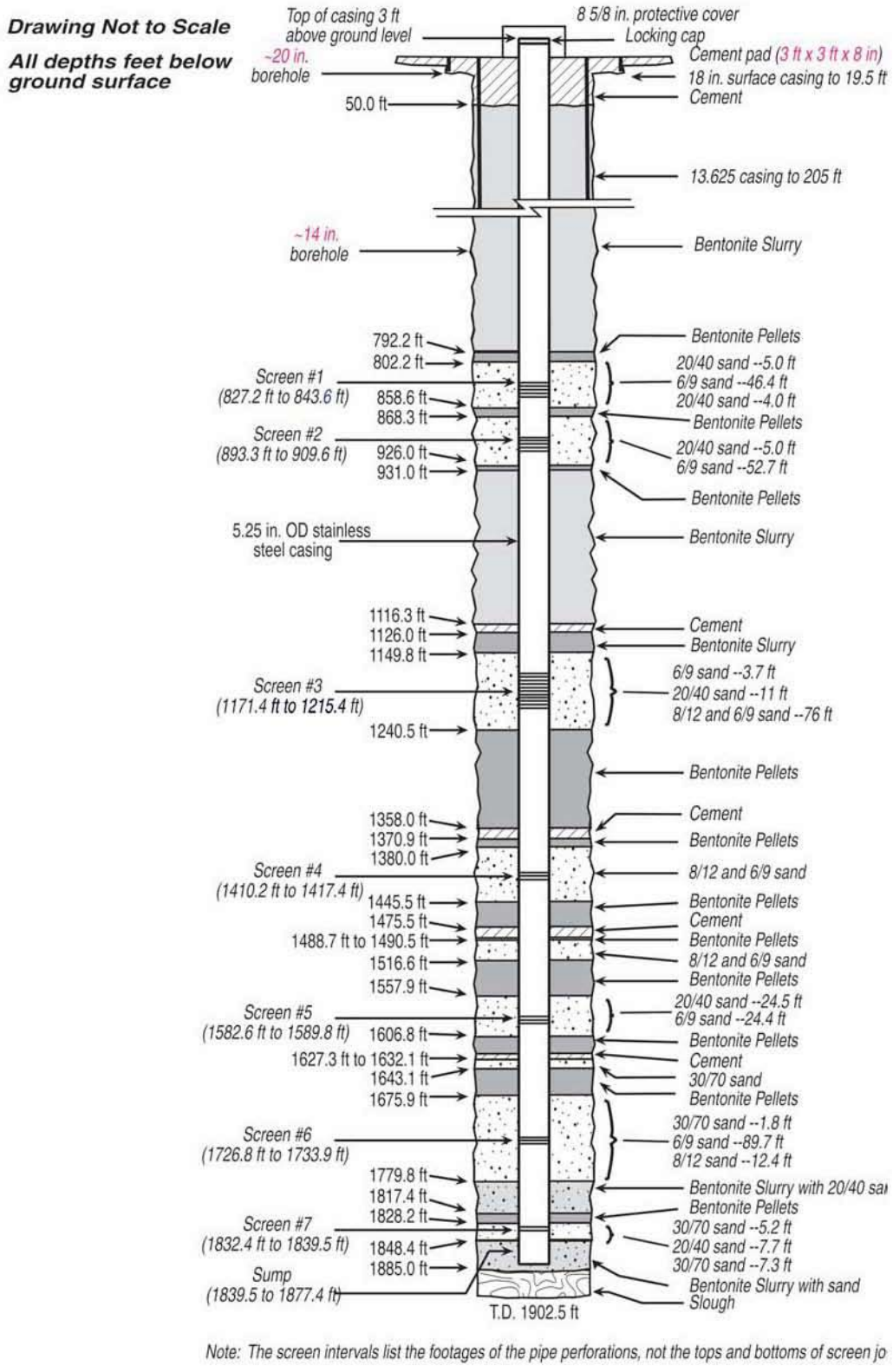

Figure 1-B-16. Completion diagram for well R-19 (Broxton et al. 2001d).

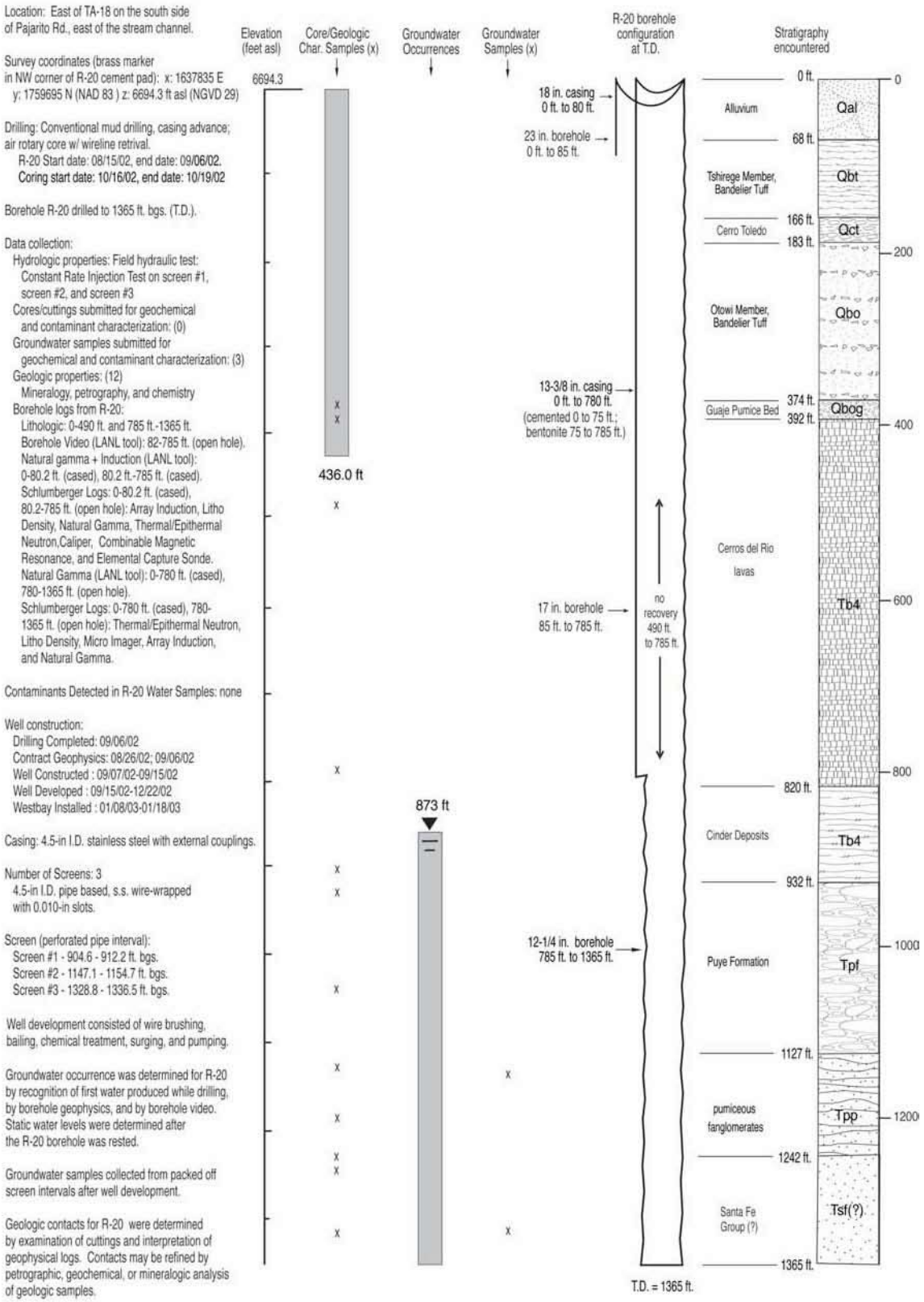

Figure 1-B-17. Completion diagram for well R-20 (LANL 2003f).

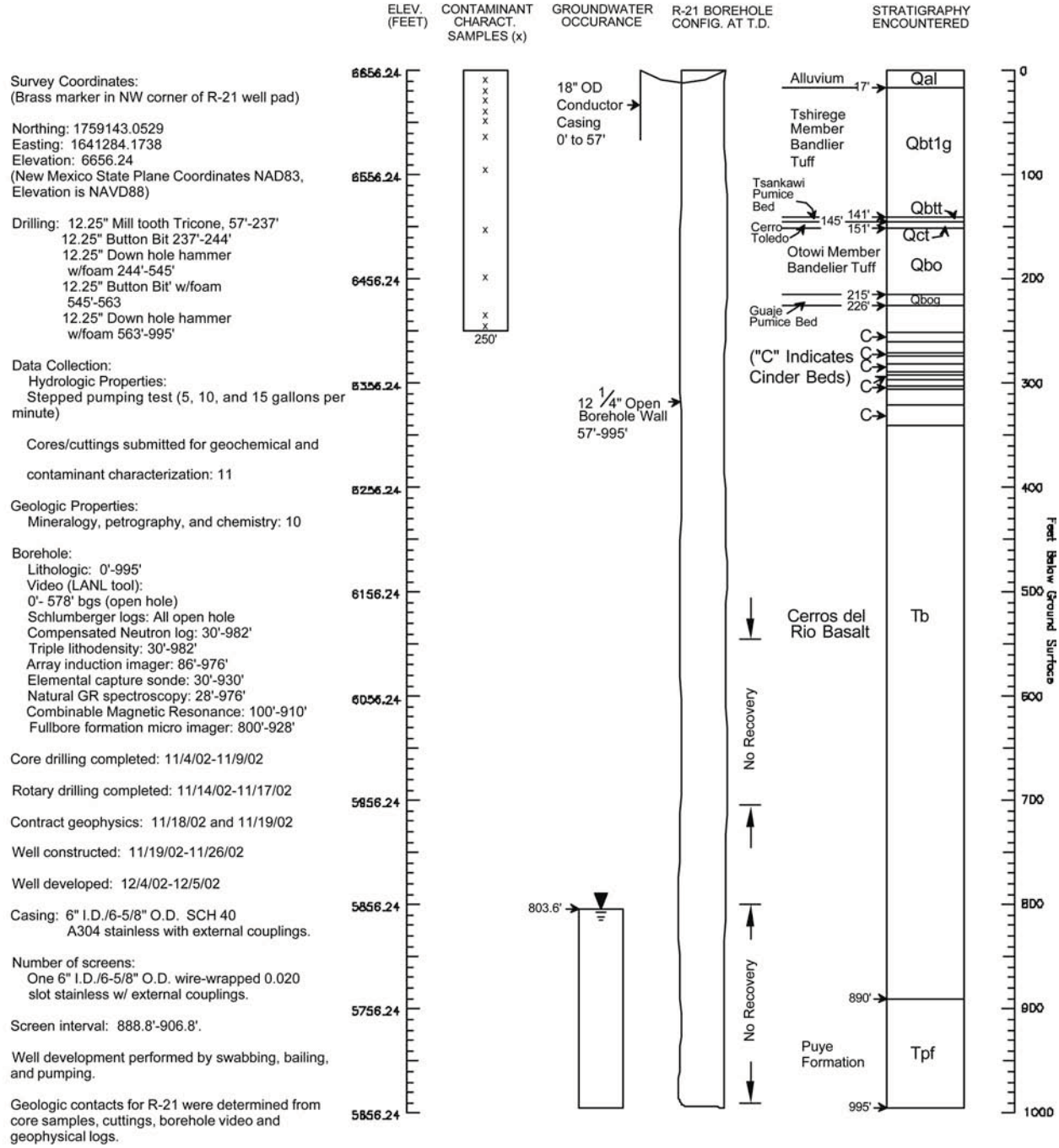

Figure 1-B-18. Completion diagram for well R-21 (Kleinfelder 2003f).

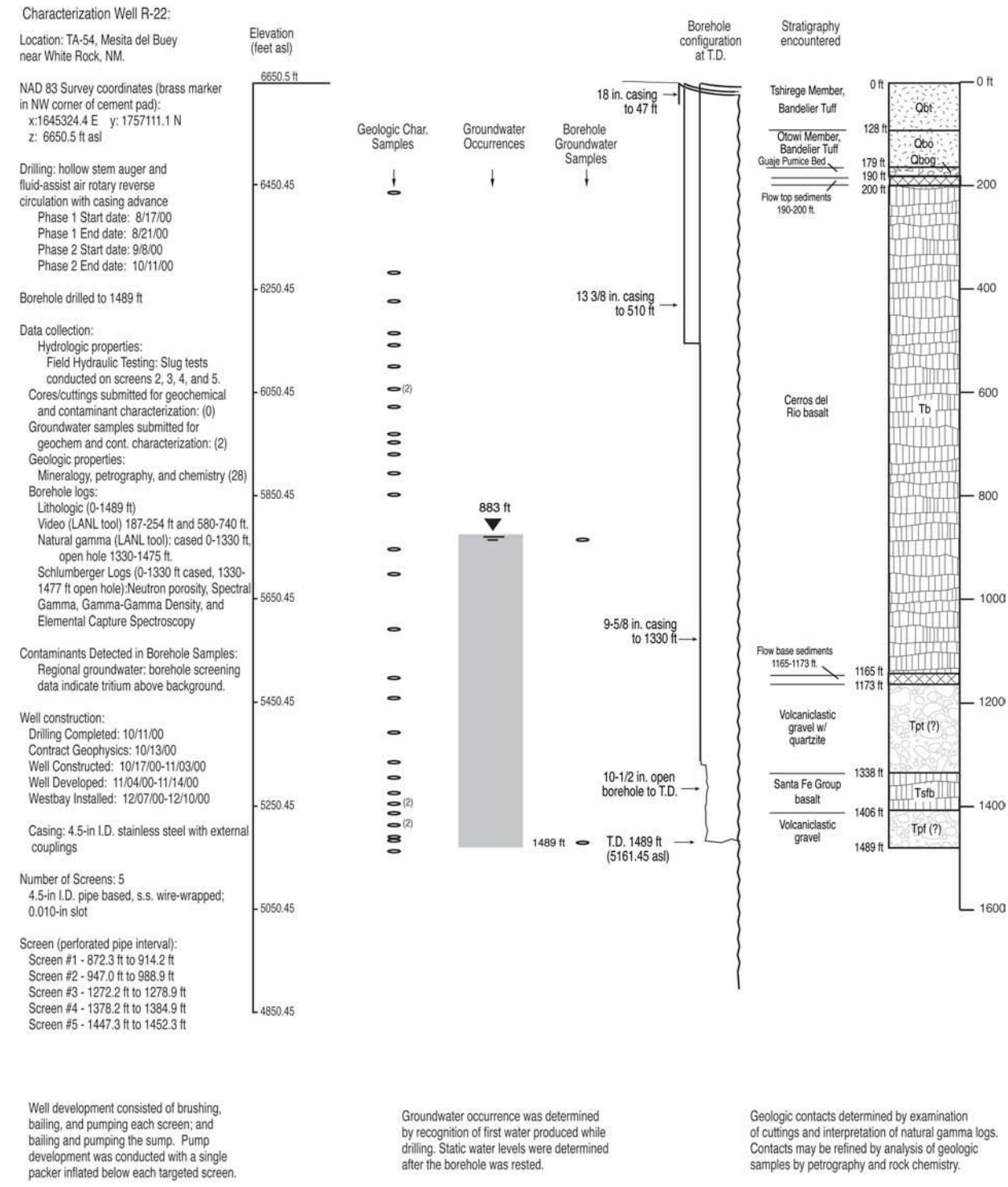

Figure 1-B-19. Completion diagram for well R-22 (Ball et al. 2002).

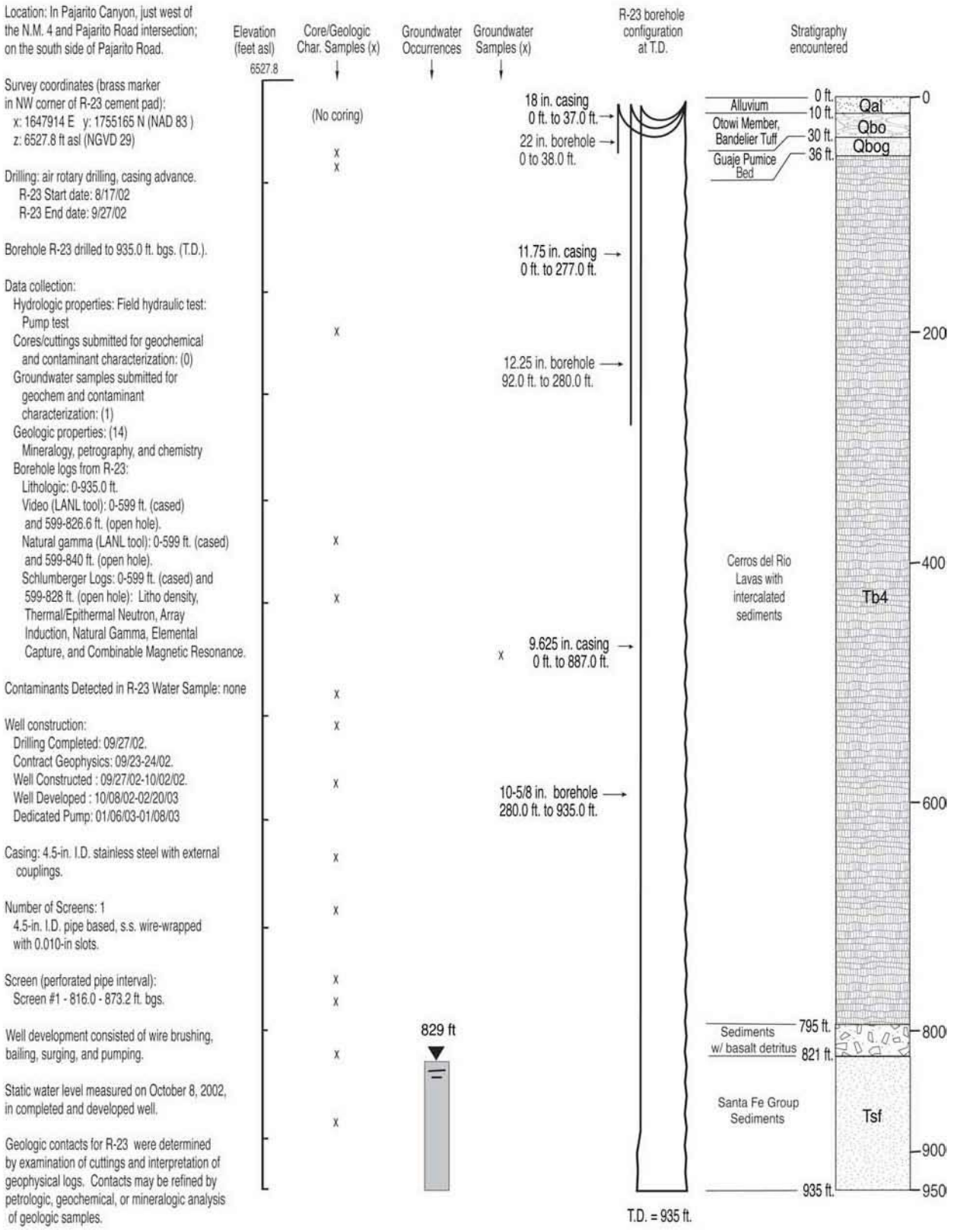

Figure 1-B-20. Completion diagram for well R-23 (LANL 2003g).

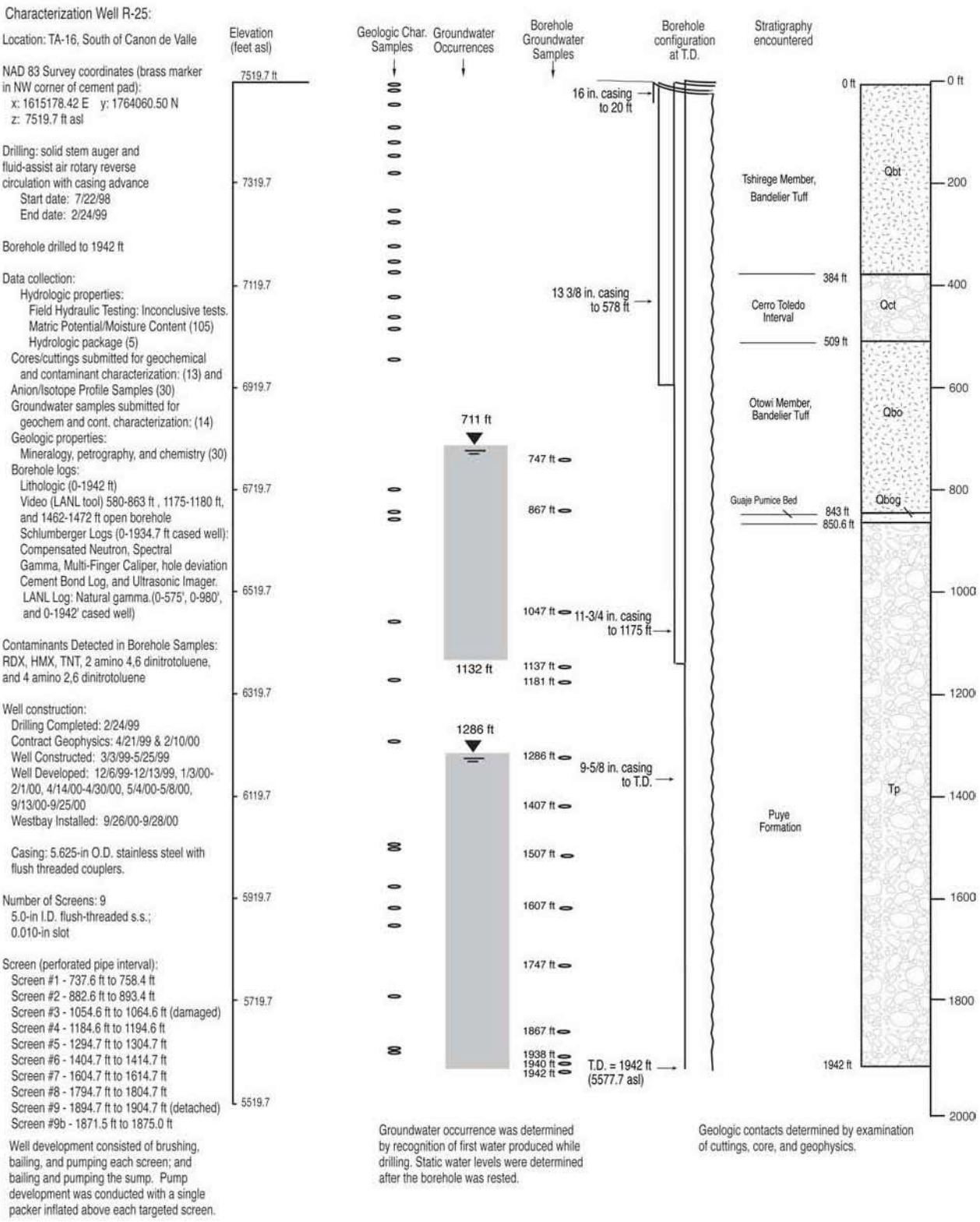

Figure 1-B-21. Completion diagram for well R-25 (Broxton et al. 2001e).

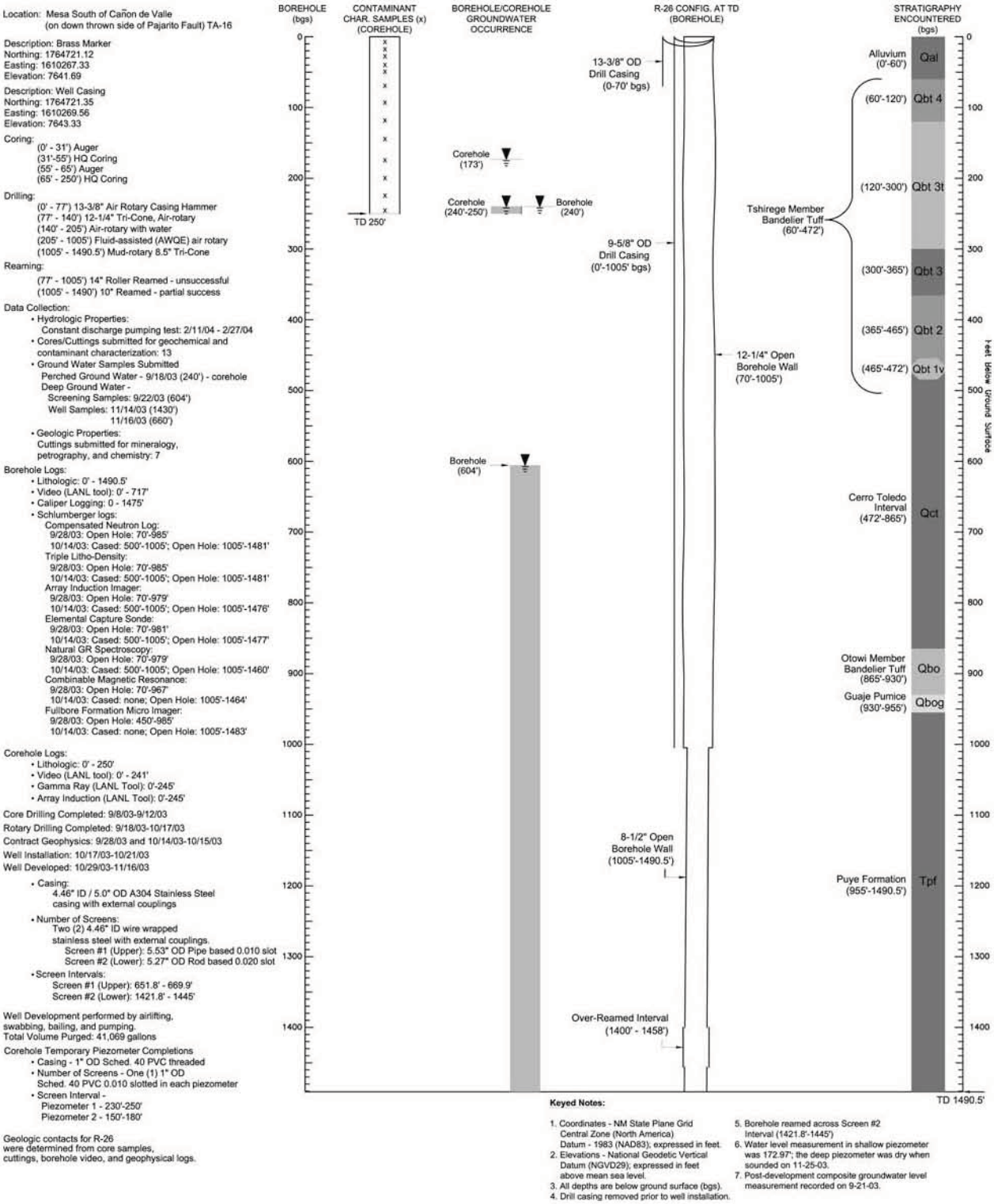

Figure 1-B-22. Completion diagram for well R-26 (Kleinfelder 2004f).

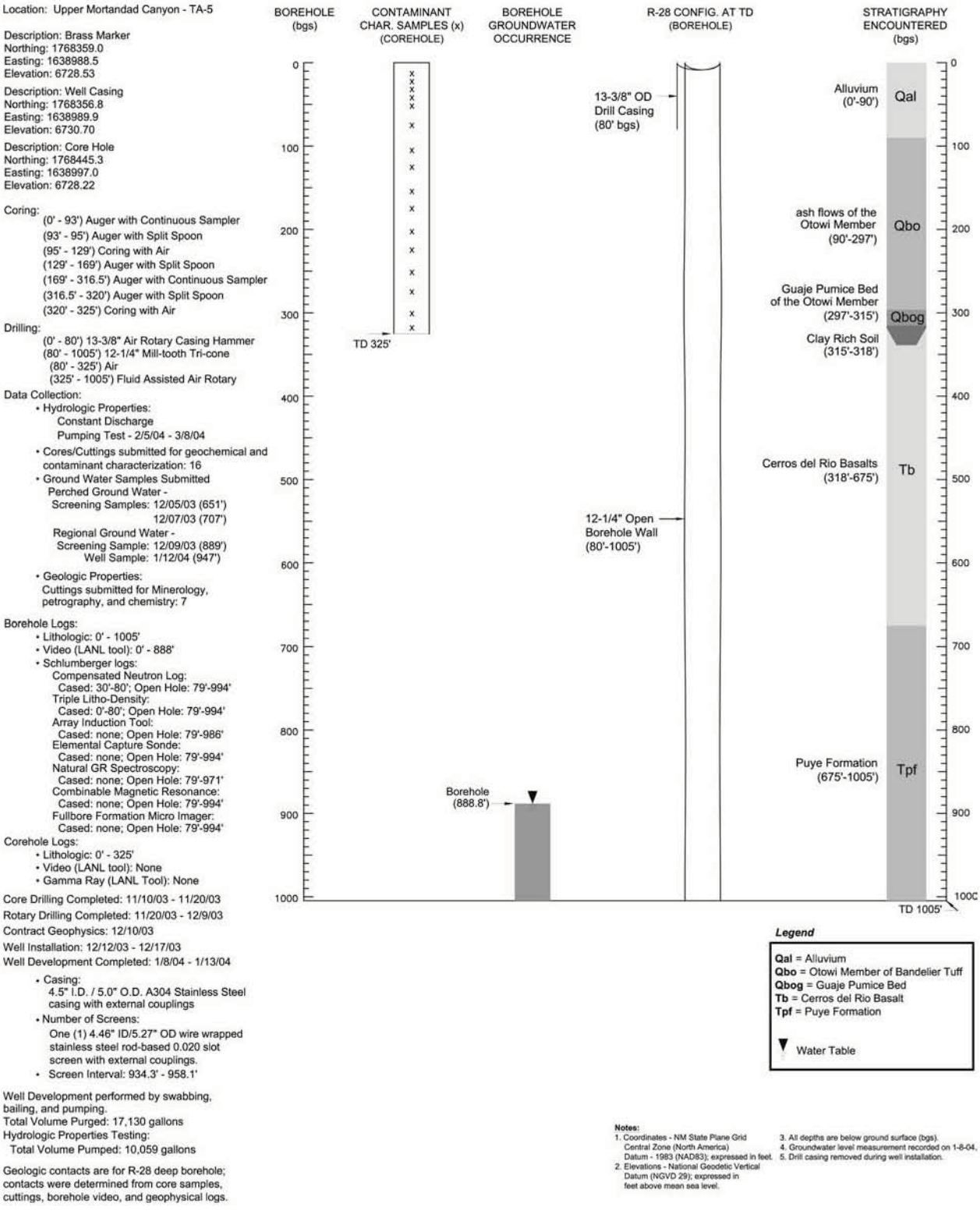

Figure 1-B-23. Completion diagram for well R-28 (Kleinfelder 2004d).

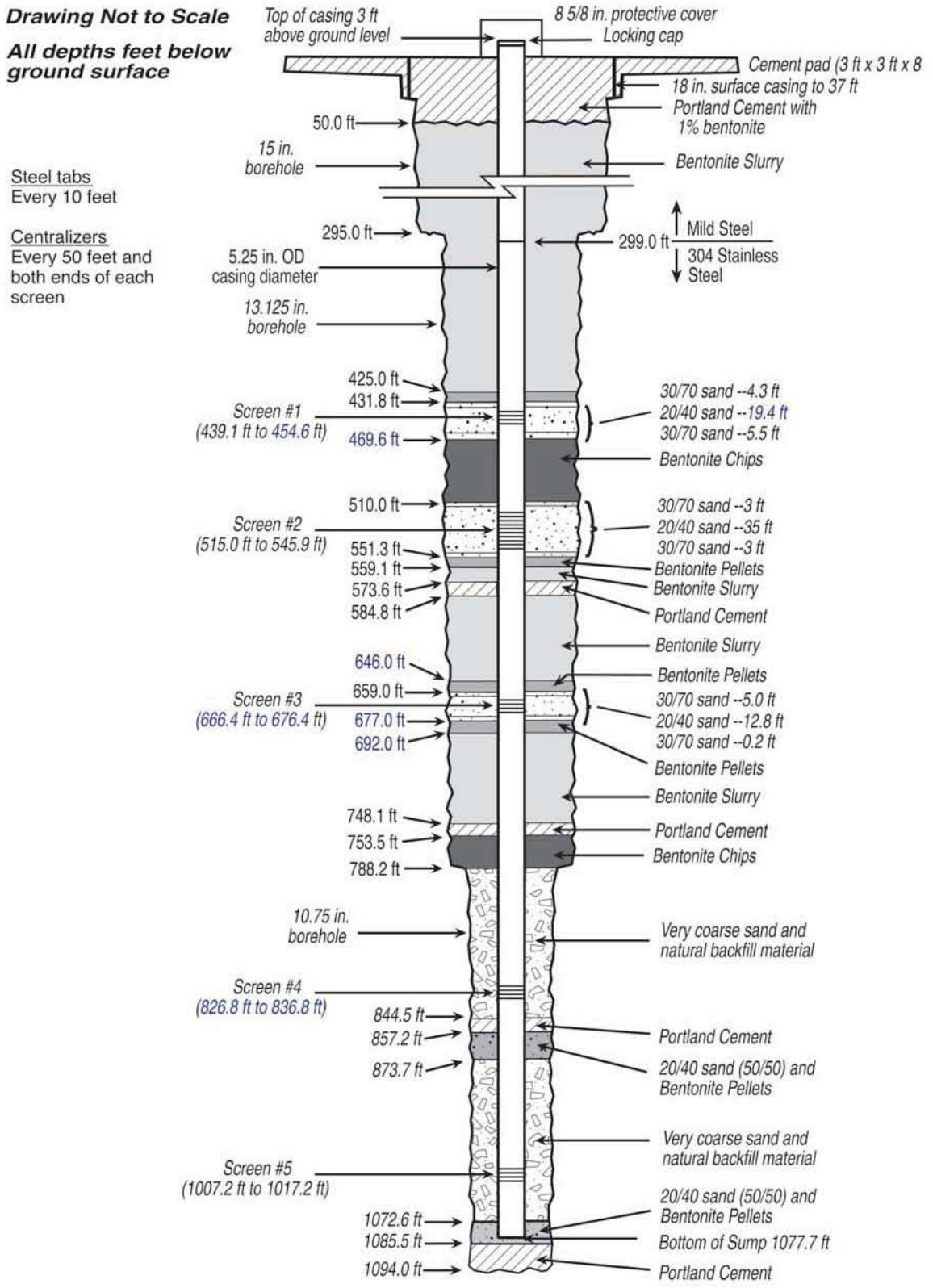

Figure 1-B-24. Completion diagram for well R-31 (Vaniman et al. 2002).

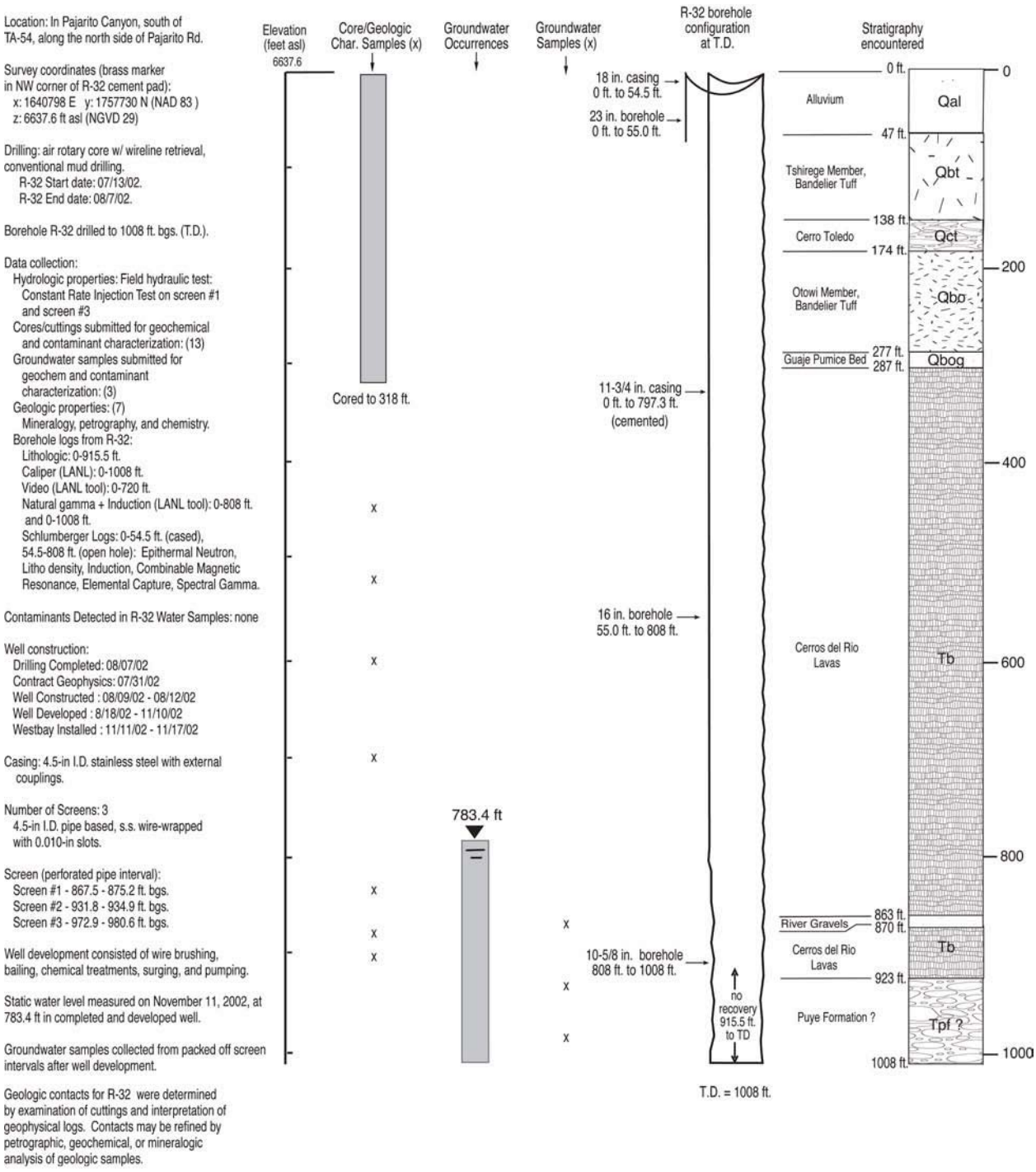

Figure 1-B-25. Completion diagram for well R-32 (LANL 2003h).

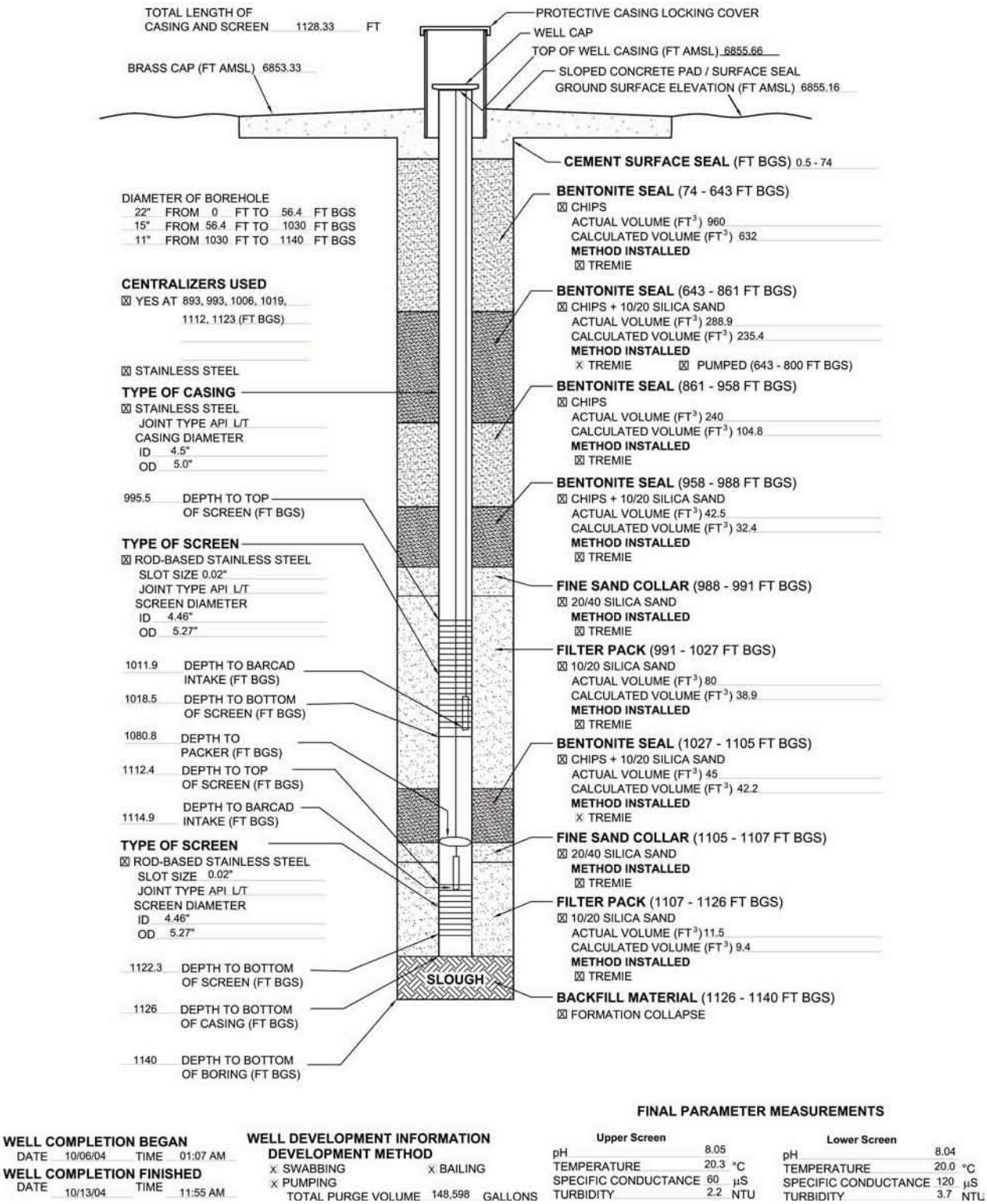

Figure 1-B-26. Completion diagram for well R-33 (Note: well completion report not available).

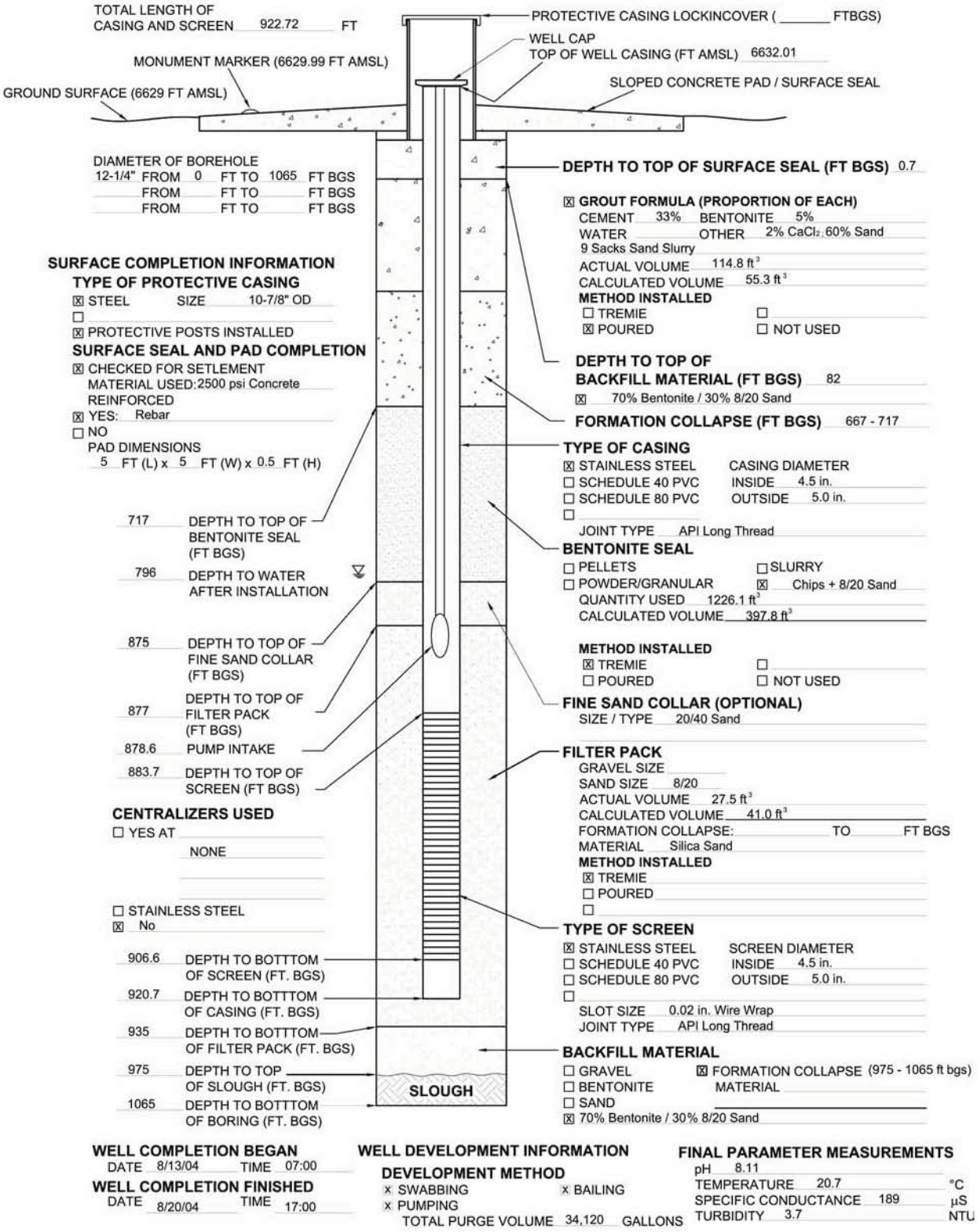

Figure 1-B-27. Completion diagram for well R-34 (Note: well completion report not available).

APPENDIX 2-A. GEOLOGIC INFORMATION USED TO DEFINE THE CONTROLS ON HYDROLOGY

2-A-1. Lithologic Information from Cuttings and Core

Drill cuttings and core were collected in all boreholes to meet the regional hydrogeologic characterization requirements described in Section 4.2 of the Hydrogeologic Workplan (LANL, 1998). Cuttings and core provide the most direct evidence for the vertical distribution of hydrogeologic units at each borehole. Correlations of rock units among boreholes are key components of the site-wide 3-D geologic model for the plateau.

Drill cuttings were the most common type of geologic samples produced during the drilling program. Approximately 500 to 700 ml of bulk drill cuttings were collected every 5 ft, as conditions permitted, to the total depth (TD) of each boring. Cuttings were stored in plastic bags labeled with the well name and footage range representing the depth interval at which the cuttings were collected. A subset of unsieved and sieved samples were collected from each cuttings interval and stored in plastic chip trays for geologic examination. The quality and representativeness of cuttings depended on a number of drilling variables including type of circulation fluids used (air, water, foam, mud), circulation type (conventional, reverse), and drill-bit pressure.

Core was collected from dedicated core holes where it was often paired with deeper drill holes. Core was also collected from selected intervals in some regional aquifer boreholes. Core was collected to fulfill a number of characterization objectives, including:

- Geologic characterization of groundwater-bearing zones and aquitards in perched groundwater systems
- Collection of moisture-sensitive samples for hydrologic and chemical analyses of vadose-zone samples (e.g. moisture, anions)
- Collection of intact rock samples to determine hydraulic properties of selected hydrogeologic units.

Rock lithologies, alteration features, and stratigraphic contacts for each borehole are summarized in lithologic logs based on visual examination of cuttings and core. A small subset of core and cuttings was selected for additional characterization to better understand alteration features relevant to rock-water interactions and to aid correlation of rock units between boreholes. The additional characterization primarily consisted of X-ray diffraction for mineralogy, X-ray fluorescence for rock chemistry, thin-section petrography, and $^{40}Ar/^{39}Ar$ age dating. The lithologic logs also incorporated information about stratigraphic contacts and rock properties based on interpretations of borehole geophysical logs.

Core and cuttings are currently archived at the ENV Division Sample Management Facility located at Technical Area 3, building 03-0271-101. All borehole materials are stored in core boxes labeled with the well name, box number, and footage range for the box.

2-A-2. Borehole Geophysical Data

Borehole geophysical data were collected to determine the geologic and hydrologic characteristics of the vadose zone, perched saturated zones, and the regional aquifer as specified in Section 4.1.6 of the workplan. A listing of geophysical logs collected during installation of Hydrogeologic Workplan wells is given in the well completion reports associated with those wells. Borehole geophysical data were obtained from two sources. Laboratory/contractor personnel collected caliper, spontaneous potential, single-point resistance and induction, and natural gamma radiation logs using the Laboratory's geophysical logging equipment, usually during breaks in the drilling process when conditions permitted the collection of open-borehole data. A wire-line logging service was contracted to obtain a more extensive suite of borehole geophysical logs once the borehole reached total depth.

The number and types of contracted wire-line geophysical logs varied as a function of borehole condition, the presence or absence of drill or well casing, whether the borehole was air or fluid filled, and technical issues addressed by a particular logging run. Drilling conditions determined whether the borehole was open or cased at the time of logging. Table 2-A-1 gives the typical suites of logs that have been run by wire-line logging services in cased and open boreholes. General logging information and borehole conditions at the time of logging were documented by site personnel.

Preliminary results of geophysical logs were generated in the logging truck at the time the geophysical services were performed. These preliminary logs were used by contractor, DOE, and LANL personnel to help select well screen locations and to evaluate borehole conditions prior to well construction.

The geophysical contractor reprocessed the field measurements to correct for borehole and formation environmental conditions, to perform an integrated analysis of the log measurements so that they were all coherent, and to combine the logs into a single presentation enabling integrated interpretation. The contractor then prepared an interpretive report that was included as an appendix in the well completion reports. The interpretive report includes information about the hydrogeologic characteristics of the rocks penetrated by the boreholes, moisture distributions as a function of depth, the location of the regional water table, borehole diameter, deviation as a function of depth, and degree of drilling fluid invasion. Depending on the suite of logs collected, the interpretive report may include information about

- total and effective water-filled porosity and pore size distribution, from which an estimate of hydraulic conductivity is made,
- bulk density and photoelectric effect, the latter of which is particularly sensitive to lithology,
- electrical resistivity at multiple depths of investigation,
- concentrations of a number of elements,
- spectral natural gamma ray, including potassium, thorium, and uranium concentrations,
- bedding orientation and geologic texture,
- borehole inclination and azimuth, and
- borehole diameter.

2-A-3. Borehole Video Logs

Borehole video logs were run in open boreholes to obtain lithologic information and to help determine stratigraphic contacts for the geologic units penetrated, to allow visual examination of borehole walls for evidence of perched saturation, and to document water levels in the boreholes. Video logs also were run when wells were completed to document the as-built condition of installed well components. Additional videos were sometimes run during and after well development to assess the effectiveness of development techniques. Finally, the borehole video logs were used during drilling operations to assess problematic borehole conditions and to guide fishing operations for tools and equipment lost downhole.

One of the principal uses of the borehole video logs was to identify potential groundwater pathways. For example, when used in conjunction with geophysical logs, video logs were an important method for locating highly porous interflow breccias sandwiched between massive basalt flows. These interflow breccias were important for determining the locations of perched zones in some boreholes. The video logs also showed whether the porosity of these interflow breccias was open or modified by deposition of extensive secondary clay minerals. Fractures are potential pathways in the massive flow interiors. Fracture density, fracture dips, and open verses sealed fractures were assessed using video logs.

2-A-4. Surface Geophysical Data

Surface geophysical data were used to help constrain the site-wide geologic model. These data include regional gravity data, airborne electromagnetic data, high-resolution resistivity, and magnetotellurics. Gravity data were used to help define regional structure beneath the Pajarito Plateau. Airborne electromagnetic data, high-resolution resistivity, and magnetotelluric data were used to focus groundwater investigations by defining the conductivity structure beneath the plateau. The remainder of this section describes the airborne electromagnetic data in more detail.

An electromagnetic (EM) and magnetic survey was flown over the Pajarito Plateau in early September 2001 by the Fugro Airborne Surveys Corporation on behalf of LANL. A total of 762 line kilometers of MegaTEM® time domain EM data and magnetic data were collected. Flight lines were spaced at 333.3 ft (105 m) within the Laboratory boundaries, and at 666.7 ft (210 m) in buffer zones adjacent to the Laboratory, oriented N20E: with tie lines at an approximate 2000-meter spacing. Because of security constraints stemming from the events of September 11, 2001, flight lines in the western 20% of the Lab, and the two tie lines in the northern portion of the Laboratory were not flown.

The contractor provided maps of Residual Magnetic Intensity (RMI), apparent conductance and conductivity depth slices at various depths, multiparameter profiles with conductivity-depth-transform (CDT) sections for flight lines and digital archives of line and grid data. The digital EM data were analyzed at a later time (end of FY01) by Condor Consulting, Inc. This analysis resulted in two additional models of CDTs along the flight paths. All of the processing assumed a “layered-earth” model, and all of the inversions were restricted to single points/multiple depths (1-D), multiple depths along individual flight lines (2-D), or a constant depth on multiple flight lines (2-D); there was no true 3-D inversion performed on the data set. Data from the existing

3-D geologic model, identifying zones of expected similar hydrologic properties, were provided to Condor and are part of the initial data analysis. Borehole geophysical logs were also provided to Condor to assist in calibrating their models. The results of all three models for each flight line are available. At some future time, a constrained 3-D inversion, utilizing the 3-D hydrogeologic model, may allow better resolution of the conductance inversion results.

Visual correlation of conductance and observed groundwater can be obtained through study of the "multiplots" of the flight lines closest to groundwater occurrences. An effort has been made to allow creation of 3-D conductance models for each of the CDT data sets. Interpolation of flight line data is accomplished through scaled interpolation within an oriented ellipsoid that samples a similar number of points in the directions: vertical, along-flight-line, and between-flight-line. Many 3-D visualization packages are capable of displaying and scaling 3-D grid data. As much of the error/uncertainty of the conductance model occurs in the depth/thickness value, real-time scaling and offsetting the z-axis of the conductance grid can allow correlation with known groundwater locations obtained from drill holes; and thus allow a projection/extrapolation of the groundwater surface beyond the limits of direct observation.

The two tie lines of the survey provide conductance signatures that correlate well with the major faults in the western portion of the Laboratory and could perhaps provide some information regarding their dips. These survey lines indicate other localities with signatures similar to those of the mapped faults, which may indicate buried faults or conductive fracture zones further to the east.

2-A-5. Drilling Information

Observations about drilling characteristics by the drillers and on-site geologists contributed to understanding the hydrogeology of the boreholes. These observational data were recorded in field logs, and they provided supplemental information that aided the interpretation of hydrogeologic data from other sources such as cuttings and geophysical logs.

Because of the heterogeneous nature of the rocks beneath the plateau, major lithologic and stratigraphic contacts were commonly marked by significant changes in drill penetration rates. Drilling rates were affected by a number of factors, but chief among them was the competency of the rocks being penetrated. Hard rock units such as strongly welded tuffs, lava flows, and boulder-rich fanglomerate deposits were characterized by slow drilling rates, whereas less competent rocks such as nonwelded tuffs and poorly indurated sands, silts, and clays drilled more rapidly. For example, drill penetration rates normally decreased downhole when going from the nonwelded tuffs at the base of Qbt 3 into the welded tuffs at the top of Qbt 2 and from the Guaje Pumice Bed into Puye Formation and/or Cerros del Rio basalt.

Information about borehole stability and lost-circulation zones also provided important site-specific information about subsurface conditions. For example, open borehole drilling at R-22 was complicated by caving conditions and by difficulty in maintaining free rotation of the drill string though thick sequences of basalt. Normally, the interiors of basalt flows are strongly competent and yield gun-barrel smooth boreholes, but the conditions at R-22 suggested that loose blocks of basalt were caving into the borehole and binding up the drill string. Subsequent

borehole video logs showed that dense networks of fractures intersected the R-22 borehole resulting in an unstable borehole. Similarly, lost circulation zones generally indicated that drilling fluids had escaped into highly porous fractures or scoria zones intersected by the borehole. At R-34, significant zones of lost circulation were associated with thick beds of loose basaltic scoria. Some cavities observed in borehole videos might be small-scale lava tubes or caverns similar to those known to occur in the Cerros del Rio volcanic field east of the Rio Grande.

Important information about water-bearing strata was obtained when drillers noted changes in the drilling fluids circulating through the borehole. Perched water and the top of the regional zone of saturation were readily recognized when water and wet cuttings were returned to the surface using air-rotary drilling methods. Water-bearing zones were identified even when using fluid-assisted air-rotary methods that involved the use of air, municipal water, foam, and other additives for circulation. When using such methods, surplus production of water and thinning of drilling foam often was associated with the intersection of groundwater.

2-A-6. Data Generated by Other Projects

Numerous local and regional mapping projects and geological studies have provided important information supporting development of geologic conceptual models and digital realizations of these models. Pioneering work by geologists of the U.S. Geological Survey (USGS) helped define the tectonic setting and the major hydrogeologic units of the region (Smith, 1960a and 1960b, Griggs, 1964; Smith and Bailey, 1966; Bailey et al., 1969; Smith et al., 1970). Regional and local studies of rock unit ages, many of which were supported by the Laboratory, provided a time scale to calibrate the timing of the volcano-tectonic development of the site: faulting and volcanism, and emplacement of the resultant volcanic flows and sedimentary units (Gardner and Goff, 1984, Gardner et al., 1986; Loeffler et al., 1988; Turbeville et al., 1989; Izett and Obradovich, 1994; Spell et al., 1990; Spell and Harrison, 1993; Spell et al., 1996; Toyoda et al., 1995; McIntosh and Quade, 1995; WoldeGabriel et al, 1996; Reneau et al., 1996; Smith, 2001; WoldeGabriel et al., 2001; Goff and Gardner, 2004). Understanding the nature of the evolving tectonic regime allowed development of models to define the conceptual, spatial distribution of hydrogeologic units, as well as explanations of their post-deposition evolution.

The New Mexico state mapping program, supported by the USGS and the New Mexico Bureau of Geology and Mineral Resources, with help from LANL scientists, produced 1:24,000-scale, surface geologic maps and accompanying cross sections for the Frijoles (Goff et al., 2002), White Rock (Dethier, 1997), Puye (Dethier, 2003), and Guaje Mountain (Kempter and Kelley, 2002) quadrangles. These four maps encompass the Laboratory site with a significant buffer zone, allowing the integration of site and regional geologic features. Other geological maps, some with cross sections, covering portions of the LANL include those by Baltz et al., (1963); Goff et al., (1990); Rogers, (1995); Vaniman and Wohletz, (1990); Reneau et al., (1995); Goff, (1995); Lewis et al., (2002); and Lavine et al., (2003).

Española Basin workshops were hosted annually by the Española Basin Technical Advisory Group and sponsored by the U.S. Geological Survey, the New Mexico Bureau of Geology and Mineral Resources, Los Alamos National Laboratory, and the city of Santa Fe. These workshops

were important forums for disseminating results of ongoing technical studies of the hydrogeologic framework of the Española Basin.

The seismic hazards program at LANL was an important source of information about faults and fractures in the vicinity of the Laboratory (Gardner and House, 1987; Gardner et al., 1990, 1993, 1999, 2001; Lewis et al., 2002; and Lavine et al., 2003). Their high-resolution, surface mapping of subunits of the Bandelier Tuff provided new information about the distribution and nature of faulting on the Pajarito Plateau and made estimates about amounts and rates of offset of geologic units. Numerous other Laboratory projects and programs helped to develop geologic information supporting geologic conceptual models. The Environmental Restoration project funded numerous projects as part of its RCRA facilities investigations that provided information about geologic framework of the site and hydrologic properties of geologic units.

Students and their advisors from the graduate programs from the University of New Mexico, New Mexico State University, and New Mexico Institute of Mining and Technology have provided additional hydrogeologic information for the Jemez volcanic field and Española Basin. Studies by graduate students from the University of Texas (e.g., Turbeville et al., 1989) were especially useful for understanding the Puye Formation.

Table 2-A-1.
Typical Wire-Line Geophysical Logging Tools

Cased Hole	Cased Hole	Open Hole	Comments
Array Induction Tool (AIT)		X	Measures open-hole formation conductivity with multiple depths of investigation at varied vertical resolution
Triple Litho Density Tool (TLD)	X	X	Evaluates formation porosity where grain density can be estimated
Combinable Magnetic Resonance Tool (CMR)		X	Provides information on water content and relative abundance of hydrous minerals and capillary-bound versus mobile water
Natural Gamma Tool	X	X	Used to distinguish lithologies by their gross gamma signature; also used to calibrate depth of other geophysical tool readings
Natural Gamma Ray Spectrometry Tool (also called the spectral gamma tool)[1]	X	X	Used to distinguish lithologies where formations vary in relative and overall concentrations of potassium, thorium and/or uranium
Epithermal Compensated Neutron Log (CNL)	X	X	Measures moisture content in unsaturated conditions and porosity in saturated conditions
Caliper		X	Measures rugosity of borehole wall
Fullbore Formation Microimager (FMI)		X	Provides high-quality image of borehole based on electrical properties; used to determine lithologies, bedding attitudes, fracture characteristics, and borehole deviation
Elemental Capture Spectrometer (ECS)	X	X	Determines formation lithology from bulk geochemistry; used primarily to determine elemental concentrations of silicon, calcium, iron, titanium, and gadolinium

[1]A total gamma log was collected with each geophysical suite to correlate separate logging runs within a borehole.

APPENDIX 2-B. PERCHED WATER OCCURRENCES

This appendix documents the field observations of the 33 occurrences of perched groundwater detected in 29 boreholes across the Pajarito Plateau. Characteristics of deep perched groundwater zones encountered in wells on the Pajarito Plateau are listed in Table 2-B-1.

In the western part of Los Alamos Canyon, perched groundwater occurs at depths of 89 to 137 m (293 to 450 ft) in the Guaje Pumice Bed and in underlying Puye Formation fanglomerate. Saturated thicknesses for these occurrences range from about 6.7 m (22 ft) in the west to about 1 m (3 ft) in the east. These groundwater occurrences in the Guaje Pumice Bed may represent a related groundwater system because of their similar geologic and geographic settings, however, in one well, R-7 (Figure 2-37), perched groundwater occurs immediately beneath the Guaje Pumice Bed, in the underlying Puye Formation. The east-west extent of perched groundwater in the Guaje Pumice Bed is about 5.6 km (3.7 mi). Little is known about the extent of perched groundwater beneath the adjacent mesas, but a dry borehole extending to the Guaje Pumice Bed (borehole 21-2523) suggests that saturation does not extend beneath the mesa north of Los Alamos Canyon. The perched groundwater is free of contamination in the central part of the canyon (e.g. well LAO(I)A-1.1) but contained 3000 pCi/L tritium in 1995 at LADP-3 (Broxton et al, 1995), the easternmost well penetrating this groundwater body. The movement of groundwater in the Guaje Pumice Bed may be controlled by paleotopography on top of the underlying Puye Formation. Structure contours indicate that the down-dip direction for the base of Guaje Pumice Bed beneath Los Alamos Canyon is towards the south and east (Section 2.2.9).

Eastward in Los Alamos Canyon, perched zones are generally thicker and occur at multiple depths. In well R-9 for example, three perched systems were encountered: 1) in the central part of the Cerros del Rio basalt, 2) in the basal part of the Cerros del Rio basalt, and 3) in pumice-rich deposits in the lower part of the Puye Formation. Saturated thicknesses for the top and bottom zones range from about 13.7 to 31.4 m (45 to 103 ft), and the middle zone was 2.1 m (7 ft) thick. The top and middle perched zones in R-9 are also present in well LAWS-1, located 396 m (1300 ft) to the east, but their lateral extent is likely to be much greater. The occurrence of more extensive perched groundwater in the eastern part of Los Alamos Canyon may be due to enhanced infiltration where the canyon floor is underlain by Puye fanglomerate and Cerros del Rio basalt rather than by Bandelier Tuff. Tritium activities of 69 to 246 pCi/L for these perched groundwaters are elevated relative to the cosmogenic baseline of 1 pCi/L, suggesting that these zones contain a component of young water that postdates the advent of atmospheric nuclear testing 60 years ago (Longmire, 2002).

Table 2-B-1.
Characteristics of Deep Perched Groundwater Zones Encountered in Wells on the Pajarito Plateau

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Pueblo Canyon	TW-2a 133 6646	110	>23	Puye Fm. fanglomerate	Within Puye Fm. fanglomerate; perching lithology not known	Tritium, nitrate	A single-screen well was installed in this zone (Griggs, 1964, Purtymun, 1995).
Pueblo Canyon	R-5 902 6473	~380	~37	Puye Fm. dacitic sands and gravels mixed with 5-15% rounded quartzite and granite river gravels	Within Puye Fm. fanglomerate; perching lithology not known	Nitrate, fluoride, chloride, uranium, and sulphate	A canyon-floor well was installed with four isolated screens (LANL, 2003). Screen #2 is complete in this perched zone. The vertical extent of this zone is poorly known.
Pueblo Canyon	TW-1a 225 6370	188-225 (?)	±37 (?)	Interflow breccia and siltstone in Cerros del Rio basalt	Possibly unfractured massive basalt	Nitrate, phosphate, chloride, boron, and uranium	Groundwater was first encountered near the top of Cerros del Rio basalts in a zone from 212- to 215-ft-deep (Griggs, 1955). Groundwater may be confined because the water level stabilized at 188 ft (Purtymun, 1995). Well screen placed from 215 to 225 ft deep.
Pueblo Canyon	POI-4 181 6372	160	>21	Cerros del Rio fractured basalt	Confining layer not penetrated	Nitrate, phosphate, chloride, boron,	Groundwater occurs in massive basalt cut by high-angle fractures. A single-screen well was installed in this zone.

Table 2-B-1.
Characteristics of Deep Perched Groundwater Zones Encountered in Wells on the Pajarito Plateau (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Los Alamos Canyon	H-19 2000 7172	450	22	Porous, well-bedded and well-sorted fall deposits of the Guaje Pumice Bed	Tschicoma Fm. lava flow top	Not sampled	Saturation in this zone was noted while drilling to reach the regional aquifer (Griggs, 1964). The perched zone was not screened, and the regional well was later abandoned.
Los Alamos Canyon	LAOI(A)1.1 323 6833	289	27	Porous, well-bedded and well-sorted fall deposits of the Guaje Pumice Bed	Top of Puye Formation; possible clay-rich soil horizon – see description for well LADP-3	None	A single-screen well was installed in this zone.
Los Alamos Canyon	R-7 1097 6779	373	9	Puye Fm. silty, clayey, and sandy gravels	Clay-rich gravels from 382 to 397 ft deep in the Puye Formation	None	A canyon-floor well was installed with three isolated screens (Stone et al., 2002). Screen #1 in well R-7 is completed in this perched zone.
Los Alamos Canyon	R-7 1097 6779	744	~23	Puye Fm. sandy gravel with abundant pumice clasts	Puye Fm.; possible perching layer from 767 to 772 ft in silty pebble gravel or from 772 to 777 ft in clayey pumiceous sands.	None	Screen #2 in well R-7 is completed in this zone. Geophysical logs and borehole videos suggest additional perched groundwater zones were encountered when the R-7 borehole was drilled.
Los Alamos Canyon	LADP-3 349 6756	320	9	Porous, well-bedded and well-sorted fall deposits of the Guaje Pumice Bed	Smectite- and kaolinite-rich soil a few inches thick at top of Puye Formation	Tritium	Soil development occurs at top of the Puye Formation in outcrops and in boreholes elsewhere. A single-screen well was installed in this zone. (Broxton et al., 1995).

Table 2-B-1.
Characteristics of Deep Perched Groundwater Zones Encountered in Wells on the Pajarito Plateau (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Los Alamos Canyon	LAOI-3.2a 165.5 ~6620	134	>31	Basal ash-flow tuffs of the Otowi Member and porous, well-bedded and well-sorted fall deposits of the Guaje Pumice Bed	The perched zone was not fully penetrated during drilling; perching lithology not known	Nitrate, perchlorate, chloride	Perched groundwater was detected while coring through the lowermost part of the Bandelier Tuff. The bottom of saturation was not penetrated by the borehole. A single-screen well was installed in this zone.
Los Alamos Canyon	Otowi 4 2806 6639	~253	Not known	Puye Fm. gravels	Within Puye Fm. fanglomerate; perching lithology not known	Not sampled	Saturation in this zone was noted while drilling to install a municipal supply well in the regional aquifer (Stoker et al. (1992). The geologic log notes: “Some perched water was visible in a video log of the 48-in hole at about 253 ft where water cascaded in from a large gravel.” This perched zone is not accessed by a well screen in Otowi 4.
Los Alamos Canyon	R-6i 660 ~6995	592	23	Puye Fm. gravels	Poorly sorted fanglomerate with a silty matrix	Nitrate and perchlorate	This zone occurs at the same elevation and may be related to the perched zone identified by borehole video in nearby supply well Otowi 4 during drilling. A single-screen well was installed in this zone.

Table 2-B-1.
Characteristics of Deep Perched Groundwater Zones Encountered in Wells on the Pajarito Plateau (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Los Alamos Canyon	R-9i 322 6383 and LAWS-01 281.5 6305	137	45-99	Cerros del Rio basalt interflow breccia and highly fractured basalt	Massive basalt with few fractures	Tritium	Groundwater was first encountered at a depth of 180 ft, but the water level quickly rose to 137 ft, indicating possible confinement. At R-9i a canyon-floor well was installed with two isolated screens (Broxton et al., 2001a,b). Screen #1 of R-9i is complete in this zone. In LAWS-01, this zone is sampled via a flexible liner with sampling ports (Stone and Newell, 2002).
Los Alamos Canyon	R-9i 322 6383 and LAWS-01 281.5 6305	275	7	Cerros del Rio basalt brecciated flow base	Clay-rich, stratified, basaltic tephra (maar deposits) from 282 to 289.8 ft	Tritium	Water first encountered at 275 ft. The water level stabilized at 264 ft and may be confined (Broxton et al., 2001a,b). Screen #2 in well R-9i is complete in this zone. In LAWS-01, this zone is sampled via a flexible liner with sampling ports (Stone and Newell, 2002).
Los Alamos Canyon	R-9 771 6383	524	48 to 103	Puye Formation sands and gravels	Clay-rich tuffaceous sands and gravels	Tritium	Three stringers of sands and gravels at 579-580.5 ft, 615 ft, and 624-626.8 ft produced perched groundwater (Broxton et al., 2001a). These occurrences probably constitute a single saturated zone because when isolated each yielded the same

Table 2-B-1.
Characteristics of Deep Perched Groundwater Zones Encountered in Wells on the Pajarito Plateau (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
							depth-to-water of 524 ft. The water-bearing stringers are enclosed by clay-rich tuffaceous sands and gravels that may be confining units or may simply be unproductive. No well screens were installed in this saturated zone.
Sandia Canyon	PM-1 2501 6513	450	Not Known	Cerros del Rio basalt	Not known	Not sampled	During installation of supply well PM-1, the geologic log notes that water was present in brecciated Cerros del Rio basalt at a depth of 450 ft (Cooper et al., 1965). No other information was given about this zone.
Sandia Canyon	R-12 886 6500	424	76-95	Fractured Cerros del Rio basalt and underlying fluvial sands and silts, and riverine gravels of the lacustrine facies of the Puye Fm.	Clay-rich lake beds of the lacustrine facies of the Puye Fm. from 519-535 ft	Tritium, nitrate	This is probably the same perched groundwater as that encountered in PM-1. Groundwater was first encountered at a depth of 443 ft, but the water level quickly rose to 424 ft before stabilizing, indicating possible confinement. A well was installed with three isolated screens (Broxton et al., 2001c). Screens #1 and #2 are complete in this perched zone.

Table 2-B-1.
Characteristics of Deep Perched Groundwater Zones Encountered in Wells on the Pajarito Plateau (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Mortandad Canyon	I-8 745	675, water level is at top of well sump	Saturated thickness is unknown, but the zone is probably very thin	Fractured Cerros del Rio basalt	Nature of confining bed is unknown	None	A small amount of water was observed trickling from a fracture at 669 ft bgs in the borehole video. A single-screen well was installed, but only a small amount of water has accumulated in the well sump.
Mortandad Canyon	MCOBT-4.4 767 6836	520	2-4 currently	Puye Fm. pebble gravel and silty sands	Top of Cerros del Rio basalt	Tritium, nitrate, perchlorate	Initial depth-to-water was 493 ft, but it has since declined to 520 ft. A single-screen well was installed in this zone (Broxton et al., 2002a).
Mortandad Canyon	I-4 540	520	2-4	Puye Fm. pebble gravel and silty sands	Top of Cerros del Rio basalt	Tritium, nitrate, perchlorate	A single-screen well was installed in this zone. This well was installed as a possible replacement well for MCOBT-4.4.
Mortandad Canyon	R-15 1107 6820	646	~99 (?)	Fractured Cerros del Rio basalt	Clay-rich flow-base rubble or underlying silty basaltic sand (745-746.7 ft)	Tritium, nitrate, perchlorate	Saturation in this zone was noted while drilling to reach the regional aquifer (Longmire et al., 2001). Saturation was first encountered at a depth 646 ft, but a zone of increased water production was noted by the driller from 707-717 ft. It is uncertain whether this occurrence represents one zone or multiple, stacked zones.

Table 2-B-1.
Characteristics of Deep Perched Groundwater Zones Encountered in Wells on the Pajarito Plateau (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Mortan-dad Canyon	I-5 717 6820	687	20	Interflow breccia in Cerros del Rio basalt	Possible confining unit in massive basalt in lower part of Cerros del Rio basalt	Tritium, nitrate, perchlorate	This well was installed adjacent to R-15 and targeted the water production zone from 707 to 717 ft that was noted in that borehole. A single-screen well was installed in this zone. It is uncertain whether the perched zone was fully penetrated by the borehole.
Mortan-dad Canyon	I-6 722 6811	662	43	Interflow breccia and fractured basalt in Cerros del Rio basalt	Possible confining unit in massive basalt in lower part of Cerros del Rio basalt	Tritium, nitrate, perchlorate	This well is 150 ft north of R-15 and I-5, near the Mortandad Canyon stream channel. A single completion well was installed in this zone. The elevation of the SWL is 16 ft higher than at I-5. It is uncertain whether the perched zone was fully penetrated by the borehole.
Pajarito Canyon	R-23 935 6528	Not known	Not known	Cerros del Rio basalt	Not known	Not sampled	Perched groundwater was probably encountered while drilling R-23 to the regional aquifer. Water accumulated in the annulus between the drill casing and the borehole wall above a clay-rich bridge. The accumulated water is probably from a perched zone within the Cerros del Rio basalt. The perched zone was not screened.

Table 2-B-1.
Characteristics of Deep Perched Groundwater Zones Encountered in Wells on the Pajarito Plateau (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Pajarito Canyon	R-19 1902.5 7066	894	18	Puye Fm. sand and gravel beds	Puye Fm. low-porosity sedimentary deposits.	None	R-19 was installed on the mesa south of Threemile Canyon. A perched zone was encountered in Puye Formation fanglomerate overlying Cerros del Rio basalt. Borehole geophysical logs indicate the perched zone is made up of high-porosity sediments overlying low-porosity sediments. A well was installed with seven isolated screens at this site (Broxton et al., 2001d). Screen #2 is complete in this perched zone.
Cañon de Valle	R-25 1942 7516	723	~409	Otowi ash-flow tuff, Guaje Pumice bed, and Puye Fm. fanglomerate	Confining layer occurs in Puye Fm. sedimentary deposits. From 1132 to 1137 ft, cuttings of fine-grained sand and silt are interbedded with gravels and cobbles. Alternating wet and dry sediments occur below this zone to a depth of 1286 ft.	High-explosive compounds and their degradation products, trichloroethene, tetrachloro-ethene	This large saturated zone is separated from the regional aquifer (depth at 1286 ft) by 154 ft of alternating wet and dry fanglomerate deposits. This upper saturated zone is currently interpreted as a perched zone with a leaky confining layer. The top of the same upper saturated zone was penetrated in nearby well CDV-16-1(i) which is located in adjacent Cañon de Valle. A multi-screen mesa-top well was installed at R-25 (Broxton et al., 2002b). Four screens are complete in this thick perched zone.

Table 2-B-1.
Characteristics of Deep Perched Groundwater Zones Encountered in Wells on the Pajarito Plateau (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Cañon de Valle	CDV-16-1(i) 683 7382	563	>120 ft; not fully penetrated	Otowi ash-flow tuff	Perching horizon not known; below drill hole depth	High-explosive compounds	Because of the proximity of CDV-16-1(i) and R-25 (~375 ft), the upper saturated zone in these wells is probably laterally connected. The top of the upper saturated zone is 28 ft higher in CDV-16-1(i) (elev. 6821 ft) compared with R-25 (elev. 6793 ft). A single-screen well was installed in this zone.
Cañon de Valle	CDV-16-2(i) 1063.1 7467	827 (?)	Not known	Puye Fm. fanglomerate	Within Puye Fm. fanglomerate; perching lithology not known	High-explosive compounds	The nature of this perched zone is currently under investigation. Borehole video logs, water level measurements, and the presence of high explosives in groundwater samples indicate that perched water is present. However, efforts to install a well in this zone(s) have not been successful.
Cañon de Valle	R-26 1490.5 7642	173	Zones of thin, dis-continuous saturation associated with fractures	Fractured densely-welded tuff in unit Qbt 3t of the Tshirege Member	Water production associated with fractures	Analyses pending	A piezometer was installed in a borehole adjaent to well R-26 to monitor water levels in this perched zone. The piezometer is screened from 175 to 185 ft deep, and the depth to water is 173 ft. Saturation appears to be associated with low-angle platy fractures in the ash-flow tuff.

Table 2-B-1.
Characteristics of Deep Perched Groundwater Zones Encountered in Wells on the Pajarito Plateau (continued)

Watershed	Well Name, Borehole Depth (ft), Surface Elev. (ft)	Depth to Water (ft)	Saturated Thickness (ft)	Groundwater Host Rock	Nature of Perching Layer	Anthropogenic Chemicals Detected	Comments
Cañon de Valle	R-26 1490.5 7642	About 604	See comments	Cerro Toledo interval	See comments	Analyses pending	R-26 was recently drilled and interpretation of perched water in this zone is preliminary. Borehole geophysical logs suggest high moisture contents below 575 ft to the top of regional saturation at 954 ft. Perched water appears most likely at depths of 580 to 662 ft and 780 to 827 ft. A water level at 604 ft depth was measured during drilling while the borehole was at a depth of 720 ft. Well R-26 was completed with two isolated well screens with the upper screen placed within the perched zone and the lower screen in the regional zone of saturation.
Water Canyon	SHB-3 860 7608	663	> 197 ft (?), probably not fully penetrated	Otowi ash-flow tuff, Guaje Pumice bed, and Puye Fm. fanglomerate	Confining layer probably not penetrated	None	Saturation occurs in the lower Bandelier Tuff and upper Puye Formation. A temporary mesa-top well was installed in the perched zone (Gardner et al., 1993).

In Pueblo Canyon perched water was identified in four wells. At wells TW-2a and R-5, perched water occurs within fanglomerate of the Puye Formation and has a saturated thickness of >7 and about 11.3 m (>23 and about 37 ft), respectively. Depth to water is 33.5 m (110 ft) at TW-2a and about 115.8 m (380 ft) at R-5. These perched zones probably represent relatively small, unrelated water bodies because of their distance from one another (4 km [2.5 mi]), the lateral heterogeneity of Puye Formation deposits, and their varying depths beneath the canyon floor. Wells TW-1a and POI-4 encountered perched water at depths of 36 to 48.8 m (118 to 160 ft), respectively, in Cerros del Rio basalt. The saturated thickness is about 11 m (37 ft) at TW-1a and 6.4 m (>21 ft) at POI-4. Saturation is associated with interflow breccia and sediments in TW-1a and with fractured basalt at POI-4.

In Sandia and Mortandad Canyons perched water was found in Cerros del Rio basalt and the Puye Formation. The water quality of these perched zones includes a component of treated waste-water effluent released to the canyons via outfalls (Longmire et al., 2001; Longmire, 2002; Broxton et al., 2002b). Depth to water is also similar, ranging from 129 to 152 m (424 to 500 ft) in Sandia Canyon and 150 to 197 m (493 to 646 ft) in Mortandad Canyon.

In Sandia Canyon, well R-12 encountered perched water from depths of 135 to 158 m (443 to 519 ft). Saturation occurs in the lower part of the Cerros del Rio basalt and extends downward into underlying lacustrine facies of the Puye Formation (Broxton et al., 2001a). The perched water in this zone may be confined because the borehole was dry until a depth of 135 m (443 ft) was reached, but the water level rose to a depth of 129 m (424 ft) once saturation was encountered. The apparent confining layer at the top of this zone is a massive basalt flow with few fractures. An alternative explanation for the observed rise in water level is that the groundwater is unconfined, but water-bearing interconnected fracture systems were not intersected by the borehole until a depth of 135 m (443 ft). The perching layer consists of clay- and silt-rich lacustrine deposits 5 m (16.5 ft) thick. The saturated thickness of this groundwater body is at least 23 m (75 ft), making it one of the thickest perched groundwater bodies identified in the eastern part of the Pajarito Plateau.

In Mortandad Canyon perched water was encountered in three boreholes. At well MCOBT-4.4, the top of perched groundwater zone occurs at a depth of about 150 m (493 ft), within pebble gravel made up of dacitic volcanic detritus in the Puye Formation. The saturated thickness of this zone is between 3 and 6 m (10 and 30 ft). The perching layer includes one or more of the following lithologies: 1) silty sands and gravels in the lower part the Puye sequence (153.3 to 157.6 m [503 to 517 ft]), 2) clay-rich brecciated rubble at the top of Cerros del Rio basalt (157.6 to 159.3 m [517 to 522.5 ft]), or 3) the massive, unfractured interior of the uppermost Cerros del Rio flow (approximately 159.3 to 163.1 m [522.5 ft to 535 ft]). At wells R-15 and I-5, located 347 m (1140 ft) down canyon of MCOBT-4.4, perched water occurs within the lower part of a thick sequence of Cerros del Rio basalts. The depth to water is 197 m (646 ft) in R-15 and 209 m (686 ft) in the adjacent well I-5 which is offset 20 m (66 ft). Saturation in both wells occurs in fractured lava flows and interflow breccias. The variable elevations of the top of perched saturation and varied saturated thicknesses of 30 m (99 ft) in R-15 and 8+ m (26+ ft) in I-5 illustrate the hetergeneous nature of perched bodies located within basaltic rocks. In R-15, the perching horizon is clay-rich flow-base rubble or underlying silty basaltic sands; the perched water at I-5 was not fully penetrated. Because of their different geologic settings, the perched

groundwater at MCOBT-4.4 and R-15/I-5 probably represent unrelated groundwater bodies of limited lateral extent. Other deep boreholes in Mortandad Canyon did not encounter perched groundwater. Based on the distribution of available boreholes, the lateral extent of individual perched groundwater bodies is probably less than 460 m (1500 ft).

Both perched water occurrences in Mortandad Canyon contain elevated tritium, nitrate, and perchlorate. The highest contaminant levels occur in MCOBT-4.4, which contains 14,750 pCi/L tritium, 12.5 mg/L nitrate plus nitrite (as N), and 179 ppb perchlorate (Longmire, 2002, personal communication). Since 1963, these contaminants were released to the canyon as liquid effluent by a waste treatment facility in the upper part of the canyon. The presence of contaminants in perched groundwater beneath Mortandad Canyon indicates that vertical transport through the vadose zone occurs on the timescale of decades.

A large area of complex perched groundwater occurrences is found in the region bounded by Cañon de Valle on the north and Water Canyon on the south in the southwest part of LANL. Five deep boreholes encountered significant zones of groundwater over a 2.6 km^2 (1 mi^2) area located just east of the Pajarito fault zone. These boreholes included R-25, R-26, CdV-16-1(i), CdV-16-2(i), and SHB-3. Depth to water in these perched zones range from about 183 m (600 ft) just east of the Pajarito fault to about 244 m (800 ft) 2.3 km (1.4 mi) farther east of the fault. Only wells R-25 and R-26 fully penetrate the perched water zones.

At R-26, a water-level measurement of 184 m (604 ft) was obtained when the borehole was 219 m (720 ft) deep. The borehole was eventually completed to a total depth of 454.3 m (1490.5 ft) with the regional water table occurring at a depth of approximately 291 m (954 ft). Borehole neutron, magnetic resonance, and induction logs indicate that high moisture contents occur in rocks below 175 m (575 ft), with perched water most likely at depths of 177 to 202 m (580 to 662 ft) and 238 to 252 m (780 to 827 ft). These perched zones occur within stratified volcaniclastic sediments of the Cerro Toledo interval. Low-permeability sediments within the Cerro Toledo interval probably provide the perching horizons.

R-25, located 1524 m (5000 ft) east of R-26, has two distinct zones of saturation separated by 47 m (154 ft) of partially saturated rocks. The upper zone, which is interpreted as a perched zone, occurs between depths of about 217 to 345 m (711 to 1132 ft) within the Otowi Member and in the upper part of the Puye Formation. An interval of partial saturation occurs below the perched zone from 345 to 392 m (1132 to 1286 ft) depth. Partial saturation was defined by casing off the perched zone and drilling through alternating zones of dry and wet rocks by coring and air-rotary methods. From 392 m (1286 ft) to the total depth of 592 m (1942 ft), continuous saturation representing regional groundwater was encountered within Puye deposits. R-25 was constructed with 9 screens separated by packers using a Westbay™ sampling system. Hydraulic head measurements in isolated screens decrease with depth, indicating downward vertical gradients. Isotopic and water quality data suggest the upper and lower zones of saturation at R-25 represent separate groundwater systems (Longmire, 2003, personal communication).

Table 3-A-1.
Guaje Canyon Watershed Description

Hydrogeologic Element	Characteristic	Description
Surface Water	Flow	Guaje Canyon heads in the Sierra de los Valles on Forest Service land, enters San Ildefonso Pueblo land, and continues to its confluence with lower Los Alamos Canyon approximately a mile west of the Rio Grande (Figure 3-A-1, Figure 3-A-2). Guaje Canyon is part of the Los Alamos Canyon watershed, but is covered separately because it is a large drainage that is largely unaffected by LANL activities. Guaje Canyon contains an interrupted stream with a perennial reach extending from springs located upstream of Guaje Reservoir to some distance downstream of the reservoir. An intermittent reach extends farther downstream to the confluence with lower Los Alamos Canyon. Snowmelt runoff does not reach the Rio Grande. Rendija Canyon heads on the flanks of the Sierra de los Valles and contains an ephemeral stream. Barrancas Canyon heads on the Pajarito Plateau and has intermittent and ephemeral flow.
	Quality	There are no known water quality effects of LANL activities.
Springs	Name	No springs have been found in any of these canyons.
	Quality	See above.
Alluvial Groundwater	Extent	Little or no alluvial groundwater is present in these canyons. Only two alluvial wells have been installed in Guaje Canyon to investigate the presence of alluvial groundwater. These wells were completed in the perennial reach of the canyon and alluvial groundwater was encountered near the stream level. For Rendija Canyon and Barrancas Canyon, no alluvial wells have been installed and no alluvial groundwater is known to exist.
	Depth/Thickness	See above.
	Quality	No impacts of LANL activities on this water are known.
Intermediate Groundwater	Extent/Hydrology	No intermediate groundwater wells have been installed and no groundwater is known to occur in these canyons. Drilling of the water supply wells in Rendija Canyon and Guaje Canyon did not find any intermediate groundwater.
	Depth/Thickness	See above.
	Quality	No LANL liquid discharges have occurred.

Table 3-A-1.
Guaje Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Description
Regional Aquifer	Depth/Hydrology	The regional aquifer occurs in the Puye Formation and the Santa Fe Group in the vicinity of Guaje Canyon. The regional aquifer probably includes rocks of the Tschicoma Formation in the western part of the canyon. The regional aquifer supplies water to the supply wells of the Guaje wellfield. Groundwater flow in the regional aquifer is from the northwest, so no Laboratory contaminant sources are located upgradient of Guaje Canyon sites. The aquifer lies at depths of about 230 to 570 ft in the Guaje wellfield.
	Quality	The water is of generally good quality except for high levels of naturally occurring arsenic—up to 40 µg/L in older, now-abandoned wells. The EPA MCL for arsenic is 10 µg/L.
Contaminants	Potential Sources	These canyons are located north of the Laboratory, mainly on Forest Service land and on San Ildefonso Pueblo. The primary Laboratory activities in the canyons have involved water supply: the Guaje reservoir is no longer in use, and the Guaje wellfield (now operated by Los Alamos County) currently includes five water supply wells. The wells in this field also extend to lower Rendija Canyon. Rendija Canyon contained a small-arms firing range and several sites used as mortar impact areas. Past Laboratory activities are described in more detail in an RFI Work Plan for the North Canyons and an RFI Work Plan for OU 1071.
	Type	
References: LANL 2001a; LANL 1992g.		

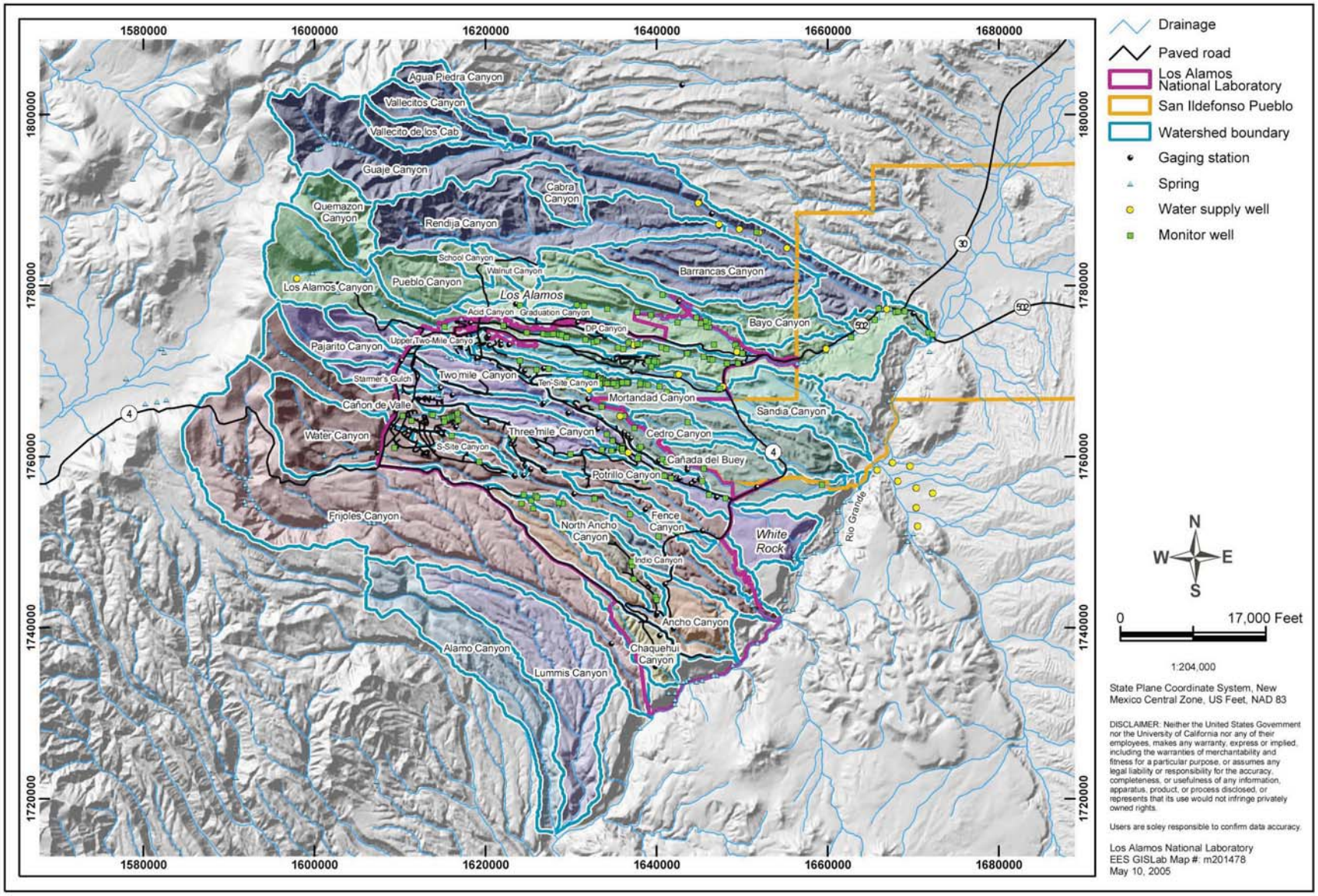

Figure 3-A-1. Watersheds on the Pajarito Plateau in the vicinity of Los Alamos National Laboratory.

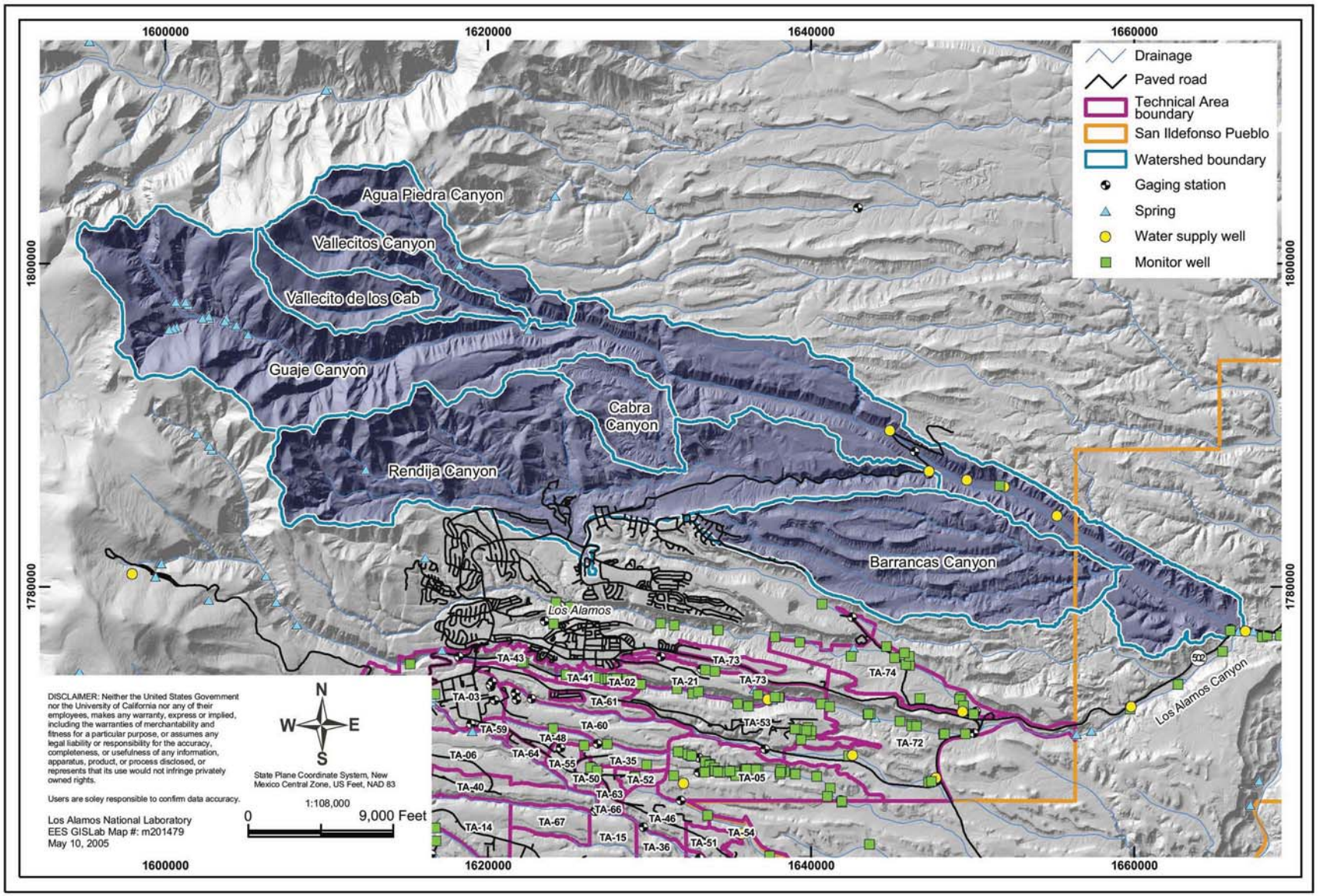

Figure 3-A-2. Guaje Canyon watershed.

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
Surface Water	Flow	Bayo Canyon heads on the Pajarito Plateau on land owned by Los Alamos County and extends across the northeast portion of the Laboratory (TA-74), crosses San Ildefonso Pueblo land to the east, and terminates at its confluence with lower Los Alamos Canyon near Totavi (Figure 3-A-1, Figure 3-A-3). The drainage area of Bayo Canyon is about 4 square miles. Surface water flow in Bayo Canyon is ephemeral and intermittent and there are no springs in the vicinity. Stream losses caused by infiltration into the underlying alluvium and evapotranspiration typically prevent surface flow from reaching Los Alamos Canyon. No alluvial or intermediate groundwater was encountered during drilling of about 90 boreholes at the TA-10 site in upper Bayo Canyon. Drilling at TA-10 has not found	Pueblo Canyon heads on USFS land, crosses Los Alamos County land, then Laboratory land where it joins Los Alamos Canyon just upstream of the San Ildefonso Pueblo boundary (Figure 3-A-1; Figure 3-A-3). The draingage area of Pueblo Canyon is about 6.5 square miles, including Acid Canyon. Surface water in Pueblo Canyon occurs as ephemeral runoff from precipitation and as perennial flow supported by effluent discharge from the Los Alamos County Sewage Treatment Plant. Generally, ephemeral surface water occurs in the upper portion of Pueblo Canyon following summer rains and snowmelt events, and perennial surface water occurs in the lower portion of Pueblo Canyon because of discharges from the Los Alamos County Sewage Treatment Plant. Surface water in Pueblo Canyon rarely flows across the length of the Laboratory. Acid Canyon heads on the Pajarito Plateau in the southwestern portion of the Los Alamos townsite and extends east-northeasterly to its confluence with Pueblo Canyon. The South Fork of Acid Canyon is a short north-trending	Los Alamos Canyon heads on USFS land, crosses Laboratory land, then San Ildefonso Pueblo land before joining the Rio Grande (Figure 3-A-1; Figure 3-A-3). Surface water occurs in Los Alamos Canyon as perennial flow in the upper reaches west of the Los Alamos Reservoir located west of DOE property, and in the lower reaches east of the confluence with Pueblo Canyon. The drainage area of Los Alamos Canyon is about 11.6 square miles, including DP Canyon. Typically, the overflow of water from the reservoir during spring snowmelt results in nearly continuous surface water flow between the western Laboratory boundary and the vicinity of TA-2 for several weeks to several months each year. For most of the year, the only surface flow in Los Alamos Canyon is in lower Los Alamos Canyon due to discharge from the Los Alamos County Sewage Treatment Plant and flow from Basalt and Los Alamos Springs east of the Laboratory boundary. Surface water in Los Alamos Canyon rarely flows across the length of the Laboratory except during snowmelt and summer storm events. Most often, surface waters are depleted by infiltration into canyon alluvium creating saturated zones of seasonally variable extent. DP Canyon heads on the Pajarito Plateau in the southeastern portion of the Los Alamos townsite and extends east-southeasterly to its confluence with Los Alamos Canyon. DP Canyon is located entirely within DOE-owned land except for a short segment at the head of the canyon on land owned by Los Alamos County. Surface flow in DP Canyon is generated by rainfall and snowmelt events. DP

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
		contamination that extends more than a few feet beneath former release sites. Groundwater in the regional aquifer is as described for Guaje Canyon.	tributary to Acid Canyon. Both of these canyons are entirely within land owned by Los Alamos County. These two canyons drain a surface area that is largely paved and developed.	Spring, located in DP Canyon, discharges continuously except for dry periods, such as during the winter and spring of 1996.
	Quality	TA-10 was used as a firing site from 1943 to 1961, for tests with high explosives and radioactive materials. The site included a radiochemistry laboratory. While in operation, the TA-10 sites in Bayo Canyon were investigated for environmental impacts. The site was decontaminated and decommissioned in 1960. TA-10 was the site of an extensive Formerly Utilized Sites Remedial Action Program investigation in 1976. In the mid-1990s the site was studied under a RFI Work Plan for Operable Unit 1079. RFI activities included shrapnel removal and investigation, remediation, or deferred action for several potential release sites. A second RFI work plan was written in 2001.	Key contaminants in Acid Canyon surface water include metals (arsenic, cadmium, manganese, zinc, and cyanide), PAHs (e.g., benzo-a-pyrene, dibenz-a-h-anthracene), and radionuclides (Pu-239, -240, strontium-90, and uranium-234). The metals COPCs are dominated by naturally occurring constituents, or constituents associated with urban runoff. The PAHs are also believed to be associated with runoff from developed areas with the Los Alamos townsite. The radionuclides were detected in bedrock pools in the South Fork of Acid Canyon and are consistent with contaminants found in sediment within the canyon from historical releases from TA-45. The radionuclide contamination generally does not extend beyond the Acid/Pueblo Canyon confluence in detectable concentrations, with the exception of Pu-239, -240 in unfiltered samples.	Key contaminants in upper Los Alamos Canyon surface water include metals (arsenic, manganese, iron, selenium, and cyanide), pesticides, and plutonium-239, -240. The metals are generally considered naturally occurring, although some minor contribution from historical Laboratory releases is possible. The cyanide detects in upper Los Alamos Canyon are believed to be related to combustion of organic matter during the Cerro Grande fire and may also be related to anti-caking and anti-corrosion agents contained in fire retardant. Pesticides are predominantly related to historical use in the Santa Fe National Forest and to use within the Los Alamos townsite. The plutonium-239 is related to outfalls (likely Hillsides 137 and 138) in former TA-1. The Pu-239 is a COPC only for the unfiltered samples indicating the potential that the sample(s) with detections may have contained suspended sediment. Key contaminants in DP Canyon surface water and springs include metals (arsenic, copper, lead, manganese, zinc, and cyanide), pesticides, and radionuclides (americium-241, and strontium-90). Chloride is also present. The metals are either naturally occurring or likely related to townsite runoff, since none of the PRSs in DP Canyon are known for metals contamination, the exception

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
			Surface water in Pueblo Canyon above the confluence with Acid Canyon also has metals COPCs and PAHs that are considered to have a source in townsite runoff. Surface water in Pueblo Canyon below the confluence with Acid Canyon shows metals COPCs (arsenic, manganese, selenium, and cyanide), and organics COPCs (pesticides and PAHs) that are both likely from townsite, national forest, or Cerro Grande fire sources. Radionuclides include Pu-239, -240, americium-241, and cobalt-60.	being the DP Tank Farm (DPTF, SWMU 21-029) which had lead contamination associated with leaks from the tanks. However, no other of the COPCs from the DPTF are present. The cyanide detections in DP Canyon are from DP Spring and a location at the very head of DP Canyon suggesting a source other than Laboratory operations. The radionuclides are COPCs only for the unfiltered samples indicating the potential that the detections are related to the presence of suspended sediment in the samples. DP Spring consistently shows elevated strontium-90 concentrations related to surface water and alluvial groundwater discharge from Reach DP-2 where strontium-90 is present throughout the sediment due to historical releases from SWMU 21-011(k). Key COPCs in surface water and springs in lower Los Alamos Canyon include metals (antimony, arsenic, beryllium, copper, possibly mercury, molybdenum, nickel, selenium, thallium, and cyanide), PAHs (benzo_k_fluoranthene), and pesticides (DDE_4_4_, and DDP_4_4_), and only strontium-90 from unfiltered surface water. The constituents present in lower Low Alamos Canyon appear to be primarily naturally occurring or related to sources other than Laboratory operations. Of the metals identified as COPCs for lower Los Alamos Canyon, only molybdenum (and mercury?) have known Laboratory sources up canyon. The cyanide is believed to be related to the combustion of organic matter during the Cerro Grande fire. Detections of cyanide in the lower canyon are thought to be related to transport of ash from burn areas in the upper watershed during floods. Strontium-90 could be

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
				from either Los Alamos or Pueblo Canyon, but based on estimated inventories of strontium-90, it is most likely associated with Los Alamos Canyon (specifically SWMU 21-011(k).
Springs	Name	There are no springs in Bayo Canyon.	There are no springs in Acid and Pueblo Canyons,	Discharge at DP Spring is highly variable, generally ranging from dry to less than one gallon per minute, and has been observed to respond rapidly to storm-water runoff from upper DP Canyon. Surface water flow generally extends for less than 50 ft down canyon from the point where spring flow joins the stream channel. Basalt Spring is recharged by water from the County Sewage Treatment Plant in Pueblo Canyon. It has variable estimated discharge rates from 1 to 10 gallons per minute. LA Spring discharges along the south slope of the canyon approximately 300 meters downstream of Basalt Spring.
	Quality	See above.	See above.	Chloride, sodium, and manganese, barium, boron, HE, and solvents at concentrations above background.
Alluvial Groundwater	Extent		Two saturated zones are known to occur in the alluvium of Pueblo Canyon. The first is in the upper reach from the headwaters to approximately the Rendija Canyon Fault. The eastern limit of this saturated zone has not been clearly defined and it may extend further down canyon. The second is in the lower reach downstream of the Los Alamos County Sewage Treatment Plant where saturated conditions are supported year-round due to effluent	Two saturated zones are known to occur in the alluvium of Los Alamos Canyon. The first is in the upper part of Los Alamos Canyon and extends eastward from the Los Alamos Reservoir to the vicinity of observation well LAO-4.5 west of State Rte. 4. The second is in the lower part of Los Alamos Canyon and extends from Basalt Spring to the Rio Grande. Alluvial groundwater in lower Los Alamos Canyon near Basalt and Los Alamos Springs is chemically similar to surface water flow supported by these springs. The chemistry of the water discharging from Basalt Spring is

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
			releases from the sewage treatment plant. The extent of saturation is variable due to fluctuation in runoff and volume of effluent released during the year. The volume of effluent released into the canyon typically decreases during the spring and early summer months as wastewater from the plant is pumped up canyon for irrigation use on the municipal golf course. From 1951 to 1964, surface flow in the mid-reach of Pueblo Canyon was augmented by liquid effluent from the former TA-45 radioactive liquid waste treatment facility via Acid Canyon. In addition, Los Alamos County operated a sewage treatment plant in upper Pueblo Canyon (known as the Pueblo Sewage Treatment Plant) until the current Los Alamos County Sewage Treatment Plant came on-line in 1963. Effluent from these past sources likely supported sustained saturated conditions throughout the mid-reach of Pueblo Canyon as well as shallow bedrock springs such as Hamilton Bend Spring, just west of the current Los Alamos County Sewage Treatment Plant. The sewage treatment plants are sources of boron and nitrate. This	similar to effluent from the Los Alamos County Sewage Treatment Plant. The chemistry of water discharging from Los Alamos Spring may represent an isolated perched system as it does not contain characteristic major ions indicative of sewage effluent. Alluvial groundwater in lower Los Alamos Canyon, from the confluence of Guaje Canyon and Los Alamos Canyon to the Rio Grande, shows chemical similarity to both regional aquifer water and surface water from the Rio Grande (LANL, 2004b, 2002, 2001a).

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
			alluvial groundwater may have provided the source for infiltration to intermediate perched zone groundwater or the regional aquifer. Shallow spring flow (including Hamilton Bend Spring) ended following closure of TA-45 and the Pueblo Sewage Treatment Plant.	
	Depth/ Thickness		See above.	In middle and upper Los Alamos Canyon, the saturated thickness in the alluvium varies seasonally from a few feet in the winter months to 25 ft in the spring and summer months when recharge is the greatest. The alluvial groundwater provides recharge to intermediate perched zones by infiltrating along preferential pathways such as faults or permeable bedrock units.
	Quality		Known contaminants at former TA-45 include nitrate, perchlorate, tritium, isotopes of uranium and plutonium, strontium-90, cesium-137, and gross-alpha radiation. The contaminant histories for nitrate, tritium, and strontium-90 illustrate trends in Pueblo Canyon surface water and groundwater. Nitrate has been present from Laboratory radioactive liquid waste effluents and from Los Alamos County Sewage Treatment Plant sanitary effluent. The highest values were found in surface water in the 1950s and 1960s, possibly related to both types of sources. With decommissioning of the radioactive outfall in 1964 and moving	Alluvial groundwater has been found in DP Canyon at wells LAUZ-1 and LAUZ-2, installed for the ER investigation at TA-21. Strontium-90, tritium, and some organic compounds have been detected at LAUZ-1. Time series plots of nitrate, tritium, plutonium-239, strontium-90, and molybdenum provide a picture of contaminant trends in Los Alamos Canyon groundwater. Nitrate in discharges into DP Canyon from TA-21 caused surface water and alluvial groundwater concentrations to exceed 100 mg/L (nitrate as nitrogen), or 10 times the MCL, until discharges ceased in 1986. Nitrate concentrations have returned to background since discharges ended. TA-21 effluent caused tritium activities in surface water and alluvial groundwater in and downstream of DP Canyon

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
			the sanitary discharge downstream to the Bayo Treatment Plant, less water and less nitrate are present in the upper portion of the drainage in recent years. Tritium and strontium-90 histories characterize the radioactive effluent releases into Acid Canyon. Tritium persisted in surface water and alluvial groundwater at fairly high levels for about a decade after effluent releases ceased, but has dropped to background levels since. The highest measured strontium-90 activity was about 500 pCi/L in Acid Canyon surface water in 1960. With no present source, levels have dropped dramatically and strontium-90 is now seen only at low activities, below 1 pCi/L in alluvial groundwater.	to reach values up to 5,000,000 pCi/L or 250 times the MCL. As with nitrate, tritium activities decreased greatly after discharges ceased. In Los Alamos Canyon above the mouth of DP Canyon, the Omega West Reactor cooling line leaked water containing tritium from 1956 to 1993. As a result of this leak, tritium activity in alluvial groundwater remained at values around 10,000 pCi/L or half of the MCL. Once the leak was shut off, tritium levels in Los Alamos Canyon water returned to background. Strontium-90 contamination in surface water and alluvial groundwater came from reactor sources at TA-2 and effluent discharges from TA-21. The strontium-90 activity in DP Canyon surface water reached 28,600 pCi/L. There is no present source, and activities of this isotope have dropped greatly after discharges ceased. However, strontium-90 persists in alluvial groundwater at levels above the EPA MCL of 8 pCi/L due to the large inventory in alluvial sediment, providing a source to groundwater. Migration of strontium-90 is considered to be controlled by cation exchange. Effects of Manhattan Project releases in upper Los Alamos Canyon cause plutonium-239, -240 activity in alluvial groundwater to remain at about 25% of the DOE 4 mrem drinking water derived concentration guide (DCG) of 1.2 pCi/L. Discharges from TA-21 resulted in plutonium-239, -240 activity in surface water much above the DOE 4 mrem DCG, even exceeding the 100 mrem DCG of 30 pCi/L in the late 1960s. Plutonium activity has decreased substantially with the end of discharges in 1986, but is still

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
				occasionally detected in surface water and alluvial groundwater below the former outfall. A short section of alluvial groundwater in Los Alamos Canyon has molybdenum concentrations near or above the New Mexico groundwater standard of 1,000 µg/L. In the early 1990s, molybdenum concentrations in Los Alamos Canyon alluvial groundwater rose sharply above background and exceeded the New Mexico groundwater limit in 2000. The source of this molybdenum is sodium molybdate, a water-treatment chemical commonly used in cooling towers at TA-53. The Laboratory discontinued use of sodium molybdate in June 2002.
Intermediate Groundwater	Extent/ Hydrology		Intermediate perched zones have been identified in two areas beneath Pueblo Canyon. One zone is in the middle reach of Pueblo Canyon where test well (TW)-2A is completed within fanglomerates of the Puye Formation. The perched zone occurs at a depth of about 120 ft. The second is in lower Pueblo Canyon (wells TW-1A and POI-4) within a thick sequence of Cerros del Rio basalts, at a depth of about 188 ft. This intermediate perched zone may be one source of water contributing to the flow from Basalt Spring in Los Alamos Canyon. Fairly rapid communication from Pueblo Canyon surface water and alluvial groundwater to the intermediate perched groundwater was interpreted	Several intermediate perched zones have been encountered in Los Alamos Canyon between TA-2 and State Road 4. A perched zone was encountered at well R-6i east of the facilities at TA-21 on the mesa top. The zone occurs within the Puye Formation at a depth of 593 ft.

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
			by the USGS based on water level measurements and similarities in water quality.	
	Depth/Thickness		See above.	The upper intermediate perched zone occurs within the Guaje Pumice Bed. This zone was encountered in borehole LADP-3 (at 325 ft). This same zone may have been penetrated by test hole H-19, west of the Los Alamos Canyon Bridge. The saturated thickness of this zone decreases from west to east, ranging from 22-ft at LAOI(A)-1.1 to 5-ft at LADP-3. A deeper intermediate perched zone was encountered in LAOI(A)-1.1 in the Puye Formation at about 317 ft. Another hole was drilled from the mesa top at MDA V in TA-21 which is approximately midway between LAOI(A)-1.1 and LADP-3 to investigate the lateral extent of the Guaje Pumice intermediate perched zone under DP Mesa. The MDA V Deep Hole (borehole 21-2523) did not find saturated conditions in the Guaje Pumice Bed at this location, indicating that this intermediate perched zone does not extend northward under DP Mesa. Other intermediate perched zones have been found in the basalt at R-9 near SR-4 at 180 and 275 ft. This well also found three possible saturated zones between depths of 570 and 626 ft, about 100 ft above the regional aquifer.
	Quality		Analysis of water samples from well TW-2A show that this perched zone contains elevated activities of tritium (2,228 pCi/L). This suggests that tritium associated with the former TA-45 treatment plant has infiltrated the canyon floor and migrated vertically, at	Average activities of tritium were 2.98 pCi/L in the perched zone, within the upper Puye Formation at well R-7 east of well LAOI(A)-1.1. Tritium was initially found in LADP-3 at 5500 pCi/L but activity has declined greatly since then, probably related to cessation of the Omega West Reactor cooling line leak in 1993. Average activities of tritium in the two intermediate perched zones at R-9i were 200 pCi/L at

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
			least to the depth of the intermediate perched zone at TW-2A. The tritium history for TW-2A shows a steep decrease the early 1980s, related to the cessation of discharges into Acid Canyon in 1964. Elsewhere in intermediate perched groundwater, tritium has been detected mainly at trace levels. In core from drilling of well R-2, perchlorate was found in more than 50% of the samples. Nitrate histories show that concentrations in TW-1A have often been up the 10 mg/L MCL. The high nitrate value in this and other wells in 1994 resulted from a sample preservation error. In about 1980, the Los Alamos County Bayo Sanitary Wastewater Treatment Plant, which discharges into Pueblo Canyon upstream of TW-1, greatly increased discharges. This increase in flow and infiltration apparently resulted in the higher concentrations of nitrate and chloride in TW-1 beginning about 1981. Nitrate (as nitrogen) concentrations in TW-2A, upstream of the Bayo treatment plant, have been 3 mg/L or less. Strontium-90 has not been consistently detected in intermediate perched	180 ft and 132 pCi/L at 275 ft during characterization sampling. Activities of tritium were 3802 pCi/L and concentrations of nitrate (as nitrogen) were 4.20 mg/L. Recharge from DP Canyon is most likely the dominant source of water to this perched intermediate zone. Perchlorate has been detected in unsaturated core samples from LADP-3 and R-8. However, perchlorate appears to have a very restricted vertical extent (<15 ft thick) in LA Canyon based on these boreholes. No other perchlorate detections occurred over the 200-350 ft sampling depth in the two boreholes. A similar situation occurs in DP canyon where LAUZ-1 perchlorate is also restricted to a narrow vertical depth range. In this borehole, all but one of the samples were non-detects for perchlorate. Vadose zone cores from DP Mesa boreholes LADP-4 (drilled on a bench above the DP canyon bottom near the former TA-21 radioactive liquid effluent outfall) and borehole 21-2523 (drilled east of MDA V), show a more extensive zone (>200 ft) of perchlorate contamination than occurs in the bottom of Los Alamos or DP canyon. In addition, both of these core holes show co-contamination of chlorate and nitrate. Chlorate has been detected in DP Spring, but chlorate and perchlorate have not been detected in other Los Alamos Canyon surface or groundwater samples.

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
			groundwater.	
Regional Aquifer	Depth/ Hydrology		Depth to the regional aquifer is known in several locations in Pueblo Canyon, including TW-4 in upper Pueblo Canyon, at well TW-2 in the middle reach, and at wells TW-1 and O-1 near the confluence with Los Alamos Canyon. Water level measurements show depths to water to be 1173 ft in 2003 at TW-4, 807 ft in 2001 at TW-2, and 686 ft in 2001 at O-1. Based on Laboratory water-level maps, the general direction of groundwater flow in the regional aquifer is east in the vicinity of Pueblo Canyon. East of the Rendija Canyon Fault, the top of the regional aquifer is within the Totavi Lentil of the Puye Formation.	Depth to the regional aquifer is known in several locations in Los Alamos Canyon; at TW-3 and O-4, at O-1 near the confluence with Pueblo Canyon, and at LA-5 and LA-1B in the lower reach. Water level measurements show depths to water to be 784 ft in 2001 at TW-3, 68 ft in 2001 at O-1, 762 ft in O-4 in 1995, and -18 ft (artesian) in 1996 at LA-1B. Based on Laboratory water-level maps, the general direction of groundwater flow in the regional aquifer is east in the vicinity of Los Alamos Canyon.
	Quality		Contaminants have been detected in the regional aquifer, particularly nitrate in TW-1, indicating that the pathways for contaminant migration may be active at least along the lower portion of the canyon. Tritium has been found in TW-1 at up to 360 pCi/L though recent levels are lower at 140 pCi/L. Perchlorate is found within the regional aquifer in Pueblo Canyon, notably in water supply well O-1 at 2.8 ppb using the LC/MS/MS analytical method. Well O-1	Tritium has been detected in the regional aquifer at up to 80 pCi/L in TW-3 (though recent samples are nondetects) and 24 pCi/L in R-9. In TW-3 nitrate (as nitrogen) values were below 0.3 mg/L prior to 1967, but have averaged above 0.6 mg/L since 1981 with values up to 0.97 mg/L in 1994. Activities of tritium were 181 pCi/L in the regional aquifer at well R-6 during development. Concentrations of nitrate (as nitrogen) were 0.49 mg/L at the well. Concentrations of perchlorate were less than detection (0.0005 ppm) using the ion chromatography method. Because tritium was detected and nitrate concentration is within background, a component of young water containing

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
			also contains a consistent 35-45 pCi/L of tritium and higher nitrate (as nitrogen) than any other regional aquifer well, excluding TW-1. Nitrate (as nitrogen) has been about 1.7 mg/L at well O-1 compared with approximately 0.5 mg/L in other water supply wells. Characterization well R-4, west of the Bayo Canyon and Pueblo Canyon confluence, contained 19.49 pCi/L of tritium and 1.39 ppm of nitrate (as nitrogen). These results indicate that the regional aquifer has experienced recent recharge that is most likely the result of past discharges to Acid Canyon to the west of well R-4.	tritium may have originated from a different source other than TA-21. This assumes that tritium, nitrate, and perchlorate were released to the environment at the same time.
Contaminants	Potential Sources		Contaminant sources affecting Pueblo Canyon include two inactive TAs (TA-1 and TA-45). TA-1 included the portion of the present-day Los Alamos townsite where the majority of the theoretical and technical work was accomplished at the Laboratory from 1943–1954. Acid Canyon was the original disposal site for liquid wastes generated by research on nuclear materials for the World War II Manhattan Engineer District atomic bomb project. From 1943 to 1951, Acid Canyon received untreated radioactive industrial effluent from the TA-1	Several contaminant sources affected upper Los Alamos Canyon. TA-2, located in upper Los Alamos Canyon, was the location of a series of nuclear reactors. The cooling line for the Omega West Reactor leaked water with tritium activity of at least 100,000 pCi/L into the alluvium, probably from 1956 until 1993. TA-21, which is on DP Mesa, north of Los Alamos Canyon, was the site of plutonium processing facilities. The site discharged treated liquid radioactive effluent into DP Canyon from 1952 to 1986 and includes Material Disposal Areas A, B, T, U, and V. TA-41, located in upper Los Alamos Canyon, was used for testing of nuclear weapons components. TA-53, the site of the Los Alamos Neutron Science Center (LANSCE) linear accelerator facility, lies on the mesa south of the canyon.

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
			research activities. The TA-45 treatment plant was completed in 1951 and discharged treated effluents containing residual radionuclides into Acid Canyon from 1951 to 1964. TA-73 is the site of the DOE airport and former landfill, above Pueblo Canyon. Pueblo Canyon also receives sanitary effluent from Los Alamos County Sewage Treatment Plant in Bayo Canyon. The county operated two other sewage treatment plants along Pueblo Canyon in the past. More detailed information about these sites can be found in the Task/Site Work Plan for Operable Unit 1049, Los Alamos Canyon and Pueblo Canyon, and the RFI Work Plans for Operable Units 1078, 1079, 1100, and 1106.	Water from National Pollutant Discharge Elimination System (NPDES) permitted outfalls, sanitary treatment, and reactor beam cooling water ponds flowed to Los Alamos Canyon. TA-1 included the portion of the present-day Los Alamos townsite where the majority of the theoretical and technical work was accomplished at the Laboratory from 1943 to 1954. Several facilities discharged untreated chemical waste streams into the canyon.
	Type		Septic tank outfall located on the south rim of Acid Canyon in the 1940s containing plutonium-239, -240 and PCBs. Former Pueblo Canyon WWTP operated from 1951 until 1991. Sludge from the Pueblo Canyon Sewage Treatment Plant contained metals at levels above background. Former Central Sewage Treatment Plant operated from 1947 until 1961. Metals and organic chemicals, including mercury and DDT, were contaminants	TA-1 Hillsides 137, 138, and 140 received discharges from septic tank outfalls from 1943 until the late 1950s. Radionuclides are the primary contaminants at these hillside sites, although some metals contamination is also present). TA-2 housed a series of research nuclear reactors, including the Omega West Reactor, which was a source of tritium releases into alluvial groundwater. Other SWMUs at TA-2 include leach fields for water boiler reactors. Cesium-137 and strontium-90 are primary contaminants associated with the leach fields, and strontium-90 has historically been detected in alluvial groundwater monitoring wells

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
			identified at the outfalls. Outfalls from former TA-1 and former TA-45. TA-45 was the site of the first radioactive liquid waste treatment facility. TA-1 outfalls into Acid Canyon were not treated. These outfalls were the most significant sources of radionuclide and other contamination in Acid and Pueblo Canyons. Plutonium-239,-240 is the primary contaminant, although other radionuclides, metals, and some organic chemicals are also present.	down canyon of the site. TA-41 was used for weapons development and long-term studies of weapon subsystems. The primary contaminant sources are a septic system and a sewage treatment plant. Initial data from these SWMUs indicate radionuclides at levels above background, but characterization of TA-41 is incomplete. TA-21 was the site of a plutonium processing plant and polonium and tritium research laboratories. Outfalls were the primary source of radionuclide contaminants in DP and upper Los Alamos Canyons. Radionuclides, particularly cesium-137, and strontium-90, are the primary contaminants discharged from this outfall. TA-53 includes a proton accelerator and associated experimental and support buildings used for research with subatomic particles; it is the current site of the Los Alamos Neutron Science Center (LANSCE). The accelerator became fully operational in 1974. Occasional releases occurred from three surface impoundments at the east end of TA-53, referred to as consolidated SWMU 53-002(a)-99, which have contributed contamination to an unnamed tributary drainage to Los Alamos Canyon. The impoundments received sanitary, radioactive, and industrial wastewater from various TA-53 buildings as well as septic tank sludge from other Laboratory buildings. The northern impoundments were active from the early 1970s until 1993. The southern impoundment was active from 1985 until 1998. Inorganic chemicals, organic chemicals, and radionuclide COPCs have been identified at the

Table 3-A-2.
Los Alamos Canyon Watershed Description

Hydrogeologic Element	Characteristic	Bayo Canyon	Acid and Pueblo Canyons	DP and Los Alamos Canyons
				impoundments and in the drainage. SWMU 21-018(a), Material Disposal Area (MDA) V, received liquid waste effluent from laundry operations and includes three absorption beds on the south side of DP Mesa that sometimes overflowed into Los Alamos Canyon. Sediment sampling in 1946 documented that plutonium from this source was entering the main channel in Los Alamos. Additional outfalls that discharged off the south rim of DP Mesa include SWMUs 21-023(c), 21-024(b), 21-024(c), 21-024(i), and 21-027(a). SWMU 21-029, the DP Tank Farm, was a fuel distribution station with aboveground and underground fuel tanks from 1946 to 1985. Diesel range organic (DRO) and gasoline range organic (GRO) hydrocarbon contamination was identified at two areas of bedrock seeps in the DP Canyon channel and observed to periodically form a sheen in surface water adjacent to the site. The MDAs at TA-21 are not considered to be important from the perspective of releases to the canyons.

References:

Broxton et al. 1995; Broxton et al. 2001a; Davis et al. 1996; Gallaher 2000; Glasco 2000; Griggs 1964; Kingsley 1947; Kleinfelder 2004a; Koch et al. 2004; Koch and Rogers 2003; LANL 1981; LANL 1991; LANL 1992a; LANL 1992c; LANL 1994b; LANL 1995; LANL 1996; LANL 1998b; LANL 2001a; LANL 2004a; LANL, 2004b; LASL 1963; Longmire 2002a; Longmire and Goff 2002; Mayfield et al. 1979; Newman 2003; Purtymun and Rogers 2002; Rogers 1998.

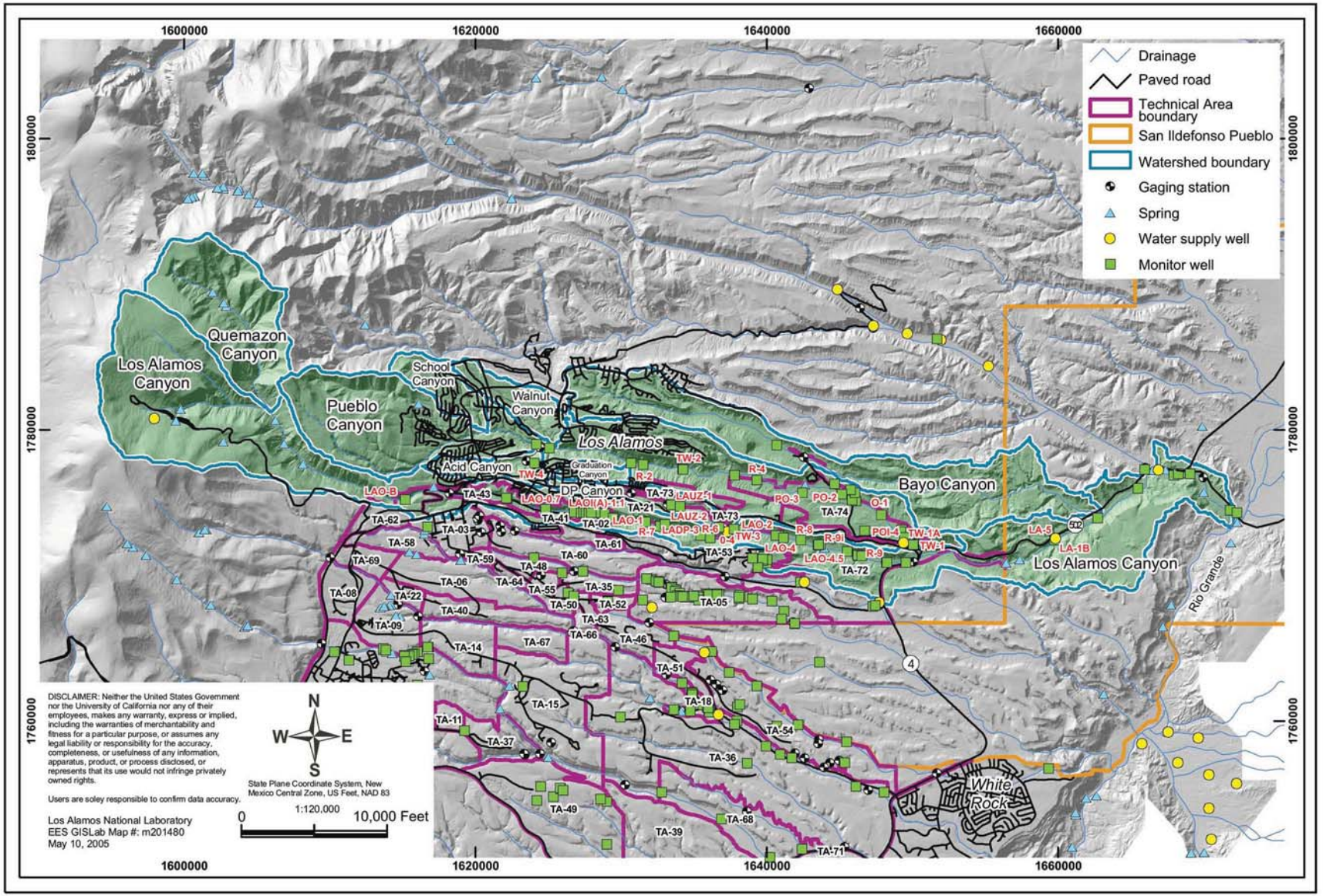

Figure 3-A-3. Los Alamos Canyon watershed, including Los Alamos Canyon, Bayo Canyon, Acid Canyon, Pueblo Canyon, and DP Canyon.

Table 3-A-3.
Sandia Canyon Watershed Description

Hydrogeologic Element	Characteristic	Description
Surface Water	Flow	Sandia Canyon is located on the plateau within the central part of the Laboratory (Figure 3-A-1, Figure 3-A-4). The canyon heads on Laboratory property within TA-3 at an elevation of approximately 7300 ft and trends east-southeast across the Laboratory, Bandelier National Monument, and San Ildefonso Pueblo land, and reaches the Rio Grande in White Rock Canyon at an elevation of 5450 ft. Sandia Canyon has a relatively small total drainage area of about 5.5 mi^2. Surface water occurs in Sandia Canyon as ephemeral runoff from precipitation and as NPDES-permitted effluent discharge from the Laboratory sanitary wastewater sewage treatment plant and the TA-3 power plant. On a volume basis, baseflow in Sandia Canyon represents one of the largest potential non-natural groundwater recharge sources at the Laboratory. The NPDES outfalls support perennial and intermittent flow within the upper 2.5 miles of the canyon, and a wetland has developed because of the artificial flows. The lower 9.5 miles of channel is ephemeral.
	Quality	Surface water quality reflects sewage effluent with nitrate, chloride, and metals slightly above background by approximately 2 to 5 times. Stream sediments contain PCBs and they are detected in surface water at low levels.
Springs	Name	Sandia Spring discharges about 1 gpm approximately 0.5 mile from the Rio Grande.
	Quality	Contaminant levels are at detection or background levels.
Alluvial Groundwater	Extent	Little is known about the occurrence of alluvial groundwater in Sandia Canyon. Most likely, infiltration of surface water creates a saturated zone of seasonally variable extent within the alluvium in the upper reach of the canyon. However, the extent and thickness of alluvial groundwater has not been characterized. Two wells were installed in 1990 to look for alluvial groundwater near the eastern Laboratory boundary as part of the HSWA permit special conditions. Both wells, SCO-1 and SCO-2, were dry at the time of installation. Periodic attempts to sample these wells as part of the Laboratory's annual environmental surveillance activities have found no water in the wells.
	Depth/Thickness	See above.
	Quality	NA

Table 3-A-3.
Sandia Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Description
Intermediate Groundwater	Extent/Hydrology	An intermediate perched zone was found within basalts near SR-4.
	Depth/Thickness	The perched zone is at about 440 ft in well R-12.
	Quality	The perched zone has tritium above background (60 to 160 pCi/L). In the borehole for R-11, nitrate (as nitrogen) was above background, at about 4.9 mg/L of nitrate (as nitrogen) at a depth of 443 ft bgs.
Regional Aquifer	Depth/Hydrology	The regional aquifer lies at about 800 ft depth below Sandia Canyon near SR-4.
	Quality	Tritium in well R-12 is about 45 pCi/L, and is above background. Concentrations of nitrate (as nitrogen) were 0.5 ppm at the regional water table during drilling. Characterization well R-11 west of supply PM-3 contained 12.8 pCi/L of tritium and 4.91 ppm of nitrate (as nitrogen), indicating that this well has experienced recent recharge. The $\delta^{15}N_{air}$ of nitrate values were +0.5 and +0.7% for the sample, which suggests that nitrate has not undergone fractionation, and the two values are very consistent with that of nitrate derived from neutralized nitric acid. The most likely source of this unique nitrate at well R-11 is Mortandad Canyon, which has a long history of discharges containing nitrate derived from neutralized nitric acid.
Contaminants	Potential Sources	Potential Release Sites (PRS) within the watershed are located at TAs-3, -53, -60, -61, -72, and former TA-20. The Laboratory started use of Sandia Canyon lands during the 1940s. The Laboratory's primary use of Sandia Canyon has been for liquid waste disposal from industrial and sanitary systems, particularly the treated effluents from the TA-46 Sewage Treatment Plant and cooling tower blowdown from the TA-3 power plant. Other sources include discharges from the TA-53 accelerator, the protective force small arms live firing range at TA-72, and a small high explosives firing site near TA-3 (former TA-20).
	Type	Nitrate, perchlorate, chromium, copper, PCBs in sediments, HE compounds, tritium, isotopes of uranium and plutonium, lead in surface soils.

References:
Broxton et al. 2001b; Kleinfelder 2004c; LANL 1996; Longmire 2002c; Purtymun and Stoker 1990.

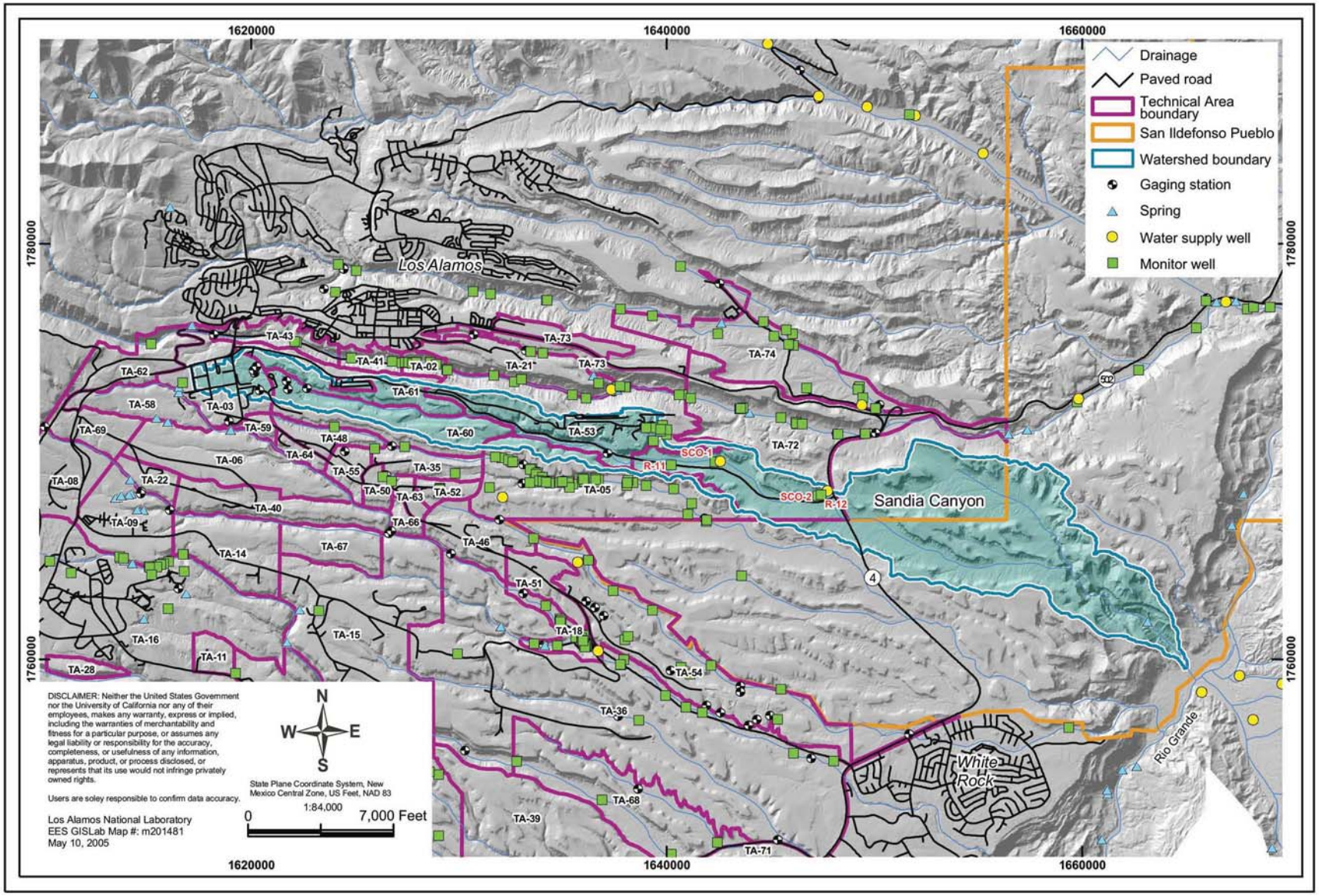

Figure 3-A-4. Sandia Canyon watershed.

Table 3-A-4.
Mortandad Canyon Watershed Description

Hydrogeologic Element	Characteristic	Mortandad Canyon	Cañada del Buey
Surface Water	Flow	Mortandad Canyon is an east to southeast trending canyon that heads on the Pajarito Plateau near the main Laboratory complex at TA-3 at an elevation of 7380 ft above sea level (Figure 3-A-1, Figure 3-A-5). The drainage extends about 9.6 mi from the headwaters to its confluence with the Rio Grande at an elevation of 5440 ft asl covering an area of 5 square miles. The canyon crosses San Ildefonso Pueblo land for several miles before joining the Rio Grande. Tributary canyons to the Mortandad Canyon drainage include Effluent Canyon, Ten Site Canyon, Cedro Canyon, and Cañada del Buey. Surface water in Mortandad Canyon is ephemeral; however, there are two segments that are effluent-dependent. The ephemeral segments flow only in response to precipitation. Historical Environmental Surveillance Program (ESP) data indicate that persistent surface flow occurs in the effluent-dependent segments at the surface water stations down canyon from the Radioactive Liquid Waste Treatment Facility (RLWTF) outfall (measured at gage E200, Mortandad below Effluent Canyon) and the Los Alamos County sewage treatment plant outfall in White Rock.	Cañada del Buey has a drainage area of 4.2 square miles and within the Laboratory boundary, it is ephemeral in character, based on flow data from three gages: E218 (Cañada del Buey near TA-46), E230 (Cañada del Buey above SR-4), and E225 (Cañada del Buey near MDA G). In the period from 1995 to 2002, the number of days of flow per year ranged from 38 at the gage near TA-46 to zero near MDA G. East of LANL in White Rock, Cañada del Buey has effluent-supported flow from the Los Alamos County sewage treatment plant, which discharges into Cañada del Buey about 2 mi upstream of its confluence with Mortandad Canyon and results in effluent-supported surface flow that regularly extends to the Rio Grande.
	Quality	Historically, the following constituents have been detected in Mortandad Canyon surface water at significant levels relative to standards: americium-241, plutonium-238 and plutonium-239, -240, strontium-90, tritium, nitrate, perchlorate, and fluoride.	Operational NPDES-permitted outfalls associated with Cañada del Buey include: 13S associated with the TA-46 SWSC Plant (effluent is sampled at 13S but not discharged; all SWSC effluent is routed to TA-3); and 04A-118 associated with water supply well Pajarito Mesa #4.

Table 3-A-4.
Mortandad Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Mortandad Canyon	Cañada del Buey
Springs	Name	No springs are present in Mortandad Canyon. However, some wetland areas occur in Pratt Canyon and occur locally downstream.	No springs are present in Cañada del Buey.
	Quality	See above.	See above.
Alluvial Groundwater	Extent	The extent, quality, and flow of alluvial groundwater in Mortandad Canyon is known from years of investigations. Major recharge to the alluvium occurs from effluent released in the upper canyon. The alluvial groundwater extends about 2 mi downstream from the TA-50 outfall.	Cañada del Buey contains a shallow perched alluvial groundwater system of limited extent, and only two observation wells here have ever contained water. Purtymun (1995) suggested that the primary source of the alluvial water is purge water from supply well PM-4, although storm water and snowmelt runoff augment the alluvial groundwater. However, the presence of water in the alluvium does not correspond to releases from the water supply wells.
	Depth/Thickness	The saturated portion of the Mortandad Canyon alluvium is generally less than 10 feet thick and there is considerable variation in saturated thickness depending on the amount of precipitation and runoff in any particular year. Groundwater flow velocity in the alluvium varies from about 60 ft/day in the upper canyon to about 7 ft/day in the lower canyon and has been estimated to be 30 to 40 ft/day between MCO-5 and MCO-8.2.	See above.
	Quality	Historically, the following constituents have been detected in alluvial groundwater in Mortandad Canyon at significant levels relative to standards: americium-241; plutonium-238 and plutonium-239, -240; strontium-90; tritium; nitrate; perchlorate; and fluoride. Nitrate (as N) concentrations in alluvial groundwater have generally reflected the concentration in RLWTF effluent. The nitrate concentration in the effluent decreased in 1999 due to improved treatment in the RLWTF,	Some alluvial groundwater samples have contained high levels of gross alpha and gross beta, but have no regular detection of any measured radioisotopes.

Table 3-A-4.
Mortandad Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Mortandad Canyon	Cañada del Buey
		and alluvial groundwater concentrations have fallen below the NM groundwater standard of 10 mg/L as a result. Perchlorate measurements are available since about 2000. The RLWTF started operating a system for removing perchlorate from the plant effluent on March 26, 2002. Prior to removal, perchlorate was measured in RLWTF effluent at an annual average concentration of 169 ppb in 2001; it has not been detected above 4 ppb since. Alluvial groundwater concentrations have fallen rapidly due to effluent improvement. During the last 10 years, tritium has been found above the 20,000 pCi/L EPA MCL at the Laboratory only in alluvial groundwater in Mortandad Canyon. At the end of 2000, the RLWTF adopted a voluntary goal of having tritium activity in its effluent below 20,000 pCi/L, and tritium activity in the effluent dropped below that in 2001 and was 10,400 pCi/L in 2003. Tritium activity in alluvial groundwater downstream has dropped correspondingly with a maximum value of 8,770 pCi/L in 2003. The discharge from the RLWTF into Mortandad Canyon creates a localized area of alluvial groundwater where strontium-90 persists at activities above the 8-pCi/L EPA drinking-water MCL. The radionuclides plutonium-238; plutonium-239, -240; and americium-241 are also present above the 4-mrem DOE DCG for drinking water.	
Intermediate Groundwater	Extent/Hydrology	Perched groundwater was encountered during drilling of R-15 and MCOBT-4.4 in different stratigraphic zones within the	No intermediate perched groundwater has been found in wells drilled near Cañada del Buey. These wells include

Table 3-A-4.
Mortandad Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Mortandad Canyon	Cañada del Buey
		Cerros del Rio basalt. The lateral extent of these intermediate depth perched zones is unknown.	PM-4, R-21, and R-22, as well as numerous wells drilled to investigate conditions beneath MDA L and MDA G.
	Depth/Thickness	Intermediate perched groundwater was found at MCOBT-4.4, where a single screen was set in a perched zone within the upper Puye Formation/Cerros del Rio basalt at a depth of 524 ft below ground surface (bgs). In R-15, perched groundwater was encountered at a depth of 646 ft bgs in the lower portion of the Cerros del Rio basalt.	See above.
	Quality	Measurements from core samples in several wells indicate that there is a large inventory of perchlorate and nitrate in the unsaturated Bandelier Tuff, extending to distances of 400 feet below the floor of Mortandad Canyon. Preliminary estimates suggest there is 415 to 1250 kg of perchlorate in the upper 300 ft of the vadose zone. Analytical results from groundwater samples collected from MCOBT-4.4 showed 12,797 pCi/L tritium, 13.2 mg/L nitrate plus nitrite (as N), and 142 ppb perchlorate. Perched groundwater encountered during the drilling of R-15 contained 3770 pCi/L tritium and 12 ppb perchlorate. Five additional intermediate-depth wells have been drilled and groundwater samples collected from the boreholes near the sediment traps. They contained nitrate, perchlorate, and tritium at concentrations similar to, but less than, those measured at well MCOBT-4.4.	See above.
Regional Aquifer	Depth/Hydrology	The regional water table occurs within the Puye Formation in the four wells that encounter the regional aquifer in the Mortandad Canyon watershed. In Ten Site Canyon, approximately 3700 ft west of the confluence with Mortandad Canyon, the regional aquifer was encountered at a depth of	Regional aquifer conditions for Cañada del Buey are covered in the column for Mortandad Canyon and the table for Pajarito Canyon.

Table 3-A-4.
Mortandad Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Mortandad Canyon	Cañada del Buey
		1182 ft in well R-14. In Test Well 8 the regional aquifer occurs at a depth of 994 ft. The regional aquifer was encountered at a depth of 964 ft in R-15, located in Mortandad Canyon approximately 2000 ft east of the confluence with Ten Site Canyon. In well R-13, located approximately 5800 feet ESE of R-15, the regional aquifer was encountered at a depth of 833 ft. Well R-28 lies between R-15 and R-13 and the regional water table occurs at 889 ft. Flow in the regional aquifer is generally west to east; some deviation may be present due to pumping in the Pajarito Mesa well field. Average flow velocity for the regional aquifer in the vicinity of Mortandad Canyon is estimated to be about 95 ft/yr.	
	Quality	Wells R-13 and R-14 have not shown contamination in the regional aquifer from samples collected during drilling and/or subsequent characterization. Regional aquifer well R-15 contained 2.4 mg/L nitrate (as N), 18 pCi/L tritium, and up to 4.2 ppb perchlorate in groundwater sampled at a depth of 1019 ft bgs. Well R-28 contains 7.2 mg/L of nitrate (as N) in a borehole sample, and 114 pCi/L of tritium.	Well R-21 contained 0.42 pCi/L of tritium and 0.299 µg/L of perchlorate (using liquid chromatography/mass spectrometry. Well R-21 is not impacted from Laboratory discharges.
Contaminants	Potential Sources	The source of contaminants to Mortandad Canyon has been from two liquid waste treatment plants. One is the NPDES-permitted outfall from the TA-50 Radioactive Liquid Waste Treatment Facility. It has been used to treat liquid radioactive waste from Laboratory operations from 1963 to the present. A second radioactive wastewater treatment plant at TA-35 treated wastes from reactor experiments from 1951 to 1963. It did not operate well, and large volumes of wastewater were released into Ten Site Canyon. Other mesa-top sites that could impact Mortandad Canyon	Cañada del Buey is bordered on the south by Material Disposal Areas G and L at TA-54.

Table 3-A-4.
Mortandad Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Mortandad Canyon	Cañada del Buey
		include MDA C near TA-50 and three waste oil surface impoundments at TA-35 closed in 1989. More information about the history of these sites and planned investigations can be found in the RFI Work Plans for OU 1129 and OU 1147.	
	Type	The effluents discharged from TA-3, TA-35, TA-48, and TA-50 have contained a variety of contaminants, including nitrate, perchlorate, tritium, cesium-137, strontium-90, americium-241, and several isotopes of uranium and plutonium.	Past discharges included accidental releases from experimental reactors and laboratories at TA-46. The Los Alamos County sewage treatment plant contributes flow to the lower portion of Cañada del Buey.

References:

Baltz et al. 1963; Broxton et al. 2002; Kleinfelder 2004d; LANL 1992b; LANL 1992h; LANL 1997; LANL 2000a; LANL 2001a; LANL 2002; LANL, 2003a; Longmire et al. 2001a; Newman 2003; Purtymun et al. 1983; Purtymun 1995.

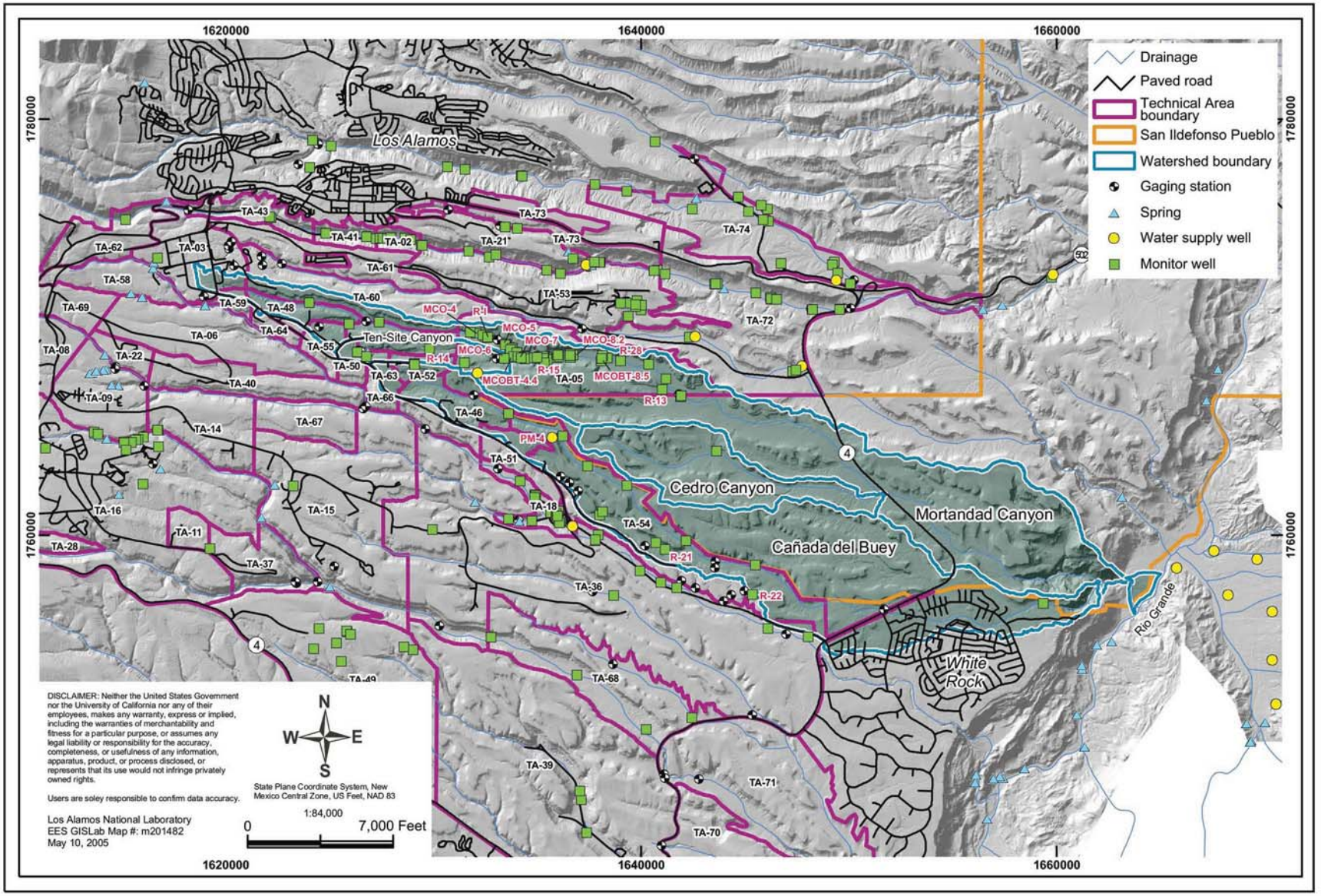

Figure 3-A-5. Mortandad Canyon Watershed including Mortandad Canyon and Cañada del Buey.

Table 3-A-5.
Pajarito Canyon Watershed Description

Hydrogeologic Element	Characteristic	Description
Surface Water	Flow	Pajarito Canyon is located on the Pajarito Plateau in the central part of the Laboratory (Figure 3-A-1; Figure 3-A-6). The canyon heads in the Santa Fe National Forest west of the Laboratory boundary at an elevation of approximately 10,434 ft and trends east-southeast across the Laboratory and Los Alamos County. It empties into the Rio Grande in White Rock Canyon at an elevation of 5422 ft. The drainage area of the Pajarito Canyon watershed is about 12 square miles. Surface water occurs in Pajarito Canyon mostly as intermittent flow. Short reaches of perennial flow occur downstream of spring discharges in Starmers Gulch and below Spring 4A in White Rock Canyon. Surface water flow is ephemeral in central Pajarito Canyon between the confluences with Twomile and Threemile Canyons. Flow is also ephemeral through White Rock. In Twomile Canyon, flow is ephemeral west of TA-3 and is possibly intermittent from TA-3 to the confluence with Pajarito Canyon. Three-mile Canyon is ephemeral except for a possible intermittent reach supported by springs above the confluence of Three-mile and Pajarito Canyons.
	Quality	High explosive compounds and metals have been detected in surface water in upper and middle Pajarito Canyon. There are no surface water chemistry results for Twomile Canyon except for a small tributary near building SM-30 in TA-3. Samples from the tributary show elevated arsenic and mercury in nonfiltered samples. RDX, SVOCs, and pesticides have been detected in a surface water sample in Threemile Canyon.
Springs	Name	Short reaches of perennial flow occur down stream of spring discharges in Starmers Gulch and below Spring 4A in White Rock Canyon. In the western portion of Pajarito Canyon, springs discharge from canyon slopes above the alluvium. The probable source of these springs is groundwater perched within the upper part of the Tshirege Member of the Bandelier Tuff. Typical discharge rates are approximately 1 to 15 gallons per minute. Springs include PC, Homestead, Upper Starmer, Charlies, Garvey, Perkins, Starmer, Josie, Keiling, and Bulldog Springs. Springs issue from the canyon floor of upper Twomile Canyon in TA-3 and TA-58. These springs include Hanlon, Anderson, SM-30, SM-30A, and TW-1.72 Springs. There are two springs in the floor of Threemile Canyon (Threemile and TA-18 Springs).

Table 3-A-5.
Pajarito Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Description
	Quality	HE compounds have been detected in spring water at TA-8 and TA-9. There are no screening data for springs in Twomile Canyon. HE compounds have been detected in Threemile Canyon.
Alluvial Groundwater	Extent	There are no alluvial wells in Pajarito Canyon upstream of TA-18. Therefore, information about the nature and extent of alluvial groundwater is limited. Most likely, infiltration of surface water creates a continuous saturated zone within the alluvium that extends from the Pajarito fault zone across the Laboratory to White Rock. Alluvial wells have been installed between TA-18 and state road NM4, which demonstrate the presence of alluvial groundwater in this part of Pajarito Canyon. The drilling of seven test holes in 1985 showed that the saturation in lower Pajarito Canyon does not extend laterally under Mesita del Buey near MDAs G and L. Three of the alluvial test holes were completed as groundwater monitoring wells (PCO-1, -2, -3). An additional 20 alluvial wells were installed between 1990 and 1998 by the Environmental Restoration Project as part of the RFI for TA-18. There are no alluvial wells in Twomile Canyon and the extent of alluvial groundwater, if present, is unknown. There are no alluvial wells in Twomile Canyon and the extent of alluvial groundwater, if present, is unknown. Alluvial groundwater has been documented in lower Threemile Canyon at 18-BG-1 and 18-MW-8.
	Depth/Thickness	Wells PCO-1, -2, and -3 are probably representative of alluvial groundwater between TA-18 and state road NM-4. When installed during 1985, depth to water was 1.3 ft in PCO-1, 6.3 ft in PCO-2, and 3.1 ft in PCO-3. Assuming continuous saturation in the alluvium, the saturated thickness is about 9.7 ft in PCO-1, 2.7 ft in PCO-2, and 8.9 ft in PCO-3. The saturated thickness and presence of water in these wells vary seasonally. Due to drought, these wells have had little water since 2000. At well 18-BG-4 in Threemile Canyon, the water level was 2.5 ft bgs.
	Quality	Data indicate the presence of metals, radionuclides, high explosives, VOCs, and anions in alluvial groundwater. Except for VOCs and some radionuclides in wells near TA-18, occurrence of these constituents is irregular and at low levels. There are no water quality data for alluvial groundwater in Twomile Canyon. Alluvial groundwater has been documented in lower Threemile Canyon at 18-BG-1 and 18-MW-8. In lower Threemile Canyon RDX and VOCs have been detected in 18-MW-8.
Intermediate Groundwater	Extent/Hydrology	Intermediate perched water is likely to occur beneath Pajarito Canyon, but knowledge of its extent and quality is incomplete. No water quality data for perched intermediate systems are available with current wells. Perched water was suggested during the drilling of PM-2 and SHB-4 in the vicinity of TA-18. At PM-2, a “show of water at 335 ft” was noted in the Otowi Member of the Bandelier Tuff during the cable-tool drilling. In SHB-4, the core tube and core from the top of the

Table 3-A-5.
Pajarito Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Description
		Otowi Member from about 125 ft to 145 ft came out of the hole wet. Test Holes 5 and 6 were drilled in 1950 to investigate perched groundwater in Pajarito Canyon south of TA-54. Test Hole 5 was drilled through the Bandelier Tuff and into basalts at a total depth of 263 ft. Test Hole 6 was also drilled through the tuff and into basalts to a total depth of 300 ft. These dry test holes indicate that perched water does not occur in the upper part of the vadose zone in this part of the canyon. Between 2000 and 2002 regional wells R-20, R-22, R-23, and R-32 were installed in lower Pajarito Canyon. Perched intermediate water was not identified during the drilling of wells R-20, R-22, and R-32. At R-23, near the eastern Laboratory boundary, there were indications that perched intermediate water may be present in Cerros del Rio basalt. However, R-23 is only screened in the regional aquifer. In Twomile Canyon, well 03-MW-1 is a 28-ft-deep mesa top well that samples shallow intermediate perched water near building SM-30 at TA-3. A thin zone of saturation occurs in the upper Tshirege Member. Characterization well R-19, located on the mesa south of Threemile Canyon, had indications of possible perched water at depths of 834 to 840 ft and 894 to 912 ft. Both zones were screened in the completed well, but only the 894 to 912 ft interval (screen 2) in the Puye Formation yields water.
	Depth/Thickness	See above.
	Quality	Characterization sampling for 03-MW-1 found elevated concentrations of Hg, tritium, and VOCs. A RFI Work Plan is being prepared to determine the extent of this perched zone. Four rounds of characterization sampling for R-19 indicate there are no impacts to the intermediate perched water from Laboratory operations. Less than detection activities of tritium indicate that groundwater in the perched zone pre-dates atmospheric nuclear testing.
Regional Aquifer	Depth/Hydrology	Water-level maps indicate that in the vicinity of Pajarito Canyon the general direction of groundwater flow in the regional aquifer is east to southeast. Depth to the regional aquifer is known in Pajarito Canyon at supply well PM-2 and in characterization wells R-20, R-22, R-23, and R-32. The nonpumping water level for PM-2 in 2001 was at a depth of 855 ft. In 2002, the regional water table was at a depth of 826 ft in R-20, 890 ft in R-22, 828 ft in R-23, and 776 ft in R-32. R-23 is completed with a single well screen, R-20 and R-32 have three well screens, and R-22 has five well screens. The regional aquifer probably discharges at Spring 4A and other springs along White Rock Canyon. There are no regional aquifer wells associated with Twomile Canyon. Well R-19 is located on the mesa south of Threemile

Table 3-A-5.
Pajarito Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Description
		Canyon. It is down gradient from firing site IJ in TA-36 and is up gradient of TA-18. In addition to two screens in the vadose zone (described above), R-19 has five screens in the regional aquifer.
	Quality	Water quality of the regional aquifer beneath eastern Pajarito Canyon shows little, if any, impacts from LANL operations. Four rounds of characterization sampling at R-22 yielded possible detects of Tc-99 in the first sampling round for screens 3 and 4, but it was not detected in any of the screens during subsequent sampling rounds. Tritium was detected above background (~1 pCi/L) in screen 2 (76.6 pCi/L) during the first sampling round, but was at background for subsequent sampling rounds. Tritium activities in screen 5 were slightly elevated relative to background in the four characterization sampling rounds (3.5 to 18.5 pCi/L). Surveillance sampling of PM-2 shows the groundwater meets regulatory standards. Wells R-20 and R-32 contained low levels of tritium less than 3 pCi/L (1.98 pCi/L of tritium for well R-20 and 2.84 pCi/L for well R-32). Followup sampling at well R-32 did not confirm the presence of low-level tritium. Low-level perchlorate was not detected at well R-20 and was detected at wells R-23 (0.21 to 0.41 µg/L) and well R-32 (0.21 to 0.29 µg/L). Results for both low-level tritium and low-level perchlorate for these three wells suggest that the regional aquifer is not significantly impacted from Laboratory discharges. The dominant fraction of groundwater in the regional aquifer is greater than 61 years of age, based on the non-detectable tritium. Four rounds of characterization sampling at R-19 indicate there are no impacts to the regional groundwater from Laboratory operations. Less than detection activity of tritium at R-19 indicate that the regional groundwater pre-dates nuclear testing.
Contaminants	Potential Sources	The primary Laboratory use of Pajarito Canyon watershed has been as the canyon-bottom location for the Los Alamos Critical Experiments Facility (LACEF) at TA-18 and for mesa-top surface and subsurface material disposal areas (MDAs) F at TA-6, Q at TA-8, MDA M at TA-9, and MDAs G, H, J, and L at TA-54. Runoff from firing sites in TA-15 and TA-36 may also be a contaminant source. A detailed description and data summary for Pajarito Canyon potential contaminants is contained within the work plan for Pajarito Canyon.
	Type	Pajarito Canyon: metals, radionuclides, HE compounds, VOCs, anions; Twomile Canyon: mercury, tritium, VOCs; Threemile Canyon: HE compounds, VOCs.

References:

Broxton et al. 2001c; Cooper et al. 1965; Devaurs 1985; Devaurs and Purtymun 1985; Gardner et al. 1993; Griggs 1955; Griggs 1964; LANL 1998a; LANL 2000b; Longmire 2002d; Longmire 2002e; Purtymun 1995.

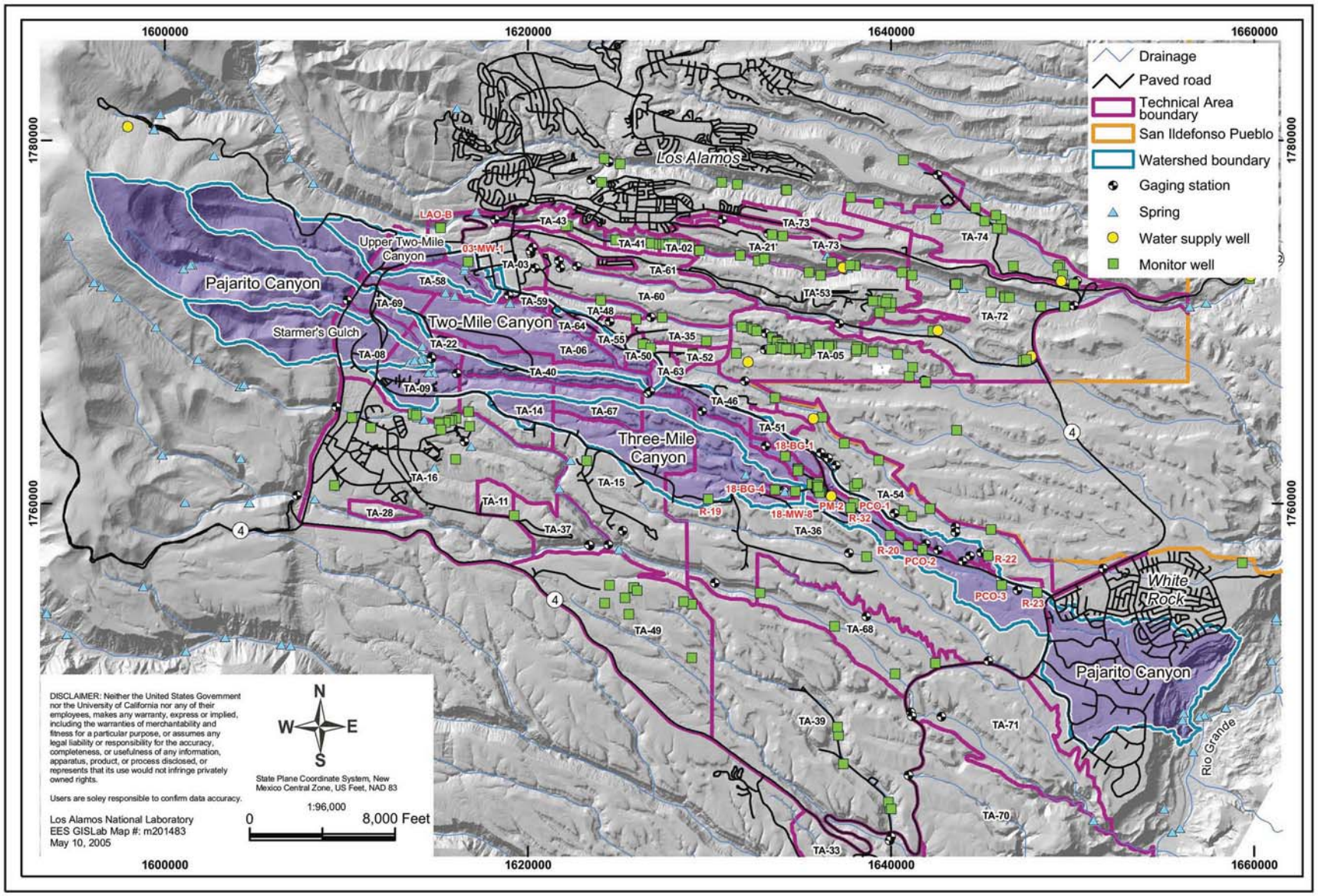

Figure 3-A-6. Pajarito Canyon watershed.

Table 3-A-6.
Water Canyon Watershed Description

Hydrogeologic Element	Characteristic	Water Canyon	Cañon de Valle	Potrillo and Fence Canyons
Surface Water	Flow	The Water Canyon drainage area is about 6 square miles. Surface water flow in upper Water Canyon is perennial from SR 501 to the eastern edge of TA-28 (Figure 3-A-1, Figure 3-A-7). Intermittent surface water occurs in upper Water Canyon (gage E252, Water above SR-501), primarily in the spring. In middle Water Canyon, flow is ephemeral at gage station E265.2 (Water below SR-4). Lower Water Canyon is ephemeral.	Cañon de Valle has a drainage area of 4 square miles and surface water is perennial from Burning Ground spring to gage E256 (Cañon de Valle below MDA P). Intermittent surface water occurs from natural and anthropogenic sources to gage E262 (Cañon de Valle above Water) Figure 3-A-1, Figure 3-A-7).	The drainage area of Potrillo Canyon and Fence Canyon together is about 4.5 square miles and the surface water flow is entirely ephemeral.

Table 3-A-6.
Water Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Water Canyon	Cañon de Valle	Potrillo and Fence Canyons
	Quality	Except for flow from the Water Canyon Gallery, no surface water quality data are available for upper Water Canyon. In middle Water Canyon, surface water chemistry results show contaminant levels are at detection or background levels. In lower Water Canyon, uranium is significantly greater than background in surface water (>10 ppb) near the firing sites, yet no significant elevation in concentration is seen at State Road 4.	Surface water concentrations of barium are 2-3 mg/L and concentrations of RDX are more than 100 µg/L or ppb.	See above.
Springs	Name	Water Canyon Gallery is a spring that issues from the Bandelier Tuff west of LANL in Water Canyon. Spring 5A is in lower Water Canyon.	Several springs issue from the Bandelier Tuff in the upper reaches of Cañon de Valle: Armistead Spring, American Spring (west of LANL) and SWSC, Burning Ground, Martin, and Hollow Springs, and others (in LANL). Note that Martin Spring actually flows into Water Canyon. It is included here because of its close location to the Cañon de Valle springs, and similar contaminant constituents.	There are no springs in Potrillo Canyon or Fence Canyon.
	Quality	Water quality data indicate that concentrations of constituents are consistent with other springs within the Sierra de los Valles.	For the on site springs, chloride, sodium, manganese, nitrate, barium, boron, HE compounds, and solvents are at concentrations above background. As in the alluvial system, the main contaminants of concern are HE compounds and barium. HMX, RDX, and TNT concentrations range	See above.

Table 3-A-6.
Water Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Water Canyon	Cañon de Valle	Potrillo and Fence Canyons
			up to 32, 330, and 3 µg/L, respectively. Barium concentrations range up to 1310 µg/L. Martin and Fishladder canyons are above 6.1 ppb RDX as well.	
Alluvial Groundwater	Extent	In upper Water Canyon, some alluvial groundwater is likely to occur near the headwaters. The occurrence and duration of alluvial groundwater likely decreases down canyon, given limited addition of water, lack of springs and seeps, and rare discharge from tributary canyons. Alluvial groundwater in Martin Canyon (a small tributary canyon to Water Canyon) is intermittent. In middle Water Canyon, alluvial groundwater is present in WCM-1 and WCM-2, but no water is present in WCO-1, WCO-2, and WCO-3. The downstream extent of alluvial groundwater may be between the WCM-2 and WCO-1.	A thin (typically <10 ft thick) alluvial system in Cañon de Valle near SWSC and Burning Ground Springs has perennial saturation. However, alluvial saturation does not extend to the confluence with Water Canyon. The down-canyon extent of saturation is highly variable and fluctuates depending on weather conditions. Saturation is also restricted by the limited extent of alluvium in the canyon. Six alluvial wells are used for water level monitoring and for alluvial water sampling.	In Potrillo Canyon, there is one known occurrence of alluvial groundwater in moisture access hole POTM-2. Several other boreholes have been drilled near this area to define the extent of the groundwater found in POTM-2 but all are dry. In Fence Canyon, no occurrences of alluvial groundwater have been documented. However, only one well was installed, well FCO-1, located near State Road 4. Based on physiography, no alluvial groundwater is expected at that location.
	Depth/Thickness	The alluvium is typically less than 10 ft thick.	See above.	See above.
	Quality	Groundwater quality in Martin Canyon shows primarily barium and high explosives as contaminants but also nitrate, many metals and organics, including values above WQCC standards.	Groundwater quality shows primarily barium and HE compounds including HMX, RDX, and TNT as contaminants. HMX, RDX, and TNT concentrations have been measured up to 610, 759, and 46 µg/L, respectively. High explosive degradation products and perchlorate	See above.

Table 3-A-6.
Water Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Water Canyon	Cañon de Valle	Potrillo and Fence Canyons
			have also been detected. Barium concentrations range up to 18,000 µg/L.	
Intermediate Groundwater	Extent/Hydrology	No perched water was encountered in any of the holes and all holes have remained dry with the exception of core hole CH-2. DT-5, DT-5P, and four core holes (CH-1, CH-2, CH-3, and CH-4) were drilled to depths of 300 to 500 ft at the main experimental area and more than 50 experimental holes were drilled as deep as 142 ft in Areas 1, 2, 2A, 2B, 3, and 4 from 1959 to 1961. CH-2 may have an undetected natural perched zone; however, this seems unlikely because this recharge pathway apparently developed more than a decade after the hole was completed.	At depths of a few hundred feet, transient zones of perched saturation within the Bandelier Tuff have been identified in two boreholes beneath the TA-16 mesa between Water Canyon and Cañon de Valle. These zones may be related to the perched water that feeds the numerous Cañon de Valle springs.	No perched zones are known in the area of these canyons, although little drilling has been done.
	Depth/Thickness	See above.	Wells R-25 and SHB-3 encountered a thick perched zone in the lower Otowi and upper Puye that apparently extends beneath a large portion of the mesa; at R-25 the perched zone extends in depth from 711 to 1132 ft. The lateral extent of this perched zone has not been determined, however.	See above.
	Quality	See above.	The transient saturation contains HE and barium contamination and appears to be from former and active HE waste water lagoons on the mesa top rather than to the building 260	See above.

Table 3-A-6.
Water Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Water Canyon	Cañon de Valle	Potrillo and Fence Canyons
			outfall. HMX, RDX, and TNT concentrations range up to 21, 2 490, and 1.3 µg/L, respectively. Barium concentrations range up to 1790 µg/L. High explosive compounds (for example, 84 µg/L RDX), HE degradation intermediates (2-amino-4,6-dinitro-toluene and 4-amino-2,6-dinitrotoluene), chlorinated solvents, and boron were detected in the perched zone at R-25. The tritium activity in this well is up to 140 pCi/L in the intermediate perched zone, indicating a component of recharge within the last 50 years. The unsaturated soils and tuff that make up the TA-16 mesa, and the alluvial sediments and soils of Cañon de Valle and Martin Canyon contain variable and localized inventories of HE and barium. Core holes in the vicinity of the 260 outfall in particular show detections of these contaminants in the upper few hundred feet of the vadose zone.	
Regional Aquifer	Depth/Hydrology	Information on the regional aquifer near Water Canyon is discussed in the table for Ancho Canyon.	Well R-25 encountered the regional aquifer at 1286 ft.	By projecting depths from water supply well PM-2, the regional aquifer lies 730 ft below the bottom of Potrillo Canyon and 620 ft below the bottom of Fence Canyon.
	Quality	See above.	High explosives were detected in R-25 although this may have been from	See above.

Table 3-A-6.
Water Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Water Canyon	Cañon de Valle	Potrillo and Fence Canyons
			cross contamination from the upper saturated zone above, which occurred during drilling (Longmire 2005). High explosives concentrations are decreasing in the regional aquifer samples with time, while they are remaining relatively constant in the upper saturated zone. Tritium activity has decreased during sampling, remaining above 2 pCi/L, suggesting a component of recharge in the past 61 years. Well R-18 located north of well R-25 contained less than -0.32 pCi/L of tritium, less than 0.001 ppm of perchlorate, and concentrations of HE compounds and degradation intermediates were less than detection (0.48 to 1.5 µg/L method detection limit). Well R-18 has not experienced recharges within the past 61 years and the well is not impacted from Laboratory discharges.	
Contaminants	Potential Sources	In upper Water Canyon, potential contaminant sources include TA-11, TA-15, and TA-16. Potential contaminants include HE compounds, barium, and solvents. In middle Water Canyon, TA-49 is a potential contaminant source possibly contributing isotopes of uranium and plutonium, lead, beryllium, and HE compounds such as TNT, RDX, HMX,	In Cañon de Valle, potential contaminant sources include TA-8, TA-9, TA-11, TA-14, TA-15, and TA-16.	In Fence Canyon and Potrillo Canyon, firing sites at TA-36 are potential sources of contaminants.

Table 3-A-6.
Water Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Water Canyon	Cañon de Valle	Potrillo and Fence Canyons
		and barium nitrate. For lower Water Canyon, TA-14, TA-15, and TA-36 are potential sources of high explosives such as TNT, nitrocellulose, trinitramines (RDX), and pentaerythritol tetranitrate (PETN). Metals may also be associated with the explosives (uranium, barium, beryllium, lithium hydride, lead, mercury, copper, and zinc).		
	Type	Soils in several of these operational areas have high levels of uranium contamination. More information for upper Water Canyon may be found in the RFI Work Plan for Operable Unit 1082. For middle and lower Water Canyon, additional detail is contained in the RFI Work Plan for Operable Unit 1144 and RFI Work Plans for Operable Units 1085, 1086, and 1130.	Potential contaminants include HE compounds, barium, nitrate, and solvents. More information may be found in the RFI Work Plan for Operable Unit 1082 and the associated RFI reports.	TNT, nitrocellulose, trinitramines (RDX), and PETN. Metals may also be associated with the explosives (uranium, barium, beryllium, lithium hydride, lead, mercury, copper, and zinc). Soils in several of these operational areas have high levels of uranium contamination.

References:
LANL 1992f; LANL 1993a; LANL 1993d; LANL 1993e; LANL 1994a; LANL 1998b; LANL 2003b.

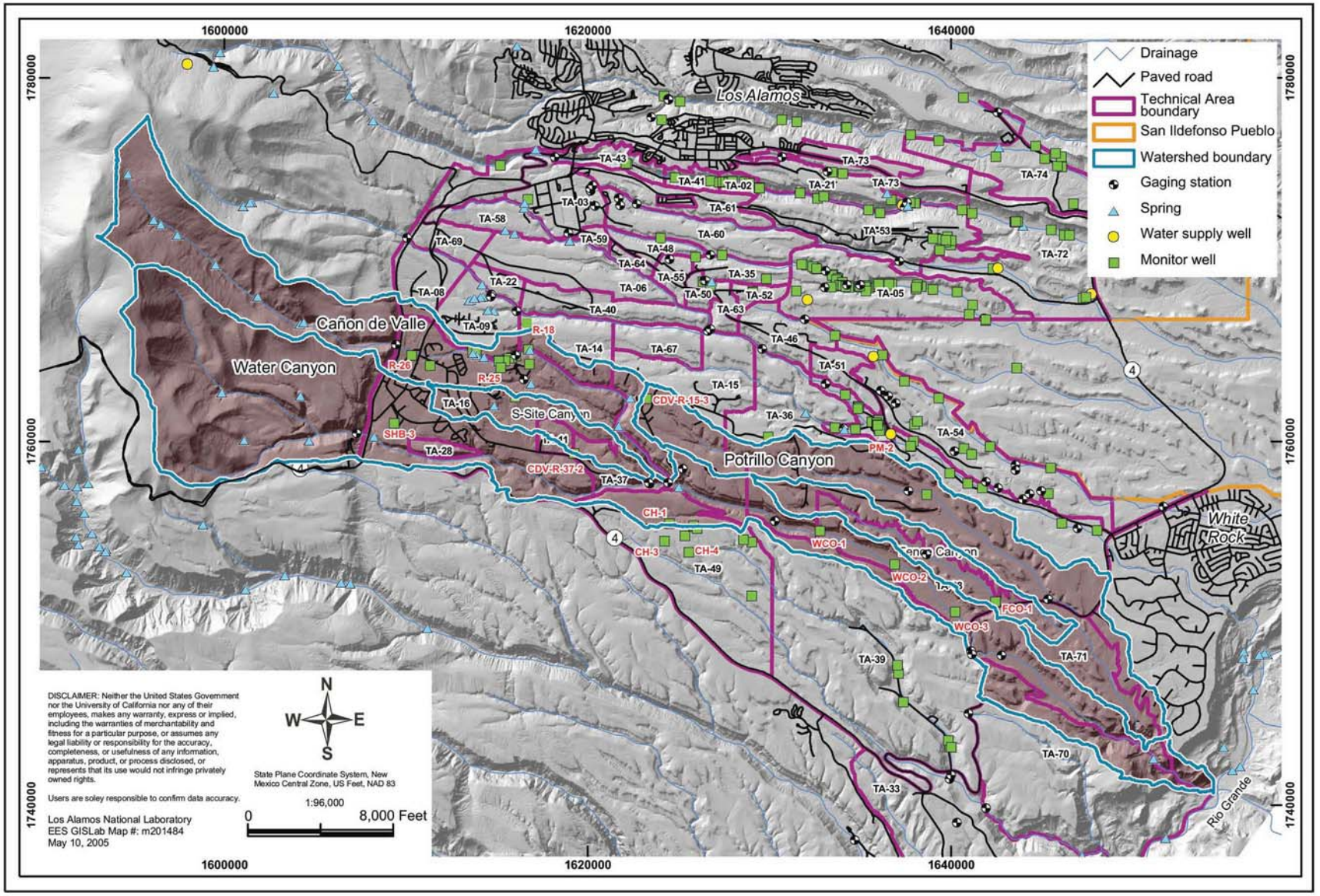

Figure 3-A-7. Water Canyon watershed including Pajarito Canyon, Cañon de Valle, Potrillo Canyon, and Fence Canyon.

Table 3-A-7.
Ancho Canyon Watershed Description

Hydrogeologic Element	Characteristic	Description
Surface Water	Flow	Ancho Canyon lies in the southeastern part of the Laboratory (Figure 3-A-1; Figure 3-A-8) and has a drainage area of 6.7 square miles. Ancho Canyon heads on the Pajarito Plateau and for the most part has ephemeral flow. The canyon has two main branches. Beginning less than a mile above the Rio Grande, flow in Ancho Canyon is perennial, fed by Ancho Spring, a regional aquifer spring.
	Quality	
Springs	Name	Ancho Spring
	Quality	Analysis of water at Ancho Spring by the Environmental Surveillance Program indicates occasional presence of HE compounds and trace levels of depleted uranium. Because the spring issues from the canyon floor, it is uncertain whether these contaminants are being transported by groundwater or if they are being mobilized from sediments in the canyon. Ancho Spring is downgradient of explosives testing sites.
Alluvial Groundwater	Extent	Little is known about the presence of alluvial groundwater in Ancho Canyon. Ancho Canyon contains thick alluvium that could host perched groundwater.
	Depth/Thickness	Three boreholes (ASC-15, ASC-16, and ASC-18) drilled by the ER Project encountered 4 ft to 9 ft of saturation in alluvium below MDA Y, but no contamination. Several boreholes drilled downgradient of MDA Y did not encounter alluvial groundwater, suggesting that the occurrence of alluvial groundwater in this area is limited in extent.
	Quality	See above.
Intermediate Groundwater	Extent/Hydrology	No intermediate perched zones have been found beneath Ancho Canyon. ER borehole DMB-1, drilled between building 69 and the Administrative Area at TA-39, penetrated 119 ft of Bandelier Tuff and 5 ft of Cerros del Rio basalts. No intermediate-depth perched water was encountered in this hole, but clay-lined fractures and vesicles in the basalt suggest that the periodic passage of groundwater through these rocks may occur. A test hole (TH-7) drilled 10 ft into basalts in Ancho Canyon below State Road 4 was dry. The hole was drilled in 1950 and has been plugged.
	Depth/Thickness	R-31 was drilled in TA-39 in the north fork of Ancho Canyon. A screen was placed from 439 to 454 ft at a possible perched zone, based on water seen in a borehole video. The zone has been dry since and no water samples have been collected from it.

Table 3-A-7.
Ancho Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Description
	Quality	See above.
Regional Aquifer	Depth/Hydrology	Groundwater flow in the regional aquifer beneath Ancho Canyon is to the east and southeast, towards the Rio Grande. The regional aquifer lies at about 1000 to 1170 ft beneath the mesa at TA-49, and is within the Cerros del Rio basalt, the underlying Puye Fanglomerate, "Totavi" gravels, and possibly the Santa Fe Group (Section 2.3.1). The regional water table, at well R-31 in TA-39, was encountered at about 530 ft within the Cerros del Rio basalt, the underlying Puye Fanglomerate, and "Totavi" gravels.
	Quality	Three regional aquifer wells at TA-49 have been sampled since the 1960s to monitor for effects of testing at that site. In general, no contaminants have been consistently found. High metal concentrations (lead, zinc, iron, manganese) in samples are related to metal well casing and fittings. Occasional detections of organic compounds are not supported by follow up sampling. Post-drilling water quality sampling has not been completed at well R-31.
Contaminants	Potential Sources	Located south of Ancho Canyon on a mesa near the Rio Grande, TA-33 was used as a firing site and for production of tritium. PRSs include landfills, septic systems, and burn areas. It is situated on a mesa top and is being investigated by the ER Project as OU 1122. TA-39 is located on the floor of middle Ancho Canyon, and it was used for open-air testing of high explosives. PRSs in this technical area include five firing sites, a number of landfills, and septic systems. The ER Project is investigating this technical area as OU 1132. More detailed information about the operational history and the PRSs can be found in the RFI Work Plans for OUs 1122 and 1132. TA-49 lies on a mesa in the upper part of the Ancho Canyon drainage. TA-49 was used for underground hydronuclear testing in the early 1960s. The testing consisted of criticality, equation of state, and calibration experiments involving special nuclear materials. The RFI Work Plan for Operable Unit 1144 describes the planned ER investigations that focus on identifying and quantifying migration of contaminants from the shafts.
	Type	There are large inventories of radioactive and hazardous materials such as isotopes of uranium and plutonium, lead, beryllium, TNT, RDX, HMX, and barium nitrate. Much of this material was left in shafts drilled into the mesa top.

References:
LANL 1992d; LANL 1992f; LANL 1993b; Purtymun and Stoker 1987.

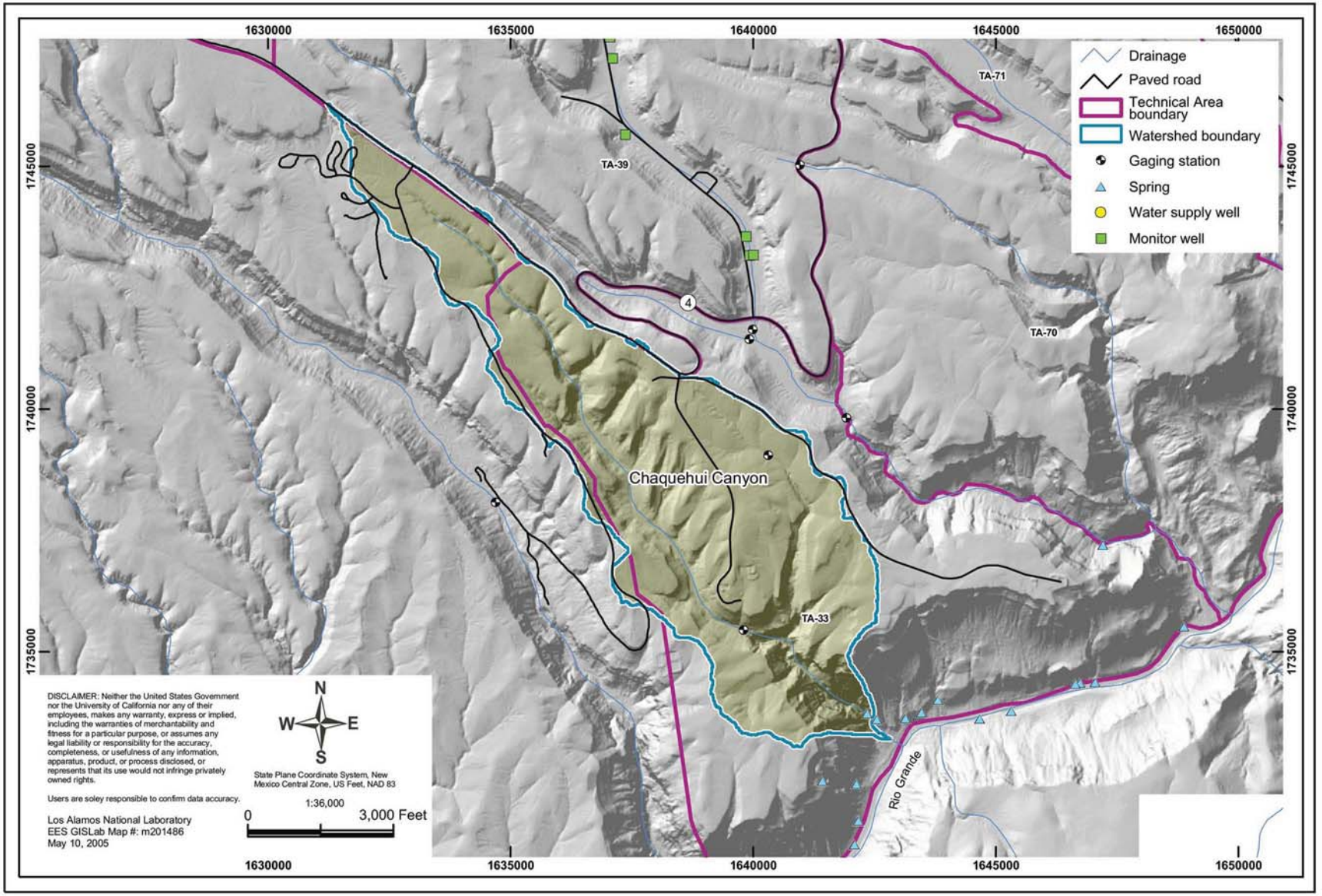

Figure 3-A-8. Ancho Canyon watershed.

Table 3-A-8.
Chaquehui Canyon Watershed Description

Hydrogeologic Element	Characteristic	Description
Surface Water	Flow	Chaquehui Canyon heads on the Pajarito Plateau and has a drainage area of about 2 square miles. It contains an ephemeral stream in its upper portion (Figure 3-A-1, Figure 3-A-9).
	Quality	
Springs	Name	Springs issue from basalts near the Rio Grande in the area of Chaquehui Canyon (Springs 8A, 9, 9A, 9B, and Doe Spring). These springs are located 130-200 ft above the Rio Grande. About 0.5 mile above the Rio Grande, Doe Spring, a regional aquifer spring, maintains a short perennial reach. Farther down the drainage, Springs 9, 9A and 9B maintain perennial flow that extends 0.25 mile to the Rio Grande.
	Quality	
Alluvial Groundwater	Extent	Little is known about the presence of alluvial groundwater in Chaquehui Canyon. Much of Chaquehui Canyon is unlikely to contain perched alluvial groundwater because most of its course forms a steep narrow drainage through basalts that are swept free of alluvium by runoff. Purtymun reported that there was water perched locally in the alluvium but provided no basis for this statement. Purtymun probably refers to alluvium downstream of Doe Spring and Springs 9 and 9A.
	Depth/Thickness	See above.
	Quality	See above.
Intermediate Groundwater	Extent/Hydrology	No intermediate groundwater is known in Chaquehui Canyon; however there has been no drilling in the area.
	Depth/Thickness	See above.
	Quality	See above.
Regional Aquifer	Depth/Hydrology	The springs may represent discharge from the regional aquifer in White Rock Canyon. Well R-31 in TA-39 (Ancho Canyon) found the regional aquifer at about 530 ft within the Cerros del Rio basalt, the underlying Puye Fanglomerate, and “Totavi” gravels.
	Quality	
Contaminants	Potential Sources	Chaquehui Canyon lies south of the mesa occupied by TA-33. TA-33 was used as a firing site and for production of tritium. PRSs include landfills, septic systems, and burn areas. TA-33 is situated on a mesa top and is being investigated by the ER Project as Operable Unit (OU) 1122.
	Type	

References:
LANL 1992d; Purtymun and Rogers 2002.

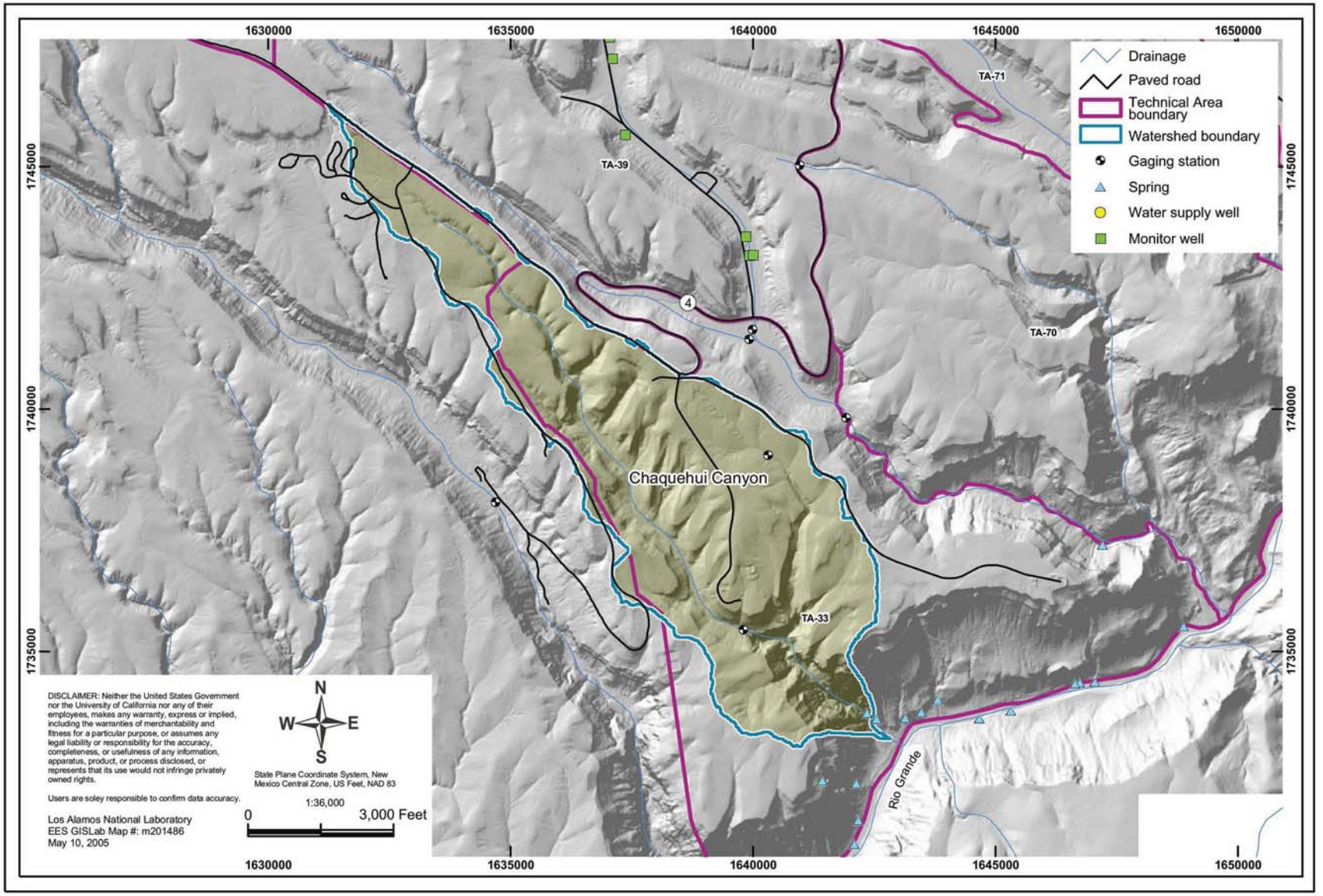

Figure 3-A-9. Chaquehui Canyon watershed.

Table 3-A-9.
Frijoles Canyon Watershed Description

Hydrogeologic Element	Characteristic	Description
Surface Water	Flow	Frijoles Canyon lies on US Forest Service and US Park Service lands south of Laboratory land and heads within the Sierra de los Valles (Figure 3-A-1; Figure 3-A-10) with a drainage area of about 19 square miles. Rito de los Frijoles is a perennial stream that originates in the upper canyon and extends to the Rio Grande.
	Quality	The Laboratory has monitored surface water quality at two locations for several decades, one near the park headquarters and one just above the Rio Grande. In general, no Laboratory-derived contamination has been observed. The National Park Service has monitored surface water quality extensively in Frijoles Canyon. High fecal coliform bacteria counts originating from local sanitary sources and horse corrals have been a major issue in surface water quality.
Springs	Name	Rito de los Frijoles originates from springs in upper Frijoles Canyon. One regional aquifer spring, Spring 10, discharges at the edge of the Rio Grande south of Frijoles stream. The spring has a very low discharge and is difficult to sample separately from adjacent river water.
	Quality	
Alluvial Groundwater	Extent	No wells have been drilled into the alluvium in Frijoles Canyon. The presence of perennial surface flow suggests a large extent of alluvial saturation.
	Depth/Thickness	The alluvium is probably thin, on the order of 6 m or less.
	Quality	See above.
Intermediate Groundwater	Extent/Hydrology	No intermediate groundwater is known to exist in the area of Frijoles Canyon; however no wells have been drilled.
	Depth/Thickness	See above.
	Quality	See above.
Regional Aquifer	Depth/Hydrology	No regional aquifer wells are located in Bandelier National Monument. The nearest wells are in Ancho Canyon.
	Quality	See above.
Contaminants	Potential Sources	Frijoles Canyon lies south of the Laboratory boundary near the Rio Grande, but is separated from TA-33 by Chaquehui Canyon. Local sanitary sources and horse corrals have been potential source of contamination.
	Type	There is a high fecal coliform bacteria count in surface water.

References:
Mott 1999; Purtymun and Adams 1980.

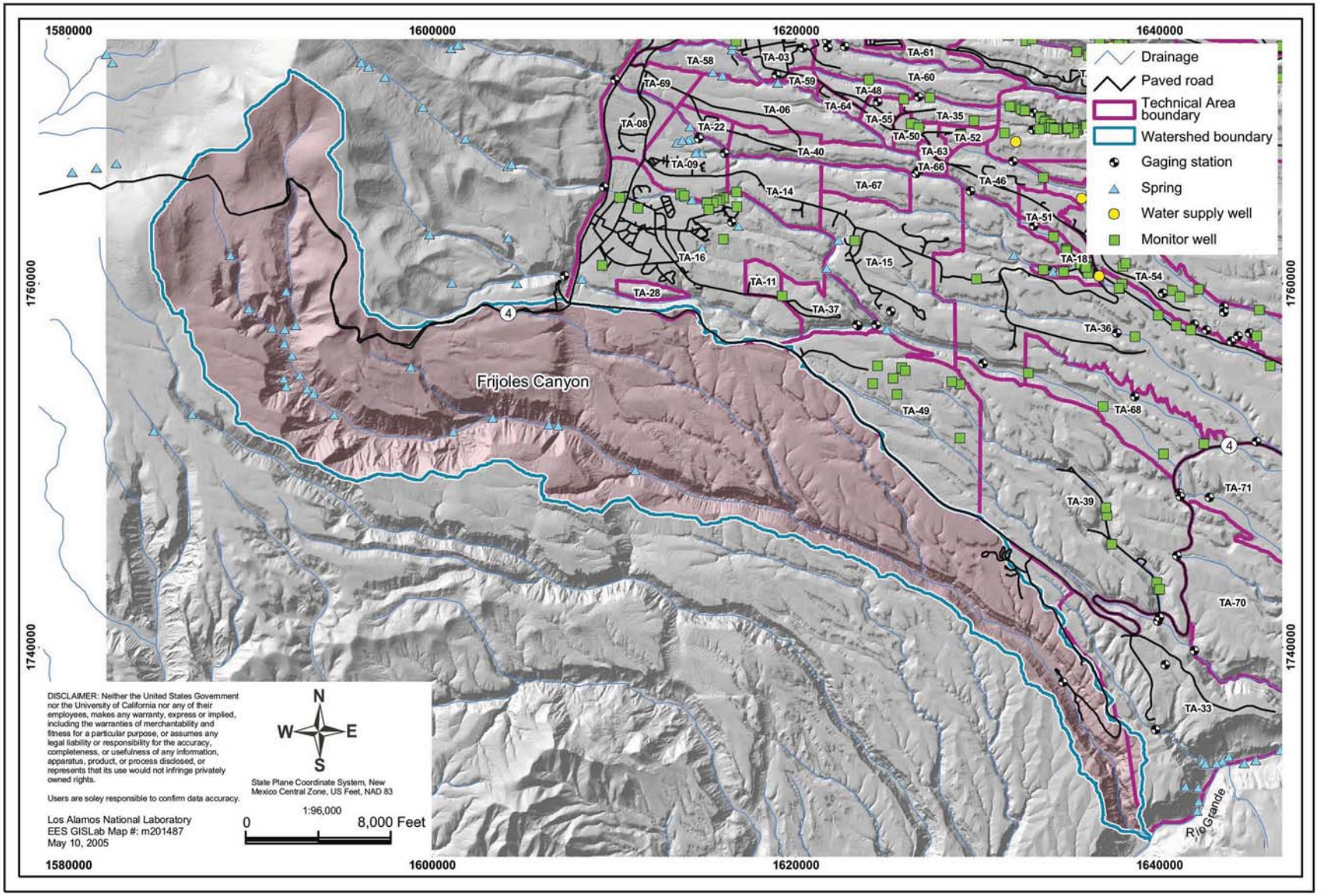

Figure 3-A-10. Frijoles Canyon watershed.

Table 3-A-10.
White Rock Canyon Watershed Description

Hydrogeologic Element	Characteristic	Description
Surface Water	Flow	Flow from regional aquifer springs supports perennial surface water flow in several canyons just above where they reach the Rio Grande: Sandia, Pajarito, Ancho, and Chaquehui canyons (Figure 3-A-1, Figure 3-A-11). Except for Sandia Canyon, these flows reach the Rio Grande. The Los Alamos County White Rock Sewage Treatment Plant discharges effluent into Mortandad Canyon just above the river at the northern county boundary.
	Quality	The discharge from the White Rock Sewage Treatment Plant is the primary surface water source and has a strong impact on the chemistry of the water that enters the Rio Grande from Mortandad Canyon, leading to higher TDS, nitrate, chloride, sulfate, and some metals. Water quality of the other streams is mainly determined by chemistry of their contributing springs (summarized in the regional aquifer description below). Purtymun (1995) and Purtymun et al. (1980) summarize flow and water quality from the White Rock Canyon springs and surface water.

Table 3-A-10.
White Rock Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Description
Springs	Name	Springs near the Rio Grande represent natural discharge from the regional aquifer. The springs discharge from two geologic units, the Tesuque Formation and the Totavi Lentil (the lower part of the Puye Formation). The Tesuque Formation consists of sandstones, siltstones, and interbedded basalts. The Totavi Lentil is a channel fill deposit made up of grain sizes ranging from gravel to boulders. Most of the springs discharge close to the elevation of the Rio Grande, though some springs discharge at elevations several tens of feet above the Rio Grande. The springs can be divided into four groups: **Group I springs** discharge from the Totavi Lentil on the west side of the river. The spring water is dominated by calcium bicarbonate with sulfate and chloride of about 4 mg/L and TDS averages 163 mg/L. **Group II springs** discharge from coarse-grained Tesuque Formation sediments on both sides of the river. These springs have sodium bicarbonate water with about 3 mg/L of sulfate and chloride, and TDS averages 183 mg/L. **Group III springs** discharge from fine-grained Tesuque Formation sediments on the west side of the river. These springs also have sodium bicarbonate water with about 10 mg/L of sulfate, 3 mg/L of chloride and TDS averages 215 mg/L. **Group IV springs** discharge from fine-grained Tesuque Formation sediments on the east side of the river near faults and basalt flows. These springs have varied chemistry with higher TDS than the other springs, of 270 to 500 mg/L. The springs discharging from the Totavi Lentil (Group I springs) follow the outcrop of this formation, increasing their elevation above the river in a downstream direction. These higher elevation springs generally occur on the flanks of or in the bottom of canyons where erosion has exposed the Totavi Lentil. The elevation of springs above the river could reflect channeling of discharge from the regional aquifer along the higher-permeability Totavi Lentil, combined with the increase in elevation of the water table with distance west of the river. An alternative hypothesis about spring origin is that the elevation of some springs (Spring 4A) above the river indicates that they discharge from perched groundwater located above the regional aquifer. As well, the elevation of springs above the river could reflect complex flow paths resulting from local variations in geology and permeability related to numerous large-scale landslides along the canyon walls.
	Quality	The US Geological Survey and the Laboratory have monitored chemistry of the White Rock Springs since the 1960s; the springs show no clear impact of Laboratory contamination. Tritium values in the springs are either in the range of regional aquifer values, namely less than 3 pCi/L, or up to 40 pCi/L, which could indicate either Laboratory impact or a component of precipitation. A few springs have relatively high natural uranium. These springs lie mainly on the east side of the river

Table 3-A-10.
White Rock Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Description
		near and north of the Buckman wellfield. Some springs (1, 3, 3A, 4, 5) also show subtle increases in nitrate over 20 years. These increases could be due to the impact of feral cattle grazing near the springs over time as well as to some change in groundwater quality. Perchlorate has been measured at low levels in some springs, but the source is not clear.
Alluvial Groundwater	Extent	Alluvial groundwater is not present in the White Rock Canyon area. However, household wells in Los Alamos Canyon (Halladay and Otowi) and household wells nearer the Rio Grande probably draw their water from Santa Fe Group sediments but may draw water in part from alluvium in these drainages.
	Depth/Thickness	See above.
	Quality	See above.
Intermediate Groundwater	Extent/Hydrology	Perched intermediate groundwater may not be present in the White Rock Canyon area. However, an alternative hypothesis about White Rock Canyon spring origin is that the elevation of some springs above the river indicates that they discharge from perched groundwater located above the regional aquifer.
	Depth/Thickness	See above.
	Quality	See above.
Regional Aquifer	Depth/Hydrology	The Rio Grande is the major groundwater discharge zone for the regional aquifer underlying the Pajarito Plateau. The river gains flow through White Rock Canyon, indicating that the local water table (the regional aquifer) lies above the river. The City of Santa Fe operates the Buckman wellfield on the east side of the Rio Grande across from White Rock (Figure 3-A-11). The wellfield includes eight pumping wells. These wells draw their water from Santa Fe Group sediments. Vesselinov and Keating (2002) concluded from a modeling study that under long-term steady state conditions, these wells might one day draw perhaps a third of their water from beneath LANL on the west side of the Rio Grande. As a result, LANL has sampled three of the Buckman wells (1, 2, and 8) since 2001 for its Environmental Surveillance Program. Water in these wells is quite old, having passed through the deeper portion of the basin fill sediments where it acquired a higher load of dissolved solutes. San Ildefonso Pueblo draws water from more than 10 community and household wells located on both sides of the Rio Grande. Little information on depth or geology for these wells is available. Many of these wells probably draw their water from Santa Fe Group sediments. At least two of the San Ildefonso wells are uncapped artesian wells.
	Quality	The US Geological Survey and the Laboratory have monitored chemistry of the White Rock Springs since the 1960s; the springs do not show a definitive impact of Laboratory contamination. Tritium activities in the springs are either in the range

Table 3-A-10.
White Rock Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Description
		of regional aquifer values, namely less than 3 pCi/L, or range from 10 to 50 pCi/L, which could indicate either Laboratory impact or a component of local precipitation—more likely the latter given spring locations. A few springs have relatively high natural uranium. These springs lie mainly on the east side of the river near and north of the Buckman well field. Some springs (1, 3, 3A, 4, 5) also show subtle increases in nitrate over 20 years. These increases could be due to the impact of feral cattle grazing near the springs over time, natural source, and seepage from impoundments within Pajarito Canyon and past effluents released in several canyons. Perchlorate has been measured at low levels in some springs, but the source is not clear. The measured perchlorate values are similar to those found in wells distant from LANL. Spring 2B below and east of the White Rock Overlook shows higher concentrations of uranium, chloride, boron, and nitrate than other springs. This spring's chemistry (except for uranium) is similar to the nearby stream in Mortandad Canyon, which is fed by effluent from the White Rock sanitary treatment plant. This similarity in chemistry, along with nitrogen isotope results that indicate a sewage source for both waters, suggests that a large part of the water from Spring 2B comes from the treatment plant effluent in lower Mortandad Canyon. It is possible that natural uranium within the Santa Fe Group sediments has been leached from mineral surfaces in contact with the bicarbonate-rich groundwater. Increasing concentrations of carbonate alkalinity are from the treated sewage effluent discharged upgradient from the spring. Some Buckman wells have exceptionally high uranium (up to 230 ppb, compared to the new EPA MCL of 30 ppb). Such naturally occurring uranium is common in the Pojoaque and Tesuque area. The Buckman wells also have high sodium, carbonate alkalinity, and TDS.
Contaminants	Potential Sources	TA-33 borders the Rio Grande at the southern end of LANL along White Rock Canyon. The RFI Workplan for OU 1122 describes environmental concerns at TA-33. To the north of TA-33 lies TA-70, a buffer area where no Laboratory activities have occurred. Adjoining TA-70 to the north, Los Alamos County land comprises the low to moderate-density residential area of White Rock. Los Alamos County formerly operated sanitary effluent lagoons near the edge of the canyon just south of Pajarito Canyon. A municipal sanitary treatment plant discharges effluent into Mortandad Canyon just above the river at the northern county boundary. This discharge is the main surface water source and has a strong impact on the chemistry of the water that enters the Rio Grande from Mortandad Canyon, leading to higher concentrations of TDS, nitrate, chloride, sulfate, and some metals. To the north of White Rock is undeveloped San Ildefonso property.

Table 3-A-10.
White Rock Canyon Watershed Description (continued)

Hydrogeologic Element	Characteristic	Description
		Los Alamos Canyon lies at the northern end of White Rock Canyon. LANL effluents have moved down Los Alamos Canyon either adsorbed onto sediments or dissolved in stream flow, affecting sediment and shallow groundwater quality in the lower portion of the canyon (Section 2.4).
	Type	TA-33 was used as a firing site and for production of tritium. PRSs include landfills, septic systems, and burn areas. It is situated on a mesa top and is being investigated by the ER Project as Operable Unit (OU) 1122. If contaminants are released from TA-33, they may impact Ancho Canyon, Chaquehui Canyon, or the Rio Grande. The discharge from the municipal treatment plant is the primary surface water source and has a strong impact on the chemistry of the water that enters the Rio Grande from Mortandad Canyon, leading to higher levels of TDS, nitrate, chloride, sulfate, and some metals.

References:
LANL 1992d; Purtymun et al. 1980; Purtymun 1995; Vesselinov and Keating 2002; LANL, 2004a.

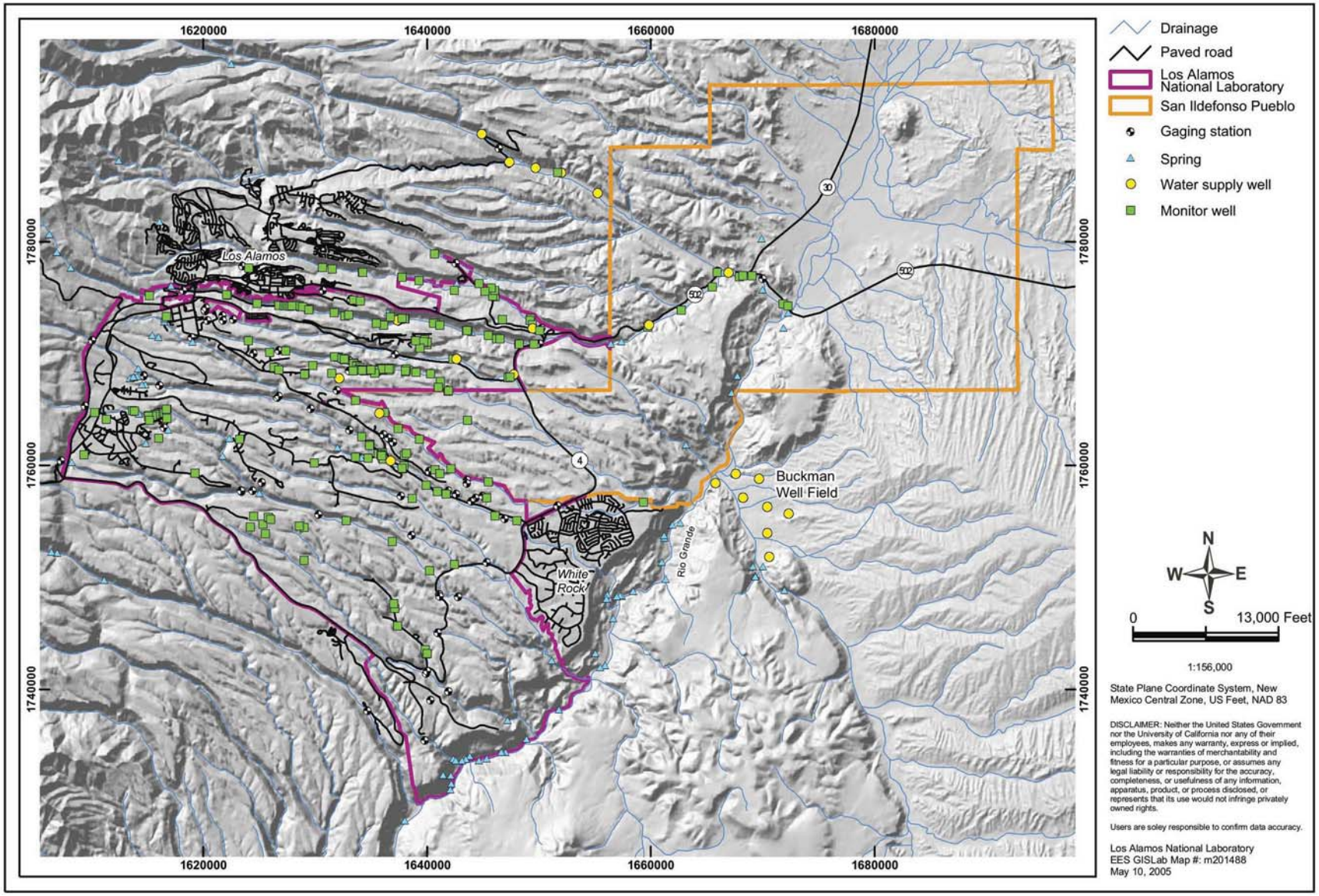

Figure 3-A-11. White Rock Canyon.

3-B. Alternative Conceptual Models of Contaminant Transport

The purpose of this section is to discuss two alternative interpretations of how water flows and contaminants behave on the Pajarito Plateau. With the uncertainty that is inherent to all subsurface investigations, it is important to examine the strengths and weaknesses of other possible interpretations of the available data. This section explores alternative conceptual models by first providing a description of the alternative model. Second the strengths and limitations of the alternative are summarized. An assessment of how the alternative conceptual model would change the current conceptual model or how risk is assessed is presented. Finally, a discussion of how the alternative conceptual model could be tested is provided.

3-B-1. Colloid-Facilitated Transport

The movement of small particles in groundwater flow systems can represent an alternate mechanism for contaminant transport. While generally not as significant overall as the movement of dissolved or immiscible species, the movement of small particles can increase the magnitude of mass transport. This section will focus on colloids, a special class of particles with properties the lie between that of the dissolved state and the solid state.

Historically, researchers have applied the term colloid to particles with a size range of 0.001 to 1 micron (1 micron is 0.001 millimeter). The colloids can be mineral particles, particulate organic matter, biological (for example, bacteria), or even microemulsions of hydrocarbons. The surface area per unit mass is very high for colloids, which greatly affects their mass transport. Contaminants can be transported as colloids resulting in unexpected mobility. This is because the transport of contaminants adsorbed to colloids is determined by the physical/chemical properties of the colloid, rather than properties of the contaminant. Work at the Nevada Test Site suggests that plutonium can be transported over significant lateral distances (~1.3 km) by colloids (Kersting et al. 1999). Predicting colloid transport is extremely difficult, however. Colloid stability and filtration depends on a complex array of factors including density, size, surface chemistry, water chemistry, water flow rates, and pore size distribution of the soil matrix. Table 3-B-1 discusses strengths and weaknesses of a colloid-facilitated transport model.

3-B-1.1 Strengths and Limitations of the Colloid-Facilitated Transport Model

Table 3-B-1.
Colloid-Facilitated Alternative Transport Model

Strengths	Limitations
Since the start of discharges in May 1963, the RLWTF has used the flocculate "calcium hydroxide" and "ferric sulfate" as a part of the treatment process, and it is likely that a continual stream of residual colloids was discharged to the canyon floor.	Bulk of radionuclide inventory appears adsorbed to stream sediments.
Work by Penrose et al. (1990) demonstrated the presence of colloids with plutonium and americium along a 3400 m segment of the perched alluvial groundwater system in Mortandad Canyon. The study concluded that the horizontal dispersal of the radionuclides through the groundwater system was due to colloid transport in the subsurface.	That conclusion was challenged, however, by a subsequent review that concluded that the radionuclide transport within the canyon was principally due to surface water, rather than groundwater transport (Marty et al. 1997).
At a mesa top site at TA-21, some of these radionuclides occur at much greater depths in the field than expected. Work by Nyhan et al. (1985) suggests that substantial hydraulic loading can enhance the vertical penetration depth. The study examined the distribution of plutonium, americium-241 and water in Bandelier Tuff beneath former liquid waste disposal sites at TA-21. Nyhan et al. (1985) found that after 17 years of migration, the Am-241 was mobilized under heavy hydraulic loading to 30 m. It is possible that the radionuclides are mobilized by other chemicals or possibly by colloid transport in preferential flow paths.	While colloids have been shown to be abundant in the alluvial groundwater, coring has not shown appreciable vertical movement (less than five feet) of plutonium or americium in the vadose zone below the alluvium (Stoker et al. 1991). Studies show that 99% of the plutonium inventory is adsorbed on alluvium and little is in the water column; the colloidal fraction in groundwater represents less than 1 percent of the total plutonium inventory in the canyon (Purtymun et al. 1984; Stoker et al. 1991). These results suggest that vertical transport of the radiocolloids has been minimal in the Bandelier Tuff beneath the canyon floor, even after decades of continual liquid release.
Occasional Pu-239, -240 detects in samples from water supply wells (1970s and 1980s mostly) may be colloid related.	No plutonium detects in recent years and earlier detections primarily limited to water supply wells---few in monitoring wells. Unable to validate earlier results because of limitations in existing records.

3-B-1.2 Effect on Current Conceptual Model and Assessment of Risk

Many radionuclides and metals are currently conceptualized to be relatively immobile at the site. If colloid-facilitated transport is significant, the subsurface travel times for these constituents to the accessible environment will be reduced. Health risks from colloid-facilitated transport, however, likely will not be greatly different from the levels presently recognized: sampling of the groundwater systems account for the total contaminant concentrations and already include any colloid contributions, if present. Monitoring of the shallower groundwater at the site, the depths where contaminated colloids should be most abundant, has identified few areas with concentrations above a regulatory standard. Given the vadose zone thickness and likely reduction in contaminated colloid concentrations with depth, contaminant concentrations due to colloid-facilitated transport in the regional aquifer are also expected to meet regulatory standards.

3-B-2. Cs-137 "Groundwater Transport" to the Rio Grande

A report written by Norm Buske (2003) for the RadioActivist Campaign (TRAC) and Concerned Citizens for Nuclear Safety (CCNS) in late October 2003 cites samples of aquatic moss from Spring 4A and the Pajarito Stream containing "…consistently low levels of cesium-137 *of LANL* origin [emphasis added]. This is the first confirmed detection of LANL radioactivity from a groundwater pathway." The report also cited moss samples from other sites, as testing positive for Cs-137 and said samples showed Cs-137 "in the range of 0.01 to 6 picocuries/kilogram…Cesium-137…is…at levels far too low to be considered a public health concern." Table 3-B-2 discusses strengths and limitations of a Cs-137 transport model.

3-B-2.1 Strengths and Limitations of Cs-137 Groundwater Transport Alternative Model

Table 3-B-2.
Cs-137 Groundwater Transport Alternative Model

Strengths	Limitations
Detections of tritium and perchlorate in other White Rock Canyon springs support this model.	Levels of these constituents may be within natural ranges. When converted to an equivalent weight basis, the amount of cesium measured by Buske (2003) in the moss samples is within the background concentrations for plants in northern New Mexico.
Cesium-137 is a major Laboratory contaminant in Los Alamos and Mortandad Canyons radioactive effluent discharges.	Cesium-137 is a common fallout radionuclide that was distributed globally during atmospheric nuclear tests. It is considerably more probable that the moss accumulated cesium from worldwide fallout rather than from groundwater. Fallout cesium-137 is universally present in surface soils and soil concentrations are one hundred times greater those found in study.
	The Buske (2003) results were very close to detection levels, in the range of 0.01 to 6 pCi/Kg wet, and the study did not include control samples (upstream) so that Cs-137 from fallout sources could not be compared.
	If Cs-137 traveled through groundwater to a spring along the Rio Grande, several non-adsorbing chemical constituents that usually reflect groundwater contamination, such as nitrate or tritium, likely would accompany and precede Cs-137. Tritium and nitrate values in Spring 4A indicate the spring water reflects background aquifer conditions unaffected by Laboratory discharges.
	From 1995 through 2003, LANL has made 121 Cs-137 measurements in White Rock Canyon springs, with only two detections in the data set. Nine of these measurements (with only one detection) were from Spring 4A. Thus, the body of data does not support the presence of Cs-137 in any White Rock spring, at an average detection limit of 3 pCi/L. In addition, Cs-137 is not detectable in regional aquifer monitoring wells upgradient of the springs.

3-B-2.2 Effect on Current Conceptual Model and Assessment of Risk

If real, the groundwater transport of Cs-137 alternative conceptual model would indicate that relatively immobile radionuclides or metals may potentially move through groundwater to the accessible environment at a faster rate than recognized. Assessment of water quality changes at those locations would continue in the future. The current monitoring results from across the regional aquifer do not indicate any location where the concentrations of these constituents are greater than regulatory standards. Given this pattern, it is highly unlikely that concentrations greater than standards would be observed in the future. Contaminant transport models that only take into account sorption and solubility may underestimate the extent a colloid-bound species is able to migrate in groundwater.

A study is being conducted by a LANL team to assess the distribution and concentrations of cesium in moss throughout northern New Mexico. The objective is to collect various moss sample specimens from springs located in northern New Mexico and southern Colorado (a great distance from LANL) and analyze them for Cs-137 activity. This program will collect the data necessary to evaluate whether Cs-137 concentrations near the Laboratory are anomalous. Additional monitoring of wells and springs in the Los Alamos area will continue to look for evidence of rapid movement of cesium (and other contaminants) through the groundwater system.

APPENDIX 4-A. METHOD FOR ESTIMATING INFILTRATION RATE IN CANYONS

Net infiltration is defined as the flux of water that percolates to depths greater than the zone in which evapotranspiration (ET) processes take place. A complete site-wide study of net infiltration has recently been completed (Kwicklis et al. 2005). That study presents estimates of net infiltration determinations with a variety of estimation techniques, including Darcy's Law, chloride mass-balance and water-balance methods. The study extrapolates these estimates to other areas within the site for which estimates do not exist. Factors used to make this extrapolation include topography, soil type, vegetation, and bedrock type. The Kwicklis et al. (2005) publication was not ready in time to be used in model predictions presented elsewhere in this report. Previous modeling analyses should be updated to include the detail from the site-wide net infiltration study, as appropriate.

Since net infiltration to the vadose zone beneath the plateau is assumed to occur mainly through canyons, the plateau is differentiated topographically as mesa or canyon. For the net infiltration map presented here, the mesa locations are all assigned the same fixed net infiltration rate. For the base-case study, this rate is 1 mm/yr (Section 2.6.1). More variability is added to the map for canyon locations because the canyons are the main source of recharge across the plateau, and also because conditions in canyons across the plateau vary from wet to dry. For these reasons, a ranking scheme was developed to classify portions of canyons by a net infiltration index (NII) that describes the net infiltration rate.

The net infiltration index ranges in value from one to five, with one representing the lowest and five representing the highest infiltration potential. The NII is based on a number of physical factors, as shown in Table 4-A-1:

- The location of the headwaters is the first factor because those canyons that head in the mountains generally have a larger drainage area, and receive more precipitation and run-off than those that head on the plateau. Anthropogenic water sources within the canyons can also yield large surface flows that contribute similarly to headwaters located higher in the mountains. For this reason, anthropogenic sources were included with the first factor.
- The persistence of surface water in the canyon bottom is the next factor used to define the NII. Those canyons with perennial streams are expected to generate higher net infiltration than those with ephemeral or intermittent streams, and therefore receive a higher ranking.
- Observation of alluvial water is the final factor used to define the NII. Some canyons have alluvial groundwater of significant depth while others have limited or no alluvial water. Those canyons with deeper alluvial groundwaters receive a higher net infiltration index than those without.

Note that the factors contributing to the NII are used to define a set of net infiltration indices that may be updated with site-specific observations and data. However, as a general approach for supporting a plateau-wide modeling effort, the NII is a reasonable simplification. In some cases, factors such as persistent surface and alluvial waters may indicate an absence of vadose-zone infiltration rather than a higher net infiltration rate. Examples of this include the surface expression of springs or perching in the alluvium caused by a large contrast in hydraulic conductivity between the alluvium and underlying tuff. Despite these types of alternative

hypotheses, the model assumes a higher NII in the wetter areas, so that it errs on the side of predicting more rapid transport. Once areas with potential fast paths are identified, more site-specific and detailed net infiltration studies can be performed to refine the predictions.

Table 4-A-1 also includes the net infiltration assumed for each NII. These estimates exhibit approximately three orders of magnitude variation in net infiltration between the driest and the wettest canyons. To assess uncertainty in infiltration, different sets of net infiltration estimates are also included in this study.

Once the NII and the associated infiltration rates for each NII have been defined, the next step is to assign net infiltration indices of canyons or portions of canyons across the Pajarito Plateau. This task was accomplished by compiling information from the LANL Hydrogeologic Workplan about the descriptive factors listed in Table 4-A-1. Major canyons from Guaje Canyon, located north of the laboratory, to Chaquehui Canyon, located south of the laboratory, were characterized with respect to the location of their headwaters, anthropogenic sources, and observations of surface and alluvial waters. In most cases, a particular canyon is split into sections because the hydrologic factors change as one moves down the canyon. The characteristics of these canyons or portions of canyons are shown in Table 4-A-1, along with the resulting net infiltration index for each section. The net infiltration index is determined by comparing the characteristics in Table 4-A-1 to the net infiltration factors in Table 4-A-1.

Figure 4-A-1 shows the resulting NII map for the study area with respect to the LANL boundary. Canyons with no portion of their reach inside the site area, in the gray area of this figure, are not assigned a NII as part of this study because laboratory-derived contaminants are not present in these canyons. Infiltration rates converted from the values in Table 4-A-1 were used as the upper water-flux boundary conditions for the series of one-dimensional vadose-zone flow and particle tracking runs.

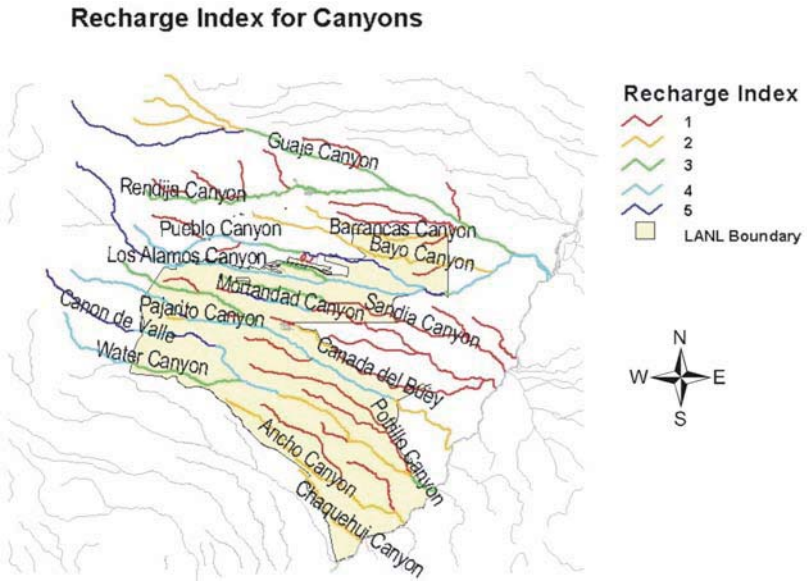

Figure 4-A-1. Infiltration on the Pajarito Plateau: result of analysis to determine the Net Infiltration Index (NII) indicator parameter across the Pajarito Plateau and surrounding region of the study area.

Table 4-A-1.
Determination of Net Infiltration
Index for Sections of Canyons on the Pajarito Plateau

Canyon/ ArcView Identifier	Reach	Headwaters (drainage <5 mi^2 unless noted)	Surface Water	Alluvial Water	Published Net Infiltration	Notes	NII
Pueblo (Pueb1)	From Headwaters to Guaje Mountain Fault	Mountains (drainage >8 mi^2)	Ephemeral	Saturated		LANL (1998) p. 4-41, 4-42	4
Pueblo (Pueb2)	Below Guaje Mountain Fault, above sewage treatment plant	Mountains	Ephemeral	May or may not be saturated		LANL (1998) p. 4-41, 4-42	3
Pueblo (Pueb3)	Below sewage treatment plant to halfway across Lab land	Mountains and anthropogenic source	Perennial	Saturated		LANL (1998) p. 4-41, 4-42	5
Pueblo (Pueb4)	Half way across Lab land to confluence with LA Canyon	Mountains	Intermittent	Saturated		LANL (1998) p. 4-41, 4-42	4
Pueblo (Historic)	Mid (below TA-45) and upper (old sewage) canyon	Mountains	Possible historic perennial flow	Possible historic saturated conditions	Previous effluent TA-45 (1951-1964); old sewage plant (pre-1963)		4 (historic)
Los Alamos (LA1)	West of the reservoir	Mountains (drainage >10 mi^2)	Perennial	Saturated		LANL (1998) p. 4-48	5
Los Alamos (LA2)	East of reservoir to TA-2	Mountains	Continuous during snow melt (weeks to months); otherwise ephemeral	Saturated (thickness varies seasonally from several feet in winter to 25 ft in spring and summer)	All LA Canyon estimates based on Gray, (1997) Table 8 714, 213, 566, 1076 mm/yr	LANL (1998) p. 4-48	4
Los Alamos (LA3)	TA-2 to confluence of Pueblo Canyon	Mountains	Ephemeral	Saturated (same as above)	222, 408 mm/yr	LANL (1998) p. 4-48	4

Table 4-A-1.
Determination of Net Infiltration
Index for Sections of Canyons on the Pajarito Plateau (continued)

Canyon/ ArcView Identifier	Reach	Headwaters (drainage <5 mi² unless noted)	Surface Water	Alluvial Water	Published Net Infiltration	Notes	NII
Los Alamos (LA4)	Confluence of Pueblo Canyon to LAO-4.5	Mountains	Perennial	Saturated	399 mm/yr	LANL (1998) p. 4-48	5
Los Alamos (LA5)	LAO-4.5 to Basalt Spring	Mountains	Ephemeral	Not Saturated	362 mm/yr	LANL (1998) p. 4-48	3
Los Alamos (LA6)	Lower; Basalt Spring to Rio Grande	Mountains	Ephemeral	Saturated	325 mm/yr	LANL (1998) p. 4-48	4
DP (DP)	All	Plateau	Ephemeral, except nearly continuous discharge near DP spring	Saturated conditions observed at wells LAUZ-1, LAUZ-2 (elsewhere ?)		LANL (1998) p. 4-48	3
Sandia (San1)	Headwaters to TA-72	Plateau with small anthropogenic source	Ephemeral	Not character-ized (likely saturated portions)	Surface water source is precipitation and treatment plant water (not much snow melt)	LANL (1998) p. 4-53	3
Sandia (San2)	Below TA-72	Plateau	Not present	Not character-ized (eastern part near SCO-1 & SCO-2 dry since 1990)		LANL (1998) p. 4-53	1
Cañada del Buey (CdB1)	All else	Plateau	Ephemeral (with snow-melt and thunder-storms)	Not saturated	<0 (Rogers et al. 1996)	LANL (1998) p. 4-59, 4-61	1
Cañada del Buey (CdB2)	Between CDBO-6 & CDBO-7	Plateau	Ephemeral (with snowmelt and thunder-storms)	Sometimes saturated within weathered tuff (near discharge of PM-4)		LANL (1998) p. 4-61	2
Pajarito (Paj1)	West of Homestead Spring	Mountains (drainage >10 mi^2)	Occurs as springs above alluvium (1-15 gpm)	Saturated alluvium (perched to ~10 ft depth)		LANL (1998) p. 4-61, 4-62	4
Pajarito (Paj2)	Several 100 yards near Homestead Spring	Mountains	Perennial	Saturated alluvium (perched to ~10 ft depth)		LANL (1998) p. 4-61, 4-62	5

Table 4-A-1.
Determination of Net Infiltration
Index for Sections of Canyons on the Pajarito Plateau (continued)

Canyon/ ArcView Identifier	Reach	Headwaters (drainage <5 mi² unless noted)	Surface Water	Alluvial Water	Published Net Infiltration	Notes	NII
Pajarito (Paj3)	Below Homestead Spring to above Three-Mile Canyon	Mountains	Intermittent to ephemeral	Saturated alluvium (perched to ~10 ft depth)		LANL (1998) p. 4-61, 4-62	4
Pajarito (Paj4)	Three-mile Canyon to eastern LANL boundary	Mountains	Ephemeral	Saturated alluvium (perched to ~10 ft depth)		LANL (1998) p. 4-61, 4-62	4
Pajarito (Paj5)	East of LANL boundary to Rio Grande	Mountains	(Not discussed) Assumed ephemeral	Not saturated		LANL (1998) p. 4-61, 4-62, 4-60	2
Ancho (Ancho)	All	Plateau	Ephemeral from precipitation (sometimes severe)	Little known (possible shallow perched zone)		LANL (1998) p. 4-69	2
Chaq-uehui (Cheq1)	Headwaters to 0.5 mile from Rio Grande	Plateau	Ephemeral	Little known (However, observed infiltration into tuff at TA-33, tritium at 100-170 ft)		LANL (1998) p. 4-74	2
Chaq-uehui (Cheq2)	0.5 miles from/to Rio Grande	Plateau	Perennial for short distance	Little known		LANL (1998) p. 4-74	2
Cañon de Valle (CdV1)	Headwaters to Pajarito Fault	Mountains	Perennial	Saturated		LANL (1998) p. 4-78, 4-79	5
Cañon de Valle (CdV2)	Pajarito Fault to 260 Outfall	Mountains	Intermittent	Saturated		LANL (1998) 4-78,4-79	4
Cañon de Valle (CdV3)	260 Outfall to MDA P	Mountains and Anthropogenic source	Perennial	Saturated		LANL (1998) p. 4-78, 4-79	5
Cañon de Valle (CdV4)	MDA P to Water Canyon	Mountains	Intermittent	Saturated		LANL (1998) p. 4-78, 4-79	4
Potrillo (Pot1)	Headwaters to POTM-wells	Plateau	Ephemeral (no significant snowmelt, discharge sink at POTM-wells)	Only saturated observance once at well POTM-2	0.01 cm/yr (Rogers et al. 1996a)	LANL (1998) p. 4-85	1

Table 4-A-1.
Determination of Net Infiltration
Index for Sections of Canyons on the Pajarito Plateau (continued)

Canyon/ ArcView Identifier	Reach	Headwaters (drainage <5 mi² unless noted)	Surface Water	Alluvial Water	Published Net Infiltration	Notes	NII
Potrillo (Pot2)	POTM-wells to Water Canyon	Plateau	Rare	Not expected		LANL (1998) p. 4-85	1
Fence (Fen1)	All	Plateau	Ephemeral (no significant snowmelt)	Little known, dry at State Rt. 4		LANL (1998) p. 4-86	1
Water (Wat1)	Headwaters to west of LANL boundary	Mountains	Mostly perennial	Assumed saturated		LANL (1998) p. 4-87, 4-79	4
Water (Wat2)	Western LANL boundary to Cañon de Valle	Mountains	Unknown	Unknown		LANL (1998) p. 4-87, 4-79	3
Water (Wat3)	Cañon de Valle to well DT-10	Mountains	Intermittent and Ephemeral	Saturated		LANL (1998) p. 4-87, 4-79	4
Water (Wat4)	DT-10 to spring 5AA	Mountains	Ephemeral	Not saturated		LANL (1998) p. 4-87, 4-79	2
Water (Wat5)	At spring 5AA	Mountains	Short perennial reach	Possibly saturated		LANL (1998) p. 4-87, 4-79	4
Water (Wat6)	Beneath 5AA to Rio Grande	Mountains	Ephemeral	Not saturated		LANL (1998) p. 4-87, 4-79	2
Mortandad (Mort1)	Headwaters to TA-50 outfall	Plateau	Ephemeral and Intermittent	Not saturated	See LANL (1998) p.4-92 for surface water loss estimates	LANL (1998) p. 4-89, 4-91	1
Mortandad (Mort2)	Downstream from TA-50 wastewater treatment plant for about 1 mile	Plateau with large anthropogenic source	Perennial for about 1 mile	Saturated (~10 ft thick)	Dander (1998) 4500 mm/yr	LANL (1998) p. 4-89, 4-91	5
Mortandad (Mort3)	Downstream from TA-50 wastewater treatment plant (from 1 mile downstream to 2 miles)	Plateau	Ephemeral	Saturated (~10 ft thick); approx. from TA-50 to just above San Ildefonso land		LANL (1998) p. 4-89, 4-91	4

Table 4-A-1.
Determination of Net Infiltration
Index for Sections of Canyons on the Pajarito Plateau (continued)

Canyon/ ArcView Identifier	Reach	Headwaters (drainage <5 mi² unless noted)	Surface Water	Alluvial Water	Published Net Infiltration	Notes	NII
Mortandad (Mort4)	From just above boundary with San Ildefonso land to the Rio Grande	Plateau	Ephemeral	Not saturated		LANL (1998) p. 4-89, 4-91	1
Guaje (Guaje1)	Upstream (near springs) to downstream from the Guaje Reservoir	Mountains	Perennial	Saturated		LANL (1998) p. 4-95	5
Guaje (Guaje2)	Downstream from Guaje Reservoir to LA Canyon	Mountains	Intermittent	Possible seasonal saturation		LANL (1998) p. 4-95	3
Rendija (Ren1)	All	Mountains	Ephemeral	Unknown			3
Barrancas (Barr1)	All	Plateau	Intermittent and Ephemeral	Potentially saturated		LANL (1998) p. 4-96, 4-97	2
Bayo (Bayo)		Plateau	Intermittent and Ephemeral	Potentially saturated (90 boreholes in former TA-10, found no alluvial water)		LANL (1998) p. 4-97	2
Three-Mile (Three)	All	Plateau	?	?		Assume like Potrillo	1
Two-Mile (Two)	All	Mountain	Assumed ephemeral	Assumed saturated		LANL, (1998) p. 4-60	3

APPENDIX 4-B. MDA G MODEL

This appendix summarizes modeling work previously reported in Birdsell et al. (2000). The purpose of this modeling presentation is to demonstrate the use of the vadose zone concepts outlined in this report and to present representative modeling results for a relatively dry mesa. This system is therefore one end member of the different types of vadose-zone behavior expected for the plateau. A model for the other extreme, a wet canyon, is presented for Los Alamos Canyon in Appendix 4-C.

4-B-1. Introduction and Motivation

Performance assessment (PA) is required to site and authorize permanent disposal facilities for radioactive waste. The purpose of the PA is to demonstrate that performance measures related to protection of human health and the environment are not likely to be exceeded for a specified period of time. Performance objectives and periods of compliance vary according to the characteristics of the radioactive waste being disposed, but groundwater protection for U.S. sites is always explicitly required for at least 1000 years. This study presents an integrated case study that predicts the groundwater pathway dose in support of the performance assessment PA of the active, low-level, solid radioactive waste site located at the Laboratory, shown in Figure 4-4 (from Figure 1 of Birdsell et al. 2000). In contrast to the modeling study of Los Alamos Canyon presented in Appendix 4-C, this model illustrates aqueous contaminant transport from a relatively dry mesa, as opposed to a canyon bottom.

The three-dimensional unsaturated zone flow and transport model captures the complex hydrogeology and topography of the site and yields radionuclide flux estimates to the regional aquifer. Within the unsaturated zone model, the source release of radionuclides is computed for 38 waste disposal pits and four shaft fields (Figure 4-5, from Figure 3 of Birdsell et al. 2000), each contributing to the total inventory. The continued migration of radionuclides through the aquifer is calculated by using a three-dimensional model designed to maintain the temporally and spatially varying distribution of radionuclide flux from the unsaturated zone.

4-B-2. Hydrostratigraphy and Hydraulic Properties

The strata that underlie the LANL waste site are composed of a series of nonwelded to moderately welded rhyolitic ash-flow and ash-fall tuffs underlain by a thin pumice bed (Guaje Pumice), a thick basalt (Cerros del Rio Basalt), and a fanglomerate (Puye Formation), as shown in Figure 4-B-1 (from Figure 3 of Birdsell et al. 2000). The tuff has eroded to leave a system of alternating finger-shaped mesas and canyons. LANL's low-level waste disposal facility is located atop one such mesa with the waste buried in disposal pits and shafts to a depth of approximately 20 m. The surrounding canyons lie 30 m below the steep-sided mesa, and the water table is located approximately 250 to 300 m below the disposal pits.

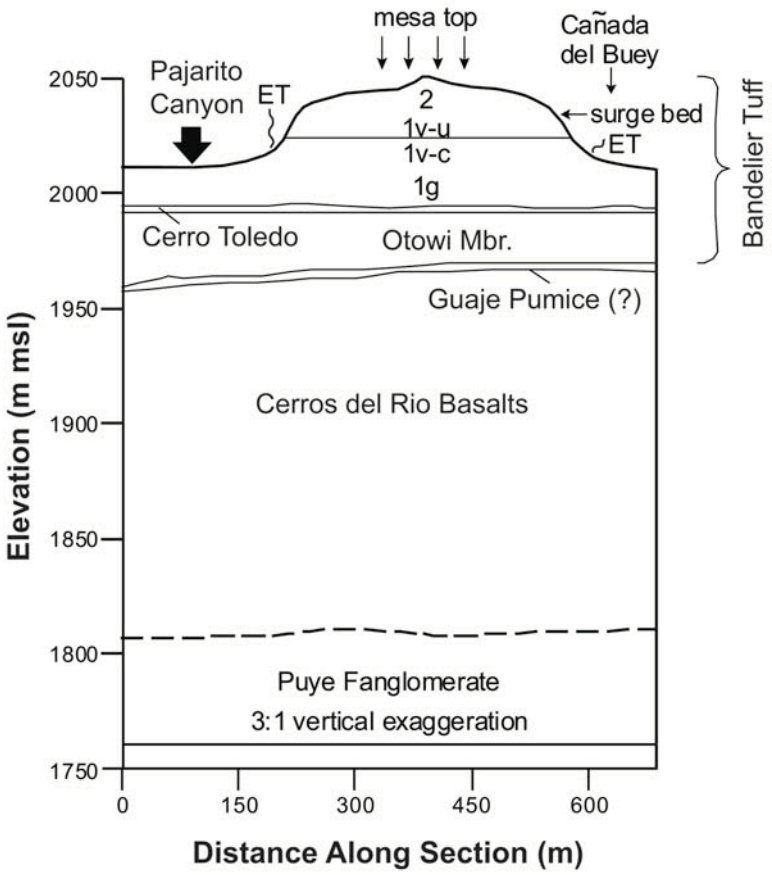

Figure 4-B-1. Conceptual model of hydrostratigraphy of the unsaturated zone for the MDA G Performance Assessment Model.

The stratigraphy at this site has several important features. The Bandelier Tuff, which composes the upper six stratigraphic units (See Figure 4-B-1), dips gently and thins toward the eastern end of the site. The top tuff layer, Unit 2, and the upper few meters of the second layer, Unit 1v-u, are extensively fractured and are separated by a thin surge bed (Krier et al. 1997). Fractures in the deeper tuff units have also been observed in outcrop (Krier et al. 1997). In addition, the Cerros del Rio Basalts, which comprise over 50% of the unsaturated zone, display significant variability (Turin, 1995). The basalts range from extremely dense with no apparent porosity, to highly fractured, to so vesicular as to appear scoriaceous. Finally, the Puye Fanglomerate lies at the base of the unsaturated zone and extends into the saturated zone. The fanglomerate consists of cobbles and boulders of volcanic debris in a matrix of silts, clays, and sands (Purtymun, 1995). Clay, silt and pumice lenses, and interbedded Cerros del Rio basalt are also common.

The van Genuchten model (van Genuchten, 1980), is used to represent the moisture retention characteristic curves for all units in the unsaturated-zone model. Birdsell et al. 2000 summarizes the hydrologic parameters used for all of the units in the unsaturated-zone flow and transport model. The parameters for the van Genuchten model (saturated permeability, porosity, inverse air entry pressure, etc.) are fairly well characterized for the six Bandelier Tuff units and for the crushed-tuff backfill but not for the deeper units. The properties for the tuff units (Krier et al.

1997), the crushed tuff, and the Guaje Pumice were measured on core samples of matrix material. Estimated values for the saturated conductivity and porosity of the Puye Fanglomerate (Purtymun 1984) are used, and we assume that the van Genuchten fitting parameters are similar to those of coarse sands.

No hydrologic property data were available for the basalts at the time this study was performed. The basalt is modeled as a composite-continuum medium made up of both fractures and matrix material (Peters and Klavetter 1988). To ensure conservatism, we set the continuum porosity of the basalt to that of the fractures, thus forcing very low residence times of solutes in this unit for which there was no hydrogeologic characterization data.

4-B-3. Infiltration

Although the average precipitation rate for the area is 35.6 cm/year (Bowen, 1990), most of this precipitation is lost to runoff and evapotranspiration, resulting in a heterogeneous infiltration pattern that is controlled by the mesa/canyon setting of the site. Infiltration is thought to be seasonal with most occurring during spring snowmelt and, to a lesser extent, during the summer thunderstorm season (Rogers et al. 1996a). Figure 4-A-1 shows the different scales of infiltration across the plateau. Based on measured rock saturations and chloride data, a very low net infiltration rate (same as net infiltration, as used in Appendix 4-A) of 1 to 10 mm/year is thought to exist within the mesa. Pajarito Canyon is wetter with an estimated net infiltration rate of 10 to 100 mm/year, while Cañada del Buey is dry with a net infiltration rate similar to the mesa top. The steep mesa sides represent an evaporative region water sink rather than a source region. The coupling of the fractured units separated by the high-permeability surge bed with the mesa's topographic relief is thought to enhance air circulation and consequently lead to evaporative drying within the mesa interior.

4-B-4. Radionuclide Releases

The waste disposal facility occupies about 300,000 m^2 atop a finger-shaped mesa with waste buried in pits and shafts to a depth of approximately 20 m (Figure 4-5). Between 1957 and 1995, solid radioactive waste was buried in 34 disposal pits and in almost 200 shafts located in five shaft fields. The waste form buried at the site contains over 60 radionuclides with the majority of the waste being ^{235}U, ^{238}U, and ^{232}Th. Currently, only low-level radioactive waste is accepted, but prior to 1971, transuranic and mixed wastes were also accepted (Schuman 1997a). An expansion area with four large pits and another shaft field is planned for operation through 2044 and is included in this study.

The waste is categorized in terms of four disposal-unit classifications that are determined by the age of the wastes, because different regulations govern wastes disposed of during different time periods and because inventory records have improved with time. Detailed inventory information for the 1971–1988 waste and the 1988–1995 waste are obtained from disposal records. However, detailed inventory data are not available prior to 1971 and are uncertain for future activities. Therefore, the inventory in the 1957–1970 waste is extrapolated backwards based on disposal operations from 1971 to 1977, and the inventory for the 1996–2044 waste is projected based on current operations and expected future operations (Schuman 1997a; Vold and Shuman 1996).

The release of radionuclides from the disposal units is represented by one of two release mechanisms: rapid release or solubility-limited release (Vold and Schuman 1996). The maximum porewater concentration of each nuclide is calculated based on its inventory, its waste volume and the moisture content in the pits. This concentration is then compared to the nuclide's solubility limit to determine which source-release model is appropriate for each nuclide in each disposal unit. That is, if the maximum porewater concentration exceeds the nuclide's solubility limit, the release concentration is held at the solubility limit until that nuclide's inventory has been exhausted. If the porewater concentration does not exceed the nuclide's solubility limit, the rapid-release model is used. Nuclides with very large solubility limits, such as ^{129}I and ^{99}Tc, are controlled by this mechanism throughout the site.

4-B-5. Computational Grids

The stratigraphic configuration used for the unsaturated zone model is derived from various sources including the then-current LANL site-wide geologic model (Vaniman et al. 1996), well-log picks, and surface observations. The data set is interpolated with the Stratagraphic Geocellular Modeling SGM Software Stratamodel to generate the three-dimensional geologic framework model. The three-dimensional unsaturated zone grid is generated with the Geomesh/X3D software (Gable et al. 1995) from this geologic framework model. An initial grid is constructed with the 45.7-m spacing of the geologic framework model and then resolved to include the 38 waste disposal pits and to better delineate the mesa sides. The final grid contains 41,542 nodes and 254,614 tetrahedral elements.

The saturated zone model extends from just west of the site to the Rio Grande. The grid is rectangular and oriented perpendicular to groundwater equipotentials. It is 9773 m long, 1280 m wide, and 100 m deep with 19,580 nodes and 102,960 tetrahedral elements. To better model the vertical dispersion of the contaminant plumes entering the aquifer from the unsaturated zone, the vertical element height is refined near the water table. The grid is also refined horizontally beneath the site to approximately 500 m downstream to accurately capture the spatial distribution of the radionuclides as they move toward the downstream compliance regions.

4-B-6. Model Implementation

Model implementation issues include how to assign the flow boundary conditions, initial conditions for transient flow, and hydraulic parameters in the model. We will also discuss some assumptions employed in model implementation.

To determine appropriate infiltration rates for the site, Birdsell et al. (2000) ran 5 two-dimensional simulations using different steady mesa-top infiltration rates of 10 mm/year, 1 mm/year, 0.1 mm/year, 0.01 mm/year and 0.0 mm/year, and compared the simulated saturation profiles to site field data. Figure 4-B-2 (adapted from Figure 5 of Birdsell et al. 2000) shows the calculated steady-state saturation profiles at the center of the mesa for the five infiltration rates along with the ranges of in situ saturation data measured in the six Bandelier Tuff units. The shape of the calculated saturation profiles shows the same trend as the data, e.g. saturations

decrease from Unit 2 to Unit 1v-u and then increase again in Unit 1v-c, etc., but no single infiltration rate yields predicted saturation values that fit the entire data set. Based on their study, together with that of Newman (1996), Birdsell et al. (2000) used a range of mesa-top infiltration rates from 1 to 10 mm/year. The bottom boundary for the unsaturated zone model is the water table.

For the saturated-zone model, a steady flow field is calculated by applying a pressure head difference of 101 m (Purtymun 1995) across the east and west sides of the model. No-flow boundaries are used for the top, bottom, north and south sides. Recharge is believed to occur mainly to the west of the site, at higher elevations in the Jemez Mountains. A water-balance estimate shows that the volume of water entering the aquifer from the unsaturated zone at the site is negligible compared to the aquifer volume (Birdsell et al. 1999). Thus, water flowing from the unsaturated zone to the aquifer is not included.

Several assumptions have been made in implementing the simulation model, including steady infiltration rates and an equivalent continuum medium for the Cerros del Rio Basalts. Although the deep percolation is thought to be seasonal with most occurring during spring snow melt and to a lesser extent during the summer thunderstorm season (Rogers et al. 1996a), Birdsell et al. (1999) studied the effects of annual transients in percolation rate on unsaturated zone transport at the site. They found that simulated transient pulses are damped with depth so that the calculated cumulative contaminant flux at the base of the Bandelier Tuff is similar under transient and steady flow fields.

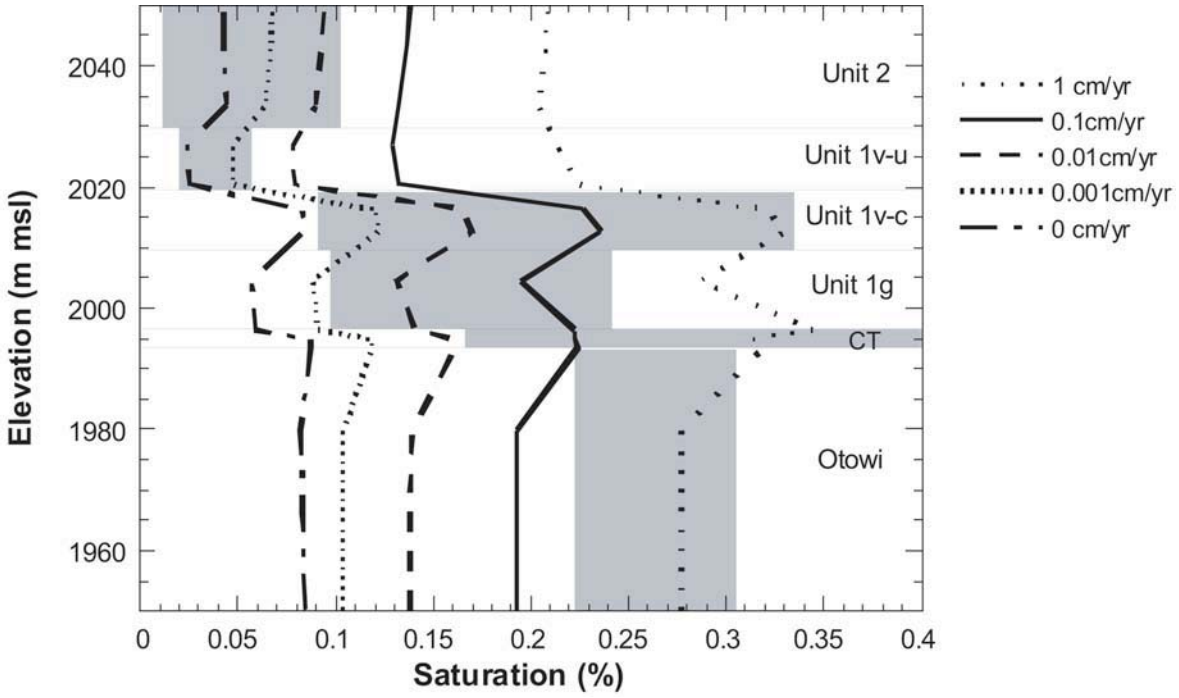

Figure 4-B-2. Comparison of site data (gray boxes) to calculated steady-state saturation profiles for several infiltration rates.

Another important assumption is that matrix flow dominates in the unsaturated tuff units at the site. This assumption is justified by considering that the pits are excavated completely through Unit 2, the most highly fractured tuff unit, thus excluding the fracture system and the likelihood of fracture flow through this unit. In addition, numerical studies of fracture flow for the site indicate that flow through fractured tuffs is difficult to maintain in low-saturation, high-capillarity systems (Soll and Birdsell 1998). Because the site in this study is a solid waste site, significant fracture flow through the unsaturated tuff units is unlikely.

Furthermore, the basalt is modeled as an equivalent continuum medium made up of both fractures and matrix material (Peters and Klavetter1988). Matrix properties are derived from analog basalts in Idaho (Bishop 1991). Fracture properties are chosen, through numerical sensitivity studies, so that no lateral diversion occurs at the top of the basalts in the simulations, even when the flow rate exceeds the matrix saturated hydraulic conductivity. The continuum porosity is set equal to the fracture volume fraction, 10^{-4}, to ensure rapid transport of 1 to 5 years through this unit, hence, foregoing any retardation due to matrix flow or sorption. Notice that this treatment of transport through the basalt yields a conservative result e.g., faster groundwater travel times and higher peak doses than actually expected.

It is evident that there is significant uncertainty in infiltration rates. For the purpose of sensitivity analyses, we defined a base-case set of infiltration rates as a reference, as listed in Table 4-B-1. Variations are made on the base-case infiltration rates to examine the impact of uncertain parameters on the model results.

4-B-7. Representative Transport Result

Unsaturated zone transport calculations were run for ^{14}C, ^{129}I, ^{237}Np, ^{99}Tc, and ^{238}U using the base-case, steady flow field, 5_1_50 (nomenclature for these model results is defined in Table 4-B-1). These nuclides were chosen because of their low distribution coefficients, ranging from 0 to 2.43 for most of the unsaturated zone units. Using screening techniques developed by Birdsell et al. (1995), Birdsell et al. (2000) chose ^{14}C, ^{129}I, and ^{99}Tc, and eliminated the remaining nuclides from consideration in the dose assessment.

Figure 4-B-3 (adapted from Figure 8 of Birdsell et al. 2000) shows the simulated ^{129}I plumes in the unsaturated zone for the four age-dependent waste classes after 1000 years using the base-case flow field. Although the infiltration rate at each source region is the same (5 mm/year), the four plumes are quite different due to both inventory variations and differences in bed thickness. The inventory distribution in the disposal units is heterogeneous, leading to large variations in radionuclide flux from the disposal units to the unsaturated zone. For example, the 1971–1988 (Figure 4-B-3b) inventory dominates the total site release of ^{129}I to the aquifer at 1000 years. Also, the 1988–1995 shafts located near the southern edge of the mesa (Figure 4-B-3c) concentrate nearly 80% of the 1988–1995 ^{129}I inventory into a small area. This localized inventory produces a predominant plume at the southern portion of the mesa, while the pits to the north and west produce the less concentrated plumes. The location of the basalt unit and the effect on plume migration of the vertical, fracture-dominated flow through this unit is readily visible in these simulations. Once the solutes reach the basalt, they migrate quickly through the unit. In the 1996–2044 waste scenario (Figure 4-B-3d), only the plume's leading edge reaches the basalt after 1000 years because the Bandelier Tuff units are much thicker beneath this proposed expansion area.

To assess the effect of uncertainty in flow rate on transport results, Birdsell et al. (2000) examined the transport of the 1988–1995 ^{129}I inventory using different flow fields and compared the nuclide fluxes through the unsaturated zone. Figure 4-B-4 (from Figure 10 of Birdsell et al. 2000) shows the total flux of ^{129}I for the five flow fields described in Table 4-B-1. By comparing the 1_1_20 case, the 5_1_20 case, and the 10_1_20 case, it is seen that increased mesa percolation leads to faster breakthrough and increased solute flux through the unsaturated zone. This flow-rate dependency is compounded by the velocity-dependent rapid-release source term. The solute flux at 1000 years for the lowest flow case, 1_1_20, is five to seven orders of magnitude less than the other cases considered. This case is used to predict the lower-bound dose in the uncertainty analysis. Comparing the 5_1_20 case to the 5_1_50 case shows that additional flow through Pajarito Canyon results in faster breakthrough and increased solute flux to the saturated zone. The 10_5_100 case represents the wettest case and yields the fastest breakthrough and highest flux to the saturated zone and, consequently, the highest dose over the first 1000 years. This case is used to estimate an upper-bound dose for the uncertainty analysis.

Table 4-B-1.
Infiltration Rates (mm/year) Used as Upper Boundary Conditions for MDA G Performance Assessment

	Mesa Top	Cañada del Buey	Pajarito Canyon
1_1_20 (lowest flow case)	1	1	20
5_1_20	5	1	20
5_1_50 (base case)	5	1	50
10_1_20	5	1	20
10_5_100 (highest flow case)	10	5	100

Source: Birdsell et al. (2000).

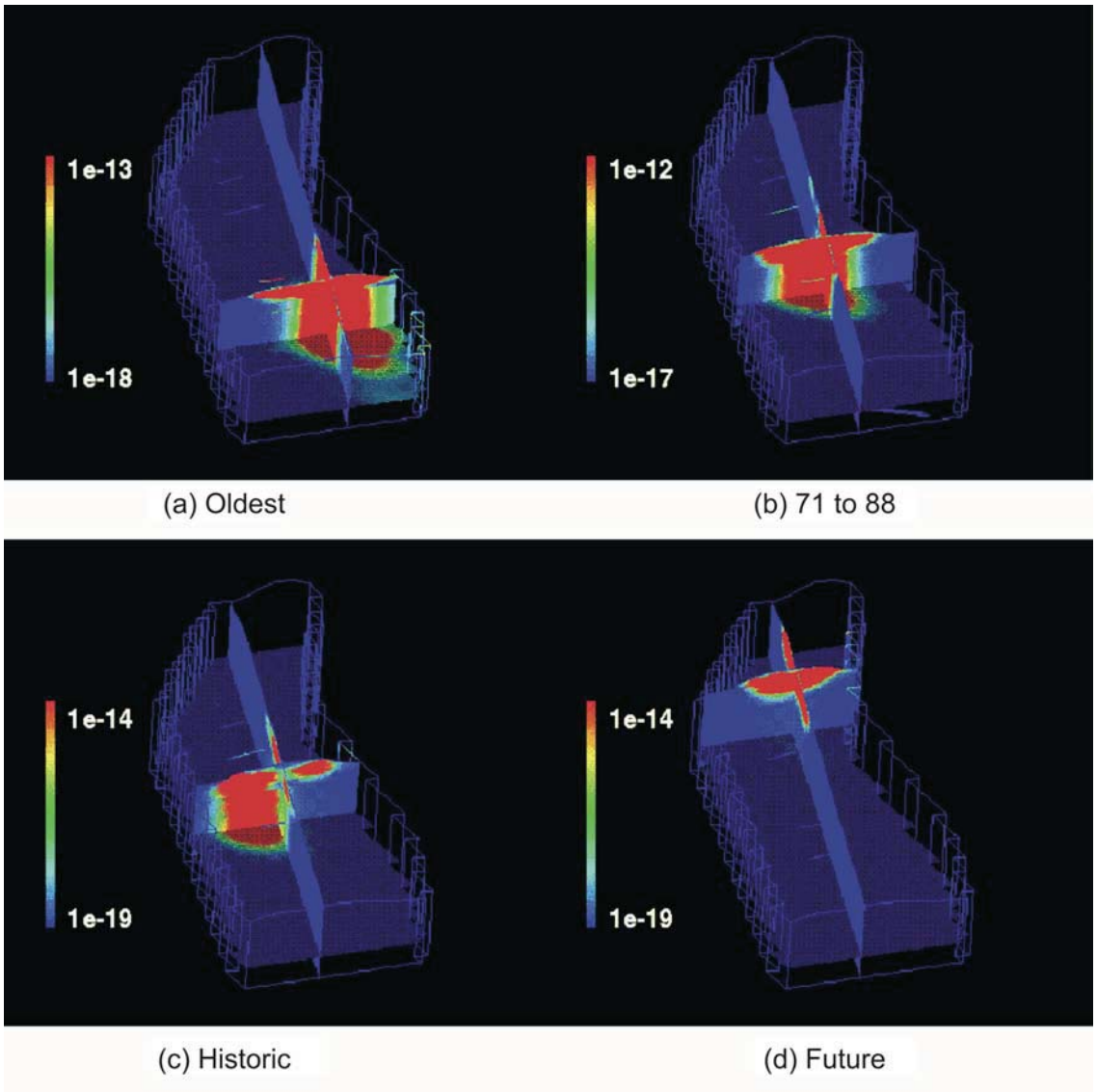

Figure 4-B-3. Iodine-129 plumes (concentration, moles/liter) in the vadose zone at 1000 years for the four different source regions, base-case flow field.

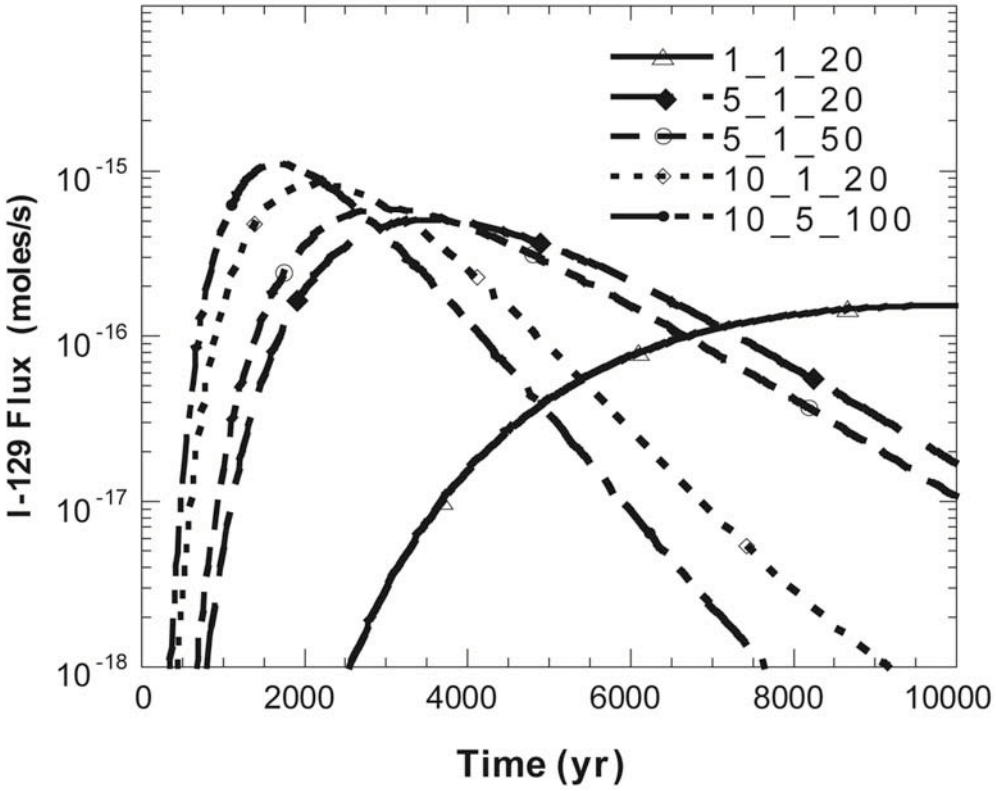

Figure 4-B-4. Total flux of the 1988–1995 ^{129}I inventory from the unsaturated zone to the saturated zone for various flow cases.

4-B-8. Discussion

Due to uncertainty in model parameters, the results of these transport simulations contain intrinsic uncertainty. The greatest uncertainties associated with predicting aquifer-related doses from the site, according to Birdsell et al. (2000), are related to the understanding of the mechanisms that control flow and transport within the unsaturated zone and our ability to model these mechanisms. At this point, they concluded that uncertainty related to the hydrologic processes themselves, i.e., conceptual model uncertainty, dominates the ability to make accurate predictions of transport at the site moreso than uncertainty related to the hydrologic and geochemical properties data. Importantly, however, predicted doses using parameters from the most conservative ends of the uncertain ranges are still well below regulatory concern.

The results of Birdsell et al. (2000) indicate that the mesa-top infiltration rate has the greatest impact on the simulated migration of waste through the unsaturated zone. It controls both the source release rate and subsequent downward solute migration. They bounded this uncertainty by considering a base-case flow field and high- and low-flow cases. As shown in Table 4-B-2, a variation in mesa-top infiltration rate from 1 to 10 mm/year results in a range of six orders of magnitude in the 1000-year groundwater-related doses. Clearly, a good understanding of this key parameter is important to the dose assessment. However, because doses are so much less than the performance objectives developed in Birdsell et al. (2000), conservative yet realistic infiltration rates seem adequate for this site. With respect to travel times, models of dry mesas such as that

associated with MDA G generally predict travel times in the neighborhood of 1000 years or more. This basic result indicates that groundwater pathway risks associated with waste disposed under dry mesa conditions are expected to be risks that will present themselves far into the future, as opposed to there being a significant present-day risk. This result applies only to the groundwater: a complete pathway assessment should be conducted that includes other exposure scenarios in addition to groundwater.

Table 4-B-2.
Maximum Ground Water and All Pathways Doses for the PA and CA Wastes, Base Case Flow Field (mrem/yr) MDA G Performance Assessment.

	PA - Ground Water	PA - All Pathways	CA - All Pathways
Performance Objective	4	25	100
1000 yr (Base Case)	2.4×10^{-7}	6.5×10^{-7}	3.7×10^{-5}
Peak Dose (Base Case)	3×10^{-5} @ ~4500 yrs	1×10^{-4} @ ~4500 yrs	2×10^{-3} @ ~3000 yrs
1000 yr (high-flow case)	8.0×10^{-6}	2.2×10^{-5}	1.4×10^{-3}
1000 yr (low-flow case)	9×10^{-12}	2×10^{-11}	1×10^{-10}

Source: Birdsell et al. (2000).

Finally, there are residual uncertainties related to flow in the deeper unsaturated-zone units for which few hydrologic data are available. The simulations take virtually no credit for transport times through the Cerros del Rio basalts, which make up more than 50% of the unsaturated zone. The transport results are based on the steady-flow assumption and on the use of matrix, hydrologic properties for all tuff units at the site. The response of this fractured system to transient flow events is not completely known. Transient calculations (Birdsell et al. 1999) indicate that the steady-flow assumption is adequate because fluctuations in both saturation and contaminant flux rates dampen with depth even when including fractures in the upper two units. Fracture infiltration studies (Soll and Birdsell, 1998) lead to the conclusion that fracture flow is difficult to initiate and is short-lived in the upper two tuff units at the observed low field saturations. These conclusions are supported by modeling studies presented for Los Alamos Canyon in Appendix 4-C, as well as the findings of Robinson et al. (2005b).

APPENDIX 4-C. LOS ALAMOS CANYON MODEL

4-C-1. Introduction and Motivation

Los Alamos Canyon, as shown in Figure 4-6, is one of the most complex sites at the Laboratory. A number of technical areas have been or are currently located in or adjacent to the canyon, resulting in multiple release locations along the canyon. This section examines, through a synthesis of available data and the development of numerical models, fluid flow and contaminant transport in the vadose zone beneath Los Alamos Canyon. The subsurface hydrology and transport in the vadose zone is also a challenging activity, given the wide range of infiltration rates, the presence of perched water, and the introduction of a host of contaminants of different chemical properties. Because the canyon serves as a collector of a wide range of contaminants, we decided that it was necessary to develop a model at the scale of the canyon, rather than at a smaller scale. The specific goals of the model are as follows:

- Synthesize the available data and conceptual understanding of the vadose zone hydrology beneath Los Alamos Canyon;
- Produce a "base-case" numerical model of the subsurface vadose zone hydrology that ultimately can be used to predict contaminant migration rates and concentrations in fluids reaching the regional aquifer beneath the canyon;
- Quantify the uncertainties associated with those predictions by establishing the bounds on system behavior through a suite of possible models, all of which are consistent with the available data, but which bracket the range of possible behavior;
- Provide a simulation tool for predicting the fate and transport of contaminants in Los Alamos Canyon under different assumed hydrologic and ER stewardship scenarios; and
- Demonstrate a model development methodology that can be used in studies of other canyons on the Pajarito Plateau.

This work focuses on the hydrology beneath Los Alamos Canyon, as a first step toward developing a predictive tool that can be used to simulate contaminant migration in the canyon. Since water is the carrier fluid for the contaminants of interest, constructing a realistic flow model that captures the most important hydrologic processes of the vadose zone is an essential first step in the development of a reliable model. Although we primarily restrict attention to flow issues, tritium transport in the vadose zone is also modeled here. Tritium, in the form of tritiated water, is an excellent tracer for groundwater, and hence is included in this modeling study as a constraint on the flow model. Although the work here is restricted to Los Alamos Canyon, we anticipate that the methodology and approach applied here can be used to develop models at other sites at the Laboratory.

4-C-2. Hydrostratigraphy

Accurate modeling of groundwater flow and transport in Los Alamos Canyon requires the integration of geologic model information with computational grids. Stratamodel was used to create a three-dimensional geologic framework model for Los Alamos Canyon. The geologic framework model consists of 20 distinct geologic units and is the product of a continuous process of model development and improvement in support of the Hydrogeologic Workplan

(LANL 1998) activities, including the development of numerical flow and transport models such as the present study. The record of model development and improvement is documented in various LANL reports (Vaniman et al. 1996, Carey et al. 1999). The different versions of the geologic models are distinguished based on the fiscal year (FY) in which they were built. Several of the sensitivity analyses were performed with the FY98 version as the geologic basis, while most of simulations are done based on the FY99 version.

The defined stratigraphic units and their accepted designators are listed in Table 4-C-1. Figure 4-C-1 shows a two-dimensional cross section of the geologic model, illustrating the complexity of the current conceptualization of the subsurface. A characteristic of this two-dimensional stratigraphic model that is different than other models developed for sites on the Pajarito Plateau such as MDA G (Birdsell et al. 1999) and Mortandad Canyon (Dander 1998) is the absence of significant thickness of the Tshirege Member of the Bandelier Tuff. Los Alamos Canyon cuts deeply into the Bandelier Tuff such that the Otowi Member is the first unit encountered beneath the alluvium in the canyon bottom over much of the model domain. In the eastern portion of the model, the Otowi is not present, and instead the Cerros del Rio (Tb4) is the first unit encountered. This is the case at R-9, where the stratigraphic section consists only of basalts and the Puye Formation. Figure 4-C-2 depicts the full three-dimensional model stratigraphy, along with the locations of important wells and facilities referred to later.

Table 4-C-2 lists the hydrologic properties used for the Los Alamos Canyon model. Permeability and porosity values used for each unit are listed first, followed by the unsaturated hydrologic parameters for the van Genuchten (1980) formulation used in the present study. It is assumed in this study that hydrologic properties are homogeneous within each individual unit. Although the appropriate hydrologic properties for the various units are thought to be somewhat site dependent, these property values are representative averages of site-wide conditions and can be used as a starting point for vadose zone numerical simulations.

Table 4-C-1.
Stratigraphic Units Present in the Vicinity of Los Alamos Canyon

Group/Formation	Unit Name	Symbol
Tshirege Member of the Bandelier Tuff	Unit 5	Qbt5
	Unit 4	Qbt4
	Unit 3	Qbt3
	Unit 2	Qbt2
	Vapor-phase altered member of Unit 1	Qbt1v
	Glassy member of Unit 1	Qbt1g
	Tsankawi Pumice	Qbtt
Cerro Toledo Interval	Cerro Toledo	Qct
Otowi Member of the Bandelier Tuff	Otowi Member ash flow	Qbof
	Guaje Pumice bed	Qbog
Puye Formation	Puye fanglomerate	Tpf
	Totavi Lentil	Tpt
Cerros del Rio basalt	Basalt 4	Tb4
	Basalt 3	Tb3
	Basalt 2	Tb2
	Basalt 1	Tb1
Tschicoma Formation	Tschicoma latite	Tt2
	Tschicoma dacite	Tt1
Santa Fe Group	Chaquehui (volcaniclastic) aquifer unit	Tsfuv
	Santa Fe Group undifferentiated	Tsfu

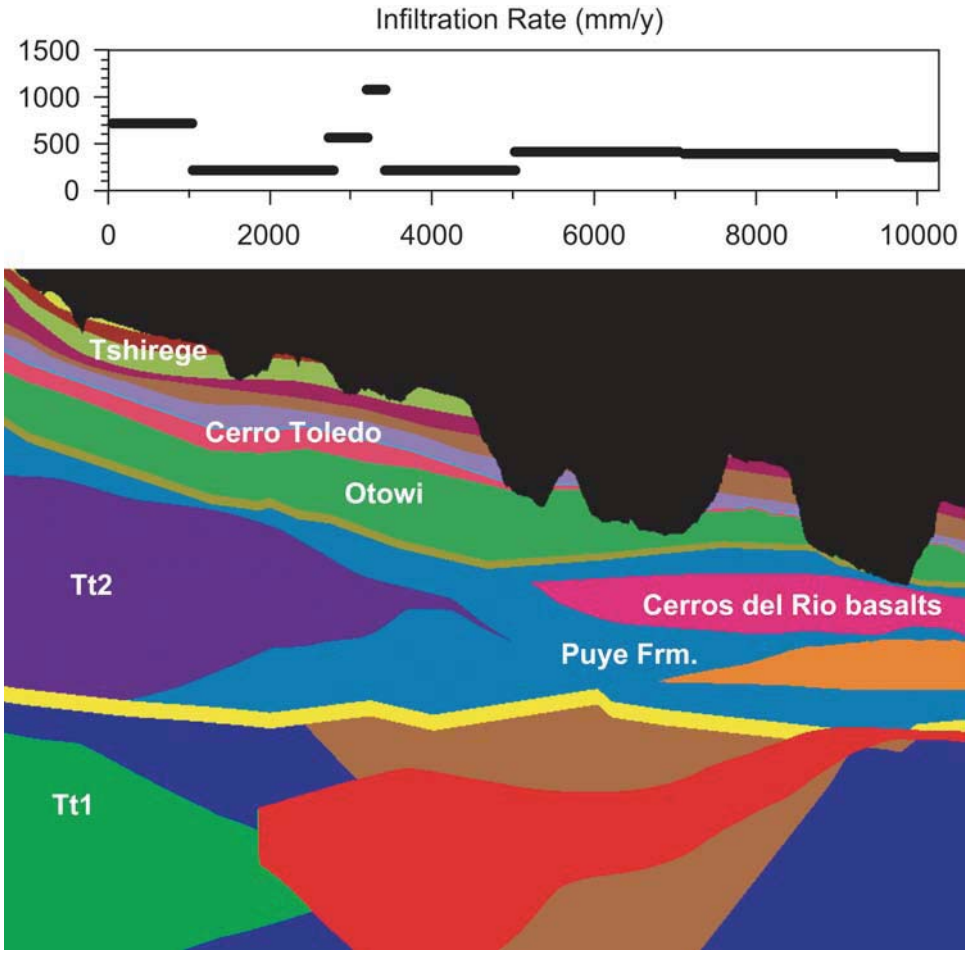

Figure 4-C-1. Cross section of stratigraphy in the vicinity of Los Alamos Canyon. Also shown is the infiltration map used along the canyon bottom (derived from water budget study of Gray 1997).

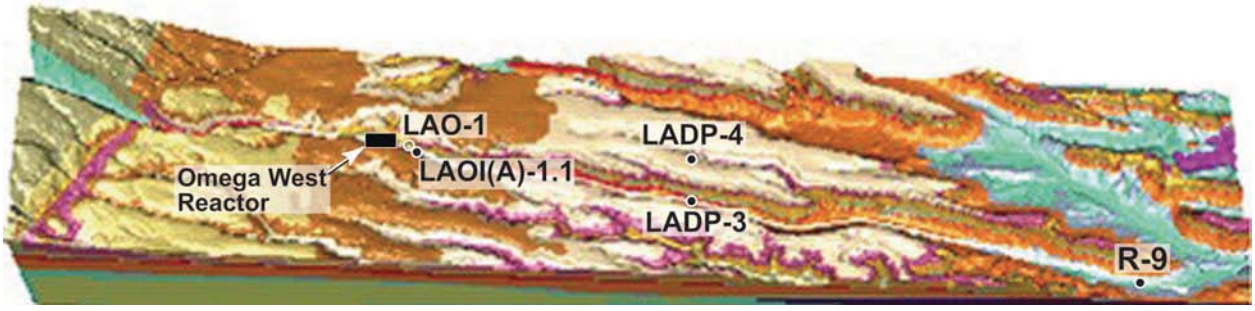

Figure 4-C-2. Three-dimensional depiction of the stratigraphic framework model used to construct the flow and transport model for Los Alamos Canyon. Important wells and the site of a nuclear reactor are also shown.

Table 4-C-2.
Hydrologic Property Values in the Los Alamos Canyon Model

Hydrogeologic Unit	Geologic Designation	Permeability, m^2	Porosity	Van Genuchten α parameter, m^{-1}	Residual Moisture Content	Van Genuchten n parameter, unitless
Unit 3, Tshirege Member	Qbt3	1.01e-13	0.469	0.29	0.045	1.884
Unit 2, Tshirege Member	Qbt2	7.48e-13	0.479	0.66	0.032	2.09
Vitric unit, Tshirege Member	Qbt1v	1.96e-13	0.528	0.44	0.009	1.66
Glassy unit, Tshirege Member	Qbt1g	3.68e-13	0.509	2.22	0.018	1.592
Basal pumice unit, Tshirege Member	Qbtt	1.01e-12	0.473	1.52	0.01	1.506
Cerro Toledo Interval	Qct	8.82e-13	0.473	1.52	0.01	1.506
Otowi Member	Qbof	7.25e-13	0.469	0.66	0.026	1.711
Guaje Pumice Bed	Qbog	1.53e-13	0.667	0.081	0.01	4.026
Cerros del Rio Basalt, Puye Formation	Tb4	2.47e-12	0.3	0.1	0.066	2.
Tschicoma dacites	Tt2	2.96e-13	0.3	0.1	0.066	2.
Miocene basalts, Santa Fe Group	Tb3	2.96e-13	0.3	0.1	0.066	2.
Puye Formation	Tpf	4.73e-12	0.25	5.	0.01	2.68
Totavi Lentil	Tpt	4.73e-12	0.25	5.	0.01	2.68
Santa Fe Group	Tsfuv	2.65e-13	0.25	5.	0.01	2.68

4-C-3. Infiltration Rates and Water Budget Model

The infiltration rate on the upper surface is one of the most important inputs in simulating flow and transport in the site. For the mesa areas, various hydrologic and chemical techniques have been employed to estimate infiltration rates in various settings. Rogers et al. (1996a) outlined an interpretive technique for estimating local infiltration rates based on measured hydrologic properties and water content values in samples collected from the vadose-zone tuffs. They obtained infiltration rates on mesas as low as 0.06 mm/yr with higher mesa values only found where surface conditions such as ponds were present. In more recent analyses, Birdsell et al. (1999) obtained a value on the order of 1 mm/yr for undisturbed mesa conditions at TA-49, and values estimated from 60-300 mm/yr beneath paved regions. At TA-16, chloride mass balance data collected by Newman (presented in Birdsell et al. 2005) were interpreted using the chloride mass balance method. Infiltration rates slightly higher than 1 mm/yr were obtained in this manner, which is consistent with the analyses of moisture content. Therefore, an infiltration rate of 1 mm/yr is assumed at all locations except the canyon bottom in the current model.

To estimate the infiltration rate along Los Alamos Canyon, we use the study of Gray (1997), who focuses on the water budget and fluid flow in the surface water stream and shallow alluvial aquifer in Los Alamos Canyon. The fundamental model equation used to evaluate the water budget is

$$I = P - R - ET - \Delta S$$

where I is infiltration, P is precipitation, R is runoff, ET is the evapotranspiration term, and ΔS is the change in fluid storage. Since there was no experimental basis for estimating ΔS, Gray assumes it to be zero, listing it as an uncertainty in his analysis. The water budget calculations employed data from several sources, including stream-flow data from three stream-flow gages that provide estimates of surface water flow rates, and meteorological data from five precipitation measurement stations. These data were used by Gray in both an overall water budget for the canyon and a detailed water budget calculation. Details can be found in Gray (1997).

Figure 15 of Gray (1997) shows the results from the overall water budget performed for Los Alamos Canyon. The key result from this aspect of Gray's work is the estimation of the relative amounts of ET, runoff, and infiltration to the deeper vadose zone. Over the three-year period of that study, Gray found that 71% to 83% of the water introduced into Los Alamos Canyon was lost to evapotranspiration. Gray points out many limitations and uncertainties in this estimate. Given the direct influence of this term in the water budget and indirectly on infiltration rate, a more comprehensive study of the processes is warranted. Most of the rest of the water not undergoing evapotranspiration is estimated to be recharging the deeper vadose zone, whereas runoff was found to be relatively small. Average infiltration rates applicable to the Los Alamos Canyon watershed were found to range from roughly 100 to 200 mm/yr for the period of study. These values are average values for the watershed, and might be expected to be higher locally directly beneath the stream channel.

In addition to the overall water budget, Gray (1997) conducted a detailed study using measured data and a numerical model to further break down the components of the water balance. A calibrated numerical flow model of the alluvial aquifer was developed to analyze the spatial and temporal distributions of infiltration in the canyon. Gray divided the canyon alluvial aquifer model into nine zones that corresponded to locations of the monitoring wells used in the model calibration. The model calibration procedure involved adjusting the drain conductance term that controlled the water flux leaving the alluvial aquifer (and entering the underlying bedrock) to match the water level data. The other terms in the water budget (excepting the storage term) were also included in the model, so that the calibration procedure provides a direct estimate of the spatially dependent infiltration rate along the canyon. Table 4-C-3 summarizes the results of this analysis. The highest infiltration rate of 1076 mm/yr occurs in Gray's Zone 4, corresponding to well LAO-0.8. This well falls near the southern projection of the Guaje Mountain fault zone, and was determined to have a strikingly low water level. This observation, and the numerical model calibrated to it, suggest high infiltration in this zone, perhaps due to an enhanced permeability due to fracturing. Zones 1 and 3 also exhibit higher than average infiltration. Gray postulates that Zone 3 may be higher because of its proximity to the Guaje Mountain fault, and Zone 1 infiltration may be high due to a greater saturated thickness in this portion of the canyon. The rest of the Los Alamos Canyon study area exhibited lower infiltration rates.

4-C-4. Contaminant Sources

A host of possible contaminant source sites exist for Los Alamos and DP canyons, resulting from past and present Laboratory operations. The most important of these for our purposes include TA-1 (Townsite), TA-41 (Weapons Development Facility), TA-2 (Omega West Reactor Site), TA-21 (DP Site), and TA-53 (LANSCE). In particular, the Omega West reactor site, located in Los Alamos Canyon, was used since 1943 to house and operate a series of research reactors. Early reactors were fueled by aqueous uranyl solutions, whereas other reactors were fueled by solid fuel elements. A variety of contaminants (mostly radionuclides) are suspected to have been released into the canyon. Most relevant to the present study is tritium, produced from a leak in the primary cooling water system at the reactor. The leak occurred from a break in a weld seam in a section of the delay line running from building TA-2-1 to the surge tank. This leak was discovered in 1993, and tritium was detected within a stretch of canyon corresponding to the southern projection of the Guaje Mountain fault zone. Typical concentrations in the cooling water ranged from 15.7×10^6 to 20.2×10^6 pCi/L. The duration of the leak is not documented, but measurements of tritium concentrations in alluvial aquifer well LAO-1 (located at the eastern boundary of TA-2) suggest that the leak may have begun between November 1969 and January 1970. This reactor was permanently shut down in 1994.

In the transport simulations, among all possible contaminants, we choose tritium, which, in the form of tritiated water, is among the simplest chemical constituents to model because its chemical state as a water molecule implies that it is a tracer for water. Other contaminants may undergo sorption, precipitation, and complex speciation processes that complicate the transport simulation.

Table 4-C-3.
Infiltration Rates for Various Portions of Los Alamos Canyon*

Zone	Location	Infiltration, mm/yr	ET, mm/yr	Downgradient Loss, mm/yr
1	LA Reservoir to 1100 ft east of bridge	714	464	56
2	End of Zone 1 to LAO-C	213	167	223
3	LAO-C to LAO-0.6	566	158	547
4	LAO-0.6 to LAO-0.8	1076	0	148
5	LAO-0.8 to LAO-1	222	195	93
6	LAO-1 to LAO-2	408	28	111
7	LAO-2 to LAO-6	399	93	46
8	State Rt. 4 to Lab boundary	362	139	19
9	East of Lab boundary	325	121	0

* Values from the analysis of Gray (1997)

4-C-5. Numerical Grids

To deal most efficiently with issues of computational demands and model accuracy, we have utilized both two- and three-dimensional models for various flow and transport model analyses. A major advantage of two-dimensional grids is the smaller number of nodes and elements. Calculations run very quickly, making the grid appropriate for scoping calculations and sensitivity studies. When very high spatial resolution is required, three-dimensional grids are also necessary. However, since the grid is two-dimensional, there are limitations as to what spatial variability of flow properties can be captured in the model. In two-dimensional simulations, the model domain implicitly assumes that flow is negligible in the direction normal to the grid. This problem is relaxed in the three-dimensional grid, at the cost of greater computational times and a somewhat reduced grid resolution. Computational grids have been built for both the two-dimensional and three-dimensional simulation models.

For the two-dimensional grid, the western boundary of the domain is located at New Mexico state plane coordinates (492916.5, 541257.7), just west of the Omega Bridge. Note that all state plane coordinates are specified in meters. The eastern boundary extends in a one-dimensional fashion from the western boundary to a coordinate location of (502959.6, 539688), just west of the intersection of State Route (SR) 4 and New Mexico State Highway (NMSH) 502. The extent of Los Alamos Canyon in the two-dimensional model is represented by drawing a one-dimensional line as closely as possible down the center of the canyon. To do this, the length of the canyon was traced from the western to the eastern boundary using a digital topographic map as a reference in Stratamodel (See Figure 4-6). The bends in Los Alamos Canyon are also accounted for. The final version of the two-dimensional grid for Los Alamos canyon consists of 57,004 nodes, 111,256 tetrahedral elements, and contains 11 materials.

In the process of selecting the simulation domain for the three-dimensional Los Alamos Canyon grid, we consider the historical information about contaminant releases and important sites along the canyon that may be relevant to contaminant transport issues in the canyon. It is deemed necessary that areas such as TA-21, TA-2 (the Omega West reactor), DP Canyon, and well R-9 be within the domain of the three-dimensional grid. The Los Alamos Canyon model domain is rectangular in shape and encompasses most of Los Alamos Canyon, DP Canyon, and some of the adjacent mesas to the north and south of Los Alamos Canyon. The model domain extends from the topographic surface to a depth of 1650 meters. Within this grid, we capture both the mesas and the canyon in the same grid, so that infiltration boundary conditions and contaminant releases can be applied correctly. One of the major constraints on the grid building process is to keep the total number of nodes as low as possible but, at the same time ensure that there is adequate resolution in the areas of interest. The final grid, shown in Figures 4-C-3 and 4-C-4, is a three-dimensional grid that is composed of 301,436 nodes, 1,688,457 elements, and 14 unique materials.

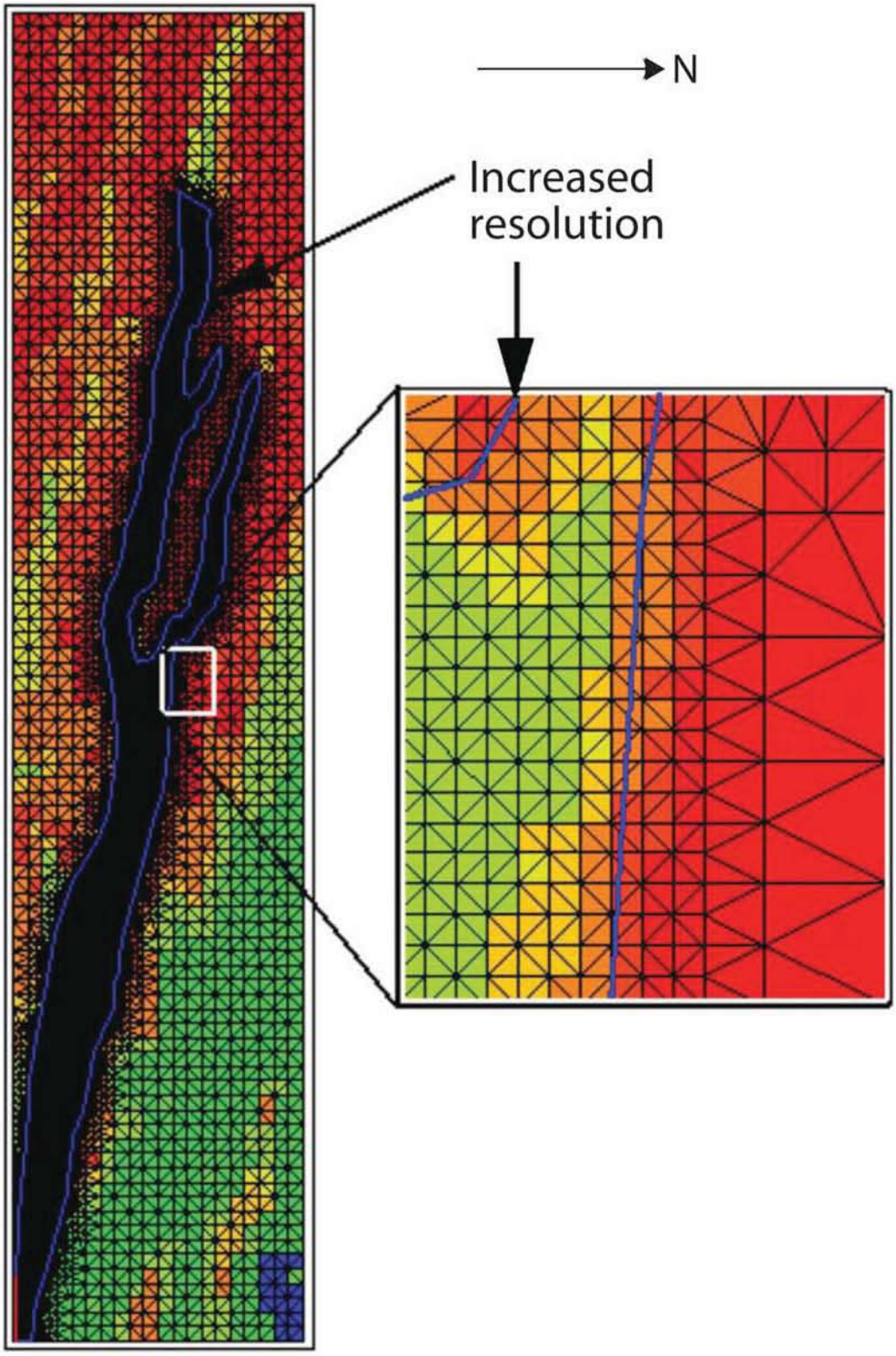

Figure 4-C-3. Three-dimensional model grid. Plan view showing the areas of enhanced grid resolution along Los Alamos and DP Canyons.

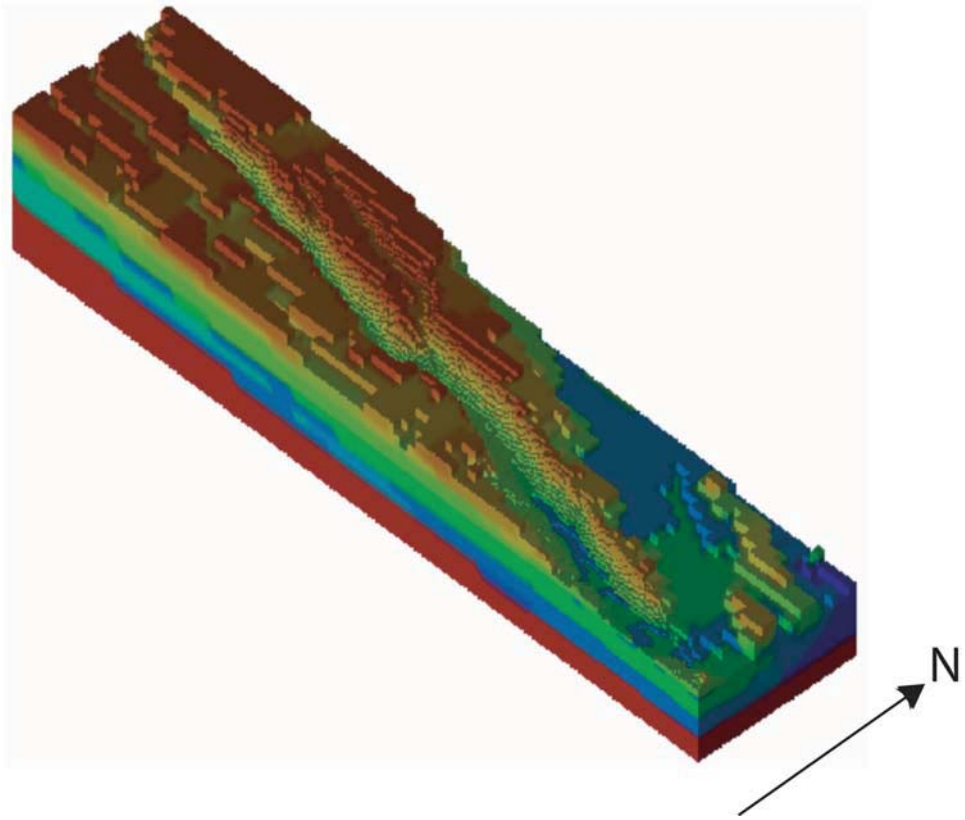

Figure 4-C-4. Three-dimensional view of the Los Alamos Canyon model numerical grid.

4-C-6. Model Implementation

Model implementation issues include how to assign the flow boundary conditions, initial conditions for transient flow, and hydraulic parameters in the model. We will also discuss some assumptions employed in model implementation.

The infiltration values obtained from Gray (1997) in Los Alamos Canyon were applied directly to the two- and three-dimensional models. In the three-dimensional model, it is relatively straightforward to apply an estimated infiltration rate on all grid nodes identified as representing the interface of the alluvium bottom and the bedrock. In a two-dimensional model, we implicitly assume that there are no variations in infiltration in the third dimension (the horizontal direction normal to the canyon). As a result, the appropriate flux to be input to the two-dimensional model is not necessarily the value along the canyon bottom. Figure 4-C-1 shows the infiltration map above the two-dimensional model domain. The infiltration rates so applied in two dimensions are expected to be maximum values. In this study, it is assumed that the relative flux entering the subsurface at different locations along the canyon remains the same, but the absolute value of infiltration is uncertain. The fluid mass flow rate at each top node is determined upon multiplying the infiltration rate at that node by the nodal area normal to the upper surface of the model (for an assumed 1 m thickness of the two-dimensional model domain).

The bottom boundary condition represents the water table. The water table is estimated from results compiled by Keating (personal communication, 1999). Any node falling below this surface is assigned a value of saturation equal to 0.999 to represent the regional aquifer. Therefore, the vadose zone model domain extends only down to this surface, and the bottom region is simply a boundary condition rather than a calculated result.

The hydrologic properties at each grid node in the two- and three-dimensional models are determined by the properties of the unit in which the node falls. The hydrologic properties used for the Los Alamos Canyon model are listed in Table 4-C-2.

It is evident that there is significant uncertainty in the hydrologic properties and infiltration rates due to, for example, the true variability of medium properties, a limited number of measurements, and measurement errors. For the purpose of sensitivity analyses, we defined a base-case set of hydrologic properties and boundary conditions as a reference. In the base case, the values for the hydrologic properties are taken from Table 4-C-2 and the infiltration rate for the canyon is taken from Table 4-C-3 (1 mm/yr for the mesas). The base case parameter set used the mean values of the hydrologic parameters for all units. This practice has been used in other modeling studies on the Plateau, including Dander (1998) and Birdsell et al. (1999). Variations are made on the base-case parameters to examine the impact of uncertain parameters on the model results.

Once the hydrologic properties and initial and boundary conditions are selected, the flow and transport equations are solved using the finite element heat and mass (FEHM) code that simulates heat conduction, heat and mass transfer for multiphase flow within porous and permeable media, and noncondensible gas flow within porous and permeable media. The code handles model geometries in two or three dimensions, and has a variety of solute transport model options available for use. For details of the fundamental model equations solved by the code, see Zyvoloski et al. (1997).

4-C-7. Fluid Saturation Model Results

Figures 4-C-5 and 4-C-6 show a full three-dimensional view of fluid saturation and a series of two-dimensional vertical slices through the three-dimensional model. As expected, the figure shows wet conditions in the canyon, dry in surrounding mesas. As with the two-dimensional model, this model result shows the overriding importance of the stratigraphy in controlling the water contents in the rock. The local infiltration rate also exerts a strong control on the results. Directly beneath the canyon, fluid saturation is much higher within a given stratigraphic unit than in other parts of the model domain, a reflection of the high infiltration in the canyon.

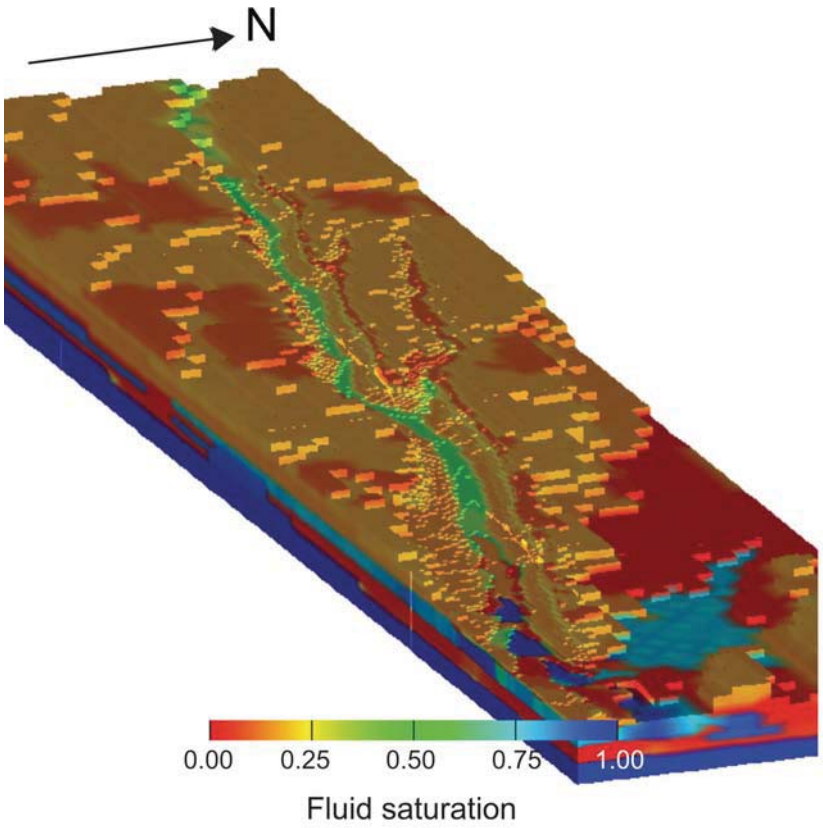

Figure 4-C-5. Full model three-dimensional flow results showing fluid saturation predictions through the model domain.

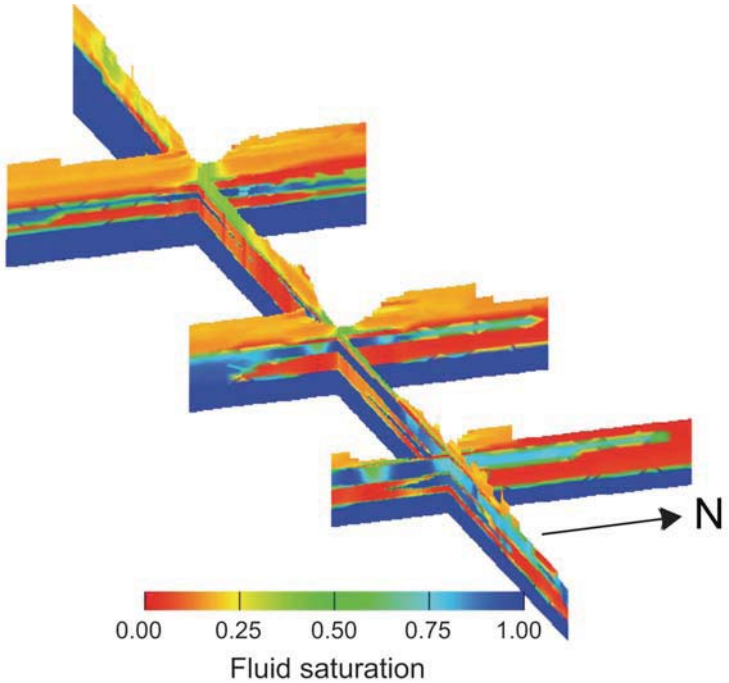

Figure 4-C-6. Fence diagram showing one north-south and three east-west cross-sections.

4-C-7.1 Moisture Comparisons to Data

We choose volumetric water content as the primary measurement used to evaluate the model results because adequate data on water content is available from virtually all vadose zone characterization wells. Robinson et al. (2005a) presents a detailed analysis of the comparisons of volumetric water contents predicted in the three-dimensional model to measured values in three wells located in Los Alamos Canyon: LADP-3, LAOI(A)-1.1, and R-9. Representative results are shown in Figures 4-C-7 and 4-C-8 for wells LADP-3 and LADP-4, respectively. The fits to the data are presented for three different levels of infiltration rates, i.e., the base-case infiltration map, a map with infiltration scaled down by a factor of three from the base map, and a map with infiltration scaled up by a factor of three. It is seen that the base infiltration map does an adequate job of jointly matching the water content profiles in these wells, despite the different stratigraphy and position relative to the canyon bottom. The good fit for LADP-4 illustrates the adequacy of the model in capturing the fluid saturations in the Tshirege Member (not present in the two-dimensional model), as well as in a region where infiltration rates are taken to be significantly lower than in Los Alamos Canyon at LADP-3. The need to apply significantly lower infiltration near LADP-4 is best understood by comparing the water content model and data for these two wells. The significantly wetter conditions in LADP-3 are simulated in the three-dimensional model through the setting of high infiltration in the canyon. It is evident from these comparisons that the model is able to capture the general features of data.

4-C-7.2 Sensitivity Analysis

As was discussed previously, there is significant uncertainty in the hydrologic property values and infiltration rates in the Los Alamos Canyon model. Therefore, it is important to investigate how the deviations of the parameter values from the base case affect the model predictions.

Sensitivity to flow transients. In model simulations presented thus far, it is assumed that the infiltration is time-independent. However, infiltration is likely to be a more transient phenomenon. Gray (1997) shows that in Los Alamos Canyon, water levels in alluvial aquifer wells fluctuate with season in response to summer storm events and spring runoff from snowmelt. It is not clear to what extent these transients are damped by the surface and alluvial aquifer flow processes. To test the potential influence on vadose zone water contents, we take a "worst-case" approach to bound the problem. In the first simulation, we test the sensitivity of the model to a very sharp impulse of water corresponding to the entire predicted infiltration of one-half year concentrated in a one-week time period. This bounding case is intended to model the case of all infiltration occurring in a single spring runoff event and a single summer storm event. Figure 4-C-9a shows the predicted water content profiles in LADP-3 in response to such an event. The influence is only felt in the uppermost ten meters or so of the vadose zone. The quantity of water input during the event, though intense, is insufficient to have a significant influence on the water content profile. These events would then be followed by a half-year of no infiltration, which would cause the profile to bounce back to nearly its original state. Therefore, the assumption of steady-state conditions over time scales of years should have no influence on the interpretation of the water content profiles in the observation wells, except possibly very close to the surface (alluvium-bedrock interface).

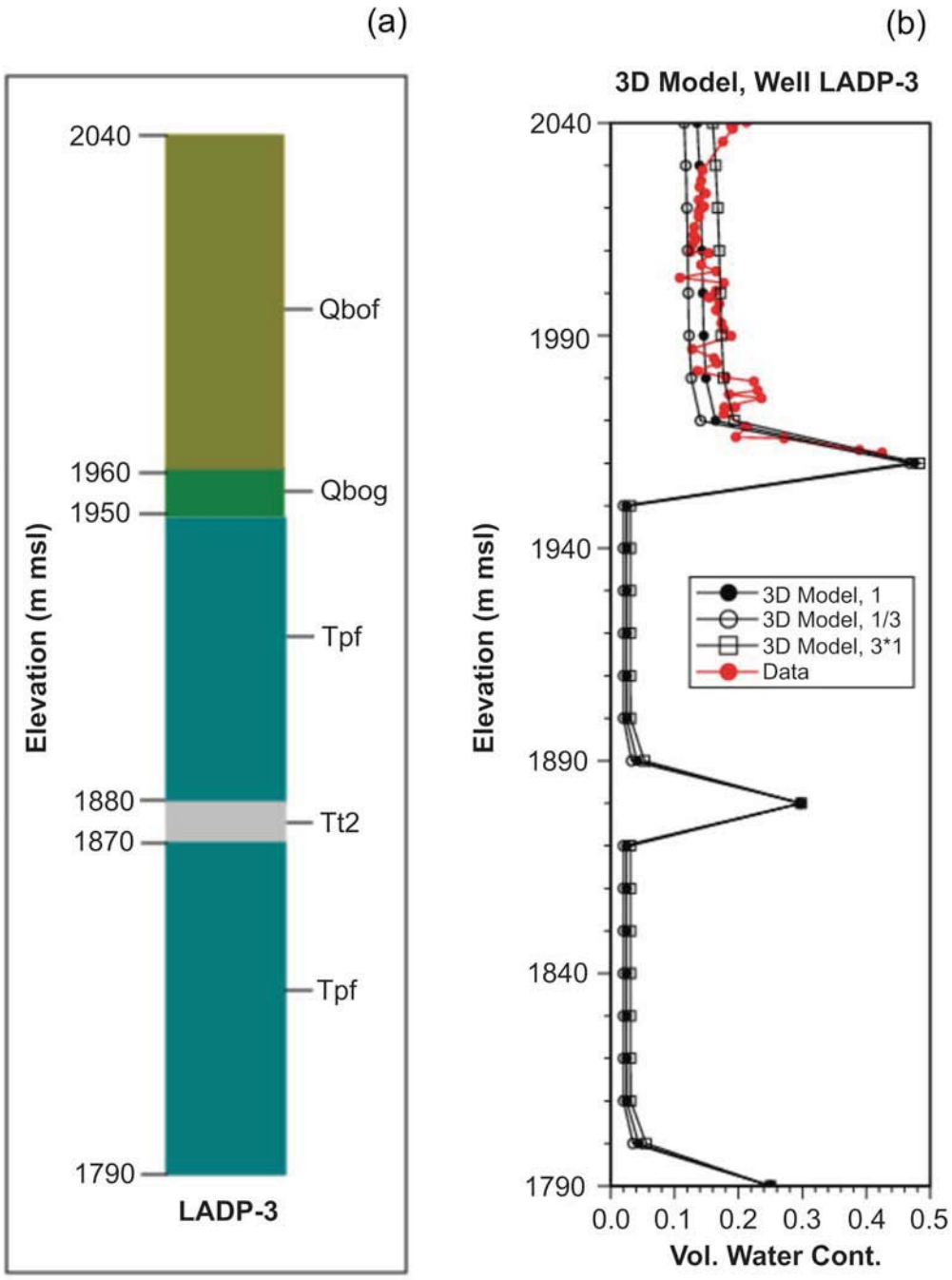

Figure 4-C-7. Comparison of data and three-dimensional model predictions for water contents in well LADP-3 (a. stratigraphy; b. data-model comparison).

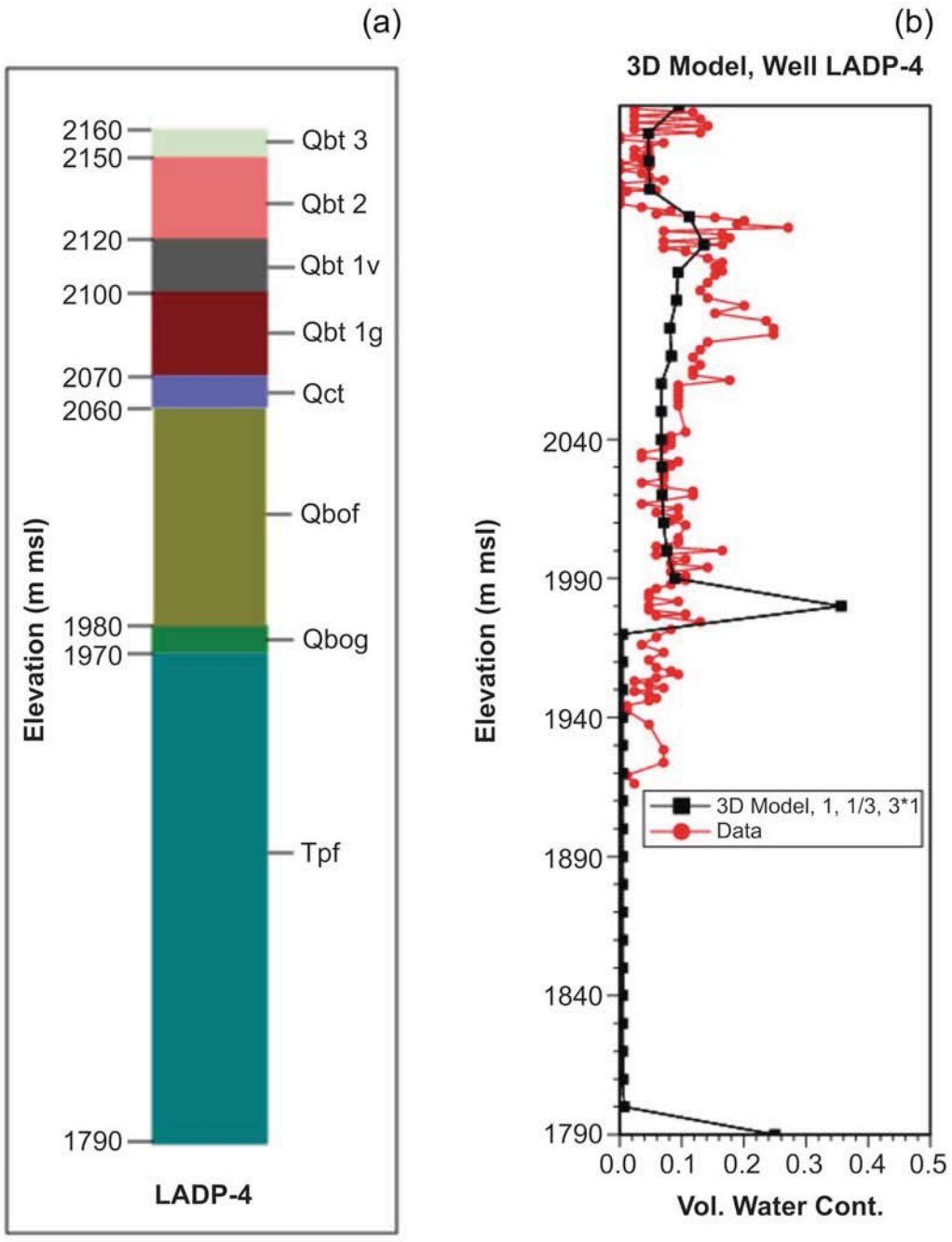

Figure 4-C-8. Comparison of data and three-dimensional model predictions for water contents in well LADP-4 (a. stratigraphy; b. data-model comparison).

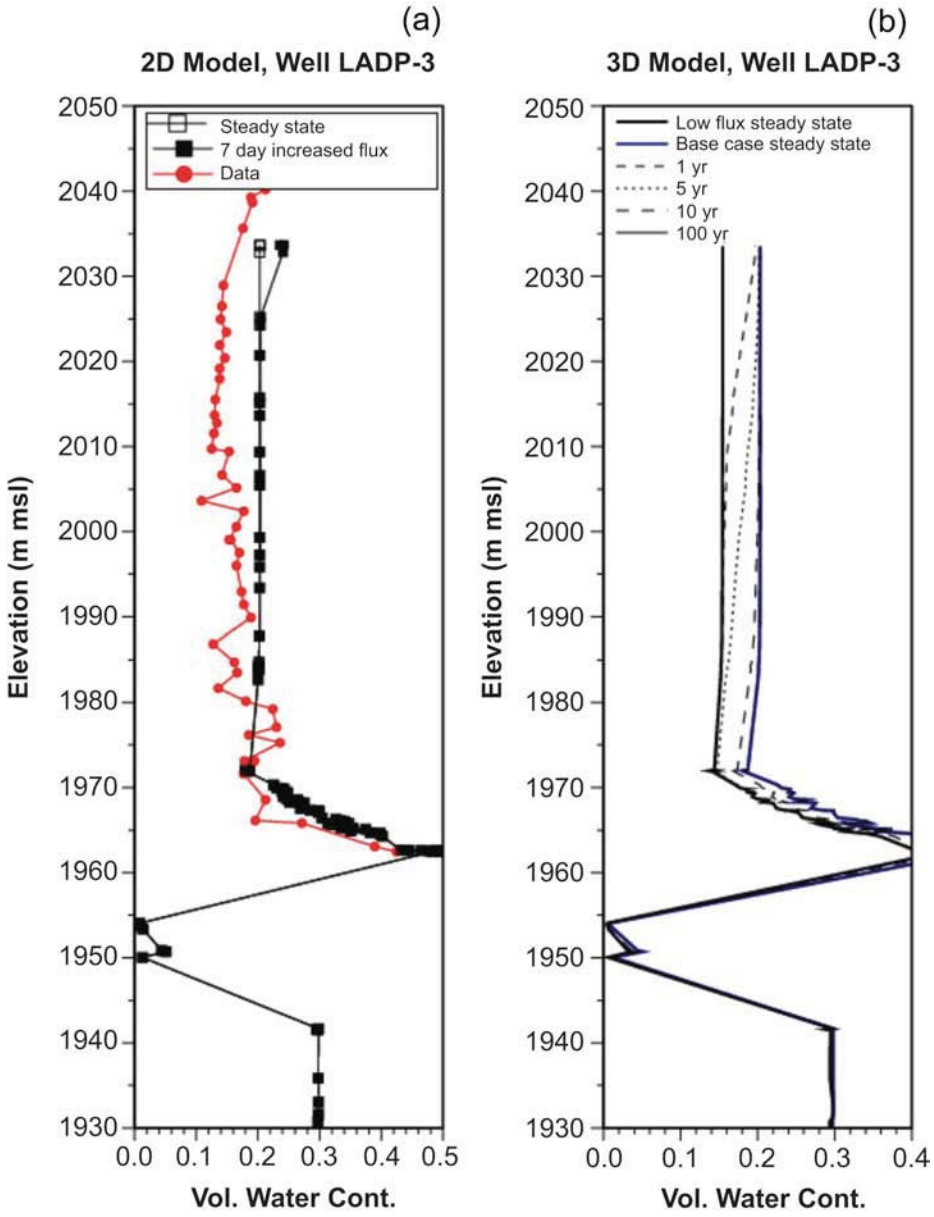

Figure 4-C-9. Two-dimensional model predictions for the water content in response to transient episodes of enhanced infiltration. (a) Well LADP-3, single one-week episode of enhanced infiltration. (b) Well LADP-3, prolonged period of enhanced infiltration (infiltration is increased by a factor of five starting at time 0).

Longer-term variability in the infiltration rate over years or decades could also complicate the interpretation of water content measurements, and thus need to be examined. Figure 4-C-9b shows the results of a simulation in which the infiltration steady state is used as an initial condition, and the rate is increased to the base-case infiltration map at time zero. The plot shows that over a time period of a few years, the water contents increase to significant depths. Within about a decade, the profile throughout the entire section of the Otowi Member reflects the new,

higher infiltration rate. At times of one or a few years, the transient water content profile shows curvature similar to that seen in several of the observation wells, including LADP-3. This does not necessarily mean that the curvature is caused by such a transient, but simply that reasonable variability in infiltration rates over years to decades complicates the interpretation of the water content profiles. This simulation is meant to provide a caution against over-interpretation of the details of the water content profiles. Furthermore, it is recognized from this analysis that the match of a steady-state model to the data in Los Alamos Canyon represents the fluid flow characteristics of the system within the previous ten to 100 years leading up to the collection of the water content data. In general, this result is dependent on the hydrologic conditions of the particular model area. Wet canyon systems with high infiltration rates have transient time periods of this order of magnitude, while dry mesas may take upward of thousands of years to attain a new steady-state water content profile when the infiltration rate changes.

4-C-8. Tritium Modeling Results

Tritium transport model results are presented to further demonstrate the validity of the model and to explore important processes occurring in the vadose zone. Figure 4-C-10 shows the three-dimensional model predictions of the tritium concentration of fluid reaching the water table in the year 1999. Significant, above-background concentrations are predicted along the canyon at locations downstream of where the Bandelier Tuff is not present in the canyon bottom. An important characteristic of the model is the preferential transport to the water table at locations downstream of the confluence of Los Alamos and DP canyons. The main reason for this result is that the thickness of Bandelier Tuff is much greater at upstream locations in the canyon, whereas in the vicinity of R-9, no Bandelier Tuff is present. Recall that the conceptual model for vadose zone flow consists of matrix flow and transport in the Bandelier Tuff, and preferential fracture flow and transport in the basalt units. Rapid transport to the water table at the downstream locations is due to fracture flow in the basalts and fairly rapid transport through the Puye Formation. Therefore, concentration levels in these locations in the canyon are predicted to be significantly greater than zero (in the thousands of pCi/l) in this portion of model domain.

The wells at which tritium concentrations in the regional aquifer can be compared are the water supply well O-4 and test well-3, both located near the confluence of Los Alamos and DP canyons, and characterization wells R-7 and R-9. Well O-4 results indicate that tritium is predicted to be mostly present in the vadose zone; however, a small but non-zero concentration is predicted to have reached the regional aquifer. Well R-7, located downstream of tritium contaminants but upstream of the Los Alamos-DP Canyon confluence, shows the slowest migration rate of tritium. By contrast, the most rapid transport to the water table is observed at R-9, where the peak concentrations of tritium are predicted to already have reached the water table. These model results are consistent with the available field data. Regional aquifer fluid collected in well R-7 has indetectable levels of tritium, whereas TW-3 and R-9 show that tritium has reached the regional aquifer. Determining more quantitatively the ability of the model to reproduce the field data is difficult because of mixing of the tritium percolating from the vadose zone with regional aquifer fluid and the subsequent mixing of contaminated and clean fluid in the wellbore itself. The latter difficulty is especially acute for the water supply wells, which may draw water from hundreds of feet of screened length.

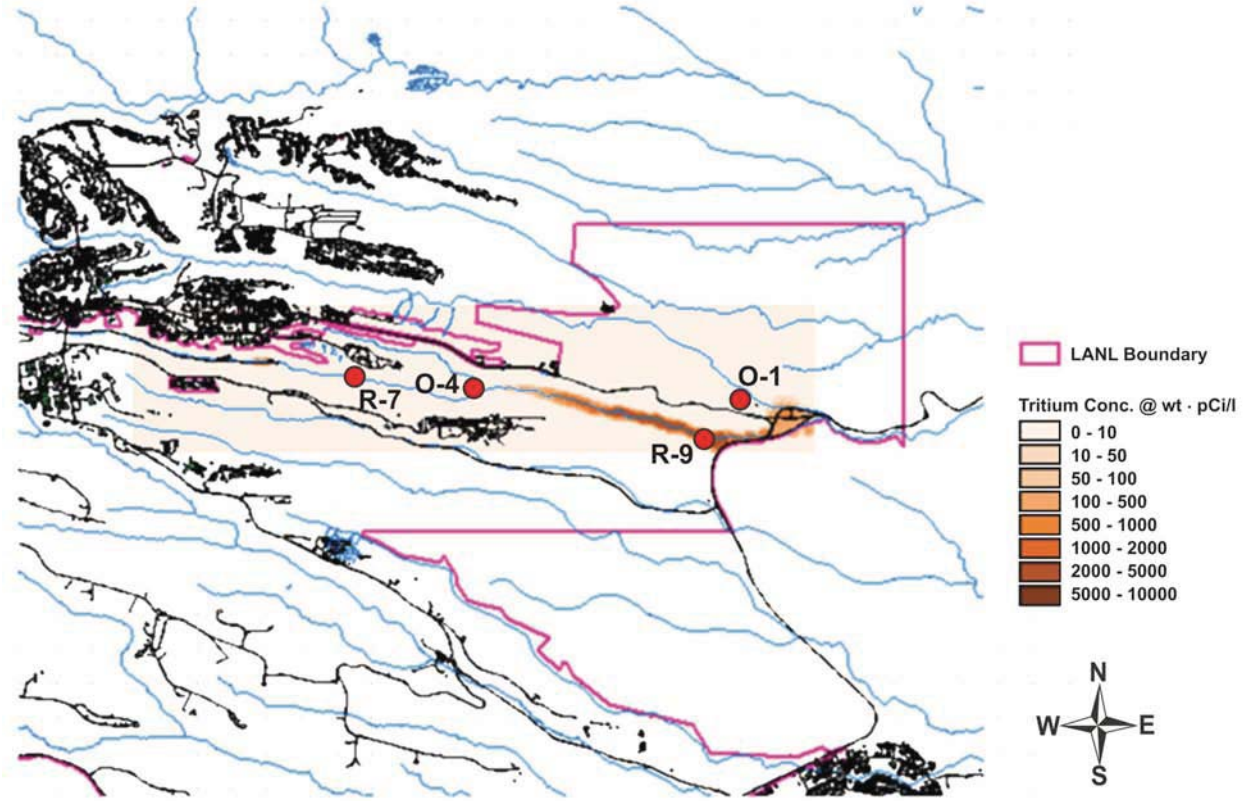

Figure 4-C-10. Three-dimensional model predictions of the tritium concentration of fluid reaching the water table in the year 1999. Significant, above background concentrations are predicted along the canyon at locations downstream of where the Bandelier Tuff is not present in the canyon bottom.

As a final comparison to the available data, we contrast the model results with regional aquifer water supply well O-1. However, because contaminant transport sources from Pueblo Canyon (north of Los Alamos Canyon) were not included in this model, the conclusions related to O-1 are more qualitative. For this comparison, monitoring information (LANL 2001) is used. Contaminants tritium, perchlorate, and nitrate are all thought to be nonsorbing in this system, and thus the combined results of all three contaminants are used in this interpretation. Well O-1 has been found to contain measurable levels of perchlorate at about a 5 ppb level, nitrate levels higher than at other regional aquifer wells in the area, and consistent, above-background levels of tritium in the 30-40 pCi/L range. All observations point to both Laboratory-derived contaminants and effluent discharges from Los Alamos County from past releases in Los Alamos and Pueblo Canyons having traversed the entire vadose zone. The present model explains these observations as a consequence of the hydrostratigraphy along the canyon, with rapid travel times at locations where the Bandelier Tuff is thin or non-existent.

Contrast these results with the transport model for MDA G presented in Appendix 4-B. Most important, travel times through the vadose zone are predicted to be orders of magnitude longer for this mesa site than for transport from the bottom of a wet canyon. The reason for this is straightforward. Infiltration rates, which directly impact transport velocities, are much larger in a canyon setting, in which all water in a catchment is channeled to the canyon bottom. A

significant percentage of that water will escape evapotranspiration and percolate into the deep subsurface along the canyon. In contrast, a mesa top typically provides opportunity for water to drain as surface water, evaporate, or transpire. Therefore, percolation rates are much lower,

APPENDIX 4-D. REGIONAL AQUIFER MODEL DEVELOPMENT

4-D-1. Grid Information

Three-dimensional groundwater models have been developed using FEHM (Zyvoloski et al. 1997); computational grids were generated using LaGriT (Trease et al. 1996). The computational grids for both the basin- and site-scale models are shown in Figures 4-D-1 to 4-D-4; grid characteristics are summarized in Table 4-D-1. The structure of the two models are identical, except for the increased vertical resolution of the site-scale model and the smaller lateral extent.

A view of the upper surface of the basin model grid is shown in Figure 4-D-1. Constant head nodes are indicated by circles. Boundary conditions for the basin-scale model are shown in Figure 4-D-2. A view of the upper surface of the site-scale model is shown in Figure 4-D-3. Boundary conditions for the site-scale model are shown in Figure 4-D-4. Horizontal grid resolution varies from 250 m near the margins to 125 m beneath LANL. Vertical resolution varies from 12.5 m in the upper portion of the aquifer to 500 m at depth.

Each node in the computational mesh is assigned to a unit according to its location relative to the 3-D hydrostratigraphic structure defined by the geologic model. Interpolation from the hydrostratigraphic model to the grid nodes is done by defining closed volumes for each hydrostratigraphic unit. Each node of the mesh can be in one and only one of these volumes. The node properties are assigned based on which volume a node resides in. In this relatively simple approach, the location of contacts between hydrostratigraphic units can only be resolved to the degree of discretization in the finite element mesh. The resulting zonation for the basin and site-scale models are shown in Figures 4-D-5 and 4-D-6.

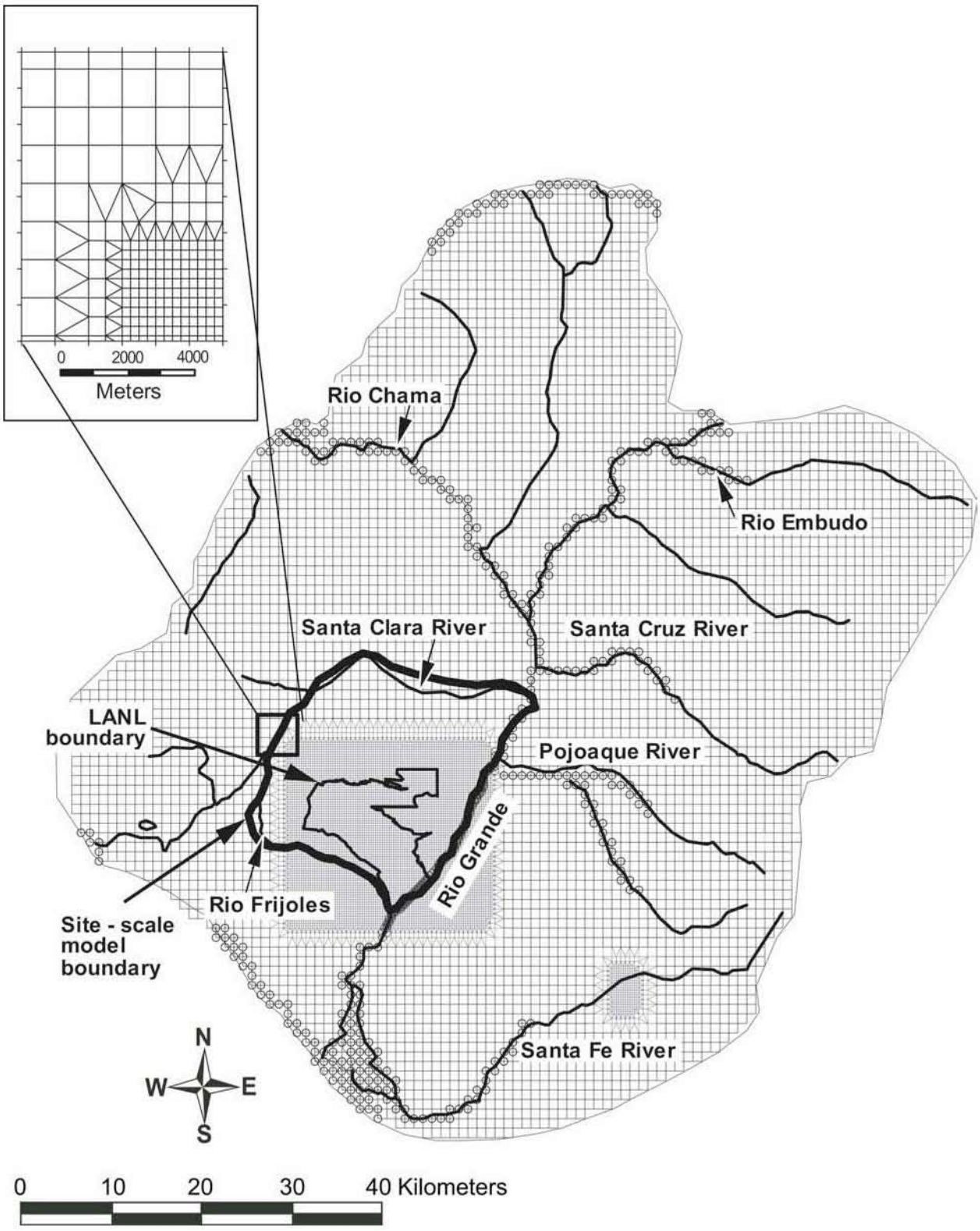

Figure 4-D-1. Top view of basin-scale model grid with side view (inset).

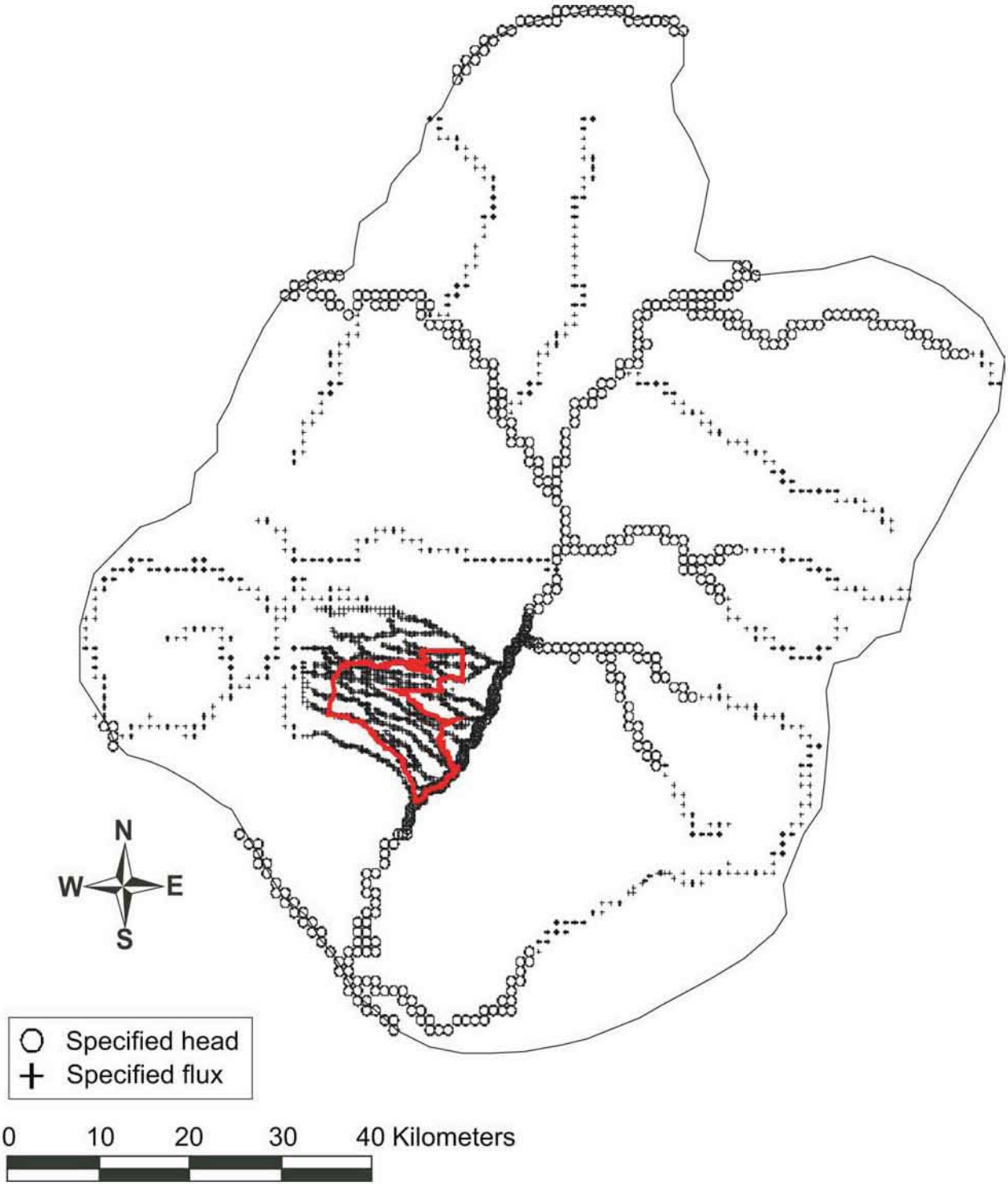

Figure 4-D-2. Boundary conditions along top surface of basin-scale model.

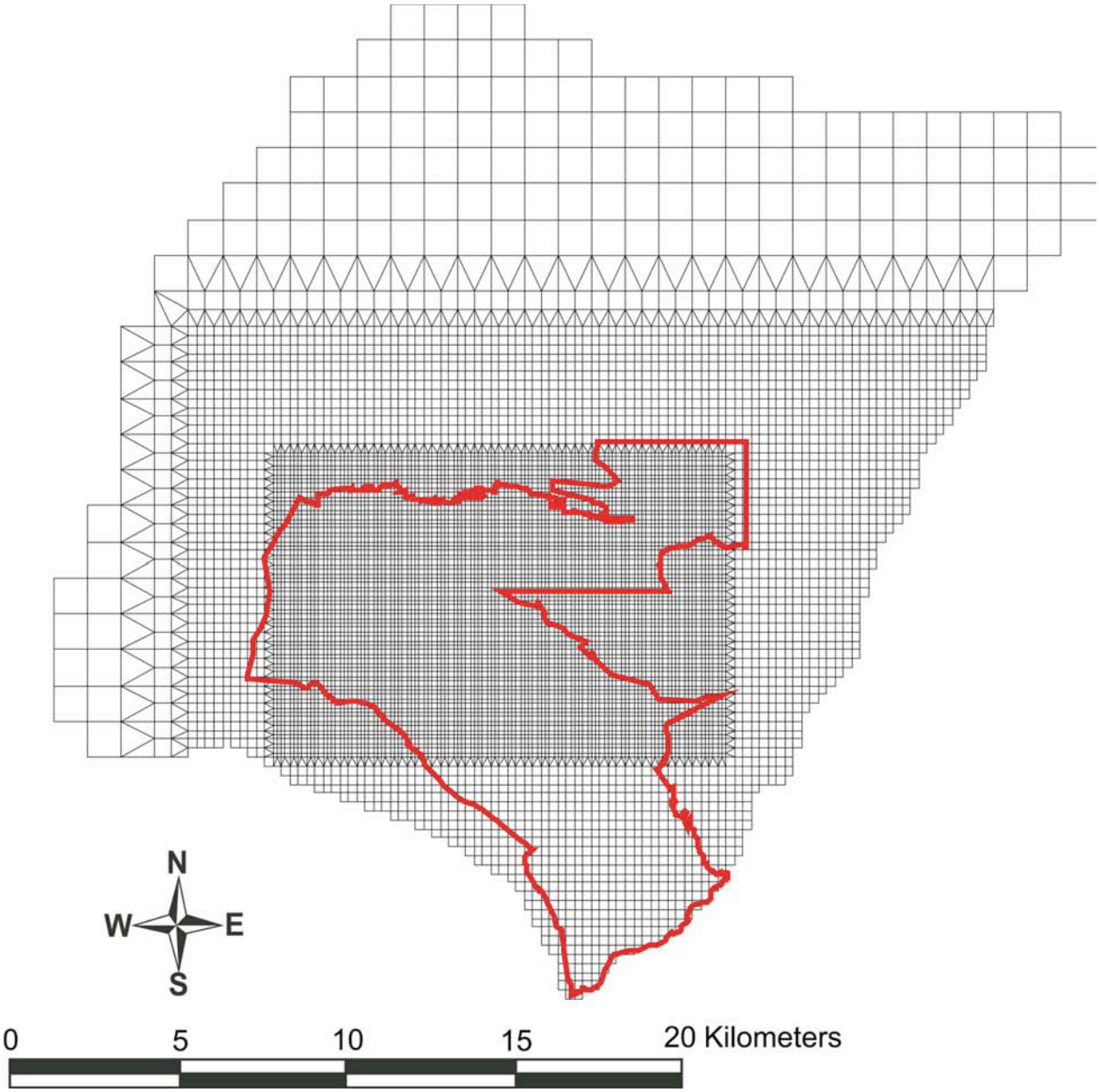

Figure 4-D-3. Plan view of the site-scale grid. LANL boundary shown for reference.

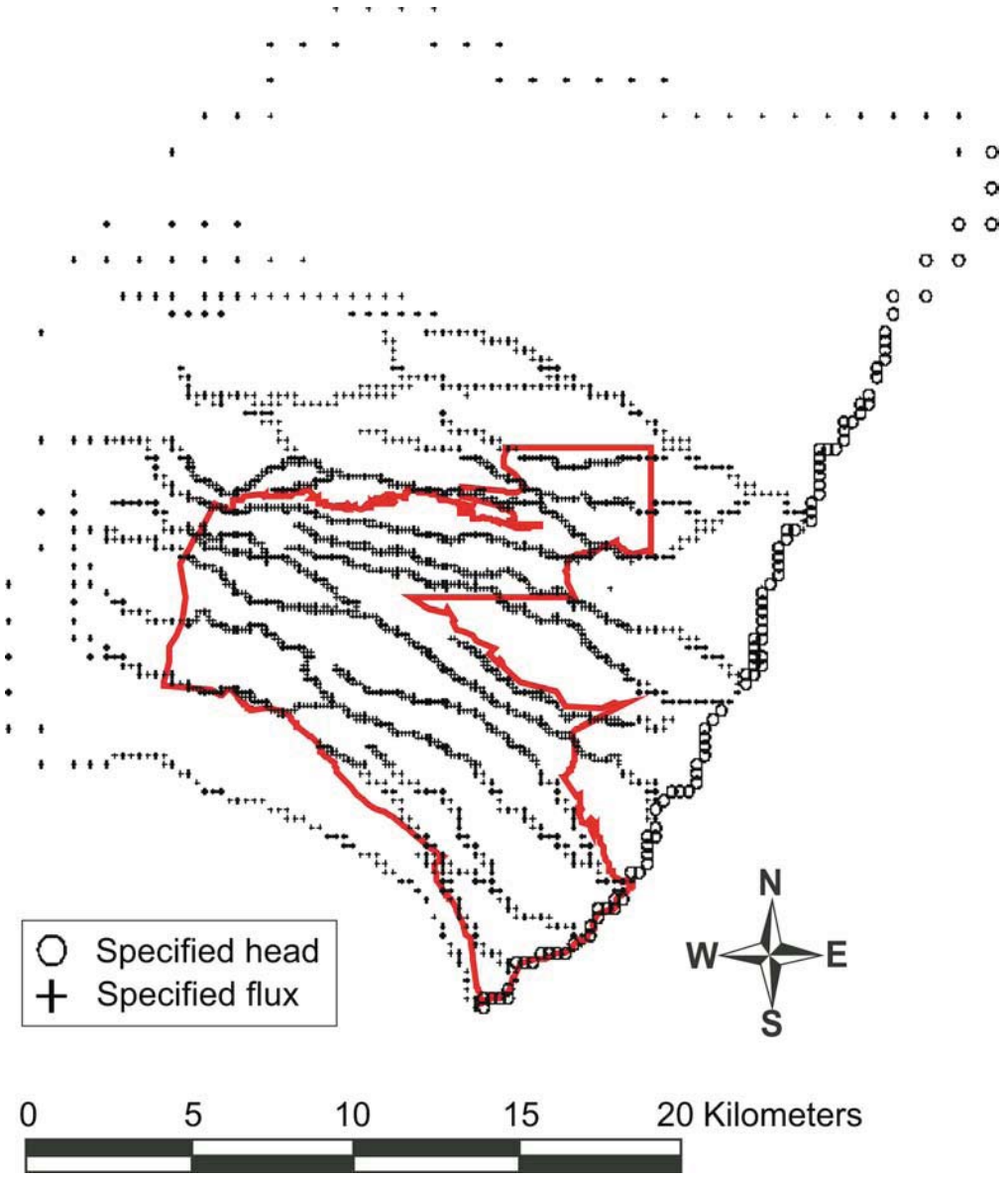

Figure 4-D-4. Boundary conditions along top surface of site-scale model.

Table 4-D-1.
Hydrostratigraphic Units in Site-Scale Model

Unit	Sub-unit	Abbreviation	Volume (km³)	Fraction of Total
PreCambrian		p€	4.50	0.005
Paleozoic/Mesozoic		PM	273.53	0.292
Santa Fe Group	Deep	Tsf-deep	36.47	0.039
	fanglomerate	Tsf-fang	23.62	0.025
	sandy	Tsf-sandy	457.58	0.489
Keres Group	deep	Tk (deep)	12.59	0.013
	shallow	Tk (shallow)	1.15	0.001
Basalts		Tb1	6.19	0.007
		Tb2	5.61	0.006
		Tb4	2.20	0.002
Tschicoma		Tt	7.09	0.008
Puye Formation	Totavi Lentil	Tpt	2.02	0.002
	Pumiceous	Tpp	1.96	0.002
	fanglomerate	Tpf	5.45	0.006
Uncertain (1)		Tb2s	14.02	0.015
Uncertain (2)		Tb4f	0.45	0.000
Pajarito Fault zone			82.04	0.088
Total volume			936.51	1.000

4-D-2. Recharge Model

We define groundwater recharge R over the model domain as follows:

$$R(x,y) = \alpha\, \xi(x,y) \cdot P[Z(x,y)], \tag{1}$$

$$\xi(x,y) = \begin{cases} 1 & Z(x,y) > Z_{\max} \\ \frac{Z_{\max} - Z(x,y)}{Z_{\max} - Z_{\min}} & Z_{\min} < Z(x,y) < Z_{\max} \\ 0 & Z(x,y) < Z_{\min} \end{cases}, \tag{2}$$

where P is precipitation, Z is ground-surface elevation defined from the digital elevation model of the region, ξ is a dimensionless weight function which is characterized by parameters $Z_{\min}$ and $Z_{\max}$, α is the fraction of precipitation that becomes recharge above $Z_{\max}$. Note that $Z_{\min}$ defines the elevation below which no recharge occurs, and above elevation $Z_{\max}$ the recharge is equal to $\alpha\, P$. The total recharge flux Q over the model domain Ω is defined as

$$Q = \iint_{\Omega} R\,dx\,dy = \alpha \iint_{\Omega} \xi P\,dx\,dy = \alpha P'(Z_{\min}, Z_{\max}), \tag{3}$$

where P' is a function of $Z_{\min}$ and $Z_{\max}$ only. We assume $P(Z)$ is a simple linear model with fixed regression parameters, which we derive using annual precipitation data for the region (Bowen, 1992; Spiegel and Baldwin 1963). Thus, there are four unknowns to be estimated (Q, α, $Z_{\min}$ and $Z_{\max}$) coupled through Equation 3. For example, to calculate Q we need to

estimate α, Z_{min} and Z_{max}. For our inverse models, we found it to be more computationally efficient to include Q, Z_{min} and Z_{max} in the estimation process, and compute α as

$$\alpha = \frac{Q}{P'(Z_{min}, Z_{max})}. \quad (4)$$

Precipitation (P) is defined as a function of elevation (Z), according to a regression equation derived from regional data (Spiegel and Baldwin 1963) and Pajarito Plateau data (Rogers 1994). Figure 4-D-7 shows these data; the derived regression relationship is

$$P \text{ (in/yr)} = -16.4 + (.004542) * Z \text{ (feet)}, \; r^2 = 0.9$$

Using a USGS DEM model for the basin, we derive a map of annual precipitation from which the recharge fluxes are derived. We apply focused recharge along the upper reaches of perennial streams in the basin; the ratio of R_f (focused recharge along perennial streams) to Q is an unknown parameter that can be estimated in the inverse analysis. Finally, recharge along ephemeral streams on the Pajarito Plateau is applied in linear proportion to the indices developed by Birdsell (see Nylander 2002). The ratio of this type of recharge to Q is defined as κ.

Figure 4-D-8 shows an example of a recharge model derived using equations 1-4. Note that this particular example applies the highest rates of recharge in the basin to the streams flowing through LANL (>>35 mm/yr). This approach assures that the maximum possible fluxes of contaminants into the regional aquifer are captured in the models. The model parameters employed to generate this particular recharge map are

$$Q = 6400 \text{ kg/s}; \; Z_{min} = 2300 \text{ m}; \; \alpha = 12.5\%; \; \kappa = 0.03, \text{ and } R_f = 0.2.$$

In summary, the full set of recharge model parameters are Q, Z_{min}, Z_{max}, R_f/Q, and κ. These five parameters can be varied to provide a wide range of recharge conditions, all within the calibration constraints of head and baseflow discharge.

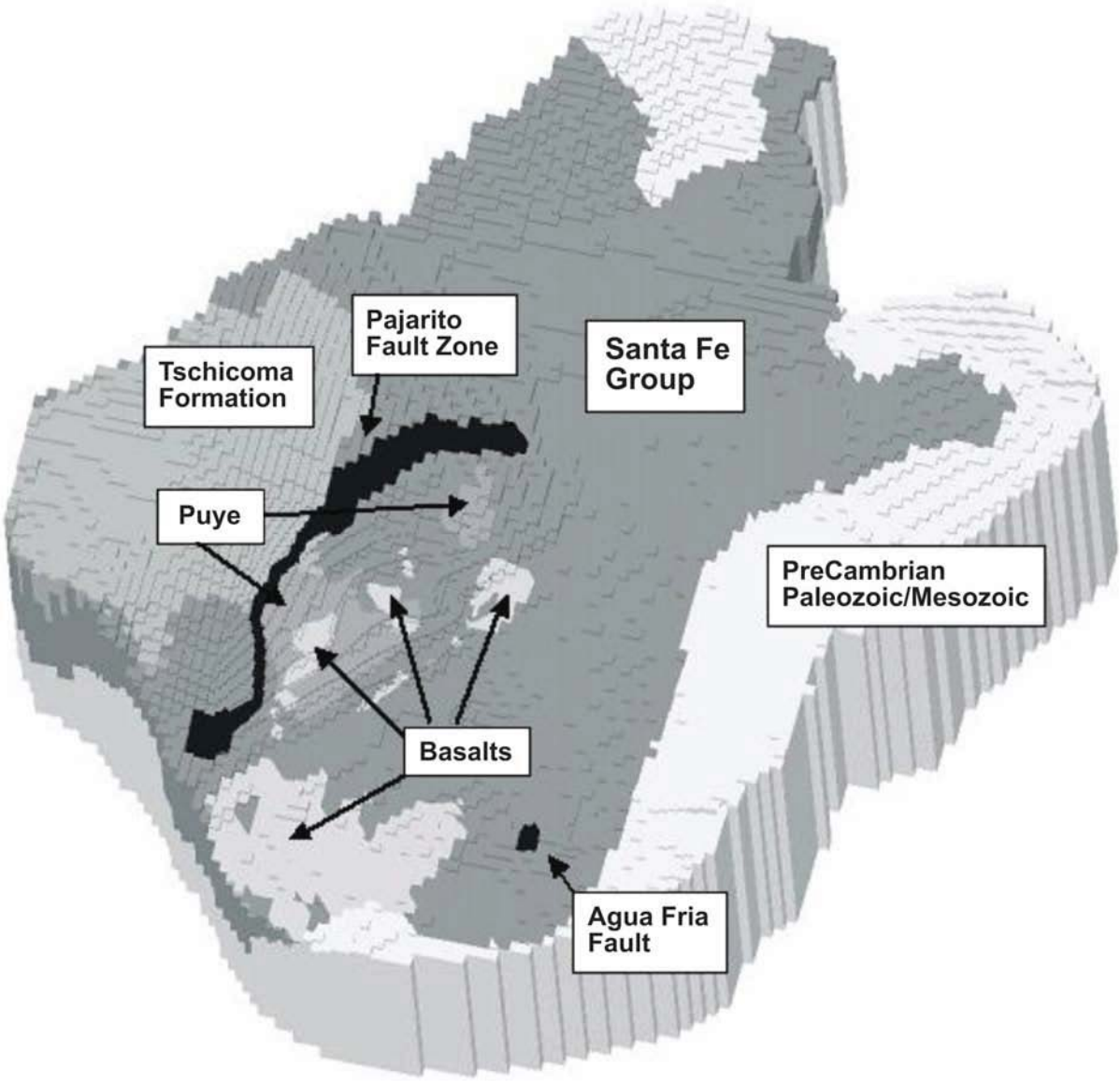

Figure 4-D-5. Three-dimensional representation of the major hydrostratigraphic units in the basin-scale model.

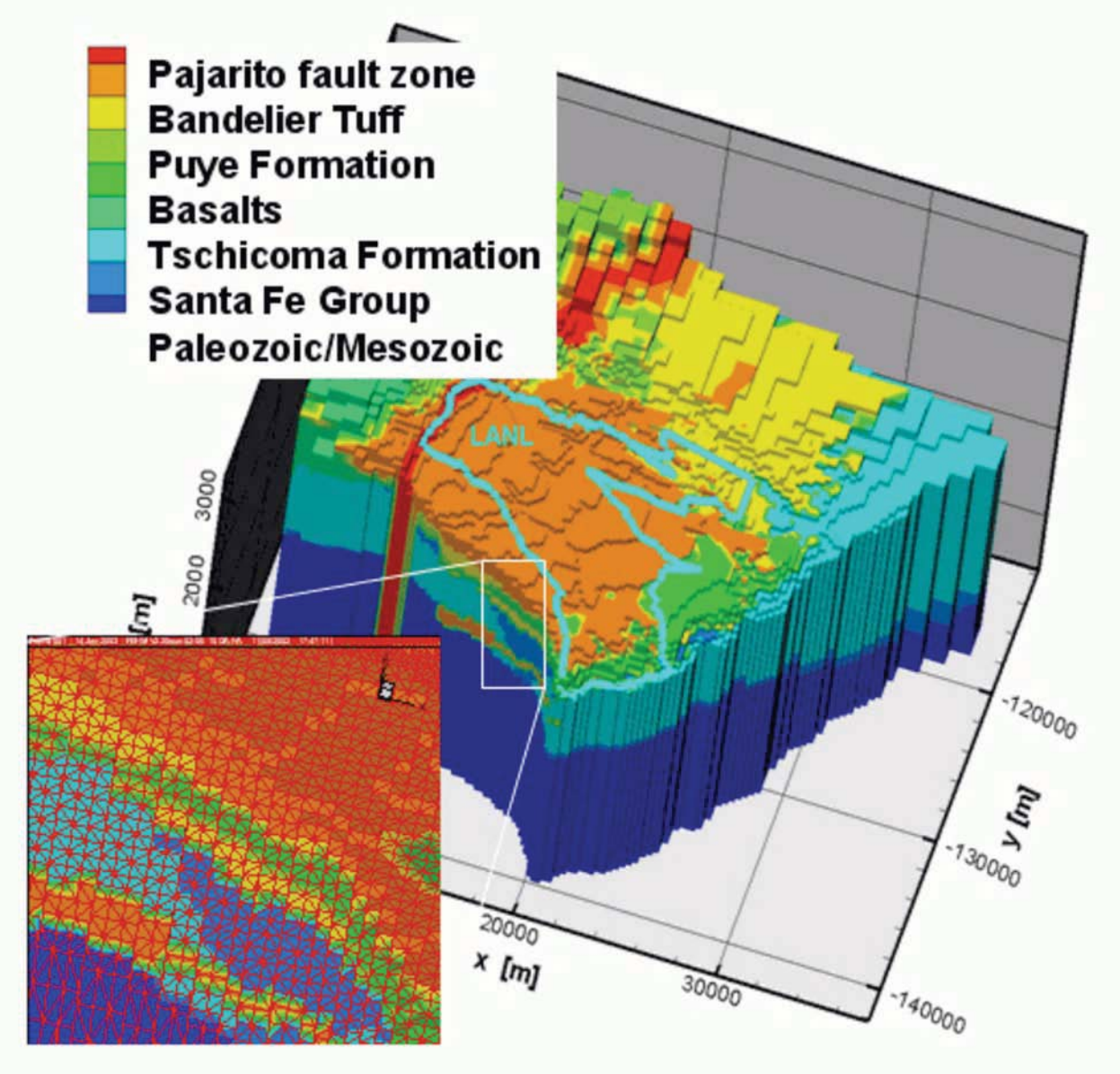

Figure 4-D-6. Site-scale model grid, colored according to major hydrostratigraphic units.

4-D-3. Flux Estimates.

Table 4-D-2 compares flux estimates from previous models developed for the Española Basin.

Table 4-D-2.
Flux Estimates Derived from Previous Models, in AFY

		cfs/.0014	0.0014	
INFLOW		McAda	Frenzel	Hearne
	Total Area (km^2)			
	Areal Recharge (cfs)	7571	3429	0
Lateral Boundaries				
Inflow (cfs) rom:	east	21571	14929	2693
	west	7429	7214	8100
	north	1429	1357	971
	south	1571	500	
Rivers				
Inflow (cfs) rom:	SF River	5357	5357	5150
	Poj. River	0	929	1261
	RG	1357	0	0
	Cochiti	0	0	0
	Tesuque	3071	2714	1772
	Rio En Medio/Nambe	2857	3000	1714
	Arroyo Hondo	500	500	0
	Santa Cruz	0	0	2936
	Head dependent rivers	0	929	0
TOTAL INFLOW		52714	40857	24597
OUTFLOW				
Lateral Boundaries				
Outflow[1] (cfs) to:	east	0	0	0
	west	12429	8643	0
	north	2143	2714	243
	south	214	1643	0
Rivers		0	0	0
Outflow (cfs) to:	Santa Fe River	4643	0	3107
	Pojoaque River	5214		2766
	Rio Grande	28071	0	11293
	Cochiti	0	0	4464
	La Cienega	0	4643	0
	Tesuque	0	0	243
	Rio En Medio/Nambe	0	0	0
	Arroyo Hondo	0	0	0
	Santa Cruz	0	0	1071
	Head dependent rivers	0	23357	0
TOTAL OUTFLOW		52714	41000	23187

[1] Outflow to "west" is outflow to the Albuquerque Basin. For comparison, subsurface inflow to the Albuquerque Basin from the north (including the Española Basin and Jemez Mountains) was estimated to be 19,400 afy (Kernodle et al. 1995), 28,500 afy (McAda and Barroll, 2002), and 2772 afy (Sanford et al. 2004).

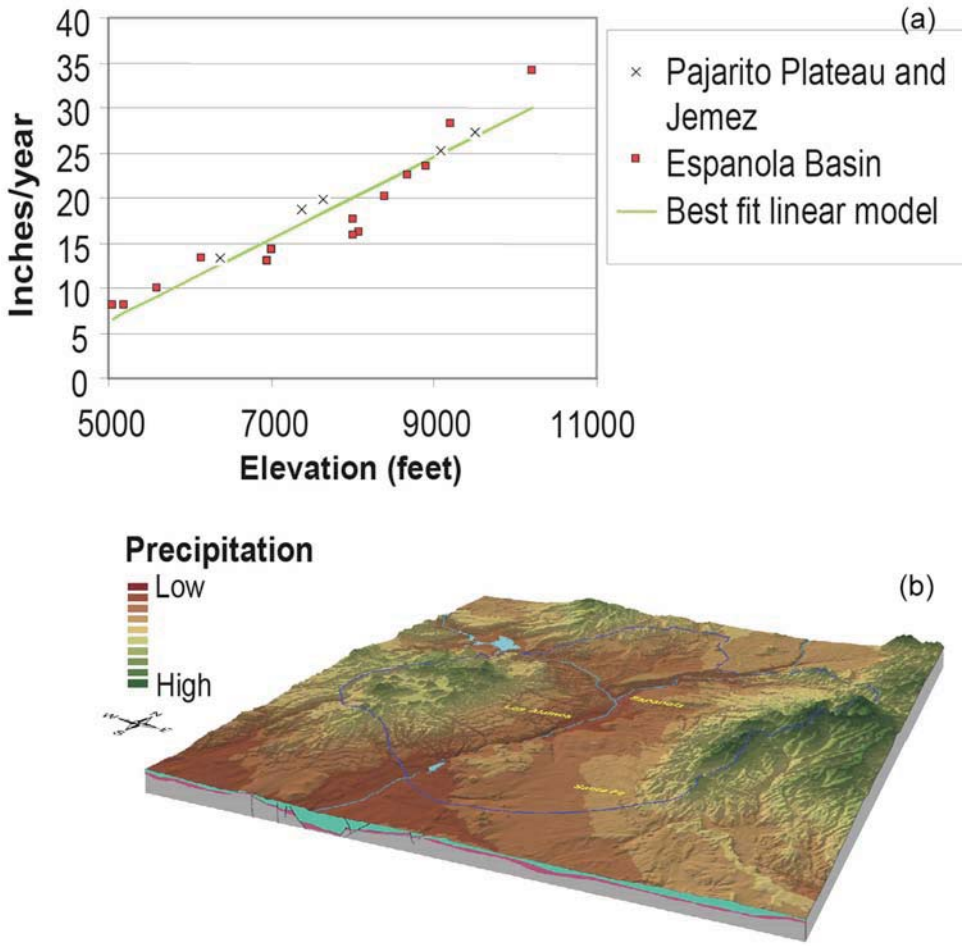

Figure 4-D-7. (a) Average annual precipitation in the vicinity of the Española Basin. (b) Regression equation for precipitation applied using USGS DEM.

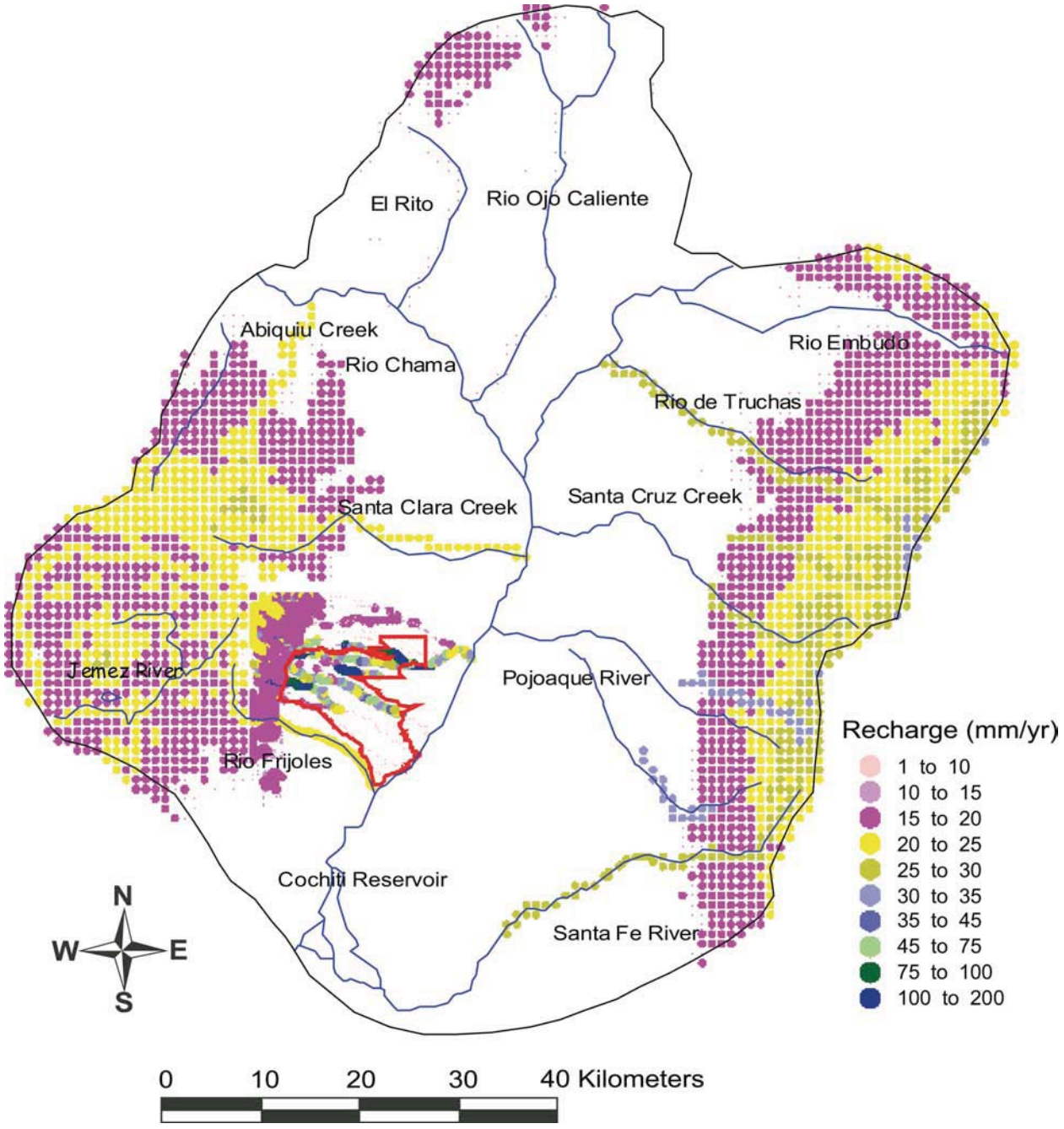

Figure 4-D-8. Average annual precipitation verses elevation derived from data of Spiegel and Baldwin (1963) and Rogers (1994).

APPENDIX 4-E. ESTIMATING AQUIFER DISCHARGE USING STREAMFLOW DATA

The method we use for estimating base flow gain along the Rio Grande is a very simple one, also used by Spiegel and Baldwin (1963), the U.S. Department of Justice (1996), and others. The strategy is to difference measured surface water flow at two gages during January, when other causes of streamflow loss/gain such as evapotranspiration and irrigation withdrawals are likely to be minimal. Because the calculated baseflow gain is generally small compared to total flow in the Rio Grande, small measurement errors in flow at the gages could have large influence on these calculations. The approach applied here assumes that measurement errors are random; therefore, their impact can be minimized by repeating the calculations over a number of years and deriving a long-term mean. Uncertainty in the mean estimate will be an indication of measurement error. Unless the record is much longer than significant temporal trends, temporal trends cannot be ascertained with this method.

We apply this approach to two reaches of the Rio Grande: (1) San Juan Pueblo (828110) to Otowi (8313000) and (2) Otowi (8313000) to Cochiti (8314500). Collectively, these two reaches span the entire length of the Rio Grande that comprises the eastern extent of the Pajarito Plateau, from Santa Clara Creek to Rio Frijoles.

(1) San Juan Pueblo (828110) to Otowi (8313000). A major tributary to the Rio Grande, the Rio Chama, enters this reach just downstream from the gage 8290000 (Rio Chama at Chamita). There was a 23-year period during which all three of these gages were operational (1963 to 1985). By comparing this period of record to a much longer period of record at the Otowi gage (1890–2004), it can be seen that flows were normal during the 1963–1985 period, except two unusually high flow years (1973 and 1975). The January flow at Otowi was highly correlated to, and slightly more than, the sum of flows at San Juan Pueblo and Rio Chama at Chamita, suggesting a consistent base flow gain component along this reach. Three minor tributaries, the Santa Cruz River, the Pojoaque River, and the Santa Clara River, contribute to gain along this reach. Insufficient data during the 1963 to 1985 prevents using measured flows for these years; instead, we use a long-term average from other years, shown in Table 4-E-1.

For each of the 23 year period from 1963 to 1985, we calculated base flow gain during January by the following relationship:

Base flow gain = measured flow (RG Otowi – RG San Juan – Rio Chama, Chamita) – long-term average measured flow (Pojoaque + Santa Clara + Santa Cruz).

The 23-average base flow gain calculated using this approach is 41.2 cfs.(+/- 12.8 at the 95% confidence interval). There is a strong trend evident for gain to be higher in years of higher flow; it is unclear whether this trend is real or is related to sources of error such as small ungaged tributaries which may only be significant at high flow. The adequacy of the derived long-term estimate is shown in Figure 4-E-1a.

(2) Otowi (8313000) to Cochiti (8314500). These two gages have both been operational since 1926, well before pumping began at the Buckman wellfield below Otowi. January flow at the

two stations is highly correlated (r^2=0.96). For most years the data suggest that the reach is gaining; for some years the data suggest a losing reach. One tributary enters the Rio along this reach, Rio Frijoles, which was gaged from 1983 to 1996. We estimate the average January flow at the Rio Frijoles to be 1.2 cfs. Accounting for the inflow from the Rio Frijoles, the gain between these reaches is 13.0 cfs +/- 8.8. The sum of the flow at Otowi and Rio Frijoles and this base flow estimate, compared to the flow at Cochiti, is shown as a yellow line in Figure 4-E-1b.

Table 4-E-1.
Comparison of Gain/Loss Calculations to Other Studies

Reach	Source	Method	Reach Length (km)	Total Gain (m^3/s)	Gain/mi ($m^3/s/km$)
Rio Grande (Otowi to Cochiti)	This report (Table 2-3)	Streamflow analysis	41.8	0.39	0.009
	U.S. Department of Justice (1996)	Streamflow analysis	41.8	0.40	0.009
	Hearne (1985)	Numerical model	38.6	0.46	0.012
	McAda (1988)	Numerical model	27.4	0.63	0.023
	Purtymun (1966)	Seepage runs	18.5	0.43	0.023
	Griggs (1964)	Seepage runs	18.5	0.37	0.020
	Spiegel & Baldwin (1963)[1]	Streamflow analysis	32.2	0.71	0.022
Rio Grande (Embudo to Otowi)	This report (Table 2-3)	Streamflow analysis	51.0	0.67	0.013
	U.S. Department of Justice (1996)	Streamflow analysis	51.0	1.50	0.029
Rio Grande (Española to Otowi)	Hearne (1985)	Numerical model	33.8	0.20	0.006
	McAda (1988)	Numerical model	17.7	0.43	0.024
	USGS seepage runs	Seepage runs	27.4	0.15	0.005
Rio Chama (Abiquiu to Chamita)	This report (Table 2-3)	Streamflow analysis	39.9	1.00	0.025
	This report (Table 2-2)	Area relation	39.9	1.19	0.030
	Hearne (1985)(lower reach only)	Numerical model		0.06	
Santa Cruz River	Hearne (1985)	Numerical model		0.04	
	This report (Table 2-2)	Area relation		0.33	
	This report (Table 2-3)	Streamflow analysis		0.14	
Pojoaque River	Reiland & Koopman (1975)	Streamflow analysis		0.40	
	McAda (1988)	Numerical model		0.21	
	This report (Table 2-2)	Area relation		0.27	
	Hearne (1985)	Numerical model		0.09	
Santa Clara River	This report (Table 2-3)	Streamflow analysis		0.09	
	This report (Table 2-2)	Area relation		0.05	
Santa Fe River	This report (Table 2-3)	Streamflow analysis		0.23	
	McAda (1988)	Numerical model		0.18	
	this report (Table 2-2)	Area relation		0.32	
	Hearne (1985)	Numerical model		0.12	
Rio Embudo	This report (Table 2-3)	Streamflow analysis		0.58	
	This report (Table 2-2)	Area relation		0.30	

[1] Their approach includes only those years when the reach was deemed "gaining." ("Losing" years were assumed to be caused by erroneous data and were deleted from the analysis.)

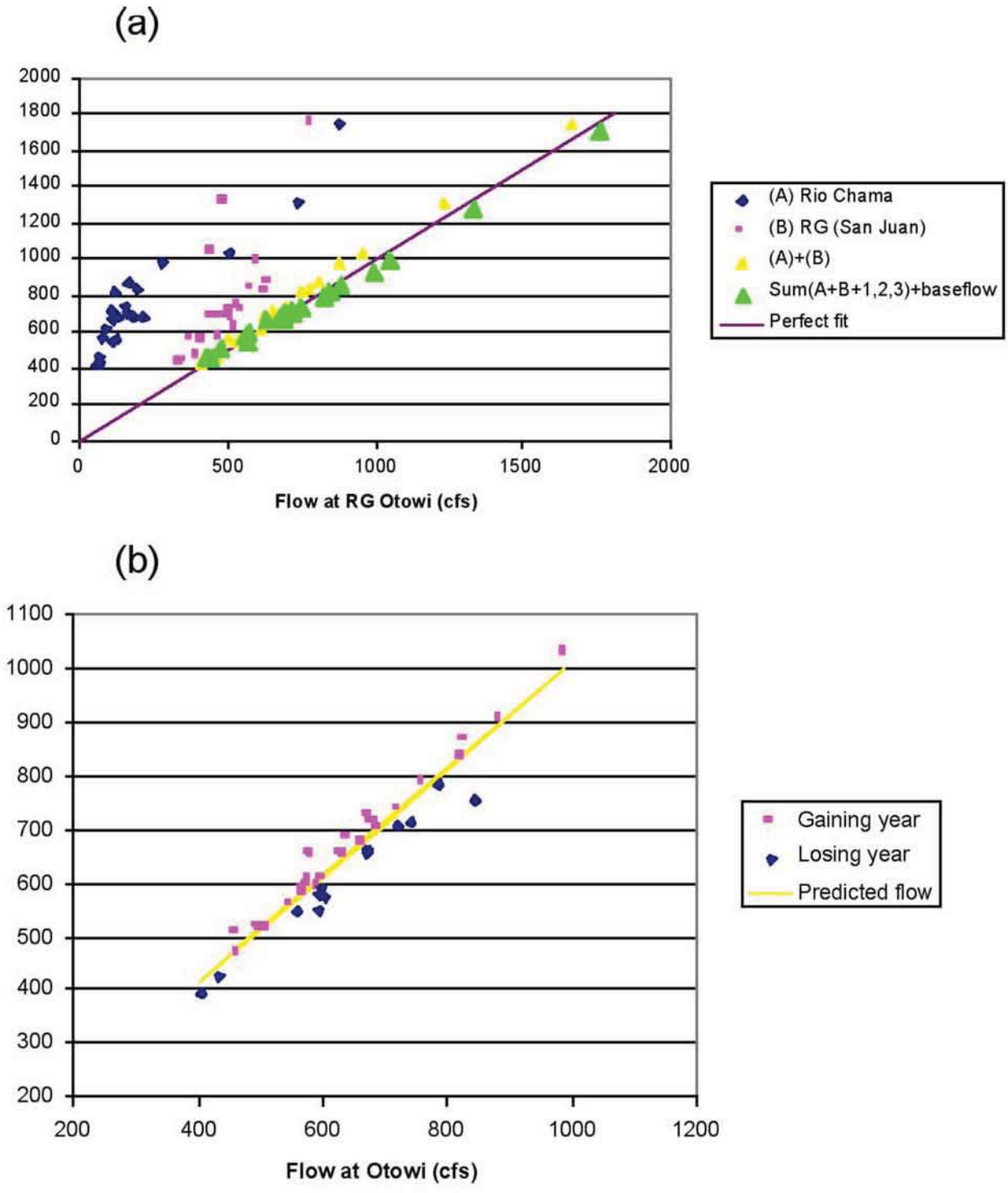

Figure 4-E-1. Measured January flow at the Otowi gage, compared to (a) contributing flow at Rio Chama, Rio Grande at San Juan, minor tributaries, and estimated base flow, and (b) measured January flow at the Cochiti gage.

To extrapolate these estimates to a slightly different reach of the Rio Grande, from Santa Clara Creek to Rio Frijoles, we calculate the ratios of stream lengths within each of the estimated reaches above. Santa Clara to the Otowi Bridge gage is approximately 6/10 the distance of RG San Juan to Otowi Bridge; we estimate 24.7 +/- 7.7 cfs gain along this reach. Otowi to Rio Frijoles is approximately $^1/_2$ the distance of Otowi to the Cochiti gage; for this reach we estimate 6.5 cfs +/- 4.4. In total, our baseflow estimate for the Santa Clara to Rio Frijoles reach of the Rio Grande is 31.2 cfs +/- 12.1 or 884 kg/s +/- 343.

Errors. Sources of errors in the method include systematic errors in streamflow measurements which do not affect all of the streamflow gages used in the differencing equations and which are persistent for the entire period of overlapping record, systematic departures of tributary flows (Pojoaque + Santa Clara + Santa Cruz) from the long-term averages shown in Table 4-E-2 and and unmeasured surface water inflows/outflows. Water budget components are estimated for watersheds in the Española Basin and are shown in Table 4-E-3.

Table 4-E-2.
Estimates of Long-Term Average Flow at Small Tributaries

Gage			Data Source	# of Years of Record	Period	Mean January Flow (cfs)
1	Pojoaque River, at mouth	Site 6	Reiland and Koopman (1975)	38	1935–1972	4.9
2	Santa Clara Creek	8292000	USGS	17	1936–1994	3.3
3	Santa Cruz River	8291500	USGS	10	1941–1950	5.9
4	Rio Frijoles	8313350	USGS	14	1983–1996	1.2

Table 4-E-3.
Water Budget Components Estimated for Watersheds within the Española Basin, Expressed as Fraction of Total Precipitation

	Watershed Area (square miles)	Area-Weighted Average Elevation[a] (feet)	Precipitation[b] (acre-ft/yr)	ET[c]	Runoff	Recharge	Sublimation	Recharge	Source
				Fraction of total precipitation				Inches/yr	
Santa Fe River	28.7	8989	36706	0.69	0.19	0.11	0.01	2.71	Wasiolek (1995)
Santa Fe River	26.95	8989	30060	0.71 0.73[d]	0.19	0.10 0.08[d]	---	2.02 1.61[d]	Anderholm (1994, Table 7)
Little Tesuque Creek	7.7	8786	9370	0.72	0.09	0.19	0.00	4.41	Wasiolek (1995)
Little Tesuque Creek	7.34	8786	8,573	0.88	0.05	0.07	---	1.61	Anderholm (1994, Table 7)
Rio Nambe	34.2	9325	48826	0.62	0.19	0.11	0.08	3.03	Wasiolek (1995)
Tesuque Creek	11.2	9197	15288	0.65	0.20	0.10	0.05	2.45	Wasiolek (1995)
Tesuque Creek	11.84	9197	13120	0.75	0.18	0.07	---	1.50	Anderholm (1994, Table 7)
Combined Little Tesuque and Tesuque Creeks	19.18	9030	21693	0.89 0.93[d]	0.04	0.07 0.03[d]	---	1.54 0.67[d]	Anderhom (1994, Table 7)
Rio en Medio	8.7	9242	11973	0.64	0.15	0.14	0.07	3.73	Wasiolek (1995)
Arroyo Hondo	8.38	?	8560	0.84	0.06	0.10	---	1.86	Anderholm (1994, Table 7)
LA Canyon '93	?	8428	13694	0.71	0.03	0.26	0.00	6.52	Gray (1997)
LA Canyon '94	?	8428	12409	0.83	0.00	0.17	0.00	4.01	Gray (1997)
LA Canyon '95	?	8428	15912	0.73	0.02	0.25	0.00	7.33	Gray (1997)

[a] Average basin elevation was calculated by the authors for drainage basins as defined by Wasiolek (1995). No adjustments were made to the average drainage basin elevations to account for the small differences in drainage basin areas between the Anderholm (1994) and Wasiolek (1995) studies.
[b] Precipitation volumes reported by Wasiolek (1995) for winter and spring had already been adjusted to reflect the effects of sublimation of snow. The precipitation volume estimated to exist before before sublimation was determined using information provided by Wasiolek (1995, p. 18). Calculated fractions for evapotranspiration, runoff, recharge, and sublimation reported here for the Wasiolek study are relative to this pre-sublimation precipitation value.
[c] The authors estimated the evapotranspiration (ET) for Anderholm's study based on Anderholm's estimates for precipition (P), runoff (RO), and recharge (R):
$ET = P - RO - R$
[d] These estimates used the chloride-based recharge estimate corrected for runoff from the basin.

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Mortandad Canyon Investigation Report



Prepared by the Environmental Programs Directorate

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EXECUTIVE SUMMARY

This investigation report for Mortandad Canyon presents the results of studies conducted from 1998 to 2005 in Effluent, Mortandad, and Ten Site Canyons and in an unnamed tributary canyon that heads in Technical Area (TA) 05 of the Los Alamos National Laboratory (the Laboratory). Together these drainage systems comprise the Mortandad watershed. These canyons have received inorganic and organic chemicals and radionuclides since the Laboratory was established in 1943. Most of the contamination related to Laboratory releases is associated with effluent discharges, and discharges of contaminants have decreased over time. The investigations reported herein address sediment, surface water, groundwater, and biota potentially impacted by solid waste management units (SWMUs) and areas of concern (AOCs) located within the watershed. Investigations occurred along 18 km (11 mi) of canyon bottom downcanyon of SWMUs or AOCs. The objectives of the investigations included defining the nature and extent of chemicals of potential concern (COPCs) in sediment, surface water, and groundwater and assessing the potential risks to human health and the environment from these COPCs. The investigations also address the sources, fate, and transport of COPCs in the canyons and evaluate the need for additional characterization or remedial actions.

Sediment investigations included geomorphic mapping, associated geomorphic characterization, and sediment sampling in 27 investigation reaches located downcanyon from SWMUs or AOCs. Analytical data collected in this investigation are supplemented by data collected by the Laboratory's Environmental Surveillance Program and other Laboratory studies to aid in determining spatial and temporal trends in sediment contamination.

Surface water investigations included sampling of persistent water at nine locations in Effluent, Mortandad, and Ten Site Canyons, which are locations where water potentially occurs persistently enough to contribute to human health risks or to adverse ecological effects associated with potential chronic exposure. Surface water and groundwater sampling occurred concurrently in two sampling events to assess relations between these media and to characterize potential seasonal effects on hydrology and contaminant concentrations. Analytical data collected in this investigation are supplemented by Environmental Surveillance Program data to provide a longer period of record and a larger data set.

Groundwater investigations included installing nine alluvial wells, eight perched-intermediate groundwater wells and boreholes, and seven regional groundwater wells within the Mortandad watershed. Data from groundwater samples collected from these wells were supplemented with historical data from preexisting wells. Groundwater investigations also included surface and subsurface geophysical surveys, installation of piezometers, water-level measurements, vector probe and flux meter analyses, and analyses of core samples and vadose-zone pore water.

Sediment COPCs in the Mortandad watershed include 38 inorganic chemicals, 74 organic chemicals, and 17 radionuclides. Surface water and groundwater COPCs include 62 inorganic chemicals, 42 organic chemicals, and 16 radionuclides. These COPCs are derived from a variety of sources, including Laboratory SWMUs and AOCs, runoff from developed areas, and naturally occurring soil, sediment, and bedrock. Assessments in this report focus on the subset of these COPCs considered most important for the evaluation of potential ecological or human health risk. The relative importance of the COPCs was determined by comparing COPC concentrations with human health screening action levels and soil screening levels, ecological screening levels, U.S. Environmental Protection Agency Region 6 and Region 9 tap water values, or U.S. Department of Energy-Derived Concentration Guidelines for drinking water. The sources of the COPCs are also considered in these assessments to determine whether they partially or largely represent Laboratory sources.

The spatial distribution of contaminants in the Mortandad watershed, supported by effluent discharge data, indicates that the TA-50 Radioactive Liquid Waste Treatment Facility (RLWTF) outfall into Effluent Canyon, which has been active since 1963, is the most important source of contamination with respect to potential human health risk and groundwater impacts. Source areas for Laboratory-derived COPCs that are most important in the assessment of potential ecological risk include TA-48 outfalls into the head of Effluent Canyon and into Mortandad Canyon, the TA-50 RLWTF outfall, and additional releases from TA-50 or TA-35 into the head of Ten Site Canyon. The impacts of additional Laboratory sources (e.g., outfalls from the former TA-35 wastewater treatment plant, wastewater lagoons, and filter beds) are indicated by the characterization data, although the concentrations, extent, and inventory of COPCs from these sources are generally minor compared with the sources listed above.

Contaminants in sediment and alluvial groundwater that were originally released from the TA-50 RLWTF outfall are largely or entirely restricted to approximately 4 km (2.5 mi) of canyon bottom downcanyon from the outfall. The infiltration of stormwater into alluvium, particularly upcanyon from the confluence of Mortandad and Ten Site Canyons, results in a complete loss of surface water in most runoff events and deposition of contaminated sediment. The most important sediment deposition area is in the 0.6 km (0.4 mi) of canyon bottom west of the confluence (reach M-3E), and approximately 50% of the inventory of most radionuclides in sediments occurs there. No floods have been recorded crossing the Laboratory-San-Ildefonso Pueblo boundary since RLWTF discharges began in 1963, and only one event before 1963 is recorded as having reached the Laboratory boundary in August 1952.

Contaminant concentrations in sediment, surface water, and alluvial groundwater in the Mortandad watershed have generally decreased over time, indicating that the initial SWMU and AOC sources are no longer major contributors to contamination in canyons media. The canyon bottom sediment deposits contain the largest inventory of adsorbed contaminants that are susceptible to remobilization and transport in floods and are now the primary source for ongoing surface water and alluvial groundwater contamination. Therefore, any future efforts that may be required to address contaminants in canyons media should address the current distribution of contaminants in sediment and associated groundwater rather than the original source areas at Laboratory outfalls.

In contrast, contaminant concentrations in deeper perched-intermediate or regional groundwater have increased over time, indicating the migration of mobile constituents from the alluvial zone into the vadose zone and into deeper zones of saturation. Vadose-zone pore water concentration profiles indicate that these mobile contaminants have percolated in the subsurface. Currently, the majority of the mass of the nonsorbing contaminants nitrate, perchlorate, and tritium is located within the vadose zone, particularly beneath the area near and just east of the confluence of Mortandad and Ten Site Canyons. Chromium is present in the regional aquifer in one characterization well (R-28) above groundwater standards, and chromium, nitrate, perchlorate, and tritium have been measured above groundwater standards in one or more perched-intermediate depth groundwater wells. Iron and manganese have also been measured above drinking water standards in regional groundwater in one well (R-14) and nickel in another well (R-33), although available data indicate that these results represent naturally occurring constituents and not Laboratory-derived contamination.

A baseline ecological risk assessment conducted as part of this investigation evaluates the potential for adverse effects by assessing risks to omnivorous mammals, insect-eating birds, plants, earthworms, aquatic invertebrates, algae, and two threatened and endangered species: the Mexican spotted owl and the southwestern willow flycatcher. Multiple lines of evidence were used to evaluate potential adverse effects on these ecological receptors. Ecological effects data were collected using small-mammal trapping arrays, a cavity-nesting bird monitoring network, seedling germination tests, earthworm mortality tests, and sediment and water toxicity tests. The assessment lines of evidence are augmented by

breeding-bird field surveys, plant surveys, habitat analyses, and spatial modeling of wildlife exposure. The weight of evidence that these investigations provide indicates that no adverse effects to terrestrial and aquatic receptors exist from COPCs in the Mortandad watershed.

The site-specific human health risk assessment uses a trail-user exposure scenario to represent the present-day and reasonably foreseeable future land use in canyons throughout the Mortandad watershed. The assessment results indicate that for the trail-user scenario, no areas in the Mortandad watershed have contaminant concentrations greater than levels acceptable for noncarcinogens (hazard index of 1) or carcinogens (incremental cancer risk criterion of 1×10^{-5}) in sediment or water. However, the radionuclide dose for one area, reach E-1E in Effluent Canyon downcanyon from the TA-50 RLWTF outfall, exceeds the target dose limit of 15 mrem/yr. The calculated dose for reach E-1E, 52 mrem/yr (corresponding to a radiological risk of approximately 2×10^{-4}), is primarily related to external gamma radiation from cesium-137 in sediment. The radionuclide dose limit of 4 mrem/yr in water was not exceeded at any location. Reach E-1E is a short, steep, and rocky area that has no developed trail within the contaminated area, and it is unlikely that recreational users of the Mortandad watershed use this reach as much as is assumed in the trail-user scenario (1 h/d and 200 d/yrr). Other protectively biased assumptions are incorporated into the exposure assessment, also contributing to an overestimate of potential dose. In addition, the area is currently posted as a "soil contamination area," and posting also states that "access is restricted to workers on official business," further discouraging recreational use in reach E-1E. Therefore, no remedial action is proposed to reduce the potential radiation dose to recreational users of Effluent Canyon, although it is recommended that appropriate posting be maintained.

Evaluations of the changes in COPC concentrations over time for sediment, surface water, and alluvial groundwater indicate that concentrations are either relatively stable or are decreasing for contaminants derived from Laboratory SWMUs or AOCs. These decreases are associated with decreased concentrations in TA-50 RLWTF effluent and processes that remobilize, transport, and dilute sediment and waterborne constituents. Radioactive decay also contributes to decreasing concentrations for some radionuclides (e.g., cesium-137, strontium-90, and tritium). Therefore, the potential for impacts to human health or ecosystems from Laboratory-derived contaminants in these media is expected to continue to decrease.

Potential future changes in the vadose-zone contamination and concentrations of contaminants in perched-intermediate and regional groundwater are less well constrained, and a corrective measures evaluation (CME) is necessary to assess the need for remedial actions. The CME will assess the fate of the contaminant mass in the vadose zone and impacts to the regional groundwater where water-supply wells are located. A more detailed evaluation of chromium contamination in groundwater is currently in progress and will be addressed in pending reports to the New Mexico Environment Department. Monitoring in the Mortandad watershed will continue through the proposed CME process and is described in the Interim Facility-Wide Groundwater Monitoring Plan.

In summary, the results of this investigation indicate that human health risks are acceptable for present-day and foreseeable future land uses, assuming that recreational use of Effluent Canyon below the TA-50 RLWTF outfall continues to be discouraged. In addition, no adverse ecological effects were observed within terrestrial and aquatic systems in the Mortandad watershed. Therefore, corrective actions are not needed to mitigate unacceptable risks. However, a CME is proposed to address contamination in groundwater.

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1.0 INTRODUCTION

Los Alamos National Laboratory (LANL or the Laboratory) is a multidisciplinary research facility owned by the U.S. Department of Energy (DOE). The Laboratory is located in north-central New Mexico, approximately 90 km (60 mi) northeast of Albuquerque and 30 km (20 mi) northwest of Santa Fe. The Laboratory is currently investigating sites potentially contaminated by past operations to ensure that contaminants do not threaten human health or the environment. The sites under investigation are designated as solid waste management units (SWMUs) or areas of concern (AOCs). Contamination in canyon bottoms and in groundwater is being investigated on a watershed basis between the sources and the Rio Grande, the master drainage in the region, in addition to investigations at individual SWMUs and AOCs.

1.1 Purpose and Scope

This investigation report presents the results of studies conducted from 1998 to 2005 in Mortandad, Effluent, and Ten Site Canyons, and an unnamed tributary to Mortandad Canyon that heads in Technical Area (TA) 05 of the Laboratory. This area is collectively referred to in this report as the Mortandad watershed. The Mortandad watershed above its confluence with the Rio Grande also includes Cañada del Buey and Cedro Canyon, but these canyons are not addressed in this report. Cañada del Buey will be the subject of future investigations under the "Work Plan for Sandia Canyon and Cañada del Buey" (LANL 1999, 64617), and Cedro Canyon is located entirely on San Ildefonso Pueblo land and contains no SWMUs or AOCs. The portion of Mortandad Canyon east of New Mexico State Road (SR) 4 is also not addressed in this report for surface water or sediments because no evidence of contaminant transport past this point has been found (as discussed in Section 7.1.1.6 and in Reneau et al. 2003, 77103). Figure 1.1-1 shows the entire Mortandad watershed and the primary subwatersheds or basins, and Figure 1.1-2 shows more detail within the primary investigation area. The investigations reported herein address sediment, surface water, groundwater, and biota potentially impacted by SWMUs and AOCs located within the Mortandad watershed. These media are collectively referred to as canyons media in this report.

The investigations were conducted to fulfill the requirements of several documents. The "Work Plan for Mortandad Canyon" (hereafter, "the Mortandad Canyon work plan" or "the work plan") (LANL 1997, 56835) describes work scope and regulatory requirements for characterizing the Mortandad watershed for the former Environmental Restoration (ER) Project. It contains a background review of SWMUs and AOCs in the watershed, the history of releases, and a review of contaminant data collected before the work plan was prepared. The New Mexico Environment Department (NMED) approved the work plan in 2002 following the Laboratory's response to a request for supplemental information (RSI) (LANL 1999, 62777; NMED 2002, 73830). The requirement to implement the work plan was also included by reference in Section IV.B.2 ("Mortandad Canyon Watershed") of the Compliance Order on Consent (hereafter, the Consent Order), signed by NMED, DOE, the Regents of the University of California, and the State of New Mexico Attorney General on March 1, 2005.

The investigations conducted for the work plan also followed the technical strategy presented in the "Core Document for Canyons Investigations" (hereafter, "the canyons core document") (LANL 1997, 55622; LANL 1998, 57666). The canyons core document was prepared after a pilot study in Los Alamos and Pueblo Canyons was implemented in 1996, with the goal of standardizing the technical strategy for work in canyons. In 1988, NMED approved the core document following the Laboratory's response to an RSI (LANL 1998, 57666; NMED 1998, 58638).

Two additional documents have been prepared to supplement the work plan. The "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613), approved by NMED in 2004 (NMED 2004,

84463), was prepared to meet requirements in the then-draft Consent Order. This plan replaces the approach and scope of the groundwater and surface water investigations contained in the work plan. The "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 89308), approved by NMED in 2005 (NMED 2005, 92084), provides a detailed biota sampling and characterization plan for the Mortandad watershed. This plan satisfies the requirement in the work plan to prepare a biological sampling plan for the Mortandad watershed.

Results of investigations of intermediate and regional groundwater beneath the Mortandad watershed described in the Laboratory's "Hydrogeologic Workplan" (LANL 1998, 59599) are also included in this report. Results of an investigation of chromium contamination in groundwater beneath the Mortandad watershed (LANL 2006, 91987) are not included in this report and will instead be reported in an interim measures report scheduled to be completed in November 2006.

Data collected during the investigations included in this report are used to describe the nature and extent of contamination within the canyon bottom and in groundwater beneath the Mortandad watershed; to update the conceptual model for contaminant distribution and transport within the canyons and underlying groundwater; to assess present-day human health and ecological risk from contaminants within the canyons; to determine and recommend potential remedial actions, if needed, that may be appropriate to achieve or maintain site conditions at an acceptable risk level; and to provide support for decisions at SWMUs and AOCs. The assessments in this report are conducted using data collected since 1998 by the former ER Project to evaluate current environmental conditions. Data from prior investigations and from environmental surveillance sampling are used to help identify temporal trends in contamination and therefore help evaluate how potential risk may change in the future relative to present-day conditions.

This report addresses characterization and risk assessment on the spatial scale of an entire canyon system, encompassing approximately 18 km (11 mi) of canyon bottom downstream of SWMUs and AOCs. The characterization and assessment approach used in this investigation provides an integrating perspective on historical and current contaminant releases to the canyon floor and subsequent contaminant redistribution resulting from various transport processes. This approach facilitates the development of conceptual models that describes expected spatial and temporal trends in contaminant concentrations and inventory, thus supporting recommendations for long-term monitoring. The results also support the Laboratory's watershed approach by providing information on the extent of contamination associated with SWMUs and AOCs and SWMU and AOC aggregates in the watershed and by helping identify and prioritize remedial activities within the watershed. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to NMED in accordance with DOE policy.

1.2 Organization of Investigation Report

This investigation report has the following sections. The outline follows a format approved by NMED on June 13, 2006 (Goering 2006, 93028). Section 1 is an introduction to the report and to the Mortandad watershed. Section 2 provides background information on the sources and history of contaminant releases, previous investigations of canyons media, and remediation activities that have occurred in the watershed. Section 3 describes the scope of activities in this investigation. Section 4 introduces the field investigations. Section 5 describes the regulatory context of this investigation. Section 6 presents screening-level assessments that identify chemicals of potential concern (COPCs) and that help focus subsequent sections on the subset of the most important COPCs for evaluating potential human health risk. Section 7 presents a physical system conceptual model, including discussions of the nature, sources, extent, fate, and transport of select COPCs that are most relevant for evaluating potential human health and ecological risk and contaminant transport. Section 8 presents baseline ecological and human

health risk results and assessments. Section 9 presents conclusions and recommendations. Section 10 presents references cited in this report.

This report has the following appendixes. Appendix A provides a list of acronyms and abbreviations and a table showing conversion of metric units to U.S. customary units. Appendix B presents field investigation methods and results. Analytical results from this investigation are contained on a compact disk and are included as Appendix C. Appendix D presents supporting information on contaminant trends and inventory. Appendix E presents supporting information on statistics and risk. Appendix F presents an alluvial water-level study. Appendix G discusses subunit variability within alluvium, colluvium, and in the Cerro Toledo interval as it pertains to subsurface hydrology. Appendix H presents results of a resistivity study. Appendix I presents documentation of techniques used in the earthVision model. Appendix J discusses constraints on saturated thickness and lateral extent of perched-intermediate water beneath the Mortandad watershed. Appendix K presents the screening results of stormwater data collected at gage stations in the Mortandad watershed. Appendix L presents an analysis of temporal variability in water-levels observed at the intermediate-depth boreholes in the Mortandad watershed and its relation to surface flow events and barometric pressure changes. Preliminary infiltration investigation results are discussed in Appendix M. Appendix N presents an analysis of spatial variability of the regional water table and generation of a contour map of the water-table elevation. In Appendix O, variability in the regional water table elevation near the Mortandad Canyon is analyzed. Appendix P presents an analysis of variability in the pumping rate and hydraulic heads at the water-supply wells near the Mortandad Canyon.

1.3 Watershed Description

The portion of the Mortandad watershed addressed in this report includes Mortandad Canyon west of SR 4, Effluent Canyon, Ten Site Canyon, and an unnamed tributary canyon that heads in TA-05 (Figure 1.1-2). The watershed heads on the Pajarito Plateau on Laboratory land in TA-03, at an elevation of approximately 2255 m (7400 ft) above sea level (asl), and extends approximately 11 km (7 mi) to SR 4 on San Ildefonso Pueblo land at an elevation of approximately 1965 m (6450 ft) asl, approximately 5 km (3 mi) upcanyon from the Rio Grande. The watershed upcanyon of SR4 has a drainage area of 8.4 km^2 (3.3 mi^2), of which 60% is on Laboratory land and the remaining 40% is on San Ildefonso Pueblo land. Effluent Canyon heads in TA-48 and has a length of approximately 0.8 km (0.5 mi) and a drainage area of 0.3 km^2 (0.1 mi^2), entirely on Laboratory land. Ten Site Canyon heads in TA-50 and has a length of approximately 2.9 km (1.8 mi) and a drainage area of 0.9 km^2 (0.3 mi^2), entirely on Laboratory land. Ten Site Canyon includes a short tributary, referred to as Pratt Canyon, which heads in TA-35. The unnamed tributary canyon that heads in TA-05 has a length of approximately 2.8 km (1.7 mi) and a drainage area of 1.4 km^2 (0.6 mi^2), of which 41% is on Laboratory land and the remaining 59% is on San Ildefonso Pueblo land.

Bedrock geologic units exposed within Mortandad Canyon and tributary canyons upcanyon from SR 4 consist of Quaternary ignimbrites of the Otowi and Tshirege Members of the Bandelier Tuff. Pliocene basaltic rocks of the Cerros del Rio volcanic field and underlying geologic units are exposed farther downcanyon toward the Rio Grande (Griggs 1964, 8795; Smith et al. 1970, 9752; Dethier 1997, 49843; Gardner et al. 1999, 63492; Lavine et al. 2003, 92527). Geologic units within the watershed are discussed in more detail in Section 7 of this report.

A comprehensive overview of the biological setting of the Mortandad watershed is provided in the "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 89308). Details on the hydrology are provided in Section 7 and Appendix B of this report.

1.4 Current Land Use

The portion of the Mortandad watershed addressed in this report is located on DOE and San Ildefonso Pueblo lands. Currently, no active Laboratory operations occur in the canyon, except for environmental work such as sediment and water sampling and the discharge of effluent from five National Pollutant Discharge Elimination System (NPDES)-permitted outfalls (Figure 1.1-2 and Plate 1). NPDES outfall 051 discharges treated radioactive effluent from the TA-50 Radioactive Liquid Waste Treatment Facility (RLWTF) into Effluent Canyon. NPDES outfall 03A181 discharges treated cooling water from TA-55 into Effluent Canyon upcanyon from the RLWTF outfall. NPDES outfall 03A021 discharges treated cooling water from TA-03 into the head of Mortandad Canyon. NPDES outfall 03A022 discharges treated cooling water from TA-03 into the upper part of Mortandad Canyon. NPDES outfall 03A160 discharges treated cooling water from TA-50 into the upper part of Ten Site Canyon. There is currently no public access to the watershed on Laboratory land, although trails in the canyons are used by Laboratory personnel for recreational activities such as hiking, running, and bike riding. The portion of the Mortandad watershed on San Ildefonso Pueblo land is undeveloped and is used for traditional activities, including hunting and wood gathering.

2.0 BACKGROUND

Inorganic chemicals, organic chemicals, and radionuclides have been released into the Mortandad watershed from a variety of sources, primarily Laboratory operations in several TAs, since the Laboratory was established in 1943. Most of the contamination related to Laboratory releases is associated with effluent discharges, and releases of contaminants and radionuclides have decreased over time due to improvements in wastewater treatment processes and decreased effluent volumes. The contaminants and radionuclides have been dispersed downcanyon from their release sites in sediments, surface water, and alluvial groundwater. Subsequently, waterborne constituents have percolated into the subsurface and are observed in vadose-zone pore water. Some nonsorbing species are present in intermediate-perched water and in regional groundwater as well. The following sections summarize the sources and history of contaminant and radionuclide releases as well as investigations that address constituent distribution and concentration in canyons media. Remediation activities implemented to reduce contamination in the canyon bottom or in source areas are also discussed.

2.1 Sources and History of Contaminant Releases

This section describes known releases of inorganic chemicals, organic chemicals, and radionuclides that have contributed to contamination within the Mortandad watershed.

2.1.1 TA-50

The Laboratory's RLWTF located at TA-50 began operations in July 1963, and water treatment continues today. The RLWTF discharges treated wastewater to Mortandad Canyon through Effluent Canyon through an outfall that is currently permitted as NPDES outfall 051 [SWMU 50-006(d)] (Plate 1). The largest amount of contamination and radionuclides released to the Mortandad watershed has come from this outfall, which is interchangeably referred to in the remainder of this document at the TA-50 outfall, the RLWTF outfall, or the TA-50 RLWTF outfall. Radioactive liquid waste is treated in Building 50-1 at the RLWTF and transferred to one of two 80,000-L holding tanks located in Building 50-2. When one of the tanks is full, the contents are discharged. Before discharge, the treated wastewater is sampled and tested for radiological and nonradiological constituents. The wastewater is recycled through the treatment plant

until the parameters in the NPDES permit are met. The holding tanks discharge in batches, taking about 30 min per batch. Currently, less than one batch per day is released.

Liquid discharge volumes and associated radionuclide and nitrate releases recorded for the RLWTF from 1963 to 2005 are summarized in Table 2.1-1. This information was collected as part of the historical monitoring of the outfall (LANL 2002, 71301; LANL 2005, 91523; LANL 2006, 93925). Discharge volumes have ranged from the recent low value of 6.8×10^6 L/yr in 2005 to a high of 6.03×10^7 L/yr in 1968, as shown in Figure 2.1-1. Generally, the highest volumes were discharged before about 1981, and volumes have declined since then.

Radionuclides released with the TA-50 RLWTF effluent include americium-241, cesium-137, plutonium 238, plutonium-239,240, strontium-89,90, and tritium. From 1963 to 2004, discharge records indicate that a minimum total of approximately 0.156 Ci of americium-241, more than 2 Ci of cesium-137, more than 0.10 Ci of plutonium-238, nearly 0.2 Ci of plutonium-239,240, approximately 1.5 Ci of strontium-89,90, and approximately 823 Ci of tritium were discharged. Most of the radionuclides americium-241, cesium-137, plutonium-238, and plutonium-239,240 apparently were discharged between 1972 and 1983, although records are incomplete before 1973 (Table 2.1-1). Much of the cesium-137, strontium-90, and tritium have been lost since initial discharge by radioactive decay, although essentially all of the other radionuclides with longer half-lives remain in the watershed.

The variability in discharge volume and in contaminant releases over time (Table 2.1-1) reflects contemporaneous Laboratory operations whose wastewater was treated at the RLWTF, new wastewater treatment methods, and evolving regulatory requirements. Historic nitrate concentrations are compared with outfall volumes in Figure 2.1-1. These illustrate that time histories of released contaminant concentrations do not necessarily track those of outfall volumes. Advanced treatment technologies and stricter regulatory requirements have resulted in reduced contaminant concentrations in effluent. For example, a new reverse osmosis and ultrafiltration system began operating at the RLWTF in 1999 to remove additional radionuclides (except tritium) from the effluent and to ensure that the discharges meet DOE public dose guidelines. Also in 1999, the RLWTF instituted a program to restrict the discharge of nitrogenous wastes into the facility's collection system. The combination of these restrictions with the ultrafiltration system has decreased the nitrate (nitrate as nitrogen) effluent concentration to below 10 mg/L. Since 2000, tritium releases have also decreased because of segregation and evaporation of tritium-contaminated waste streams. The effects of these facility enhancements can be seen in the recent information given in Table 2.1-1.

Measurement of perchlorate releases in RLWTF liquid effluent began in 2000. That year, the RLWTF discharged 4.74 kg of perchlorate for an average concentration of 254 μg/L in the effluent. In 2001, 2.29 kg of perchlorate was released, resulting in an average concentration of 169 μg/L. In 2002, ion-exchange resins were installed at the RLWTF, and this addition has successfully reduced perchlorate in effluent to below the detection limit of 4 μg/L. Other inorganic chemicals released with RLWTF wastewater include chromium, fluoride, sodium, and chloride. Historic chromium releases since 1976 are shown in Figure 2.1-2; the estimated mass of chromium released since 1976 is 26 kg.

Fluoride is also released at the TA-50 RLWTF outfall. Highest effluent concentrations occurred between 1982 and 1990, ranging from about 6 mg/L to a maximum of 28 mg/L. Since 1999, enhanced fluoride treatment has kept effluent concentrations below the New Mexico groundwater standard of 1.6 mg/L. In 2005, the average effluent fluoride concentration was 0.24 mg/L (LANL 2006, 93925).

Before 1975, outfalls at TA-50 (other than the RLWTF) discharged into the head of Ten Site Canyon through drain lines originating in Buildings TA-50-1 and TA-50-2 (LANL 1997, 56835, pp. 2-22–2-23). In 1974, two unplanned releases of untreated waste occurred because of overflow of a sump in TA-50-2.

The drain lines were removed in 1982, and cesium-137, plutonium-239, ruthenium-106, strontium-89, strontium-90, and yitrium-90 were encountered during excavation of the lines. The area near the head of Ten Site Canyon was partially decontaminated in 1981. A Resource Conservation and Recovery Act (RCRA) field investigation (RCRA RFI) was performed in 1993 for SWMU 50-006(a). Soil samples were collected near the outfalls of the two former drain lines, on both banks of the drainage channel, and in the canyon drainage channel at a distance of about 1300 ft downstream from the TA-50 boundary. COPCs identified included polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and the radionuclides americium-241, cobalt-60, cesium-137, potassium-40, plutonium-238, plutonium-239,240, Ra-226, strontium-90, and thorium-232 (LANL 1997, 56835, pp. 2-22, 2-23).

2.1.2 TA-35

Historic outfalls located at TA-35 (Figure 1.1-2 and Plate 1), formerly called Ten Site, are sources of radionuclides and other contamination in the watershed. TA-35 is highly developed industrially, and stormwater runoff from paved areas may also contribute to contaminants in the watershed. The following paragraphs summarize source information compiled in the Mortandad Canyon Work Plan (LANL 1997, 56835).

From 1951 to 1963, treated wastewater containing radionuclides was discharged from the Ten Site Laboratory (Building TA-35-2) into Pratt Canyon (SWMU 35-003(d)-00), a small tributary of Ten Site Canyon. This wastewater originated while hot cells were used to prepare kilocurie sources of radioactive lanthanum (lanthanum-140) and barium (barium-140), waste from experimental reactors (Los Alamos power reactor experiment-1 and -2 and Los Alamos molten plutonium reactor experiment), plutonium research laboratories, and a tritium laboratory. During the operation of the TA-35 wastewater treatment plant (WWTP), approximately 2.7 × 106 gal. (10,220 m^3) of water were discharged to Pratt Canyon (LANL 1997, 56835). The total activity discharged was about 20 Ci gross-beta activity and 1.4 Ci of strontium-89 and strontium-90. The gross-beta activity consisted of a combination of barium-140, lanthanum-140, strontium-89, strontium-90, and trace amounts of cesium-137, ruthinium-106, plutonium, technetium-99, and uranium (Emelity 1958, 793; LANL 1997, 5683; Aeby 1952, 741; Aeby 1954, 742). Many of these radionuclides are short lived, and a decay-corrected inventory estimate made in 1996 considering barium-140, lanthanum-140, strontium-89, and strontium-90 calculated that approximately only 0.2 Ci of strontium-90 remained from the historic releases at TA-35 (LANL 1997, 56835). Unknown quantities of tritium were also disposed of from 1953 to 1974 (Rogers 1998, 59169, p. 2). In addition, chemicals such as nitric acid, strontium nitrate, iron sulfate, and ferric chlorate were released to Pratt Canyon either as wastewater constituents or as treatment chemicals. The TA-35 WWTP was closed in 1963, underwent initial decontamination and decommissioning (D&D) in 1984 and 1985 (Elder et al. 1986, 03089), and underwent further D&D in 1995 and 1996 (LANL 1997, 56835).

Sanitary septic systems that previously discharged from TA-35 were also a source of nitrates in the Mortandad watershed. From 1951 to 1975, two septic systems discharged to Mortandad Canyon and two discharged to Ten Site Canyon. These four systems had no documented releases of contaminants other than treated sewage (LANL 1997, 56835). From 1975 to 1992, the TA-35 sanitary septic sewage lagoons released treated effluent to Ten Site Canyon at NPDES-permitted outfall 10S. Records from 1987 to 1992 show that an average of 45,000 gal. was discharged daily (LANL 1997, 56835).

Photographic waste discharge, noncontact cooling water, and treated cooling water were also previously released at now inactive outfalls into Ten Site and Mortandad Canyons. Chromium may have been released with some cooling water, especially from NPDES-permitted outfall 04A-127.

Currently, only NPDES-permitted outfall 03A160 (Plate 1) discharges from TA-35. It discharges cooling tower blowdown associated with a large generator within Building TA-35-124 to Ten Site Canyon above reach TS-1W.

2.1.3 TA-48

Radiochemistry and nuclear medicine research has been conducted at TA-48 (Figure 1.1-2 and Plate 1), the Radiochemistry Site, since 1957. Discharges to Mortandad Canyon and to the head of Effluent Canyon from TA-48 are believed to have begun at about that time (LANL 1997, 56835). Historically, outfalls handling once-through cooling water and treated cooling tower blowdown have discharged to the canyons [SWMUs 48-007(a), 48-007(b), 48-007(d), 48-010)]; additional small wastewater sources such as floor, roof, and sink drains [SWMUs 48-007(c) and 48-007(f)] also existed. Soil samples collected at these sites in 1993, 1995, and/or 1997 showed the presence of radionuclides and inorganic chemicals. Some radionuclides observed were americium-241, cobalt-60, cesium-137, sodium-22, plutonium isotopes, ruthinium-106, and strontium-90 and uranium isotopes; some inorganic chemicals detected above background levels were barium, copper, lead, mercury, manganese, strontium, and zinc. Currently, no NPDES-permitted outfalls are present at TA-48.

In addition to liquid effluent, the air exhaust system at TA-48 vented acidic vapors (such as perchloric, hydrochloric, hydrofluoric, and nitric acids) that may have contributed contaminants to that watershed.

2.1.4 TA-03

A small portion of the southern part of TA-03, mainly near the Chemistry and Metallurgy Research (CMR) Building (Building TA-03-29) and the Materials Science Laboratory (Building TA-03-1698), is located in the upper reaches of the Mortandad watershed. Some unintentional spills to Mortandad Canyon have occurred, as summarized in the Mortandad Canyon Work Plan (LANL 1997, 56835).

- Six releases of cooling water from the new Sigma Building occurred before 1975; no information was reported regarding possible contaminants associated with the cooling water (Purtymun 1964, 11822).
- During summer 1974, two accidental releases from a radioactive liquid-waste line (near the CMR building) resulted in radioactive contamination of soil near the leaks, SWMU 03-054(e). The waste contained predominantly plutonium-238, with lesser concentrations of cesium-137, plutonium-239, strontium-89, and strontium-90. Remediation of soils was conducted in 1974 and 1984.

Treated cooling water and electroplating solutions were released at SWMU 03-049(a) starting in 1960. Trace amounts of metals (including chromium), acids, cyanide, and depleted uranium were likely released with electroplating rinse waters.

Currently, NPDES-permitted outfalls 03A021 (CMR Building seasonal cooling) and 03A022 (Sigma Complex seasonal cooling) discharge treated cooling water to the upper part of Mortandad Canyon at TA-03 (Plate 1).

In addition to the TA-03 sites located around Mortandad Canyon, it is possible that potassium chromate discharged from TA-03 into Sandia Canyon may be a source of chromium contamination observed in the regional aquifer at well R-28 in Mortandad Canyon (LANL 2006, 91987). Potassium chromate was used from approximately 1956 to 1972 as a corrosion inhibitor in the cooling towers that serviced the TA-03 Power Plant. Possible usage averaging 16.3 kg/d (35.9 lb/d) (DOE 1987, 52975) makes this the largest

known usage of chromium at the Laboratory. Cooling tower blowdown was discharged through an outfall to Sandia Canyon (currently NPDES-permitted outfall 01A001) at approximate rates of 128,000 to 288,000 gal./d. Chromium contamination is being further investigated under the "Interim Measures Work Plan for Chromium Contamination in Groundwater" (LANL 2006, 91987).

2.1.5 TA-55

TA-55 was established in 1973 for the plutonium-processing laboratory. Activities include chemical and metallurgical processes for recovering, purifying, and converting plutonium and other actinides into many compounds and forms. Waste streams are treated at the TA-50 RLWTF. NPDES-permitted outfall 03A181 (Plate 1) currently discharges to upper Effluent Canyon near reach E-1W and west of outfall 051. This outfall releases small volumes of treated blowdown from a cooling tower.

2.1.6 Other Technical Areas

SWMUs and AOCs at several other Laboratory TAs within the Mortandad watershed could have potentially contributed contamination to the canyon bottoms, including TA-60, former TA-04, TA-05, TA-52, former TA-42, and TA-63. Firing sites and outfalls at TA-05 that were active from approximately 1944 to 1959 are the only sources of potential contamination for an unnamed tributary canyon that joins Mortandad Canyon immediately east of the Laboratory-San Ildefonso Pueblo boundary (LANL 1997, 56835, p. 2-11).

2.1.7 Runoff from Developed Areas

The Laboratory's technical areas that surround Mortandad Canyon are industrially developed, including Laboratory facilities, storage locations, and parking lots. Runoff from developed areas transport various contaminants associated with urban areas into the canyons. Contaminants commonly found below developed areas include constituents in motor oil, gasoline, diesel, and asphalt, road salt, PCBs, heavy metals, and pesticides. PAHs, suspected carcinogens that are frequently associated with vehicle usage and asphalt, are a common class of contaminants associated with developed areas (Edwards 1983, 82302; Lopes and Dionne 1998, 82309; van Metre et al. 2000, 82262). Metals that have been identified as associated with runoff from roads include cadmium, chromium, copper, lead, nickel, and zinc (Walker et al. 1999, 82308; Breault and Granato 2000, 82310). Consistent with studies in other regions, investigations in other canyons in and near the Laboratory have identified various inorganic and organic COPCs as being associated with runoff from developed areas (LANL 2004, 87390, pp. 7-14, 7-16).

2.1.8 Cerro Grande Fire

In May 2000, the Cerro Grande fire burned a large part of the Mortandad watershed west of SR 4. Approximately 5.7 km^2 (1410 acres) of the watershed was within the burn perimeter (BAER 2000, 72659), comprising 68% of the watershed above the highway. Most of this area, 82%, was classified as low burn severity or not burned and the remainder as moderate burn severity. Various naturally occurring inorganic chemicals (e.g., barium, cobalt, and manganese) and anthropogenically created fallout radionuclides (e.g., cesium-137, plutonium-239,240, and strontium-90) were concentrated in Cerro Grande ash at levels exceeding that of background sediments before the fire, and the transport of ash has resulted in elevated levels of these analytes in post-fire sediment deposits in some canyons (Katzman et al. 2001, 72660; Kraig et al. 2002, 85536; LANL 2004, 87390). Elevated levels of inorganic chemicals and radionuclides that can be attributed to the transport of ash have also been found in stormwater samples in some canyons (Gallaher and Koch 2004, 88747). Post-fire changes in sediment or water chemistry may have

occurred in the Mortandad watershed, although these effects are expected to be relatively minor compared with other canyons because of the low burn severity and because no layers of ash-rich sediment have been observed.

2.2 Contamination in Canyons Media

Contamination in sediment, surface water, and groundwater in the Mortandad watershed has been evaluated in many studies before this report, dating back to 1956 (Purtymun et al. 1965, 11847). This previous work documented the presence of elevated levels of inorganic chemicals, organic chemicals, and radionuclides in canyon media and has evaluated the potential effects of contaminants on biota. Some key studies, summarized below, provide background and supplemental data for the investigations presented in this report. Relevant information from these studies is also included in subsequent sections of this report.

2.2.1 U.S. Geological Survey

The U.S. Geological Survey (USGS) performed initial studies of contaminants in the Mortandad watershed, beginning with sampling and analyzing sediment below the TA-35 WWTP outfall into Pratt Canyon in 1956 (Purtymun et al. 1965, 11847) and continuing with studies in Effluent and Mortandad Canyons (Purtymun et al. 1966, 11848; Purtymun 1967, 8987; Purtymun and Kunkler 1967, 8888). This work provides documentation of contamination in the initial years of effluent discharge in the watershed and of downcanyon decreases in radionuclide concentration at that time.

2.2.2 Environmental Surveillance Program

The Laboratory's Environmental Surveillance Program (ESP) has sampled and analyzed sediments, surface water, and groundwater at numerous locations in the Mortandad watershed since 1969. This work, reported in annual Environmental Surveillance reports (e.g., ESP 2001, 71301; ESP 2002, 73876; ESP 2004, 83635; ESP 2004, 88421; ESP 2005, 92222) and in other reports (e.g., Purtymun 1971, 4795; Purtymun 1973, 4971; Purtymun 1974, 5476; Purtymun 1975, 11787; Purtymun et al. 1977, 11846; Purtymun et al. 1983, 6407; Devaurs and Purtymun 1985, 7415; Stoker et al. 1991, 7530; Ferenbaugh and Gladney 1997, 93715; Gallaher et al. 1997, 59165), supports the evaluation of long-term trends in contamination in different media and an understanding of the role of stormwater transport.

2.2.3 Environmental Science Group

The Laboratory's Environmental Science Group conducted a series of detailed studies of radionuclides in sediments within the Mortandad watershed in the 1970s; this group has also conducted ecological investigations in contaminated canyon-bottom areas (Hakonson et al. 1973, 4974; Hakonson and Bostick 1976, 29678; Hakonson et al. 1976, 8920; Nyhan et al. 1976, 11746; Nyhan et al. 1976, 11747; Nyhan et al. 1978, 5726; Hakonson et al. 1980, 8924; Nyhan et al. 1982, 7164). This work included documenting downstream changes in contaminant concentrations and relations between contaminant concentration and sediment particle size in the canyon below the RLWTF outfall into Effluent Canyon.

2.2.4 Ecology Group

The Laboratory's Ecology Group has conducted studies on the uptake of contaminants by biota in Mortandad Canyon. These studies include addressing potential uptake of contaminants by small mammals and plants (Bennett et al. 1996, 56035), peregrine falcons (Podolsky 2000, 73477), and an

initial ecotoxicological risk screen in Effluent and Mortandad Canyons (Gonzales and Newall 1996, 56045). Additional studies by the Ecology Group were conducted as part of this investigation and are summarized in Section 8.1.

2.2.5 Environmental Restoration Project

Since 1998, detailed studies of canyons media in the Mortandad watershed have been conducted by the former ER Project and successor organizations. Summaries of results of sediment investigations through 2003 have been presented previously (Reneau et al. 2003, 77103; LANL 2005, 89308). Supplemental data on contamination in canyons media are available through other ER Project reports (e.g., LANL 1995, 49925; LANL 1996, 54422; LANL 2005, 91699). The work presented in this investigation report builds on these previous studies.

2.2.6 NMED and EPA

NMED and the U.S. Environmental Protection Agency (EPA) and their subcontractors have collected and analyzed samples from canyons media in the Mortandad watershed as part of oversight activities (e.g., Hanlon-Mayer and Jacquez 2000, 82261; EPA 2001, 70669). These data provide supplemental information about contamination in the watershed.

2.3 Remediation Activities

Several remediation activities in the Mortandad watershed have reduced the potential for contaminant transport or reduced the concentrations or inventory of contaminants in canyon media. The activities most relevant to this investigation are summarized below.

2.3.1 Pratt Canyon

After removing structures at the former TA-35 WWTP at the head of Pratt Canyon in the early to mid-1980s [SWMUs 35-003(d,e,l,q)], backfill was placed at the head of the canyon to fill excavations and prevent erosion of potentially contaminated soil. Subsequent runoff events incised the backfill on the slope, leading to concerns about remobilizing contaminants such as strontium-90. In 1996, the ER Project conducted an interim action (IA) in Pratt Canyon to reduce the potential for erosion (LANL 1996, 55809). The IA activities included replacing fill in the incised channel, stabilizing the slope, and installing a berm to divert runoff from the slope.

2.3.2 Ten Site Canyon

Excavation of contaminated sediment from Ten Site Canyon reach TS-1W (Plates 1 and 3) occurred in an IA in 1996 (LANL 1997, 55834). This IA targeted a location in the stream channel where unusually high concentrations of plutonium-238 (5190 pCi/g) had been found in one sample, which is the maximum reported anywhere in the Mortandad watershed. This contamination was derived from accidental releases from TA-50 in 1974, designated SWMU/AOC 50-006(a). The site has been described as a “hummock,” and the geomorphic setting indicates that the location was probably a sandbar next to a scour hole that formed below boulders in the channel. Only a single sample from this area had plutonium concentrations >100 pCi/g, suggesting that the 5190 pCi/g result was anomalous and included a small particle of plutonium. A total of 0.55 m^3 (0.72 yd^3) of sediment was removed in this IA.

2.3.3 Sediment Traps

Sediment deposits were excavated from sediment traps #1 and #3 in Mortandad Canyon reach M-4 (Plates 1 and 4) in June 2000 after the Cerro Grande fire (WGII 2000, 70735). This sediment removal was intended to increase capacity in trap #1 to prepare for possible post-fire floods and to remove some fine-grained sediment in trap #3. Excavation of a fill pile adjacent to trap #1 that resulted from prior trap maintenance activities in 1992 also occurred. An estimated 1680 m^3 (2200 yd^3) of sediment was removed in these activities. The contaminant inventory removed in these activities is probably relatively low, compared with the total inventory in reach M-4 because measured radionuclide concentrations in the traps and the fill piles were relatively low. In addition, much of the excavated volume probably consisted of sediment that predated contaminant releases in the watershed.

2.3.4 Permeable Reactive Barrier

In January and February 2003, the Laboratory installed a permeable reactive barrier (PRB) in Mortandad Canyon reach M-3W to evaluate in situ treatment of a suite of COPCs in shallow alluvial groundwater (Kaszuba et al. 2002, 93891; DBS&A 2006, 93888). The PRB was designed to remove americium-241, plutonium-238, plutonium-239,240, strontium-90, nitrate, and perchlorate. Because of their geochemical variability, no single treatment media was optimal for removing all of these COPCs. Consequently, a multiple-layer PRB was designed with multiple treatment zones arranged in series to sequentially remove each of the COPCs. The PRB employs a funnel-and-gate system with a sequential series of four reactive media cells. The funnel consists of a row of sheet piles driven through the alluvium and into the underlying bedrock that directs the alluvial groundwater so that it will flow through the four cells (the gate). The four reactive media cells, ordered by sequence of contact with the groundwater, consist of (1) gravel-sized scoria for colloidal removal; (2) mineral apatite (calcium phosphate) for removing metals and radionuclides; (3) biobarrier cell composed of 65% pecan shells and 10% cotton seed mixed with 25% pea gravel to deplete dissolved oxygen and break down nitrate, perchlorate, and potential RCRA organic compounds; and (4) gravel-sized limestone for pH buffering and anion adsorption. Performance monitoring of the PRB consisted of collecting several rounds of groundwater samples between 2003 and 2005 from the PRB sampling ports and nearby alluvial monitoring wells that were analyzed for major cations and anions and radionuclides (DBS&A 2006, 93888). These data indicated that successful treatment of COPCs occurred in the apatite and biobarrier cells. However, dissolved concentrations of key COPCs measured in the limestone cell and a downcanyon monitoring well—notably, perchlorate, nitrate, and strontium-90—were essentially equivalent to the untreated water upcanyon of the PRB. This pattern of chemical behavior was observed initially under very low alluvial saturation levels in 2003 that created stagnant groundwater flow conditions in the alluvium but also during higher saturation levels in 2004 and 2005 when normal groundwater flow conditions prevailed. Possible explanations for the apparent impaired performance include hydraulic bypass or errors associated with sampling techniques. The performance of the PRB is the subject of ongoing investigations to evaluate these issues.

3.0 SCOPE OF ACTIVITIES

The scope of activities in this report include investigations of sediment, surface water, groundwater, and biota in the Mortandad watershed, as presented in the Mortandad Canyon work plan and subsequent documents (LANL 1997, 96835; LANL 1999, 62777; LANL 2004, 82613; LANL 2005, 89308). These investigations are discussed below.

3.1 Sediment Investigations

The sediment investigations presented in this report focused on characterizing the nature, extent, concentrations, and inventory of contaminants in post-1942 sediment deposits in a series of reaches in the Mortandad watershed. Data from these reaches are used to evaluate potential human health and ecological risks and to identify spatial trends in contamination at a watershed scale, including variations in contaminant concentration and inventory at increasing distances from source areas and temporal trends in contamination. The investigation methods are discussed in Section 4 and Appendix B, Section B-1, of this report; in the "Mortandad Canyon Work Plan" (LANL 1995, 96835; LANL 1999, 62777); and in the canyons core document (LANL 1997, 55622; LANL 1998, 57666).

The scope of this investigation originally included up to 13 investigation reaches in the Mortandad watershed, as presented in Section 7.2.4 of the work plan (LANL 1997, 55622; pp. 7-12–7-30). The scope of work subsequently increased, as discussed below, and a total of 27 investigation reaches have been characterized. Table 3.1-1 lists the sediment investigation reaches and the years in which samples were collected in each reach. Table 3.1-1 also provides abbreviations for reach names included in this report and the approximate length and distance of each reach from the Rio Grande, as well as additional information on the reaches. Figure 3.1-1 and Plate 1 show the location of the investigation reaches within the Mortandad watershed. Note that Pratt Canyon (reach PCYN), a short tributary to Ten Site Canyon below the former TA-35 WWTP, is included in Table 3.1-1, Figure 3.1-1, Plates 1 and 3, and in the physical system conceptual model in Section 7 for completeness but not in the screening assessment in Section 6 or in the risk assessments in Section 8. An evaluation of COPCs and potential risk in Pratt Canyon was completed as part of investigations at TA-35 (LANL 2005, 91867).

During implementation of the work plan in 1998 to 2004, additional investigation areas were added in the Mortandad watershed, and some reaches were subdivided to better identify contaminant sources and to characterize variations in contamination in these canyons. For example, reach TS-2 was subdivided into reaches TS-2 West, TS-2 Central, and TS-2 East, with reach boundaries placed at outfalls from specific SWMUs. Reaches M-3 and M-4 were subdivided to help evaluate variations in contaminant concentrations and inventory related to geomorphic variations in the canyon bottom, although data from all subdivisions of M-3 are evaluated together for risk assessment and also for all subdivisions of M-4. M-3 West consists of the relatively narrow upcanyon portion of M-3; M-3 East consists of the broader downcanyon portion that extends to the confluence with Ten Site Canyon. M-4 West consists of the part of Mortandad Canyon between the Ten Site Canyon confluence and sediment trap #3, M-4 Central consists of the area east of sediment trap #2 where radionuclide concentrations are relatively high, and M-4 East consists of the area farther east where radionuclide concentrations are relatively low.

In 1998, reach M-1 West was added and investigated upcanyon of reach M-1 as shown in the work plan, and the original M-1 was renamed M-1 East. M-1 West is located at the head of Mortandad Canyon just east of Diamond Drive and was investigated to better determine contaminant levels that would be associated with releases from TA-03. In 2001, reach M-2 East was investigated downcanyon of reach M-2 as shown in the work plan, and the original M-2 was renamed M-2 West. M-2 East is located downstream of the easternmost SWMU at TA-35 and was investigated to better determine if TA-35 SWMUs or AOCs have had a measurable impact on sediments in Mortandad Canyon. Investigation of M-2 East was partially in support of planned work at TA-35 under the "Sampling and Analysis Plan for the Middle Mortandad/Ten Site Aggregate" (LANL 2002, 73092). Other objectives of the M-2 East investigation were to obtain additional data on contaminants released from TA-50 and to reduce the length of the nonsampled area between Effluent Canyon and reach M-3. In 2004, reaches E-1 Far West, M-1 Central, and M-5 West were added to the investigation. E-1 Far West is located at the head of Effluent Canyon, upcanyon of the westernmost TA-55 SWMU and was investigated to better determine

relative contributions from TA-48 and TA-55. M-1 Central is located between M-1 West and M-1 East, upcanyon of the westernmost TA-48 SWMU and was investigated to better determine relative contributions from TA-03 and TA-48. M-5 West is located in the middle of a long previously unsampled part of Mortandad Canyon between M-4 and the San Ildefonso Pueblo boundary and was investigated to better determine the eastern extent of recognizable contamination; the previous reach M-5 was renamed M-5 East.

Sediment characterization was also conducted to support the biota investigations according to the study plan presented in the "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 89308). This sampling was conducted to provide additional data to support the assessment of potential ecological effects from contamination found in sediment. This characterization included resampling previously sampled sediment layers in some reaches and collecting samples at new locations in other reaches. Details of the methodology are presented in Section B-3 of Appendix B.

3.2 Surface Water and Groundwater Investigations

The water investigations presented in this report focus on characterizing the nature, extent, and concentrations of contaminants in persistent surface water, alluvial groundwater, and perched-intermediate groundwater in and beneath the Mortandad Canyon watershed. Wells extending into the regional aquifer are also considered. Data from these components of the hydrogeologic system are used to evaluate potential human health and ecological risk as well as to identify spatial trends in contamination at a watershed scale, including variations in contaminant concentration at increasing distances from the source areas and as a function of seasonal and annual hydrologic variations. The data are also used to identify temporal trends in contamination. This work involved sampling persistent surface water; drilling and installing monitoring wells and piezometers; sampling new and preexisting groundwater wells; and measuring water level variations in all groundwater sources. Persistent surface water generally refers to effluent-supported flow, standing water in bedrock pools in the channel, snowmelt runoff, and other surface water not related to short-duration stormwater runoff (Section 7.2 further discusses the hydrology of the watershed). Figure 3.2-1 shows the locations of surface and groundwater sites that were sampled as part of this investigation. The investigation methods are discussed in Section 4.2 and Appendix B of this report. The scope of the investigation is described in the "Work Plan for Mortandad Canyon" (LANL 1997, 56835) and the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). The investigation activities described above are discussed in the following sections.

3.2.1 Monitoring Well Installations

Nine alluvial monitoring wells were installed in Mortandad and Ten Site Canyons between 1998 and 2005 to fulfill the requirements of the "Work Plan for Mortandad Canyon" (LANL 1997, 56835) and the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). Well completion diagrams and geologic logs for these wells are provided in the reports "Alluvial Groundwater Monitoring Well Completions, 1994-2001" (LANL 2001, 73307) and "Final MCA Wells, MCB Boreholes, and MCRES Boreholes Completion Report 2004–05 Mortandad Canyon Drilling Program, Los Alamos National Laboratory, Los Alamos, New Mexico, Project 49436" (Kleinfelder 2006a, Appendix 92486). Downhole gamma and induction logs were collected in several boreholes either before plugging and abandonment or before well installation. Other alluvial monitoring wells installed in Mortandad Canyon from 1960 to 1990 for surveillance monitoring were used in these investigations (Purtymun 1995, 45344). In 1994, 24 additional water balance wells were installed in Mortandad Canyon to investigate spatial and temporal changes in alluvial saturation (McLin 1997, 85422). Well completion diagrams and geologic logs for these early wells are compiled in Purtymun (1995, 45344) and McLin (1997, 85422). Figure 3.2-1 and Plate 1 show the locations of the alluvial monitoring wells in the Mortandad Canyon watershed.

Eight intermediate perched monitoring wells and boreholes were installed in Mortandad Canyon in 2001 to fulfill the requirements of the "Work Plan for Mortandad Canyon" (LANL 1997, 56835) and in 2004 and 2005 to fulfill the requirements of the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). Well completion diagrams and geologic logs for these wells are provided in the following reports: "Characterization Well MCOBT-4.4 and Borehole MCOBT-8.5 Completion Report" (Broxton et al. 2002, 76006) and "Final I Wells Completion Report 2004-05 Mortandad Canyon Drilling Program, Los Alamos National Laboratory, Los Alamos, New Mexico, Project 49436" (Kleinfelder 2006b, 92494, Appendix B). Downhole gamma and induction logs were collected in the boreholes either before plugging and abandonment or before well installation. Schlumberger, Inc., collected a more comprehensive suite of geophysical logs in three of the wells (Kleinfelder 2005, 90045; MCOBT-4.4, MCOBT-8.5, and MCOI-5). Figure 3.2-1 and Plate 1 show the locations of intermediate-perched monitoring wells and boreholes in the Mortandad Canyon watershed.

Three additional perched intermediate wells were identified in the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613) as contingent wells that could be installed if results from the seven other intermediate wells indicated the need for additional perched zone characterization. These included a well in upper Ten Site Canyon near R-14 (MCOI-2), a well on the bench south of Mortandad Canyon and south of GS-2 (MCOI-7), and a well on the mesa top south of Mortandad Canyon 1500 ft east of supply well PM-5 (MCOI-9). Intermediate well MCOI-2 was designed to investigate the occurrence of perched groundwater near the TA-35 outfall. Because no perched groundwater was encountered when drilling nearby well R-14, and the regional aquifer has not shown the presence of contaminants, including perchlorate, nitrate, and tritium, MCOI-2 was not considered essential for determining the nature and extent of contaminants in this area and was not discussed. Intermediate well MCOI-7 was not drilled after results from well MCOI-1 indicated there was insufficient groundwater to make a useful well in the narrow part of Mortandad Canyon between Effluent Canyon and TW-8. Intermediate well MCOI-9 was not drilled after results from borehole MCOI-10 indicated that perched groundwater does not extend under the mesa south of Mortandad Canyon.

Four regional groundwater characterization and monitoring wells were installed in Mortandad Canyon; two regional wells were installed in Ten Site Canyon; and one regional well was installed in Cedro Canyon from 1998 to 2005 to fulfill the requirements of the "Work Plan for Mortandad Canyon" (LANL 1997, 56835) and the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). Well completion diagrams and geologic logs for these wells are provided in the following reports: "Revision 1 Well R-1 Completion Report, Los Alamos National Laboratory, Los Alamos, New Mexico" (Kleinfelder 2005a, 90045), "Characterization Well R-13 Completion Report" (LANL 2003a, 76060), "Characterization Well R-14 Completion Report" (LANL 2003b, 76062), "Characterization Well R-15 Completion Report" (Longmire 2001, 70103), "Revision 1 Well R-28 Completion Report, Los Alamos National Laboratory, Los Alamos, New Mexico" (Kleinfelder 2005b, 94042), "Final Completion Report Characterization Well R-33, Los Alamos National Laboratory, Los Alamos, New Mexico" (Kleinfelder 2005c, 94041), "Final Completion Report Characterization Well R-34, Los Alamos National Laboratory, Los Alamos, New Mexico (Kleinfelder 2004, 92199), "Final MCA Wells, MCB Boreholes, and MCRES Boreholes Completion Report 2004-05 Mortandad Canyon Drilling Program" Los Alamos National Laboratory, Los Alamos, New Mexico, Project No. 49436 (Kleinfelder 2006, 92486), and "Final I Wells Completion Report 2004–05 Mortandad Canyon Drilling Program, Los Alamos National Laboratory, Los Alamos, New Mexico, Project No. 49436" (Kleinfelder 2006, 92494). The last two reports listed above are provided in electronic format as part of Appendix B on the attached CD. Schlumberger, Inc., collected a comprehensive suite of geophysical logs in all of the regional well boreholes before well installation Kleinfelder 2005, 90045). TW-8 was installed in Mortandad Canyon in 1960 to determine the hydrologic characteristics of the Mortandad Canyon area and to monitor the regional aquifer for contaminants (Baltz et al.1963, 08402; Purtymun 1995, 45344). The well completion diagram and geologic log for TW-8 are

summarized in Baltz et al. (1963, 08402) and Purtymun (1995, 45344). Historic water-quality data from TW-8 were used with data from the more recent characterization wells to examine spatial and temporal trends in contaminants as part of this investigation report. Figure 3.2-1 and Plate 1 show the locations of the regional groundwater characterization and monitoring wells in the Mortandad Canyon watershed.

3.2.2 Piezometer Installations

Six piezometers were installed in 2004 to fulfill the requirements of the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). The piezometers were installed in Mortandad Canyon to collect information about groundwater flow directions, hydraulic gradients, saturated thicknesses, and extent of saturation in alluvial groundwater west of the confluence with Ten Site Canyon and east of the sediment traps. Well completion diagrams and geologic logs for these piezometers are provided in the report "Final MCA Wells, MCB Boreholes, and MCRES Boreholes Completion Report 2004-05 Mortandad Canyon Drilling Program, Los Alamos National Laboratory, Los Alamos, New Mexico, Project 49436" (Kleinfelder 2006a, 92486). Figure 3.2-1 and Plate 1 show the locations of the piezometers in the Mortandad Canyon watershed.

3.2.3 Surface Water and Groundwater Sampling

Since release of the "Work Plan for Mortandad Canyon" (LANL 1997, 56835), surface water, alluvial groundwater, intermediate-perched groundwater, and regional groundwater samples have been collected in the Mortandad Canyon watershed, supplementing years of data collected by the Laboratory's Environmental Surveillance Program. These investigations were conducted to address characterization requirements presented in the "Work Plan for Mortandad Canyon" (LANL 1997, 56835) and the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613) and to fulfill the requirements of the Laboratory's Environmental Surveillance Program. The "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613) updated the sampling approach initially presented in "Work Plan for Mortandad Canyon" (LANL 1997, 56835) by selecting wells and surface water locations for sampling based on bounding of key potential contaminant sources and collecting data useful for assessing human health and ecological risk.

Based on the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613), sampling of surface water and groundwater was coordinated to provide a "snapshot" in time to evaluate the relationship between constituents in surface water and various groundwater bodies. The snapshot sampling efforts were conducted in 2005 and included two sampling events that were scheduled to coincide with periods of relatively dry and wet hydrologic conditions. Surface water locations were selected from areas where persistent surface water was present. Surface water sampling was also conducted to support the biota investigations (LANL, 2005, 89308), discussed in Section 4.3.

The list of surface water sites and groundwater monitoring wells that were sampled as part of the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613) and the rationale for selecting each sample site are presented in Table 3.2-1. Other wells and surface water locations in the watershed were sampled as part of earlier investigations but are not included in Table 3.2-1. Figure 3.2-1 shows the locations of the sample sites listed in Table 3.2-1. Plate 1 shows those same locations as well as additional monitoring wells, surface water sampling locations, and production wells in the Mortandad Canyon watershed.

3.2.4 Water-Level Measurements

Both manual and automated water-level data have been collected from alluvial monitoring wells, piezometers, intermediate-perched monitoring wells, and regional monitoring wells in the Mortandad watershed. A summary of water-level measurements for wells at LANL, including those in the Mortandad Canyon watershed, is given in the report "Groundwater Level Status Report for 2005, Los Alamos National Laboratory" (Allen and Koch 2006, 93652). Table 3.2-2a shows the list of wells and period of record for the manual water-level data for each well; Table 3.2-2b shows the list of wells and period of record for the automated water-level data for each well. Details of the field methodology and results are presented in Section B-2.2 of Appendix B.

3.2.5 Infiltration Investigation

An infiltration investigation is currently being conducted to fulfill requirements of the "Work Plan for Mortandad Canyon" (LANL 1997, 56835) and the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). The purpose of the infiltration investigation is to constrain the various terms of the water budget to quantify water movement within the deep percolation contaminant transport pathway. These data will support future assessment of groundwater infiltration under varying conditions and for differing source-reduction scenarios (e.g., elimination of TA-50 discharges). To assess flow dynamics within the alluvial aquifer, system vector probes were installed in selected boreholes. Water content and matric potential sensors were also installed in other selected boreholes to analyze vadose-zone dynamics below alluvium. Instrumentation was also installed at locations in the canyon floor to assess percolation rates. Preliminary results for the infiltration study are discussed in Appendix M.

3.2.6 Surface Geophysics

Two surface-based direct-current (DC-) resistivity surveys were conducted in Mortandad Canyon in 2002 and 2004. The 2004 survey fulfills requirements of the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). The objective of the resistivity surveys was to identify regions of higher conductivity beneath the canyon floor that may be related to perched alluvial groundwater and to zones of infiltration in subcropping bedrock units. The surveys were optimized to characterize variations in electrical conductivity in the upper 150 to 200 ft of the vadose zone. Details of the methodology and results for the resistivity surveys are provided in the reports "Pilot Geophysical Studies in Mortandad Canyon, Los Alamos National Laboratory, Los Alamos, NM, Job No. 1171" (Geophex 2002, 94040, Appendix B) and "DC Resistivity Profiling in Mortandad, Ten Site and DP Canyons, Los Alamos National Laboratory, Los Alamos, NM, Job No. 1247" (Geophex 2004, 84540, Appendix B). Locations of the resistivity survey lines are shown in Plate 1.

3.2.7 Characterization Core Holes

Thirteen of 16 planned characterization core holes were installed in Mortandad Canyon in 2004 and 2005 to fulfill the requirements of the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). Two of the planned characterization core holes, MCB-3 and MCB-4, could not be installed because the sites are located in an inaccessible, deeply incised portion of Mortandad Canyon. Access to one site (MCB-13) was denied because it was located in a protected archeological area. Table 3.2-3 describes the characterization boreholes and provides information about their locations, purpose, and depths. Diagrams and geologic logs for these core holes are provided in the report "Final MCA Wells, MCB Boreholes, and MCRES Boreholes Completion Report 2004-05 Mortandad Canyon Drilling Program, Los Alamos National Laboratory, Los Alamos, New Mexico, Project 49436" (Kleinfelder 2006a, 92486, Appendix B). Additional core was collected during installation of intermediate-perched and

regional groundwater monitoring wells, described in Sections 3.2.2 and 3.2.3 above. Figure 3.2-1 and Plate 1 show the locations of the alluvial monitoring wells and piezometers in the Mortandad Canyon watershed.

3.2.8 RES Coreholes

Cores from four boreholes and from one regional aquifer well were collected to compare vertical electrical profiles from the 2002 surface-based DC-resistivity survey with moisture profiles and perched groundwater occurrences detected in boreholes. Table 3.2-3 describes the RES boreholes and provides information about their locations, purpose, and depths. These resistivity boreholes investigations fulfill the requirements of the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). Diagrams and geologic logs for these boreholes are provided in the following reports: "Final MCA Wells, MCB Boreholes, and MCRES Boreholes Completion Report 2004-05 Mortandad Canyon Drilling Program, Los Alamos National Laboratory, Los Alamos, New Mexico, Project 49436" (Kleinfelder 2006a, 92486, Appendix B), "Characterization Well MCOBT-4.4 and Borehole MCOBT-8.5 Completion Report" (Broxton et al. 2002, 76006), and "Revision 1 Well R-28 Completion Report, Los Alamos National Laboratory, Los Alamos, New Mexico" (Kleinfelder 2005b, 94042). Figure 3.2-1 and Plate 1 show the locations of the three RES holes, MCOBT-4.4, and R-28.

3.3 Biological Investigations

The biological investigations presented in this report focused on characterizing the potential for adverse effects of contaminants in post-1942 sediment deposits and surface water on terrestrial and aquatic ecological receptors. These investigations fulfill the general objectives identified in the work plan (LANL 1997, 96835; LANL 1999, 62777) and in the canyons core document (LANL 1997, 55622; LANL 1998, 57666). These investigations build upon the results obtained from sediment and surface water characterization, and the basis for the investigation approach is documented in the "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 89308). The investigation methods are discussed in Section 4.3 and Section B-3.0 in Appendix B of this report.

3.4 Deviations from Planned Activities

The sediment, surface water, groundwater, and biota investigations discussed in this report deviated in several respects from that proposed in the original plans. Most of the deviations consisted of additions to scope, such as the investigation of additional sediment investigation reaches that was discussed in Section 3.1. Other deviations resulted when the original work plan (LANL 1997, 56835; LANL 1999 62777) was superseded by later documents, such as the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613) or the "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 89308). This section focuses on work proposed in the most recent, applicable document that was not accomplished or that was otherwise changed in a manner that has the potential to negatively affect the scope of this investigation.

Plans for drilling 9 alluvial wells, 16 characterization boreholes, 3 resistivity boreholes, and 7 intermediate wells were described in the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). Four regional wells (R-1, R-28, R-33, and R-33) were also described in that plan; details of activities and well construction for these holes to the regional aquifer are described in dedicated borehole completion reports for each well (Kleinfelder 2004, 92199; Kleinfelder 2005a, 90045; Kleinfelder 2005b, 94042; Kleinfelder 2005c, 94041). Exceptions and modifications to the other alluvial wells as well as characterization boreholes, resistivity boreholes, and intermediate wells are detailed in Table 3.4-1. Among the alluvial wells installed, MCA-4 provided an adequate sample only for the first round of

sampling. Nearby, alluvial well MCO-2 has been sampled in instances where an adequate sample could not be obtained from MCA-4 (see Table 3.2-1), and data from both wells have been used to represent the alluvial system in Effluent Canyon upstream of the TA-50 outfall.

The biota investigation was completed as planned with several exceptions. It was planned to analyze earthworms used in the earthworm toxicity test for COPECs, but the analytical laboratory instead disposed of these samples, and analyses were not obtained. It was planned to collect aquatic invertebrates using a Hess sampler for taxonomic identification and comparison to NMED's draft "Stream Condition Index for New Mexico Wadeable Streams;" but flow was insufficient to use the Hess sampler. It was also planned to submit aquatic invertebrates obtained with a dip net for radiological analyses, but insufficient invertebrate mass was obtained for these analyses.

4.0 FIELD INVESTIGATIONS

Field investigations in the Mortandad watershed included investigations of sediment, surface water, groundwater, and biota. The approaches and methods of these investigations are briefly discussed in the following subsections. A more detailed discussion of the methods and the results of the field investigations is presented in Appendix B.

4.1 Sediment

Sediment investigations in the Mortandad watershed included detailed geomorphic characterization and sediment sampling in a series of discrete reaches, following the general process described in the NMED-approved work plan and canyons core document (LANL 1997, 55622; LANL 1997, 56835; LANL 1998, 57666; LANL 1999, 62777). The geomorphic characterization in most reaches included preparing a detailed geomorphic map delineating the horizontal extent of geomorphic units with varying physical characteristics, contaminant concentrations, and/or age. Field radiological screening measurements were used to help delineate geomorphic units in reaches where the levels of radionuclide contamination in post-1942 sediment exhibited higher levels of radiation than nearby pre-1943 sediment. The geomorphic characterization also included measuring the thicknesses of potentially contaminated post-1942 sediment deposits to estimate the volume of contaminated sediment and the contaminant inventory in each reach. Several methods were used to identify the bottom of post-1942 sediment deposits, including determining the depth of buried trees and associated buried soils, and noting the presence or absence of materials imported to the watershed after 1942 (e.g., quartzite gravel, plastic).

Field data on the volume and radiation levels in the different geomorphic units in a reach were used to help allocate samples for analysis at off-site laboratories. In most reaches, samples were collected in multiple phases, and analytical results from initial sampling phases were used to help guide subsequent sampling. Section B-1 of Appendix B includes a more detailed discussion of the investigation methods. All analytical results of the sediment sampling incorporated in this investigation report are presented in Appendix C on a CD included with this report.

Plates 2 to 5 present geomorphic maps for reaches in the Mortandad watershed and sample locations, field radiological measurement locations, and stratigraphic description locations within these reaches. The horizontal extent of contaminated or potentially contaminated sediment deposits in each reach is delineated by the extent of the channel ("c") and floodplain ("f") units in these maps. Section B-1 of Appendix B includes field investigation results, including field radiological screening results.

4.2 Surface Water and Groundwater

The surface water and groundwater investigations in the Mortandad Canyon watershed are designed to define the nature and extent of contamination, to identify the physical and chemical processes controlling contaminant distributions, and to identify the transport pathways that could result in potential human health and ecological risk. This work includes sampling persistent surface water; drilling and installing monitoring wells and piezometers; sampling new and preexisting groundwater wells; and measuring water level variations in all groundwater sources. In addition, core was collected to characterize the distribution contaminants and moisture in rock units of the upper vadose zone. The investigation methods are discussed in Appendix B of this report. The scope of the investigation is described in the "Work Plan for Mortandad Canyon" (LANL 1997, 56835) and the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613).

4.2.1 Monitoring Well Installations

Nine alluvial wells, eight intermediate wells, and seven regional wells were installed to fulfill the requirements of the "Work Plan for Mortandad Canyon" (LANL 1997, 56835) and the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). Detailed well completion reports describe the investigation methods, well completion diagrams, geologic logs, and borehole geophysical logs for these wells. These well completion reports are described in Section 3.2.1 of this investigation report. Table 3.2-1 provides information about the location, purpose, and depth of these wells.

4.2.2 Piezometer Installations

Piezometers were installed to evaluate groundwater flow directions, hydraulic gradients, saturated thicknesses, and extent of saturation in the alluvial groundwater system. The piezometers were installed at two locations, each containing three closely spaced piezometers to monitor water levels in the alluvial system. The piezometers consist of 0.8-in. I.D. (1.1-in. O.D.) PVC casings coupled to 1.4-in. O.D. prepacked screens surrounded with 10/20 sand. Slot sizes are 0.01 in., and the screens are 6 in. long. Slug tests were conducted in the completed piezometers.

One group of piezometers consisting of MCA-3a, MCA-3b, and MCA-3c (Figure 3.2-1) was installed in Mortandad Canyon west of the confluence with Ten Site Canyon. MCA-3a and MCA-3c were installed in the same borehole and are screened across the lower and upper parts of the alluvial system, respectively. MCA-3b was installed in an adjacent borehole, and it is screened across the middle portion of the alluvial system. Slug tests were conducted in the three piezometers.

The second group of piezometers consisting of MCA-3d, MCA-3e, and MCA-3f (Figure 3.2-1) was installed east of the sediment traps, near the eastern limit of persistent alluvial saturation. The three piezometers were installed in a single borehole to measure water levels in the upper (MCA-3f), middle (MCA-3e), and lower (MCA-3d) parts of the alluvial system. Slug tests were conducted in MCA-3d.

4.2.3 Surface Water and Groundwater Sampling

As described in Section 3.2, sampling of persistent surface water, alluvial groundwater, perched-intermediate groundwater, and regional groundwater was coordinated to provide a snapshot in time to evaluate the relationship between constituents in surface water and various groundwater bodies. Snapshot sampling was conducted in 2005 and included two sampling events that were scheduled to coincide with periods of relatively dry and wet hydrologic conditions. The first round of samples was collected in late April to mid-June during relatively dry conditions. The second round of samples was

collected in mid-August to mid-September during wet conditions, coinciding with the summer monsoon season. Samples were collected at designated locations described in the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). Under this work plan, alluvial groundwater monitoring wells and surface water locations were sampled concurrently (typically within a period of less than 6 weeks) to obtain a comprehensive and current data set and a synoptic perspective of the hydrology and contaminants present in water within the watershed. A key objective was to characterize potential contaminant variability associated with variations in surface water and alluvial groundwater conditions. Sampling surface water and alluvial groundwater concurrently also allows for evaluating the relation between surface water and alluvial groundwater quality. Sampling was attempted at designated locations in each of the two sampling rounds, and samples were collected if sufficient water was present. Some additional surface water stations and wells, in addition to the designated locations required in the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613), were added to the rounds of snapshot sampling to replace dry sample locations and to provide more comprehensive water quality data for the watershed. Table 4.2-1 summarizes the sampling conducted during the two rounds required under the work plan, as well as other sampling conducted as part of Laboratory facility-wide surveillance sampling and during early RFI sampling in the watershed conducted under the "Work Plan for Mortandad Canyon" (LANL 1997, 56835).

Most of the surface water and groundwater samples were collected in accordance with ER Project standard operating procedures (SOPs), and a few were collected as part of annual surveillance monitoring using Water Quality and Hydrology (WQH) procedures. The procedures for sample collection are described in Appendix B, and the analytical results of the sampling are discussed in Appendix C and provided on a CD included with this report. With the exception of R-33, which had equipment problems, a water-level measurement was collected from each well before purging for a sampling event. The water-level measurements associated with sampling are also presented in Appendix F. Water-quality field parameters including pH, specific conductance, temperature, and turbidity were measured for each surface water and groundwater sample collected. Measurements of field parameters were taken as part of groundwater sampling to evaluate the effectiveness of purging. Field parameters data were also collected for surface water and groundwater samples to provide data potentially useful for evaluating contaminant variability. These field parameters were logged in a water-quality stabilization record form for each sample and are presented in tables in Section B-2 of Appendix B. The methodology for collecting field parameters and results is also described in Section B-2.0.

4.2.4 Water-Level Measurements

Historical and new water-level data were compiled for alluvial, intermediate, and regional wells in Mortandad Canyon. These data, which included both manual and automated measurements, allow interconnections between groundwater bodies to be assessed by comparing water-level responses with storm events and seasonal variations in precipitation. Water-level data are also collected to determine hydraulic gradients within groundwater bodies and to assess hydraulic conductivity. Details of the field methodology and results are presented in Section B-2.2 of Appendix B.

Systematic manual water-level measurements for selected alluvial observation wells (MCO series) began in 1960 to document seasonal water-level fluctuations in the alluvial groundwater system. In 1994, water balance wells were installed in Mortandad Canyon to investigate spatial and temporal changes in alluvial saturation (McLin et al. 1997, 85422). Manual water-level measurements were taken in selected water balance wells in 1995 and 1996 and automated, high-frequency water-level data were collected using pressure transducer probes from 1997 to 2005. Automated pressure transducer probes were also placed in the alluvial wells and piezometers installed in 2004 and 2005.

Automated pressure transducers were also installed for acquisition of water levels in intermediate-perched groundwater. An automated pressure transducer has collected intermittent water-level data for intermediate-perched monitoring well MCOBT-4.4 since 2002. Automated pressure transducer probes were also placed in wells MCOI-4, MCOI-5, MCOI-6, and MCOI-8.

Water-level data for the regional aquifer wells includes both manual and automated water-level measurements. At first, water-level measurements were collected manually from the regional aquifer wells during water sampling events. In late 2004 and early 2005, automated pressure transducer probes were installed in all but one of the regional aquifer wells installed for the "Work Plan for Mortandad Canyon" (LANL 1997, 56835) and the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613). R-33 is the only regional well without an automated transducer because there is an equipment problem with the multiport sampling system. TW-8 has the longest period on record of all the regional aquifer wells. An automated pressure transducer was installed in TW-8 in 1992 and it has collected water-level data intermittently since then.

4.2.5 Infiltration Investigation

The "Work Plan for Mortandad Canyon" (LANL 1997, 56835) specifies that field-based work is needed to quantify the movement of water through the vadose zone (including the alluvial aquifer system). The Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613) also contains a requirement to assess subsurface water movement in the canyon. Therefore, the Mortandad Canyon infiltration study was implemented to understand spatial and temporal variability of the rates of water movement above, below, and within the alluvial aquifer system and to determine unsaturated zone fluxes in selected locations where no current alluvial water exists. Multiple approaches were used to address these goals, and these are described from shallowest to deepest below. Preliminary results of the infiltration investigation are discussed in Appendix M.

One potential pathway for contaminant transport and recharge in the canyon is percolation through the bottom of the streambed. To quantify this loss, instrumentation was installed at nine locations in the canyon to collect high-time-resolution temperature profiles down to about 180 cm below the stream channel. This method uses heat as a tracer to determine downward fluxes (Constantz et al. 2003, 94090). From the temperature data, the frequency and duration of streambed infiltration events can be determined and downward fluxes can be estimated.

Borehole data from Mortandad Canyon shows that the extent of perchlorate and nitrate contamination extends laterally well beyond the incised channel. Thus, it is important to quantify percolation in the floodplains and terraces as well as the channel. Twelve fiberglass wicktype flux meters were installed at various canyon locations (away from the channel) to measure downward unsaturated flow rates at a depth of approximately 100 cm below the canyon floor. At two of these locations, paired matric potential and water content sensors were also installed. These sensors are used to quantify downward fluxes that are below the detection level of the flux meters and also to quantify rates and durations of upward flux events.

Vector probes were installed in five boreholes (MCB-5, MCB-6, MCB-9, MCB-14, and MCRES-2) to assess flow dynamics within the alluvial aquifer system (see www.hydrotechnics.com for more information about the probes). The vector probes were emplaced in selected MCB and MCRES holes at depths thought to represent the most transmissive alluvial aquifer flow zones identified during drilling (typically above the alluvium/tuff contact). The vector probes provide quantitative information on flow rates and directions within the alluvial aquifer system and how they might vary with time.

A series of volumetric water content and matric potential sensors were also installed in six boreholes (MCB-2, MCB-7, MCB-8, MCB-11, MCB-16, and MCRES-4) below the alluvium (within the tuff) to quantify fluxes in bedrock units. These sensors provide data on the spatial and temporal variability of deep fluxes within the canyon and help constrain recharge fluxes to the deeper intermediate-perched aquifer zone in the canyon.

4.2.6 Surface Geophysics

A DC-resistivity survey was conducted in Mortandad Canyon in summer 2002 to determine whether this geophysical method was an effective and appropriate means to identify zones of saturation and moisture within the alluvial and upper vadose zone systems (Geophex 2002, 94040, Appendix B). Geophysical survey lines are shown in Figure 4.2-1. Geophex conducted the geophysical surveys and prepared a summary report that was submitted to NMED on March 26, 2003 (Geophex 2002, 94040). Nine DC resistivity profiles were compiled in the middle portion of Mortandad Canyon. One profile was collected continuously along the centerline of the canyon from a point upstream of the PRB to a point near well R-13, a distance of 2830 m (9290 ft) to the east (Figure 4.2-1). The remaining profiles consisted of a series of transects across the canyon at selected locations. Profile depths of penetration varied according to the length of the line and the spacing of electrodes. In the upper reaches of the canyon, the shortest profile penetrated approximately 6 to 9 (20 to 30 ft) below ground surface (bgs). The longest profiles imaged to depths of over 60 m (200 ft) bgs.

A second DC resistivity survey was conducted by Geophex in December 2003 to cover additional parts of upper Mortandad Canyon that were not included by the 2002 survey (Geophex 2003, 84540). Geophysical survey lines are shown in Figure 4.2-1. One DC resistivity profile was completed for a distance of 1800 m (5904 ft) along the centerline of upper Mortandad Canyon from a point upstream of the PRB to the confluence with Effluent Canyon. A second profile was compiled for a distance of 220 m (722 ft) along the centerline of lower Effluent Canyon. A third profile was completed for a distance of 475 m (1558 ft) along the centerline of lower Ten Site Canyon from a point where the canyon becomes broad and flat eastward to the confluence with Mortandad Canyon. A fourth line is a north-south transect that extends 192 m (631 ft) across the mouth of Effluent Canyon into Mortandad Canyon.

4.2.7 Characterization Core Holes

A list of the characterization core holes and information about their locations, purpose, and depths are provided in Table 3.2-3. These core holes were drilled to depths ranging between 25 to 87 m (84 and 284 ft) in Effluent, Mortandad, and Ten Site Canyons. Cores collected from the boreholes were used to determine moisture content, adsorption capacity, and the nature and the extent of contamination in the alluvium and upper portions of the Bandelier Tuff/Cerro Toledo interval. Geologic and hydrologic data from these core holes also provide site-specific data for modeling hydrological and geochemical-contaminant transport mechanisms.

Core was collected using hollow-stem auger methods without the use of drilling fluids. Cores were collected from all major stratigraphic units, including the alluvium at a nominal sample interval of 3 m (10 ft) to determine contaminant distributions in the upper vadose zone. Samples were containerized to prevent moisture loss and were analyzed for moisture content, metals, anions, stable isotopes, and radionuclides. Where feasible, borehole gamma and induction logs were collected in uncased portions of the boreholes. In general, the core holes were plugged and abandoned with bentonite after reaching total depth. However, five of the boreholes were instrumented before being backfilled as part of infiltration investigations as described in Section 4.2.5.

Analytical data for cores are discussed in Section 7.2.2. Appendix D contains plots of contaminated profiles in cores and in pore waters extracted from cores. Appendix B presents moisture profiles for the core holes.

4.2.8 RES Coreholes

The 2002 DC resistivity survey suggested that various moist zones might be mapped by the electrical profiles. The degree of saturation or moisture within these zones is not known and can only be confirmed by measuring the moisture content in the boreholes. The high resistivity areas are inferred to be either "dry" or "dryer" unconsolidated sediments or dry bedrock, for example, in the upper portions of the Bandelier Tuff. The dry bedrock zones vary in elevation across the deeper portions of the profiles. Vertical zones of lower resistivity appear to cut through dry bedrock zones and extend to greater depths in certain areas. These features are interpreted to be either "moist" or clay-rich fracture zones within the dryer bedrock.

Core holes MCRES-2, MCRES-3, MCRES-4 (Figure 3.2-1) targeted areas of low and high resistivity identified in the 2002 resistivity survey to evaluate the relationship between the electrical profiles and in situ moisture and physical property measurements determined from core. Core holes MCRES-3 and MCRES-4 are located near TW-8 in resistive and conductive zones, respectively. Near the confluence of Mortandad and Ten Ste Canyons, core was collected from MCRES-2 for comparison to the moisture profile collected from existing well MCOBT-4.4. The 2002 DC resistivity profile suggests that MCOBT-4.4 was drilled in an area where high conductivity extends to greater depths than at MCRES-2. Core was also collected from the upper 45 m (150 ft) of R-28 to evaluate conductivity data from a spot yet farther downcanyon. At R-28, a sharp electrical boundary at 24-m (80-ft) depth separates a conductive zone above from a resistive zone below. Core samples collected at a nominal interval of 3 m (10 ft) were analyzed for moisture content, grain size, porosity, and clay content.

4.3 Biota

Biological data were collected to evaluate the potential for adverse ecological effects from contaminants in sediment and surface water. Biota investigations in the Mortandad watershed included a range of activities, as presented in the NMED-approved "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 89308). Field investigations included studies of bird nest boxes, plant and bird surveys, collection of sediment samples for earthworm toxicity tests, seedling germination tests, aquatic toxicity tests, and collection of water samples for algae toxicity tests. The nest box study included adding nest boxes to an existing network, collecting data on occupancy, and collecting samples of eggs and insects for laboratory analyses. These activities are discussed in more detail in Section 8.1 and Section B-3.0 of Appendix B.

5.0 REGULATORY CRITERIA

This section provides information on the regulatory context, human health screening levels, ecological screening values, and water standards and screening levels.

5.1 Regulatory Context

Regulatory requirements governing the Laboratory's canyons investigations are discussed in Section 1.4 of NMED-approved canyons core document (LANL 1997, 55622, LANL 1998, 57666). In particular, these investigations address requirements of the Laboratory's Hazardous Waste Facility Permit (Module VIII) under RCRA, including "the existence of contamination and the potential for movement or transport to or

within Canyon watersheds" (EPA 1990, 1585; EPA 1994, 44146). RCRA and the New Mexico Hazardous Waste Act (NMHWA) regulate releases of hazardous wastes and hazardous waste constituents. DOE Order 5400.1, "General Environmental Protection Program," establishes requirements for managing residual radioactivity at DOE facilities.

As a result of the operational history of sites in the Mortandad watershed, this investigation addresses both radioactive and hazardous components. NMED has authority under the NMHWA over the cleanup of hazardous wastes and hazardous constituents, while DOE has authority over the cleanup of radioactive contamination. Radionuclides are regulated under DOE Order 5400.5, "Radiation Protection of the Public and the Environment," and DOE Order 435.1, "Radioactive Waste Management."

The regulatory requirements for conducting investigations in the Mortandad watershed are incorporated into Module VIII through work plans approved by NMED. The approved work plans include the "Work Plan for Mortandad Canyon" (LANL 1997, 56835; LANL 1999, 62777), the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613), and the "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 89308). Corrective actions at the Laboratory are subject to the Consent Order, which contains general requirements and those specific to the Mortandad watershed (Section IV.B.2, "Mortandad Canyon Watershed"). The Consent Order was issued pursuant to NMHWA, New Mexico Statutes Annotated (NMSA) 1978 § 74-4-10 and the New Mexico Solid Waste Act (NMSWA), NMSA 1978, § 74-9-36(D). The requirements of the Consent Order now supersede those of Module VIII.

Surface water discharges that are subject to a permit under Section 402 of the federal Clean Water Act, including stormwater discharges, are not regulated under the Consent Order. Requirements for stormwater monitoring are contained in a Federal Facility Compliance Agreement/Administrative Order (FFCA/AO) between EPA and DOE.

The assessments in this report are primarily risk based for all media and contaminants. Surface water and groundwater standards are used to support the assessment of nature and extent of contamination in canyons media. Concentrations of chemicals and radionuclides are compared with various risk-based screening levels, which are described in Sections 5.2 and 5.3. Applicable water standards are discussed in Section 5.4.

5.2 Human Health Screening Levels

In Section 6, soil screening levels (SSLs) for inorganic and organic chemicals and screening action levels (SALs) for radionuclides are media-specific concentrations derived for residential exposures. If environmental concentrations of contaminants are below SALs or SSLs, then the potential for adverse human health effects is considered highly unlikely. For sediment nonradionuclide COPCs with carcinogen or noncarcinogen endpoints, SSLs from revision 4.0 of NMED guidance (NMED 2006, 92513) were used if available. If values were not available from NMED then residential screening values were obtained from EPA Region 6 or EPA Region 9. The SSLs for noncarcinogens are based on a hazard quotient (HQ) of 1.0. The SSLs for carcinogens are based on a cancer risk level of 10^{-5} (10E-5). For nonradionuclide COPCs without NMED SSLs, approved surrogate values were used (NMED 2003, 81172). SALs for radionuclides were obtained from Laboratory guidance (LANL 2005, 88493). The radionuclide SALs for sediment have a target dose limit of 15 millirem per year (mrem/yr), which is consistent with guidance from DOE (DOE/AL 2000, 67153).

Human health screening levels for water are EPA Region 6 Human Health Medium Specific Screening Level (HHMSSL) tap water screening levels for carcinogens and noncarcinogens and DOE-Derived Concentration Guidelines (DCG) for radionuclides. The screening levels for carcinogens and

noncarcinogens in water are based on the same HQ and cancer risk levels as the SSLs. The screening values for radionuclides in groundwater were calculated based on a target dose limit of 4 mrem/yr, which is the radiation dose limit for a public drinking water supply in DOE Order 5400.5, "Radiation Protection of the Public and the Environment." The screening values for radionuclides in surface water were calculated based on a target dose limit of 100 mrem/yr, which is the radiation dose limit for the general public from all sources in DOE Order 5400.5, "Radiation Protection of the Public and the Environment."

Additional information regarding the potential for human health risks from affected media in the Mortandad watershed is provided in Section 8.2.

5.3 Ecological Screening Levels

Ecological screening levels (ESLs) are used to determine chemicals of potential ecological concern (COPECs) for water and sediment data. The document "Screening Level Ecological Risk Assessment Methods, Rev. 2" (LANL 2004, 87630) contains information about how ESLs are derived. ESLs are developed for a suite of receptors designed to represent individual feeding guilds, such as invertivorous mammal or carnivorous bird. Receptors such as robins and kestrels are modeled with multiple diets to represent multiple feeding guilds. The representative concentration of each COPC was compared with ESLs from the ECORISK Database Versions 2.1 (LANL 2004, 87386) or 2.2 (LANL 2005, 90032).

Additional information regarding the potential for ecological risks from affected media in the Mortandad watershed is provided in Section 8.1.

5.4 Water Standards and Screening Levels

COPCs are identified by comparing concentrations in water with applicable water standards and screening values. All surface water sampling locations in the Mortandad watershed are designated ephemeral. Water standards that apply to ephemeral surface waters (not including stormwater runoff) include the following.

- Aquatic Acute Life (New Mexico Water Quality Control Commission [NMWQCC] Acute Aquatic Life criteria, New Mexico Administrative Code [NMAC] 20.6.4.900 (H), (I), and (J), effective July 2005. Hardness-dependent criteria are calculated using 100 mg/L $CaCO_3$.)
- Livestock Watering (NMWQCC Livestock Watering criteria, NMAC 20.6.4.900 (F) and (J), effective July 2005)
- Wildlife Habitat (NMWQCC Wildlife Habitat criteria, NMAC 20.6.4.900 (G) and (J), effective July 2005)
- Human Health Persistent (NMWQCC human health criteria for persistent toxic pollutants, NMAC 20.6.4.900 (J), effective July 2005. Human health criteria for toxic, carcinogenic, and persistent pollutants only)

Concentrations of radionuclides in surface water were compared with the following values to identify COPCs:

- DCG based on 100 mrem/yr

To identify COPCs in groundwater, comparisons to the lowest of the following standards were performed:

- Human Health (NMAC 20.6.2.3103.A: Human health standards)

- Other Standards for Domestic Water (NMAC 20.6.2.3103.B: Other standards for domestic water supply)
- EPA maximum contaminant levels (MCLs)

If none of the above standards exist for an analyte, the following values were compared with concentrations in groundwater to identify COPCs:

- DCG based on 4 mrem/yr
- EPA Region 6 HHMSSLs for tap water (EPA 2005, 91002)

Stormwater discharges are regulated under the federal Clean Water Act, and no applicable standards for stormwater are under the Consent Order. For informational purposes, available stormwater monitoring data for the Mortandad watershed are compared with water screening action levels (wSALs) established under the FFCA/AO. The wSAL for an analyte is designated as the lowest numeric criterion of the applicable NMWQCC water quality criteria (WQC) established in State of New Mexico Standards for Interstate and Intrastate Surface Waters (NMAC 20.6.4), if one exists. The wSALs for each contaminant are determined in stepwise fashion by evaluating, in the following order

- requirements for any FFCA-monitored segment that is included in a classified water of the state in 20.6.4.101 through 20.6.4.899 NMAC;
- requirements for any FFCA-monitored surface water that is not included in a classified water of the state in 20.6.4.101 through 20.6.4.899 NMAC; or
- *Federal Register,* EPA. Multi-Sector General Permit benchmark values for Sector K, Hazardous Waste Treatment, Storage, or Disposal Facilities.

Classified waters of the state that are described in NMAC 20.6.4.101 through 20.6.4.899 have segment-specific designated uses. Nonclassified surface waters are described as ephemeral (NMAC 20.6.4.97), intermittent (NMAC 20.6.4.98), or perennial (NMAC 20.6.4.99), each of which has designated uses. The designated uses for surface water are associated with use-specific WQC, including numeric criteria. Stormwater in the Mortandad watershed is described as nonclassified, ephemeral; the relevant list of wSALs and their bases are provided in Appendix C.

6.0 CANYONS CONTAMINATION

This section describes the methodology and results of analytical data screening assessments for samples collected to identify COPCs in sediment, surface water, groundwater, and core samples. Identifying COPCs forms the basis for evaluating contamination in canyons media. All COPCs identified in this section are evaluated in human health risk assessments in Section 8.2 and have been considered in developing the measures evaluated in the baseline ecological risk assessment in Section 8.1. A subset of these COPCs is discussed in the conceptual model in Section 7. Section 6.1 briefly describes how the data were prepared for the screening processes. Section 6.2 presents the screens for sediment, Section 6.3 presents the screens for surface water and groundwater, and Section 6.4 presents the screens for core samples. The term “sediment” includes all post-1942 sediment deposits in the canyon bottoms, including deposits in abandoned channels and floodplains as well as in active stream channels; therefore, sediment includes alluvial soils as defined in some other studies.

6.1 Data Preparation

The data used in the following assessments were obtained from the Environmental Restoration Database (ERDB) and the Water Quality Database (WQDB) (on DVD as Attachment 1). All data are presented in Appendix C, Analytical Results (on CD).

Certain analytical results are not evaluated in the screens and subsequent risk assessments for the following reasons.

- Semivolatile organic compound (SVOC) results from samples analyzed by a volatile organic compound (VOC), PAH, or high explosives (HE) analytical method. These duplicate results are excluded from the screen because the VOC, PAH, and HE analytical methods provide lower detection limits than the SVOC method.
- Field duplicate results. These results are from samples obtained for quality assurance/quality control (QA/QC) purposes and not as primary characterization data.
- Isotopic thorium results by gamma spectroscopy. For sediment, these results are excluded because gamma spectroscopy analysis yields results that cannot be directly compared with sediment background values (BVs).
- Results from composite sediment samples collected to support ecological risk studies. These composite samples are used to support the ecological risk assessment in Section 8.1, but they cannot be compared with the other samples in this investigation; therefore, they have been excluded from the screens and from the subsequent human health risk assessments.
- Samples collected from material that has since been excavated (indicated by a "Y" in the excav_flag field in the Appendix C analytical results tables). These data are not representative of current site conditions, so they are excluded from the COPC identification process. However, these data are used in the conceptual site model in Section 7.1.
- Results from water samples collected before 2000. These results are not used in the COPC screens because in many instances the data do not have accompanying data packages for validation and are considered screening level. Also, concentrations in older data are not representative of current site conditions. However, pre-2000 data are used in the trend analyses presented in the conceptual site model in Section 7.2.

6.2 Contaminants in Sediment

This section presents the process for screening analytical results obtained from sediment samples collected in the Mortandad watershed. Samples collected and analyses performed by the analytical laboratories are presented in Table C-2.0-1 in Appendix C. Sample locations are presented in Plates 2 through 5. Analytical results were screened to develop a list of COPCs, as presented in Section 6.2.1.

6.2.1 Identification of Sediment COPCs

Sediment COPCs are identified by a screening process that includes comparing the maximum chemical concentrations by reach with Laboratory-specific sediment BVs (presented in LANL 1998, 59730). Analytes are retained as COPCs using rules specific to the class of analyte. This process is discussed below.

For inorganic chemicals, an analyte is retained as a COPC in a reach if

- the analyte has a BV and a detected or nondetected result in the reach exceeds the BV, or
- the analyte does not have a BV, but at least one detected result is in the reach.

For radionuclides, an analyte is retained as a COPC in a reach if

- the analyte has a BV and at least one detected result in the reach exceeds the BV, or
- the analyte does not have a BV but has at least one detected result in the reach.

There are no BVs for organic chemicals, and retaining an organic chemical as a COPC is based solely on detection status. For organic chemicals, an analyte is retained as a COPC in a reach if there is at least one detected result in the reach.

A total of 38 inorganic chemicals, 74 organic chemicals, and 17 radionuclides were retained as COPCs in sediment in the Mortandad watershed. Maximum sample results in each reach for these COPCs are presented in Tables 6.2-1, 6.2-2, and 6.2-3 for inorganic chemicals, organic chemicals, and radionuclides, respectively.

6.2.2 Comparison of Sediment COPC Concentrations to Residential SSLs and SALs

Maximum concentrations (including detection limits for inorganic chemicals) of sediment COPCs in each reach were compared with residential SSLs for inorganic and organic chemicals or residential SALs for radionuclides to identify which are most important for understanding potential human health risk. A total of three inorganic COPCs, two organic COPCs, and nine radionuclide COPCs have maximum concentrations exceeding residential SSLs or SALs in the Mortandad watershed, and these are included in the conceptual model for sediment in Section 7.1. These COPCs are highlighted in gray in Tables 6.2-1, 6.2-2, and 6.2-3.

6.3 Contaminants in Surface Water and Groundwater

This section presents the process for screening surface water and groundwater sample results from the Mortandad watershed. Samples collected and analyses performed by the analytical laboratories are presented in Table C-2.0-2 in Appendix C. Sample locations are presented in Plates 2 through 5. Analytical results from water samples were screened to develop a list of COPCs, as presented in Section 6.3.1.

6.3.1 Identification of Surface Water and Groundwater COPCs

There are no BVs for water data, and COPCs are identified by a screening process that is based only on the detection status. This process is performed for groups of data defined by field preparation (filtered or nonfiltered samples) and analyte type (inorganic chemicals, organic chemicals, and radionuclides). No organic chemical analyses were obtained from filtered water samples. An analyte is retained as a COPC for a location if the chemical has at least one detected result.

A total of 62 inorganic chemicals, 42 organic chemicals, and 16 radionuclides were retained as COPCs in surface water and/or groundwater in the Mortandad watershed. Maximum sample results at each sample location for these COPCs are presented in Tables 6.3-1 through 6.3-5.

6.3.2 Comparison of Water COPC Concentrations to Standards

Maximum detected concentrations of water COPCs by location and field preparation were compared with applicable water standards, as discussed in Section 5, to identify which are most important from a regulatory perspective. A total of six inorganic chemicals and one radionuclide have maximum detected concentrations in intermediate-depth or regional groundwater exceeding groundwater standards and are

discussed in the conceptual model for water in Section 7.2. COPCs exceeding standards are highlighted in gray in Tables 6.3-1 through 6.3-5.

6.4 Contaminants in Core Samples

This section presents the process for screening analytical results obtained from core samples collected in the Mortandad watershed. Samples collected and analyses performed by the analytical laboratories are presented in Table C-2.0-3 in Appendix C. Sample locations are presented in Plates 2 through 5. Analytical results were screened to develop a list of COPCs, as presented in Section 6.4.1.

6.4.1 Identification of Core COPCs

COPCs in core samples are identified by a screening process that includes comparing the maximum inorganic chemical or radionuclide concentrations by location and geologic unit with Laboratory-specific BVs presented in LANL (1998, 59730). Analytes are retained as COPCs using rules specific to the class of analyte. This process is discussed below.

For inorganic chemicals, an analyte is retained as a COPC in a borehole if

- the analyte has a BV and a detected or nondetected result in the geologic unit that exceeds the BV, or
- the analyte does not have a BV, but there is at least one detected result in the geologic unit.

For radionuclides, an analyte is retained as a COPC in a borehole if

- the analyte has a BV and at least one detected result in the geologic unit exceeds the BV, or
- the analyte does not have a BV but has at least one detected result in the geologic unit.

A total of 22 inorganic chemicals and 8 radionuclides were retained as COPCs in core samples in the Mortandad watershed. Maximum sample results at each borehole for these COPCs are presented in Tables 6.4-1 and 6.4-2 for inorganic chemicals and radionuclides, respectively. No organic chemical analyses were obtained from core samples, so there are no organic COPCs identified in the boreholes.

6.4.2 Comparison of Core COPC Concentrations to Residential SSLs and SALs

Maximum concentrations (including detection limits for inorganic chemicals) of COPCs by borehole and geologic unit were compared with residential SSLs for inorganic chemicals or residential SALs for radionuclides for purposes of comparison with results in other media. Only one inorganic COPC, iron, has a maximum result from a borehole exceeding residential SSLs. This result is highlighted gray in Table 6.4-1. No radionuclides exceeded residential SALs.

6.5 Summary

Table 6.5-1 presents a summary of the COPCs in sediment, water, and core samples collected from the Mortandad watershed to allow comparisons between media. Table 6.5-1 also indicates which COPCs have maximum results in the watershed exceeding SSLs, SALs, and standards.

7.0 PHYSICAL SYSTEM CONCEPTUAL MODEL

This section discusses aspects of the physical system conceptual model that are relevant for understanding the nature, sources, extent, fate, and transport of contaminants in the Mortandad watershed. The discussion on contaminants focuses on COPCs that are shown to be most important for evaluating potential present-day human health risk based on the comparisons with SALs, SSLs, and standards in Section 6 and that represent known contaminant releases into the watershed. These COPCs are included in evaluations of potential human health risk in Section 8.2. This section also includes discussion of other COPCs that were identified as study design COPECs and are relevant for evaluating potential present-day ecological risk. Some additional COPCs are discussed to provide insights into sources and trends of contaminants historically or otherwise important in the watershed, including some COPCs that were detected on San Ildefonso Pueblo land and that are relevant for understanding the downcanyon extent of Laboratory-derived contamination. As used in this section, "contaminants" refers to COPCs that are known to represent releases from Laboratory SWMUs or AOCs or other anthropogenic sources, whereas "COPC" is a more general term that also includes analytes identified in Section 6 that may or may not represent such releases.

The following discussion is divided into three sections. Section 7.1 describes spatial and temporal trends for contaminants in sediments and the fluvial processes controlling their distributions. Section 7.2 describes the hydrology of the watershed, including descriptions of surface water, alluvial groundwater, pore water, intermediate-perched groundwater and regional groundwater, and summarizes spatial and temporal trends for contaminants in these media. Together, the data presented in Sections 7.1 and 7.2 are used to identify contaminant sources and to understand contaminant transport away from the source areas. Section 7.3 presents a summary of the physical system conceptual model based on the combined contaminant and pathways data. Key aspects of the physical system conceptual model are shown in Figure 7.0-1. Supporting information about trends in hydrologic conditions and contaminant distributions that support the conceptual model is presented in Appendixes B, D, F, G, H, I, J, K, L, M, N, O and P.

In the following discussion, metric units followed by English units in parentheses are generally employed. However, some data such as transducer data for alluvial wells, precipitation data collected at TA-06, and streamflow gage data were all collected and reported in English units (feet, inches, and cubic feet per second, respectively). Because of the voluminous nature of these data, the original units are maintained in some graphs and tables.

7.1 Contaminants in Sediments

This section discusses general aspects of contaminants associated with sediment in the Mortandad watershed, including how the distribution and concentration of contaminants are affected by fluvial processes acting over decadal time periods after releases. Subsequent sections discuss details of the distribution and concentration of specific COPCs in sediment deposits in the watershed that are important for evaluating potential human health or ecological risk or the downcanyon transport of contaminants in floods. In this section, the term "contaminant" is used to refer to COPCs that are known to represent releases from Laboratory SWMUs or AOCs or other anthropogenic sources, whereas "COPC" is a more general term that also includes analytes identified in Section 6 that may or may not represent such releases. For example, some COPCs identified by comparison with BVs or detection limits may represent naturally elevated concentrations or false positives from analytical laboratories, as discussed below.

Most contaminants in sediment in the Mortandad watershed that were derived from Laboratory sources were originally released in wastewater from outfalls (Purtymun 1967, 11785; Purtymun 1971, 4795; Hakonson and Bostick 1976, 29678; Nyhan et al. 1982, 7164; LANL 1997, 56835). Because streambeds

on the Pajarito Plateau are usually dry, effluent that did not infiltrate into soils between the outfalls and the channel generally infiltrated into the streambeds. The downcanyon extent of effluent flow varied with release volume and prior moisture conditions along the channel. Nyhan et al. (1978, 5726) reported that in the early 1970s, when the discharge volume was relatively high (Figure 2.1-1), effluent extended for 1.5 km (1 mi) or less downcanyon from the TA-50 RLWTF outfall, indicating that infiltration of effluent in Mortandad Canyon during this period generally occurred upcanyon from reach M-3W. Observations from the early to mid-1960s indicate that effluent sometimes reached M-3W when TA-48 and TA-50 were concurrently discharging wastewater (Purtymun 1967, 11785, p. 36). Discharge volume has been progressively decreasing since the early 1980s (Figure 2.1-1), and infiltration of effluent at present occurs over a shorter stretch of channel.

Once in the streambed, dissolved contaminants commonly adsorb to sediment particles or organic matter because of the geochemical behavior of most radionuclides, metals, and organic chemicals that are of concern in this investigation (Watters et al. 1983, 11888; Salomons and Forstner 1984, 82304; Lopes and Dionne 1998, 82309). Exceptions include perchlorate and tritium which are highly soluble, nonsorbing analytes that remain dissolved in water; as discussed in more detail in Section 7.2. Many contaminants preferentially bind to clay minerals or organic particles, but they will also bind to other mineral particles. Contaminants will preferentially bind to smaller particles because of their larger ratio of surface area to mass and greater electrostatic attractions, and Nyhan et al. (1976, 11747) have documented a general inverse relation between contaminant concentration and particle size of streambed sediment on the Pajarito Plateau. Preferential adsorption to finer particles and organic matter also occurs when wastewater infiltrates into soils on hillslopes. Because of the general inverse correlation of contaminant concentrations with sediment particle size, concentrations can be an order of magnitude higher in the finest-grained sediment deposits, which contain up to 80% or more silt and clay than in coarse-grained sediment deposits that contain < 5% silt and clay (Reneau et al. 2004, 93174; LANL 2004, 87390).

Once adsorbed to sediment particles in the streambed, contaminants can subsequently be redistributed by floods that scour the streambed and mobilize the bed sediment. Contaminants in the streambed that originated as solid particles will behave similarly to those originally released as dissolved components in wastewater. Contaminants associated with coarse-size fractions (coarse sand and coarser; >0.5 mm [0.02 in.]) are generally transported as bed load along the streambed, whereas contaminants associated with fine-size fractions (fine sand and finer; <0.25 mm [0.01 in.]) are generally transported in suspension (Malmon 2002, 76038, pp. 108–114; Malmon et al. 2004, 93018). Contaminants associated with medium sand (0.25–0.5 mm [0.01–0.02 in.]) can be either transported as bed load or as suspended load. The coarse sediment fractions typically travel shorter distances during a flood than fine fractions because of their interactions with other sediment particles on the streambed, and they are usually redeposited within the channel during waning stages of a flood. In areas where the channel is aggrading (raising its elevation through sediment deposition) and where there are no stream banks or where banks are low, coarse sediment can be deposited over adjacent floodplains. In floods that overtop stream banks or where there are no stream banks, some of the fine particles and associated contaminants carried in suspension are also deposited on adjacent abandoned channels or floodplains as flow depth, and velocity decreases relative to the main channel. In large flood events, contaminants can be distributed across the entire width of floodplains in canyon bottoms. In reaches where transmission losses into the streambed exceed discharge, all sediment is deposited. Additional fine particles are deposited on or infiltrate into the streambed during waning stages of flow to be potentially scoured and resuspended in subsequent events.

During floods, sediment from a variety of sources is mixed, changing contaminant concentrations longitudinally along a channel. Where runoff from a contaminant source area enters a stream draining noncontaminated or less-contaminated areas, contaminant concentrations in sediment carried by a flood typically decrease relative to the source area while they increase relative to areas upstream from the

contaminant source. Downcanyon, where runoff from tributaries draining noncontaminated or less-contaminated areas joins a stream in flood, concentrations may be further reduced. Some of the sediment transported in floods is eroded from the bed and banks of the channel, and this erosion can also change contaminant concentrations in a flood. As a flood from noncontaminated areas erodes contaminated sediment downcanyon from source areas, contaminant concentrations in transported sediment increase. Similarly, when a flood draining contaminated areas erodes noncontaminated or less-contaminated material along the channel, concentrations in transported sediment decrease. The net result is a general downcanyon decrease in contaminant concentrations in sediment with distance from a contaminant source area (e.g., Marcus 1987, 82301; Graf 1996, 55537; Reneau et al. 2004, 93174) and an increase in contaminant concentrations along main channels where significant amounts of contaminants are provided from tributaries (LANL 2004, 87390).

Contaminant concentrations in sediment carried in floods also change over time in relation to the history of contaminant releases. Concentrations are generally highest during the period of peak contaminant releases and decrease over time as a result of the mixing processes discussed above. Such decreases over time have been documented in the Los Alamos and Pueblo Canyon system (Malmon 2002, 76038, pp. 315–322; LANL 2004, 87390, pp. 7–8; Reneau et al. 2004, 93174, pp. 1216–1217), as well as in other regions (Lewin et al. 1977, 82306, p. 357; Rowan et al., 1995, 82303, p. 61). Removing or stabilizing contaminants in source areas can help accelerate these natural decreases in contaminant concentrations over time.

Multiple floods occurring over decadal time periods result in sediment deposits in each reach that have a range in age and particle size distribution and hence in contaminant concentration. Schematic cross sections illustrating the distribution of coarse and fine sediment in reaches in the Mortandad watershed are shown in Figures 7.1-1, 7.1-2, and 7.1-3. The term “coarse facies” is used to refer to sediment with median particle size in the less than 2-mm (0.08-in.) fraction of medium to very coarse sand, and these deposits commonly have a high gravel content. The term “fine facies” is used to refer to sediment with median particle size of silt to medium sand. The active channel (c1 geomorphic unit) is typically dominated by relatively young coarse facies sediment deposits. In some parts of the Mortandad watershed, cattail wetlands occur along the active channel (c1ct unit; e.g., reach E-1W in Figure 7.1-2), and fine facies sediment is commonly deposited in these areas where floodwaters spread and energy drops. Abandoned channels (c2 and c3 units), which are areas occupied by the channel sometime after 1942 but subsequently abandoned following channel migration and/or channel incision, typically include fine facies sediment overlying older coarse facies sediment. Abandoned channels can also include coarse deposits as the uppermost, youngest layer (e.g., reach M-4C in Figure 7.1-3). Post-1942 floodplains (f1 unit) typically include thinner layers of post-1942 fine facies sediment that bury pre-1943 soils. (See Section B-1 of Appendix B for additional discussion of sediment facies and geomorphic units.)

As shown in Figures 7.1-1 and 7.1-3, the layers with the highest contaminant concentration in a reach are typically at depth, buried by younger sediment layers with lower concentrations, although they can also occur at the surface (e.g., cesium-137 in reach M-3E, Figure 7.1-2). The highest concentrations can also occur in very small sediment deposits in narrow canyons close to the sources, including the watershed maximums for americium-241, cesium-137, and strontium-90 in reach E-1E and chromium in reach E-1FW (Figure 7.1-1). These figures also show how the relation of sediment layers to trees provides one means of estimating the thickness and age of different sediment layers (tree age determined from tree-ring dating [dendrochronology]; see Section B-1 (in Appendix B) for more discussion of field investigation methods). Plates 2 through 5 show the distribution of geomorphic units in the investigation reaches.

Volumes of contaminated post-1942 sediment vary longitudinally along the canyons, resulting in part from variations in channel gradient and the width of post-1942 geomorphic units, as shown in Figure 7.1-4. Mortandad Canyon contains relatively large volumes of post-1942 sediment associated with wide areas of the canyon bottom near the Ten Site Canyon confluence. Width and volume of post-1942 sediment deposits in Mortandad Canyon increase beginning in reach M-3W, where the channel gradient decreases and the canyon bottom widens. Maximum volume is in reaches M-3E and M-4C, and the maximum average width of about 60 m (200 ft) is in M-4C. Other areas of locally high volume and width and lower gradient, relative to nearby reaches, include reaches E-1W, PCYN, TS-1C, and TS-3. In contrast, width and volume are generally lowest in relatively steep reaches, such as E-1FW, E-1E, and TS-2E.

Parts of Mortandad Canyon include discontinuous channels, features that are common in many arid and semiarid areas (Bull 1997, 93908) and that enhance the spreading and infiltration of floodwaters and the deposition of sediment and associated contaminants. Where channels end and runoff becomes unconfined, floodwaters can spread over large areas, such as M-4C and the western part of M-5W (Figure 3.2-1 and Plate 4). Runoff from these areas typically feed into headcuts, below which flow is again generally confined within narrow channels. Examples of the beginning of channels at headcuts occur in reaches M-4E and M-5W (Plate 4).

Most of the contaminants in sediments in Mortandad watershed occur in areas of post-1942 sediment deposition outside the active stream channels, as also seen in the Los Alamos and Pueblo watershed (LANL 2004, 87390; Reneau et al. 2004, 93174) and in Cañon de Valle (LANL 2003, 77965; Reid et al. 2005, 91247). At present, these deposits probably constitute the primary source for contaminants carried by floods, as observed in other regions (e.g., Rowan et al. 1995, 82303, pp. 63–64), with active channels and erosion from hillslopes constituting lesser sources. The concentration and inventory (amount) of contaminants in deposits outside the active channel vary longitudinally within the canyons. Concentrations are typically highest in fine sediment deposits near the sources that date to the period of contaminant releases and decrease in younger deposits, in coarser deposits, and downcanyon. Contaminant inventories display more irregular patterns than contaminant concentrations and are related to longitudinal variations in the volume, grain size, and age of sediment deposits within a canyon. Subsequent sections provide examples of the variations in contaminant concentration and inventory in sediment deposits within the Mortandad watershed.

Variations in background concentrations of some analytes in sediment can complicate the identification and evaluation of contaminants related to Laboratory releases. For example, background concentrations of fallout radionuclides in sediments have been shown to vary between regional rivers and reservoirs (McLin and Lyons 2002, 82305) and between these settings and canyons on the Pajarito Plateau (Ryti et al. 1998, 59730; McDonald et al. 2003, 76084). Background concentrations of some inorganic chemicals in sediments have also been shown to vary between different areas on the Pajarito Plateau as a result of local variations in soils or bedrock (Drakos et al. 2000, 68739). Because soils on the Pajarito Plateau have higher concentrations of many inorganic chemicals than sediments (Ryti et al. 1998, 59730), deposition of sediment derived from locally eroded soils provides a possible source for elevated concentrations of inorganic chemicals in sediments.

Mineralogic variations within naturally occurring sediment can also contribute to background variations, for example, the higher concentrations of many metals in black magnetite-rich sands on the Pajarito Plateau, such as iron, manganese, nickel, thallium, vanadium, and zinc (Reneau et al. 1998, 62050, pp. 12–14). Additional variations in background concentrations are the result of incorporation of ash transported from the Cerro Grande burn area, since ash contains higher concentrations of fallout radionuclides and many inorganic chemicals than pre-fire sediment (Katzman et al. 2001, 72660; Gallaher et al. 2002, 82265; Kraig et al. 2002, 85536; Johansen et al. 2003, 82312; LANL 2004, 87390).

Finally, concentrations of various inorganic and organic chemicals in sediment may be elevated near urbanized or industrial areas as a result of runoff from roads and other developed areas (Edwards 1983, 82302; Lopes and Dionne 1998, 82309; Walker et al. 1999, 82308; Breault and Granato 2000, 82310; van Metre et al. 2000, 82262), further complicating the identification and evaluation of contaminants related to Laboratory releases. The topics of variations in background concentration and contributions from developed areas as they relate to key contaminants in the Mortandad Canyon system are discussed in subsequent sections.

7.1.1 Radionuclides in Sediments

Nine radionuclides detected in sediments in the Mortandad watershed have maximum results greater than residential SALs and are more important for assessing potential human health risk: americium-241, cesium-137, cobalt-60**,** plutonium-238, plutonium-239,240, strontium-90, thorium-228, thorium-230, and thorium-232. This section focuses on spatial and temporal variations in radionuclides in the Mortandad watershed, and supporting information is included in Appendix D.

7.1.1.1 Sources and Spatial Variations in Radionuclide Concentrations

Radionuclides in sediments in the Mortandad watershed have several sources, as indicated by their spatial distribution, and concentrations typically decline downcanyon from the source areas. Subsequent discussions focus on the nine radionuclides that are most important for evaluating potential human health risk, based on comparison to residential SALs in Section 6.2.2: americium-241, cesium-137, cobalt-60**,** plutonium-238, plutonium-239,240, strontium-90, thorium-228, thorium-230, and thorium-232. Figure D-1.1.1 in Appendix D includes additional plots that show all sample results for radionuclide COPCs plotted against distance from the Rio Grande. Figure D-1.1.1 plots help to identify sources, although these data are biased high because fine-grained sediment layers from the most contaminated geomorphic units in a reach were preferentially sampled. In addition, these plots include some relatively high values from earlier sampling events that could not be replicated in later events.

Figures 7.1-5 to 7.1-10 show the estimated average concentrations of radionuclides whose concentrations and spatial trends indicate clear sources at Laboratory SWMUs or AOCs and whose maximum concentrations exceed residential SALs: americium-241, cesium-137, cobalt-60**,** plutonium-238, plutonium-239,240, and strontium-90. These are volume-weighted averages in post-1942 fine facies sediment in investigation reaches, where average radionuclide concentrations in a geomorphic unit in a reach are weighted by the volume of fine facies sediment in that unit, removing most of the bias introduced during sample collection. (Sample collection is biased toward geomorphic units and sediment facies with relatively high contaminant concentrations, as discussed in Section B-1 of Appendix B, and straight averages of all sample results from a reach are overestimates of true averages.) Averages for fine facies sediment are shown because average concentrations in this type of sediment are, with a few exceptions, higher than in coarse facies sediment, and fine facies deposits are therefore more important for evaluating risk. Average concentrations for both fine and coarse facies sediment in each reach are presented in Tables D-1.5-1 to D-1.5-6 (Appendix D). In Figure 7.1-10, the sediment BV for strontium-90 is shown for comparison; BVs are too low for the other radionuclides to show at the scales used in the figures.

The most important sources for radionuclide COPCs in the Mortandad watershed are the TA-50 RLWTF outfall into reach E-1E, the former TA-35 WWTP outfall into Pratt Canyon (reach PCYN), and the accidental releases in 1974 from TA-50 into the head of Ten Site Canyon (reach TS-1W), as shown in Figures 7.1-5 to 7.1-10. Average concentrations of americium-241, cesium-137, cobalt-60**,** and plutonium-239,240 are highest in reach E-1E in Effluent Canyon, and plutonium-238 and strontium-90 are

also present there above background concentrations. Average concentrations of plutonium-238 are highest in Ten Site Canyon between TA-50 and Pratt Canyon; americium-241, cesium-137, cobalt-60, plutonium-239,240, and strontium-90 have also been identified there as COPCs. Average concentrations of strontium-90 are highest in Pratt Canyon; and americium-241, cesium-137, cobalt-60, plutonium-238, and plutonium-239,240 have also been identified there as COPCs. Some of these radionuclide COPCs have been detected above BVs in other areas that suggest the possibility of additional sources, but concentrations are low, and no significant increase in average concentrations is indicated in Figures 7.1-5 to 7.1-10. If releases of radionuclides occurred from other SWMUs or AOCs, they were apparently small.

The pattern of downcanyon decline in radionuclide concentrations is notably different between the different sources, as shown in Figures 7.1-5 to 7.1-10. Downcanyon from the RLWTF outfall into Effluent Canyon, radionuclides generally show decreasing trends for about 3–4 km (1.9–2.5 mi), east of which their average concentrations are similar to background levels. In Ten Site Canyon, the highest concentrations of plutonium-238 are found within 1 km (0.6 mi) of the accidental releases from TA-50, and concentrations are much lower downcanyon—less than in Mortandad Canyon, which is an equal distance downcanyon from the RLWTF (Figure 7.1-8). Similarly, although the average concentration of strontium-90 is much higher in Pratt Canyon than in Effluent Canyon, concentrations are relatively low farther downcanyon in Ten Site Canyon compared with Mortandad Canyon above the Ten Site Canyon confluence (Figure 7.1-10). The occurrence of relatively low-gradient areas near the contaminant sources in Pratt and Ten Site Canyons, where sediment is preferentially deposited (Figure 7.1-4), contributes to the differences seen between canyons. The relatively small drainage areas of Pratt and upper Ten Site Canyons, compared with Mortandad Canyon below the Effluent Canyon confluence, also lead to smaller-magnitude floods and lower transport rates of sediment and associated contaminants from Pratt and upper Ten Site Canyons.

Several deviations from the general downcanyon decline in average radionuclide concentrations are seen in Figures 7.1-5 to 7.1-10 that reflect some of the complexity in the present distribution of contaminants. This complexity probably results at least in part from the combined effects of temporal variations in contaminant releases and spatial and temporal variations in downcanyon sediment erosion and deposition during floods in the subsequent decades, as documented previously in the Los Alamos and Pueblo watershed (LANL 2004, 87390; Reneau et al. 2004, 93174). For example, the higher average concentrations of cesium-137 and other radionuclides in reach M-3E than the concentrations that are immediately upcanyon in M-3W probably records preferential deposition of sediment in M-3E during the period of peak cesium-137 releases from the RLWTF and the general stability of these sediment deposits since that time (as discussed later). In contrast, analytical data from reach M-3W indicate that most of the sediment is younger, postdating the period of peak releases, recording either nondeposition or subsequent erosion of deposits from that time period. The higher average concentrations of cesium-137 and plutonium-238 in M-2E relative to M-2W may similarly record preferential deposition in M-2E during the period of peak releases of these radionuclides, in contrast to americium-241, cobalt-60, plutonium-239,240, and strontium-90, which have higher average concentrations in M-2W.

The general downcanyon decrease in average radionuclide concentrations discussed above applies only to historic sediment deposits that integrate the effects of changing discharge from the sources and downcanyon transport over decadal time frames. Samples collected from the active channel (c1 unit) and associated low surfaces (c1b unit) in 2004 from the TA-50 RLWTF outfall to near the confluence of Mortandad and Ten Site Canyons show a different pattern. This pattern indicates the primary source of radionuclides currently transported by floods is remobilization of sediment previously stored along the channel and in adjacent geomorphic units. Figure 7.1-11 shows that fine facies sediment adjacent to the channel in 2004 (median particle size of coarse silt to fine sand) had the lowest concentrations of cesium-137 in reach E-1E near the RLWTF outfall and that concentrations progressively increased

downcanyon. Cesium-137 concentrations in coarse facies sediment (median particle size of coarse to very coarse sand) were much lower than in the fine facies sediment but also showed relatively low concentrations near the outfall and higher concentrations downcanyon. Concentrations in fine facies sediment increased downcanyon in 2004 because of the erosion of sediment deposits along the channel containing relatively high concentrations of cesium-137. The relatively low concentrations in E-1E, close to the outfall in the reach with the highest concentrations of cesium-137 in older sediment deposits, suggest that most of the sediment in the active channel in this reach is derived from upcanyon of the RLWTF outfall, with relatively small contributions from bank erosion in E-1E. In contrast to the fine facies samples, cesium-137 concentrations in coarse facies samples are similar from M-2W to M-3E, except for a somewhat higher result in M-3W (Figure 7.1-11), suggesting that neither net enhancement nor dilution of cesium-137 is occurring over this 2-km stretch of canyon in coarse sediment associated with mixing of sediment from different sources.

Data from environmental surveillance sampling stations (e.g., ESP 2005, 92222), representing sediment collected from the stream channel, show the same lack of systematic variations in cesium-137 concentration between Effluent Canyon and the Ten Site Canyon confluence (reaches M-2W to M-3E) as seen in coarse facies samples from 2004. Figure 7.1-12 shows average concentrations of cesium-137 in samples collected over the 10-yr period from 1996 to 2005 at surveillance stations in Mortandad Canyon. Concentrations are relatively high and similar at the stations below Effluent Canyon (gaging station E200, reach M-2W), at well MCO-5 (reach M-3W), and above the sediment traps (gaging station E202, confluence of Mortandad and Ten Site Canyons). Concentrations decrease downcanyon from there to well MCO-9.5, west of reach M-5W, and are at background levels farther downcanyon. Cesium-137 concentrations are also at background levels in Mortandad Canyon above Effluent Canyon (Figure 7.1-12).

For several radionuclides that have maximum results above residential SALs, available data do not indicate clear sources at Laboratory SWMUs or AOCs and/or releases that were large enough to noticeably affect average concentrations in a reach. Specifically, thorium-228, thorium-230, and thorium-232 all have maximum values above sediment BVs, but average concentrations calculated for both fine and coarse facies sediment are generally less than background averages, as shown in Table D-1.5-7. Thorium-228 only had one result above the BV, from reach TS-1C in 2004 (sample CAMO-04-53373), and resampling of this sediment layer in 2005 yielded a result below the BV (sample CAMO-05-63743). Thorium-230 had only three results above the BV: two from TS-1C (samples CAMO-04-53373 and CAMO-04-53376) and one from reach MCW-1 (sample CAMO-03-49826). The MCW-1 result was only 7% higher than the BV (2.44 vs. 2.28 pCi/g), and resampling of the TS-1C sample layers in 2005 yielded thorium-230 results below the BV (samples CAMO-05-63743 and CAMO-05-63744). Thorium-232 had three results above BVs: one from M-1C and two from TS-1C. The M-1C result was less than twice the BV (3.48 vs. 2.33 pCi/g), and the TS-1C results were not confirmed upon the resampling discussed for thorium-228 and thorium-230. In summary, available data for these thorium isotopes do not clearly indicate sources at SWMUs or AOCs, and if releases occurred, they were too small to elevate average concentrations in a reach above background averages.

7.1.1.2 Collocation of Radionuclides

The different radionuclide COPCs are generally collocated in sediment deposits in the different reaches in the Mortandad watershed, primarily occurring in post-1942 sediment deposits and preferentially occurring in fine rather than coarse facies sediment. However, the maximum concentrations of each radionuclide may not occur in the same sediment layers in each reach because the relative concentrations of radionuclides in effluent released from outfalls varied over time both as a result of changes in research activities at the Laboratory and changes in wastewater treatment methods. These variations are

discussed further in Section 7.1.1.3. Additional variations result from the mixing of sediment and associated contaminants from different sources and possibly from variable geochemical behavior between radionuclides.

The best correlations between radionuclides downcanyon from the TA-50 RLWTF outfall generally occur between americium-241 and plutonium-239,240 and between cesium-137 and strontium-90, suggesting similar histories of release and transport for these pairs of radionuclides. Good correlations can also exist between other pairs of radionuclides in a reach, although in the complete data set more variability is present that indicates the presence of multiple populations of samples. As examples, Figure 7.1-13 presents scatter plots that show relations between select pairs of radionuclides in M-2E and in the entire data set from the RLWTF outfall through M-4. Both data sets show good correlations between cesium-137 and strontium-90. Correlations are also generally good between americium-241 and plutonium-239,240, although a scattering of samples with high results for plutonium-239,240 deviate from the general trend. Good correlations exist between cesium-137 and plutonium-238 in M-2E, but in the entire data set, distinct populations can be seen that record differences in the ratios between these radionuclides, and the overall correlation is poor. For comparison, relations between plutonium-238 and plutonium-239,240 are poor in both data sets. As discussed in Sections 7.1.1.3 and D-1.6 (Appendix D), populations of samples with different radionuclide ratios are associated with changes in the RLWTF release history and reflect sediment deposits of different age.

Plutonium-238 has maximum concentrations in the Mortandad watershed in Ten Site Canyon upcanyon from Pratt Canyon, and plutonium-239,240 is also elevated in the same reaches. The maximum measured concentrations of both plutonium-238 and plutonium-239,240 in Ten Site Canyon occur in the same sample (CAMO-04-53381), a subsurface layer of fine facies sediment in reach TS-1E. Similar but slightly lower values of both isotopes occur in a subsurface layer of fine facies sediment in reach TS-1C (CAMO-04-53378). These data support simultaneous release and similar behavior of these plutonium isotopes in this part of Ten Site Canyon.

Radionuclide concentrations in Ten Site Canyon show less collocation downcanyon from Pratt Canyon, consistent with mixing of sediment from different sources and variable release histories. The highest concentration of strontium-90 in Ten Site Canyon was measured in a fine facies sediment layer in reach TS-2E, about 420 m (1380 ft) downcanyon from Pratt Canyon. The highest plutonium-239,240 concentration in this part of Ten Site Canyon was measured in a different layer in TS-2E, and the highest plutonium-238 concentration downcanyon from Pratt Canyon was measured in a fine-grained sediment layer in TS-2W.

7.1.1.3 Temporal Variations in Radionuclide Concentration

Data from Mortandad Canyon show that the concentrations of radionuclides in both fine- and coarse-grained sediment generally decreased over time following peak contaminant releases. Some examples of these data are presented below. Additional plots of environmental surveillance data for key radionuclides are presented in Section D-1.2 of Appendix D.

Figure 7.1-14 shows time series of cesium-137 concentrations measured at three environmental surveillance stations in Mortandad Canyon since 1977, supplemented by active channel samples from the reach investigations in 1998 to 2005 and from investigations by the Environmental Science Group in 1972 and 1973 (Nyhan et al. 1978, 5726; results from 0–7.5-cm depth). During this period, concentrations in reach M-2W were highest in the 1970s, decreasing to near present values by 1985. Concentrations in reach M-3W were highest in the early 1970s, decreasing more gradually to near present values by 1995.

Concentrations in reach M-4W were highest from the late 1970s to the early 1980s, also decreasing to near present values by 1995. Cesium-137 concentrations have been relatively constant in the active channel at all three sites since about 1995. These data indicate that the effects of the discharge of cesium-137 from the RLWTF were most pronounced close to the source, but concentrations also decreased most rapidly there. Reductions in cesium-137 concentration over time in channel sediments were slower farther downcanyon, although concentrations have been relatively stable for 10 yr in these areas.

Data collected by the Environmental Science Group in 1972 and 1973 (Nyhan et al. 1978, 5726) document the high variability and high concentrations that existed in radionuclides in the active stream channel close to the RLWTF outfall during the early period of releases. Analyses from the Effluent Canyon channel include the highest reported cesium-137 concentrations from the Mortandad watershed, greater than 3000 pCi/g. Figure 7.1-15 plots the results of this sampling (0–7.5-cm depth) versus distance from the outfall and shows that cesium-137 concentrations varied by a factor of 6 in reach E-1E in a single year and also varied between years. In samples from two locations in reach M-2W, cesium-137 concentrations varied by a factor of 2 between 1972 and 1973. Farther downcanyon, in reaches M-2E and M-3W, cesium-137 concentrations were less variable between years. These data support the conceptual model first proposed by Purtymun et al. (1966, 11848; see also Purtymun 1971, 4795; Nyhan et al. 1978, 5726) that during periods of radioactive effluent release, radionuclides first build up in the stream channel alluvium where the effluent infiltrates into the bed. These radionuclides are subsequently remobilized by higher magnitude stormwater runoff events that scour the bed, being transported with sediment particles farther downstream. The high spatial and temporal variability seen in reaches E-1E and M-2W in Figure 7.1-15 is interpreted to correspond to the area where most of the effluent was infiltrating into the streambed and being periodically scoured, and the lower variability downcanyon is interpreted to largely record the effects of sediment mixing during subsequent downcanyon transport, although some direct contact with effluent was reported at the M-2E site (Nyhan et al. 1982, 7164, p. 532).

Figure 7.1-16 shows reconstructions of the concentrations of five key radionuclides in fine facies sediment in reaches M-3, M-4W, and M-4E near the confluence of Mortandad and Ten Site Canyons between 1960 and 2005. These reconstructions use data from sediment samples collected in this investigation and provide trends consistent with discharge records from the RLWTF. The basis for age estimates for individual sediment layers is discussed in Section D-1.6 in Appendix D. Plots for cesium-137 and strontium-90 have been adjusted for radioactive decay to show both estimated average concentrations at the time of deposition and average concentrations in 2006 when this report was written.

Americium-241 and plutonium-239/240 show very similar trends, with very low concentrations before 1975, well-defined maximum concentrations at ca. 1979–1983, and concentrations near current levels after about 1990 (Figure 7.1-16). Discharge records similarly show maximum releases of these radionuclides in 1981–1983 (LANL 1997, 56835, pp. 2-20, 2-21), which indicates rapid transport over the 3 km from the outfall to the confluence of Mortandad and Ten Site Canyons. Plutonium-238 is present at much lower concentrations, with an earlier peak at ca. 1975–1977 that is consistent with discharge records indicating peak releases in 1974–1975 (LANL 1997, 56835, pp. 2-20, 2-21). Plutonium-238 also has a secondary peak of slightly lower magnitude at ca. 1979–1983. Cesium-137 shows more variability in concentrations, with similar-magnitude peaks in the late 1960s and at ca. 1975–1977; no cesium-137 discharge data from the RLWTF are available from this period for comparison. Strontium-90 shows the highest concentrations in the late 1960s, which is consistent with discharge records that indicate the peak releases in 1964–1965 (LANL 1997, 56835, pp. 2-20, 2-21). Figure 7.1-16 shows that by 2006, concentrations of cesium-137 and strontium-90 in sediment deposits from the late 1960s have been

reduced by about 60% due to radioactive decay. Both cesium-137 and strontium-90 show gradual decreases in concentration since about 1987, which may also be largely caused by radioactive decay.

7.1.1.4 Relations between Particle Size and Radionuclide Concentration

The particle size distribution of sediment deposits can have a strong influence on radionuclide concentrations because of the preferential tendency for radionuclides to adsorb onto small particles, although these relations can be obscured because of temporal variations in radionuclide release history and other factors (Reneau et al. 1998, 59160; Reneau et al. 2004, 93174; LANL 2004, 87390). General inverse relations between contaminant concentration and particle size within streambed sediment in Effluent and Mortandad Canyons were previously documented by Nyhan et al. (1976, 11747) for samples collected in the early 1970s. The data collected in this investigation provide additional insights into relations between particle size and radionuclide concentrations in the Mortandad watershed, as discussed below.

Figure 7.1-17 plots concentrations of select radionuclides in sediment samples from the Mortandad watershed against percent silt and clay content (percent in the <2-mm fraction of the sample). Cesium-137 is shown for plots in Effluent and Mortandad Canyons downcanyon from the TA-50 RLWTF outfall (reaches E-1E, M-2W, M-2E, M-3, and M-4), and strontium-90 is shown for Ten Site Canyon downcanyon from Pratt Canyon (reach TS-2). With one exception, radionuclide concentrations in these reaches are highest in fine facies sediment deposits with relatively high silt and clay content. The exception is reach M-2W, where cesium-137 concentrations are highest in coarse facies sediment collected from the c3 and f1g units, although within these samples there is a good correlation between cesium-137 and silt and clay content (Figure 7.1-17). The coarse facies deposits in c3 and f1g are interpreted to represent the active streambed during the period of highest cesium-137 discharges, with the high concentrations resulting from the direct interaction of effluent with streambed sediment. Lower concentrations in coarse facies sediment in other reaches suggest that sampled deposits did not have direct contact with effluent during this period.

The highest radionuclide concentrations in other reaches generally occur in deposits with relatively high silt and clay contents, although there is generally much scatter between radionuclide concentrations and silt and clay content in each reach (Figure 7.1-17). This variability probably results in part from the large temporal variations in radionuclide concentrations discussed in Section 7.1.1.3, combined with the mixing of sediment from different sources. Subsets of the data in a reach can display much more systematic relations, such as the good correlations between cesium-137 and silt and clay content in sediment from ca. 1990 to 2005 in M-3 and M-4 (Figure 7.1-17). The effect of deposit age can be seen in M-4, where the samples with the highest cesium-137 concentration (148–276 pCi/g) were from silt and clay-rich sediment deposited ca. 1974–1978. The relatively high cesium-137 concentrations in fine facies sediment in c3 and f1 units in E-1E and in c3 and f1g units in M-2E (Figure 7.1-17) probably also record sediment deposited during periods of high cesium-137 releases.

7.1.1.5 Radionuclide Inventory

Data collected in this investigation define the general geographic variations in the amount, or inventory, of radionuclides contained in sediment deposits in different parts of the Mortandad watershed. Table 7.1-1 summarizes the geographic distribution of americium-241, cesium-137, cobalt-60, plutonium-238, plutonium-239,240, and strontium-90 in sediment deposits in the watershed, which updates and expands on estimates of cesium-137 inventory in a previous report (Reneau et al. 2003, 77103). Supporting data for Table 7.1-1 are presented in Section D-1 of Appendix D. No inventories are estimated for reaches where these analytes are not COPCs (which would largely or entirely represent inventories associated

with background concentrations). Inventory estimates are also not shown for Mortandad Canyon above Effluent Canyon, Mortandad Canyon east of M-5E, or the unnamed tributary canyon that heads in TA-05 because these areas include less than 0.2% of the estimated inventory for each radionuclide. The inventory estimates in Table 7.1-1 are not adjusted for sediment removed during maintenance of the sediment traps in 2000 (WGII 2000, 70735), although the inventory removed is expected to be minor because of the low concentrations present in the traps and in adjacent fill piles. Estimated inventories are also not adjusted for radioactive decay, which would be more important than the maintenance activities for cesium-137, cobalt-60, and strontium-90 because of their relatively short half-lives (30.1, 5.27, and 28.8 years, respectively; Parrington et al. 1996, 58682). For example, radioactive decay would reduce the concentration of cesium-137 and strontium-90 in a layer sampled in 1998, the first year of this investigation, by about 17% by 2006, the date of this report. Estimates of the amount redistributed by floods since characterization was done are not included, although these will have resulted in some reduction in inventory in upcanyon reaches and increases in downcanyon reaches since this investigation began. Estimates of additions of radionuclides from the RLWTF outfall or from erosion from SWMUs or AOCs are also not included, although these are expected to be minor relative to the total watershed inventory in the canyon bottoms.

Table 7.1-1 shows that reach M-3E in Mortandad Canyon upcanyon from the Ten Site Canyon confluence contains the largest amounts of key radionuclides in the watershed, an estimated 50% to 55% of the americium-241, cesium-137, cobalt-60, and plutonium-239,240. Mortandad Canyon between Effluent Canyon and M-3E contains the second largest amounts of these radionuclides, and reach M-4 contains the third largest amounts. Effluent Canyon contains relatively small amounts of all radionuclides because of the small sediment volumes in the steep and narrow canyon below the TA-50 RLWTF outfall. Ten Site Canyon contains an estimated 33% of the plutonium-238, indicating the importance of the accidental releases in 1974 from TA-50 into the head of the canyon but contains relatively low percentages of the remaining radionuclides. Pratt Canyon is notable for strontium-90, containing an estimated 39% of the watershed inventory, although geomorphically Pratt Canyon is not as well characterized as other reaches and has more uncertainty in the strontium-90 inventory. Because sampling in Pratt Canyon was biased to layers with relatively high field radiation measurements, the total strontium-90 inventory is probably overestimated.

Figure 7.1-18 shows the inventory of cesium-137 in Effluent and Mortandad Canyons plotted against distance from the Rio Grande. The cesium-137 inventory in this figure is plotted both as a normalized inventory in each reach per kilometer of channel ([a] units of mCi/km) and as cumulative amounts from the TA-50 RLWTF outfall to reach M-6 adjacent to SR 4 ([b] units of mCi). The cumulative plot extrapolates between sampled reaches. Figure 7.1-18 shows the estimated inventories in coarse and fine facies sediment deposits as well as the total inventory. Cesium-137 was chosen for these plots because it is the most important radionuclide in the watershed from the perspective of potential human health risk, based on a comparison to residential SALs, and because it illustrates the distribution of a key radionuclide downcanyon from the major source area.

Figure 7.1-18 shows that the radionuclide inventory varies considerably between reaches and that essentially the entire inventory is confined to approximately 4 km (2.5 mi) of canyon between the TA-50 RLWTF outfall and reach M-5W. Most of the inventory is contained within fine facies sediment deposits, and an estimated 79% of the cesium-137 in Effluent and Mortandad Canyons is in deposits of fine facies sediment. The most significant area for cesium-137 inventory in Mortandad Canyon is in reach M-3E, 2.1 to 2.7 km (1.3 to 1.7 mi) downcanyon from the outfall. The inventory is relatively high in this reach because of the deposition of large amounts of sediment where the stream gradient decreases and the canyon bottom widens (Figure 7.1-4). Data from a gross-gamma radiation walkover survey clearly show

the general pattern of cesium-137 deposition in M-3E where floodwaters spread over the canyon bottom (Figure 7.1-19).

7.1.1.6 Flood Attenuation and Downcanyon Extent of Radionuclide Contamination

Gaging station records of stream discharge (e.g., Shaull et al. 2005, 92225; Shaull et al. 2006, 93735), observations made during this investigation, and historical records presented in the work plan (LANL 1997, 56835) indicate that floods generated from upper Mortandad Canyon, Effluent Canyon, and Ten Site Canyon significantly attenuate as they move downcanyon, recording transmission losses into the alluvium. For example, from 1997 to 2004, 16 stormwater events occurred with estimated peak discharges exceeding 10 ft^3/s) recorded at gaging station E200 in Mortandad Canyon, 30 m (100 ft) below the Effluent Canyon confluence, and no events of this size recorded at gaging station E202 2.5 km (1.5 mi) downcanyon, near the confluence of Mortandad and Ten Site Canyons (Shaull et al. 2005, 92225, pp. 49, 125). Field observations indicate that stormwater that reaches the west end of reach M-3E near test well TW-8 generally infiltrates into the alluvium completely before arriving at the Mortandad-Ten Site Canyon confluence 0.6 km (0.4 mi.) downcanyon. These observations are consistent with the occurrence of over 50% of the cesium-137 inventory in M-3E (Section 7.1.1.4), recording deposition of most of the historic sediment load as stormwater infiltrates into the alluvium in this reach. In this area, both the canyon bottom and the active channel widen substantially and the channel gradient decreases (Figure 7.1-4 and Table B-1.0-1 [in Appendix B]), which slows stormwater and enhances its ability to infiltrate.

The distribution of cesium-137 and other radionuclides indicates that stormwater that passed the Mortandad-Ten Site Canyon confluence also generally infiltrated into the alluvium within reach M-4, even before excavation of the current sediment traps in 1986 or the original smaller traps in 1976. The canyon bottom does not have a defined channel in M-4C, east of the sediment traps, and stormwater that reached this area historically spread over an area averaging about 60 m (200 ft) in width, further enhancing infiltration and sediment deposition. The estimated cesium-137 inventory in the first 210 m (690 ft) past the sediment traps, in M-4C, is 4 times as high as the inventory in the next 230 m (755 ft), in M-4E (Table D-1.4-2), documenting this deposition of sediment and associated contaminants. The construction of the sediment traps therefore helped enhance a process of infiltration and sediment deposition that was occurring previously.

Since construction of the current sediment traps in 1986, there are only five known occurrences of overflow: June 7, 1987; July 24, 1991; August 6, 1991; August 24, 2005; and August 25, 2006. The downcanyon extent of the 1987 flood is not known, but in 1997 it was reported to be the “largest runoff event in Mortandad Canyon since hydrologic studies began in the canyon in 1960” (LANL 1997, 56835, p. 3-77). In 1991 flow was reported to have extended 200 m (650 ft) past sediment trap #3 (EPG 1993, 23249; LANL 1997, 56835, pp. 3-80, 3-83), and in 2005 flow extended 85 m (280 ft) past the overflow point of sediment trap #3 before infiltrating into the alluvium (Plate 4). The largest flood since initial releases from the TA-50 RLWTF occurred on August 25, 2006, with flow extending to reach M-5E within 65 m (215 ft) of the Laboratory boundary.

Records of earlier flows are sparse, and only one known event has had possible flow to the Laboratory boundary in reach M-5E, in August 1952, when a record 11.2 in. of precipitation was recorded in Los Alamos in 1 month, and flow in this event may have extended to SR 4 below reach M-6 (LANL 1997, 56835, pp. 3-16, 3-81). This was before initial releases from the TA-50 RLWTF in 1963 but after releases began from the TA-35 WWTP into Pratt Canyon in 1951. An additional large runoff event was noted in November 1978, with flow as far east as well MCO-9, between reaches M-4E and M--5W (Purtymun 1994, 52951, pp. 132–135; LANL 1997, 56835, p. 3-77).

Radionuclides display the clearest evidence of contamination in sediment deposits in the Mortandad watershed from Laboratory releases, possessing the highest concentrations relative to BVs or detection limits and the most systematic downcanyon trends. Therefore, radionuclide data provide insight into the downcanyon extent of Laboratory-derived contaminants that have been transported by floods. Five radionuclides have been detected above BVs in sediment downcanyon of reach M-4E (cesium-137, plutonium-238, plutonium-239,240, strontium-90, and uranium-235), and one additional radionuclide without a BV has been detected east of M-4E (cesium-134). None of these radionuclides were identified as COPCs in reach M-6 near SR 4, indicating the absence of recognizable transport of Laboratory-derived contaminants past SR 4.

The eastern identified extent of strontium-90 above the BV is in reach M-5W, although only one sample had a result above the BV (CAMO-04-53299, 1.68 pCi/g, vs. BV of 1.04 pCi/g). The other five radionuclides are COPCs in reach M-5E at the Laboratory boundary, although with generally low detection frequencies and low values above BVs. Cesium-137 was detected in only 1 out of 23 samples slightly above the BV (sample CAMO-00-0033, 0.93 pCi/g vs. BV of 0.9 pCi/g). Plutonium-238 was detected in 2 out of 23 samples above the BV, with a maximum of 0.09 pCi/g (sample CAMO-04-53326, vs. BV of 0.006 pCi/g). Plutonium-239,240 was detected in 8 out of 23 samples above the BV, with a maximum of 0.13 pCi/g (sample CAMO-04-53326, vs. BV of 0.068 pCi/g). Uranium-235 was detected in 1 out of 10 samples above the BV, with a maximum of 0.27 pCi/g (sample CAMO-04-53325, vs. BV of 0.2 pCi/g). Cesium-134, without a BV, was detected in 4 out of 18 samples, with a maximum of 0.1 pCi/g (sample CAMO-04-53325). In summary, the available analytical data indicate possible transport of several radionuclide COPCs as far as reach M-5E but not as far as M-6. The highest values relative to BVs are for plutonium-238 and plutonium-239,240, and the highest detection frequency above BVs is for plutonium-239,240. However, understanding the source of plutonium isotopes is complicated by the inference from regional soil data that plutonium may also be dispersed at levels above BVs by local Laboratory stack emissions and/or by fugitive dust from Laboratory sites (Fresquez et al. 1998, 76063), and the plutonium results in M-5E may or may not record past flood transport.

7.1.1.7 Future Fate and Transport of Radionuclides in Sediment

The concentrations and distribution of radionuclides present in sediment deposits in the Mortandad watershed will continue to change over time as a result of redistribution by floods and radioactive decay, as well as from any additional effluent discharges. Available data show progressive decreases in radionuclide concentration over time, driven largely by decreasing releases from the RLWTF, combined with the effects of mixing of sediment from different sources during transport and radioactive decay for radionuclides with relatively short half-lives such as cesium-137, cobalt-60, and strontium-90. Barring significant increases in the discharge of radionuclides, concentrations can be expected to generally continue declining over time, with a simultaneous downstream redistribution of inventory toward the confluence of Mortandad and Ten Site Canyons. Therefore, the present state of the watershed represents “worst-case” conditions from the perspective of potential future radionuclide contamination.

7.1.2 Inorganic Chemicals in Sediments

Three inorganic chemicals detected in sediments in the Mortandad watershed have maximum concentrations greater than residential SSLs and are most important for assessing potential human health risk: arsenic, chromium, and iron. Additional inorganic chemicals detected in sediment samples are important for assessing potential ecological risk (e.g., copper, cyanide, lead, mercury, perchlorate, thallium, vanadium, and zinc), for understanding relations between COPCs in water and sediment (e.g., lead, manganese, perchlorate, and selenium), or for understanding potential off-site transport onto San Ildefonso Pueblo land (e.g., copper cyanide, and selenium). The spatial distribution of these

inorganic chemicals (discussed below) indicates that they are derived from a variety of sources, including Laboratory SWMUs or AOCs, roads and other developed areas, and naturally occurring soils and bedrock. Once in the canyon bottoms, most of these inorganic chemicals adsorb to sediment particles and organic matter, and their subsequent fate is expected to be similar to that of radionuclides discussed in Section 7.1.1. However, inorganic chemicals derived from runoff from developed areas or from erosion of natural soils in the watershed differ from radionuclides in that these chemicals will not show the same decreases over time, and the concentrations of constituents derived from runoff from developed areas may actually increase over time.

This section focuses on spatial variations in inorganic chemicals in the Mortandad watershed. Supporting information is included in Appendix D. Table D-1.7-1 presents average concentrations in each reach for inorganic chemicals that are discussed in this section, substituting one-half of the detection limit for nondetected sample results. Averages presented here are weighted by the volume of sediment in each geomorphic unit in each reach, as discussed in Section D-1.3. Table D-1.7-1 presents the upper and lower bounds on these averages using either the detection limit or zero for nondetects, respectively, which indicate uncertainties in the average values. This table shows that on average, concentrations of these inorganic chemicals are generally lower in coarse facies sediment than in fine facies sediment, and Figure 7.1-20 and the discussions in the following sections focus on data from fine facies sediment. Figure 7.1-16 and Table D-1.7-1 also indicate that considerable uncertainty in the average concentration of some inorganic chemicals exists in some reaches because of elevated detection limits and/or detected concentrations close to detection limits, such as selenium and thallium.

The plots in Figure 7.1-20 include both the BV for each inorganic chemical, which is an estimate of the upper level of background concentrations, and the average value from the background sediment data set, where available (averages from McDonald et al. 2004, 76084, Table 10, p. 49–50). The background averages are included to be consistent with the presentation of averages from potentially contaminated samples. The spatial distribution of inorganic chemicals indicates that several TAs have been important Laboratory sources for these constituents in the Mortandad watershed, as discussed below.

Average concentrations of arsenic in fine facies sediment are greater than the sediment BV in two reaches, E-1FW and M-1E, both downgradient from TA-48 SWMUs or AOCs (Figure 7.1-20), indicating a source at this TA. Decreasing concentrations are present downcanyon from these reaches, and arsenic concentrations are similar to background averages east of M-2W in Mortandad Canyon. Average arsenic concentrations in M-1W and TS-2E are also above background averages but below the BV, indicating possible sources in TA-03 and from the TA-35 sand filter-bed outfall (AOC C-35-007).

Chromium data indicate a clear source at TA-48, with maximum concentrations in the Mortandad watershed in reach E-1FW, at the head of Effluent Canyon, and decreasing concentrations downcanyon. These data are consistent with known usage of potassium dichromate as a corrosion inhibitor in cooling towers at TA-48, as discussed in Section 7.2.2.1. Average chromium concentrations in fine facies sediment in E-1FW are roughly 100 times greater than in the next highest reach, E-1E, and average concentrations are the same as background averages by the Mortandad-Ten Site Canyon confluence (reach M-4W), 3.3 km (2.0 mi) downcanyon (Figure 7.1-20). Data from M-1C and M-1E, where average concentrations are greater than the BV, indicate one or more additional sources from TA-03 and possibly TA-48 into Mortandad Canyon. An additional minor source is suggested at the TA-35 sand filter-bed outfall by data from TS-2E where average concentrations of chromium are greater than the background average and close to the BV. Analyses of seven samples from E-1FW and E-1W indicate that the chromium in sediment is dominated by trivalent chromium (chromium[III]), with <0.4% hexavalent chromium (chromium[V1]). This contrasts with data from groundwater that indicate a dominance of

chromium(VI) in that media and is consistent with chemical reduction of chromium associated with the presence of organic carbon in sediments (Section 7.2.2.1).

Chromium is an important contaminant in the regional groundwater system beneath Mortandad Canyon (Section 7.2.2.1; LANL 2006, 91987), and the inventory of chromium present in sediment deposits in the Mortandad watershed as a result of Laboratory operations was estimated to allow comparison with the estimated amount released into the adjacent watershed of Sandia Canyon. The inventory estimates are presented in Table D-1.8-1 of Appendix D and indicate that about 75% of the anthropogenically added chromium in the watershed (subtracting background concentrations) is within Effluent Canyon, almost all above the TA-50 RLWTF outfall, and an additional 12% is within Mortandad Canyon downcanyon of the Effluent Canyon confluence. Most of the chromium associated with sediment has therefore been retained within sediment deposits near the source, with relatively small amounts transported farther downcanyon. The chromium inventory between the main source at TA-48 and SR 4 (reach M-6) is shown graphically in Figure 7-1-21. The inventory estimate indicates that an additional 11% of the watershed inventory is within Mortandad Canyon upcanyon from Effluent Canyon, and only about 1% is in Ten Site Canyon (Table D-1.8-1). About 60% of the estimated inventory is contained within fine facies sediment deposits, and 40% is contained in coarse facies deposits. The total estimated mass of anthropogenically-added chromium in sediment deposits in the Mortandad watershed is about 195 kg (430 lb) (Table D-1.8-1), which is <1% of the amount reported to have been released into Sandia Canyon (an average of 35.9 lb/d from 1950 to the mid-1970s or >100,000 lb; LANL 2006, 91987, p. 3).

A comparison of chromium concentrations with particle-size data indicates that the highest concentrations are in samples with high silt and clay content in reach E-1FW, indicating an affinity for fine-grained sediment particles, as seen with radionuclides (Figure 7.1-22). However, the highest concentration downcanyon in E-1W is in a sample of coarse facies sediment with relatively low silt and clay content. The high concentration in a coarse sediment sample in E-1W is interpreted to represent streambed sediment that was in direct contact with chromium-bearing effluent, as discussed for cesium-137 in M-2W in Section 7.1.1-5.

Chromium analyses obtained from the active channel between the TA-50 RLWTF outfall and the sediment traps in 1979 (Ferenbaugh and Gladney 1997, 93715) provide insights into both temporal and spatial trends in chromium concentration in Effluent and Mortandad Canyons. Figure 7.1-23 plots chromium results from 1979 as a function of distance from the RLWTF outfall and also shows average values from environmental surveillance samples (1992–2005) and active channel samples from the reach investigations (1998–2005). The 1979 data indicate much higher concentrations than at present and a progressive downcanyon decrease in concentrations, attaining present-day concentrations (below the background average) in reach M-3. The data indicate that chromium was being actively released into Effluent Canyon in 1979 or earlier and that by the early 1990s, little chromium was remaining in the active channel of Effluent or Mortandad Canyons downcanyon from the RLWTF outfall.

As with chromium, copper data indicate a clear source at TA-48, with maximum concentrations in the Mortandad watershed in reach E-1FW, and decreasing concentrations downcanyon. Average copper concentrations in fine facies sediment in E-1FW are roughly 5 times greater than in the next highest reach, E-1E, and remain above background averages through M-4 (Figure 7.1-20). Copper is not a COPC farther downcanyon. The spatial distribution of copper indicates additional sources into Ten Site Canyon from TA-35, with a local maximum in reach TS-2C below the outfalls from the TA-35 wastewater lagoons. Copper is not a COPC in TS-1W but is in TS-1C and downcanyon, indicating one or more sources at other TA-35 SWMUs or AOCs. Additional sources of copper into the upper part of Mortandad Canyon from TA-03 and TA-48 are indicated by average concentrations in fine facies sediment that exceed the background average in reaches M-1W and M-1E. The M-1W data may indicate a source from

road runoff, as copper is reported to be a common contaminant associated with vehicles (Breault and Granato 2000, pp. 48–49).

Cyanide has a maximum concentration in sediment samples in reach MCW-2W, on San Ildefonso Pueblo land below TA-05 SWMUs or AOCs. This was the only detected result above the BV (1.37 mg/kg in sample CAMO-03-49844, vs. BV of 0.82 mg/kg), and additional samples were collected in 2005 to see if this result could be confirmed. Resampling of that location and additional samples from two nearby locations in the same geomorphic unit yielded results below the BV (0.14 to 0.19 mg/kg, samples CAMO-05-63588, CAMO-05-63608, and CAMO-05-63609). There is therefore no evidence of cyanide from Laboratory SWMUs or AOCs impacting sediments in the Mortandad watershed.

Iron data suggest releases from the same sources as for arsenic and chromium, although average concentrations are generally within the background range and background variations at least partially affect the results. Only one reach, M-1E, has average concentrations in fine facies sediment slightly greater than the BV, indicating collocation with arsenic and chromium (Figure 7.1-20). Average concentrations in E-1FW and TS-2E are above background averages and suggest additional sources into the head of Effluent Canyon and into Ten Site Canyon, although average concentrations of iron are also greater than background averages in M-5W, downcanyon from significant Laboratory-derived contamination. The M-5W iron results above the BV are interpreted to represent a locally elevated background, as also found in Cañada del Buey, the next canyon to the south (Drakos et al. 2000, 68739).

Lead data indicate multiple sources in the upper parts of Effluent, Mortandad, and Ten Site Canyons. The average concentrations of lead in fine facies sediment are above the sediment BV in reaches E-1FW, M-1C, and M-1E and close to the BV in M-1W and TS-1C (Figure 7.1-20). Lead concentrations decrease downcanyon from these areas, and lead is not identified as a COPC downcanyon from M-4E. Lead is a common contaminant found below roads and other developed areas, and one source is leaded gasoline (Walker et al. 1999, 82308, p. 364; Breault and Granato 2000, 82310, p. 48; Callender and Rice 2000, 82307, p. 232). The distribution of lead in the Mortandad watershed suggests runoff from developed areas is one source, although releases from Laboratory SWMUs or AOCs is also possible, particularly from sites like TA-48 where the sediment data indicate releases of other metals (e.g., arsenic, chromium, copper, mercury, and vanadium).

Manganese data suggest releases from one or more sources in the Mortandad watershed, although background variability appears to be responsible for at least some of the results above the BV. Average manganese concentrations in fine facies sediment are greater than the BV in reaches M-1E and E-1W (Figure 7.1-20), suggesting releases from TA-48 and possibly TA-55. These are also reaches with relatively high concentrations of manganese in surface water (Section 7.2.2.1). Manganese is also elevated relative to background averages in E-1FW, E-1E, and TS-3. Although the elevated concentrations in E-1FW and E-1E suggest releases from one or more outfalls into Effluent Canyon, the TS-3 results apparently record background variations because manganese is not a COPC in the TS-2 reaches, closer to potential contaminant sources.

Mercury data indicate multiple sources in the Mortandad watershed, with the TA-50 RLWTF outfall into Effluent Canyon reach E-1E and the TA-35 sand filter-bed outfall into Ten Site Canyon reach TS-2E being most important (Figure 7.1-20). These two reaches and reaches M-2W and M-2E in Mortandad Canyon downcanyon from Effluent Canyon have average mercury concentrations in fine-grained sediment deposits greater than the BV, and several other reaches have averages greater than the background average, including E-1FW, M-1W, M-1E, and TS-2C. Data from these reaches indicate additional sources of mercury at TA-03, TA-35, and TA-48. Concentrations generally decrease downcanyon, and mercury was not identified as a COPC east of M-4.

Perchlorate data from sediment are relatively sparse but indicate a recognizable source at the TA-50 RLWTF outfall into reach E-1E, consistent with effluent discharge records, and transport downcanyon into M-4 (Figure 7.1-20). Perchlorate was not detected in Effluent Canyon upcanyon from the RLWTF outfall or in Ten Site Canyon but was detected in every reach between the RLWTF outfall and the east end of M-4. The absence of detected perchlorate in sediment in Ten Site Canyon contrasts with its detection in a borehole in Pratt Canyon, as discussed in Section 7.2.2.1, that indicates releases from the former TA-35 WWTP. Perchlorate concentrations in sediment in the Mortandad watershed are low, with a maximum measured concentration of 0.959 mg/kg in reach M-2W (sample CAMO-01-0072). Average concentrations suggest a secondary peak in reach M-4E (Figure 7.1-20), although this is not considered to be reliable because of the low sample numbers and high frequency of nondetects (67% nondetects between the RLWTF outfall and the east end of M-4). The low-detection frequency and low concentrations in sediment samples are consistent with the high solubility of perchlorate and indicate a relatively small inventory in the near-surface sediment deposits in Mortandad Canyon.

Selenium is a COPC that exceeds the wSAL in stormwater in the Mortandad watershed and that NMED has requested be included in biota evaluations (NMED 2005, 92084). Selenium has been identified as a COPC in sediment in all reaches in the watershed except one (M-5W) and has detected results greater than the sediment BV of 0.3 mg/kg in most of the other reaches (except M-6, MCW-2N, and TS-1W, where nondetect values exceed the BV). Understanding the sources and distribution of selenium in the Mortandad watershed is complicated by elevated detection limits in many samples and by local background concentrations that appear to be greater than the BV. Selenium detection limits as high as 11.5 mg/kg have been provided by analytical laboratories for sediment samples from the Mortandad watershed, which results in large uncertainties in estimates of average concentrations, as shown in Figure 7.1-20. Elevated background levels are indicated by data from units with little or no evidence of Laboratory contamination, such as five samples from the area designated as f2?(Qt?) in reach M-4E. Selenium concentrations from this geomorphic unit average 0.37 mg/kg and range from 0.26 to 0.51 mg/kg. Data from the adjacent watershed of Cañada del Buey also indicate an elevated local background for selenium, and sediment from drainages with no upgradient SWMUs or AOCs has yielded selenium results as high as 1.2 mg/kg (Drakos et al. 2000, 68739). These data indicate local background concentrations of selenium significantly above the BV of 0.3 mg/kg and at least as high as 1.2 mg/kg. Review of the maximum detected selenium concentrations shows that they are geographically dispersed and do not indicate a clear Laboratory source, contrasting with the distribution of other inorganic chemicals discussed in this section. For example, the four detected selenium results that exceed 1 mg/kg (range of 1.1 to 1.6 mg/kg) were obtained from four different reaches (E-1E, M-1E, TS-1E, and TS-2C). Therefore, although selenium data indicate the possibility of releases from Laboratory SWMUs or AOCs, if releases occurred, they were apparently small in relation to local background levels; natural background variations may account for much or all of the elevated selenium results.

Thallium is a potentially important COPC for evaluating ecological risk, as discussed in Section 8.1. Thallium data suggest relatively small releases into Effluent Canyon from the TA-50 RLWTF and rapid downcanyon attenuation. Only five detected thallium results are above the BV of 0.73 mg/kg: three in reach E-1E and two in M-2W. In both reaches, the average thallium concentration in fine facies sediment is above the background average but well below the BV (Figure 7.1-20). Thallium is a COPC in only three other reaches (M-5E, TS-1W, and TS-1C) and only because detection limits for some samples are greater than the BV.

Vanadium is a potentially important COPC for evaluating ecological risk, as discussed in Section 8.1, and vanadium data indicate releases from multiple Laboratory sources. The average concentrations of vanadium in fine facies sediment are greater than the BV in reaches M-1E and E-1FW (Figure 7.1-20), both downcanyon from outfalls at TA-48 and indicating releases from this site into Mortandad Canyon and

into the head of Effluent Canyon. Concentrations attenuate rapidly downcanyon from these reaches, and vanadium is not a COPC in either E-1E or M-2W. Vanadium concentrations are also elevated in Ten Site Canyon, with average concentrations being close to the BV in reach TS-2E, downcanyon from the TA-35 sand filter-bed outfall. Elevated concentrations in TS-1W, TS-1C, and TS-2W suggest additional sources into Ten Site Canyon from TA-50 and TA-35.

Zinc is a potentially important COPC for evaluating ecological risk, as discussed in Section 8.1, and zinc data indicate multiple sources in the Mortandad watershed. The highest average zinc concentrations in fine facies sediment are in reach M-1W at the head of Mortandad Canyon, and zinc concentrations progressively decrease downcanyon (Figure 7.1-20). Reach M-1W receives runoff from large areas of paved roads and parking lots, and zinc is commonly found in urban runoff; one important source for zinc is tire-wear particulates (Walker et al. 1999, 82308, p. 364; Breault and Granato 2000, 82310, p. 49; Callender and Rice 2000, 82307, p. 232). Similarly, the highest average concentrations of zinc in the Los Alamos and Pueblo watershed were found in the upper parts of Acid and DP Canyons, which also receive runoff from large paved areas (LANL 2004, 87390, p. 7-14). The average concentration of zinc in M-1W, about 85 mg/kg, is less than that found in reaches in upper Acid and DP Canyons, 100-130 mg/kg. A secondary maximum for zinc occurs in reach E-1FW at the head of Effluent Canyon, indicating a source in runoff from developed areas at TA-48 and/or releases from outfalls. In comparison to upper Mortandad and Effluent Canyons, Ten Site Canyon has lower levels of zinc in relation to background levels, with average concentrations in fine facies sediment being greater than the background average but less than the BV (Figure 7.1-20).

In summary, the sediment data indicate that inorganic chemicals in the Mortandad watershed have multiple sources, including Laboratory SWMUs or AOCs, runoff from developed areas, and naturally occurring soils. TA-48 is apparently the most important source for several metals, including arsenic, chromium, copper, vanadium, and possibly iron, and included releases into Mortandad Canyon and particularly into the head of Effluent Canyon. The TA-50 RLWTF outfall into Effluent Canyon is the most important source for mercury, perchlorate, and possibly thallium. The former sand filter-bed outfall from TA-35 into Ten Site Canyon is apparently a secondary source for several metals, such as arsenic, chromium, mercury, and vanadium. Runoff from developed areas is apparently the most important source of zinc and possibly lead. Some of the variations in concentrations of inorganic chemicals are also attributable to background variations, such as iron in reach M-5W and perhaps elsewhere and selenium in many reaches. Concentrations generally decrease downcanyon from the sources, and in some cases the contaminants are largely contained in sediment deposits near the sources, such as chromium in the upper part of Effluent Canyon. Remobilization of these chemicals by erosion will result in a progressive downcanyon shift of the inventory and accompanying decreases in concentrations, as discussed for radionuclides.

7.1.3 Organic Chemicals in Sediments

Two organic chemicals detected in sediments in the Mortandad watershed have maximum results greater than residential SSLs and are more important for assessing potential human health risk: the PCB Aroclor-1264 and the PAH benzo(a)pyrene. Additional organic chemicals detected in sediment samples are important for assessing potential ecological risk (e.g., bis(2-ethylhexyl)phthalate, di-n-butylphthalate, DDT[4,4-], and endrin aldehyde), for understanding relations between COPCs in water and sediment (e.g., bis(2-ethylhexyl)phthalate), or for understanding potential off-site transport onto San Ildefonso Pueblo land (e.g., acenaphthene, acetone, and bis(2-ethylhexyl)phthalate). These organic chemicals are derived from a variety of sources, including Laboratory SWMUs or AOCs and runoff from roads and other developed areas, as indicated by their spatial distribution (discussed below). Once in the canyon bottoms, most of these organic chemicals will adsorb to sediment particles and organic matter, and their

subsequent fate and transport by fluvial processes are expected to be similar to that for the radionuclides, which were discussed in detail in Section 7.1. Similar to some of the radionuclides, the organic chemicals discussed here have relatively short environmental half-lives associated with biodegradation and/or volatilization in the environment. Therefore, the concentrations will decrease over time unless contaminants are added to the canyon bottoms (such as from road runoff). However, the degradation rates are not well constrained and will vary with local environmental conditions.

This section focuses on spatial variations in organic chemicals in the Mortandad watershed, and supporting information is included in Appendix D. Table D-1.7-2 presents average concentrations in each reach for organic chemicals that are discussed in this section, substituting one-half of the detection limit for nondetected sample results. Table D-1.7-2 also presents the upper and lower bounds on these averages, using either the detection limit or zero for nondetects, respectively. This table indicates that on average, concentrations of these organic chemicals are lower in coarse than in fine facies sediment, and the discussions and figures in the following sections focus on data from fine facies sediment. Table D-1.7-2 also indicates that considerable uncertainty exists in the average concentration of organic chemicals in some reaches because of elevated detection limits.

7.1.3.1 PCBs

PCBs have low solubilities and a strong affinity for organic material and sediment particles (Chou and Griffin 1986, 83419). PCBs were widely used in electric transformers and other industrial applications (e.g., Walker et al. 1999, 82308, pp. 364–365), and their wide use is consistent with their spatial distribution in sediments in the Mortandad watershed. Figure 7.1-24 presents average concentrations of Aroclor-1260 and Aroclor-1254 in fine facies sediment in the Mortandad watershed, substituting one-half of the detection limit for nondetected sample results and showing upper and lower bounds on these averages. These data indicate that PCBs come from multiple sources in the watershed and that concentrations generally decrease downcanyon from these sources, as discussed below.

Aroclor-1260 has been detected in almost every reach in Effluent and Ten Site Canyons and in Mortandad Canyon as far east as M-4 but not farther downcanyon or in the unnamed tributary canyon that heads in TA-05. Aroclor-1260 has the highest average concentrations in reaches TS-1W and TS-1C, indicating one or more sources from TA-50 and possibly TA-35 into the upper part of Ten Site Canyon (Figure 7.1-24). These are also the only reaches with maximum concentrations above residential SSLs (1.37 and 1.3 mg/kg vs. an SSL of 1.12 mg/kg). Average concentrations of Aroclor-1260 decrease rapidly downcanyon in Ten Site Canyon. The data indicate additional sources into Effluent and Mortandad Canyons but at lower levels than in Ten Site Canyon.

Aroclor-1254 has a lower frequency of detection and was detected at lower concentrations and in fewer reaches than Aroclor-1260. The spatial distribution of Aroclor-1254 is somewhat different than for Aroclor-1260. Aroclor-1254 has the highest average concentrations in reach E-1FW (Figure 7.1-24), indicating the most important source for this PCB is TA-48, and concentrations decrease rapidly downcanyon in Effluent Canyon. Additional minor sources are indicated in upper Ten Site Canyon above reach TS-1W.

7.1.3.2 PAHs

PAHs have a range of chemical properties with some being less volatile and less soluble, and these chemicals are more likely to become adsorbed to and persist in sediments (Neff 1979, 83420). Some PAHs, such as naphthalene, are relatively volatile and should have the lowest affinity for sediments, whereas others, such as benzo(a)pyrene, are less volatile and less soluble and have a stronger affinity

for sediments. The different PAHs also have somewhat different spatial distributions in the Mortandad watershed, indicating different sources, as discussed below. Considerable uncertainty exists in the average concentrations of PAHs in some reaches because of elevated detection limits in data obtained from the SVOC analytical suite (method SW-846:8270C), although detection limits and associated uncertainties are lower in reaches with data obtained from the PAH analytical suite (method SW-846:8310).

Benzo(a)pyrene is the only PAH in the Mortandad watershed with concentrations above residential SSLs and has been detected in most reaches in Effluent and Ten Site Canyons and in Mortandad Canyon as far east as M-4 but not farther downcanyon or in the unnamed tributary canyon that heads in TA-05. Benzo(a)pyrene has the highest average concentrations at the head of Mortandad Canyon in reach M-1W, downcanyon from large paved areas and a major road in TA-03 (Diamond Drive) (Figure 7.1-25), consistent with a primary source in runoff from developed areas. Drainage from tar roofs is another possible source of benzo(a)pyrene and other PAHs in runoff from developed areas. A clear association between benzo(a)pyrene and runoff from developed areas was also seen in the Los Alamos and Pueblo watersheds (LANL 2004, 87390, p. 7-16), where average concentrations are up to several times higher than in the Mortandad watershed (the average concentration in fine facies sediment in reach AC-1 at the head of Acid Canyon is approximately 2.3 mg/kg, compared with approximately 0.7 mg/kg in M-1W). Benzo(a)pyrene is also notably elevated in reaches TS-1C and TS-1E in upper Ten Site Canyon (average of approximately 0.5 mg/kg, Figure 7.1-19), indicating a source from developed areas at TA-35 and/or TA-50. Lower concentrations are present in Effluent Canyon (average of approximately 0.2 mg/kg, Figure 7.1-19) and farther downcanyon in Mortandad Canyon.

Acenaphthene is the only PAH detected east of reach M-4, in reach M-5E, and the maximum detected concentration in the Mortandad watershed is also in M-5E (1.8 mg/kg). The apparent spatial distribution of acenaphthene is very irregular (Fig. 7.1-25), and the apparently elevated concentrations in M-5E are not considered reliable because of the absence of other evidence for significant transport of other contaminants this far downcanyon (Section 7.1.1.6). In addition, the elevated concentrations of acenaphthene in M-5E were obtained from the SVOC analytical method in 2000, and subsequent sampling in 2004 using the PAH method, with lower detection limits (0.025 mg/kg), did not provide any detected results. Interpretation of the acenaphthene results in upcanyon reaches is complicated by elevated detection limits and a high frequency of nondetects in many reaches, although the elevated results in M-1C are considered reliable because they were obtained with the PAH method, and the M-1C data had a relatively high-detection frequency (50%). These data therefore indicate a source for acenaphthene in upper Mortandad Canyon, such as runoff from developed areas as inferred for benzo(a)pyrene, and perhaps other less important sources in Effluent and Ten Site Canyons (Figure 7.1-25).

7.1.3.3 Other SVOCs

Besides PAHs, several other SVOCs are important in the Mortandad watershed for assessing potential human health or ecological risk, understanding sources of COPCs in water, or assessing potential transport off-site onto San Ildefonso Pueblo land. Sources and average concentrations of these SVOCs are typically uncertain, as discussed below.

Bis(2-ethylhexyl)phthalate was identified by ECORSK9 modeling as being the most important COPEC for the Mexican spotted owl, a T&E species (Gonzales et al. 2006, 93786). This SVOC also exceeds drinking water standards and has been detected in sediment samples collected on San Ildefonso Pueblo land. As shown in Figure 7.1-26, bis(2-ethylhexyl)phthalate displays no clear spatial trends in fine facies sediment, and the estimated average concentrations have much uncertainty associated with high frequencies of

nondetects (82% in sediment samples in the watershed) and with detection limits that are similar to reported detected values. Anomalies in the data set also indicate many of the detected values are suspect and/or do not represent releases from Laboratory SWMUs or AOCs. For example, five out of nine samples from reach M-6 are reported as detects, and the estimated average concentration here is similar to in upcanyon reaches closer to potential sources (Figure 7.1-26), but there are no detects in the next two upcanyon reaches (M-5W and M-5E) and no evidence for transport of other COPCs as far downcanyon as M-6. EPA has identified bis(2-ethylhexyl)phthalate as a common laboratory contaminant (EPA 1989, 8021, p. 5-16), which may explain some of the results. Therefore, although the available bis(2-ethylhexyl)phthalate data indicate the possibility of releases from SWMUs or AOCs, because of uncertainties in the data set, no sources can be clearly identified, and concentrations in sediment in the watershed are poorly constrained.

Di-n-butylphthalate was identified by ECORSK9 modeling as being the most important COPEC for the western bluebird and southwestern willow flycatcher, a T&E species (Gonzales et al. 2006, 93786). This SVOC has a high frequency of nondetects in sediment samples from the Mortandad watershed (99.5% nondetects) and was detected only in three reaches (MCW-2N, TS-1W, and TS-1C). As with bis(2-ethylhexyl)phthalate, di-n-butylphthalate displays no clear spatial trends in fine facies sediment (Figure 7.1-26), and the estimated average concentrations have much uncertainty associated both with the low detection frequency and detection limits that are similar to reported detected values. EPA has also identified di-n-butylphthalate as a common laboratory contaminant (EPA 1989, 8021, p. 5-16). Therefore, although the available di-n-butylphthalate data indicate the possibility of releases from SWMUs or AOCs, because of uncertainties in the data set no sources can be clearly identified, and concentrations in sediment in the watershed are poorly constrained. It is possible that the detected values at least in part reflect artifacts of the laboratory analyses (e.g., false positives).

7.1.3.4 Pesticides

Several pesticides in sediments have been identified as potentially important in assessing ecological risk in the Mortandad watershed. These organic chemicals have low solubilities and a strong affinity for organic material and sediment particles (Pionke and Chesters 1973, 83423; Nowell et al. 1999, 83422). The spatial distribution of pesticides in sediments in the Mortandad watershed indicates that these analytes have multiple sources at the Laboratory, which is consistent with their expected dispersed use in pest-control efforts. However, understanding their spatial distribution and sources is in part complicated by a high frequency of nondetects and detected concentrations close to detection limits. As two examples, Figure 7.1-27 presents average concentrations of DDT and endrin aldehyde in fine facies sediment in the reaches, substituting one-half of the detection limit for nondetected sample results and showing upper and lower bounds on these averages.

DDT is the pesticide with the highest aquatic HQ in the Mortandad watershed. It was detected at low concentrations in many reaches, although it has a relatively low detection frequency in the watershed (84% nondetects). The data suggest that the highest concentrations are in Mortandad Canyon from Effluent Canyon to reach M-3W, although much uncertainty is present associated with the influence of nondetects (Figure 7.1-27). Ten Site Canyon has detects only in reach TS-3 and not in upcanyon reaches closer to sources, indicating the apparent spatial patterns may not be reliable. Effluent Canyon reach E-1FW also has no detects of DDT, although downcanyon reaches do.

Endrin aldehyde is the pesticide with the highest terrestrial HQ in the Mortandad watershed. Endrin aldehyde has a low frequency of detection in sediment samples in the Mortandad watershed (97% nondetects) and was detected only in reaches E-1E, M-1C, M-2W, and M-3. Sources for endrin aldehyde are uncertain, and its spatial distribution does not display clear trends, showing the highest

concentrations in reaches M-2W and M-3 (Figure 7.1-27). Average concentrations are also uncertain because of detected values that are similar to the detection limits.

7.1.3.5 VOCs

VOCs have been detected in many reaches within the Mortandad watershed at low concentrations, but their spatial distribution is irregular and it is not certain to what degree the reported detects represent releases from SWMUs or AOCs or instead artifacts of the analyses (e.g., false positives). Detects in downcanyon reaches (M-5W and M-5E), at similar or greater concentrations than in upcanyon reaches closer to potential sources, indicate that at least some of these results do not represent releases from the Laboratory. Examples are discussed below for acetone, benzene, and methylene chloride.

Acetone has been detected in most reaches within the Mortandad watershed, with the highest average concentrations in fine facies sediment in M-1E and E-1FW below TA-48, suggesting releases from this TA (Figure 7.1-28). Acetone data also suggest releases from one or more sites into Ten Site Canyon, with estimated highest average concentrations in TS-1C and TS-2E. However, acetone concentrations are also relatively high in M-5W and M-5E, and it seems unlikely that the M-5W and M-5E data represent transport of acetone from Laboratory sites because these reaches are downcanyon of significant transport of radionuclide COPCs (Section 7.1.1.6). EPA has identified acetone as a common laboratory contaminant (EPA 1989, 8021, p. 5-16), and some of the results may represent false positives.

Benzene has also been detected downcanyon in M-5E in a single sample (CAMO-04-53325, 0.0006 mg/kg), at a concentration similar to in upcanyon reaches closer to potential sources. Of the nine detects in sediment samples from the Mortandad watershed (4% detection frequency), six are from Ten Site Canyon, with a maximum from TS-2E (CAMO-04-53394, 0.0008 mg/kg). The benzene data therefore indicate possible releases from Laboratory sites into Ten Site Canyon, although the detect in M-5E indicates that at least some of the data represent artifacts of the laboratory analyses.

Methylene chloride has been detected in five reaches in the Mortandad watershed (M-3, M-4, M-5W, M-5E, and TS-1C), and the maximum concentrations and the highest frequency of detects are in reaches M-5W and M-5E (Figure 7.1-28). Other reaches closer to potential sources have only single detects, at lower concentrations. The apparent spatial distribution of methylene chloride is therefore inconsistent with releases from Laboratory sites and subsequent downcanyon transport by floods. EPA has identified methylene chloride as a common laboratory contaminant (EPA 1989, 8021, p. 5-16), and these data largely or entirely represent artifacts of the laboratory analyses.

7.2 Conceptual Models for Hydrology and Contaminant Transport in Groundwater

The hydrology of the Mortandad watershed is described in Section 7.2.1 and includes surface water, alluvial groundwater, pore water in the upper vadose zone, intermediate-perched water, and regional groundwater. Contaminant distributions and transport processes are described in Sections 7.2.2 and summarized in Section 7.3.

7.2.1 Watershed Hydrology

The Mortandad watershed heads in the central part of the Pajarito Plateau in TA-03 and extends east southeast for 15.8 km (9.8 mi) to the Rio Grande (Plate 1). The watershed has a catchment area of about 15.5 km^2 (6 mi^2), which is relatively small compared with larger watersheds that head in the mountains, such as the Los Alamos and Pueblo Canyons watershed. The Mortandad watershed has no naturally perennial reaches. As a result, the surface water, alluvial groundwater, unsaturated zone and

intermediate-perched zone hydrology of the Mortandad watershed is largely controlled by the location and discharge volumes of anthropogenic water sources and by runoff from developed (e.g., paved) Laboratory technical areas. The subsequent distribution of surface water, sediments, groundwater, and contaminants is strongly influenced by the canyon geology and topography.

The Mortandad drainage heads entirely within the upper units of the Tshirege Member of the Bandelier Tuff. From its headwaters, the stream channel drops about 300 m (1000 ft) over a 13-km (8-mi) passage to the bluffs above White Rock Canyon, with an additional 245-m (800-ft) drop in elevation along the last ~3 km (~1.8 mi) of steep channel to the Rio Grande. Along the 13-km (8-mi) segment of shallower gradient, the stream channel cuts progressively down section through the Tshirege Member of the Bandelier Tuff, Cerro Toledo deposits, the Otowi Member of the Bandelier Tuff, and perhaps some minor amounts of Puye Formation fanglomerate that wedge out eastward on top of Cerros del Rio lava flows. The steep channel near the Rio Grande cuts through resistant Cerros del Rio lavas capping poorly consolidated stream gravels (Totavi Lentil) and Santa Fe Group sediments. These relations are illustrated in the conceptual hydrogeologic cross section in Figure 7.0-1.

For the purposes of the following hydrologic discussion, the Mortandad Canyon watershed on Laboratory property is subdivided into five canyon segments based on their hydrogeologic characteristics. The locations of these hydrologic segments are shown in Figure 7.2-1. These five segments include the

- Upper Mortandad Canyon hydrologic segment extending from the headwaters near Diamond Drive to the confluence with Effluent Canyon,
- Effluent Canyon hydrologic segment extending from the headwaters of Effluent Canyon to the confluence with Mortandad Canyon,
- Middle Mortandad Canyon hydrologic segment extending from the confluence with Effluent Canyon to the confluence with Ten Site Canyon,
- Ten Site Canyon hydrologic segment extending from the headwaters of Ten Site Canyon to the confluence with Mortandad Canyon, and
- Lower Mortandad Canyon hydrologic segment property extending from the confluence of Ten Site Canyon to the eastern Laboratory boundary.

7.2.1.1 Surface Water Hydrology

The conceptual model for surface water hydrology is based on gaging station data, outfall discharge records, and visual observations. Figure 7.2-1 shows the locations and modes of surface water occurrences throughout the watershed and the current locations of Laboratory NPDES outfalls and surface water gages. Canyon reaches defined for sediment sampling and their designations are also shown since they provided the basis for documenting visual observations of surface water occurrence.

The primary sources of surface water in the Mortandad watershed, aside from seasonal runoff and snowmelt, are currently five NPDES outfalls (Figure 7.2-1):

- TA-03-29, CMR Building (NPDES outfall EPA03A-021)
- TA-03-2274, Sigma Building (NPDES outfall EPA03A-022)
- TA-55-6, Plutonium Facility Complex (NPDES outfall EPA03A-181)
- TA-50-1, Radioactive Liquid Waste Treatment Facility (NPDES outfall 051)
- TA-35-124, Large Generator (NPDES outfall EPA03A-160)

The TA-03 outfalls consist of treated water associated with cooling at the CMR and Sigma Buildings and provide seasonal, intermittent discharges (generally April or May through October) to the upper Mortandad Canyon hydrologic segment above reach M-1W. The TA-55 outfall provides intermittent discharge of treated cooling water to upper Effluent Canyon above reach E1-W. Historically, each outfall discharged about 38 L/min ($6.3x10^{-4}$ m^3/s) (LANL1997, 57236), but discharges are discontinuous, variable, and seasonal. The TA-50 outfall consists of treated effluent discharges from the RLWTF into reach E-1E. Since 1997, the RLWTF discharges have averaged approximately 37.4 cubic meters per day (m^3/d). However, these discharges have decreased significantly in recent years from an average 63.7 m^3/d L/d in 1998 to an average 17.3 m^3/d in 2006 (through September 4, 2006). The TA-35 outfall discharges cooling tower blowdown associated with a large generator to Ten Site Canyon above reach TS-1W. These outfalls combined provide a significant component of surface water flow in the watershed beyond that produced by naturally occurring runoff and snowmelt. Annual discharge totals for the Mortandad outfalls from 2004 to 2005 are shown in Table 7.2-1 (LANL 2004, 94068; LANL 2005, 94073).

A total of five streamflow gaging stations are operated within the Mortandad watershed (Figure 7.2-1), from which data are regularly reported (Shaull et al. 2005, 92225; Shaull et al. 2006, 93735). Gage E200 is located in the uppermost portion of the middle Mortandad Canyon hydrologic segment approximately 30 m (100 ft) below the confluence of Effluent Canyon and 230 m (755 ft) below the TA-50 RLWTF outfall. This gage records the sum of natural runoff plus RLWTF effluent and TA-55 outfall discharges. Gage E202 is located at the boundary between the middle and lower Mortandad Canyon hydrologic segments upstream of the sediment traps at the Ten Site confluence. This gage only occasionally measures flow during extreme runoff events and records no flow most of the time. Gage E2015 is located in the Ten Site Canyon hydrologic segment approximately 400 m (1310 ft) upstream from E202. This gage has recorded only occasional minor intermittent flows since October 2000. Gage E203 is located in the lower Mortandad Canyon hydrologic segment at the outlet to sediment trap #3, approximately 260 m (850 ft) downstream from E202, and gage E204 is located in the lower Mortandad Canyon hydrologic segment approximately 15 m (50 ft) upstream from the Laboratory/San Ildefonso Pueblo boundary. Gage E203 has been continuously dry since October 1996 except for two recent sediment trap overflow events on August 24, 2005 (Shaull et al. 2006, 93735, pp. 44-45,) and August 25, 2006. Gage E204 has been continuously dry since October 1993, but there has been no known flow at San Ildefonso boundary since RLWTF discharges began in 1963. Table 7.2-2 shows the number and percentage of days with recorded flow at each streamflow gaging station. These data show the effects of infiltration losses on surface water between the middle and lower Mortandad Canyon hydrologic segments. Whereas gage E200 recorded flow for 75% of the days of record, E202 recorded flow for only 14% of the days of record, while E203 and E204 have been continuously dry during the period of record.

Since gage E200 is the uppermost reported streamflow gage in the watershed, a comparison of outfall discharges to the streamflow measured at gage E200 was made to assess the magnitude of the component of outfall discharges to total flow in the canyon (Figure 7.2-2). These data illustrate a variable relation between the volumes of outfall discharges and recorded flow at E200. The RLWTF is the only outfall whose flow reaches gage E200; flow from the others stops upcanyon, while the TA-35 effluent enters Mortandad Canyon below the gage (actually never making it out of Ten Site Canyon) and does not contribute to streamflow at E200. Data from 2004 and 2005 show streamflow significantly exceeding outfall volumes for the four contributing outfalls; these years had fairly normal natural runoff volumes. The RLWTF outfall percentage of flow at E200 was 4% and 9% during 2004 and 2005, respectively.

Surface water occurrences were determined from a series of field observations made during site visits to the various sediment sampling reaches in the canyon between June 2003 and September 2005 (Reneau, 2005). Canyon reaches with surface water observations are subdivided into ranges of percentage of observations with surface water present. Reaches identified in 100% of the observations are considered

"perennial" where water flow is continuous throughout most of the year. Reaches identified in 50%–99% of the observations are considered "intermittent" where the stream channel is predominantly dry throughout much of the year but have some extended periods of flow from snowmelt runoff, spring discharge, or groundwater discharge associated with high groundwater levels. Reaches identified in 1%-49% of the observations are considered "ephemeral" where the stream channel is predominantly dry throughout most of the year but may experience short periods of flow (i.e., hours to days) in response to storm events, particularly summer thunderstorms.

Approximately 87% of the Mortandad watershed upstream from the boundary with San Ildefonso Pueblo burned in the Cerro Grande fire of 2000 (BAER 2000, 72659). However, the burn was of low intensity and little to no change is surface water flow was recorded in the years immediately following the fire. Gage records indicate similar peak discharges before and after the fire (Shaull et al. 2003, 76042).

Upper Mortandad Canyon Hydrologic Segment

In upper Mortandad Canyon, above the confluence of Effluent Canyon, welded tuffs underlying the stream channel are relatively impermeable and limit the amount of infiltration along the stream channel. Persistent surface water originates primarily at TA-03 from runoff events (snowmelt and rainfall) and from seasonal outfall discharges from noncontact cooling water. Reach M-1W is indicated in Figure 7.2-1 as a perennial reach with surface water present during 100% of the observations made during the 2003-2005 surveillance period. Reach M-1W is downstream from NPDES outfall EPA03A-021 from the CMR Building in TA-03 and also receives runoff from extensive paved areas at the head of the watershed. Water was always observed in bedrock pools in the east part of M-1W and was usually observed in a bedrock area closer to the outfall and in the middle of the reach downstream from a headcut into alluvium where a small cattail wetland is supported. Plunge pools occur where the stream channel becomes steeper as the drainage incises into the upper part of Tshirege unit Qbt 2. Intermittent flow conditions exist below reach M-1W, as indicated by observations in reaches M-1C (below TA-48) and M-1E. A small cattail wetland exists adjacent to the stream channel below TA-48, and cattail wetlands are also present in reach M-1E where the stream has a bedrock channel as the canyon steepens eastward. Relatively deep and persistent bedrock pools are present downstream from reach M-1E. Historically, other outfalls from TA-48 have also contributed to surface water in this canyon segment. No gage is located within this canyon segment, but 79% of the observations made in reach M-1E indicate the intermittent presence of surface water there while 50% of the observations in reach M-1C indicated intermittent water associated with a fluctuating water table in the alluvium.

Effluent Canyon Hydrologic Segment

In Effluent Canyon, welded tuff bedrock underlying the stream channel limits infiltration along the stream channel. Intermittent flow occurs in reach E1F-W with surface water present during 75% of the observations. Here, water is fed by storm runoff that supports willows and cattails. Perennial flow is indicated in reaches E-1W (fed by the TA-55 outfall) and E-1E (fed by the TA-55 and TA-50 outfalls). Surface water was present during 100% of the observations made in these reaches between 2003 and 2005.

The TA-50 RLWTF has discharged to Effluent Canyon since 1963 at NPDES-permitted outfall EPA 051. Annual effluent discharge volumes have ranged from a high of 60.28 million liters (60,280 m^3) in 1968 to 6.93 million liters (6,930 m^3) in 2005 (Table 2.1-1 and Figure 2.1-1). Discharges are released from two 79,000-L (79-m^3) holding tanks. Effluent is released from one tank at a time when full. Timing of releases is variable, ranging from over 2 weeks between releases to daily releases over several consecutive days. Usually only one release occurs during a day, but occasionally two or three releases are made in a single

day. Between 1997 and September 2006, releases occurred an average of 3 d/wk. Historically, seasonal variability in discharge volumes has been significant, but quarterly release volumes have been relatively consistent since 2005 (Figure 7.2-3).

Effluent Canyon also receives stormwater runoff from portions of TA-48, TA-55, and TA-35, which contributes to a small wetland at the head of the canyon between TA-48 and the discharge point for the TA-50 outfall.

Middle Mortandad Canyon Hydrologic Segment

From west to east in the middle Mortandad Canyon hydrologic segment, bedrock becomes progressively less welded and more permeable, and canyon-bottom alluvium thickens. Surface flow generally infiltrates in the eastern part of this segment. Outfall discharges from Effluent Canyon are a major source of surface water to the middle Mortandad Canyon hydrologic segment below the confluence with Effluent Canyon and above the confluence with Ten Site Canyon (Figure 7.2-2). These discharges comprise a significant percentage of the flow at gage E200, which measures surface flow entering the middle Mortandad Canyon hydrologic segment from both the Effluent Canyon and upper Mortandad Canyon hydrologic segments. Based on visual observations between 2003 and 2005, indicating that surface water was present during 100% of the observations in reach M-2W, surface water flow in the middle Mortandad Canyon hydrologic segment is indicated as perennial in reach M-2W for a distance of approximately 570 m (1870 ft) below the Effluent Canyon confluence (fed by the TA-55 and TA-50 outfalls and road runoff) (Figures 7.2-1 and 7.0-1). Surface water in reach M-2W, however, is typically discontinuous, with stretches with no surface water, and water was present partly as bedrock pools and emergence from saturated alluvium rather than as a through-flowing stream. The region of surface water flow coincides with relatively thin alluvium in a channel underlain by the welded portions of Qbt 2. However, gage E200 has recorded flow for 75.4% of the days during its period of record since 1995, indicating that persistent surface flow is not uninterrupted in this canyon segment. Intermittent flow occurs in reach M-2E with surface water present as discontinuous flowing water and pools during 78% of the observations made during 2003–2005 surveillance period. No flow was observed below reach M-2E during the 2003–2005 observations, indicating the point below which water has infiltrated into the thickening canyon bottom alluvium or is lost to evaporation. Beyond reach M-2D, surface water is ephemeral in response to high discharge volumes or to upstream runoff. Only infrequently, generally following severe summer thunderstorms, does surface water exit the middle canyon. This is illustrated in Figure 7.2-4 which depicts the hydrographs for streamflow measured in reported gages during 2005 and 2006. The hydrograph for gage E202 shows that this gage recorded flow on only 11 of the 587 days of record during this period. Except for a larger flood event on August 24, 2005, during which the mean daily discharge was about 48 liters per second (L/s [1.7 cfs]), only minor flow events from about 1 to 6 L/s (0.04 to 0.2 cfs) mean daily discharge were measured at E202 during the 2005–2006 period (through August 14, 20/06).

Gage E200 provides the most consistent record of persistent flow in the watershed. A comparison of cumulative daily TA-50 effluent and gage E200 streamflow discharge volumes since 1997 is shown in Figure 7.2-5. From mid-1997 to 2000, the cumulative TA-50 discharges were roughly half of the total flow recorded at E200. Since 2001, the rate of discharge from TA-50 has declined while total runoff at E200 has increased. Notable flow increases were recorded at E200 in January 2002 and January-March 2004 associated with snowmelt or flood events. By August 2006, cumulative discharges from TA-50 were only about 19% of the cumulative total flow at E200 for the period from 1997 to August 2006.

A comparison of seasonal (quarterly) discharge volumes since 1997 for the TA-50 outfall and the E200 gage is shown in Figure 7.2-6. The streamflow volume for the quarter ending on 3/31/04 is literally off the chart in this figure. The total streamflow volume recorded at E200 during this quarter exceeded

175,000 m^3, which is nearly 5 times greater than the total flow at E200 in any other quarter since 1997. Otherwise, the highest quarterly streamflow totals are generally associated with spring snowmelt runoff and summer-fall monsoon rains while lower streamflow amounts are generally recorded in the winter, though several exceptions to this pattern are present (e.g., occasional high winter flows and low summer-fall flows). After the RLWTF discharges peaked in 1999, a subtle seasonal pattern of higher discharges in the summer and lower discharges in the winter is apparent for the TA-50 outfall, while the declining trend in discharge volume is clearly evident. The seasonal TA-50 percentage of E200 streamflow discharge is shown in Figure 7.2-7. Data from the second quarter of 1998 and the second and third quarters of 2000 were compromised by extended periods of equipment failure at E200 and are thus excluded from this graph. A clear pattern of seasonality for this parameter is not readily apparent from these data. Examining the extreme conditions for this parameter shows that the highest proportions of TA-50 contributions to total flow (exceeding 80%) occurred in the first and fourth quarters of 1997, the third quarter of 2000, the second quarter of 2004, and the first quarter of 2006. These occurrences are related to drought conditions leading to abnormally low inputs of naturally occurring runoff or snowmelt during these periods and not a regular seasonal variation. The lowest proportions of TA-50 contributions to total flow (less than 8%) occurred in the fourth quarter of 2001 and first quarter of 2002, the fourth quarter of 2003 and first quarter of 2004, and the first and third quarters of 2005. A relatively low proportion of TA-50 flow was also recorded in the fourth quarter of 2004 (about 14%). An inconsistent seasonal pattern is thus apparent during the winters of 2001–2002, 2003–2004, and 2004–2005 when higher runoff occurred leading to low relative contributions of outfall discharges to total flow. This analysis indicates that winter runoff is frequently (since 2001) a significant contributor to total surface flow in the upper and middle watershed.

The seasonal TA-50 outfall percentage of E200 flow since 1997 is summarized in Table 7.2-3. The mean and median percentages are nearly equal for the first and second quarters at about 41% and 47%, respectively. The third quarter exhibits the lowest proportion of TA-50 flow with mean and median percentages of about 23% and 25%, respectively, illustrating the effects of monsoonal rains to total flow in the watershed. The fourth quarter proportion of TA-50 flow has a mean percentage of about 34% but a median value of about 28%. These data suggest that overall, surface water flowing from the upper Mortandad Canyon hydrologic segment generated by naturally occurring runoff makes up a large percentage of E200 flow during the summer and fall. In addition, building cooling-water discharges from the CMR and Sigma Buildings at TA-03 may also contribute seasonally. The proportion of TA-50 flow during the summer and fall is only about one-fourth of the total streamflow, whereas during the winter and spring seasons, the TA-50 discharges comprise nearly half of the total flow recorded at gage E200. The annual averages clearly show the declining influence of the TA-50 outfall on surface flow in the watershed. Whereas in 1997 the TA-50 outfall comprised 63% of the flow recorded at E200, by 2005, its contribution was only 21%.

Ten Site Canyon Hydrologic Segment

Pratt Canyon is a small tributary to Ten Site Canyon, which is a tributary to Mortandad Canyon. Before 1963, Pratt Canyon received effluent from the TA-35 Waste Water Treatment Plant (Section 2.1). Purtyman (2002, 11787) reported that historical effluent discharges from Pratt Canyon to Ten Site Canyon were insufficient to reach Mortandad Canyon as surface flow.

Surface flow conditions in the Ten Site Canyon hydrologic segment are currently recorded at gage E2015, which is located near the mouth of canyon (Figure 7.2-1). As seen in Figure 7.2-4, mean daily flows recorded at E2015 seldom exceed 3 L/s (0.1 ft^3/s), and the gage is dry most of the time. As noted in Table 7.2-2, flow was recorded in this gage on only 11% of the days during its period of record (since 2000). Virtually all of this flow is attributed to runoff from paved areas, but the current TA-35 outfall (03A-160) releases into the head of Ten Site Canyon and may also contribute. As depicted in

Figure 7.2-1, surface water conditions range from intermittent in reaches TS-1W, TS-1C, and TS-2E to ephemeral in reaches TS-1E, TS-2W, and TS-2C. During the period of visual surveillance in 2003–2005, reaches TS-1W, TS-1C, and TS-2E contained surface water during 69%, 58%, and 73% of the observations, respectively. Relatively persistent water was found in depressions between boulders or scour holes (TS-1W and TS-1C), and in shallow bedrock depressions (TS-1E). Reaches TS-1E, TS-2W, and TS-2C contained surface water during 41%, 31%, and 17% of the observations, respectively. Although occasional small flows were recorded at gage E2015, no water was ever observed in reach TS-3.

Lower Mortandad Canyon Hydrologic Segment

Surface water is ephemeral and occurs infrequently in the lower Mortandad Canyon hydrologic segment. This canyon segment is characterized by a broad flat canyon floor with an indistinct drainage system. It contains thick alluvial deposits (up to 30 m [100 ft]) that rapidly imbibe the rare surface water flows that reach this part of the canyon.

No visual observations of surface water were ever made below the confluence with Ten Site Canyon during the 2003–2005 surveillance period. However, an exception flood event did occur in August 2006. As noted in Table 7.2-2, gage E202, which records flow entering this section of the canyon, recorded measurable flow during only about 14% of the days during its period of record (since 1997). As illustrated in Figure 7.2-4, flows are infrequent and normally very small, with the exception of occasional major flood events. When flow occurs, the water is routed through three sediment traps dug into the alluvial channel. The sediment traps dam the water into retention basins so that contaminated sediments settle, and the impounded surface water then infiltrates into the permeable alluvium. Gage E203 (Figure 7.2-1), located below the sediment traps, has never recorded flow during its period of record since 1996. Before 2005, the sediment traps were generally continuously dry since December 1997 except for a post-fire event in the upper sediment trap on May 26-29, 2001. Since then, the upper sediment trap has filled with water on August 24, 2005 and August 25, 2006. Gage E204 (Figure 7.2-1) at the Laboratory boundary with San Ildefonso Pueblo has also never recorded flow during its period of record (since 1993). Stream flow extended nearly to the Laboratory boundary for a major flood that occurred on August 25, 2006 (after the streamflow gage data for this report were compiled). Clearly, however, surface water flow in the lower Mortandad Canyon hydrologic segment is a rare event.

In the lower Mortandad Canyon Hydrologic Segment from the San Ildefonso boundary to the Rio Grande, flow is probably derived from local rainfall events and/or flow from tributaries entering Mortandad Canyon below the Laboratory boundary. Although no documented flow measurements in this reach are available, the stream channel shows evidence of at least occasional flow in places, and tributaries like Cedro Canyon have likely fed water locally into lower Mortandad Canyon. Flow is ephemeral only to the confluence of Cañada del Buey. Intermittent or perennial flow occurs from the Cañada del Buey, confluence to the Rio Grande, fed by White Rock WWTP discharges.

7.2.1.2 Alluvial Groundwater

Surface water infiltrates into the canyon bottom alluvial sediments until its downward movement is impeded by zones of lower permeability, usually weathered tuff, forming a perched alluvial aquifer with intermittently varying levels of saturation. The alluvial groundwater conceptual model is based on water-level responses to precipitation and streamflow data, and to effluent discharge. In addition, recent field observations have added to the conceptual understanding of the alluvial groundwater system, indicating that the system is complex and heterogeneous. In much of the watershed, a perched zone of saturation exists at the base of the alluvium where it overlies less permeable bedrock. Otherwise, the

alluvium above and adjacent to the perched zone is unsaturated. Figure 7.2-8 shows the extent of the alluvial groundwater based on average alluvial water levels for the summer of 2005. Figure 7.2-9 is an isopach map showing thickness variations in the alluvium from the confluence of Mortandad and Ten Site Canyons to the eastern Laboratory boundary. Figure 7.2-10 shows the distribution of geologic units beneath the alluvium in the same area.

A series of plots, shown in Appendix F, present time series of water levels at selected alluvial wells. These time series are discussed in the following sections to illustrate the relationship of alluvial water-level fluctuations to precipitation and runoff events. Historically, effluent discharges from the TA-50 RLWTF have represented a large percentage of the watershed water balance. However, they have steadily declined since 1998 to where they comprised only about 10% of the flow recorded at gage E200 in 2005 (Figure 7.2-2). Whereas historically the main volume of the alluvial groundwater body may have been fairly steady, it has gradually become more dependent on recharge from naturally occurring runoff as the influence of outfall discharges throughout the watershed has diminished. This has resulted in highly variable saturation conditions in the alluvium with notable transient responses to recharge from major runoff events.

In addition to temporal variations, the model also addresses spatial variations in the nature of the water-level record and the relation of water-level responses to precipitation and streamflow. A series of plots, shown in Appendix F, also incorporate these data to describe the system. The plots include daily precipitation measured at the TA-06 meteorological station located on Two-Mile Mesa, approximately 970 m (3180 ft) south-southwest of the headwaters of the upper Mortandad Canyon hydrologic segment, as well as mean daily discharge measured at streamflow gaging stations E200 and E202. The TA-06 precipitation record, obtained from the Laboratory meteorological database (http://weather.lanl.gov), was chosen because it is the station closest to the upper part of the watershed, which is the main source area for runoff.

The following discussion describes variations in alluvium thickness and downcanyon changes in suballuvium geology for the Mortandad watershed. Results of the alluvial water-level study are also summarized from Appendix F. The reader is referred to Appendix F for a detailed discussion of spatial and temporal variations in water-level data for the alluvial wells in each of the hydrologic segments in the watershed.

Upper Mortandad Canyon Hydrologic Segment

Alluvium is generally thin in the upper Mortandad Canyon hydrologic segment. The thickness of alluvium is about 1 m (3 ft) at MCO-0.6, located below TA-48 approximately 780 m (2560 ft) above the Effluent Canyon confluence, and 1.8 m (5.9 ft) at MCA-1, located approximately 70 m (230 ft) above the Effluent Canyon confluence (Figure 3.2-1, Plate 1). Alluvium is underlain by poorly welded to nonwelded tuffs of Tshirege unit Qbt 3 in the westernmost part of this hydrologic segment and by strongly welded tuffs of Tshirege unit Qbt 2 in the central and eastern parts of this hydrologic segment (Figure 7.0-1).

Since mid-2005, the alluvial groundwater system has typically been dry or nearly dry in the late winter, spring, and early summer seasons until recharged by summer storm runoff. The thin alluvium results in a limited ability to store groundwater. As a result, alluvial saturation levels in the upper canyon areas respond nearly instantly to recharge from runoff events, and recession of water levels is generally rapid afterwards.

Effluent Canyon Hydrologic Segment

Alluvium in the Effluent Canyon hydrologic segment is generally less than 1 to 2 m (3 to 6 ft) thick, and portions of the stream flow in a bedrock channel. Alluvium is 1.6 m (5.4 ft) thick in the wetlands at MCA-4, but the stream forms a steep-walled channel with little alluvium east of the wetlands. Alluvium is underlain by poorly welded to nonwelded tuffs of Tshirege unit Qbt 3 in the headwaters of this drainage and by strongly welded tuffs of Tshirege unit Qbt 2 in the central and eastern parts of this hydrologic segment.

Hydrograph data (Appendix F) show similar aquifer behavior to that seen in the upper Mortandad Canyon hydrologic segment. Alluvial water levels rise rapidly in response to stormwater runoff events associated with summer and fall precipitation events, and the groundwater responses occur virtually instantaneously, correlating well with the streamflow record at gaging station E200. However, alluvial saturation levels are more persistent in the Effluent Canyon hydrologic segment due to the TA-50 and TA-55 outfalls that contribute to recharge that provides a base flow saturation level of generally 0.3 to 0.6 m (1 to 2 ft).

Middle Mortandad Canyon Hydrologic Segment

Alluvium is generally thin in the western half of the middle Mortandad Canyon hydrologic segment, and it becomes progressively thicker from approximately the center of the segment to the confluence with Ten Site Canyon to the east (Figure 7.2-9). Alluvium is about 1.8 m (6 ft) thick at MCA-5 at the upper end of the segment, 8.8 m (29 ft) thick at MCB-5, and 18 m (60 ft) thick at RES-2 near the confluence with Ten Site Canyon. Because of the inaccessible terrain, there are no boreholes between MCA-5 and MCB-5 (Figure 3.2-1, Plate 1), and there is no information on the thickness of alluvium in that part of the canyon. The thin alluvium in the western half of the middle Mortandad Canyon hydrologic segment overlies strongly welded tuffs of Tshirege unit Qbt 2. The thickening alluvium in the eastern half of the middle Mortandad Canyon hydrologic segment overlies progressively older and more porous bedrock units in a downcanyon direction, including the poorly welded tuffs at the base of Qbt 2, nonwelded tuffs in Qbt 1v and Qbt 1g, and poorly consolidated sediments of the Cerro Toledo interval (Figures 7.0-1 and 7.2-8).

The alluvial groundwater in the middle Mortandad Canyon hydrologic segment is a transitional zone between the dynamically responding behavior of the upper canyon segments and a more stable and slowly responding system in the lower canyon segments. In the upper part of the middle Mortandad Canyon hydrologic segment (about 200 m [655 ft] below the Effluent Canyon confluence), a thin perched aquifer is restricted within a narrow bedrock channel and has little capacity for aquifer storage. This results in highly transient saturation conditions with instant responses to runoff recharge events followed by rapid recessions (generally a few days). Here the alluvial aquifer was dry about half the time (during the winter and spring seasons) since mid-2005.

Farther downcanyon (about 400 m [1310 ft] above the Ten Site confluence), intermittent and variable saturation levels still exist. A time lag of several weeks between a major surface runoff event and a corresponding rise in the water level indicates that alluvial groundwater recharge in this canyon segment is primarily from groundwater underflow that was recharged by infiltration of runoff further upcanyon. Only after persistent levels of alluvial saturation are maintained do flood events result in nearly instantaneous water-level rises showing the influence of rapid recharge from local infiltration.

Near the Ten Site confluence, the delayed recharge effect is more pronounced with time lags of several months between major streamflow events and alluvial groundwater recharge responses. Also, much longer recessional limbs (weeks to months) in the alluvial hydrographs from this area reflect an enlarged aquifer storage capacity attributable to the deepening package of alluvial sediments present beneath the widening canyon floor. Most water movement in the alluvial aquifer near the Ten Site confluence is

probably lateral within the alluvium, but some percolation losses from the base of the alluvium are also possible.

Ten Site Canyon Hydrologic Segment

Alluvium is relatively thin in the western half of the Ten Site Canyon hydrologic segment. This alluvium overlies poorly welded to nonwelded tuffs of Tshirege unit Qbt 3 in the headwaters of the canyon and strongly welded tuffs of Tshirege unit Qbt 2 near well R-14 (Plate 1). In the eastern part of the Ten Site Canyon hydrologic segment, as the canyon exits the hard tuffs of Tshirege unit Qbt 2, the valley floor flattens and broadens eastward, and the alluvium becomes significantly thicker. At well TSCO-6 the alluvium is 6.5 m (21.3 ft) thick, and at R-33 the alluvium is 20 m (66 ft) thick (Figure 7.2-9). Alluvium in the eastern half of the Ten Site Canyon hydrologic segment overlies progressively older bedrock units in a downcanyon direction, including the poorly welded tuffs at the base of Qbt 2, nonwelded tuffs in Qbt 1v and Qbt 1g, and poorly consolidated sediments of the Cerro Toledo interval (Figure 7.2-10).

Alluvial well TSWB-6 has been dry during every measurement event since its installation in 1994. Newly installed well TSCA-6 encountered alluvial water but the period of record is too short to evaluate the hydrograph. Therefore, no water-level data for Ten Site Canyon are summarized here.

Lower Mortandad Canyon Hydrologic Segment

Alluvium reaches its maximum thickness in the lower Mortandad Canyon hydrologic segment (Figure 7.2-9). From west to east, the thickness of alluvium varies from 21.2 m (69.5) ft at MCB-8, 25 m (82 ft) at MCB-10, 34.3 m (112.5 ft) at MCOBT-8.5, and 32.8 m (107.5 ft) at MCA-9 (Figure 3.2-1, Plate 1). From the vicinity of R-15 to the San Ildefonso Pueblo boundary, the alluvium-filled basin is asymmetric, with deeper alluvium occurring beneath the northern part of the canyon floor (Figure 7.2-9). Drill-hole data and cross-canyon resistivity profiling (see Section 7.2.1.3 and Appendix H) support the interpretation of asymmetry in the alluvial-filled basin, with gentler suballuvial slopes to the south and steeper slopes to the north. Mass-wasting apparently contributed to the alluvial fill along the steep north wall of the canyon; colluvial blocks up to 3 m (10 ft) in diameter are intercalated with fluvial sediments at MCOBT-8.5 (Broxton et al., 2002, 76006). Alluvium is underlain by Cerro Toledo fluvial deposits in the western part of the lower Mortandad Canyon hydrologic segment and by Otowi Member ash flow tuffs in the central and eastern parts (Figure 7.2-10).

In the lower Mortandad Canyon hydrologic segment, where alluvial groundwater is most prevalent, time lags of 5 to 6 months between runoff events and recharge responses in the alluvial aquifer are typical. Greater aquifer storage is available because of the thickening alluvial sediments causing long recessional limbs in alluvial hydrographs of up to 2 years. Infiltration losses from the alluvium in this canyon segment limit the extent of saturation. The downgradient extent of alluvial saturation occurs near a point about 700 m (2300 ft) below the Ten Site confluence where infiltration losses from the alluvium have led to less than fully saturated conditions spanning time periods of several years. In the easternmost wells with alluvial saturation, time lags of 8 to 17 months for response to upstream recharge events have been observed.

7.2.1.3 Vadose Zone

The vadose zone is defined as the region between the land surface and the top of the regional aquifer (see Figure 7.0-1). The vadose zone is about 365 m (1200 ft) thick beneath the upper Mortandad Canyon hydrologic segment and 245 m (800 ft) thick beneath the eastern portion of the lower Mortandad Canyon hydrologic segment. The discussion in this section will focus on the unsaturated portions of the vadose

zone. Sections 7.2.1.2 and 7.2.1.4 provide detailed descriptions of the alluvial groundwater and intermediate-perched zones, respectively, which are saturated intervals located within the vadose zone. This subsection initially focuses on the shallow vadose zone (i.e., from the land surface through the Bandelier Tuff), and then concludes by discussing the deep vadose zone (including the Cerros del Rio basalts and the Puye Formation, Figure 7.0-1). In addition, specific discussions of flux meter measurements and VECTOR in situ permeable flow sensor data collected in the Mortandad watershed are presented in Appendix M.

Volumetric Water Content

One of the most important hydrologic characteristics of the vadose zone is water content, and volumetric water content profiles for recent Mortandad boreholes are shown in Appendix B. The borehole profile data show that water contents vary widely with depth as well as up and down and laterally across the canyon. For example, in MCB-7, volumetric water contents range from less than 5% to saturation (e.g., 40%–50%) within the alluvium. Variability such as this plays an important role in the rates of water and contaminant movement in the canyon because fluxes in unsaturated media (both vertical and lateral) are strongly controlled by water content. As a demonstration of this variability, average volumetric water contents are summarized for each borehole by stratigraphic unit (and in one case by depth interval) in Table 7.2-4. Boreholes are also ordered from upcanyon (at the top of the table) to downcanyon so that along-canyon values can be compared. Note that MCB-15 is in Ten Site Canyon, and MCI-1 and MCI-10 were not drilled in the Mortandad Canyon bottom.

A cross section showing the spatial distribution volumetric water content along the axis of Mortandad Canyon is shown in Figure 7.2-11. This figure shows an interpolated representation of all available volumetric water content data collected in the Mortandad watershed as of 2005. The contours indicate that a large fraction of the vadose-zone moisture is located near and below the confluence of Mortandad Canyon and Ten Site canyons. This area is represented in Figure 7.0-1 as the zone of greatest percolation of alluvial groundwater to the deeper vadose zone, as represented by the large vertical arrows. This area coincides with zones containing persistent and intermittent alluvial groundwater and the only occurrences of intermediate-depth perched groundwater that show influences from Mortandad sources. Much of this wetter area is underlain by thick alluvium overlying the Cerro Toledo interval with locally high moisture contents (Figures 7.0-1, 7.2-9, and 7.2-10). Together, these data suggest alluvial groundwater is the source of enhanced percolation to the underlying rocks of the vadose zone. The loosely consolidated sediments of the Cerro Toledo interval may facilitate deep percolation in this area.

Alluvial groundwater is often perched at or near the contact between alluvium and underlying Cerro Toledo deposits. However, high moisture contents (as well as soluble contaminants such as perchlorate) commonly extend downward into the underlying Cerro Toledo deposits (Figure 7.2-11 and 7.2-12). Moisture and contaminant profiles indicate that the base of saturation does not represent a no-flow barrier. Rather, elevated values for moisture and soluble contaminants persist into deeper bedrock units that are not fully saturated.

Table 7.2-4 compares moisture contents for rocks of the upper vadose zone on a unit-by-unit basis. From these data, it is evident that the 0–6-m (0–20-ft) depth interval has the lowest overall water contents. Water contents at this depth are affected greatly by evapotranspiration (evaporation plus transpiration) losses, and the 0–6-m (0–20-ft) depth interval likely has the largest temporal variability, especially close to the ground surface, because of the dynamics between evapotranspiration, infiltration, and percolation. These data suggest that although the RLWTF outfall and runoff provide significant water to the canyon, evapotranspiration still plays a large role in the canyon water balance. Additional evidence for this control is described later in the discussion on stable isotope profiles.

Deep alluvium (>6 m [>20 ft]) shows a great deal of variability in volumetric water content, much of which is related to the presence or absence of alluvial saturation. There is a suggestion that water contents decrease in the deep alluvium in locations near the Laboratory boundary (i.e., MCOBT-8.5 and R-28); however, MCB-16 has a relatively high average water content of 21%.

Tshirege Member unit Qbt 2 (>6 m [>20 ft]) was observed in only two canyon bottom holes (MCB-1 and MCB-2), and average water contents vary between 10% and 24%. MCB-1 is located in Effluent Canyon above the TA-50 RLWTF outfall, and MCB-2 is located at the confluence of Mortandad and Effluent canyons (Plate 1). None of the Qbt 2 samples in these two boreholes had water contents over 25%, and both boreholes were dry when drilled. Thus, the strongly welded nature Qbt 2 and the upper canyon hydrological conditions appear to inhibit the formation of shallow perched saturated zones in this setting.

Tshirege Member unit Qbt 1 has a similar range of average water contents to Tshirege unit Qbt 2; however, Qbt 1 was observed in more boreholes. One interesting note is that a horizon of nearly saturated or saturated tuff was observed in MCB-2 near the contact of Tshirege subunits Qbt 1v and Qbt 1g. Similar occurrences of enhanced moisture at the Qbt 1v/Qbt 1g contact have been observed in other parts of the Laboratory (e.g., borehole 49-2-700-1 at TA-49, Stimac et al., 2002, p.7).

The Cerro Toledo interval has some of the highest average water contents presented in Table 7.2-4. Some of these water contents may be high because of leakage from the alluvial perched horizons during drilling. However, the number of observed high values indicates that the Qct is one of the wetter units within the canyon.

The Otowi Member average water contents tend to center around the high teens to low twenties, indicating that the Otowi is 30%–40% saturated (assuming 45% porosity) from R-1 to near the Laboratory boundary. However, the specific water-content profiles for boreholes MCB-14, MCOI-6, MCOI-8, R-1 and R-15 (Appendix B) show extensive intervals with water contents approaching thirty. These wells are located in an area with persistent alluvial groundwater and are shown in Figure 7.0-1 as being located in the region of enhanced vadose-zone flow.

In contrast to the upper vadose zone described above, there is much less information available about the deeper vadose zone (e.g., the Cerros del Rio basalts and the Puye Formation). Only one hole was cored within the deep zone, and no core data exist for the Puye Formation in Mortandad Canyon. At R-15, volumetric water contents in the basalt are less than 10% from about 150 to 215 m (500 to 700 ft) (Longmire et al. 2001, 70103). Below the intermediate perched zone, water contents increase to about 30% near the contact with the Puye Formation. The basalt units are difficult to characterize because they can have a wide range of porosities and hydraulic conductivities, depending on whether the basalts are massive or fractured, or if interflow/paleosol zones are present. Fracture porosity is a possible route for fast transport through the basalts. The closest proxies for the deep vadose zone in Mortandad Canyon are R-12 and R-9 in Sandia and Los Alamos canyons, respectively. R-12 and R-9 water contents in the Cerros del Rio basalts are generally similar to the 150 to 215 m (500–700 ft) zone at R-15 (i.e., <10%; Broxton et al., 2001a, 2001b). However, R-12 water contents increase to over 20% in interflow zones at basalt subunit contacts. At R-12 and R-9, water contents are also around 10% in the clay-poor sedimentary deposits in the upper part of the Puye Formation. In the lower Puye Formation (near the regional aquifer), water contents increase to 30%–40% in clay-rich sedimentary deposits. The Puye deposits beneath Mortandad Canyon are most similar to the clay-poor deposits in the upper Puye Formation at R-9 and R-12.

The water contents in rocks beneath Mortandad and Ten Site canyons (i.e., MCB-15) are generally higher than is observed beneath mesa locations on the Pajarito Plateau. For example, MCI-10, a mesa borehole adjacent to Mortandad Canyon, has the lowest water contents observed in this investigation for Tshirege

unit Qbt 1 and the Otowi Member (Table 7.2-4). Thus, higher fluxes are expected to be confined to those areas beneath Mortandad Canyon and are not expected to extend beneath the adjacent mesas. These results are consistent with observations made in other areas of the Laboratory, which show that canyons are often wetter than mesa locations (Birdsell et al., 2005, 92048; Newman 1996, 59118)

Oxygen and Hydrogen Stable Isotope Profiles

Pore water oxygen ($\delta^{18}O$) and hydrogen (δD) stable isotopes are another set of data that provide insights on vadose zone processes within Mortandad Canyon. These data were described previously by Longmire et al. (2001, 70103) and Broxton et al. (2002, 76006). They are useful in vadose zone studies because they are sensitive indicators of processes such as evaporation and mixing. Stable isotope profiles were collected from core samples from R-15, MCOBT-4.4, and MCOBT-8.5; $\delta^{18}O$ depth profiles are shown in Figure 7.2-13. The figures show two key features. The first feature is that all three holes show a zone in the shallow alluvium (Qal) where pore waters are isotopically heavy (less negative). For example, R-15 has a $\delta^{18}O$ of –5 ‰ in the shallow alluvium, and the MCOBT holes have values in the –7 to –8 ‰ range. As discussed by Broxton et al. (2002, 76006), such values are characteristic of waters that have undergone evaporation. Mortandad Canyon alluvial well samples collected in 1999 and 2005 range from –6 to -12 ‰. Some of the heavier values may be related to evaporated waters that are generated during water treatment and are subsequently released through outfalls to the canyon. However, the heavier alluvial aquifer values are also consistent with the low water contents observed in the shallow tuffs and alluvium (e.g., <6 m [<20 ft] in Table 7.2-4). Thus, it is likely that evaporative losses within the canyon are an important part of the canyon water budget. Although the stable isotopes are not sensitive to transpiration, the substantial amount of vegetation (including ponderosa pines) in the canyon indicates that there is also large water loss through transpiration. Thus, evapotranspiration (evaporation plus transpiration) must play a significant role in the canyon water budget despite the additions of water from runoff and five operating outfalls.

The second feature in the isotope profiles (Figure 7.2-13) is the shift from isotopically heavy values near the surface to relatively constant but significantly lighter values with depth. The reduction of variation in isotope values (with a few exceptions) occurs within the Qct and Qbo, and values are similar to the average annual precipitation values for the plateau (–10 to –11 ‰). Seasonal- and precipitation event-based variations in the isotopic composition of water inputs to the canyon are substantial based on the Mortandad alluvial data discussed above and on other studies on the plateau (e.g., LANL 1998, 59891; Newman et al. 1998, 76883). Thus, the shallow parts of the Mortandad Canyon profiles likely reflect some of this variation. In addition, isotope values at and below the base of the alluvium may contain alluvial groundwater from an upcanyon effluent source that flowed laterally to the particular location. After about 15 m (50 ft), much of the variation is dampened out. This reduction of variability in the deeper parts of the profiles indicates that substantial mixing occurs as water from different sources (i.e., effluent, runoff and evaporated precipitation, all from different time periods) moves through the upper vadose zone. Mixing is an important aspect of the canyon hydrology because it means that variations in contaminant inputs over time will be substantially smoothed out as well.

Surface DC Resistivity Survey

Surface DC resistivity surveys of the Mortandad watershed were conducted in 2002 and 2003 (Geophex,Ltd., 2003, 84540, Appendix B) and are summarized in Appendix H. This technique allows for noninvasive interrogation of large portions of the subsurface and can potentially identify conductive zones that may be related to moisture distribution (see Section 3.2). Figure 7.2-14 shows the survey results for the line run in the narrow section of the middle Mortandad Canyon hydrologic segment, from the

confluence with Effluent Canyon to just past well MCB-5. The survey results are compared with gravimetric moisture and perchlorate concentration profiles with depth at three wells.

In Effluent Canyon downcanyon of the TA-50 RLWTF outfall, thin alluvium overlies strongly welded tuff that forms an impermeable barrier to infiltration. The surface DC resistivity profile down the axis of the canyon (Geophex Ltd., 2003, 84540) indicated that the rocks beneath the channel are highly resistive (perhaps drier) below depths of a few feet.

In the western portion of the middle Mortandad Canyon hydrologic segment, between MCA-5 and MCB-5, resistivity profiling (Geophex 2003, 84540) indicates deepening of an upper conductive horizon as the stream channel progressively cuts down section through bedrock tuffs that are strongly welded (middle of Tshirege unit Qbt 2) into the poorly welded tuffs at the base of Tshirege unit Qbt 2 and in Tshirege unit Qbt 1v (Figure 7.2-14). The resistivity data suggest that infiltration is restricted to relatively shallow depths in the western portion of the middle Mortandad Canyon hydrologic segment. Nevertheless, core moisture profiles at MCOI-1, drilled along the Qbt 2 bench within the canyon, show that moisture can accumulate along deeper small scale features such as the Tshirege Qbt 1v/Qbt 1g contact, albeit with no evidence of associated contamination (Figure 7.2-14).

In the lower part of the Ten Site Canyon hydrologic segment, the surface DC resistivity profile down the axis of the lower canyon (Geophex 2004, 84540; see Appendix H) indicates that the rocks beneath the channel are moderately conductive at depths of 15 to 30 m (50 to 100 ft).

The eastern part of the middle Mortandad Canyon hydrologic segment and the western part of the lower Mortandad Canyon hydrologic segment from R-1 to approximately the location of MCOBT-8.5 include the most abundant and widespread shallow conductive intervals in electrical profiling (resistivity <100 ohm-m). Much of this conductive structure is beneath alluvium and within the Cerro Toledo deposits (see Appendix H). In this section of the canyon, the axial alluvial deposits thicken from about 10 to 33 m (30 to 110 ft). The contact between base of alluvium and the Cerro Toledo deposits is irregular, indicating branching channels cut into the top of the Cerro Toledo interval. Stratigraphy within the Cerro Toledo interval is complex and may lead to locally variable hydrogeologic properties at the base of alluvium (see Appendix G for discussion of heterogeneity in alluvium/colluvium and the Cerro Toledo interval).

7.2.1.4 Intermediate-Perched Zones in Mortandad Canyon

This section describes the physical setting of intermediate-depth perched groundwater in Mortandad Canyon. These perched groundwater bodies represent local areas of saturation in the deeper parts of the vadose zone and are too small for use as municipal water supplies. Nonetheless, they are of interest because (1) their chemical and isotopic characteristics help constrain groundwater transport rates through the vadose zone; (2) perching horizons may facilitate, divert, slow, or stop vertical migration of groundwater through the vadose zone, or they may indicate the presence of a fast subsurface pathway, depending on their hydraulic characteristics; and (3) they can be used as vadose-zone monitoring points that provide early warning of contaminants approaching the regional aquifer. The following descriptions of intermediate perched zones in Mortandad Canyon are modified from the recent paper by Robinson et al. (2005, 91682). Additional discussion about the constraints on saturated thickness and lateral extent of these perched zones relevant to Mortandad Canyon is provided in Appendix J.

Two groups of wells encounter perched water within the Cerros del Rio basalts beneath Mortandad Canyon. In one set of wells, MCOBT-4.4 and MCOI-4 near the Ten Site Canyon confluence, a thin perched zone occurs at a depth of about 160 m (520 ft), within the clay-rich basaltic rubble at the top of the Cerros del Rio basalts (Figure 7.0-1). The saturated thickness of this zone is approximately 1 m (3 ft). The mean water elevation is 1925.0 m (6315.7 ft) for MCOBT-4.4 and 1925.0 m (6317.1 ft) for MCOI-4.

Appendix J provides a discussion of temporal water-level fluctuations in the two wells. The apparent perching horizon at this location is a massive lava flow with few fractures. The massive lava causes perching because it lacks sufficient permeability at the existing level of saturation to drain the influx of new water. Fractures within the massive perching lava apparently do not conduct substantial groundwater flux. The inability of fractures to drain the perched zone is probably due to a combination of factors including the sealing of fractures by clay minerals and/or the limited number of fractures along the flow paths (flux along the fractures is smaller than the infiltration rate feeding the perched zone). Contaminant concentrations in groundwater in both wells vary over time (see Sections 7.2.2 and 7.2.3.), indicating water in the perched zone is flowing along a hydraulic gradient (i.e., not static).

About 350 m (1150 ft) downcanyon, a second group of wells, including MCOI-5, MCOI-6, and R-15, encountered perched water in the lower part of the Cerros del Rio basalt (Figure 7.0-1). The depth to water is 210 m (689 ft) at MCOI-5 and 202 m (664 ft) at MCOI-6. At R-15, the depth to water is poorly constrained by data collected during the drilling program, but it probably occurs between 197 m (646 ft) and 222 m (729 ft) (see Appendix J for more discussion of R-15 water-level data). The equivalent water elevations are 1869 m (6130.4 ft) at MCOI-5, 1874 m (6147.1 ft) at MCOI-6, and between 1857 and 1882 m (6091 and 6173.6 ft) at R-15. Minimum saturated thicknesses are 16.8 m (55 ft) at MCOI-5 and 21.9 m (72 ft) at MCOI-6; at R-15 estimates of saturated thickness range between 4.9 m (16 ft) and 30 m (99 ft). The perched water occurs in a combination of fractured and porous media. The fractured media consist of dense, massive lava flows cut by high-angle cooling fractures. These fractured lava flows are separated by nearly horizontal beds of porous interflow breccias. The variable static water levels and differences in saturated thicknesses within these closely spaced wells may be caused by the heterogeneous nature of perched groundwater systems located within basaltic rocks. This heterogeneity can reflect poor hydrologic communication among fractures, partial drainage of poorly connected perched zones during drilling, or spatial and temporal variability in the infiltration rate feeding the perched zone at the time of drilling. At R-15, the perching horizon appears to be clay-rich, flow-base rubble or underlying silty basaltic sands. The perched zones at MCOI-5 and MCOI-6 were probably not fully penetrated during drilling, and the perching horizons in these boreholes are uncertain.

Because of their different geologic settings, the perched groundwater occurrences at MCOBT-4.4/MCOI-4 and R-15/MCOI-5/MCOI-6 probably represent two unrelated groundwater bodies of limited lateral extent along the canyon axis (Figures 7.0-1 and 7.2-11). Based on the distribution of water-bearing vs. dry boreholes, the lateral extent of these perched groundwater bodies is probably less than 450 m (1500 ft).

A potential intermediate perched water zone was noted while drilling well MCOI-8, located about 325 m (1100 ft) upcanyon of the Ten Site Canyon confluence. A well was installed in the lower Cerros del Rio basalt where saturation was considered most likely based on borehole water-level measurements, video logs, and induction logs. Water-level measurements made since well installation indicate that water is present in the well sump but not in the screen. At the time of this report it is uncertain whether intermediate-perched groundwater is present at MCOI-8. A continuous-record water-level transducer is installed, and water levels are being monitored.

Other potential intermediate-perched water zones were also noted in the well completion report for boreholes MCRES-4 and MCB-7 (Kleinfelder 2006, 92486; Appendix B). At MCRES-4, possible perched water was noted in the lower Tshirege Member (Qbt 1g) between 21.3 and 22.9 m (70 and 75 ft). At MCB-7, the completion report indicates perched water occurred in the lower Tshirege Member (Qbt 1g) between 21 and 22.6 m (69 and 74 ft) and in the Cerro Toledo interval between 25.6 and 27.1 m (84 and 89 ft). Both boreholes encountered alluvial groundwater systems and there were problems sealing off the alluvial water from the deeper parts of the boreholes. Because of these problems, the intermediate-

perched groundwater at MCRES-4 and MCB-7 are considered possible, but poorly constrained, occurrences.

Figure 7.0-1 shows deep perched water within the lower Cerros del Rio lavas based on evidence from drill holes R-12 and R-10/10A, which are located in lower Sandia Canyon near the Laboratory boundary. There are no wells in this part of Mortandad Canyon, and it is not known whether these perched waters extend beneath the eastern part of the Mortandad watershed. Sources of the deep perched water observed at R-12 and R-10/10A are poorly constrained, but water-quality data indicate that these groundwaters do not contain contaminants associated with the Mortandad hydrologic system.

Water-level fluctuations in some of the perched intermediate zones were observed in 2005 following large rainstorms. These were originally hypothesized as rapid flow from the surface to the intermediate locations. However, the water-level fluctuations are probably not caused by infiltration of surface water during flood events but are a result of barometric pressure effects, as discussed in Appendix L.

7.2.1.5 Regional Aquifer Model

The water table of the regional aquifer, which lies approximately 300 m (1000 ft) below the canyon floor in Mortandad Canyon occurs within Miocene pumiceous sedimentary deposits that underlie the Pliocene Puye Formation. At a larger scale, the regional aquifer comprises several sedimentary and volcanic hydrostratigraphic units of varying thickness, lateral extent, and permeability. The hydraulic conductivity of aquifer rocks is highly heterogeneous and averages approximately 1 m/d (3 ft/d) at a regional scale. The regional aquifer is a complex hydrogeological structure that includes confined and unconfined zones that are characterized by a spatially varying degree of hydraulic communication.

The shallow portion of the regional aquifer near the water table is predominantly under phreatic (unconfined) conditions. The phreatic zone is mainly encountered in the Puye Formation and the underlying pumiceous sedimentary deposits and has limited thickness (approximately 30 to 50 m [100 to 165 ft]). The groundwater flow and transport in this zone are believed to generally follow the shape of the regional water table. The flow directions are then east-southeast, toward the Rio Grande. The hydraulic gradient along the regional water table is relatively steep; on the order of 0.01. The shape of the regional water table (i.e., the flow directions in the phreatic zone) is predominantly controlled by the existing areas of regional recharge (the Jemez Mountains with some contributions on the Pajarito Plateau) and discharge (springs in White Rock Canyon and the Rio Grande). The impact of Pajarito Plateau water-supply pumping on the flow directions in the phreatic zone is negligible (Appendix O).

The deep portion of the regional aquifer is predominantly under confined conditions. Water-supply pumping is performed predominantly in the deep portion of the regional aquifer. The pumping has negligible impact on the flow directions in the phreatic zone above beneath the Mortandad watershed because of poor hydraulic communication (Appendix O). The boundary between the shallow phreatic and the deep confined zones is not well defined. The hydraulic separation is caused by stacking highly stratified, gently dipping sedimentary deposits made up of individual beds characterized by highly variable hydraulic permeabilities and varying spatial extents. These strata are encountered in the Puye Formation and Santa Fe Group (Figure 7.0-1). Therefore, the boundary between the shallow phreatic and the deep confined zones is not a well-defined aquitard but instead represents the net effect of stacked beds with variable hydraulic properties, resulting in a vertical permeability that is at least 3 orders of magnitude lower than the horizontal permeability parallel to the bedding. For all the practical purposes, this causes a dominant hydraulic separation between the shallow phreatic and the deep confined aquifer zones that can be considered to be equivalent to an “aquitard.” However, the poor hydraulic communication does not necessarily preclude the possibility for contaminants to migrate through the “aquitard.”. Because of

pumping in the deep aquifer, there is a substantial vertical component of the hydraulic gradient between the shallow phreatic and the deep confined zones. This creates the possibility for groundwater flow and contaminant migration through the aquitard along hydraulic windows by shortcutting between the layering.

A regional representation of the water-table elevation is shown Figure 7.2-15. Similar spatial analysis of the hydraulic pressures in the deep portion of the regional aquifer is not feasible because of limited data.

Appendix N provides a spatial analysis of water-table variability and discusses the assumptions implemented in the generation of a regional water-table map (Figure 7.2-15). Appendix O provides analysis of temporal variability of water-table elevations measured at the monitoring boreholes near Mortandad Canyon (R-1, R-11, R-13, R-15, and R-28). Appendix P discusses the available information for the pumping-rate variability at the water-supply wells. These appendixes provide more detailed analyses of the potential impact of water-supply pumping on the groundwater flow and transport directions in the shallow phreatic zone of the regional aquifer. More details about this conceptual model of groundwater flow and transport beneath the Pajarito Plateau can be found in (Vesselinov 2005, 89753; Vesselinov 2005, 90040; Vesselinov 2004, 90117).

7.2.2 Contaminant Transport

Contaminant transport in the Mortandad watershed generally occurs along the pathways depicted in Figure 7.0-1. Adsorbing contaminants adhere to sediment to become part of the sediment load, as described in Section 7.1, and either stay relatively close to the release location or are transported down the canyon with surface flow events. Nonadsorbing species travel with water and follow the same flow paths that water takes. Weakly adsorbing constituents may travel with sediments or with water but generally migrate more slowly than nonadsorbing species. Strongly adsorbing species may travel with sediment or adsorb onto immobile rock surfaces. Therefore, adsorptive contaminants tend to exhibit retarded migration in the environment, and the nonadsorbing species are those that are detected in vadose-zone porewater and deeper groundwater zones.

The sections of this report that follow describe the nature and extent of COPCs in water. For each COPC, its current distribution in water is described and time histories are presented to illustrate the evolution of the COPC in the environment. The following format is used to describe these distributions.

- For surface water and alluvial groundwater, box plots showing recent (2000 to 2005) concentration data at different locations are used to define current COPC distributions throughout the watershed. Then time series plots give longer records in these waters to show concentration responses to long-term changes in effluent concentrations from the TA-50 RLWTF. In addition, shorter time series from 2000 to 2005 are presented to describe more recent concentration responses to treatment-plant enhancements and to flood events.
- For the vadose zone, contaminant distributions are described based on vadose-zone pore-water concentrations or contaminant masses as estimated from core samples. Time series concentrations are available for some perched-intermediate zones, and contaminant trends for these groundwaters are discussed.
- For the regional aquifer, time series plots present trends in concentration data for those few mobile contaminants that are observed in that zone.

A full series of plots in Appendix D provides a comprehensive overview of the spatial and temporal trends of COPCs in the Mortandad watershed. The discussion and supporting plots below provides additional information on the spatial and temporal distributions of these contaminants in key areas of the watershed.

- Box plots show concentration data between 2000 and 2005 for surface water and alluvial groundwater at sampling locations from west to east in relation to distance from the Rio Grande. These plots are useful for describing the present-day spatial distribution of COPCs and are also useful for identifying both the historical source(s) of each contaminant and the present-day "secondary" source areas. Three watershed segments are plotted. (1) The Effluent and Mortandad Canyons segment covers locations from the head of Effluent Canyon to the Mortandad Canyon confluence and then follows Mortandad Canyon eastward to the Rio Grande. (2) The Mortandad Canyon segment covers locations from the head of Mortandad Canyon to the confluence with Effluent Canyon and eastward to reach M-2E (Plate 1). (3) The Ten Site Canyon segment covers locations from the head of Ten Site Canyon to the confluence with Mortandad Canyon at well MCA-2. The sampling locations included in the plots were selected to bound known or suspected contaminant sources and generally include locations that have enough data to show variability in contaminant concentrations. The upper and lower ends of the boxes are the 75th and 25th percentiles of the data distribution, and upper and lower lines outside the boxes indicate 90th and 10th percentiles, respectively. Nondetect values are included in the plots. The paired numbers below each box indicate the number of detects (left) and nondetects (right) at each location. Detected values are represented in the plots with filled symbols, and the nondetect values are open symbols.
- Time series plots show available concentration data for surface water station E200 (and its nearby precursor GS-1) and many alluvial wells throughout the watershed for their full periods of record, which covers over a 40-yr period at many locations. Time series plots are also presented for regional wells and perched intermediate wells. Although these records are quite short, some apparent trends can be observed.
- Contaminant depth profiles show concentration as a function of corehole depth for porewater and solid-phase core. Samples for these analyses were collected when the boreholes were drilled and subsequently analyzed.

Overall, the spatial distributions of inorganic chemical and radionuclide concentrations indicate only a few key sources of the COPCs observed in groundwater and vadose-zone pore water, as described in Section 2.1. The most important source is the outfall from the TA-50 RLWTF into Effluent Canyon. Other sources include the former TA-35 WWTP outfall in Ten Site Canyon, possible discharges from cooling towers and radiochemistry laboratories at TA-48 in Effluent Canyon west of the TA-50 outfall (Plate 1) and in Mortandad Canyon west of gage E200, and sources at TA-03 with releases into upper Mortandad Canyon above the Effluent confluence. The cooling towers for the TA-03 power plant in the Sandia watershed may also have been a potential source of contaminants, especially chromium, to the groundwater beneath Mortandad Canyon.

Monitoring wells in the regional aquifer consist of both single- and multi-screen construction. Groundwater chemistry data from the single-screen completions are representative of predrilling conditions. However, two multi-screen wells do not provide fully representative data for the groundwater, especially for certain constituents subject to dissolution and desorption resulting from the affects of reducing conditions (e.g., chromium iron, perchlorate, and nitrate). The two affected wells/screens are R-14, screen 2 and R-33, screen 2.

7.2.2.1 Inorganic Chemicals in Water

Several inorganic chemicals are identified in Section 6 as being COPCs in water. Subsections below present a discussion of the spatial distribution and conceptual model for these COPCs.

Nitrate and perchlorate are the most mobile of the inorganic chemicals historically released in the watershed. Nitrate and perchlorate concentrations have been measured in surface water, and in alluvial, perched-intermediate and regional groundwaters. Their presence has also been observed in vadose-zone pore water collected from core samples from several boreholes drilled in and around Mortandad Canyon (Plate 1) since 1998. These combined results provide a comprehensive picture of subsurface contaminant distributions and migration at various locations in the watershed. In light of these results, this subsection first discusses contaminant nature and extent characteristics specific to nitrate and perchlorate within the watershed. The distributions of these nonadsorbing contaminants yield key information about subsurface pathways. The nitrate and perchlorate results in particular are useful because of the high mobility of these contaminants in the subsurface (i.e., they move at similar rates to subsurface pore water). Thus, their distribution is likely to bound the subsurface extent of other nonadsorbing contaminants that have followed the same migration pathway.

Nitrate

Nitrate is detected in surface water, alluvial and perched-intermediate groundwater, and the regional aquifer beneath Mortandad Canyon. There are both natural and anthropogenic sources of nitrate within the watershed, with Laboratory-derived nitrate produced from the dissociation of nitric acid that is neutralized before discharge. The other Laboratory source of nitrate is from treated sewage effluent in which nitrate concentrations are typically less than 5 mg/L due to denitrification taking place before discharge. Natural nitrate is common on the Pajarito Plateau and in the American Southwest (Walvoord et al., 2003, 93787). Thus, detectible levels of nitrate do not necessarily mean that contamination is present. However, it is clear that for many locations in the Mortandad watershed, the nitrate concentrations are elevated and related to historical Laboratory releases. Under oxidizing conditions, nitrate is mobile as an anion in groundwater and does not significantly adsorb onto clay minerals, ferric (oxy)hydroxide, solid organic matter, and other naturally occurring adsorbents. In the presence of denitrifying bacteria and reactive solid and dissolved organic carbon, nitrate becomes reduced to nitrogen gas. Other types of nitrate-reducing bacteria are capable of reducing nitrate to ammonium under oxygen-depleted conditions. In the discussion that follows, nitrate concentrations are based on different sampling and analysis techniques to obtain the largest data sets. Results for nitrate and nitrate plus nitrite are combined because nitrite is generally a very small part of the measured concentration. Filtered and nonfiltered results are also combined because filtration has little to no effect on nitrate concentration. Nitrate concentrations in the discussions that follows are reported in the units “Nitrate (as N, mg/L),” unless otherwise noted.

Nitrate in Surface Water and Alluvial Groundwater

Nitrate transport within the surface water and alluvial groundwater is controlled by the flow paths in these systems, which spread the contaminant laterally down the canyon, as described in Sections 7.2.1.1 and 7.2.1.2. The spatial trends in recent (2000–2005) nitrate concentrations in surface water and alluvial groundwater are shown in the box plots of Figures 7.2-16(a-c). In upper Mortandad Canyon (Figure 7.2-16[a]), in upper Effluent Canyon (Figure 7.2-16(b) above the TA-50 outfall, and in Ten Site Canyon (Fig. 7.2-16[c]), the nitrate concentrations are low (<1 mg/L), indicating that there are no recent sources contributing to the nitrate mass already in those canyon segments. However, nitrate concentrations increase in Effluent Canyon (Figure 7.2-16[b]) below the TA-50 RLWTF outfall and in

Mortandad Canyon below the confluence with Effluent Canyon (Figure 7.2-16[a]), indicating that the TA-50 RLWTF outfall continues to be the primary source of nitrate to the watershed.

Figure 7.2-17 is a time series plot covering the period 1960 through 2005. It shows the annual nitrate concentration in TA-50 effluent and the resulting concentrations at alluvial wells MCO-3, MCO-5, MCO-6, MCO-7 and MCO-7.5. The outfall nitrate concentrations averaged over 200 mg/L from 1981 to 1995, with maximum concentration approaching 500 mg/L. During this same period, nitrate concentrations in the alluvial wells were elevated with many measurements over 100 mg/L (as N). After 1995, outfall concentrations dropped below 100 mg/L, and from 2000 to 2004, the average outfall concentration was less than 3 mg/L due to improvements in wastewater treatment at the TA-50 RLWTF and concurrent source reduction implemented at Laboratory facilities that have their wastewater treated at the RLWTF. Correspondingly, concentrations in the alluvial wells have declined.

Nitrate concentrations increase spatially from west to east in Mortandad Canyon below the Effluent Canyon confluence from well MCO-5 to approximately well MCO-7.5. The trend is indicative of a dilution lag in the alluvial aquifer from west to east since improved nitrate removal began at the RLWTF in late 1999 (Section 2.1.1). The lag is due, in part, to distance from the outfall, but the increasing alluvial storage from west to east (Section 7.2.1.2) is probably a more important factor. To illustrate this, Figure 7.2-18 is a time series plot analogous to Figure 7.2-17, but it covers the period of low nitrate effluent concentrations, 2000 through 2004–2005. At well pair MCO-3/MCA-5 (Plate 1), which is located in the westernmost portion of the middle Mortandad Canyon hydrologic segment and has little alluvial storage, the concentration decline occurs almost immediately in 2000 following the drop in effluent concentration. At wells MCO-5 and MCO-6, near the eastern end of the middle Mortandad Canyon hydrologic segment, where the canyon is still narrow but the alluvium starts to thicken, the decline is delayed slightly with the greatest change in 2000 and 2001. Finally, nitrate concentrations at wells MCO-7 and MCO-7.5 have declined slowly since 2000. These wells are located in the lower Mortandad Canyon hydrologic segment where the highest amount of alluvial storage occurs. Nitrate concentrations at these distal locations should continue to decline in response to lower treated effluent concentrations and to periodic high runoff events. With few exceptions, the recent surface water and alluvial groundwater nitrate concentrations are less than the EPA Region 6 tap water MCL of 10 mg/L (Figure 7.2-17 and Figures 7.2-16[a–c]). In alluvial groundwater, these exceptions are two values at well MCO-7 (12.5 and 10.9 mg/L in February 2000 and August 2001, respectively) and one value at well MCO-7.5 (18 mg/L in 2000).

Nitrate in Vadose-Zone Pore Water and Perched-Intermediate Groundwater

Nitrate has migrated from the surface water and alluvial groundwater into the deeper vadose-zone, probably since effluent releases began in the watershed at TA-35 in 1951. Depth profiles of pore-water nitrate concentrations reflect the combined releases to the watershed (Appendix D, Figures D-2.3-1 through D-2.3-21). Nitrate was detected in every core hole analyzed in the watershed, and vadose-zone pore-water concentrations sometimes exceed 100 mg/L. The historic concentrations of nitrate in the alluvial groundwater (from 1960, these are shown in Figure 7.2-17) became the nitrate source for the deeper vadose zone in areas where perched-alluvial groundwater was present.

Figure 7.2-19 depicts the vadose-zone nitrate concentration along a longitudinal cross section through Mortandad Canyon. The figure shows nitrate concentrations measured from pore water and groundwater collected from representative characterization boreholes and regional and perched intermediate wells in the watershed. These data are also spatially interpolated using a minimum-tension technique (as implemented in the earthVision software, see Appendix I) to evaluate a generalized distribution of the concentrations between boreholes and wells, which can be used to describe characteristics about nature and extent of nitrate and migration pathways beneath the canyon.

Figure 7.2-20 depicts the distribution of nitrate mass along a longitudinal cross section through Mortandad Canyon. This mass distribution is estimated by multiplying the pore water and groundwater nitrate concentrations (Figure 7.2-19) and volumetric water content (Figure 7.2-11). Approximately 198,000 kg of nitrate has been reported as being released through the TA-50 RLWTF outfall into the Mortandad watershed from 1963 to 2005 (see Table 2.1-1). The distribution of mass, as estimated using the earthVision model (Figure 7.2-20, Appendix I), was used to estimate the current nitrate mass as it now exists distributed within and beneath the canyon, including nitrate in the alluvial groundwater, the unsaturated pore water (including alluvium), and the perched-intermediate zones. The estimated mass is approximately 228,000 kg nitrate (as N). Table 7.2-5 shows the mass distribution by strata. The estimated mass using in situ concentrations is 15% higher than the estimate made from outfall records (which also contains some inherent uncertainty), showing that the model technique provides a reasonable method for estimating in situ mass. Nearly the entire mass (99.7%) is estimated to be in the vadose-zone pore water within and stratigraphically above the Otowi member (Qbo). Only 0.1% and 0.2% of the nitrate mass are estimated to be in the alluvial groundwater and perched intermediate groundwater, respectively.

In terms of vertical extent, there is a region of elevated nitrate concentrations and mass located in approximately the upper 90 m (300 ft) of the vadose zone that extends into the mid- to lower-Otowi Member, as described above. In particular, nitrate has migrated into the Otowi Member at locations between about MCB-5 and MCOBT-8.5 (Figure 7.2-19). This is also the zone where the Otowi Member has elevated water content (Section 7.2.1, Figure 7.2-11 and Appendix B), alluvial groundwater is persistent to intermittent, perched-intermediate groundwater is observed, and apparent greater vadose-zone fluxes (Appendix M) are present. The broad zone of fairly well-defined contaminant extent is consistent with the general conceptual model of transport depicted in Figure 7.0-1.

The vertical migration of nitrate in the vadose zone west of MCB-5 is poorly constrained because of the inaccessibility of drill rigs to this part of Mortandad Canyon. However, the presence of thin alluvium over less permeable bedrock units 500 to 1000 m (1640 to 3280 ft) west of MCB-5 probably limits infiltration in that portion of the canyon. Borehole MCB-1 (Plate 1), located in Effluent Canyon above the TA-50 outfall, has very little nitrate (maximum pore-water concentration less than 1 mg/L, Figure D-2.3-1), reflecting the lack of a nitrate source and/or no migration pathway. At MCB-2, located east of the RLWTF outfall near the Mortandad Canyon confluence, observed pore-water nitrate concentrations remain low (less than 21 mg/L, Figure D-2.3-2) despite the presence of a nitrate source. Transport at this location is considered to be dominated by lateral surface water flow resulting in very little infiltration and vadose-zone transport. There is a marked change near the eastern end of the middle Mortandad Canyon hydrologic segment, where the canyon begins to widen and alluvium thickens around borehole MCB-5. From MCB-5 and further downcanyon to about MCOBT-8.5, elevated concentrations and vadose-zone mass are observed as described above.

The zone of low nitrate concentration and mass between MCOBT-8.5 and R-28 in Figures 7.2-19 and 7.2-20 is of interest. This zone likely contains a greater mass of nitrate than shown in the figures. Nitrate was detected within this zone in core holes MC-1 and MC-2, which were drilled as characterization boreholes for the proposed Advanced Hydrotest Facility (AHF). However, because of sample preservation problems (described in Appendix M), the nitrate pore-water concentrations are not accurate and were not used to generate the visualized nitrate distributions. Thus, the zone of elevated nitrate may extend east of MCOBT-8.5 toward R-28, at least down to the top of the Otowi Member, which was the maximum depth of the MC boreholes.

From R-28 east to MCB-16, near the Laboratory boundary, the frequency of high nitrate concentrations (above 100 mg/L) is substantially lower, especially when compared with the area between R-1 and MCBT-8.5. At R-28, there was only one nitrate detection above 100 mg/L. Pore-water concentrations of

nitrate are also low at MCB-16, except for three detections above 100 mg/L in an approximately 30-ft interval in the unsaturated alluvium (Figure D-2.3-13).

In order to bound the migration rates that have led to the current distribution of the main nitrate mass observed in the Mortandad watershed, several studies have estimated transport velocities based on vadose-zone chemical distributions. Estimates of vertical transport velocities of nitrate, based on a release of unique isotopically light nitrogen from October 1986 to September 1989, range between 2.5 and 2.9 m/yr (8.2 and 9.5 ft/yr) for wells MCOBT-4.4 and MCOBT-8.5, respectively (Broxton et al. 2002, 76006). Estimates of transport rates based on peak tritium releases to the canyon suggest that vertical transport rates have declined substantially from a possible maximum of 11 m/y (36.1 ft/y) in the late 1970s to about 1.36 m/yr (4.46 ft/yr) in 1999 (Kwicklis et al 2005, 90069). Finally, calibration to nitrate profiles in R-15 and MCOBT-8.5 yield approximate transport velocities of 6 m/y (20 ft/yr) in 1968 to 1.2 m/y (4 ft/yr) in 2002 (Birdsell et al. 2005, 92048). These studies apply to nonadsorbing constituents, such as nitrate, perchlorate and tritium, and indicate that vadose-zone transport velocities were greater in the past and over time have declined in response to declining outfall volumes.

Elevated nitrate concentrations are observed in perched-intermediate zones located beneath Mortandad Canyon. The presence of deep contamination indicates that there are some preferential pathways through the vadose zone that have transported comparatively small masses of nitrate to depths below the Otowi Member and beyond the main mass of the nitrate contamination. Nitrate concentrations have increased slightly from 13.2 to 16.2 mg/L in filtered samples within the perched-intermediate zone at well MCOBT-4.4 from 2002 to 2005 (Figure 7.2-21). This may indicate advancing nitrate-contaminated vadose-zone waters. Nitrate is also observed in perched-intermediate groundwaters at wells MCOI-4, MCOI-5, and MCOI-6 where reported nitrate concentrations for filtered samples over two sampling rounds in 2005 were 13 and 14.2 mg/L, 3.07 and 4.22 mg/L, and 13.7 and 16.8 mg/L, respectively (Figures D-2.2-16[f], D-2.2-17[f], D-2.2-18[f]).

In Ten Site Canyon, pore-water nitrate concentrations from the core collected at R-14 (Figure D-2.3-19), at the head of the canyon, and MCB-15 (Figure D-2.3-12), at the lower end of the canyon near the Mortandad Canyon confluence, are consistently low (less than 10 mg/L). However, pore-water concentrations exceed 1000 mg/L in the shallow part of borehole 35-2028 in Pratt Canyon, while concentrations are less than 4 mg/L below 12 m (69 ft) in this borehole. The 35-2028 results are indicative of releases to the Ten Site drainage; however, the vertical extent of nitrate is interpreted to be a function of relatively small mass and/or the lack of a continuous aqueous driver in Pratt and Ten Site Canyons.

Nitrate in the Regional Aquifer

Anthropogenic nitrate has been detected in the regional aquifer beneath Mortandad Canyon. Nitrate concentrations in filtered samples occur at 2 to 2.5 mg/L at R-15 during the 2000 to 2005 period, as shown in Figure 7.2-22. Isotopic analyses of the groundwater at R-15 suggest that nitrate is not significantly fractionated, having δ^{15}N ratios ranging from –0.8 to +1.3‰ (Longmire 2002, 72614). These values are characteristic of nitrate derived from neutralized nitric acid (Broxton et al. 2001, 71252), most likely released from TA-50 RLWTF. Nitrate concentrations varied from 3.10 to 4.89 mg/L at R-28 in 2005, as shown in Figure 7.2-23. These are the highest concentrations of nitrate measured in the regional aquifer beneath Mortandad Canyon. δ^{15}N values for several samples collected from R-28 ranged from 5.51 to +11.88‰, suggesting that nitrate is fractionated and was derived from a sewage source enriched in nitrogen-15 (Clark and Fritz 1997, 59168). Two potential sources of sewage-derived nitrate include the TA-35 lagoons within Ten Site Canyon and sanitary effluent discharges into Sandia Canyon. The Sandia Canyon source is considered most likely caused by the collocation at R-28 of chromium contamination

also thought to have its source in Sandia Canyon. The vadose-zone moisture content and nitrate profiles (Figures 7.2-11 and 7.2-19) at these two wells support the concept of different transport pathways (and hence possible different sources) for the nitrate in the regional aquifer at these locations. Elevated moisture contents and pore-water nitrate concentrations from core obtained during drilling of R-15 extent down into the Otowi Member and into a perched-intermediate zone within the Cerros del Rio basalt, indicating further downward migration of water and nitrate to the regional aquifer from the TA-50 source. Drier conditions and very little nitrate are observed in the vadose zone at R-28, indicating little vertical migration at that location. Nitrate in the regional aquifer at R-28 probably entered the regional aquifer upgradient and arrived at the well by horizontal flow within the regional aquifer.

Several other regional aquifer wells sampled during this investigation had nitrate concentrations of less than 1.0 mg/L including R-1, R-13, R-14, R-33, R-34, and TW-8. Concentrations of nitrate plus nitrite(N) were less than analytical detection (<0.05 mg/L) in four samples collected at R-14. The majority of groundwater samples analyzed from R-14 contained detectable nitrate plus nitrite. The nondetections are most likely due to the presence of residual drilling fluid in screen 2.

The spatial extent of nitrate detected in the regional aquifer correlates with the nitrate mass observed in the vadose zone.

Perchlorate

Perchlorate is detected in surface water, alluvial and perched-intermediate groundwater, and the regional aquifer beneath Mortandad Canyon. Perchlorate has been discharged into Mortandad Canyon from the TA-50 RLWTF outfall probably since 1963. The primary source of perchlorate is from perchloric acid ($HClO_4$), a strong oxidizing acid used in actinide research and processing at the Laboratory. Perchlorate is mobile and stable as an anion in groundwater and does not significantly adsorb onto clay minerals, ferric (oxy)hydroxide, solid organic matter, nor other naturally occurring adsorbents. Filtered and nonfiltered results are combined in the discussions that follow because filtration has little to no effect on measured perchlorate concentration.

Perchlorate in Surface Water and Alluvial Groundwater

Perchlorate travels laterally downcanyon with the surface water and alluvial groundwater in the watershed. The spatial trends in recent (2000–2005) perchlorate concentrations in surface water and alluvial groundwater are shown in the box plots of Figures 7.2-24 (a–c). In upper Mortandad Canyon (Figure 7.2-24(a)), in upper Effluent Canyon (Figure 7.2-24(b)), and in Ten Site Canyon (Figure 7.2-24(c)) the perchlorate concentrations are low (<10 μg/L), indicating that there are no recent perchlorate sources contributing to the perchlorate mass already in these canyon segments. The perchlorate concentration at surface water station E-1E SW in Effluent Canyon (Figure 7.2-24(b)) does not show an increase to indicate a TA-50 RLWTF outfall source; however, these data were all collected in 2005, approximately 3 yr after perchlorate treatment was improved at the TA-50 RLWTF and concentrations were greatly reduced in effluent (see Section 2.1.1). Perchlorate concentrations are higher in Mortandad Canyon beyond the confluence with Effluent Canyon (Figure 7.2-24(a)), indicating that previous perchlorate releases from the TA-50 RLWTF outfall were the primary source of perchlorate to the watershed. Figure 7.2-24(b) shows a trend of increasing concentration spatially from west to east in Mortandad Canyon beyond the Effluent Canyon confluence similar to that observed for nitrate. As for nitrate, this trend is indicative of a dilution lag in the alluvial aquifer from west to east since improved perchlorate removal began at the RLWTF in 2002 (see Section 2.1.1), with the lag being a function of both the distance from the outfall and the volume of alluvial groundwater storage.

Figure 7.2-25 is a time series plot covering the period 2000 through 2005 when perchlorate concentrations were regularly measured and removal of perchlorate from the TA-50 RLWTF effluent occurred. The plot shows annual perchlorate concentration in the effluent and the resulting concentrations at alluvial wells MCO-3, MCO-5, MCO-6, MCO-7, and MCO-7.5. Outfall perchlorate concentrations have dropped from 257 and 305 μg/L in 2000 and 2001, respectively, to nondetect since 2003 (LANL 2005, 91523). Correspondingly, concentrations in the alluvial wells have declined to values ranging from about 10 to 50 μg/L in 2005. Alluvial concentrations should continue to decline in response to the greatly reduced perchlorate concentrations in the effluent, with a lag similar to those seen in the nitrate responses at corresponding alluvial wells (Figure 7.2-18).

Perchlorate in Vadose-Zone Pore Water and Perched-Intermediate Groundwater

Perchlorate has migrated from the surface water and alluvial groundwater into the vadose zone. The vertical extent of perchlorate contamination in the vadose zone is similar to nitrate in most of Mortandad Canyon, as depicted in Figure 7.2-26 and in Appendix D (Figures D-2.3-1 through D-2.3-21). The collocation is likely an indication of the same release site (TA-50 RLWTF) and similar release histories. Within a given borehole, perchlorate and nitrate concentrations are often highly correlated with depth (for example, see Figures D-2.3-16 and D-2.3-20), and within some boreholes, correlation coefficients between perchlorate and nitrate are above 0.9. These correlations suggest a similar long-term release history for the two contaminants and similar transport rates in the vadose zone. Correlations tend to be poorer in the alluvium. However, this is a zone where variable mixing of recharge water and some denitrification is likely occurring (LANL 2005, 91696). In contrast, there is no evidence for natural perchlorate degradation in Mortandad Canyon (e.g., no chlorate and chlorite, byproducts of perchlorate degradation).

Until 1999, no records were kept for perchlorate in the TA-50 RLWTF effluent. The present-day distribution of perchlorate mass is estimated from the interpolated concentration data shown in Figure 7.2-26 in the same manner that is used to estimate the nitrate mass (Appendix I). Table 7.2-5 lists the approximate in situ perchlorate mass as 1248 kg and includes the distribution by stratigraphic interval. As for nitrate, nearly the entire perchlorate mass (95.6%) is estimated to be in the vadose-zone pore water within and stratigraphically above the Otowi Member. Only 2.6% and 1.7% of the mass are estimated to be in the alluvial groundwater and perched-intermediate groundwater, respectively.

The vadose-zone distribution of perchlorate is also quite similar to that of nitrate. Perchlorate concentrations are mostly below analytical detection in Effluent Canyon (MCB-1 and MCB-2, Figures D-2.3-1 and D-2.3-2), but concentrations are significantly higher where the canyon widens near the Ten Site Canyon confluence (from MCB-5 downcanyon), which also supports the conceptual model shown in Figure 7.0-1. There is one notable exception to the similarity in horizontal extent between nitrate and perchlorate. In contrast to nitrate, the zone of little to no perchlorate beyond borehole MCOBT-8.5 depicted in Figure 7.2-26 is probably real. In fact, pore-water perchlorate results suggest that there is not much perchlorate from approximately AHF borehole MC-1 eastward to the Laboratory boundary. Pore-water concentrations for boreholes MC-1, -2, -3, and MCB-16 (Figure D-2.3-13) show no perchlorate detections, and there were only two isolated detections in pore water in R-28 (Figure D-2.3-21). Note that the sample preservation problems with the AHF MC boreholes mentioned in Appendix M would increase estimated concentrations.

It is possible that a continuous area of perchlorate contamination occurs in the vadose zone between MCOBT-8.5 and R-28 in the mid- to lower-Otowi Member because the MC holes were only drilled to the top of the Otowi Member. However, the limited detections and low perchlorate concentrations at R-28

suggest that the zone of contamination becomes discontinuous somewhere between MCOBT-8.5 and R-28.

Perchlorate also occurs in perched-intermediate groundwater beneath Mortandad Canyon. Perchlorate concentrations increased from 32.1 to 256 μg/L at perched-intermediate well MCOBT-4.4 sampled from 2001 to 2005 (Figure 7.2-21). Concentrations of perchlorate collected at MCOI-4 varied from 134 to 159 μg/L during 2005 (Figure D-2.2-16(g)). Perchlorate concentrations at MCOI-4 are lower than those observed at MCOBT-4.4, even though the two wells are close to each other and screened across the same zone in the Puye Formation. At well MCOI-5, perchlorate concentrations generally increased from 81.6 to 104 μg/L during 2005 (Figure D-2.2-17(g)). Concentrations of perchlorate at MCOI-6 varied from 159 to 246 μg/L during 2005 (Figure D-2.2-18(g)).

Occurrence of perchlorate in Ten Site Canyon is different than that observed for nitrate. Although nitrate was observed at low concentrations (<10 mg/L) in core collected for well R-14 in upper Ten Site Canyon, perchlorate concentrations are elevated to a depth of 90 m (300 ft) with maximum pore water concentrations over 200 μg/L (Figure D-2.3-19). Perchlorate was also detected in pore water down to 27 m (90 ft) in borehole 35-2028 in Pratt Canyon, and some concentrations exceeded 500 μg/L. In addition, there were two chlorate detections in the upper 27-m (90-ft) zone, and these are the only chlorate detections observed in the entire Mortandad watershed borehole data set. It is possible that the chlorate is an in situ perchlorate degradation product. It is also possible that it is a remnant of an older radiochemistry process similar to that used at TA-21. This difference in observations for nitrate and perchlorate indicates that there was not a Ten Site Canyon nitrate source that was correlated to the apparent perchlorate source.

The R-14 and 35-2028 results show that there were historical releases of perchlorate into the Ten Site drainage, likely through Pratt Canyon. This is also supported by the results from MCB-15 at the bottom of Ten Site Canyon where perchlorate concentrations up to 37 μg/L in pore water are observed (Figure D-2.3-12). The MCB-15 profile shows that there are two distinct intervals of perchlorate contamination, one extending from 3 to 6 m (11 to 21 ft) (and possibly shallower) and the other extending from 40 to 46 m (131 to 151 ft) (and possibly deeper). The upper zone is within the alluvium and does not extend past the contact with unit Qbt1g tuff. The top of the deeper zone lies roughly 9 m (30 ft) below the top of the Otowi Member. It is not clear why these isolated zones are present, but there are some alternative hypotheses. The shallow zone probably developed from surface water infiltration or episodic alluvial groundwater migration within Ten Site Canyon, similar to that observed in Mortandad Canyon. An explanation for the contamination in the deeper interval is less clear. It could represent a deeper, but separate, flow path within Ten Site Canyon or a lateral southward flow component from Mortandad Canyon, given the proximity between the two canyons.

Perchlorate in the Regional Aquifer

Perchlorate released from TA-50 has migrated to the regional aquifer in Mortandad Canyon. The highest concentrations of perchlorate were measured at R-15. Concentrations of perchlorate at R-15 generally increased from 4.71 to 6.39 μg/L from 2003 to 2005 (Figure 7.2-22). Concentrations of perchlorate at R-28 ranged from 0.99 to 1.13 μg/L during 2005 (Figure 7.2-23). Concentrations of perchlorate are observed at R-1, R-13, R-33, R-34, and TW-8 (see Appendix D, Section D-2.2) were much lower than those observed at R-15 and R-28. Detectable concentrations of perchlorate, analyzed by liquid chromatography-mass spectrometry/mass spectrometry (EPA SW846 modified Method 6850) to obtain a lower detection limit, ranged from 0.12 to 0.48 μg/L at R-1, R-13, R-14, R-33, R-34, and TW-8. Concentrations of perchlorate were less than analytical detection (<0.05 μg/L) in three samples collected at R-14 (screen 2). The nondetects of low-level perchlorate are most likely due to the presence of residual

drilling fluid in screen 2, R-14. The spatial extent of perchlorate detected in the regional aquifer correlates with the perchlorate mass observed in the vadose zone.

Chromium

Chromium is detected in surface water, alluvial and perched-intermediate groundwater, and the regional aquifer beneath Mortandad Canyon. Chromium speciation controls its mobility in groundwater.

- Chromium(VI) is soluble as anions and is subsequently mobile in oxidizing groundwater. Chromium(VI), in the form of potassium dichromate ($K_2Cr_2O_7$), was used in cooling towers at the TA-03 power plant as a corrosion inhibitor from approximately 1956 to 1972 (LANL 2006, 91987), and cooling tower blowdown (effluent) was released into Sandia Canyon. It may have been used in other cooling towers at TA-03, TA-35 and TA-48 with blowdown released directly to the Mortandad watershed as well. Chromic acid may also have been used in electroplating operations at facilities on Sigma Mesa at TA-03 (LANL 2006, 91987). Both potassium dichromate and chromic acid dissociate to the anions CrO_4^{2-} and $HCrO_4^-$, which are hypothesized to be the dominant mobile species in surface water and groundwater. Chromium(VI) is the dominant species when concentrations of chromium in filtered and nonfiltered sample pairs are similar.
- Chromium(VI) can be reduced to chromium(III) in the presence of reducing agents, such as solid organic matter present within wetlands and alluvial sediments and ferrous iron within glass, silicates, and oxides in the alluvium and Cerros del Rio basalt. Once reduced, the chromium(III) is insoluble and precipitates from solution as amorphous or crystalline $Cr(OH)_3$ and co-precipitates with ferric iron as $(Fe_xCr_{1-x})(OH)_3$ (Rajet et al 1987, 91686; Raji and Zachara 1986, 91684) and is subsequently much less mobile in groundwater. Below pH 7, chromium(III) is stable as a cation that adsorbs onto solid organic matter. In any of these phases, chromium(III) is associated with suspended particles present in nonfiltered samples. Chromium(III) is the dominant species when chromium concentrations in nonfiltered samples exceed those in filtered samples.

The role of speciation on chromium mobility will be further evaluated under the “Interim Measures Work Plan for Chromium Contamination in Groundwater” (LANL 2006, 91987) and under subsequent related work plans as appropriate.

Chromium in Surface Water and Alluvial Groundwater

The spatial trends in recent (2000–2005) total (nonspeciated) chromium(III and VI) concentrations in surface water and alluvial groundwater are shown in box plots in Appendix D, Figures D-2.1-7 through D-2.1-9, for different portions of the Mortandad watershed. Box plots for both filtered (dissolved) and nonfiltered (dissolved and suspended fractions) samples are presented separately because filtration tends to remove trivalent chromium from the sample and thus allows speciation information to be gleaned from the total chromium analyses, as discussed above. The spatial distributions of chromium concentrations shown in Figures D-2.1-7 through D-2.1-9 indicate that chromium in surface water and alluvial groundwater in the Mortandad watershed are predominantly, if not entirely, Laboratory derived.

At the heads of Mortandad Canyon (Figure D-2.1-7) and Effluent Canyon (Figure D-2.1-8), and throughout Ten Site Canyon (FigureD-2.1-9), total chromium concentrations in surface water and alluvial groundwater are higher than at downstream locations, indicating that separate chromium sources are discernible in reaches at the heads of these canyons. At each of these locations, chromium(III) dominates over chromium(VI) in the surface water and alluvial groundwater samples because the nonfiltered fraction constitutes the majority of total chromium. In upper Mortandad Canyon, the highest chromium concentrations occur in surface water below TA-03 within reach M-1W where total chromium was

observed at 27.5 μg/L in a nonfiltered water sample. In Effluent Canyon, the highest concentration of total chromium is 100 μg/L in a nonfiltered alluvial groundwater sample collected at MCO-2/MCA-4 west of (above) the TA-50 outfall. In Ten Site Canyon, total chromium is identified in surface water within reaches TS-1C, TS-2C, and TS-2E (Figure D-2.1-9). The maximum detected concentration of total chromium is 20.8 μg/L in surface water in reach TS-1C. The higher apparent presence of chromium(III) in the upper portions of these canyon segments indicates that the chromium(III) is relatively immobile and is probably related to the presence of chromium(III)-contaminated sediments redistributed downcanyon of small historical sources at TA-03, TA-48, and TA-35 (Section 2.1). The predominance of chromium(III) in that area is also likely related to the several small wetlands that exist within the canyon floor in that area. The concentrations and frequency of detection generally decrease east of the TA-50 RLWTF outfall in Effluent Canyon and in Mortandad Canyon past the confluence with Effluent Canyon. From reach E-1W eastward, low-detected concentrations of total chromium occur in surface water and alluvial groundwater. Although chromium(III) dominates in the samples, detection of chromium in both filtered and nonfiltered samples indicates the co-occurrence of chromium(III and VI) in the surface water and groundwater samples. Concentrations in filtered samples of both surface water and alluvial groundwater do not exceed 50 μg/L or 100 μg/L, the NMWQCC groundwater standard and EPA Region 6 drinking water MCL, respectively.

Chromium in Vadose-Zone Pore Water and Perched-Intermediate Groundwater

The hypothesis for chromium transport in the vadose zone is that chromium(VI) migrates from the alluvial groundwater into the vadose zone and travels as the mobile anions CrO_4^{2-} and $HCrO_4$. Chromium(VI) can be reduced to chromium(III) along vadose zone flow paths by naturally occurring minerals and volcanic glass that act as reducing agents. Ferrous iron concentrated within the Cerros del Rio basalt is considered to be another potential reductant for chromium(VI). Once reduced, chromium(III) precipitates from solution or adsorbs onto ferric (oxy)hydroxide and clay minerals.

Analytical results for chromium and iron measured on vadose-zone core samples are plotted in Appendix D, Figures D-2.4-1 through D-2.4-21. Potential anthropogenic chromium was identified in the core samples at concentrations exceeding background for the Bandelier Tuff-Cerro Toledo Interval (2.24 to 7.14 mg/kg) and/or sediments (10.5 mg/kg) (Ryti et al. 1998, 59730) at MCB-2, -7, -8, -9, -10, -11, -12, -14, -15, and -16, R-14, and R-15. Chromium is found concentrated at or near the interfaces of the alluvium with Unit Qbt1g and of Unit Qbt1g with the Cerro Toledo Interval (Figures D-2.4-1 through 2.4-21). The highest concentration of anthropogenic chromium (440 mg/kg) was detected in core collected at R-15 at a depth of 37 m (120 ft) at the contact between the Cerro Toledo Interval and Otowi Member of the Bandelier Tuff (Figures D-2.4-20 and D-2.4-21) (Longmire et al. 2001, 70103). With respect to the MCB boreholes, the highest concentration of anthropogenic chromium (71 mg/kg) was detected at MCB-14 at a depth of 66 m (215 ft) (Figure D-2.4-11) within the Otowi Member of the Bandelier Tuff. In fact, MCB-14 contains the greatest chromium mass of any borehole with five measured chromium concentrations above 15 mg/kg over the depth interval 52 to 82 m (170 to 270 ft). Excluding the sample from core collected at R-15, core samples from the remainder of the boreholes did not have chromium concentrations exceeding 15 mg/kg. Concentrations of chromium are within background at MCB-1, MCB-5, and MCB–6.

Analysis conducted on core samples did not differentiate chromium(III) from chromium(VI). However, because of the ability of iron-bearing minerals to reduce and then adsorb chromium(III), the co-occurrence of chromium and iron is indicative of adsorbed chromium(III). The chromium and iron profiles (Figures D-2.4-1 through D-2.4-21) indicate a strong correlation between chromium and iron, that is, higher chromium concentrations are collocated with higher iron concentrations, meaning that the chromium is likely relatively immobile. Under acidic pH conditions, CrO_4^{2-} and $HCrO_4^-$ adsorb onto ferric

(oxy)hydroxide to a greater extent than under alkaline pH conditions. Therefore, chromium(VI) may partly account for some of the association between iron and chromium in the unsaturated zone.

Elevated chromium(VI) concentrations are observed in perched-intermediate zones located beneath Mortandad Canyon. The presence of deep contamination indicates that there are some preferential pathways through the vadose zone that have transported comparatively small masses of chromium to depths below the Otowi Member. Perched-intermediate wells sampled during 2005 include MCOI-4, MCOI-5, MCOI-6 (Figures D-2.2-16[a], D-2.2-17[a], and D-2.2-18[a]), and MCOI-8, whereas MCOBT-4.4 (Figure 7.2-21) was sampled from 2001 to 2005. The data show spatially variable results with chromium(VI) dominating in some of the perched zones and chromium(III) at others.

Concentrations of total chromium in filtered and nonfiltered samples decreased from 53.3 to 37.4 μg/L and 53.6 to 41.4 μg/L, respectively, at perched-intermediate well MCOBT-4.4 during 2002 and 2003 (Figure D-2.2-15[a]). Concentrations of total chromium in filtered and nonfiltered samples were similar, indicating that chromium(VI) dominants over chromium(III) at MCOBT-4.4.

Concentrations of total chromium in nonfiltered samples collected at MCOI-4 in 2005 have decreased from 135 to 61.3 μg/L (Figure D-2.2-16[a]) and sample turbidity decreased from 31.9 to 18 nephelometric turbidity units (NTUs). Total chromium in filtered samples increased from 25 to 29.4 μg/L in the samples during 2005. Concentrations of total chromium in nonfiltered samples initially exceeded those in filtered samples suggesting that chromium(III) dominates.

Concentrations of total chromium in nonfiltered samples collected at MCOI-5 in 2005 decreased from 770 to 545 μg/L (Figure D-2.2-17[a]) and sample turbidity decreased from 83.6 to 16.6 NTU. This well is located on the south side of Mortandad Canyon near regional aquifer well R-15. Concentrations of total chromium in filtered samples at the well also decreased from 3.5 to 3.1 μg/L. This suggests that chromium(III) dominates and that chromium(VI) represents a small fraction not removed from solution by adsorption and/or precipitation processes.

Concentrations of total chromium in nonfiltered samples at MCOI-6 in 2005 were 52.2 to 58.9 μg/L (Figure D-2.2-18[a]) and sample turbidity was 4.86 and 6.41 NTU. Concentrations of total chromium in filtered samples collected at the well also increased from 48.4 to 58.2 μg/L, suggesting that chromium(VI) dominates. Variation in total chromium in nonfiltered samples is caused by the presence of suspended particles that probably contain natural and anthropogenic chromium(III). Well MCOI-8 was sampled for chromium in 2006, and analytical results will be reported in the "Chromium Interim Measures Report."

Overall, perched-intermediate groundwaters from MCOBT-4.4, MCOI-4, and MCOI-6 have elevated chromium(VI), represented by total chromium concentrations in filtered samples, ranging from 25 to 58 μg/L that is most likely anthropogenic. Suspended particles in these samples probably contain both natural and anthropogenic chromium(III). Chromium(VI) concentrations, represented by total chromium concentrations in filtered samples in intermediate groundwater from MCOI-5 are low at 3.5 μg/L or less. This well may not be impacted by anthropogenic sources.

Chromium in the Regional Aquifer

Regional aquifer wells sampled during this investigation included R-1, R-13, R-14, R-15, R-28, R-33, R-34, and TW-8 (see Appendix D, Section 2.2). Concentrations of total chromium within the regional aquifer in the Puye Formation are the highest beneath the axis of Mortandad Canyon at R-28 (Figure 7.2-23) and decrease to the southeast and southwest at R-13 (Figure D-2.2-20[a]) and R-15. (Figure 7.2-22).

Concentrations of total chromium at R-15 varied from 3.6 to 14.7 μg/L in nonfiltered samples collected from 1999 to 2005 (Figure D-2.2-22[a]). Concentrations of total chromium varied from 2.6 to 7.9 μg/L in filtered samples at the well (Figure 7.2-22 and D-2.2-22[a]). Concentrations of total chromium at R-28 generally increased from 375 to 404 μg/L (Figure 7.2-23) and from 389 to 416 μg/L (Figure D-2.2-23[a]) in filtered samples and nonfiltered samples, respectively, collected during 2005. These are the highest concentrations of total chromium(III, VI) and chromium(VI) measured in the regional aquifer beneath the Laboratory. Detectable concentrations of total chromium in nonfiltered and filtered samples ranged from 2.73 to 12.3 μg/L and from 0.93 to 8.2 μg/L, respectively, at R-1, R-13, R-14, R-33, and R-34 (Appendix D, Section D-2.2). Concentrations of total chromium varied from 3.36 to 7.92 μg/L in nonfiltered samples collected at TW-8 from 2001 to 2005 (Figure D-2.2-26[a]). Concentration of total chromium in three filtered samples were less than analytical detection (<1 μg/L) at R-14 (Figure D-2.2-21[a]) in 2004 and 2005. The majority of water samples from R-14 contained detectable total chromium. The nondetection of total chromium is most likely due to the presence of residual drilling fluid in screen 2, R-14.

Iron

Solid and aqueous species of iron occur within stream sediments, alluvial and perched-intermediate groundwater, the regional aquifer, and unsaturated and saturated rock. Under oxidizing and circumneutral pH conditions, such as in the Mortandad watershed, ferric iron precipitates from solution typically as insoluble ferric (oxy)hydroxide and ferric oxide (hematite) (Langmuir 1997, 56037). Iron is stable in the +II (ferrous) and +III (ferric) oxidation states in aqueous solution and forms complexes with hydroxide, sulfate, chloride, and bicarbonate. These complexes influence the solubility of iron(II, III) solids. Ferric (oxy)hydroxide is an important adsorbent for many trace elements and radionuclides, including americium, arsenic, cadmium, chromate, cobalt, lead, nickel, plutonium, selenium, thorium, uranium, and zinc. The specific surface area of hydrated ferric hydroxide (ferrihydrite) is 600 m^2/g as compared with that of quartz having a value of 0.14 m^2/g (Langmuir 1997, 56037). Iron(III) dominates over iron(II) when concentrations of iron in nonfiltered samples exceed those of filtered samples. Iron and manganese have similar chemical properties, and iron is typically collocated with manganese in sections of the Mortandad watershed. Under reducing conditions enhanced by the presence of residual organic-based drilling fluids, iron(III) solids dissolve and iron(II) aqueous species and solids becomes stable. Desorption of trace elements can take place during reductive dissolution of ferric (oxy)hydroxide, resulting in an increase of these solutes in groundwater.

Iron in Surface Water and Alluvial Groundwater

The spatial trends in total (nonspeciated) iron(II and III) concentrations in surface water and alluvial groundwater from 2000-2005 are shown in box plots in Appendix D, Figures D-2.1-10 through D-2.1-12, for different portions of the Mortandad watershed. Box plots for both filtered (dissolved) and nonfiltered (dissolved and suspended fractions) samples are presented separately to help differentiate speciation. The highest concentrations of total iron in nonfiltered samples are measured within reach M-1W (25.5 mg/L, Figure D-2.1-10) in upper Mortandad Canyon just east of TA-03 (Plate 1) and at well MCO-2/MCA-4 (26 mg/L) in Effluent Canyon (Figure D-2.1-11). Most of the iron at these locations occurs as a precipitate associated with suspended material because concentrations of total iron in nonfiltered samples are greater than total iron in filtered samples. Surface water at reach E-1W is also elevated (approximately 5 mg/L in both nonfiltered and filtered samples). Concentrations of total iron are much lower in surface water and alluvial groundwater within Mortandad Canyon east of the Effluent Canyon confluence (Figure D-2.1-11). These distributions indicate sources at the head of Mortandad Canyon in TA-03 and to Effluent Canyon west of the TA-50 RLWTF outfall.

In Ten Site Canyon, the highest concentration of iron is identified in surface water within reach TS-1C (Figure D-2.1-12). Iron(III) precipitate(s) associated with suspended material dominate within this reach because concentrations of total iron in nonfiltered samples greatly exceed dissolved iron in the surface-water samples. Concentrations of total iron in nonfiltered samples decrease downcanyon to the Mortandad confluence (Figure D-2.1-12). Concentrations of iron detected in surface water in reach TS-1C are possibly related to the presence of iron-contaminated sediments redistributed down canyon of the TA-35 source. Ferric chloride and ferric sulfate were identified as chemicals present in the TA-35 wastewater or used to treat the wastewater before discharge (LANL 1997, 56835).

Iron in Vadose-Zone Pore Water, Perched-Intermediate Groundwater, and the Regional Aquifer

Analytical results for iron measured on vadose-zone core samples are plotted in Figures D-2.4-1 through D-2.4-21. Background concentrations of iron range from 0.37 to 1.45 wt% within the Bandelier Tuff and are 1.38 wt% in sediments (McDonald et al. 2003, 76084; Ryti et al. 1998, 59730). Background concentrations of iron are observed at MCB-1, MCB-2, MCB-5, MCB-6, MCB-14, and MCB-16, R-14, and R-15. Concentrations of iron exceeding background occur at MCB-7, MCB-8, MCB-9, MCB-10, MCB -11, MCB -12, and MCB-15, which could be represented by a combination of anthropogenic and natural iron in the forms of ferric (oxy)hydroxide, Fe_2O_3 (hematite) and Fe_3O_4 (magnetite) The co-occurrence of iron and chromium, as discussed in the chromium section above, suggests that adsorption processes are important in concentrating chromium within the vadose zone.

Anthropogenic forms of iron discharged from the Laboratory most likely have not migrated to perched-intermediate zones and the regional aquifer because of the elements' low solubility under circumneutral pH and oxidizing conditions dominant in the subsurface. Distributions of natural iron in the deeper saturated zones are controlled by specific hydrogeochemical conditions including redox conditions, groundwater composition, and aquifer mineralogy. Biologically induced breakdown of drilling fluids results in reductive dissolution of ferric (oxy)hydroxide and hematite (LANL 2005, 91533). Concentrations of total dissolved and total iron range from 2.33 and 4.50 mg/L and 4.24 and 6.85 mg/L, respectively, at R-14 (screen 2). Elevated concentrations of dissolved iron show the presence of residual drilling fluid at the well.

Fluoride

Fluoride has been detected in surface water, alluvial and perched-intermediate groundwater, and the regional aquifer within the Mortandad watershed. There are both natural and anthropogenic sources of fluoride within the watershed, with Laboratory-derived fluoride produced from the dissociation of hydrofluoric acid that is neutralized before discharge. Fluoride has been released at the TA-50 RLWTF outfall, but since 2000, effluent concentrations have been below the New Mexico WQCC groundwater standard of 1.6 mg/L, and in 2005 the average concentration had dropped to 0.24 mg/L (LANL 2006, 93925). Fluoride is mobile in groundwater as an anion and does not significantly adsorb onto clay minerals, ferric (oxy)hydroxide, solid organic matter, and other naturally occurring adsorbents. In the presence of calcium, fluoride precipitates from solution as CaF_2 (fluorite), and its solubility is independent of pH.

Fluoride in Surface Water and Alluvial Groundwater

Fluoride travels laterally downcanyon with surface water and alluvial groundwater in the watershed. The spatial trends in recent (2000–2005) fluoride concentrations in nonfiltered samples of surface water and alluvial groundwater are shown in box plots in Appendix D, Figures D-2.1-13 through D-2.1-15, for different portions of the Mortandad watershed. Fluoride was detected in all surface water samples

collected within upper Mortandad Canyon west of the Effluent confluence (Figure D-2.1-13). The highest concentration of fluoride was 0.72 mg/L measured in reach M-1W. Concentrations of fluoride decrease in surface water to the Effluent Canyon confluence and then increase downcanyon (Figure D-2.1-14). The maximum concentrations of fluoride are 1.92 mg/L at wells MT-1 and MT-3 in 2005, just slightly over the New Mexico WQCC groundwater standard of 1.6 mg/L. In Ten Site Canyon, detectable concentrations of fluoride are low, ranging between 0.03 and 0.42 mg/L in surface water samples. Effluent from the TA-50 RLTWF has been a source of fluoride to the watershed. However, it appears that fluoride has also entered the watershed at TA-03 and may have come from TA-48 (to both Mortandad and Effluent canyons) as well.

The overall distribution of fluoride concentrations in surface water and alluvial groundwater is very similar to that observed for nitrate. That is, fluoride concentrations increase spatially from west to east in Mortandad Canyon beyond the Effluent Canyon confluence. As for nitrate, the trend is indicative of a dilution lag in the alluvial aquifer from west to east since improved effluent quality in 2000 (Section 2.1.1). The lag is caused by the distance from the outfall and to increasing alluvial storage from west to east (Section 7.2.1.2). Time series plots for surface water at gage E200 (Figure D-2.2-1[b]) and several alluvial wells (e.g., Figures D-2.2-6[b], D-2.2-7[b], D-2.2-9[b]) show a decline in fluoride concentrations since 2000. In 2005, only the most distal alluvial wells, MCOBT-7.5, MT-1, and MT-3 have concentrations slightly over the New Mexico WQCC groundwater standard (1.92 mg/L vs. 1.6 mg/L). None of the surface water or alluvial water concentrations is currently above the EPA Region 6 tap water standard of 4 mg/L. Over time, fluoride concentrations at the alluvial wells will decline even further in response to improved effluent quality at the TA-50 outfall and to dilution by occasional surface water runoff events.

Fluoride in Vadose-Zone Pore Water and Perched-Intermediate Groundwater

Fluoride appears to have mobility similar to nitrate in the vadose zone and is present in vadose-zone pore water into the Otowi Member and at a few locations is present in perched-intermediate groundwater. For instance, at wells MCOBT-4.4 and MCOBT-8.5, pore-water concentrations of fluoride range from approximately 4 to 20 mg/L throughout the Otowi Member (Broxton et al. 2002, 76006). Concentrations of fluoride have varied within the perched-intermediate zones from 2002 to 2005, which may be indicative of natural conditions with a slight impact from the TA-50 outfall. Concentrations of fluoride in filtered and nonfiltered samples slightly varied from 0.4 to 0.42 mg/L at MCOBT-4.4 during 2002 and 2003. At MCOI-4, concentrations of fluoride in nonfiltered samples varied from 0.21 to 0.24 mg/L. At MCOI-5, concentrations of fluoride in filtered and nonfiltered samples increased from 0.24 to 0.33 mg/L. Concentrations of fluoride in filtered and nonfiltered samples at MCOI-6 increased slightly from 0.54 to 0.59 mg/L during 2005.

Fluoride in the Regional Aquifer

Fluoride within the regional aquifer beneath Mortandad Canyon is generally variable within a narrow concentration range. Concentrations ranged from 0.01 to 0.48 mg/L, representing natural conditions within the regional aquifer.

Lead

Lead is a naturally occurring trace metal found in surface water and groundwater environments. It is also a widespread environmental contaminant associated with industrial discharges, bullets, batteries, leaded gasoline, paint, solder, and other waste forms or chemicals. Lead is stable in the +II oxidation state in aqueous solution (Langmuir 1997, 56037) and forms complexes with hydroxide, sulfate, chloride, and bicarbonate. Lead also precipitates from solution in the form of hydroxide, carbonate, sulfate, and

phosphate minerals. Lead strongly adsorbs onto ferric (oxy)hydroxide through surface complexation reactions (Langmuir 1997, 56037) under circumneutral pH conditions. Lead is very immobile in groundwater if it occurs as a cation and is not complexed with organic ligands or anions.

Lead in Surface Water and Alluvial Groundwater

The spatial trends in recent (2000–2005) lead concentrations in nonfiltered samples of surface water and alluvial groundwater are shown in box plots in Appendix D, Figures D-2.1-16 through D-2.1-18. The two highest concentrations of lead measured within the Mortandad watershed, exceeded 30 μg/L and 27 μg/L in nonfiltered surface water samples collected in upper Ten Site Canyon (Figure D-2.1-18) and upper Mortandad Canyon (Figure D-2.1-16), respectively. Concentrations of lead in nonfiltered surface water samples lower substantially downcanyon. In Effluent Canyon, the highest concentration of lead (22 μg/L) was measured in a nonfiltered alluvial groundwater sample collected at well MCO-2/MCA-4 above the TA-50 RLWTF outfall (Figure D-2.1-17). A dissolved concentration of lead of 3.5 μg/L was measured at alluvial well MCO-2/MCA-4, located above the Mortandad Canyon confluence. The sources of lead at these locations, which are all near the head of their respective canyons, are most likely anthropogenic, originating from TA-35, TA-03 and TA-48 discharges, respectively, and/or atmospheric and roadside deposition of leaded gasoline that contains tetraethyl lead. Most of the lead within the watershed is associated with suspended material because concentrations of this metal in nonfiltered samples are greater than that found in filtered samples. Concentrations of dissolved lead in surface water and alluvial groundwater within the watershed are less than the New Mexico WQCC groundwater standard of 50 μg/L and the EPA Region 6 tap water standard of 15 μg/L.

Lead in Vadose-Zone Pore Water, Perched-Intermediate Groundwater, and the Regional Aquifer

Anthropogenic forms of lead discharged from the Laboratory most likely have not migrated substantially into the vadose zone and have not reached perched-intermediate zones and the regional aquifer because of the element's high capacity to adsorb onto surfaces of aquifer material containing smectite and ferric (oxy)hydroxide. At well R-15, lead analyses of vadose-zone core samples showed lead within the Bandelier tuff and the Cerro Toledo interval (Longmire et al. 2001, 70103). However, this was attributed to naturally occurring elements within the tuff samples. Detectable concentrations of lead in nonfiltered samples from perched-intermediate zones ranged from 0.56 to 13.8 μg/L at MCOI-4, MCOI-5, MCOI-6, and MCOI–8 and MCOBT-4.4. Dissolved (filtered) concentrations of lead are generally not detected (upper detection limit of 0.5 μg/L) within perched-intermediate zones and the regional aquifer. When detected, dissolved concentrations of this trace metal are less than 0.3 μg/L. Distributions of natural lead in the deeper saturated zones are controlled by specific hydrogeochemical conditions including groundwater composition and aquifer mineralogy. Elevated concentrations of lead may occur in wells resulting from corrosion of components and solder associated with electrical wiring.

Manganese

Manganese is stable in the +II, +III, and +IV oxidation states in aqueous solution in which a large stability field for dissolved Mn(II) occurs (Langmuir 1997, 56037). Manganese (III, IV) solids are stable under oxidizing conditions typical of aquatic environments with little or no dissolved or solid organic matter. Manganese(IV) solids are considered to be important minerals present within aquifer and vadose material in the watershed based on oxidizing conditions. Manganese(IV) solids are important adsorbents for many trace elements similar to that of ferric (oxy)hydroxide (Langmuir 1997, 56037). Manganese (III, IV) oxides are less abundant than ferric (oxy)hydroxide and hematite in aquifer material and surface sediments at the Laboratory based on much higher concentrations of iron (in the weight percent range) than

manganese (in the parts per million range). Manganese has a spatial distribution that is, in part, similar to that of iron in sections of the watershed.

It is widely accepted that bacterially mediated reduction of manganese depends upon sediment moisture conditions, the availability of labile organic carbon, and the presence of poorly crystalline manganese oxides (Lovley 1991, 85523; Lovley and Chapelle 1995, 85506). In wetlands within upper Mortandad Canyon, dissolved and solid organic matter are concentrated in sections with abundant vegetation including grasses, shrubs, cattails, and coniferous and deciduous trees. Persistent saturated conditions in these reaches ensure environmental stability for microbial communities, and abundant manganese oxides associated with volcanic rocks, especially weathered tuffs, on the Pajarito Plateau provide optimal conditions for manganese reduction in wetland pore water. In addition, the slow oxidation kinetics of manganese and the progressively longer residence time of stagnant water within wetlands result in an accumulation of soluble manganese (Hem 1981, 85505).

Manganese in Surface Water and Alluvial Groundwater

The spatial trends in recent (2000–2005) manganese concentrations in nonfiltered and filtered samples of surface water and alluvial groundwater are shown in box plots in Appendix D, Figures D-2.1-19 through D-2.1-21. Concentrations of manganese in filtered and nonfiltered surface water samples range from 6.3 to 958 μg/L and from 7.4 to 1080 μg/L, respectively, within Effluent Canyon. Concentrations of manganese in filtered and nonfiltered alluvial groundwater samples range from 1510 to 2266 μg/L and from 1670 to 2375 μg/L, respectively, at MCA-4. Concentrations of manganese exceeding 2 mg/L are associated with both nonfiltered and filtered samples in surface water in reach M-1E and in alluvial groundwater at MCO-0.6 (Figure D-2.1-19), both located in or near wetland areas in upper Mortandad Canyon west of the Effluent Canyon, and in alluvial groundwater collected from MCO-2/MCA-4 within Effluent Canyon west of the TA-50 RLWTF outfall (Figures D-2.1-20). The presence of abundant wetlands in upper Effluent Canyon and Mortandad Canyon suggests that the manganese observed in this portion of the watershed is naturally occurring. Concentrations of manganese sharply decrease immediately east of the TA-50 outfall and remain low throughout Mortandad Canyon. Most of the detectable manganese is stable as soluble manganese(II) based on similar concentrations within filtered and nonfiltered samples. Concentrations of manganese in filtered and nonfiltered surface water samples range from 1.67 to 33.7 μg/L and from 2.5 to 108 μg/L, respectively, within Mortandad Canyon. Concentrations of manganese in filtered and nonfiltered alluvial groundwater samples range from 0.296 to 7.6 μg/L and from 0.296 to 45.6 μg/L, respectively, within Mortandad Canyon.

In Ten Site Canyon, manganese is identified in surface water within reaches TS-1C and TS-2E (Figure D-2.1-21). The maximum concentrations of total manganese in filtered and nonfiltered water samples are 449 and 1690 μg/L, respectively, in surface water in reach TS-1C. This distribution suggests that particulates of manganese(III, VI) oxides occur within the reach, and the surface water is moderately oxidizing. The maximum concentrations of total manganese in filtered and nonfiltered samples are 875 and 887 μg/L, respectively, in surface water in reach TS-2E. This distribution suggests that manganese(II) is stable and that reductive dissolution of manganese(III, IV) oxides has taken place within the reach. It is not clear whether the manganese in Ten Site Canyon represents a natural condition or a Laboratory source of manganese.

Manganese within Perched-Intermediate Groundwater and the Regional Aquifer

Any anthropogenic forms of manganese that may have been released by the Laboratory most likely have not migrated to perched intermediate zones and the regional aquifer because of the elements' low solubility under circumneutral pH and oxidizing conditions dominating in the subsurface. Distributions of

natural manganese in the deeper saturated zones are controlled by specific hydrogeochemical conditions including redox conditions, groundwater composition, and aquifer mineralogy. Biologically induced breakdown of drilling fluids results in reductive dissolution of manganese oxide (LANL 2005, 91533).

Nickel

Nickel is stable in the +II oxidation state in aqueous solution as Ni^{2+}, $NiHCO_3^+$, and $NiCO_3^0$ (Langmuir 1997, 56037). Free or noncomplexed Ni^{2+} is stable under acidic pH conditions, whereas the complexes $NiHCO_3^+$ and $NiCO_3^0$ are stable under circumneutral pH conditions in the presence of total carbonate alkalinity. Nickel(II) solids, including $Ni(OH)_2$ and $NiCO_3$, are stable under a wide range of redox conditions. Natural nickel is concentrated within the Cerros del Rio lavas, ranging between 35 and 154 ppm (Vaniman et al. 2002, 72615) and is a trace element associated with olivine, basaltic glass, and weathering products such as ferric (oxy)hydroxide, smectite, and iddingsite. Nickel(II) adsorbs onto ferric (oxy)hydroxide and clay minerals (Langmuir 1997, 56037) through surface complexation and cation exchange reactions, respectively.

Elevated concentrations of nickel in filtered and nonfiltered samples were measured at MCOI-5 and R-33 (screen 1) during one or two sampling rounds conducted in 2005. Well MCOI-5 was sampled on June 9 and September 9, 2005. Concentrations of nickel in filtered and nonfiltered samples were 55.8 and 62.2 μg/L and 414 and 282 μg/L, respectively, at MCOI-5. Concentrations of iron in the same filtered and nonfilter samples were 62.4 and 69.8 μg/L and 6980 and 4360 μg/L, respectively, at MCOI-5. Concentrations of iron in nonfiltered samples suggest the presence of iron-rich solid phases associated with suspended material. Turbidity values were 83.6 and 16.6 NTU in the two samples collected on June 9 and September 9, 2005, respectively. Well MCOI-5 is completed within Puye Formation/Cerros del Rio basalt. One hypothesis for explaining the elevated nickel concentrations at MCOI-5 is that natural adsorbents for nickel and other metals such as ferric (oxy)hydroxide, olivine, smectite, and volcanic glass are present as suspended particles.

Well R-33 was sampled on June 24 and 27 and September 14 and 15, 2005. Concentrations of nickel were 168 and 25.1 μg/L, respectively, in filtered and nonfiltered samples collected on June 24, 2005, at R-33 (screen 1) using EPA Method SW-846-6010B. The analytical result for nickel in the filtered sample is suspect because it is greater than that for the nonfiltered sample. The turbidity measured for the sample was 24.1 NTU. Concentrations of iron in the same filtered and nonfilter samples were 163 and 251 μg/L, respectively, which were also analyzed by using EPA Method SW-846-6010B. Other samples collected at R-33 in September 2005 did not show any discrepancies within metal analyses.

7.2.2.2 Organic Chemicals in Water

Aroclor-1260

Aroclor-1260 generally was not detected in surface water and alluvial groundwater samples collected within the Mortandad watershed (Appendix D, Figures D-2.1-22 through D-2.1-24). The maximum instrument detection limit (IDL) for aroclor-1260 was 1.4 μg/L. Arochlor-1260, however, was detected at a concentration of 1.1 μg/L in one nonfiltered surface water sample collected in Ten Site Canyon within reach TS-1C (Figure D-2.1-24). Aroclor-1260 is not considered to be a widespread COPC in surface water or alluvial groundwater within the watershed.

Bis(2-ethylhexyl)phthalate

Bis(2-ethylhexyl)phthalate was detected between concentrations of 0.5 and 7 μg/L in nonfiltered surface water and alluvial groundwater samples within Mortandad Canyon (Appendix D, Figures D-2.1-25 through D-2.1-27). The highest concentration of bis(2-ethylhexyl)-phthalate was measured at well MT-1. The maximum practical quantitation limit (PQL) for bis(2-ethylhexyl)-phthalate is 22 μg/L. Detects of bis(2-ethylhexyl)-phthalate are typically less than the PQLs but are above the minimum detection limit (MDL) of 0.5 μg/L. Bis(2-ethylhexyl)phthalate was observed in regional well R-15 from 2000 to 2005 and in R-33 in 2005 at ranges of 2 to less than 11 μg/L. Bis(2-ethylhexyl)phthalate is a component of plastics and could be derived from several sources, including bailers used during sample collection, Laboratory discharges and runoff, and analytical laboratories in which water samples come in contact with plastic during analysis.

1,4-Dioxane

Perched-intermediate groundwater has shown detections of 1,4-dioxane at MCOI-4 (53.3 and 50.8 μg/L) and MCOI-6 (52.2 and 56.4 μg/L). Other wells sampled in the Mortandad watershed did not contain detectable concentrations of 1,4-dioxane. The analytical detection limit for recent samples analyzed for 1,4-dioxane is 50 μg/L using gas chromatography-mass spectrometry. 1, 4-dioxane is completely miscible in aqueous solution and does not adsorb onto solid surfaces. 1, 4-dioxane is used as a solvent for cellulosics and a wide range of organic products including lacquers, paints, varnishes, paint and varnish removers, cleaning and detergent preparations, cements, cosmetics, deodorants, and fumigants (Verschueren 1983, 63044). The source(s) of 1,4-dioxane have not been identified.

7.2.2.3 Radionuclides in Water

Several radionuclides are identified in Section 6 as being COPCs in surface water, alluvial and perched-intermediate groundwater and/or the regional aquifer in the Mortandad watershed. These include tritium, strontium-90, plutonium-238, plutonium-239,240, and americium-241. A series of plots in Appendix D provides a high-level overview of the spatial trends of the radionuclide COPCs in the Mortandad watershed. The discussion below provides additional information on the spatial distribution of these contaminants in key areas of the watershed. Overall, the spatial distribution of radionuclide concentrations indicates only a few key sources of contaminants in water. The most important sources include the TA-50 outfall within Effluent Canyon and the former TA-35 WWTP outfall adjacent to reach TS-1C in Ten Site Canyon (Plate 1). Ash from the Cerro Grande fire may be a potential minor source of radionuclide constituents measured in water.

Tritium

Tritium is detected in surface water, alluvial groundwater, perched-intermediate groundwater, and the regional aquifer in Mortandad Canyon. Tritium has been discharged into the Mortandad watershed from approximately 1953 to 1974 at TA-35 and since 1963 at the TA-50 RLWTF (see Section 2.1). Tritium is a radioactive isotope of hydrogen with a relatively short half-life of 12.32 yr, which decays to helium-3 with the emission of a beta particle (Clark and Fritz 1997, 59168). It is extremely mobile because it can replace hydrogen within a water molecule and travel as groundwater.

Tritium in Surface Water and Alluvial Groundwater

Tritium travels laterally down canyon with the surface water and alluvial groundwater in the watershed. The spatial trends in recent (2000–2005) tritium concentrations in surface water and alluvial groundwater

are shown in the box plots of Figures D-2.1-28 through D-2.1-30. Tritium concentrations are low (< 1000 pCi/L) in upper Mortandad Canyon (Fig. D-2.1-28), in upper Effluent Canyon (Fig. D-2.1-29), and in Ten Site Canyon (Fig. D-2.1-30) indicating that there is little, if any, recent tritium disposal contributing to these canyon segments. The highest concentrations of tritium in surface water are observed at gage E200 with two detections greater than the groundwater MCL of 20,000 pCi/L. All other surface water and alluvial groundwater detections, except for one high value at well pair MCO-3/MCA-5, are far below the MCL.

Figure 7.2-27 is a time series plot covering the period 1967 through 2005. It shows the annual tritium concentration in TA-50 RLTWF effluent and the resulting concentrations at alluvial wells MCO-3/MCA-5, MCO-5, MCO-6, MCO-7 and MCO-7.5. From 1976 to 1992, the outfall tritium concentrations averaged over 300,000 pCi/L, with maximum concentration exceeding 3,000,000 pCi/L. During this same period, tritium concentrations in the alluvial wells were elevated with many values over 20,000 pCi/L. Since 2001, outfall concentrations have dropped below 20,000 pCi/L. Correspondingly, concentrations of tritium have decreased in surface water and alluvial groundwater.

Current concentrations of tritium in alluvial groundwater are generally higher in the Mortandad Canyon segment between wells MCO-3/MCA-5 and MCO-7.5 (Figure D-2.1-29) are lower east of MCO-7.5. Previous releases from the TA-50 RLWTF are the likely source of tritium. Similar to nitrate and perchlorate, tritium demonstrates a trend of increasing concentration spatially from west to east in Mortandad Canyon beyond the Effluent Canyon confluence. Again, this trend is indicative of a dilution lag in the alluvial aquifer from west to east since improved tritium removal began in 2000 (see Section 2.1.1), with the lag being a function of both the distance from the outfall and localized alluvial storage. To illustrate this, Figure 7.2-28 is a time series plot analogous to Figure 7.2-27, but it covers the period of low tritium effluent concentrations, 2000 through 2004/2005. The observed decline in tritium concentration over time is completely analogous to that observed for nitrate. That is, at the westernmost well pair MCO-3/MCA-5, the concentration decline occurs almost immediately in 2000 after the drop in effluent concentration. At wells MCO-5 and MCO-6, the decline is delayed slightly with the greatest change in 2000 and 2001. Finally, tritium concentrations at the most distal wells, MCO-7 and MCO-7.5, have declined slowly since 2000. Tritium concentrations at these distal locations should continue to decline in response to lower effluent concentrations

Tritium in Vadose-Zone Pore Water and Perched-intermediate Zones

Tritium has migrated from the surface water and alluvial groundwater into the vadose zone. Figures D-2.3-22 through D-2.3-42 show the distribution of tritium concentrations in core samples collected at the MCB-, MCOI- and R- boreholes or wells in the Mortandad watershed. These values are presented here as pore-water concentrations. Both the vertical and horizontal (downcanyon) extent of tritium in the vadose zone is similar to that of nitrate and perchlorate in most of the canyon. This is demonstrated by comparing vadose-zone concentrations for tritium (Figures D-2.3-22 through D-2.3-42) to analogous profiles for nitrate and perchlorate (Figures D-2.3-1 through D-2.3-21). Tritium was detected in core samples collected at 9 of the 13 MCB- boreholes and at MCOI-6, MCOI-8, and MCOI-10, R-1, R-14, R-15, and R-28. A maximum concentration of 3.75×10^6 pCi/L of tritium was measured at MCB-10 at a depth of 18 m (60 ft) within the alluvium. Samples collected at MCB-9, MCB-10, and MCB-11 also had peak concentrations of detectable tritium within the alluvium. At MCB-5, MCB-6, and MCB-7, and R-1, peak concentrations of detectable tritium occur within the Bandelier Tuff, Unit Qbt1g. Peak concentrations of detectable tritium occur within the Cerro Toledo Interval at MCB-8 and MCB-12. The deepest pore-water measurements were observed in the Otowi Member in MCB-14, MCOI-6, MCOI-8, R-1, and R-15, which coincides with that part of Mortandad Canyon below the confluent with Ten Site Canyon and represented as an area with the enhanced deep percolation (Figure 7.0-1). At some locations

(e.g., MCB-14 in Figure D-2.3-32; R-1 in Figure D-2.3-39), tritium does not extend as deep as nitrate and perchlorate, which might be due to radioactive decay in the deepest (and oldest) vadose-zone porewater within the Bandelier Tuff. Tritium was not detected at MCB-1 and MCB-2, west of the RLTWF outfall within Effluent Canyon, or at MCB-15, MCB-16, MCOI-1, or MCOI-10.

Tritium is observed in perched-intermediate groundwater. Concentrations of tritium within saturated portions of the Puye Formation and Cerros del Rio basalt are the highest beneath the axis of Mortandad Canyon east of the confluence with Ten Site Canyon. Concentrations of tritium at MCOBT-4.4 ranged from 9700 to 14,900 pCi/L from 2001 to 2003, when tritium concentrations generally increased over time (Figure 7.2-21). The concentration of tritium was 21,007 pCi/L in a sample collected from the well during 2005. Concentrations of tritium at MCOI-4 varied from 11,700 to 12,900 pCi/L, whereas lower concentrations of tritium occur at MCOI-5 ranging from 4310 to 5370 pCi/L during 2005 (Figures D-2.2-16[l] and D-2.2-17[l]). Concentrations of tritium at MCOI-6 varied from 12,200 to 13,100 pCi/L (Figure D-2.2-18[l]). The concentration of tritium measured at MCOI-8 was 137 pCi/L, confirming that recharge from surface water or perched alluvial groundwater infiltrates to perched-intermediate zones immediately west of the Ten Site confluence.

Tritium in the Regional Aquifer

Based on available data, concentrations of tritium within the regional aquifer in the Puye Formation are the highest beneath the axis of Mortandad Canyon at R-28 and decrease to the south at R-15. Concentrations of tritium at R-28 increased from 152 to 181 pCi/L during 2005 (Figure 7.2-23). These are the highest concentrations of tritium measured in the regional aquifer within Mortandad Canyon. Concentrations of tritium at R-15 increased from 1.12 to 31 pCi/L from 1999 to 2005 (Figure 7.2-21). Concentrations of tritium at regional aquifer well TW-8 varied from 4.21 to 140 pCi/L from 2003 to 2005 (Figure D-2.2-26[l]). TW-8 was drilled by the cable tool method and was completed in 1960, which may have resulted in leakage of alluvial groundwater down the well casing. R-1, a replacement well for TW-8, was drilled 75 m (246 ft) west of TW-8 does not contain tritium (Figure D-2.2-19[l]). Concentrations of tritium are slightly above the IDL of 0.29 pCi/L, using electrolytic enrichment, at R-1 and R-14 (screen 1) (Figures D-2.2-19[l] and D-2.2-21[l]). Concentrations of tritium are less than analytical detection at wells R-13, R-14 (screen 2), R-33, and R-34 (Figures D-2.2-20[l], D-2.2-21[l], D-2.2-24[l], D-2.2-25[l]).

Strontium-90

Strontium-90 has a half-life of 28.78 y and decays to yttrium-90 through emission of a beta particle. Strontium-90 reversibly adsorbs onto sediments containing clay minerals through cation exchange reactions (Langmuir 1997, 56037). Strontium is stable in the +II oxidation state in aqueous solution. Strontium forms complexes with bicarbonate ($SrHCO_3^+$, $SrCO_3^0$) under near-neutral pH conditions. Cationic forms of strontium are considered to be less mobile than neutral forms under alkaline pH conditions because cation exchange dominates over anion exchange (Langmuir 1997, 56037). Stable or natural strontium and strontium-90 precipitates from solution as $SrCO_3$ (strontianite), which has an aqueous solubility of $10^{-9.27}$ moles/L (6.63×10^6 pCi/L) (Langmuir 1997, 56037). Therefore, precipitation is another potential process for removing strontium-90 from solution. Surface water and groundwater have much higher concentrations of stable strontium than of strontium-90, which enhances precipitation of $SrCO_3$ within the watershed for long periods of time exceeding 30 years.

Strontium-90 in Surface Water and Alluvial Groundwater

The spatial trends of current (2000 through 2005) strontium-90 concentrations in both nonfiltered and filtered surface water and alluvial groundwater samples are shown in box plots in Appendix D, Figures

D-2.1-31 through D-2.1-33. These plots indicate that the TA-50 RLWTF outfall and former discharges from the TA-35 WWTP are important Laboratory sources of strontium-90 within the Mortandad watershed. Dissolved strontium-90 makes up approximately 50% to 90% of total strontium-90 within surface water and alluvial groundwater in the Mortandad watershed, suggesting that this radionuclide reversibly adsorbs onto sediments through cation exchange reactions. In Mortandad Canyon, concentrations of strontium-90 are generally higher in surface water at location E200 east of the confluence with Effluent Canyon and in reach M-2E and in alluvial water in the segment of Mortandad Canyon between wells MCO-3/MCA-5 and MCO-6 (Figure D-2.1-32). In Effluent Canyon, concentrations in surface and alluvial groundwater are elevated east of the RLWTF outfall, which is clearly a source of strontium-90 to the watershed. The maximum concentration of strontium-90 in surface water is approximately 48 pCi/L measured in surface water in Mortandad Canyon at location E200. The highest concentration of strontium-90 was 81.6 pCi/L at MCO-5, the alluvial groundwater monitoring well located east of the PRB and west of the confluence with Ten Site Canyon (Figure D-2.1-32). Concentrations of total strontium-90 sharply decrease downcanyon to less than 4 pCi/L at alluvial well MCO-7 and other wells farther to the east. Groundwater mixing and/or an increase in the adsorptive capacity of the alluvium (silt-sized material) may explain concentration decreases of strontium-90 between alluvial wells MCO-6 and MCO-7. Persistent surface water was uncommon in this portion of the Mortandad watershed during the investigation period; therefore, contamination was generally limited to alluvial groundwater.

The spatial distribution of strontium-90 concentrations in surface water in Ten Site Canyon above the Mortandad Canyon confluence indicate that the bulk of strontium-90 has migrated downcanyon to reach TS-2E (Figure D-2.1.33). The highest concentration of total strontium-90 within this reach is 21.3 pCi/L. A portion of the strontium-90 released from TA-35 WWTP, however, occurs in upper Ten Site Canyon in surface water within reach TS-1C with a maximum concentration of 7 pCi/L.

Figure 7.2-29 is a time series plot for strontium-90 covering the period 1963 through 2005. It shows the annual strontium-90 concentration in RLWTF effluent and the concurrent concentrations at alluvial wells MCO-3/MCA-5, MCO-5, MCO-6, MCO-7, and MCO-7.5. The strontium-90 concentrations in the outfall averaged 380 pCi/L from 1963 to 1989, with a maximum concentration of 1725 pCi/L. During this same period, strontium-90 concentrations in the alluvial wells were elevated with many measurements over the MCL of 8 pCi/L. Concentrations at the alluvial wells that are located closest to the TA-50 outfall, MCO-3 and MCO-5, tend to rise in response to outfall releases. Those wells farther downcanyon, MCO-7 and MCO-7.5, have relatively constant, low concentrations of strontium-90. It is likely that adsorption onto various adsorptive phases within alluvial sediments retards further strontium-90 transport. After 1993, outfall concentrations dropped below 10 pCi/L, and from 2000 to 2004, the average outfall concentration has been less than 4 pCi/L due to source reduction implemented by the waste generators before entering the TA-50 RLWTF and through cation exchange and/or reverse osmosis treatment at the facility. Correspondingly, concentrations in the alluvial wells have declined. The rate of decline of strontium-90 concentrations in alluvial groundwater is controlled by concentration decreases in the TA-50 effluent, by cation exchange and dilution in the environment, and by radioactive decay.

Figure 7.2-30 shows the alluvial aquifer response to strontium-90 source reduction for the period 2000 through 2005, when outfall concentrations dropped to below 4 pCi/L. This response is not similar to that observed for nitrate, perchlorate, or tritium, which showed a lag in dilution at alluvial wells located farther from the source. Here the more distal wells (MCO-7 and MCO-7.5) maintain low concentrations because they were not elevated in the first place. Concentrations at wells MCO-3/MCA-5, MCO-5, and MCO-6 are slowly declining in response to the source reduction. This response may be delayed by desorption of strontium-90 from the sediment and alluvial load.

Strontium-90 in Vadose-Zone Pore Water, Perched-Intermediate Groundwater, and the Regional Aquifer

Plots of concentration versus depth for strontium-90, shown in Figures D-2.4-22 through D-2.4-38, indicate that this radionuclide is concentrated within the alluvium and at the alluvium/bedrock contact. Higher concentrations of strontium-90 are observed in alluvial groundwater indicating that a fraction of this radionuclide adsorbs onto alluvial material, as discussed above. Strontium-90 was detected in core samples collected at MCB-5, MCB -6, MCB-7, and R-1 at depths less than 11 m (35 ft). The maximum concentration of strontium-90 is approximately 1.16 pCi/g measured at borehole MCB-5 at a depth of 6 m (20 ft) within the alluvium. The strontium-90 values shown in these plots are generally below the analytic detection limit, as indicated by the open blue triangles. Concentrations of strontium-90 in core samples were less than analytical detection at MCB-1, MCB-2, MCB-8, MCB-9, MCB-10, MCB-11, MCB-12, MCB-14, MCB-15, MCB-16, R-14, R-15, and R-28. Strontium-90 is not consistently detected within perched-intermediate zones and the regional aquifer within the Mortandad watershed due to its ability to adsorb onto silt- and clay-sized material present within the alluvium and weathered Bandelier Tuff.

Plutonium-238 and Plutonium-239,240

The half-life of plutonium-238 is 87.7 yr, and the isotope decays to uranium-234 by emission of an alpha particle (Parrington et al. 1996, 58682). The half-lives of plutonium-239 and plutonium-240 are 2.410×10^4 and 6.56×10^3 yr, respectively, and they decay to uranium-235 and uranium-236, respectively, by emission of alpha particles (Parrington et al. 1996, 58682). Plutonium strongly adsorbs onto sediments containing clay minerals and ferric (oxy)hydroxides (Langmuir 1997, 56037) through surface complexation reactions. Plutonium is stable in the +III, +IV, +V, and +VI oxidation states in aqueous solution. Plutonium(III, V, and VI) forms complexes with bicarbonate (for example, near pH 7, $PuCO_3^+$, $PuO_2CO_3^-$, $PuO_2(CO_3)_2^{2-}$, and $PuO_2CO_3^0$). Plutonium(IV and V) hydrolyzes to form $Pu(OH)_4^0$ and PuO_2^+. Plutonium(V and VI) complexes are considered to be the most stable in oxidizing surface water and alluvial groundwater within the Mortandad watershed based on the co-occurrence of nitrate, perchlorate, chromium(III, VI), and solid organic matter in the sediments. Cationic forms of complexed plutonium are considered to be less mobile than anionic forms under alkaline pH conditions because most adsorbents tend to have net-negative surface charges (Langmuir 1997, 56037). Plutonium(IV) oxide, consisting of plutonium-239, is characterized by low aqueous solubility of $10^{-35.38}$ moles/L ($6.15 \times 1\ 0^{-23}$ pCi/L) at pH 7, calculated using thermodynamic data cited in Langmuir 1997 (56037); therefore, precipitation from the aqueous phase provides another potential process for removing plutonium from solution.

Plutonium-238 and -239 in Surface Water and Alluvial Groundwater

The spatial trends in plutonium-238 and plutonium-239 concentrations in surface water and alluvial groundwater from 2000–2005 are shown in box plots for different portions of the Mortandad watershed in Appendix D, Figures D-2.1-34 through D-2.1-36 and Figures D-2.1-37 through D-2.1-39, respectively. Detections of plutonium-238 and plutonium-239,240 occur in both filtered and nonfiltered samples throughout the Mortandad watershed, but the highest concentrations are from nonfiltered surface water samples, indicating the preference for plutonium to adsorb to fine-grained sediment and solid organic matter and the presence of plutonium-contaminated suspended solids in the samples.

The distributions of detected values of plutonium-238 and plutonium-239,240 are attributed to two primary sources: the TA-50 RLWTF outfall and the former TA-35 WWTP outfall (Section 2.1). In Mortandad Canyon, the highest frequency of detected plutonium-238 and plutonium-239 concentrations occurs in surface water immediately east of the TA-50 outfall within reach E-1E and below the Mortandad

confluence at gage E200. The concentrations and frequency of detection decrease immediately downcanyon. From monitoring well MCO-3/MCA-5 down Mortandad Canyon, only scattered detected concentrations occur in surface water and alluvial groundwater. Overall, a higher frequency of detection occurs in nonfiltered samples, indicating the presence of plutonium-contaminated suspended solids in the samples.

In Ten Site Canyon, above the confluence with Pratt Canyon, plutonium-238 was detected in filtered and nonfiltered surface water samples within reaches TS-1C and TS-1E with maximum detected concentrations of 0.234 and 1.79 pCi/L, respectively (Figures D-2.1-33 and D-2.1-36). Maximum concentrations of plutonium-239 detected in filtered and nonfiltered surface water samples were 0.0712 and 0.79 pCi/L, respectively, in the same reaches (Figures D-2.1-36 and D-2.1-39). Concentrations of both plutonium-238 and plutonium-239 are less than detection east of reach TS-1C within Ten Site Canyon. The limited concentrations of plutonium detected in surface water in reach TS-1C are probably related to the presence of plutonium-contaminated sediments redistributed downcanyon from the TA-35 sources (Section 7.1).

Appendix D, Section D-2.2, shows a time series plot for plutonium-238 and plutonium-239 covering the period 1963 through 2005 for surface water gage E200 and the entire series of alluvial wells. These plots show the highest concentrations of plutonium occurred just downstream of the TA-50 outfall in surface water at gage E200 and in alluvial groundwater in well MCO-3. Concentrations decline rapidly down canyon because of adsorption of plutonium onto sediments and alluvial deposits. Maximum plutonium concentrations in surface and alluvial groundwater occurred during the 1980s when releases were highest (Table 2.1-1). Surface water and alluvial groundwater concentrations of plutonium-238 and plutonium-239 are currently both less than 7 pCi/L in nonfiltered samples and less than 2.5 pCi/L in filtered samples.

Plutonium-239,240 in Vadose-Zone Pore Water, Perched-Intermediate Groundwater, and the Regional Aquifer

Figures D-2.4-22 through D-2.4-38 show the distribution of plutonium-239 concentrations in core samples collected from Mortandad Canyon and Ten Site Canyon. Both plutonium and americium adsorb onto solid surfaces, and these two actinides are generally collocated in the core samples, although plutonium was detected at a higher frequency in samples at depth. Plutonium-239 was detected in core holes MCB-5, MCB-6, MCB-7, MCB-9, MCB--10, R-1, and R-14. Plutonium-239 was detected at a concentration of 0.03 pCi/g at a maximum depth of 61 m (200 ft) within the Cerro Toledo interval at R-14. This occurrence could be attributed to translocation or downward movement during coring operations at R-14. The maximum concentration of plutonium-239 was 1.16 pCi/g measured at core hole MCB-7 at a depth of 3 m (10 ft) within the alluvium. Several samples from MCB-5, MCB-7, MCB-9, and MCB-10, contained detectable plutonium-239 at depths suggesting that colloid transport under saturated and unsaturated flow conditions has taken place. Plutonium-239 was not detected at core holes MCB-1, MCB-2, MCB-8, MCB-11, MCB-12, MCB-15, MCB-16, R-14, R-15, and R-28.

Plutonium-239,240 is not frequently detected within perched-intermediate zones and the regional aquifer within the Mortandad watershed due to its ability to strongly adsorb onto silt- and clay-sized material present within stream channels, alluvium, and weathered Bandelier Tuff. Possible detections of plutonium-239, 240 within deep saturated zones occur in nonfiltered samples, and transport mechanisms may include adsorption onto colloids migrating through fractured media.

Americium-241

Americium-21 has a half-life of 432.7 yr and decays to neptunium-237 through emission of an alpha particle. Americium is stable in the +III oxidation state in aqueous solution (Langmuir 1997, 56037). Americium-241 very strongly adsorbs onto sediments containing clay minerals and ferric (oxy)hydroxide, through cation exchange and surface complexation reactions (Langmuir 1997, 56037). Americium forms complexes with bicarbonate. At pH 7, it is stable as $AmCO_3^+$ at a partial pressure of CO_2 gas = 10^{-2} bar, typical of groundwater. Under surface water conditions with a partial pressure of CO_2 gas = $10^{-3.5}$ bar, americium is mainly stable as $AmOH^{2+}$ at pH 7 (Langmuir 1997, 56037). Americium-241 precipitates from solution as $AmOHCO_3$, and its solubility minimum is $10^{-8.7}$moles/L (1.64×10^6 pCi/L) at pH 8.3. Adsorption of americium-241 onto clay minerals and ferric (oxy)hydroxide is the dominant process taking place in the watershed for removing this actinide from solution.

Americium-241 in Surface Water and Alluvial Groundwater

The spatial trends in americium-241 concentrations in surface water and alluvial groundwater from 2000 to 2005 are shown in box plots for different portions of the Mortandad watershed in Appendix D, Figures D-2.1-40 through D-2.1-42. The release history of americium-241 from the TA-50 RLWTF is similar to that of plutonium-239,240, even though less americium-241 was released in comparison to plutonium-239,240 (Table 2.1-1 and LANL 1997, 56835). The spatial distribution of americium-241 in water is similar to plutonium-239 in that highest concentrations detected in water are near the TA-50 source, and the concentrations and frequency of detection decrease rapidly downcanyon (Figures D-2.1-40 through D-2.1-41). In Effluent Canyon, the highest frequency of detected americium-241 concentrations occurs in surface water in reach E-1E below the TA-50 outfall and at gage E200 immediately east of the confluence with Mortandad Canyon. From monitoring well MCO-3/MCA-5 down Mortandad Canyon, detected concentrations occur in surface water and alluvial groundwater. Overall, a higher frequency of detection occurs in nonfiltered samples, indicating the presence of americium-contaminated suspended solids in the samples.

A smaller source of americium-241 occurred at the TA-35 WWTP. In Ten Site Canyon, americium-241 is identified in surface water only within reach TS-1C at a maximum total concentration of 0.2 pCi/L (Figure D-2.1-42). The concentrations of americium-241 detected in water in Ten Site Canyon are probably related to the presence of americium-contaminated sediments redistributed down canyon of the TA-35 source.

Appendix D, Section D-2.2, shows time series plot for americium-241 covering the period 1963 through 2005 for surface water gage E200 and the entire series of alluvial wells. The trend shown in these plots is very similar to that for plutonium in that the highest concentrations of americium occurred just downstream of the TA-50 outfall in surface water at gage E200 and in alluvial groundwater in well MCO-3. Concentrations decline rapidly downcanyon because of adsorption onto sediments and alluvial deposits. Recent nonfiltered samples show that surface water concentrations are less than 15 pCi/L, and alluvial groundwater concentrations are less than 5 pCi/L at MCO-3 and decline rapidly downcanyon from there.

Americium-241 in Vadose-Zone Pore Water, Perched-Intermediate Groundwater, and the Regional Aquifer

Figures D-2.4-22 through D-2.4-38 show the distribution of americium-241 concentrations in core samples with depth collected at the MCB holes in Mortandad Canyon. Americium-241 was infrequently detected in core samples collected at MCB-5, -6, -7, -8, and -14. This actinide was detected (0.04 pCi/g) at a maximum depth of 68.6 m (225 ft) within the Bandelier Tuff at MCB-14. This occurrence could be

attributed to translocation or downward movement during coring operations at MCB-14. Detectable concentrations of americium-241 typically occurred at depths less than 9.1 m (30 ft) within the alluvium due to its strong affinity for ferric (oxy)hydroxide and clay minerals. Core hole MCB-8 contained one detect of americium-241 at a depth of 27 m (90 ft), which may have resulted from coring operations. Core hole MCB-14 contained detectable concentrations of americium-241 at 12 and 21 m (40 and 70 ft) within the alluvium and at the contact of the alluvium-Cerro Toledo interval, respectively. The maximum concentration of americium 241 was approximately 1.05 pCi/g measured at core hole MCB-7 at a depth of 3 m (10 ft) within the alluvium. Americium-241 was not detected in samples collected from core holes MCB-1, MCB-2, MCB-9, MCB-10, MCB-11, MCB-12, MCB -13, MCB-15, and MCB-16.

Americium-241 is not consistently detected within perched-intermediate zones and the regional aquifer (see Appendix D, Section D-2.2) within the Mortandad watershed due to its ability to strongly adsorb onto silt- and clay-sized material present within the alluvium and weathered Bandelier Tuff. Possible detections of americium-241 within deep saturated zones occur in nonfiltered samples and transport mechanisms may include adsorption onto colloids migrating through fractured media.

7.3 Summary of Physical System Conceptual Model

This section summarizes the main elements of the physical system conceptual model whose individual elements were discussed in more detail in Sections 7.1 and 7.2. The primary focus of this section is the fate and transport of contaminants released from the TA-50 RLWTF because it is identified as the main source of contaminants in the Mortandad watershed. Other significant sources such as TA-35 and TA-48 are discussed at length in Sections 7.1 and 7.2, and the conceptual model discussed below also applies to the fate and transport of contaminants from these sources. Figure 7.0-1 illustrates key aspects of the physical system conceptual model.

Most contaminants in the Mortandad watershed are derived from Laboratory sources that released wastewater from outfalls into tributary drainages of Mortandad Canyon. Contaminants include radionuclides, inorganic chemicals, and organic chemicals as detailed in Sections 7.1 and 7.2. The mobility of contaminants is controlled by the geochemical characteristics of each contaminant and the geochemical properties of the medium along transport pathways (aqueous solubility, speciation, oxidation/reduction, precipitation/dissolution, adsorption/desorption, microbial and mineralogical characteristics of sediments and aquifer material). The nature and volume of effluent released from outfalls varied over time as a result of changes in research activities at the Laboratory, changes in wastewater treatment methods, and changes in environmental standards. As a result, the present-day distribution of contaminants in the watershed reflects the geochemical properties of individual contaminants, the complex history of releases from multiple Laboratory sites, and hydrological and mineralogical properties of aquifer material. Redistribution of contaminants by surface water, sediment transport, and groundwater is an ongoing process within the Mortandad watershed.

Initially, contaminants are transported from their release sites dissolved in water or adsorbed onto sediment particles and solid organic material. Some contaminants are deposited in soils between outfalls and stream channels, but most are transported down tributary drainages into the main canyon system by surface-water flow and sediment transport. Once adsorbed onto sediment particles in the streambed, contaminants are redistributed by floods that scour the streambed and mobilize the bed sediment. Contaminants associated with coarse-size fractions (coarse sand and coarser) are generally transported as bed load along the streambed, whereas contaminants associated with fine-size fractions (fine sand and finer) are generally transported in suspension. These include cesium-137, americium-241, plutonium-238, plutonium-239,240, chromium(III), lead, mercury, and PCBs. Contaminants are generally collocated in the sediment deposits, primarily occurring in post-1942 sediment deposits and preferentially

occurring in fine rather than coarse facies sediment. During floods, sediment from a variety of sources, much of it not contaminated, is mixed, changing contaminant concentrations longitudinally along the channel. The net result is a general downcanyon decrease in contaminant concentrations in sediment with distance from a contaminant source area (Figure 7.0-1). In general, the inventory of contaminants in sediments increases in downcanyon areas, primarily because post-1942 sediment accumulated in thicker and more extensive deposits where the canyon floor widens eastward. Most of the contaminant inventory in Mortandad Canyon occurs in reach M-3E, upcanyon from the Ten Site Canyon confluence. A notable exception to this trend is the deposition of chromium in Effluent Canyon close to its release site at TA-48.

In Effluent Canyon, the transport of contaminants by surface water is facilitated where thin alluvium overlies relatively impermeable bedrock in the stream channel; this limits the amount of infiltration along the stream channel and results in greater movement of surface water downcanyon. The downcanyon extent of surface water flow varies with effluent discharge rates, runoff from storm events and snowmelt, and prior moisture conditions along the channel. In Mortandad Canyon below the Effluent Canyon confluence, surface water infiltrates the Mortandad Canyon channel where the alluvium thickens and groundwater storage capacity increases (Figure 7.0-1). The maximum extent of persistent surface water occurred in the 1960s to early 1970s when effluent discharge volumes were highest. During this time, surface flow generally extended about 1.5 km (1 mi) or less downcanyon from the TA-50 RLWTF outfall. Discharge volume from the TA-50 RLWTF outfall has progressively decreased since the early 1980s, and today persistent surface water flow generally extends only about 600 m (1970 ft) below the Effluent Canyon confluence (Figure 7.0-1). Runoff from storm events and snowmelt sometimes causes ephemeral flow and episodic infiltration to occur as far east as the sediments traps (and rarely farther downcanyon), but these events are infrequent. Contaminant concentrations in surface water have decreased over time in response to improved treatment technologies employed at the TA-50 RLWTF, especially since 2000.

Infiltration of surface water in the stream channel recharges alluvium within the watershed. Stable isotope data suggest that some surface water and shallow subsurface moisture is lost through evapotranspiration. The remaining water recharges alluvial groundwater that generally accumulates in the lower part of the alluvial deposits, most often perching on weathered bedrock units. Perched alluvial groundwater is a major pathway for the downcanyon transport of soluble contaminants. In Mortandad Canyon, the thickest and most persistent perched alluvial groundwater occurs between MCB-5, where the canyon begins to widen eastward to MCB-11 located east of the sediment traps (Figure 7.0-1). Alluvial groundwater occurs on an intermittent basis as far east as alluvial well MT-4 (Figure 3.2-1). Well hydrographs suggest that the alluvial groundwater levels respond relatively quickly to precipitation events in areas closest to zones of surface water infiltration and that significant lag times may occur at the eastern limit of alluvial saturation. These data support the interpretation that the alluvial groundwater system is recharged by infiltration of persistent and intermittent surface water in gradually thickening alluvium west of MCB-5 and that underflow within the alluvium is the dominant recharge process for alluvial groundwater farther down canyon. Saturation is not uniformly distributed within the alluvium, and in some cases, dry boreholes were drilled next to a location or well where alluvial groundwater was encountered. Similarly, hydrographs for adjacent alluvial wells frequently respond at different times to precipitation events and runoff events. These observations suggest that alluvial groundwater flows along preferential pathways within the highly heterogeneous alluvium and that the aquifer may resemble a network of cross-connected channels rather than a continuous zone of saturation at the base of alluvium. Contaminant concentrations in alluvial groundwater have decreased over time in response to improved treatment of effluent at the TA-50 RLWTF. Concentrations in alluvial groundwater currently account for an estimated 0.1% of the nitrate mass and 2.8% of the perchlorate mass in the watershed. Although overall concentrations are declining, there is a trend of increasing concentration for mobile constituents downcanyon from well MCO-5 to approximately well MCO-7.5 (Figure 3.2-1). This trend is indicative of a lag in the response of alluvial groundwater to the application of improved effluent treatment technologies.

The lag is related in part to distance from the outfall, but increasing alluvial storage from west to east is probably a more important factor. Concentrations at more distal locations will continue to decline in response to lower effluent concentrations and to further dilution by runoff events.

Deeper infiltration of alluvial groundwater into bedrock units results in the vertical transport of contaminants into the suballuvium vadose zone. Transport of contaminants to these deeper zones is generally limited to soluble constituents such as nitrate, perchlorate, fluoride, tritium, sulfate, and chromium(VI). Contaminant profiles from core holes indicate that maximum contaminant concentrations of these mobile constituents and most of the contaminant mass (an estimated 96.6% of the nitrate mass and 94.6% of the perchlorate mass) occurs in bedrock units in the upper half of the vadose zone in the region extending from MCB-5 on the west to MCOBT.8.5 on the east (Figure 7.0-1). The Otowi Member of the Bandelier Tuff accounts for an estimated 55.8% of the nitrate mass and 67.7% of the perchlorate mass in Mortandad Canyon. The western extent of vadose-zone contamination is poorly constrained because Mortandad Canyon is inaccessible to drilling between the Effluent Canyon confluence and MCB-5. Thinning of alluvium over less permeable tuffs 500 to 1000 m (1640 to 3280 ft) west of MCB-5 probably controls the western limit of significant alluvial groundwater infiltration. The eastern extent of vadose-zone contamination is constrained by core hole data from MCOBT-8.5 and R-28. The greatest mass of contamination in the vadose zone occurs beneath the portion of the canyon that contains the thickest and most persistent alluvial groundwater. Bedrock units such as Tshirege unit Qbt 1g, the Cerro Toledo interval, and the Otowi Member underlie the alluvium in this area, and because of their porous nature, alluvial groundwater is able to percolate through these units. Moisture associated with vadose-zone contamination is elevated relative to other parts of the canyon, but the rocks are generally not fully saturated. Movement of moisture and contaminants probably occurs as gravity-driven porous flow. Estimates of vertical transport velocities of nitrate based on a release of unique isotopically light nitrogen from October 1986 to September 1989 range between 2.5 and 2.9 m/y (8.2 and 9.5 ft/y). Estimates of transport rates based on peak tritium releases to the canyon suggest that vertical transport rates have declined substantially from about 11 m/yr (36.1 ft/y) in the late 1970s to about 1.36 m/yr (4.46 ft/y) today. Finally, calibration to nitrate profiles in R-15 and MCOBT-8.5 yield approximate transport velocities of 6 m/yr (20 ft/yr) in 1968 to 1.2 m/yr (4 ft/yr) in 2002. These studies apply to mobile constituents and indicate vadose-zone transport velocities were greater in the past and that over time, transport velocities decreased as discharges to the watershed from outfalls declined. Adsorbing constituents have much slower transport rates and are generally not present within the suballuvium vadose zone.

A thin zone (<1m [<3 ft]) of perched-intermediate groundwater occurs within the clay-rich basaltic rubble at the top of the Cerros del Rio basalt near the Mortandad–Ten Site Canyon confluence (Figure 7.0-1). A thicker zone (up to 21.9 m [72 ft]) of perched saturation occurs near the base of the Cerros del Rio basalt near R-15. These perched-intermediate zones probably represent two unrelated groundwater bodies of limited lateral extent along the canyon axis (Figure 7.0-1). Based on the distribution of boreholes encountering perched-intermediate groundwater, the lateral extent of these groundwater bodies is probably less than 450 m (1500 ft). Contaminant concentrations within these perched zones show increasing trends over time, indicating that limited masses of the most mobile constituents (nitrate, perchlorate, chromium(VI), and tritium) have migrated from upgradient areas through the vadose zone along preferential pathways. Concentrations in perched-intermediate groundwater currently account for only an estimated 0.10% of the nitrate mass and 1.6% of the perchlorate mass in Mortandad Canyon. Perched-intermediate groundwater percolates into the Puye Formation, resulting in further vertical transport of contaminants into the lower vadose zone (Figure 7.0-1). Mobile constituents percolate through the lower vadose zone, reaching the regional water table.

The water table of the regional aquifer lies approximately 300 m (984 ft) below the canyon floor in Mortandad Canyon (Figure 7.0-1). The regional aquifer is a complex, heterogeneous system that includes

confined and unconfined zones. Hydraulic communication between these zones is uncertain and spatially variable. The shallow portion of the regional aquifer (along the water table) is predominantly under phreatic (unconfined) conditions and has limited thickness (approximately 30–50 m [98–164 ft]). The groundwater flow and transport directions in this zone generally follow the gradient of the regional water table; the flow is east/southeast toward White Rock Canyon springs and the Rio Grande. The shape of the regional water table is predominantly controlled by areas of regional recharge (Sierra de los Valles and some Pajarito Plateau canyons) and discharge (White Rock Canyon springs and the Rio Grande). The deep portion of the regional aquifer is predominantly under confined conditions, and it is heavily stressed by Pajarito Plateau water-supply pumping. The pumping likely has a small impact on the flow directions in the phreatic zone because of poor hydraulic communication (cf. Appendix O). Capture of contaminants by supply well PM-3 seems unlikely because of this poor vertical hydraulic communication. However, the poor hydraulic communication does not preclude the possibility that some contaminant migration may occur between the shallow and deep zones. Between the two zones, the hydraulic gradient has a substantial vertical component due to water-supply pumping, creating the possibility that downward contaminant flow may occur along hydraulic windows and possibly along filter packs in water-supply wells. However, upward vertical gradients near PM-3 might provide natural protection against entry of contaminants from the phreatic zone into the well screen. Mobile contaminants, including nitrate, perchlorate, chromium(VI), and tritium, are observed only in the shallow zone of the regional aquifer beneath the Mortandad watershed. Some wells, such as R-15 and R-28, show increasing contaminant concentrations over time, suggesting breakthrough of mobile constituents from the vadose zone is increasing over time. Differences in nitrate isotopic ratios for some wells (e.g., R-28 vs. R-15) indicate that contamination in regional groundwater beneath Mortandad Canyon includes contributions from mixed source areas. The future pathways of contaminant movement from these locations should follow the groundwater flow direction along the regional water table. The contaminant flow should be to the east without substantial temporal changes due to seasonal effects.

8.0 RISK ASSESSMENTS

This section presents the methods used to evaluate the potential for adverse ecological and human health risks from COPCs in sediment and surface water. Risk characterization results, uncertainty analysis, and risk assessment summary are also provided for each assessment.

8.1 Baseline Ecological Risk Assessment

Biological data were collected in the Mortandad watershed to evaluate the potential for adverse ecological effects from contaminants in sediment and persistent surface water. A biological investigation work plan was developed based on the application of the eight-step EPA ecological risk assessment guidance for Superfund (ERAGS) (EPA 1997, 59370) to COPECs in sediment and persistent surface water (LANL 2005, 89308).

Steps 1 and 2 of ERAGS include the screening-level ecological risk assessment (SLERA) (LANL 2004, 87630), which identifies COPECs and ecological receptors potentially at risk. Ecological screening results based on the comparison of ecological screening levels (ESLs) with available sediment and water data are provided in the “Mortandad Canyon Biota Investigation Work Plan” (LANL 2005, 89308) and in Appendix E-1. Also presented in the biota investigation work plan is a comparison of available data with DOE biota concentration guidelines (BCGs) for radionuclides (DOE 2002, 85637; DOE 2004, 85639). These screening-level assessments identified COPECs and formed the basis for proceeding to the baseline ecological risk assessment (ERAGS Steps 3 to 8).

Steps 3 and 4 of ERAGS comprise problem formulation and study design, which include refining the list of COPECs, developing a conceptual exposure model, selecting assessment endpoints, and selecting associated measures of effect and exposure. The study design required for these measures was included in the biota investigation work plan (LANL 2005, 89308). Aspects of study design were modified based on field verification of the design (ERAGS Step 5) and on comments received from NMED (NMED 2005, 92084). Deviations to the original biota work plan are discussed in Section 8.1.2. ERAGS Steps 6 and 7 comprise the implementation of the study design, analysis of ecological exposure and effects, and risk characterization. ERAGS Step 8 is risk management and the conclusions that may lead to risk management activities are documented in Section 9.

8.1.1 Problem Formulation

This section addresses the baseline ecological risk assessment problem formulation, which is Step 3 of ERAGS. A problem formulation was presented in Appendix D of the "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 89308, pp. D-1–D-3). Problem formulation includes refinement of the list of COPECs, a literature search on known ecological effects, the conceptual exposure model, and the selection of assessment endpoints. Additional samples have been collected since the initial problem formulation in the biota investigation work plan, and new COPECs have been identified; therefore the problem formulation elements are updated and presented in the following sections.

8.1.1.1 Refinement of COPEC list

The third step of the ERAGS process involves refinement of the COPEC list from the screening to focus on those COPECs that have the largest impact on the potential ecological risk. As explained in the SLERA methods document (LANL 2004, 87630, p. 31), the criterion for retaining a COPC as a COPEC is a HQ greater than 0.3. The ESL screening excludes only COPCs with an HQ less than or equal to 0.3, which are COPCs for which no potential for ecological risk exists. To determine whether areas of the canyon may pose a risk to ecological receptors, and therefore what areas should be included within the scope of the biota investigation, the criterion of an HQ greater than 3 was used. An HQ greater than 3 represents levels that may impact receptors and is therefore appropriate for determining which COPECs should be included in site-specific biota studies in the Mortandad watershed. This criterion of 3 is based on the geometric mean of the ratio between the no observed adverse effect level (NOAEL) and the lowest observed adverse effect level (LOAEL) (Dourson and Stara 1983, 73474). Concentrations corresponding to LOAELs represent levels where impacts to individuals or populations may occur, and these levels represent a more appropriate criterion for determining which COPECs should be included in site-specific biota analyses to assess if impacts to ecological receptors have actually occurred. The same criterion of an HQ greater than 3 was used to refine the list of COPECs for the baseline studies conducted in Los Alamos and Pueblo Canyons (LANL 2004, 87390, p. 8-2). Receptors representing threatened and endangered (T&E) species are evaluated versus an HQ greater than 1 to ensure protection of each individual within the population.

Selection of study design COPECs for soil was based on comparison of the maximum detected concentrations in all geomorphic units within a reach with the minimum soil ESL. Active channel sediments may be exposed due to the transient nature of water flow in the channels in this watershed; therefore concentrations in the active channel geomorphic unit (c1) were included in the screening for terrestrial receptors. The COPECs for soil identified in the biota investigation work plan are: arsenic, barium, cadmium, chromium, copper, total cyanide, lead, manganese, mercury, selenium, silver, thallium, vanadium, zinc, americium-241, cesium-137, plutonium-238, plutonium-239, strontium-90, Aroclor-1254, Aroclor-1260, acenaphthene, chrysene, naphthalene, di-n-butyl phthalate, and endrin aldehyde (LANL 2005, 89308). Study design COPECs for sediment were chosen based on a comparison of maximum

detected concentrations in geomorphic unit c1 (the active channel sediments) with the ESLs for sediment. The study design COPECs in sediment identified in the biota investigation work plan include: aluminum, arsenic, barium, copper, mercury, silver, vanadium, acenaphthene, acetone, anthracene, Aroclor-1260, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, alpha-chlordane, gamma-chlordane, chrysene, 4,4-DDT, di-n-butylphthalate, dibenz(a,h) anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, 4,4'-methoxychlor, 2-methylnaphthalene, naphthalene, phenanthrene, and pyrene. Study design COPECs for water were based on the comparison to ESLs and DOE BCGs. Study design COPECs for water identified in the biota investigation work plan are: aluminum, barium, cadmium, copper, cyanide (total), lead, manganese, silver, zinc, americium-241, and radium-226.

After its review of the biota investigation work plan, NMED requested considering gross alpha and selenium as COPECs in all evaluations (NMED 2005, 92084). There is no ESL for gross alpha, but gross alpha has an NMED surface water standard in 20.6.4 NMAC. Therefore, gross alpha was evaluated through screening of surface water against this standard. Individual alpha-emitting radionuclides were screened against the ESLs and DOE BCGs for each individual radionuclide. In the screening conducted for the biota investigation work plan (LANL 2005, 89308), selenium was designated as a study design COPEC only for plants. In response to NMED's concerns the evaluation of the results of each field study and the modeling of COPEC ingestion through the food chain to avian and mammalian receptors includes selenium.

Subsequent to the screening against minimum ESLs, the study design COPECs were screened against the ESLs for individual receptors to determine which COPECs should be addressed by each of the field measures. Table D-6.0-1 of the biota investigation work plan (LANL 2005, 89308) lists the COPECs for individual receptors; these subsets of COPECs were used to determine the appropriate analytical suites and locations for each measure. The COPECs and analytical suites associated with each measure are described in the discussion of each individual field measure in Section 8.1.2. The receptors potentially at risk from exposure to soil COPECs include plants, soil invertebrates (earthworms), small mammals, mammalian carnivores, omnivorous birds, and carnivorous birds representing a T&E species, the Mexican spotted owl (*Strix occidentalis lucida*). Receptors at potential risk from exposure to sediment include the swallow (which also represents a T&E species, the southwestern willow flycatcher [*Empidonax traillii extimus*]), the bat, and the aquatic community (which represents a number of aquatic species). Receptors at potential risk from exposure to COPCs in water also included representatives of the aquatic community (aquatic invertebrates and algae).

Screening Against ESLs and BCGs for 2005 Sediment and Water Data

Sediment samples were collected in 20 of the investigation reaches in the Mortandad watershed and in the background reach in Los Alamos Canyon in 2005 after preparation of the biota investigation work plan. The concentrations of COPCs in these samples were screened against ESLs and BCGs to determine if any new study design COPECs (COPECs with an HQ >3) were identified by the additional sampling. Screening the data from 2005 samples was conducted with ECORISK Database Version 2.2 (LANL 2005, 90032); the screening documented in the "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 89308) used the version of the ESL database that was current at the time that the report was written, ECORISK Database Version 2.1 (LANL 2004, 87386). The tables for this screening are presented in Section E-1.2 of Appendix E. The section below includes a discussion of the results of the screening and whether new COPECs were identified based on higher detected maximum concentrations or a decrease in the ESL between the versions of the database.

Additional COPECs for Soil

Tables E-1.2-1 to E-1.2-3 in Appendix E show the HQs for soil COPECs based on the screening of the 2005 samples. The maximum detected concentrations of analytes in soil for these samples are available in the data files in Appendix C.

Soil samples from two reaches with the highest concentrations of chromium were analyzed for hexavalent chromium in 2005. n reach E-1FW, the HQ for both the earthworm and the plant for hexavalent chromium was 5.8. Based on other study design COPECs, reach E-1FW was already included in the plant and earthworm toxicity studies that includes metals; therefore, no additional studies are necessary based on the designation of hexavalent chromium as a study design COPEC.

The SVOC bis (2-ethylhexyl) phthalate is also a new COPEC for soil based on the screening of the data from the 2005 samples; bis (2-ethylhexyl) phthalate is a COPEC in soil for reach TS-1C. The ESL for bis (2-ethylhexyl) phthalate in the ECORISK Database Version 2.2 (LANL 2005, 90032) is lower for terrestrial avian receptors than in the previous version of the database (LANL 2004, 87386) due to a revision to the transfer factor EPA recommended for calculating the dose to avian receptors (LANL 2005, 90032). Bis (2-ethylhexyl) phthalate is a COPEC in sediment only for reach TS-1C. Additional nest boxes were added to reach TS-1C in 2005 as part of the field studies. Therefore the existing studies for the Mortandad watershed include the potential effects of this and other COPECs on avian receptors.

Existing study design COPECs for soil, particularly inorganic COPECs, were designated as study design COPECs for additional reaches as a result of the screening of data from the 2005 samples: cadmium and lead in E-1FW, chromium and copper in TS-2E, manganese in TS-1E, vanadium in TS-1W, and Aroclor-1254 in E-1E. Mercury is now a study design COPEC in a number of additional reaches because of an updated transfer factor EPA recommended for calculating the ESL for avian species (LANL 2005, 90032), and the current ESL is one-fourth of the ESL used for the original screening in the biota investigation work plan. The additional reaches for which mercury is a COPEC are M-1E, M-2W, M-2E, and M-3. Some existing study design COPECs were also detected at higher concentrations in reaches in which they were already study design COPECs. These COPECs were already considered in the study designs for other reaches and were not detected at concentrations greatly exceeding the concentrations detected in earlier samples. Therefore, no additional studies are indicated for these COPECs based on the screening of the new data.

Additional COPECs for Sediment

Tables E-1.2-4 to E-1.2-6 in Appendix E show the HQs for sediment COPECs based on the screening of the 2005 samples. The maximum detected concentrations of COPCs in sediment for these samples are available in the data files in Appendix C.

Based on the screening of 2005 samples iron is a study design COPEC in active channel sediments. No iron ESL for sediment was available at the time of the screening against ESLs in the biota investigation work plan; the new ESL is based on exposure to aquatic community organisms (LANL 2005, 90032). Based on the screening of the 2005 sediment data, iron would be a study design COPEC in reaches E-1W, M-1E, and M-4. The HQs for all three reaches are similar, and reach E-1W was already included in the study for ecological risk to the aquatic community (the *Chironomus tentans* laboratory toxicity assay). Therefore the existing field studies for the Mortandad watershed address this additional COPEC.

The SVOC bis (2-ethylhexyl) phthalate is also a new COPEC based on the screening of the 2005 sediment data, combined with revisions to ESLs. The ESL for bis(2-ethylhexyl) phthalate in the ECORISK Database Version 2.2 (LANL 2005, 90032) is lower for the avian receptor (the violet green swallow)

exposed to sediment than the ESL in the previous version of the database due to a revision in the transfer factor EPA recommended for calculating the dose to avian receptors. Bis(2-ethylhexyl)phthalate is a COPEC in sediment only for reach TS-1C. Additional nest boxes were added to reach TS-1C in 2005 as part of the field studies. Therefore, the existing studies for the Mortandad watershed include the potential effects of this and other COPECs on avian receptors.

Several existing study design COPECs for sediment are designated as study design COPECs for additional reaches based on the screening of the 2005 sediment data. Anthracene is now a study design COPEC for aquatic community organisms in sediment in two additional reaches, E-1E and M-2W. Mercury is now a study design COPEC for avian receptors in reach M-1E in addition to the existing reaches for which it was already a study design COPEC. These COPECs were considered in the study designs for aquatic community and avian species in other reaches and were not detected at concentrations greatly exceeding the concentrations in earlier samples. Therefore, no additional studies are indicated for these COPECs based on the screening of data from the 2005 sediment samples.

Additional COPECs in Surface Water

Samples of nonfiltered nonstormwater (nonstormwater includes base flow, snowmelt, and persistent pools), filtered nonstormwater, and filtered stormwater were collected from individual water locations within the Mortandad watershed in 2005. Tables E-1.2-7 to E-1.2-12 in Appendix E show the HQs for surface water COPECs based on the screening of the 2005 samples. The maximum detected concentrations of analytes in surface water for these samples are available in the data files in Appendix C.

In the filtered nonstormwater samples (see Tables E-1.2-7 and E-1.2-8 [Appendix E]), two additional surface water COPECs were designated. Cobalt had an HQ of 4.7 for the maximum detected concentration in reach E-1FW. E-1FW was not included in the aquatic studies, but these surface water screening results are unlikely to indicate a widespread ecological risk within the watershed as the HQ in only one reach exceeded 3. Iron, which did not have an ESL for water at the time of the screening presented in the biota investigation work plan, is designated as a study design COPEC for reaches E-1FW, E-1W, and M-1W. Reaches E-1W and M-1W were already included in studies both for toxicity to aquatic invertebrates and toxicity to algae. (Radium-226 was already a study design COPEC for water based on the screening conducted by subwatershed for the biota investigation work plan.) The screening of the 2005 samples confirmed that radium-226 should be considered as a study design COPEC for reaches E-1E, M-1W, M-1E, and M-2W.

In the nonfiltered nonstormwater (see Tables E-1.2-9, E-1.2-10, and E-1.2-11 [Appendix E]), cobalt is also designated as a new study design COPEC in reaches E-1FW and TS-1W. Iron was designated as a new study design COPEC in reaches E-1FW, E-1W, M-1W, M-1E, TS-1C, and TS-1W. Radium-226 was already a study design COPEC for water based on the screening conducted for the biota investigation work plan. The screening of the 2005 samples confirmed that radium-226 should be considered as a study design COPEC for reaches E-1W, M-1W, and M-2W.

No new COPECs were detected in the filtered stormwater samples from 2005; the HQs for filtered stormwater are shown in Table E-1.2-12.

8.1.1.2 Literature Search in Known Ecological Effects

The following is a synopsis of the screening ecological receptors with the highest HQs (HQ >3) and the feeding guilds they represent. This section reviews both the original COPECs from the biota investigation

work plan and the new COPECs designated based on the screening of the 2005 data. The toxic effects are based on toxicity studies used as the basis for the ESLs as described in the ECORISK Database Version 2.2 (LANL 2005, 90032) and are summarized in Appendix E in Tables E-1.1-2 through E-1.1-7. The section below also reports the count of sediment investigation reaches in which the study design COPECs are located. The names of these reaches and HQs for screening against individual receptors can be found in Tables D-2.2.1 through 2.2.10 of the biota investigation work plan (LANL 2005, 89328, pp. D-31– D-41).

Mammals

Soil Pathway Receptors

The deer mouse as a representative for mammalian omnivores had HQs greater than 3 for four COPECs: arsenic, manganese, thallium and naphthalene. Study design COPECs were found in 6 of the 23 reaches.

The montane shrew as a representative for mammalian invertevores had HQs greater than 3 for seven COPECs: arsenic, cadmium, manganese, thallium, vanadium, chrysene and naphthalene. Study design COPECs were found in 10 of the 23 reaches.

The red fox as a representative for mammalian carnivores had HQs greater than 3 for three COPECs: cesium-137, Aroclor-1254, and Aroclor-1260. Study design COPECs were found in 4 of the 23 reaches.

Sediment Pathway Receptors

The occult little brown myotis bat as a representative for mammalian aerial insectivores had HQs greater than 3 for three COPECs: aluminum, arsenic, and naphthalene. Study design COPECs were found in 4 of the 23 reaches.

Birds

Soil Pathway Receptors

The American robin (with invertevore diet) as a representative for avian invertevores had HQs greater than 3 for 10 COPECs: copper, lead, mercury (inorganic), silver, vanadium, zinc, Aroclor-1254, bis-2-ethylhexylphthalate, di-n-butyl phthalate, and cyanide (total). Study design COPECs were found in 13 of the 23 reaches.

The American kestrel (with flesh diet) as a representative for avian carnivores had HQs greater than 3 for three COPECs: mercury (inorganic), cesium-137, and Aroclor-1254. Study design COPECs were found in 1 of the 23 reaches.

Sediment Pathway Receptors

The violet green swallow as a representative for avian aerial insectivores had HQs greater than 3 for nine COPECs, including aluminum, barium, cadmium, copper, mercury (inorganic), silver, vanadium, zinc, and cyanide (total). Study design COPECs were found in 14 of the 23 reaches.

Terrestrial Plants

The terrestrial plant as a representative of primary producers had HQs greater than 3 for 12 COPECs, including barium, chromium (total), hexavalent chromium, copper, manganese, selenium, silver, thallium, vanadium, zinc, acenaphthene, and endrin aldehyde. Study design COPECs were found in all of the 23 reaches.

Terrestrial Invertebrates

The earthworm as a representative of invertebrate detritivores had HQs greater than 3 for six COPECs: chromium (total), hexavalent chromium, copper, mercury (inorganic), americium-241, and plutonium-239,240. Study design COPECs were found in 15 of the 23 reaches.

Aquatic Community Organisms

Water Pathway Receptors

The aquatic community organism that represents various aquatic functional and feeding guilds had HQs greater than 3 for 13 COPECs: aluminum, barium, cadmium, cobalt, copper, total cyanide, iron, lead, manganese, silver, zinc, americium-241, and radium-226. Most COPECs were identified in samples from station E200, which include COPECs from filtered stormwater.

Sediment Pathway Receptors

The aquatic community organism that represents various aquatic functional and feeding guilds had HQs greater than 3 for 15 COPECs, including barium, copper, iron, mercury (inorganic), silver, acenaphthene, anthracene, dibenz(a,h)anthracene, fluorene, methylnaphthalene, naphthalene, Aroclor-1260, chlordane (alpha), chlordane (gamma), and DDT [4,4'-]. Study design COPECs were found in 9 of the 23 reaches.

8.1.1.3 Conceptual Exposure Model

An ecological scoping checklist was completed for the Mortandad watershed during June and July 2003. A separate Part B checklist was completed for each of several subsets of reaches that were similar in habitat. All the completed ecological scoping checklists appear in Appendix C of the "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 89308). In Mortandad Canyon above the confluence with Ten Site Canyon (which includes reaches M-1W, M-1C, M-1E, M-2W, M-2E, M-3W, and M-3E), the terrestrial vegetation cover consists primarily of ponderosa pine, mixed-conifer species, box elder, scrub oak, and various deciduous shrubs. Wetland vegetation (e.g., cattails, rushes, and willows) and aquatic receptors are also found in riparian areas along this part of Mortandad Canyon, particularly in reach M-1W, which contains a cattail wetland. Wildlife noted in this part of the canyon included many species of birds (including bluebirds), burrowing animals, garter snakes, lizards, harvester ants, and evidence of large mammals (deer and bear). Chironomids and stonefly larvae were noted in aquatic areas within reach M-1W. A wide selection of wildlife receptors was noted throughout the reaches within Mortandad Canyon. In Mortandad Canyon east of the Ten Site Canyon confluence (which includes reaches M-4, M-5W, M-5E, and M-6), the vegetation cover consists of piñon-juniper woodland, with scattered ponderosa pine, and numerous shrub species and many of the same wildlife species seen in the Mortandad Canyon reaches farther west. In Effluent Canyon (which includes reaches E-1FW, E-1W, and E-1E), terrestrial plant species include ponderosa pine and wetland species (willows, rushes, and cattails) that were common throughout reach E-1W. In Ten Site Canyon (including reaches TS-1W, TS-1C, TS-1E, TS-2W, TS-2C, TS-2E, and TS-3), the vegetation cover includes ponderosa pine, mixed-conifer

species, and oak, along with deciduous shrubs and forbs and associated terrestrial wildlife species. Some areas of riparian and aquatic vegetation (willows, rushes, and cattails) occur in reaches TS-1C, TS-2W, TS-2C and TS-2E. Reach TS-2E also contained aquatic insects at the time of the site visits. The unnamed tributary canyon that heads in TA-05 (including reaches MCW-1 and MCW-2) contains ponderosa pine mixed with piñon-juniper woodland and some shrub oak with a low level of vegetative cover.

Some of the reaches also represent potential or actual habitat for T&E species (Keller 2004, 87688). All the reaches considered in this study are rated as low potential forage areas for the bald eagle except for reach M-6, which is rated as a moderate potential forage area for the eagle. The Mexican spotted owl, however, is believed to actively use several reaches within the canyon (E-1E, M-2W, M-2E, and M-3W). Additional reaches (TS-1E, all TS-2 reaches, and M-3E) are designated as very high potential foraging area, with a number of other reaches considered high or moderate as potential foraging area for the Mexican spotted owl (Keller 2004, 87688). Reaches M-1W and E-1W both contain habitat in which the southwestern willow flycatcher may be assumed to forage at a moderate frequency (Keller 2004, 87688), although this species has not yet been observed in the watershed. The biota studies therefore include explicit consideration of risk to both the Mexican spotted owl, which nests within Mortandad Canyon, and the southwestern willow flycatcher, for which potential habitat exists within the Mortandad watershed.

Surface water in the Mortandad watershed originates either as effluent releases, stormwater, or snowmelt runoff. Where present, surface water can be discontinuous within a reach, alternately stopping where the flow entirely infiltrates into alluvium and emerging downstream where the alluvium thins. Transitions from alluvial channels to bedrock channels are common locations of surface water as water discharges from the shallow alluvial groundwater. Table D-2.3-1 in the “Mortandad Canyon Biota Investigation Work Plan” (LANL 2005, 89308) presents the results of a survey of surface water occurrence in the Mortandad watershed.

Historical contaminant releases to the soils, sediments, and persistent surface water in the Mortandad watershed have occurred from multiple SWMUs and AOCs, primarily through releases of effluent, as discussed in Section 2.1. For ecological receptors, the primary impacted media in the canyons are sediment deposits in the canyon bottoms, surface water derived from effluent releases or persistent pools, and reaches of water that remain for some time after periods of runoff. Active channel sediments (c1 geomorphic unit), potentially subject to persistent water, are referred to as “sediment” in this section. Sediment in other geomorphic units (abandoned channels and floodplains) is referred to as “soil” in this section. The active channel sediments in the Mortandad watershed were also evaluated as part of the soil because all sediments within any of the reaches may be exposed and dry for at least some period of the year, and therefore terrestrial receptors could also be exposed to these sediments.

Persistent surface water exists only in limited sections of the active channel in the watershed. Even so, all active channel deposits are considered in this assessment to be potentially subject to persistent flow under different climatic conditions and therefore to potentially harbor aquatic receptors, i.e., organisms dependent on water, such as algae or chironomids (LANL 2004, 87630, p.26). Floodplains and abandoned channels generally have well-developed terrestrial plant and animal populations and do not support truly aquatic species. Thus, only active channel sediments and surface water potentially have complete exposure pathways to truly aquatic species, whereas terrestrial animals and plants are exposed to COPECs in surface water, soil, or sediment. It is important to recognize that the aquatic species in the watershed represent a fairly simple food web that does not include aquatic vertebrates because surface water is limited both spatially and temporally.

Exposure pathways to terrestrial receptors can occur through the following:

- Air—through respiration of vapors, inhalation, and deposition of particulates
- Surface soil—through root uptake and rain splash on plants, food web transport to plants and animals, incidental ingestion of soil, dermal contact with contaminated soil, and external irradiation
- Persistent surface water and sediments—through root uptake and rain splash on plants, food web transport to animals, incidental ingestion of water and sediment, dermal contact with contaminated water or sediment, and external irradiation from sediment

The major soil-related exposure pathways are plant uptake, food web transport, incidental ingestion of contaminated soil, and external gamma radiation exposure. Water and sediment pathways are of lesser importance to terrestrial receptors because of the limited temporal and/or spatial extent of persistent surface water in the watershed. Exposure to vapors is unlikely because of the infrequent detection of VOCs in the watershed, the low VOC concentrations measured in sediment and water, and the rapid volatilization of VOCs in sediments near the ground surface. Exposure to airborne particulates is a minor pathway because of the limited amount of contamination at the ground surface and the dense plant cover in some reaches.

The remaining pathways related to exposure to surface soil (dermal contact) and surface water and sediment (food web transport, incidental ingestion of contaminated sediment and water, dermal contact, and external radiation exposure) are also minor because of the limited amount of contamination at the ground surface or in surface water. In addition, soil exposure pathway analysis EPA performed to support the development of its ecological soil screening levels (Eco-SSLs) has shown that inhalation and dermal pathways contribute a small fraction of the dose obtained orally (EPA 2003, 76077). All complete exposure pathways are at least qualitatively evaluated in the assessment in this report because some of the measures proposed in this investigation are field measures of effect or exposure.

8.1.1.4 Assessment Endpoints

Assessment endpoints consist of an entity (a receptor species) and an attribute (survival, growth, or reproduction) of that entity that is being assessed. Seven assessment endpoints for the Mortandad watershed are identified based on the study design COPECs summarized in Section 8.1.1.1 (and the associated tables) and the conceptual exposure model. These endpoints were selected to represent T&E receptors (the Mexican spotted owl and the southwestern willow flycatcher) as well as receptors that are representative of the terrestrial and aquatic food web in the Mortandad watershed (food webs are shown in Figures 3.4-1 and 3.4-2 of LANL 2004, 87630). The conceptual exposure model indicates that ingestion exposure pathways and, in particular, food web transport, are important pathways for these COPECs. Assessment endpoints were developed for the five terrestrial feeding guilds (including aerial insectivores) that represented the receptors with the highest HQs, as well as for the surrogates for the T&E species. Because aquatic environments in the Mortandad watershed are generally not perennial and rely on effluent and persistent water from storm runoff, a single assessment endpoint for the aquatic study design was selected. The seven assessment endpoints (AE1 through AE7) are as follows:

- Survival and reproduction of the Mexican spotted owl (AE1)
- Population abundance or persistence and species diversity of avian ground invertevore feeding guild species (e.g., American robin, bluebird) (AE2)

- Population abundance or persistence and diversity of mammalian invertevore and omnivore feeding guild species (e.g., shrews and deer mice) (AE3)
- Survival and growth of detritivore species (earthworms) (AE4)
- Native plant species presence and diversity (AE5)
- Survival and reproduction of the southwestern willow flycatcher (AE6)
- Abundance and survival of the aquatic community in the reaches of the Mortandad watershed that retain surface water long enough to support aquatic communities (AE7)

Assessment endpoints were used as the basis for developing the measures of exposure and the measures of effects. Those measures evaluate impacts to the attributes of survival, growth, or reproduction in the receptor species and in the feeding guilds that those receptor species represent. The measures included field, laboratory, and model data. For the biota investigation in the Mortandad watershed, the measures are based on extension of the field biota investigation done in the Los Alamos and Pueblo watershed (LANL 2004, 87390).

8.1.2 Study Design, Field Verification, and Site Investigation

This section discusses the ecological risk assessment study design, field verification, and site investigation; this encompasses ERAGS steps 4 and 5 and the first part of step 6. Biological data were collected as measures of exposure and effect (lines of evidence) to evaluate the potential for adverse ecological effects from contaminants in soil, sediment, and persistent surface water. The initial design of each study is documented in the "Mortandad Canyon Biota Investigation Work Plan" (LANL 2005, 89308). As a result of discussions with NMED during the review of the biota investigation work plan, an additional measure was added. Algal toxicity tests were added to assess potential risk to algae from radionuclides in surface water. These algal toxicity tests are described in Section 8.1.2.11. Figure 8.1-1 shows reaches and the sample locations in the Mortandad watershed and the background site (reach LA-BKG). Shrews were trapped in two of the reaches (E-1W and LA-BKG) designated for the general small mammal trapping. The plant diversity field studies were conducted in the same reaches indicated for the plant and earthworm toxicity studies. Field bird surveys are not indicated on the map because they did not correspond directly to individual locations in reaches, as explained in Section 8.1.2.5. The rapid bioassessment characterization studies were collocated with the chironomid toxicity tests indicated in Figure 8.1-1. Table 8.1-1 shows the reaches included in each type of study, as well as the study design COPECs used as the basis for including that reach for that type of study.

8.1.2.1 Small Mammal Trapping and Analysis of Pelts and Carcasses

Trapping small mammals was conducted in three reaches within the Mortandad watershed and one background reach in Los Alamos Canyon. The results of the trapping determined measures of effect on the small mammal population including relative abundance, species composition, reproductive status, and body weight. The field measures of the small mammals were lines of evidence for the effects to the small mammals themselves (see Table D-4.0-4 in LANL 2005, 89308) in support of AE3.

Small mammals were also collected for laboratory analysis to determine the concentration of COPECs in tissues. The concentrations in the tissues were lines of evidence for the exposure of the Mexican spotted owl (AE1) as well as for the mammalian carnivore (the red fox), which was not designated as an individual assessment endpoint. All the individuals of most species from each reach were separated into pelts and carcasses; the pelts and carcasses were then combined so that one pelt and one carcass sample from each species was sent for analytical analysis for each reach. The exception is for shrews, which were too

small to allow separation into pelt and carcass, and instead whole body samples were submitted. Table B-3.0-2 shows the sample IDs associated with these tissue samples as well as the weights for the composite pelt and tissue samples from each species. Individuals of some species (particularly wood rats) have enough mass that not all animals trapped were included in the composite pelt and carcass samples. Also, animals that tested positive for Hanta virus after collection were not included in the composite samples.The total number of animals trapped of each species is discussed in Section 8.1.3.4. The number of animals collected (excluding released or hanta virus infected animals) for each pelt or carcass sample from each reach is shown in Table 8.1-2.

The analytical suites were prioritized based on study design COPECs for predators, as shown in Table D-6.0-2 (LANL 2005, 89308). Analyses conducted on these carcass and pelt samples included EPA Method SW-846 6010B metals, perchlorate, mercury, PCBs, americium-241, cesium-137, and strontium-90.

As discussed in Section 7.1.2, cyanide is designated as a study design COPEC based on sediment concentrations exceeding the BV only in reach MCW-2W. Resampling done in that location and two adjacent locations in the same area produced values below the BV (see Section 7.1.2 and Tables E-1.2-1 and Table E-1.2-4). Cyanide was therefore not considered further in sediment in this investigation report. Total cyanide was also designated as a study design COPEC for aquatic organisms in the biota work plan based on detected concentrations in water at gage station E200 (Table B-7.1-1 in LANL 2005, 89308). Water from E200 was collected as the reach M-2W sample and included in the algae toxicity studies. Neither this water sample nor any other new water samples from other reaches contained cyanide at concentrations that would make cyanide a study design COPEC (see Table E-1.2-7 and E-1.2-9) at this water station or the others sampled. Cyanide was detected in water for the algae test only in the samples from TS-1C and TS-2C, and the concentrations were less than 3 μg/L. Sediment from reach M-2W was also used for the chironomid toxicity test to assess risk to aquatic organisms. Regression analysis was conducted for each analyte detected (except sodium) in the carcass or pelt samples of each species, even if the analyte was not a study design COPEC. These regression analyses compared the concentration of a COPEC in the composite sediment samples collected at the trapping arrays, discussed in Section 8.1.2.2, against the concentration of the COPEC detected in tissues. Some analytes were detected in some tissue samples but not other samples; plots and regressions for analytes that were detected at least once in tissue include nondetects for that analyte as values at their detection limit

8.1.2.2 Soil Characterization

Samples of sediment were collected from the locations in the Mortandad watershed used for laboratory toxicity tests and also from sediment within the small mammal trapping arrays for additional characterization of exposure to small mammals. Table B-3.0-3 shows the reach, location ID, and geomorphic unit associated with each of these samples. For the earthworm and plant toxicity tests, discrete samples were collected from 0–30 cm (0–1 ft) for the toxicity assays and for the analytical analysis of the same samples. Samples for the earthworm and plant toxicity tests were collected from geomorphic units outside the active channel (generally c2, c3, or f1 units). Sediment samples for the *Chironomus tentans* toxicity tests were collected from 0–15 cm (0-0.5 ft) in the c1 geomorphic unit (the active channel) to represent the sediment to which these aquatic organisms would be exposed. At the four sites for the small mammal trapping, composite samples were collected for Laboratory analysis to estimate COPEC concentrations the mammals would be exposed to. The composite samples consisted of 10 subsamples collected from 0–15 cm (0–0.5 ft) at 10 locations within each trap array.

8.1.2.3 Owl Pellet Analysis

Owls regurgitate pellets containing fur and bones from prey items they have consumed; the contents of these pellets were examined to determine the species of prey consumed as an ancillary line of evidence for AE1. For this study, 46 pellets collected from four owl roosting sites were sent for taxonomic identification of the bone and tooth fragments (Bennett et al. 2006, 93774). Three of the roosting sites are known to be occupied by the Mexican spotted owl. One roosting site lies within Mortandad Canyon near reach M-2W. Two additional Mexican spotted owl roosting sites are in Cañon de Valle. The analysis of species included 17 taxonomic groups of mammals as well as birds. The complete list of number and type of each species found is described in Bennett et al. (2006, 93774). The primary use of this information in this study was to determine which species of small mammals from the tissue COPEC concentration analysis were appropriate to use for modeling the COPEC concentrations ingested during prey consumption by the Mexican spotted owl, as described in Section 8.1.2.1. The results of this comparison are described in Section 8.1.3.1.

8.1.2.4 Nest Box Studies

An avian nest box monitoring network has existed in the vicinity of the Laboratory since 1997; the network includes both potentially contaminated and noncontaminated areas. As part of the baseline ecological risk assessment for the Mortandad watershed, additional nest boxes were placed in the canyon bottoms or canyon bench areas within Mortandad Canyon and its major tributary canyons. Figure 8.1-1 shows the boxes within the Mortandad watershed that were sampled for the biota studies. Both the western bluebird (*Sialia mexicana*) and the ash-throated flycatcher (*Myiarchus cinerascens*) occupy these boxes. Measures collected using the nest box network included field measures of effect on reproductive success of these avian species (including clutch size, fledgling success, growth of fledglings, etc.) and measures of exposure through analysis of COPEC concentrations in unhatched western bluebird eggs and unconsumed prey (insects) collected within the boxes. Table B-3.0-5 shows the egg and insect samples collected for analytical analysis within the Mortandad watershed; the locations of the boxes within the reaches are shown in Figure 8.1-1. Boxes in Cañada del Buey and in the Cañada del Buey watershed (near TA-51) and boxes from two areas outside the Laboratory (the Los Alamos golf course and the Guaje Pines Cemetery; LANL 2004, 87390, Figure 8.1-1) were also included in the study for reference. Eggs from individual boxes within a reach were submitted as samples. In some cases, individual boxes contained sufficient material for analysis, but in other cases insects from more than one box in a reach were combined to obtain sufficient sample size for analysis. Table 8.1-3 shows a summary of the eggs and insects collected per reach.

Because of sample size limitations, egg and insect samples were analyzed only for metals. These measures were collected to evaluate AE2, the endpoint for avian ground invertevores. The COPEC concentrations in nest box insects were used as a measure for AE6, the avian insectivore (southwestern willow flycatcher) and the mammalian insectivore (the occult little brown myotis bat); the bat is being evaluated for possible exposure through prey even though this species does not represent a specific assessment endpoint in the baseline ecological risk assessment studies. Results of the field measures of effect through reproductive success are discussed in Section 8.1.3.3. The measures of exposure through COPEC concentrations measured in insects are discussed in Section 8.1.3.2 and exposure based on COPEC concentrations in eggs is discussed in Section 8.1.3.3.

8.1.2.5 Breeding Bird Survey

An additional study done as a measure for AE2 and AE6 for the avian ground invertevore and the avian insectivore was a survey of the level of use of upper Mortandad Canyon and Ten Site Canyon by avian

species. The survey recorded species, sex, and age of birds within these canyon bottom areas and provides an estimate of the diversity of species in the survey areas. The survey areas were not restricted to the designated reach areas but included birds seen or heard in the majority of the canyon bottoms in these areas during the walkover survey. The complete survey results are presented in Keller (2005, 93690). The results relevant to this investigation are discussed in Section 8.1.3.3.

8.1.2.6 Earthworm Toxicity Tests

Sediment collected from the 0- to 30-cm (0- to 1-ft) depth interval was used for the earthworm toxicity tests (a measure for AE4). The earthworm tests used the standard American Society for Testing and Materials (ASTM) method E1676-97. The toxicity tests compared the growth and mortality of the earthworms from the seven reaches shown in Table 8.1-1 with the reference site in reach LA-BKG. As shown in the table, the reaches were selected to represent a gradient of concentrations for COPECs associated with both the soil invertebrate receptor and the mammalian and avian receptors that feed on the soil invertebrate. The biota investigation work plan (LANL 2005, 89308) originally proposed that this assay would also include a bioaccumulation test to determine concentrations of COPECs in the worm tissues after 28 days' exposure to the sediment samples. Unfortunately, the earthworms were inadvertently discarded at the conclusion of the test before being sent for laboratory analysis for COPEC concentration. Therefore, the dose to avian receptors in Section 8.1.3.3 is calculated based on concentrations detected in earthworms in the Los Alamos and Pueblo Canyon studies (LANL 2004, 87390) from sediments with the same COPEC concentrations or on extrapolated values from those studies. Section 8.1.3.5 discusses the results of the statistical analysis of the growth and mortality between sites.

8.1.2.7 Seedling Germination Tests

Sediment collected from the 0-30-cm (0-1-ft) depth interval was used for the plant toxicity tests (a measure for AE5). The plant toxicity tests used the standard ASTM method E1963-98. The plant toxicity tests compared survival rates, shoot height, root length, and shoot and root mass in plants grown in soil the same seven locations used for the earthworm toxicity tests with plants grown in the soil sample from the background site. The tests used yarrow (*Achillea millefolium* L. var *occidentalis*), which has more variable results than some other available test species of plant but is more relevant to the ecosystems found at the Laboratory. Section 8.1.3.6 discusses the results of the statistical analysis of the growth and mortality between sites.

8.1.2.8 Plant Survey

A field plant survey was conducted in reaches within the Mortandad watershed to provide ancillary information for the small mammal trapping (AE3); significant differences in the amount of plant cover may affect the number or type of small mammals caught. The field plant survey also serves as an ancillary line of evidence for ecological risk to plants (AE5), although the plant toxicity test is the major line of evidence for that assessment endpoint. The plant survey encompassed nine reaches (see Table 8.1-1) including all of the mammal trapping reaches, all reaches for the plant and earthworm toxicity tests, and the background reach.

In these surveys, vegetation was identified as tree, shrub, forb, cacti, or graminoid (with identification to species where possible) and percent canopy cover for each species was categorized (Balice and Sandoval 2006, 93689). Two measures of diversity, the Shannon diversity function and species richness, were used to compare the vegetation between sites. A brief summary of the results and their relevance to other measures is provided in Section 8.1.3.6.

8.1.2.9 *Chironomus tentans* Toxicity Test

Sediment samples from the eight reaches shown in Table 8.1-1 were used in the EPA Method 100.2 (EPA 2000, 73776) 10-day growth and survival test with the larval insect *Chironomus tentans*. Each sediment sample was tested at 100% only; dilution series were not run on the sites. Standard control and reference toxicants were included. The endpoints for this test include both survival and growth (as ash-free dry weight). The results of the test are discussed in Section 8.1.3.7.

8.1.2.10 Rapid Bioassessment Characterization

Rapid bioassessment characterization was conducted at five reaches in the Mortandad watershed that had sufficient flow to potentially support aquatic macroinvertebrate communities (Henne and Buckley 2006, 93687), using the EPA Rapid Bioassessment Protocol (EPA 1999, 73728). Collection of aquatic macroinvertebrates was conducted in association with the bioassessment. Collection and assessment were attempted at all reaches specified in Table 8.1-1 in June and September 2005, but becaue of absence of wate,r neither TS-1C nor TS-2C underwent an assessment or invertebrate collection in June 2005. Similarly, reaches M-2W and TS-1C could not be sampled in September due to lack of water. The biota investigation work plan (LANL 2005, 89308) specified use of a Hess sampler to collect aquatic macroinvertebrates when sufficient water was present to use this sampler. However, none of the sites had sufficient water to use the Hess sampler in either June or September 2005. The Hess sampler is needed to collect data for comparison to the NMED Stream Condition Index (SCI); therefore, no comparisons to the SCI were done for the aquatic macroinvertebrate sampling in the Mortandad watershed. Semiquantitative sampling using a D-frame dip net to determine taxonomic composition of macroinvertebrates was done at the sites. The biota investigation work plan indicated that the collected macroinvertebrates would be submitted for Laboratory analysis if sufficient mass could be collected for analysis. The field team was unable to collect sufficient mass of aquatic macroinvertebrates to submit for analysis.

8.1.2.11 Algal Toxicity Test

Water samples collected from the reaches shown in Table 8.1-1 were used for the EPA Method 1003.0 short (96-hr) chronic toxicity algal growth test. This test uses the green algae *Selenastrum capricornutum*. The test methods, conditions, and results are described in Pacific Ecorisk (2005, 91270). Samples were collected from M-2W, E-1W, E-1E, M-1W, and LA-BKG in July 2005 for the test. Locations in TS-1C, TS-1E, and TS-2C were dry at that time, but water samples were collected from these locations in August 2005 for the toxicity test. Controls and reference toxicants were run with both sets of samples. The results of the test are discussed in Section 8.1.3.7.

8.1.2.12 Spatial Modeling Using ECORSK.9.

The ECORSK.9 model was used to model HQs and hazard indices (HIs) across the Mortandad watershed for the Mexican spotted owl, southwestern willow flycatcher, deer mouse, and western bluebird, as presented in Gonzales et al. (2006, 93786). ECORSK.9 includes both canyon and noncanyon sources as well as measured and interpolated concentrations of COPECs from these sources. The model estimates exposure based on an environmental exposure unit (EEU) that consists of foraging throughout the home range centered on known or potential nest sites input into the model. For the Mexican spotted owl, the model restricted the nest sites to within the buffer area for this T&E species. For the southwestern willow flycatcher, the model restricted the nest sites to within the wetland area designated as potential flycatcher habitat. For the deer mouse and western bluebird, the modeled area included the entire Mortandad watershed west of SR 4. The model produces mean total HIs that provide

an estimate of risk to populations and are most useful for species such as the deer mouse and western bluebird. For evaluating T&E species, risk to individuals and therefore the number of individual grid cells with elevated HIs are a better indicator of locations and COPECs that may need additional investigation. The model calculates both unadjusted HQs and HIs and adjusted HQs and HIs; the adjusted values do not include the contribution of background concentrations of COPECs. For this investigation report, the model was run with two scenarios: In the first scenario all nondetects were included as values at one-half of their detection limit. For many organic chemicals, nondetects constituted 75% to 98% of the data set values, resulting in detection limits heavily influencing the HQ and HI values. To overcome this problem, a second scenario was run in the model in which nondetects for organic chemicals were treated as zeros to focus the results on the actual detected COPECs in the model.

8.1.3 Characterization of Exposure and Effects

This section discusses the baseline ecological risk assessment characterization of exposure and effects, which represents the second part of ERAGS Step 6. This section provides the results from the studies and their interpretation as well as the supporting information in tables and figures. Revised calculations of dose to predators based on concentrations of COPECs in prey are also presented in this section. Although the screening of concentrations of COPCs in sediment and water samples collected in 2005 is also a line of evidence supporting the evaluation of potential ecological risk in the Mortandad watershed, that evaluation is separate from the field studies conducted for the base line ecological risk assessment. Screening the 2005 sediment and water samples against ESLs is presented in Appendix E and summarized in Section 8.1.1.1.

8.1.3.1 Mexican Spotted Owl

ECORSK.9 Model

In the ECORSK.9 model, a number of grid cells within the Mortandad watershed with elevated HIs indicated there may be areas of potential risk to individual Mexican spotted owls (Gonzales et al. 2006, 93786). This was true for both the unadjusted and adjusted mean HI. The adjusted mean HQ and mean HI values calculated in the second scenario (all organic nondetects treated as zeros, as explained in Section 8.1.2.12) are considered the most representative of potential risk from Laboratory sources to the modeled receptors, although the adjustment for background made little difference for the HQ and HI values for the owl. The adjusted total mean HI with nondetects treated as zeros for the owl is 1.6; only bis(2-ethylhexyl)phthalate had an HQ >1.0. Lead was the second most important COPEC (HQ = 0.6). The HI was ≥1 in 49% of the focal points; almost all of these HIs were less than 10. The area with the highest adjusted HI values indicating potential risk to the Mexican spotted owl were in part of Ten Site Canyon, including TA-35 and reaches TS-2E and TS-2C, and in Mortandad Canyon reach M-2E. Although it is difficult to pinpoint the individual source of elevated HIs in the model for a receptor with a home range as large as the owl, the primary sources of high HI values in the model appear to be from samples from noncanyon sources, particularly sources of COPECs associated with TA-35.The adjusted HI for the grid cell in Mortandad Canyon in which a pair of owls has nested was only 0.2. Therefore, the adjusted HI for the grid cell in Mortandad Canyon containing a confirmed owl nest indicates little to no threat of potential adverse effects from Laboratory-related contaminants.

Concentrations of COPECs in Prey

Remains of prey found in the owl pellets from the collection site near reach M-2W in Mortandad Canyon were dominated by wood rats (*Neotoma sp.*), which made up approximately half the identified pellets (Bennett et al. 2006, 93774). Wood rats were collected and analyzed from all trapping sites except the

LA-BKG site. Deer mice, brush mice, and pinyon mice were also found in pellets from this site. All these species were collected during the small mammal trapping done for this study. Two other pellet collection sites lie outside of the Mortandad watershed but within the home range of Mexican spotted owls at the Laboratory. These two other sites are also used for roosting by the Mexican spotted owl. Pellets from both these sites also contained wood rats; in addition, one site contained the remains of brush mice and another site contained pellets with the remains of long-tailed voles. The analysis of the pellets collected from these three sites indicate that the species collected from the small mammal trapping locations are appropriate to use in the refined calculation of the estimated doses to the Mexican spotted owl. The dose was calculated using the maximum detected concentrations in any prey species, although because wood rats may represent the dominant prey species; use of maximum concentrations from other species may overestimate the dose to the Mexican spotted owl.

COPECs for the Mexican spotted owl were identified in the initial screening of the sediment data (LANL 2005, 89308, p. D-37). While only Aroclor-1254 met the criterion for a study design COPEC (HQ >1 for a T&E species), mercury and cesium-137 had HQs just above 0.8. These three COPECs were not detected in the tissues of the small mammals sent for Laboratory analysis in this study. The detection limits for mercury and Aroclor-1254 are conservatively used to represent the tissue concentration in the refined dose calculation for the Mexican spotted owl. Cesium-137 results are not used in the dose calculations, as discussed below. Based on comments by NMED (NMED 2005, 92084), selenium is also a study design COPEC for all avian receptors although the HQ did not indicate that selenium should be included.

Small mammals are also assumed to be the prey of the receptor representing the carnivorous mammal, the red fox. Study design COPECs for the fox identified in the screening conducted for the biota investigation work plan (LANL 2005, 89308, p. D-35) include cesium-137, Aroclor-1254, and Aroclor-1260. Detected concentrations of Aroclor-1260 are used in the refined estimate of the dose to the fox, and the detection limit for Aroclor-1254 is conservatively used as tissue concentrations for this COPEC.

As described in the biota investigation work plan (LANL 2005, 89308 p. D-14), an HQ for the owl can be calculated by dividing the avian toxicity reference value (TRV) for a COPEC from the ECORISK Database, Version 2.2 (LANL 2005, 90032) by the normalized food intake of the owl of 0.102 mg fresh weight (fw) food/kg body weight (bw)/day (LANL 2005, 89308, p. D-14). Because the TRV for cesium-137 is based on a radiation dose to the organism and not on an amount ingested, this COPEC is not amenable to these calculations. Table 8.1-4 shows the calculations to combine the maximum detected concentrations in carcass and pelt into the equivalent concentration in a whole animal. This table also shows the HQ calculated by dividing the concentration in the reconstructed whole animal by the food ESL calculated as described above. The proportions of methylated mercury and inorganic mercury in the tissues were not measured, but the calculations in Table 8.1-4 demonstrate that the HQ is <0.5 for the owl regardless of whether the mercury is in the inorganic or methylated form.

8.1.3.2 Southwestern willow flycatcher

ECORSK.9 Model

In the ECORSK.9 model, a number of grid cells within the Mortandad watershed with elevated HIs indicated there may be areas of potential risk to southwestern willow flycatchers (Gonzales et al. 2006, 93786). This was true for both the unadjusted and adjusted HI. The adjusted mean HI value for the flycatcher was 6.2. The dominant COPECs were mercury (HQ = 1.7), di-n-butyl phthalate (HQ = 1.5), boron (1.4), and bis (2 ethylhexyl) phthalate (HQ = 0.48). HIs were ≥1.0 in 81% of the grids; approximately half of these HIs were less than 10. The flycatcher was modeled only for areas that contain

flycatcher habitat; therefore, the area with elevated HIs are limited to the Effluent Canyon area. The elevated HQs for di-n-butyl phthalate resulted primarily from measured values in the noncanyons portion of the data set used in the ECORSK.9 model. There is no BV for boron, and it is unknown whether the detected boron values represent releases from Laboratory sites or instead background levels.

Concentrations of COPECs in Prey

This section estimates the potential dose to the southwestern willow flycatcher using the concentrations in the insects collected from the nest boxes. As described in the biota investigation work plan (LANL 2005, 89308, p. D-14), an HQ for the flycatcher can be calculated by dividing the avian TRV for a COPEC from the ECORISK Database Version 2.2 (LANL 2005, 90032) by the normalized food intake. For the flycatcher, normalized food intake was calculated from the body weight of 12.7 g (LANL 2005, 89308, p. D-14) and estimating the food ingestion rate using the allometric equation for passerine birds from EPA's Wildlife Exposure Factors Handbook (EPA 1993, 59384, equation 3-4). The calculated food ingestion rate is 0.0034 kg/day. This food ingestion rate is in grams of dry weight per day, and was converted to fresh weight using the dry weight to fresh weight ratio for honeybees (Fresquez and Ferenbaugh 1999, 91269). The final insect ingestion rate used in the calculations for the southwestern willow flycatcher is therefore 0.79 kg fw food/ kg bw/day. Table 8.1-5 shows the calculated HQs for the flycatcher based on ingestion of the concentration measured in nest box insects. In some reaches, more than one insect sample could be analyzed, so the arithmetic mean of the concentrations was used (nondetects treated as one-half of the detection limit) as the sample size was too small for calculation of a UCL of the mean. In reaches with only one insect sample analyzed, the maximum detected concentration was used.

The HQs for food ingestion are shown in Table 8.1-5 and predict a much lower level of potential ecological risk than the screening against ESLs did, even though HQs for five COPECs still exceed one (barium, copper, mercury [assumed to be methyl], vanadium, and zinc). Four of these COPECs also had HQs elevated above one in samples collected outside the Mortandad watershed in the Cañada del Buey, Pueblo, and Rendija watersheds. The concentration of these metals in insects is therefore unlikely to be correlated with the concentration of COPECs in soil. The TRVs for these metals probably result in an overprediction of riskbecause the TRV is likely to be based on a more toxic form of the COPEC than is found in the insects. In addition, the southwestern willow flycatcher has not been observed in this part of the Laboratory, so the risk is hypothetical at this time. However, further evaluation may be warranted if the flycatcher is observed to utilize this area in the future.

Bis(2-ethylhexyl)phthalate could not be evaluated in this study, as the mass of insect tissue collected was sufficient only to run the metals analytical suite. However, potential effects of bis(2-ethylhexyl)phthalate are considered in the nest box study evaluation described in Section 8.1.3.3.

8.1.3.3 Avian Invertevore Feeding Guild

This section provides results for trends of COPEC concentration in sediment versus field measures for the avian invertevore feeding guild in the Mortandad watershed, such as nest success and eggshell thickness. This section also evaluates trends of COPEC concentration in sediment versus concentration in eggs. Field measures are derived from Colestock and Fair (2005, 93691).

Nest Success for Bluebirds

As part of the Laboratory's nest box monitoring program, a large number of field measures are collected from the nest boxes each year (Colestock and Fair 2005, 93691). Two of these measures that relate to

juvenile survival were selected for this study for comparison to concentrations of COPECs in sediment. The measures selected are percent fledged and percent female (the latter may relate to specifically to PCBs as COPECs). Occupied bird boxes were found in five reaches within the Mortandad watershed: M-3, M-4, M-5, TS-2C, and TS-2W. All species occupying the nest boxes (western bluebirds, violet green swallows, ash-throated flycatchers, and mountain bluebirds) are included in the analysis of the measures to provide a larger dataset as the overall number of occupied boxes in the reaches is fairly small. Appendix E provides box plots comparing these two measures between species; no significant differences are seen. Comparisons of the selected nest measures between these reaches are shown in Figure 8.1-2 for percent fledged and Figure 8.1-3 for percent female. Boxes in these figures indicate the interquartile range of the sample results, with the upper and lower ends defined by the 75th and 25th percentiles, respectively. Horizontal lines within the boxes indicate median values, and horizontal lines above and below the boxes represent the 5th and 95th percentiles of the data. Neither measure appears to differ significantly between the reaches, but there are small sample sizes for some measures (e.g., percentage of females in reaches TS-2C and TS-2W). These measures were recorded from 1997 to 2005; bivariate plots of each measure versus year were made and are shown in Appendix E. These measures do not correlate significantly with the year, so data from all years are included on the plots.

In addition to the comparison conducted between reaches, the combined data from all reaches within the Mortandad watershed are compared with other areas within the nest box monitoring network. The groups are Mortandad (Mort), Cañada del Buey (CdB), the cemetery (Cem, unimpacted area), the golf course (GC, unimpacted area), TA-35 (impacted, boxes are near SWMUs or AOCs), Los Alamos and Pueblo Canyons (LA/P, impacted by SWMUs and AOCs), and other (representing the boxes in the nest box network not included in the other groups). Figure 8.1-4 shows a comparison of the percent fledged between the groups and Figure 8.1-5 shows a comparison of the percent female nestlings between the groups. For both measures the results for the Mortandad watershed do not differ from the other areas.

Eggshell Thickness

Another set of parameters collected as part of the nest box network are related to the condition of the eggs. Numerous parameters have been collected; three of these parameters were chosen for inclusion in this study. Eggshell length (in millimeters) and total egg weight correlate well with each other and provide an estimate of egg size. Eggshell thickness was also chosen because previous studies had shown that some thinning of eggshells has occurred in Sandia Canyon (Fair and Meyers 2002, 82655). As with the other nest measures described above, all species are included to provide a larger dataset. Appendix E shows the comparison between species for egg length, egg weight, and eggshell thickness; the comparison shows no significant differences between species for these parameters. Appendix E also compares length, weight, and thickness across years in bivariate plots. None of the three measures vary significantly with year, so data from all years are included in the analysis.

The measures for the eggs are compared between the same five reaches (M-3, M-4, M-5, TS-2C, and TS-2W) as the other nest measures and are also compared among the same areas (Mortandad, cemetery, golf course, Cañada del Buey, TA-35, Los Alamos and Pueblo Canyons, and other). Figures 8.1-6 to 8.1-8 show the comparisons for the egg measures between reaches within the Mortandad watershed. Figures 8.1-9 to 8.1-11 show the comparisons for these measures between the areas. The sample sizes vary between reaches and between groups; however, the three measures do not show any significant differences between reaches or between groups.

COPEC Concentration in Eggs

The concentrations of metals measured in eggs were plotted against the reach average sediment concentration of that COPEC in the reach from which the egg was collected. The concentration in eggs does not correlate significantly with the concentration in sediment for any of the metals. The plots and regression calculations for all metals are presented in Appendix E. For two of the metals that generated higher HQs for the robin—mercury and copper—in the screening conducted for the biota plan and that were detected in the eggs, the graphs are presented in Figures 8.1-12 and 8.1-13. In addition, NMED requested retaining selenium for all evaluations in the report (NMED 2005, 92084), even though the initial screening did not show this as a COPEC; therefore the graph for selenium is presented in this section in Figure 8.1-14.

COPEC Concentration in Worms

As discussed in Section 8.1.2.6, COPEC concentrations in earthworms were not obtained from the Mortandad watershed in this study. Therefore estimates of potential risk to birds in the avian invertevore feeding guild cannot be directly made using measured concentrations in earthworms. In this report, regressions based on data from the Los Alamos and Pueblo watershed (LANL 2004, 87390) are used to estimate potential concentrations in earthworms in the Mortandad watershed for COPECs that had a significant correlation between detected concentrations in soil and worms in the Los Alamos and Pueblo watershed. For COPECs without significant correlations, the transfer factor from the ECORISK Database Version 2.2 (LANL 2005, 90032) is used. For both types of calculations, the concentration of the COPEC in the composite sample used for the earthworm toxicity test in a reach is used to estimate the concentration in earthworms from that reach. This estimated concentration in the worms is then compared with the concentration in food items expected to have no toxic effects (the food ESL) to derive an HQ for each reach reflecting risk from consumption of earthworms exposed to soil from that reach. Table 8.1-6 shows the basis of the calculations of the estimated concentrations in the worms, the food for each COPEC, the concentration in each soil composite sample by reach, and the HQ from worm ingestion. Two of the two organic COPECs (bis(2-ethylhexyl)phthalate, di-n-butyl phthalate) are not included in Table 8.1-6 because neither COPEC was detected in any of the soil composite samples used in the earthworm toxicity tests. An HQ >3 appears in all reaches, including the reference reach, for mercury based on assuming all mercury is in the methylated form. Only reach E-1E shows an HQ >3 for mercury in the non methylated form. Risk from both types of mercury are included in the table to provide bounding estimates. Because mercury speciation was not measured, the actual ratio of methylated to non methylated mercury in soil and worms is not known. No COPECs, except mercury, produced an HQ >3 in the modeling of dose through earthworms.

Field Surveys of Bird Abundance and Diversity

Field surveys of bird species were done in two areas: Mortandad Canyon from reaches M-1 through M-2, and adjacent parts of Effluent Canyon, and Ten Site Canyon from reaches TS-1 through TS-2, and adjacent areas in Pratt Canyon (Keller 2005, 93690). Species diversity was measured by calculating a Shannon-Weaver Index for each site. The index value was 2.7 for Mortandad and Effluent Canyons and 2.5 for Ten Site Canyon, indicating similar diversity of species between the two areas. The composition of species based on diet type was also similar between the two areas: most of the species in both areas were insectivores (including both ground-feeding insectivores and aerial insectivores). This finding supports using COPEC analysis in earthworms for assessing the risk to avian receptors in the Mortandad watershed.

The surveys yielded similar results for both areas even though there are some differences in bird COPECs between Mortandad and Effluent Canyons and Ten Site Canyon. As shown in Tables D-2.2-6 and D-2.2-8 (LANL 2005, 89308; pp. D-36 and D-38), the study design COPECs for the robin in that part of Mortandad Canyon are predominantly copper, lead, mercury, vanadium, and Aroclor-1254. In Ten Site Canyon, Aroclor-1254 and mercury are also study design COPECs, but other metals have HQs less than 3. Di-n-butyl phthalate was also a study design COPEC only in Ten Site Canyon. Study design COPECs for the violet-green swallow in Mortandad and Effluent Canyons included primarily aluminum and zinc. Other metals (cadmium, copper, mercury, and vanadium) were the dominant COPECs for the swallow in Ten Site Canyon. Both areas have a number of study design COPECs for birds, but the field surveys support that a good diversity of avian species are still found in these areas.

ECORSK.9 Model for Western Bluebird

Based on the ECORSK.9 model (Gonzales et al. 2006,93786), the percentage of the western bluebird population in the Mortandad watershed that has potential for adverse effects predicted by elevated HIs is too low to affect population viability. The adjusted mean HI for the bluebird is 1.2. The dominant COPEC for this receptor based on the adjusted HI is mercury (mean HQ = 0.38). Other metals (cyanide, zinc, and vanadium) dominated the unadjusted HI, but the entire contribution of these three COPECs was attributable to background. HIs in 24% of the focal points were greater than 1.0.

8.1.3.4 Mammalian Invertevore Feeding Guild

Field Surveys of Small Mammal Relative Abundance and Reproductive Status

A variety of field measures were collected during the trapping and collection of small mammals for this biota investigation (Bennett et al. 2006, 93701). The mean percent daily capture rate, which is an estimate of relative population density, was highest in reach E-1W at 22% and lowest in reach LA-BKG at 7%. The results are shown in Figure 8.1-15. The trend within the Mortandad watershed reaches of decreasing mean daily capture rates with distance downcanyon is probably related to habitat; the trend is consistent with the total percent vegetation canopy cover discussed in Section 8.1.3.6. Species diversity expressed as a Shannon-Weaver Index (see Figure 8.1-16) follows the same trend. The HQ and HI values for deer mouse COPECs also decrease downcanyon; so increasing COPEC concentrations cannot be responsible for the drop in capture rates.

Species composition (the frequency of capture for each species at a site) was very similar between the three Mortandad watershed reaches; species composition in all the Mortandad reaches differed from the Los Alamos Canyon reference site. Data collected during the trapping study indicated no differences in ratios of males to females, body weights, or reproductive status between reaches, using chi square analysis (Bennett et al. 2006, 93701); however, the size of the sample set in this study is somewhat small for evaluation of effects on these parameters.

Concentrations of COPECs in Small Mammals

As described in Section 8.1.3.4, several species of small mammals were trapped and collected in each reach used in the study. All the individuals of most species from a reach were separated into pelt and carcass; the pelts and carcasses were combined so that one pelt and one carcass sample from each species was sent for analysis for each reach. The exception is for shrews, where whole bodies were sent for analysis because of the small size of these mammals. Distinct differences in tissue concentration versus sediment concentration were not seen between species. Regression analysis of concentrations of study design COPECs in carcasses of all species and concentrations in sediment are presented in

Appendix E and show statistically significant correlations for only three of the detected COPECs: aluminum, iron, and perchlorate, although two of the correlations are negative. As shown in Figures 8.1-17 and 8.1-18, aluminum and iron concentrations in tissue are negatively correlated with sediment concentrations, indicating no significant uptake by small mammals from the soil. Figure 8.1-19 shows perchlorate in body tissue; perchlorate was positively correlated with sediment concentrations, indicating uptake by small mammals from the soil. At NMED's request (NMED 2005, 92084), selenium was retained as a COPEC in this evaluation. Selenium concentrations in small mammal tissue did not have a significant correlation with concentrations in soil, as shown in Figure 8.1-20. Figures presenting concentrations in carcass and concentrations in soil for all other detected analytes are in Appendix E.

Regression analysis of concentrations in pelts of all species and COPEC concentrations in sediment showed statistically significant correlations for only two of the detected analytes: americium-241 and arsenic. Concentrations of both these COPECs in pelts were positively correlated with sediment concentration. Figure 8.1-21 shows the concentration of americium-241 in pelt versus sediment. Figure 8.1-22 shows the concentration of arsenic in pelt versus sediment. Selenium concentrations in pelt versus sediment are shown in Figure 8.1-23, and indicate a positive correlation**.** In contrast, lead concentrations in pelts seem to be negatively correlated with sediment concentrations, although the regression was not statistically significant ($p = 0.07$ for regression). Because analyses of pelts include soil particles adhering to the pelt, these analyses are not as useful as concentrations in carcasses in indicating potential uptake, although they still provide information for possible transfer to higher levels of the food chain. Appendix E presents regression equations and figures showing concentrations in soil versus concentrations in pelts for other detected analytes. The other study design, COPECs detected in pelt and carcass samples were not correlated with sediment concentrations in the study reaches. Graphs of carcass and pelt concentration versus sediment concentration for all other detected COPECs are presented in Appendix E. For some COPECs, this result may indicate that concentrations in tissues are unrelated to environmental exposure. For COPECs that are known bioaccumulators, such as Aroclor-1260, these results indicate that the sediment in the study reaches is not a significant contributor to the total body burden of these small mammals.

Concentrations in the pelts and carcasses were multiplied by the proportional masses of the pelts and carcasses to reconstruct an estimate of the whole animal body tissue concentration. This information was used in Section 8.1.3.1.1 to refine the estimate of dose to the Mexican spotted owl. The same information is used here for comparison to the results of small mammal trapping studies conducted in other canyons; those studies all used concentrations determined from analysis of whole animals. Regression analysis of estimated concentrations in whole bodies of all species and concentrations in sediment show statistically significant correlations for only two of the detected analytes, with positive correlations for americium-241 and perchlorate. Regression equations and figures showing concentrations in soil versus concentrations in whole animals for other detected analytes are presented in Appendix E.

Concentrations of Aroclor-1260 in small mammals from the Mortandad watershed (except for the shrew, which was not included in previous studies) are similar to concentrations detected in small mammals trapped in the Los Alamos and Pueblo watershed. These two watersheds have similar concentrations of Aroclor-1260 in soil from the mammal trapping areas. This indicates a consistent relationship between this COPEC in soil and in small mammal tissue, indicating that this correlation may have some predictive value.

ECORSK.9 Model for Deer Mouse

The percentage of deer mouse population in the Mortandad watershed that has potential for adverse effects predicted by elevated HIs in the ECORSK.9 model is too low to affect population viability

(Gonzales et al. 2006, 93786). Mean HI values exceeded 1.0 in only 8% of the focal points for the deer mouse. Based on the unadjusted HI (the adjusted HI showed no COPECs with an HQ >0.3), the dominant COPEC would be thallium. Nondetects constituted 72.5% of the thallium values used in the data set, and the mammalian TRV for thallium is very low. The model likely overpredicts the potential risk from thallium based on detection limits; thallium was detected in relatively few of the canyon bottom samples (37% detection frequency). In addition, thallium was only detected above the BV in five sediment samples in the Mortandad watershed, three in E-1E and 2 in M-2W. This indicates relatively small releases of thallium from the TA-50 RLWTF and low levels of thallium contamination in a small area, as discussed in Section 7.1.2.

Refinement of COPEC Dose to the Shrew from Earthworms

Some COPECs in the ecological screening in the biota investigation work plan had HQs exceeding three for deer mice and for shrews. All deer mouse COPECs were also shrew COPECs. Therefore, the shrew (which has a higher exposure because the diet is modeled as 100% earthworm versus 50% earthworm for the deer mouse) was evaluated through modeling of the dose through earthworms based on estimated concentrations in earthworms. Regression equations or concentrations based on transfer factors from the ECORISK Database Version 2.2 were used, as explained for the avian receptors in Section 8.1.3.3. The results of the calculations are shown in Table 8.1-7. Only thallium has an HQ >3 for the shrew; this would also be the case for the deer mouse. Thallium has a very low TRV for mammals and uses a default transfer factor of one to estimate the concentration in earthworms. Table 8.1-8 provides some additional information on the comparison of thallium HQs between reaches. Because these factors are so conservative, the thallium HQ shown in the table is likely to overestimate risk. As discussed above and in Section 7.1.2, there is also evidence of only very small releases of thallium into the canyon bottoms.

8.1.3.5 Detritivores

The earthworm toxicity tests measured growth and survival of earthworms at seven locations in the Mortandad watershed in comparison with the background location in reach LA-BKG (EP&T 2005, 91267). The results for this test, including all replicates, are summarized with box plots for survival and growth (as weight change) in Figures 8.1-24 and 8.1-25. Negative and positive control samples from the laboratory are also shown (LAEW-Neg and LAEW-Pos). The boxes on these plots indicate the interquartile range of the sample results, with the upper and lower ends defined by the 75th and 25th percentiles, respectively. Horizontal lines within the boxes indicate median values, and lines above and below the boxes represent the 5th and 95th percentiles of the data. Dunnett's t-Test results are presented in the right-hand section of each figure. The comparison circles indicate statistical differences between the tests and the reference site (LA-BKG). The background sample for the Dunnett's t-Test is displayed as a heavy red circle, and the text for the reference site is printed in bold red text on the x-axis. Thin red circles represent samples that are not statistically different ($p < 0.05$), and the reach names for these reaches are in red on the axis. Heavy gray circles represent samples that are statistically different, and these reach names are printed in black on the x-axis. No significant differences in survival were seen between any of the sites and the reference site; survival was almost 100% in all replicates, except the Laboratory positive controls (LAEW-Pos samples). In all treatments, including the negative Laboratory control (LAEW-Neg sample), worms showed weight loss, which is typical of earthworms in this assay (EP&T 2005, 91267). Only one reach, M-2W, showed a significant decrease in weight compared with the reference site in LA-BKG. The composite sediment samples from each reach were also analyzed for COPECs; the concentrations of all earthworm study design COPECs in M-2W were lower than the concentrations of these COPECs in some other reaches that did not have as high a weight loss (Table 8.1-9). The higher weight loss of worms in

the sample from this reach is therefore unlikely to be related to the presence of earthworm COPECs in the soil.

Organic matter in soil can serve as a food source for earthworms during this type of test. The organic matter was measured in each of these samples, but the organic matter in the sample did not correlate with the percent survival or weight change in the test groups (see figures in Appendix E).

8.1.3.6 Plant (Primary Producers)

Seedling Germination and Growth

A number of measures of plant growth and survival are included in the Laboratory toxicity test on samples collected from the Mortandad watershed; these measures include mass of dry shoots, mass of dry roots, mass of wet shoots, mass of wet roots, percent survival, mean root length, and mean shoot length. The complete results are provided in EP&T (2005, 91268). The results are plotted on box plots with the results of the Dunnett's t-Test comparison printed on the right-hand side of the figure; this type of figure is explained in Section 8.1.3.5. As shown in Figure 8.1-26, the dry mass of roots, dry mass of shoots, and mean root length showed no significant differences between reaches, although the test sites did differ from the negative and positive (boric acid) laboratory control samples. In the analysis of wet root length shown in Figure 8.1-27, the plants grown in soil from reach TS-2C had significantly higher mass of wet roots and wet shoots than the other reaches, which were not significantly different from each other. The dry weight of roots and shoots in TS-2C did not differ from the other reaches.

The soil samples used in the plant toxicity test were also analyzed for study design COPECs. The results of those analyses show that reach TS-2C had lower concentrations of chromium, copper, manganese, thallium, vanadium, and zinc than some of the other reaches, although that soil sample had the maximum detected concentration of silver (Table 8.1-9).

Plant survival by reach is shown in Figure 8.1-28. The Dunnett's test results indicate the reaches can be divided into two groups. Reaches E-1W, E-1E, and M-2W represent a group with the highest survival rate. Reaches E-1FW, M-4, TS-1C, TS-2C, and the reference site (LA-BKG) form a second group with slightly lower survival. Although survival in the two groups differ statistically, it is important to note that survival in all replicates from all reaches (except a single replicate from M-4) exceeded 87%, and the background sample was also in the lower survival group. Differences in survival are therefore unlikely to have population level effects and are not related to the presence of COPECs.

Mean shoot length is shown in Figure 8.1-29. The Dunnett's test for this measure also divided the reaches into two groups; these groups did not contain the same reaches as seen in the results for survival discussed above. For the measure of shoot length, reaches E-1E and TS-2C are statistically the same as the reference site (LA-BKG). Reaches E-1FW, E-1W, M-2W, M-4, and TS-1C form a second group with a slightly decreased mean shoot length.

Nutrients in soil can strongly influence growth in soils during this test. Therefore, nutrient parameters such as phosphate, nitrate, and percent organic matter were measured on the soils used in the plant toxicity test. The laboratory negative control sample, for example, contains 10% organic matter, which is the primary reason the control growth always exceeds the growth in the soils from the Laboratory, which are much lower in organic matter. Each growth measure is compared with phosphate, nitrate, and percent organic matter in the bivariate plots in Appendix E. Based on the bivariate plots, percent organic matter may influence plant growth measures in the test regardless of the presence of COPECs in the soil sample.

Abundance and Diversity of Plants

Data from a field survey of plant abundance and diversity in the Mortandad watershed (Balice and Sandoval 2006, 93689) provide supplemental information on plant communities between reaches and possible effects of COPECs on plants. Table 8.1-10 provides the total species richness, the Shannon diversity index for all species, and the total percent canopy cover for all species. These same reaches were surveyed in 2003 for species richness, and the average species richness of 36 from 2005 is much higher than the 2003 species richness of 25. This increase in species richness occurred for all vegetation categories except cacti and is associated with the lessening of drought conditions between surveys. The increase in plant species richness with higher precipitation from one survey year to the next supports the results of the toxicity assay, indicating that COPECs in the canyon soils are not inhibiting the germination or growth of plants in these areas. Part of the variability in species between reaches is caused by variations in climate, including the general increase in annual precipitation from east to west across the study area. Differences in local topography and hydrology, such as canyon width and depth and presence or absence of wetlands, also affect plant communities. Total species richness, Shannon diversity index, and total percent canopy cover for each reach are plotted versus distance from the Rio Grande as a measure of relative precipitation in Figure 8.1-30. The Shannon diversity index has a significant positive correlation with distance from the Rio Grande (primarily caused by diversity at reach LA-BKG representing an outlier value), suggesting that climate is a primary control on this measure. In contrast, total species richness and total percent canopy cover have much variability with distance, which suggests other factors are important. Total species richness is least in reaches M-2W, E-1W, and E-1E, and total percent canopy cover is also least in E-1E at intermediate distances from the Rio Grande. E-1E and M-2W are the narrowest reaches included in this study, bounded by Bandelier Tuff bedrock, and E-1W is the reach with the largest wetland in this study, suggesting that these factors have negatively affected species richness and canopy cover. The presence of COPECs in canyon soils may also potentially affect these parameters, although the results of the toxicity assay indicate that COPECs in the canyon soils are not inhibiting the germination or growth of plants in these areas.

8.1.3.7 Aquatic Community

Chironomus Tentans Toxicity Bioassay

The *Chironomus tentans* toxicity test measures survival and growth of larval insects in active channel sediment collected from the eight reaches specified in Table 8.1-1. A complete description of the test conditions and results is contained in Pacific Ecorisk (2005, 91271). Figure 8.1-31 shows box plots of the number of live larvae remaining per replicate per reach at the conclusion of the test. This box plot shows no significant differences in larval survival between the selected reaches or between the reaches with COPECs and the reference site in reach LA-BKG. Figure 8.1-32 shows the mean dry weight of surviving larvae in each replicate test for each reach. This box plot also shows no significant difference between reaches for this measure of larval growth. Box plots of two other measures of larval growth, total ash-free dry larvae weight and mean ash-free dry larvae weight, are presented in Appendix E. Neither of those growth measures showed any difference between reaches. These results indicate that sediment COPECs do not have an effect on the growth or survival of *C. tentans*.

Rapid Bioassessment Characterization

Data on collected macroinvertebrates, habitat scores, and dissolved oxygen levels in reaches E-1W, M-1W, and M-2W indicate that these sites are marginal for sustaining a diverse community of aquatic life (Henne and Buckley 2006, 93687). However, the assessment protocols used are based on perennial streams and may be biased toward rating ephemeral streams as degraded. Hess sampling could not be

used because of low flow conditions, so quantitative estimates are not available for comparison to the NMED metric. Macroinvertebrates were collected from each reach by D-frame dip net. During both sampling events (June and September 2005), 25% of the taxa at reach E-1W were chironomids. In June, chironomids constituted 85% of the identified individuals from this site as well. Chironomids represented 25% of the taxa and 92% of the individuals in M-1W in June, and 16% of taxa and 71% of individuals in September. The site in reach M-2W also contained predominantly chironomids; chironomids were 33% of the taxa and 69% of individuals in June, and the site was dry in September. The predominance of chironomids at the sites also supports the use of the *Chironomus tentans* Laboratory toxicity test as the appropriate assay to determine if sediment COPECs are adversely impacting the macroinvertebrate communities in these ephemeral stream systems.

Algal Toxicity Test

Water was collected from areas of intermittent or persistent water in reaches E-1W, E-1E, M-1W, M-2W, and LA-BKG in July 2005 for tests of algal toxicity, and from reaches TS-1C, TS-1E, and TS-2C in August 2005 after summer rainstorms provided enough water in these drier reaches. These two sampling events resulted in two separate tests for toxicity of water to algae. For these short-term tests, the endpoint is growth expressed as number of cells versus the control. The results of the toxicity tests are reported in Pacific Ecorisk (2005, 91270). Different rates of growth were seen in the controls between the two tests, so the results for the two tests are shown separately. Figure 8.1-33 shows a box plot comparing the samples from each reach (this type of plot is explained in Section 8.1.3.5) with the July samples, which include the reference site (LA-BKG). Laboratory controls are labeled ”control” and “0.5 ZN” (0.5 ppm zinc as a positive control) through “20 ZN” (20 ppm zinc as a positive control). Figure 8.1-34 shows a box plot for the laboratory controls and samples from Ten Site Canyon collected in August. The box plots show that for both sets of tests, growth in all reaches except TS-1C exceeded both the negative (Laboratory control water) and positive laboratory controls (the range of zinc growth-inhibiting concentrations) for the test.

Table 8.1-11 shows the concentrations of detected radionuclides in algal test samples that are study design COPECs and the value for the algal HQ based on these concentrations. Radium-226 was detected in the M-1W sample, and americium-241 was detected in the E-1E, M-2W, and TS-1C samples. A comparison between Figures 8.1-33 and 8.1-34 and Table 8.1-11 shows that the differences in growth do not correspond to the detected concentrations of radium-226 and americium-241. The only reach sample in which algal growth was inhibited was in TS-1C; this sample contained the lowest detected concentration of americium-241, and radium-226 was not detected in that sample. The growth rates for all reaches were compared with general water quality parameters, which can strongly influence the results of this type of test. For both tests, the mean algal cell density correlates extremely well with water hardness, as shown in the bivariate plots in Figure 8.1-35. These results indicate that differences in the growth rates of algal cells between reaches (including reach TS-1C) result from the differences in water hardness between samples from the reaches and not from the concentrations of radionuclides in the water samples. Bivariate plots of algal cell density against conductivity and alkalinity are presented in Appendix E. None of these parameters correlated with cell growth as well as the water hardness.

The detected concentration of radium-226 in the M-1W sample has an HQ >3 (equivalent to a study design COPEC), but this sample did not show adverse impacts to the growth of green algae when compared with positive controls in the test. The detected concentrations of americium-241 are below the ESL, and the test results do not indicate adverse impacts to populations of green algae.

Estimate of COPEC Dose through Food to the Bat

Although several COPECs in the Mortandad watershed had HQs >3 for the bat (aluminum, arsenic, and naphthalene), the bat was not identified as an appropriate measure for an assessment endpoint in the biota investigation work plan because its large home range and high food ingestion rate indicate that much of a bat's food would be obtained from outside the watershed. However, because nest box insect tissues were analyzed to evaluate avian receptors, these same analytical results were used to refine the potential COPEC dose through food to the occult little brown myotis bat, as shown in Table 8.1-12. Because of the size of the insect samples, only metals analyses could be run on the insects. Therefore, naphthalene was not included in these calculations. Aluminum was included in the analytical suite for the nest box insects, but the ESL for aluminum has been updated to follow EPA guidance that aluminum is only a potential COPEC in soils with a pH below 5.5 (EPA 2003, 85645); therefore, aluminum no longer fits the ESL model for accumulation through the food chain and is also not included in Table 8.1-12. The HQ for arsenic for bioaccumulation through insects into the bat is 0.6, indicating no potential risk to the bat through ingestion of insects even if all insects come from the canyon bottom areas within the Mortandad watershed.

8.1.3.8 Refinement of COPEC Dose to the Fox through Ingestion of Small Mammals

The red fox was not evaluated as the measure for a specific endpoint in this study, but Aroclor-1254, Aroclor-1260, and cesium-137 had HQs greater than 3 for the red fox in the ecological risk screening (LANL 2005, 89308, p. D-35). For the two PCBs, maximum detected concentrations in whole small mammals were used to refine the dose estimate. These calculations and the resulting HQs are shown in Table 8.1-13. Aroclor-1254 and cesium-137 were not detected in small mammal tissues, so this COPEC is not evaluated further. For Aroclor-1260, the maximum whole body concentration was detected in a montane shrew. The calculated HQ for Aroclor-1260 is 0.003, indicating no potential risk to the red fox from PCBs through ingestion of small mammals

8.1.4 Risk Characterization

ERAGS Step 7 is risk characterization, which includes risk estimation and the uncertainty analysis. Risk estimation includes a summary of the results for the measures used to evaluate potential for ecological effects. A qualitative weight of evidence (WOE) criterion was assigned to each measure in Appendix D of the biota investigation work plan (LANL 2005, 89308). If measures indicate different outcomes, meaning one measure indicates a potential for adverse effects and one does not, then the overall conclusion would be weighted toward the measure with the higher WOE.

8.1.4.1 Risk Estimation

Mexican Spotted Owl

The two main measures for the Mexican spotted owl are the ECORSK.9 modeling and the modeling of estimated dose through the food chain from the study design COPECs detected in small mammals. The WOE assigned to each measure is shown in Table 8.1-14. In the ECORSK.9 model, the total adjusted mean HI (using zero for nondetects) across the core and buffer areas for the owl was 1.6. This value exceeds the HI target of 1.0, indicating a small potential for effects to individual owls, primarily from bis(2-ethylhexyl)phthalate (Section 8.1.3.1 and Gonzales et al. 2006, 93786). This SVOC has a high frequency of nondetects in sediment samples from the Mortandad watershed (99.5% nondetects; Section 7.1.3.3), and the potential risk is largely from analyses of samples collected outside the canyon bottoms. One Mexican spotted owl nest currently exists in the Mortandad watershed, and the adjusted HI for this

nest location is 0.2, which does not indicate potential risk to the Mexican spotted owl. The other measure estimated the dose to the Mexican spotted owl based on detected concentrations in mammal tissue (Section 8.1.3.1). The dose modeling was conducted for the nonradionuclide COPECs for the owl (Aroclor-1254, mercury, and selenium) as determined by the screening against ESLs in the biota investigation work plan. The dose modeling shows no HQs greater than 0.5, indicating no potential risk to the owl. Small mammals were not analyzed for SVOCs. Bis(2-ethylhexyl)phthalate was not a study design COPEC in the original screening because it had a higher ESL in the version of the ECORISK Database (Version 2.1, LANL 2004, 87386), which was current at that time. The owl pellet analysis showed that the small mammal species used in the dose modeling are among the species consumed by the Mexican spotted owl in the Mortandad watershed. Based on the dose modeling and on the ECORSK.9 model results for the portion of the canyon in which Mexican spotted owls currently nest, the WOE indicates no adverse effects of COPECs on survival and reproduction of the Mexican spotted owl (AE1).

Southwestern WillowFlycatcher

The aerial insectivores applicable measures for the southwestern willow flycatcher are the ECORSK.9 model, the results of estimated dose through prey using the concentrations of COPECs detected in nest box insects and the field nest box measures. The WOE assigned to each measure is presented in Table 8.1-15. The ECORSK.9 model had a total mean adjusted HI of 6.2, indicating some potential for risk to the flycatcher through exposure to mercury, di-n-butyl phthalate, boron, and bis (2ethylhexyl) phthalate (Section 8.1.3.2 and Gonzales et al. 2006, 93786). The food chain modeling showed HQ values >1 for six metals when the maximum detected concentration in insects was used for the calculation. When the mean detected concentration in the insects is used in the calculations, the HQs are still elevated for mercury (if all the mercury is considered to be in the methylated form), copper, vanadium, and zinc. These calculations indicate potential for risk to flycatchers from ingestion of the nest box insects. The WOE from these measures indicates some potential for adverse effects to survival and reproduction of the southwestern willow flycatcher (AE6) from COPECs in sediment. However, the field measures (nest box studies) of other avian insectivores do not show impacts to nest success, which indicates that the models used for assessing the flycatcher overestimate the potential for ecological risk to avian insectivores. In addition, the southwestern willow flycatcher has not been observed in this part of the Laboratory, so the risk to this species is hypothetical at this time.

Avian Ground Invertevore Feeding Guild

A number of measures were evaluated for the avian ground invertevore feeding guild. The WOE assigned to each measure is provided in Table 8.1-16. ECORSK.9 modeling using the western bluebird indicated a total mean adjusted HI of 1.2, too low to have effects on populations of avian invertevores (Section 8.1.3.3 and Gonzales et al. 2006,93786). Modeling the estimated dose of COPECs to the robin through earthworms was also done, although this analysis had to employ estimated concentrations of COPECs in the earthworms instead of measured concentrations as initially planned. The dose modeling indicates a potential for risk to avian ground invertevores through ingestion of COPECs in earthworms. The primary COPECs are mercury, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, and Aroclor-1254. A number of field measures of impacts on avian invertevore species were also conducted. The measures of nest success through percent fledged, percent female nestlings, and egg size and thickness show no differences between reaches with and without COPECs. Concentrations of COPECs in eggs do not correlate with sediment concentrations, indicating that uptake into the birds is less than the levels predicted by models, including the dose modeling from earthworms. Field surveys of avian species in Effluent, Mortandad, and Ten Site Canyons did not show any differences in species diversity or avian diet types represented between the canyons, even though di-n-butyl phthalate was a study design COPEC in

Ten Site Canyon and not in Effluent and Mortandad Canyons. Overall, the WOE indicates that COPECs in the Mortandad watershed do not pose a risk to population abundance or persistence and species diversity of avian ground invertevore feeding guild species (AE2).

Mammalian Invertevore and Omnivore Feeding Guild

The mammalian invertevore and omnivore feeding guild includes both the deer mouse (an omnivore) and the shrew (an insectivore). Four lines of evidence were evaluated for these species, and the WOE for these lines is presented in Table 8.1-17. The unadjusted HI had only thallium as a COPEC; this results because thallium has a low TRV and the data set consisted mostly of nondetects that elevated the HQs. ECORSK.9 modeling for the deer mouse showed no COPECs with the adjustment to remove the contribution of thallium (Section 8.1.3.4 and Gonzales et al. 2006, 93786). The tissue and pelt concentrations of COPECs were measured in small mammals as well. This line of evidence was primarily for dose modeling to receptors that eat small mammals, but the results are also relevant to the small mammals themselves. Very few of the COPECs detected in the small mammals correlated with the concentrations in sediment: three COPECs correlated with body tissue, two with pelt, and two with whole animals. These results indicate that the ESL model overestimates the uptake of COPECs into small mammals. Thallium was one of the COPECs that did not correlate with soil concentrations in any of the tissues tested.

The third measure for the small mammals was to estimate the potential dose to them through ingestion of earthworms. As with the avian receptors, estimated COPEC concentrations in earthworms had to be substituted for the planned analytical results. Both the shrew and deer mouse are modeled for the ESL development with invertebrates in their diet, but as explained in Section 8.1.3, the dose modeling was conducted using the shrew. Only thallium had an HQ >3 for the small mammals; this results because thallium has a low TRV and a default transfer factor of 1. Thallium in earthworms did not correlate with soil concentrations of thallium in the study in the Los Alamos and Pueblo watershed; therefore, the thallium result from the modeling is likely to greatly exceed the actual risk and not be a strong line of evidence for small mammals. Overall, the WOE for small animals indicates that COPECs in soil do not have adverse effects on population abundance or persistence and diversity of mammalian invertevore and omnivore feeding guild species (AE3).

Mammalian Carnivore Feeding Guild

Although the fox did not represent a specific assessment endpoint because carnivores were evaluated through AE1, the ecological screening presented in the biota investigation work plan indicated that PCBs may impact this receptor. The mammal tissue concentrations of PCBs were used to calculate a refined estimate of dose through the food chain (Section 8.1.3.8). Only Aroclor-1260 was detected in small mammal tissue and the HQ for Aroclor-1260 was less then 0.01, indicating that there is no risk to this receptor through ingestion of small mammals in the Mortandad watershed.

Detritivores

ALaboratory toxicity test measured both survival and weight change in earthworms from samples in reaches with and without soil COPECs (Section 8.1.3.5). The WOE for this measure and measures of detritivores relevant to other receptors is given in Table 8.1-18. There was no difference in survival between any of the reaches. There were differences in weight loss between the reaches, but the differences in weight loss did not correlate with COPEC concentration. The WOE for detritivores indicates that COPECs in soil in the Mortandad watershed do not adversely impact survival and growth of detritivore species (AE4).

Plants (Primary Producers)

Lines of evidence and their WOE for plants are provided in Table 8.1-19. The main line of evidence is the seedling germination test with supporting information from the field survey of plants in reaches with different concentrations of COPECs. Survival and most measures of growth in roots and shoots showed no difference between reaches (Section 8.1.3.6). Two measures (wet root length and mean shoot length) differed between reaches but did not correlate with COPEC concentration. The field survey of plants showed no differences between reaches that could be directly related to variations in COPEC concentrations, and all reaches that had been previously surveyed had more species diversity than previously, supporting the finding that germination and growth are not inhibited. The overall WOE indicates no adverse effects of COPECs in soil on native plant species presence and diversity (AE5).

Aquatic Community

The measures used as lines of evidence for evaluating impacts to the aquatic community in the Mortandad watershed, and the WOE assigned to each measure are provided in Table 8.1-20. The Laboratory toxicity test using *C. tentans* showed no difference in survival and no difference in growth correlated with COPEC concentration. The field bioassessment characterization indicated that chironomids dominate the aquatic community in sampled reaches and that the toxicity test using chironomids is therefore an appropriate measure of impacts to the aquatic community. The Laboratory algal toxicity test showed differences in cell growth with reaches, but these differences were attributable to water hardness and not to COPECs in water. The WOE for measures of the aquatic community indicates there are no adverse effects from COPECs in sediment and water on abundance and survival of the aquatic community in the reaches of the Mortandad watershed (AE7).

8.1.4.2 Uncertainty Analysis

Exposure Uncertainty

Uncertainties in the ecological risk assessment are potentially associated with the characterization for sediment and surface water. Maximum detected concentrations were used for some comparisons, which would overestimate the exposure concentration in a reach. For comparisons to bird boxes, arithmetic mean concentrations in soil in each reach were used for comparison; because sampling is biased towardlocations where contaminant concentrations are highest, use of straight means generally provide overestimates of actual exposure concentrations, as discussed in Section B-1.0 of Appendix B. Media concentrations for evaluating the results of Laboratory toxicity tests came from the actual water and sediment samples used in those tests and provide a good estimate of the exposure concentration for the assay organisms. These concentrations would overestimate exposure concentrations throughout the sampled reaches because sampling was biased to specific locations with higher concentrations of COPECs in these reaches. For the small mammal trapping, composite soil samples for comparison were obtained from the traps within the array.This provides a good representation of the concentration in the trapping array, but because the arrays were centered in areas with contaminated sediment deposits, the data are expected to overestimate exposure concentrations for mammals that largely forage outside these areas.

Another uncertainty is the adequacy of the toxicity and bioaccumulation data used to develop the assessment endpoints and select the associated measures and develop the study design. In fact, a number of toxicity values and transfer factors in the ECORISK database and the associated food chain and ECORSK.9 modeling were changed between the design of the studies and their evaluation in this investigation report. These changes brought new COPECs into consideration. Gaps also exist for toxicity

for some classes of COPECs on some receptors that hamper evaluating those COPEC-receptor combinations except in the field studies. The study design included field, Laboratory, and model components to provide complementary information and reduce uncertainties related to toxicity and bioaccumulation data.

Field Measures

Empirical ecological effects data are the most relevant data for determining if there are adverse effects on ecological receptors, especially at the population level. However, these data are inherently more variable and difficult to quantify than laboratory measures. Uncertainty associated with a limited number of locations and a limited number of sampling events is mitigated by collecting information across a variety of measures of exposure and effect.Factors unrelated to COPECs, such as drought and other climatic variations, fire, and annual variation in species, can have confounding effects on analysis of field measures.

Field measures can also provide some information on adverse effects that cannot be obtained with other methods. This includes an estimate of impacts from COPECs for which there are not toxicity values. Field measures also provide valuable information on the usefulness of models and transfer factors in predicting ecological effects.

Laboratory Measures

Laboratory toxicity tests provide more standardized results than field data because they are conducted under controlled conditions, but they are still subject to uncertainties associated with sample collection and representativeness. Confounding factors are also possible, as was demonstrated in this investigation by the effect of water hardness on the results of the algal toxicity test (Section 8.1.3.7). Other confounding factors may include variability in the test species selected; for example, the yarrow used in the plant toxicity test for these studies is more variable in growth than standard assay plants, but it is also more relevant to the ecosystems under consideration. Mortandad watershed soils are generally nutrient-poor, which can influence growth in plant, earthworm, algae, and chironomid tests. Sample sites were also selected to represent a gradient of COPEC concentrations to improve the representativeness of the toxicity tests to potential COPEC impacts.

Model Measures

ECORSK.9 represents a modified exposure model with many of the limitations of the simple exposure models used of screening-level ecological risk assessments. ECORSK.9 blends more realistic information on spatial use of the watershed with simple models of contaminant bioaccumulation and toxicity (Gonzales et al. 2006, 93786). In ECORSK.9, conservatism is still present for key parameters like TRVs and bioaccumulation factors. For example, the TRVs are based on NOAELs or the geometric mean of NOAEL values, and risks are assessed assuming additivity of response or summing of exposure across COPECs. ECORSK.9 is also based on conservative estimates of COPEC concentrations in soil; it assumes that the average of the sample data for a model grid cell is representative of the true concentration, although sampling is typically biased toward areas with higher concentrations of contaminants (Section B-1.0 of Appendix B). For this study, nondetected concentrations of organic chemicals were handled as either one-half their detection limits or as zero.The different results demonstrate that assumptions regarding nondetects can obscure sources of problem contaminants and overestimate risks. The simple dose modeling from concentrations in food done for this investigation is subject to many of the same uncertainties arising from toxicity values, transfer factors, and assumptions about concentrations and nondetects as the ECORSK.9 modeling.

8.1.5 Summary

Many COPECs were identified as study design COPECs in the ecological screening of soil, sediment, and surface water in the Mortandad watershed. The WOE demonstrated by the various lines of evidence for the seven assessment endpoints indicates there are no adverse effects of COPECs on terrestrial and aquatic receptors in the Mortandad watershed. The overall WOE from field studies, analysis of COPEC concentrations in tissues, and Laboratory toxicity tests supports this conclusion. Some of the results from modeling (both ECORSK.9 modeling and the dose through food ingestion modeling) indicate a potential for some ecological risk. However, these two models incorporate many of the same conservative factors (TRVs and transfer factors) inherent to the original screening using ESLs, which are designed to overestimate potential effects to provide a conservative screen. Therefore these models are not as strong a line of evidence as the other studies mentioned. Thus, no COPECs are retained for any further assessment or mitigation as a result of this baseline ecological risk assessment.

8.2 Human Health Risk Assessment

This human health risk assessment evaluates the potential for adverse effect on human health in the Mortandad watershed for COPCs identified in Section 6 of this report. The risk assessment approach used in this report follows guidance from EPA (1989, 08021), LANL (2004, 87800), NMED (2006, 92513), and EPA (2005, 91002) and is organized in seven major subsections. The approach utilizes media- and scenario-specific media-based screening levels to evaluate the potential for human health risks from sediment and surface water in the Mortandad watershed. Section 8.2.1 provides the basis for selecting exposure scenarios for the human health risk assessment. In Section 8.2.2, the data collection and evaluation processes described in previous sections of the report are summarized, focusing on aspects of data analysis that are pertinent to the risk assessment. Section 8.2.2 also lays out the logic for selecting COPCs for the human health risk assessment. The exposure assessment (Section 8.2.3) provides information used in quantifying human exposure to COPCs in sediments and water. The toxicity assessment (Section 8.2.4) provides information on potential human health effects from chemicals and radionuclides evaluated in the risk assessment. Section 8.2.4 provides the sources for the media- and scenario-specific screening levels. Risk characterization (Section 8.2.5) is based on the SOF method for evaluating the potential for additive effects with COPCs that are classified as noncarcinogens, carcinogens, or radionuclides. Uncertainty related to the various assumptions and inputs used in the risk assessment is evaluated in Section 8.2.6 to support interpretation of the risk characterization. A summary of the risk assessment is provided in Section 8.2.7.

8.2.1 Problem Formulation

The purpose of this risk assessment is to evaluate potential human health risks related to the COPCs identified in sediments and surface water in the Mortandad watershed. This information can be used to inform a risk management decision. This risk assessment uses information pertaining to current and reasonably foreseeable future land use to assess potential impacts under reasonable maximum exposure (RME) conditions. The canyon bottoms in the Mortandad watershed include a mixture of Laboratory property and San Ildefonso Pueblo lands, potentially supporting a variety of land use alternatives.

The assessment in this report primarily employs the trail user exposure scenario to represent the current and reasonably foreseeable future exposure activities for contaminated sediments and surface waters in the watershed. The trail user scenario describes an adult individual who contacts contaminated sediments and surface water while hiking or jogging in the canyons. This use is considered to be inclusive of realistic present-day potential exposure activities in canyon bottoms in areas of the watershed where contaminants are at levels requiring a human health risk assessment.

One supplemental exposure scenario, residential, is evaluated in the human health risk assessment for comparison purposes only. A description of this supplemental exposure scenario is provided in Section 8.2.3.3. Unlike the trail user scenario, residential use is not currently applicable across the watershed. A residential scenario does not represent current or reasonably foreseeable future land uses in the canyon bottoms, and residential development in particular is not a feasible land use within the parts of the canyons subject to flooding.

Assessment results for the trail user scenario are provided in Section 8.2.5. The results of risk calculations for the residential scenario are provided in Section E-3 of Appendix E.

8.2.2 Data Collection and Evaluation

The approach to sampling design, data collection, and characterization is described in Sections 3 and 4 and Appendix B. Sample locations, sample results, and data quality for data employed in the human health risk assessment are presented in Appendix C. Section 6 describes how sediment data were separated into reaches and status and how sediment data within reaches were combined for the comparison of contaminant data maxima with BVs. Water data were evaluated at each surface water sampling location, as described in Section 6.

Identifying COPCs for the Human Health Risk Assessment

COPCs for the human health risk assessment are identified based on screening level risk calculations using a residential exposure scenario. This process is initially inclusive of all COPCs and evaluates the potential for human health risks under a protective residential scenario. This process includes calculating a ratio, which is the maximum concentration of an analyte in a specific media in a reach or at a water sampling station divided by the media-specific risk-based screening level. This is analogous to the HQ as used in Section 8.1 for assessing potential ecological risk. An SOF is also calculated for a risk type; i.e., carcinogens (SOF_{ca}), noncarcinogens (SOF_{nc}), and radionuclides (SOF_{rad}). These are analogous to HIs calculated in Section 8.1. Ratios for all COPCs within a reach or water location are summed to calculate the SOF for the risk class of those analytes (carcinogen, noncarcinogen, or radionuclide). For all reaches or water locations with an SOF >1.0 for a risk class, all COPCs within that risk class with ratios greater than 0.1 are retained as COPCs for the site-specific risk assessment. COPCs with a ratio ≤0.1 based on maximum sample results are excluded because they are unlikely to significantly contribute to risk.

Sediment COPCs: The human health screening levels for nonradionuclides in sediment used in this screening assessment are the NMED residential SSLs from Revision 4 of NMED guidance (NMED 2006, 92513). For analytes for which NMED does not provide a value, the residential screening value from EPA Region 6 (EPA 2005, 91002) or EPA Region 9 (epa.gov/region09/waste/sfund/prg/files/04prgtable.pdf) was used as the SSL (carcinogens are adjusted to a 10^{-5} risk level to be consistent with the NMED target risk level). NMED-approved surrogate compounds were used for some COPCs that lack NMED or EPA screening levels (NMED 2003, 81172). SALs related to residential land use for radionuclides are based on the soil guidelines for unrestricted release of property (DOE Order 5400.5, “Radiation Protection of the Public and the Environment”); these values are derived using RESRAD version 6.21 as described in “Derivation and Use of Radionuclide Screening Action Levels Revision 1” (LANL 2005, 88493).

Tables 8.2-1 to 8.2-3 contain the set of human health residential SSLs and SALs used to calculate ratios; these tables also provides the SOFs for each reach for each risk class for all sediment COPCs. COPCs and reaches shaded gray are those retained for the risk assessment. Table 8.2-1 provides the results for noncarcinogens, Table 8.2-2 provides the results for carcinogens, and Table 8.2-3 provides the results for radionuclides.

Surface Water COPCs: Screening levels for surface water for organic and inorganic chemicals are the EPA Region 6 risk-based screening levels for tap water (EPA 2005, 91002). The EPA Region 6 values were supplemented by screening values from EPA Region 9 , available at (epa.gov/region09/waste/sfund/prg/files/04prgtable.pdf). Radionuclide screening levels are based on a dose of 4 mrem/yr and are from the DOE DCG (DOE Order 5400.5, "Radiation Protection of the Public and the Environment").

Tables 8.2-4 to 8.2-6 contain the set of human health water screening levels used to calculate ratios; these tables also provide the SOFs for each type of field preparation (filtered or unfiltered) for each water location, and each risk class for all surface water COPCs. COPCs and water locations shaded gray are those retained for the further assessment. Table 8.2-4 provides the results for noncarcinogens; Table 8.2-5 provides the results for carcinogens; Table 8.2-6 provides the results for radionuclides. Surface water data have been obtained from the surveillance station "Mortandad at Rio Grande" (monitoring station A-11), and there is no associated reach for this location. The primary source of surface water at station A-11 is effluent from the Los Alamos County wastewater treatment plant in White Rock. The SOF_{nc} for station A-11 was 1.01, and the primary contributors to the sum were fluoride and vanadium. Because station A-11 has no associated sediment sample results, and surface water is wastewater effluent, this location will not be retained for evaluation in the human health risk assessment.

COPC Summary: Table 8.2-7 presents a summary of endpoints and reaches considered in the human health risk assessment for the Mortandad watershed. For each reach and endpoint combination with both sediment and water COPCs retained, a multimedia assessment is also assessed for this reach. Table 8.2-7 shows that the most downstream reach in the Mortandad watershed requiring further human health risk assessment is reach M-4.

Calculating Representative Concentrations

Sediment: The investigation approach for sediments resulted in samples associated with discrete geomorphic units and sediment facies within each reach. These data are combined to estimate weighted averages and weighted 95% upper confidence limits (UCLs) on the averages for COPCs retained for the human health risk assessment in each reach. The approach to estimating weighted averages and weighted 95% UCLs is well established in the statistical methods for stratified sampling, (e.g., Gilbert 1987, 56179; Cochran 1977, 84462). A description of these methods is provided in Section E-3 of Appendix E. Many of the data sets for combinations of COPCs and reaches or COPCs and water sampling locations include nondetect values. The approach to estimating averages and 95% UCLs with data that include nondetects is also described in Section E-3 (Appendix E).

The trail user exposure scenario uses representative sediment concentrations calculated from surface-area weighted averages and surface-area weighted 95% UCLs for sediment facies that typically occur in the uppermost parts of geomorphic units because trail user exposures predominantly occurs with near-surface sediment. In addition, the uppermost sediment facies is usually finer grained and contains higher contaminant concentrations than deeper sediment, thus providing a more protective assessment. The calculation approach for the averages and 95% UCLs uses the relative areas of the different geomorphic units in a reach to derive the weights. The residential exposure scenario includes activities that penetrate the ground surface, resulting in direct exposure to buried sediments. Therefore, the residential exposure scenario uses the volumes of sediment deposits within geomorphic units to derive weights rather than the surface areas. The area weights and volume weights for each unit in each reach are presented in Table D-1.3-1 in Appendix D. Representative sediment concentrations for the trail user scenario are presented in Section 8.2.5.

Surface Water: Water COPC concentrations are evaluated for each sampling location, unlike sediments where multiple sample locations are combined to generate a representative concentration for a reach. The only exception is for locations that are basically collocated within a few meters of each other. As a result, methods to estimate weighted averages and weighted 95% UCLs are not used to calculate water representative concentration. The approach to calculating averages and 95% UCLs for the water data follows the approach described in Section E-3 (Appendix E). Representative surface water concentrations for the trail user scenario are presented in Section 8.2.5.

8.2.3 Exposure Assessment

The trail user scenario is the exposure scenario that applies to all reaches identified in Table 8.2-3. Additionally, potential risk associated with the residential scenario is provided as a point of comparison. The two exposure scenarios employed in the human health risk assessment have been described in other documents. The trail user scenario is the adult receptor in the recreational scenario document (LANL 2004, 87800) and the recreational scenario in the radionuclide SALs document (LANL 2005, 88493). An adult trail user is evaluated in this assessment because access to these reaches is limited to Laboratory workers or trespassers, and it is unlikely that young children would accompany either workers or trespassers on recreational visits to these reaches. Exposures to surface water ingestion are evaluated based on the trail user scenario described in the "Los Alamos and Pueblo Canyon Investigation Report" (LANL 2004, 87390, p. 8-37), which also provides risk-based concentrations for trail user surface water exposures (LANL 2004, 87390, p. E-317). Residential SSLs are in NMED guidance (NMED 2006, 92513), and residential SALs are in LANL guidance (LANL 2005, 88493).

8.2.3.1 Exposure Scenario Description

The human health risk assessment focuses on potential risks resulting from direct exposure to contaminants in sediments through ingestion, inhalation, external irradiation (radionuclides only), and dermal contact (chemicals only). The water pathways for the trail user consist of ingestion and dermal contact (chemicals only) using persistent surface water data. Exposure to stormwater is not assessed because stormwater is transient and does not occur frequently enough to sustain chronic exposures. Exposure to groundwater is not evaluated because no groundwater in the Mortandad watershed is available for human uses under current conditions or for the reasonably foreseeable future. A summary of potentially complete exposure pathways, by scenario, is provided in Table 8.2-8.

Exposure scenario parameters were selected to provide an RME estimate of potential exposures. As discussed in EPA (1989, 8021), the RME estimate is generally the principal basis for evaluating potential health impacts. In general, an RME estimate of risk is at the high end of a risk distribution, i.e., 90th–99.9th percentiles (EPA 2001, 85534). An RME scenario assesses risk to individuals whose behavioral characteristics may result in much higher potential exposure than seen in the average individual.

The trail user scenario addresses limited site use for outdoor activities such as hiking and jogging. The receptor for this scenario is anticipated to be a Laboratory employee using the canyon over an extended period of time. Therefore, receptors for the trail user scenario are defined as adults. A complete description of the parameter values and associated rationale is provided in Laboratory guidance (LANL 2004, 87390, p. 8-37). Exposure parameters for the trail user are provided in Appendix E-3.

8.2.3.2 Supplemental Exposure Scenario

Risk estimates are provided for a resident as a supplemental exposure scenario. A more detailed discussion of the basis and parameterization of this scenario is provided in NMED guidance (2006,

92513) and Laboratory guidance (LANL 2005, 88493). Exposure parameters for the resident are provided in Appendix E-3.

8.2.3.3 Spatial Scales of Application for the Exposure Scenarios

Each exposure scenario is evaluated at the scale of a reach for sediments and at the scale of individual sampling locations for water. Each of the surface water sampling locations has been associated with a reach for combining results into a multimedia assessment (where appropriate). The investigations evaluated in this report have multiple investigation reaches and water sampling locations. The risk assessment does not attempt to integrate exposure across multiple reaches for sediment or across water sampling locations for surface water. By assessing each reach and associated water sampling locations separately, the impacts of local variability in COPC concentrations upon the risk assessment results are preserved.

8.2.4 Toxicity Assessment

This section of the human health risk assessment provides information related to the basis for distinguishing among the three classes of chemicals that are evaluated in this assessment: systemic toxicants (noncarcinogens), chemical carcinogens, and radionuclides. This information provides a context for interpreting the results of the risk assessment, which employs COPC-specific values of toxicity and radiation dose to evaluate potential health impacts.

Using media-specific risk-based screening levels simplifies aspects of the risk assessment in that exposure and toxicity information has been compiled in available guidance documents and reports. The sources for toxicity data used for this risk assessment include NMED and LANL guidance documents and the "Los Alamos and Pueblo Canyon Investigation Report" (LANL 2004, 87390) and its supplement (LANL 2005, 91918). The "Los Alamos and Pueblo Canyon Investigation Report" is used as a source of surface water screening values because there is no guidance document available with such values, and the exposure information provided therein is germane to trail user exposures in other Laboratory canyons. Toxicity information used to develop surface water screening values is also generally consistent with values used in NMED and LANL guidance documents (as discussed below).

Media-specific risk-based screening levels are from seven sources based on COPC type and exposure medium.

- Recreational scenario (trail user) for carcinogens and noncarcinogens
    - Sediment: used the recreational SSLs developed in Laboratory guidance (LANL 2004, 87800)
    - Surface water: used the risk-based concentrations for trail user surface water ingestion and dermal contact developed in the "Los Alamos and Pueblo Canyon Investigation Report" (LANL 2004, 87390, except lead is from LANL 2005, 91918)
- Recreational scenario (trail user) for radionuclides
    - Sediment: used the recreational SALs developed in Laboratory guidance (LANL 2005, 88493)
    - Surface water: used the risk-based concentrations for trail user surface water ingestion developed in the "Los Alamos and Pueblo Canyon Investigation Report" (LANL 2004, 87390)

- Residential scenario for carcinogens and noncarcinogens
    - Sediment: used the SSLs from NMED guidance (NMED 2006, 92513), except for certain values from EPA Region 6 (EPA 2005, 91002) and EPA Region 9 (epa.gov/region09/waste/sfund/prg/files/04prgtable.pdf)
- Residential scenario for radionuclides
    - Sediment: used the residential SALs developed in Laboratory guidance (LANL 2005, 88493)

Table 8.2-9 provides the compilation of the sediment and surface water media-specific risk-based screening levels and target adverse effect-levels. Comparing the screening values with COPCs for a given risk endpoint provides some information of the relative toxicity of these analytes. Because these risk-based screening values are obtained from references prepared from 2004 to 2006, there is potential for differences in the toxicity values used in the screening level calculations. The slope factors and reference doses were compared with the COPCs listed in Table 8.2-9 among the sources; differences in these toxicity values are summarized in Table 8.2-10. This information will be considered in the uncertainty analysis of this assessment.

8.2.5 Risk Characterization

In this section of the human health risk assessment, information provided in the exposure and toxicity assessments (Sections 8.2.3 and 8.2.4, respectively) is integrated to characterize potential adverse effects. The risk characterization is conducted on the basis of the general principles described in Section 8.0 of the risk assessment guidance for Superfund (EPA 1989, 8021). Potential adverse effects related to noncarcinogens, chemical carcinogens, and radionuclides are discussed in Sections 8.2.5.1, 8.2.5.2, and 8.2.5.3, respectively. The presentation of potential adverse effects focuses on the quantitative expressions of potential impacts. In the uncertainty analysis (Section 8.2.6), the confidence associated with the quantitative risk estimates is discussed through an evaluation of the uncertainties pertaining to each step of the risk assessment process.

This risk assessment employs media-specific risk-based screening levels to evaluate COPCs for potential adverse health effects. COPC intake and toxicity are combined within the screening value calculations; therefore, separate calculations of intake and health effects (cancer risk, hazard, and dose) were not generated. Human health effects were assessed using the ratios of representative concentrations to media-specific risk-based screening levels for each COPC retained in this assessment for each of the exposure scenarios. These ratios were summed for an investigation reach and (when applicable) a water sampling location within the COPC classes of chemical carcinogens, noncarcinogens, and radionuclides (SOFs). A sum of less than 1 indicates that exposure is unlikely to result in an unacceptable cancer risk, hazard, or radiation dose. The SOF values were multiplied by the target effect level (i.e., HI = 1, risk = 1×10^{-5}, or dose = 15 mrem/yr) to provide risk estimates for each COPC class.

For the trail user scenario, exposure to sediment and surface water is evaluated through a multimedia sum. For COPCs with a common target adverse effect level (e.g., all carcinogens are based on 1×10^{-5} incremental cancer risk), the multimedia sum can be converted into an approximate effect level. Carcinogen and noncarcinogen screening levels are based on a common adverse effect level across sediment and surface water, but the radionuclide adverse effect levels are not the same for sediment (15 mrem/yr) and surface water (4 mrem/yr).

The trail user scenario multimedia sums and the risk values for noncarcinogens, carcinogens, and radionuclides based on 95% UCLs are summarized in Table 8.2-11. Most of the carcinogen and

radionuclide multimedia sums are similar to the sediment risk values, which indicate that there is greater potential for effects from the sediment concentrations and exposure pathways than from surface water. For noncarcinogens, this observation is reversed for many reaches: the multimedia sum is similar to the surface water risk values. There is one reach where the multimedia sum and the sediment risk values are greater than the target risk level for the trail user scenario: radionuclide dose in reach E-1E.

Table 8.2-12 presents the COPC and reach-specific recreational risk values for sediment; Table 8.2-13 presents the COPC and reach-specific recreational risk values for surface water. The representative concentrations for sediment are presented in Table 8.2-14; the representative concentrations for surface water are presented in Table 8.2-15. Results for the supplemental exposure scenario (residential) are provided in Tables E-3.5-2 and E-3.5-3.

8.2.5.1 Noncarcinogenic Effects

Chemical hazard for an individual chemical is commonly defined by the HQ, which is calculated as the ratio of the chemical intake to the reference dose (RfD) for that chemical. An HQ greater than 1 is indicative of the potential for adverse effects; therefore, an HQ of 1 was used in the calculation of screening values for noncarcinogenic effects. When the potentially additive effects of two or more chemicals are considered, HQs may be summed to generate an HI. However, summing of chemical HQs to create an HI assumes that the target organs and mechanisms of toxicity are similar. The SOF_{nc} values in this human health risk assessment are functionally equivalent to generating an HI. The protective approach of summing these ratios does not warrant refinement because the HI values are in all cases well below 1.0.

The four largest HI values for the trail user scenario were between 0.4 and 0.7 (Table 8.2-11) and related mostly to the potential for adverse effects from lead in surface water (reaches M-1W and TS-1C; Table 8.2-13) or aluminum and iron in sediment (reaches M-1E and E-1FW; Table 8.2-13). The HI was between 0.1 and 0.4 in four other reaches (E-1W, E-1E, M-2W, and TS-2E) with the key contributors to these noncarcinogenic sums being aluminum, arsenic, iron, and manganese in sediment and lead and perchlorate in surface water.

8.2.5.2 Carcinogenic Effects

Cancer risk for an individual chemical is defined by the incremental cancer risk (ICR), which is calculated as the product of exposure to a single chemical and the cancer slope factor (SF) for that chemical. ICRs for each exposure route and chemical are then summed to calculate the total ICR to an individual. A target risk level of 1×10^{-5} was used in this human health risk assessment to calculate risk-based concentrations for carcinogenic effects (NMED 2006, 92513). Lifetime cancer risk is considered to be additive over time; childhood and adulthood exposures are summed to calculate the ICR.

The potential risk from carcinogens was evaluated in 12 investigation reaches, and the range of sediment or multimedia ICR for the trail user scenario was from 8×10^{-7} to 6×10^{-6} (Table 8.2-7). The maximum ICR (6×10^{-6}) was calculated for reach M-1W. The primary contributors to the ICR in these reaches from sediment were arsenic and PAHs (Table 8.2-12). Carcinogenic COPCs were not significant contributors to the ICR for trail users from surface water exposure.

8.2.5.3 Radiation Dose

The radiation dose associated with the EPA dose conversion factors (DCFs) used in the human health risk assessment is the annual committed effective dose equivalent (internal) or annual effective dose

equivalent (external), expressed in units of millirems per year. The target dose limit used for calculating media-specific risk-based screening levels related to soil pathways is 15 mrem/yr, which is consistent with guidance from DOE (DOE-AL 2000, 67153). For water-based exposure pathways, media-specific risk-based screening levels were calculated using a target dose limit of 4 mrem/yr. Use of this more protective dose limit for water pathways is based on the radiation dose limit for a public drinking water supply in DOE Order 5400.5, "Radiation Protection of the Public and the Environment." Consistent with EPA guidance (EPA 1989, 8021), dose through dermal absorption is not quantified because it is probably negligible compared with the other exposure pathways.

The potential risk from radionuclides in sediment was evaluated in 12 reaches; the potential risk from radionuclides in surface water was evaluated in four reaches, and multimedia sums were also calculated in these four reaches. The range of sediment or multimedia radionuclide dose was from 0.01 to 44 mrem/yr; the range of surface water radionuclide dose was from 0.04 to 0.3 mrem/yr (Table 8.2-11). One reach had a radionuclide dose value for the trail user scenario greater than 15 mrem/yr: reach E-1E had a multimedia dose of 44 mrem/yr. Americium-241, cesium-137, plutonium-238, and plutonium-239,240 contributed more than 99% of the dose from radionuclide sediment COPCs for all reaches except TS-1C (Table 8.2-8). In reach TS-1C, thorium-228, thorium-230, and thorium-232 contributed approximately 59% of the radionuclide dose from sediment. Approximately 80% of the dose in reach E-1E from sediment was from cesium-137.

8.2.6 Uncertainty Analysis

The uncertainty analysis uses qualitative and semiquantitative information to evaluate the uncertainty associated with the risk, hazard, and dose estimates described in Section 8.2.5. This uncertainty analysis pertains to the results of the trail user scenario. The uncertainty analysis is organized according to the major aspects of the human health risk assessment: data collection and evaluation (Section 8.2.6.1), exposure assessment (Section 8.2.6.2), and toxicity assessment (Section 8.2.6.3).

8.2.6.1 Data Collection and Evaluation

All analytes that were identified as COPCs in Section 6 were retained for evaluation in the human health risk assessment. COPCs that were retained for calculation of representative concentrations were those that had ratios greater than 0.1 for endpoints with SOF values greater than 1 for the residential screen. Thus, the analytes retained represent an inclusive list of potential human health risk drivers.

No BVs are available for surface water. The inability to distinguish COPCs in surface water based on comparisons with background concentrations is a substantial source of uncertainty in the results of the human health risk assessment for this media. For example, concentrations of arsenic and iron in surface water, which contribute to HI, could be associated with local background and not with releases from Laboratory SWMUs or AOCs.

Overestimating representative concentrations for investigation reaches is another potential source of uncertainty. Five approaches were used to minimize that possibility. First, the emphasis of the geomorphic characterization and sediment sampling was to identify and sample post-1942 sediment deposits, which focuses sampling on potentially contaminated areas. The process of characterizing reaches and focusing sampling is discussed further in Section 4.1 and Section B-1 of Appendix B. Second, the canyon bottoms include other geomorphic units that are not impacted or are only minimally impacted by Laboratory releases. Samples from these other geomorphic units were not included in the area-weighted and volume-weighted averages to provide more protective estimates of COPC concentrations for use in the human health risk assessment. Third, 95% UCLs on the area-weighted

average sediment concentrations were employed as representative concentrations to minimize the chance of underestimating representative concentrations in a reach. Fourth, it was assumed that exposure in most geomorphic units for the trail user scenario was entirely caused by fine facies sediment deposits where concentrations are generally highest, as discussed in Section 7.1, excluding data from coarse facies sediment deposits where concentrations are generally lower. Fifth, for radionuclides, no correction was made for radioactive decay since the time of sampling, although present-day concentrations are lower than at the time of sampling for some key radionuclides. For example, the maximum concentration of cesium-137 measured in the Mortandad watershed was in a sample collected from reach E-1E in 1998, and concentrations in 2006 when this report was written would be about 17% lower in that sediment layer due to radioactive decay. Accounting for radiological decay would decrease the calculated dose in reach E-1E from 44 mrem/yr to approximately 38 mrem/yr.

A similar uncertainty exists for estimating representative concentrations for water sampling locations. COPC concentrations often change with hydrologic conditions and can either increase or decrease seasonally or related to effluent discharges. The data evaluated in this assessment represent a snapshot of the current hydrological conditions and generally reflects a range of hydrologic conditions at each sampling location. As discussed in Section 7.2.1 and Appendix B, Section B-2, sampling occurred during a range of water-level conditions and field parameters, such as pH and dissolved oxygen. The representative concentrations calculated from these data represent the range of COPC concentrations at the sampling locations. Using the 95% UCL on the average minimizes the chance of underestimating the representative concentrations for a sampling location.

8.2.6.2 Exposure Assessment

Uncertainty pertaining to exposure parameters was addressed in the human health risk assessment by using RME estimates for several exposure parameters (see Appendix E-3). The use of RME assumptions, coupled with upper-bound estimates of the average concentration of COPCs in sediment, is intended to produce a protective bias in the risk calculations. The results of the risk assessment, discussed in Section 8.2.5, include a description of the key COPCs and exposure pathways associated with potential health impacts. This evaluation of uncertainty in exposure is focused on these COPCs and pathways.

Key exposure pathways for contaminated sediments across hazard, ICR, and dose for the trail user exposure scenario include dermal absorption, incidental soil ingestion, and external irradiation. A common source of protective bias in the exposure assessment for these pathways is that the entire 1-h daily exposure time defined for the trail user scenario is spent on contaminated sediment deposits within a reach. To the extent that time may be spent in other canyon areas such as uncontaminated stream terraces, colluvial slopes, or bedrock areas during recreational activities, exposure to contaminated sediment deposits is overestimated.

The assessment also includes no consideration of the current signage in the canyon, which reads “No Trespassing: Access to Mortandad Canyon is Restricted to Workers on Official Business.” In addition, the area at the head of reach E-1E at the TA-50 RLWTF outfall is posted as “Caution: Soil Contamination Area.” Because each reach is treated equally from an exposure perspective, no consideration is made regarding ease of access or land area available for recreation. For example, reach E-1E has the highest estimated radionuclide dose (44 mrem/yr for the trail user scenario), but it is one of the shortest, narrowest, and roughest reaches in the Mortandad watershed and has no developed trails or other features that attract trail users. Reach E-1E is also in a part of the Laboratory with access controls and access requirements and has signs that discourage the specific recreational activity being assessed. In addition, the estimated dose of 44 mrem/yr is below the 100 mrem/yr dose limit established by DOE for

radiation workers, indicating that trained workers conducting environmental or other work in this area would not be expected to exceed dose limits for these specific and occasional activities. As a further point of comparison, dose to the trail user would be less than 15 mrem/yr if 50 h/yr was spent in reach E-1E (instead of the 200 h//yr assumed for the trail user).

For both carcinogens and radionuclides, the exposure assessment should be evaluating incremental exposures that are greater than background. Representative concentrations are calculated that include background concentrations. For the most part, background exposures are likely negligible with the exception of some metals in sediment and surface water (e.g., arsenic) and do not lead to overestimating risk or dose.

Dermal contact with sediments and incidental soil ingestion exposure pathways each have a second exposure characteristic in addition to time spent on-site that was biased in a protective manner. The soil adherence factors that were used to define soil loading on skin for children and adults are both protectively biased. The adult adherence factor is based on a high-exposure activity (gardening) that probably would result in greater exposure than would be the case during trail use. Adult soil ingestion was assumed to be 100 mg/d, which is twice the EPA-recommended value for adults (EPA 1997, 66596).

Radionuclides in reach E-1E represent the greatest potential for risk for adult trail users, and the largest fraction of dose is related to external gamma radiation from cesium-137. Because external gamma radiation is the main contributor to radionuclide dose, the assessment should also be protective of child exposures because behaviors that increase child exposure through some pathways (incidental soil ingestion and dermal contact) play basically no role in external gamma dose.

Exposure related to external irradiation from soil is primarily a function of time spent on-site. However, the external DCFs used in the calculation of external dose protectively assume an effectively infinite area and depth of contamination. The contaminated sediments in reach E-1E, where external irradiation was an important contributor to trail user dose, are approximately 200 m long and average 3 m in width and less than 1 m in depth. The calculated dose through external irradiation from cesium-137, assuming an infinite source, would likely be twice as large as would actually be the case given the described source geometry of reach E-1E. Actual external irradiation received during recreational activities would probably be lower, assuming that receptors are not consistently in the center of the contaminated area.

An important aspect of uncertainty in exposure to COPCs in surface water relates to exposure intensity. Dermal contact and surface water ingestion were assumed to occur 20 times per year for 30 years (trail user). There is no empirical basis for this assumption, which was developed to bound a high-end exposure condition. Potential contact by adults with surface water in the Mortandad watershed would be highly intermittent at some locations based on the limited availability of water. It is also unlikely that a Laboratory employee would be drinking surface water, which is in some cases nonpotable effluent.

8.2.6.3 Toxicity Assessment

The evaluation of uncertainty pertaining to the toxicity assessment focuses primarily on the toxicology of cesium-137 because this COPC was primarily responsible for the calculated radionuclide dose to be greater than 15 mrem/yr in one reach. Nearly all of the dose for cesium-137 for the trail user scenario is associated with external gamma radiation (LANL 2005, 88493, Table A-2, p. A-2). The main uncertainties associated with the external radiation DCF relate to the geometry of the source and the receptor. Uncertainties associated with the source term were discussed in Section 8.2.6.2.

Table 8.2-10 provides a summary of the COPCs where the reference dose or SF values differ between various sources used in this assessment. The toxicity values used by NMED or EPA Region 6 are

basically the same, but these values differ from the sources used in Laboratory guidance or reports. For barium, copper, and manganese, the Laboratory toxicity values were more protective. There are three cases where the values used by NMED are more protective and the impact on the assessment for these analytes is considered.

- *Aroclor-1254*: The inhalation cancer risk slope factor used by NMED is 6 times more protective than the Laboratory value. However, the inhalation pathway is orders of magnitude less important than soil ingestion from an exposure perspective, so this difference in the inhalation cancer slope would not change the estimated risks from Aroclor-1254.
- *Thallium*: The oral reference dose used by NMED is about 20% lower (more protective) than the Laboratory value. This level of difference in thallium toxicity would not change any of the noncarcinogen assessments because the largest ratio for thallium was 0.003.
- *Vanadium*: The oral reference dose used by NMED is 7 times lower (more protective) than the Laboratory value. This level of difference in vanadium toxicity would not change any of the noncarcinogen assessments because the largest ratio for vanadium was 0.004.

8.2.7 Summary of the Human Health Risk Assessment

The health effects associated with COPCs in the Mortandad watershed were assessed relative to a radiological dose criterion of 15 mrem/yr for sediment and 4 mrem/yr for water, a chemical cancer risk criterion of 1×10^{-5}, and a chemical hazard criterion of 1.0. The risk assessment results are below these thresholds for the trail user with one exception. The calculated radionuclide dose for reach E-1E was 44 mrem/yr, and this was almost entirely related to sediment COPCs and primarily related to external gamma radiation from cesium-137.

The sediment radionuclide dose corresponds to a radiological risk of approximately 2×10^{-4} based on risk-based recreational radionuclide SALs. Radiological risks from surface water in reach E-1E will be negligible as sediment contributed about 99.4% of the dose. Radiological risks from sediments for reaches M-2W, M-2E, and M-3 were 2×10^{-5} to 3×10^{-5}, and radiological risks in other reaches ranged from 2×10^{-8} to 9×10^{-6}.

The nonsuitability of E-1E for traditional trail use and access restrictions in this part of the Laboratory, combined with conservatism included in the risk assessment, indicates that it is unlikely that actual recreational users of the Mortandad watershed would receive a dose exceeding 15 mrem/yr. Surface water risk results are below all adverse effect levels.

9.0 CONCLUSIONS AND RECOMMENDATIONS

Investigations of sediment, surface water, and groundwater in the Mortandad watershed indicate that inorganic, organic, and radionuclide COPCs are present in these media at concentrations above screening levels and federal and/or state groundwater standards. These COPCs are derived from several sources, including Laboratory SWMUs and AOCs, runoff from developed areas, and natural sources such as noncontaminated soils, sediments, and bedrock.

The spatial distribution of contaminants in the Mortandad watershed, supported by effluent discharge data, indicates that the TA-50 RLWTF outfall into Effluent Canyon, which has been active since 1963, is the most important source of contamination with respect to potential human health risk and groundwater impacts. Source areas for Laboratory-derived COPECs that are most important in the assessment of potential ecological risk include TA-48 outfalls into the head of Effluent Canyon and into Mortandad

Canyon, the TA-50 RLWTF outfall, and additional releases from TA-50 or TA-35 into the head of Ten Site Canyon. The impacts of additional Laboratory sources (e.g., outfalls from the former TA-35 WWTP, wastewater lagoons, and filter beds) are indicated by the characterization data, although the concentrations, extent, and inventory of COPCs from these sources are generally minor compared with the sources listed above.

Contaminants in sediment that were originally released from the TA-50 RLWTF outfall are largely or entirely restricted to approximately 4 km (2.5 mi) of canyon bottom downcanyon from the outfall. The COPCs in alluvial groundwater derived from the RLWTF outfall are also restricted to this area. The infiltration of stormwater into alluvium, particularly upcanyon from the Mortandad–Ten Site Canyon confluence, results in a complete loss of surface water in most runoff events and deposition of contaminated sediment. The most important sediment deposition area is in the 0.6 km (0.4 mi) of canyon bottom west of the confluence (reach M-3E), and approximately 50% of the inventory of most radionuclides in sediments occurs there. No floods have been recorded crossing the Laboratory-San Ildefonso Pueblo boundary since RLWTF discharges began in 1963, and only one event before 1963 is recorded as having reached the Laboratory boundary in August 1952. Construction of the current sediment traps in Mortandad Canyon east of the Ten Site Canyon confluence in 1986 enhanced a process of infiltration and sediment deposition that was occurring previously.

Contaminant concentrations in sediment, surface water, and alluvial groundwater in the Mortandad watershed have generally decreased over time, indicating that the initial SWMU and AOC sources are no longer major contributors to contamination in canyons media. The canyon bottom sediment deposits contain the largest inventory of adsorbed contaminants that are susceptible to remobilization and transport in floods and are now the primary source for ongoing surface water and alluvial groundwater contamination. Therefore, any future efforts that may be required to address contaminants in canyons media should address the current distribution of contaminants in sediment and associated groundwater rather than in the original source areas.

In contrast, contaminant concentrations in deeper perched-intermediate or regional groundwater have increased over time, indicating the migration of mobile constituents through the vadose zone and into deeper zones of saturation. Vadose-zone pore-water concentration profiles indicate that these mobile contaminants have percolated in the subsurface. Currently, the majority of the mass of the nonsorbing contaminants—nitrate, perchlorate, and tritium—is located within the vadose zone, particularly beneath the area near and east of the confluence of Mortandad and Ten Site Canyons. Chromium is present in the regional aquifer in one characterization well (R-28) above groundwater standards; chromium, nitrate, perchlorate, and tritium have been measured above groundwater standards in perched intermediate-depth groundwater in one or more wells. Iron and manganese have also been measured above drinking water standards in regional groundwater in one well (R-14) and nickel in another well (R-33), although available data indicate that these results represent naturally occurring constituents and not Laboratory-derived contamination. Additional evaluations will be necessary to further understand contamination in intermediate-depth and regional groundwater and to consider potential remedial actions. A more detailed evaluation of chromium contamination in groundwater is currently in progress (LANL 2006, 91987) and will be available in an interim measures report scheduled for completion in November 2006.

Many organic, inorganic, and radionuclide COPECs have been identified in the ecological screening assessments; subsequently, a plan for a base line ecological risk assessment was developed. This process is based upon the eight-step EPA ecological risk assessment guidance for Superfund (EPA 1997, 59370). The base line ecological risk assessment evaluated evidence of ecological risks from COPECs to omnivorous mammals, insect-eating birds, plants, earthworms, aquatic invertebrates, algae, and two T&E species: the Mexican spotted owl and the southwestern willow flycatcher. The multiple lines

of evidence did not identify adverse effects to terrestrial or aquatic receptors that currently inhabit the watershed. Therefore, no mitigation is necessary.

The site-specific human health risk assessment uses a trail user exposure scenario to represent the present-day and reasonably foreseeable future land use in canyons throughout the Mortandad watershed. The assessment results indicate that for the trail user scenario, no areas in the Mortandad watershed have contaminant concentrations greater than levels acceptable for noncarcinogens (HI of 1) or carcinogens (incremental cancer risk criterion of 1×10^{-5}) in sediment or water. However, the radionuclide dose for one area, reach E-1E in Effluent Canyon downcanyon from the TA-50 RLWTF outfall, exceeds the target dose limit of 15 mrem/yr. The calculated dose for reach E-1E, 52 mrem/yr (corresponding to a radiological risk of approximately 2×10^{-4}), is primarily related to external gamma radiation from cesium-137 in sediment. The radionuclide dose limit of 4 mrem/yr in water was not exceeded at any location.

As discussed in Section 8.2.6, reach E-1E is a short, steep, and rocky area that has no developed trail within the contaminated area, and it is unlikely that recreational users of the Mortandad watershed use this reach as much as assumed in the trail user scenario (1 h/d and 200 d/yr). Other protectively biased assumptions are incorporated into the exposure assessment, also contributing to an overestimate of potential dose. In addition, the area is currently posted as a "soil contamination area," and posting also states that "access is restricted to workers on official business," further discouraging recreational use in reach E-1E. Therefore, no remedial action is proposed to reduce the potential radiation dose to recreational users of Effluent Canyon, although it is recommended that appropriate posting be maintained.

Evaluations of the changes in COPC concentrations over time for sediment, surface water, and alluvial groundwater indicate that concentrations are either relatively stable or are decreasing for contaminants derived from Laboratory SWMUs or AOCs. These decreases are associated with processes that remobilize, transport, and dilute sediment- and waterborne constituents. Radioactive decay also contributes to decreasing concentrations for some radionuclides (e.g., cesium-137, strontium-90, and tritium). Therefore, the potential for impacts to human health or ecosystems from Laboratory-derived contaminants in these media is expected to continue to decrease in the absence of new sources.

Potential future changes in the vadose-zone contamination and concentrations of contaminants in perched-intermediate and regional groundwater are less well constrained, and a corrective measures evaluation (CME) is necessary to assess the need for remedial actions. The CME will assess the fate of the contaminant mass in the vadose zone and impacts to the regional groundwater where water-supply wells are located. A more detailed evaluation of chromium contamination in groundwater is currently in progress and will be addressed in pending reports to the NMED. Monitoring in the Mortandad watershed will continue through the proposed CME process and is described in the Interim Facility-Wide Groundwater Monitoring Plan.

In summary, the results of this investigation indicate that human health risks are acceptable for present-day and foreseeable future land uses, assuming that recreational use of Effluent Canyon below the TA-50 RLWTF outfall continues to be discouraged. In addition, no adverse ecological effects were observed within terrestrial and aquatic systems in the Mortandad watershed. Therefore, corrective actions are not needed to mitigate unacceptable risks. However, a CME is proposed to address contamination in groundwater.

10.0 REFERENCES

The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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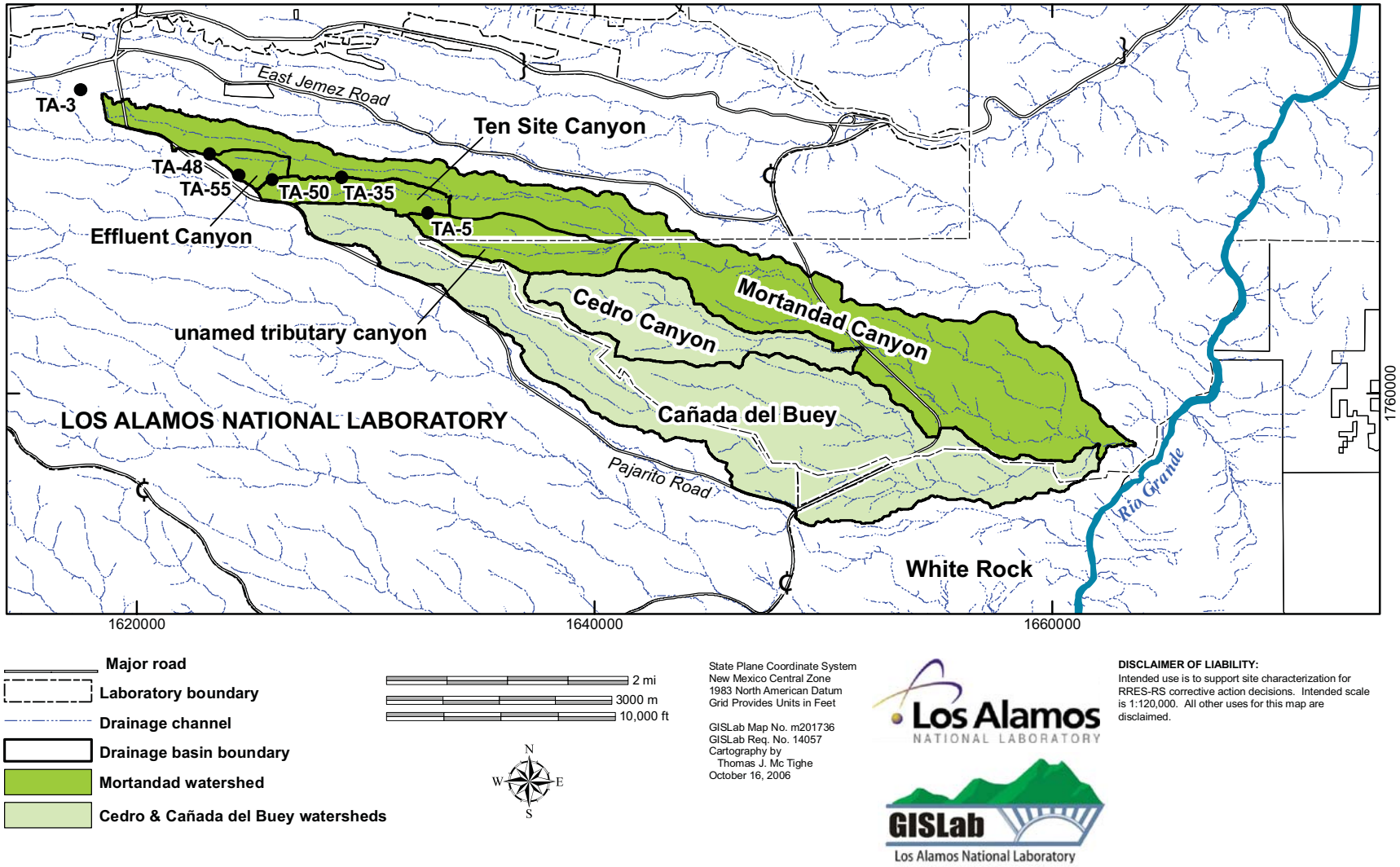

Figure 1.1-1. Map of the Mortandad Canyon watershed, showing major subbasins

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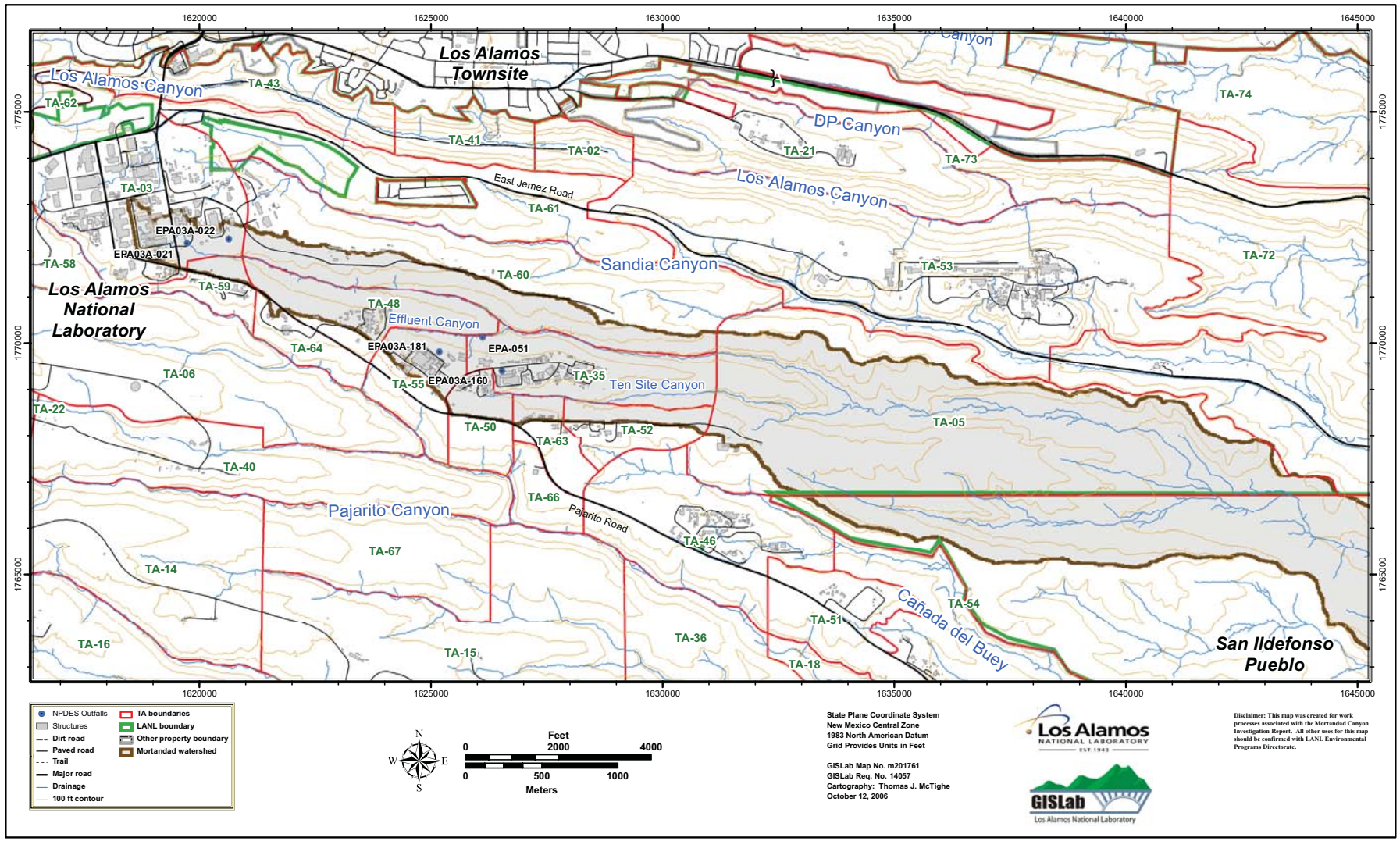


Figure 1.1-2. Mortandad watershed, showing TA boundaries and active NPDES outfalls

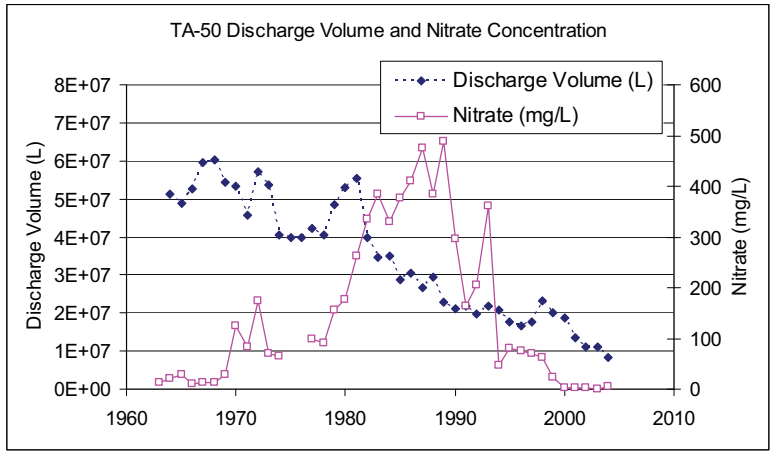


Figure 2.1-1. Historical discharge volumes (L/yr) and outfall nitrate concentrations (mg/L as N) for the TA-50 RLTWF, NPDES EPA-051

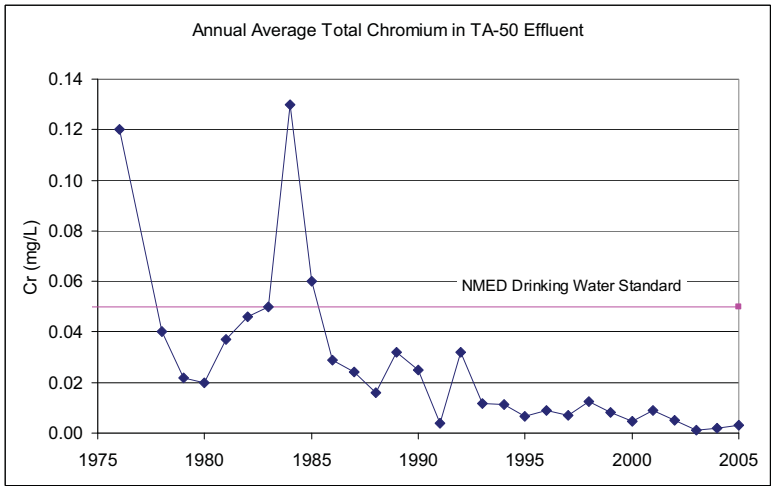


Figure 2.1-2. Historical outfall total chromium concentrations for the TA-50 RLTWF, NPDES EPA-051

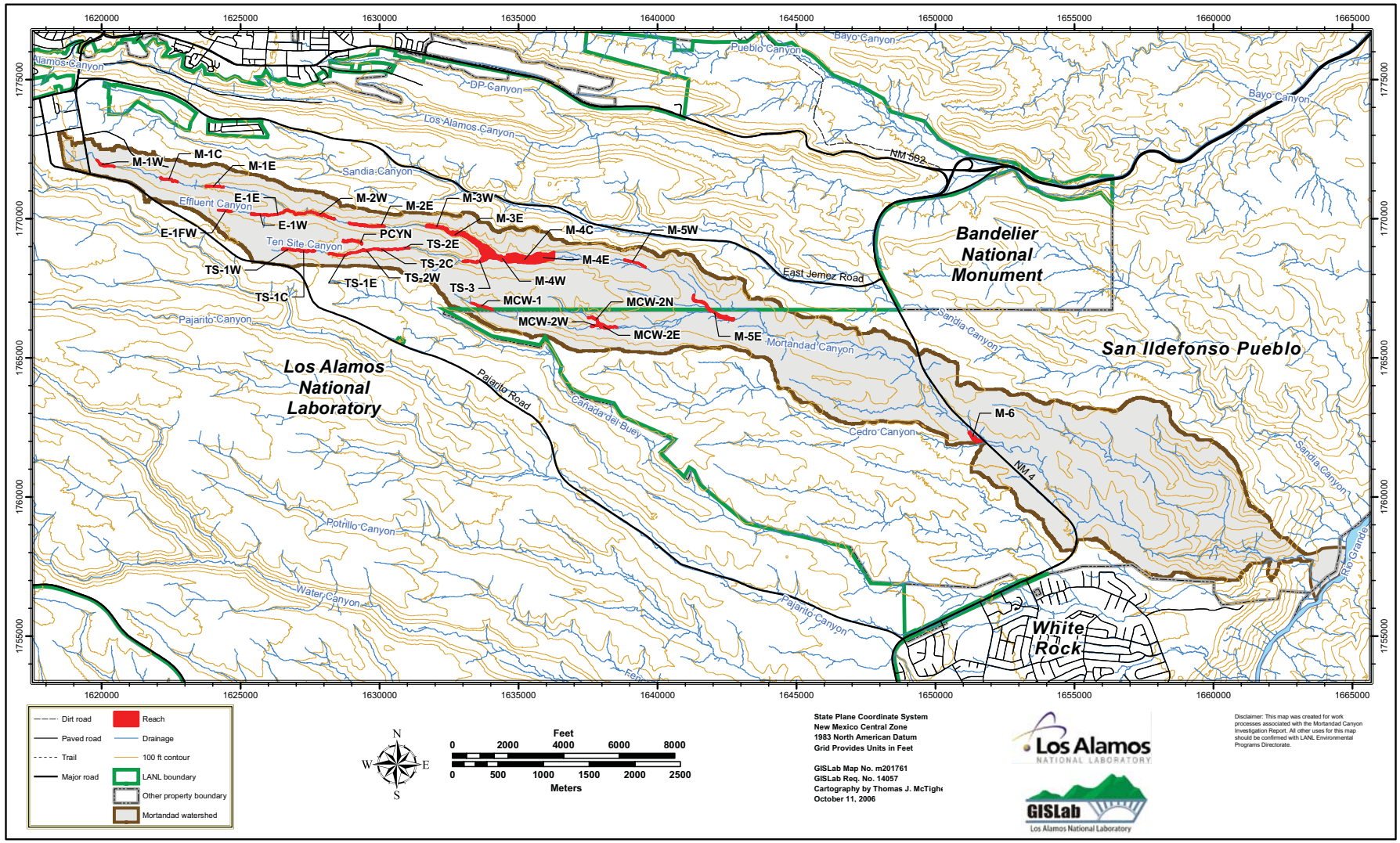


Figure 3.1-1. Reaches in the Mortandad watershed

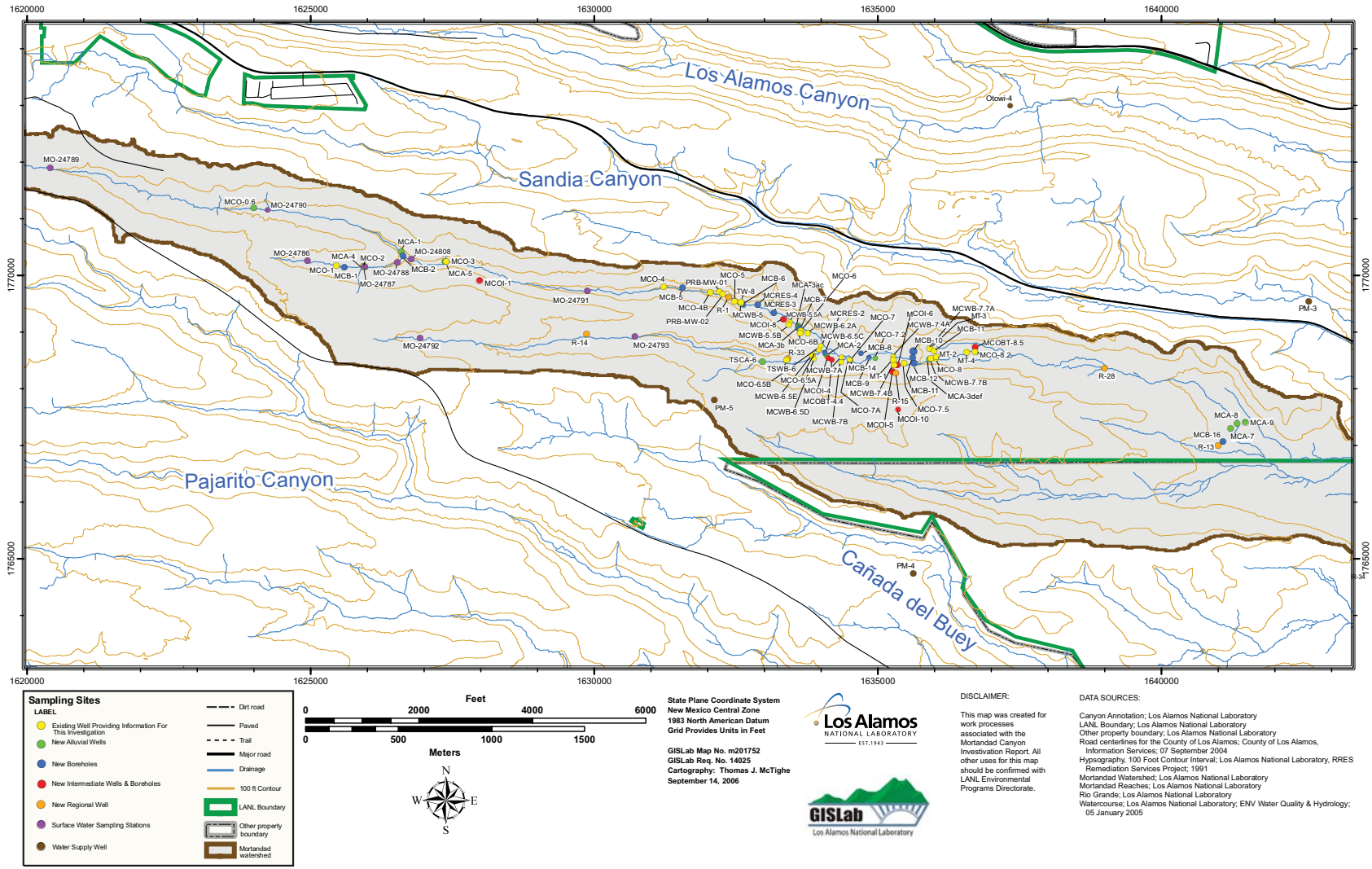


Figure 3.2-1. Water-sampling locations in the Mortandad watershed

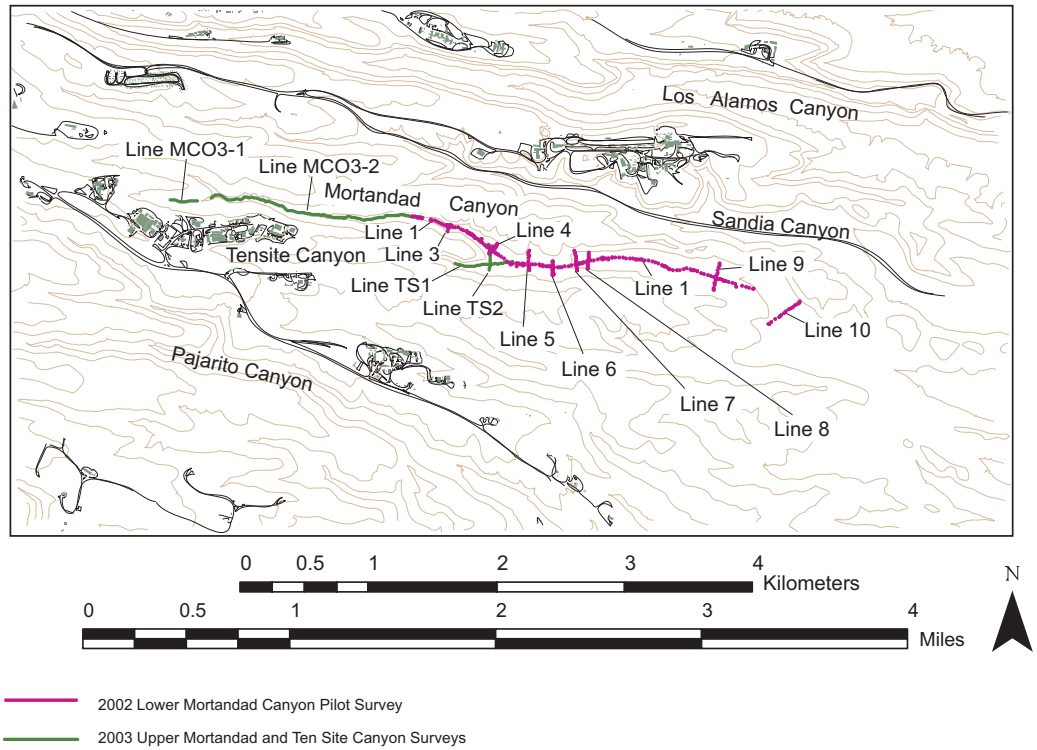
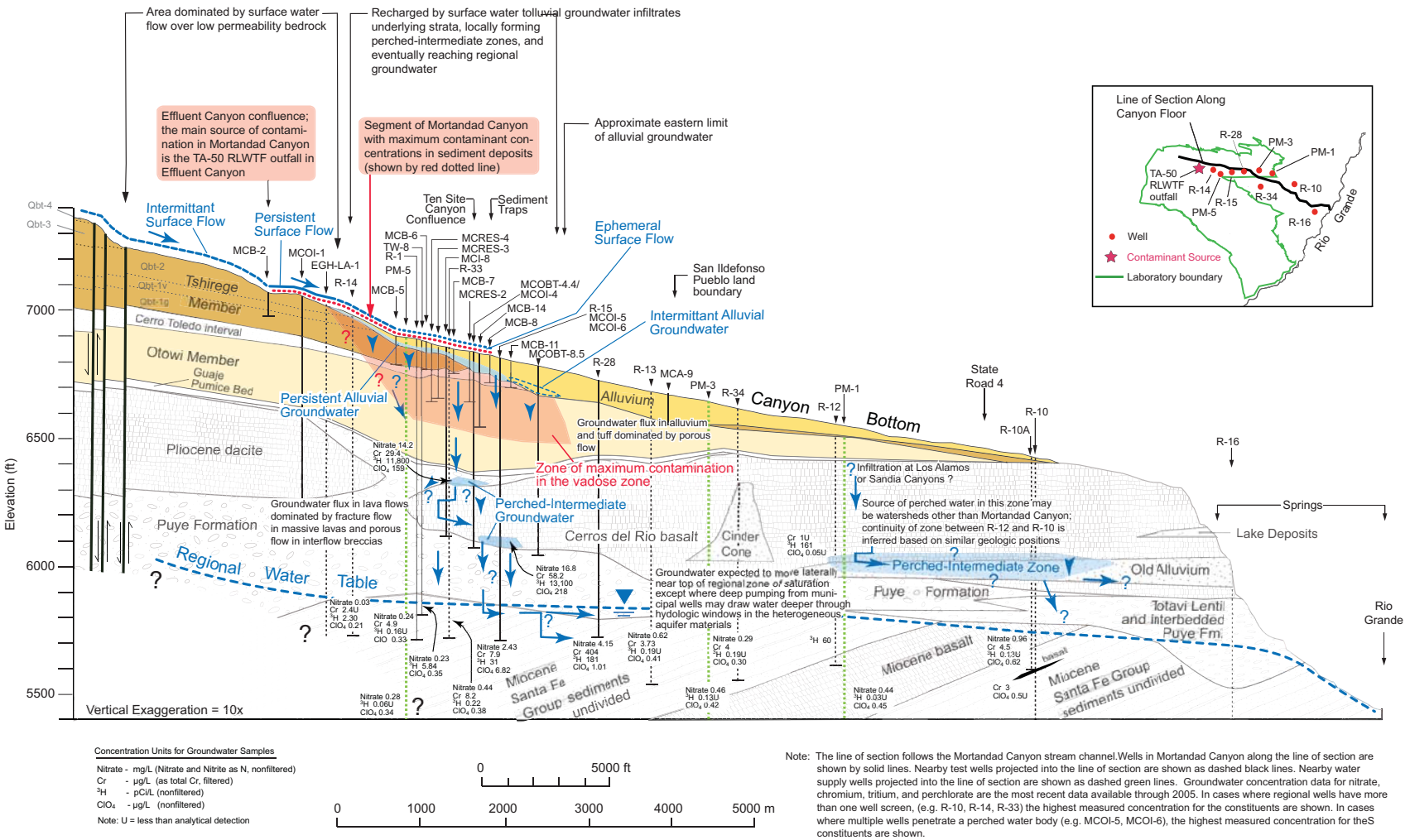


Figure 4.2-1. Locations of Surface-Based Direct-Current Resistivity Lines Collected by Geophex, Inc. in Mortandad Canyon



Note: The line of section follows the Mortandad Canyon stream channel.Wells in Mortandad Canyon along the line of section are shown by solid lines. Nearby test wells projected into the line of section are shown as dashed black lines. Nearby water supply wells projected into the line of section are shown as dashed green lines. Groundwater concentration data for nitrate, chromium, tritium, and perchlorate are the most recent data available through 2005. In cases where regional wells have more than one well screen, (e.g. R-10, R-14, R-33) the highest measured concentration for the constituents are shown. In cases where multiple wells penetrate a perched water body (e.g. MCOI-5, MCOI-6), the highest measured concentration for theS constituents are shown.

Figure 7.0-1. Conceptual hydrogeologic cross section showing potential contaminant transport pathways and the most recent concentration data through 2005 for selected contaminants in groundwater

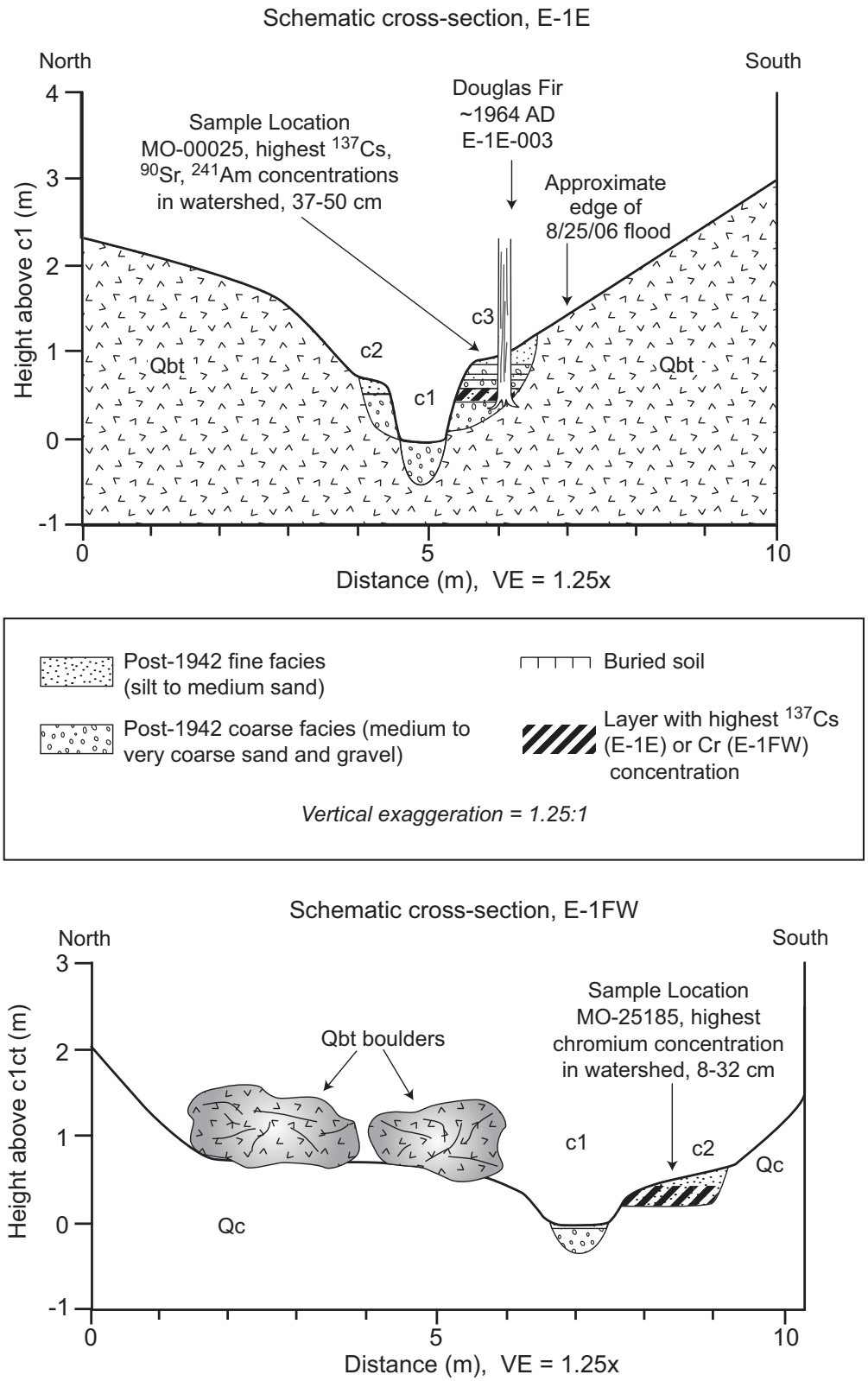


Figure 7.1-1. Schematic cross sections showing post-1942 coarse facies and fine facies sediment deposits in reaches E-1FW and E-1E

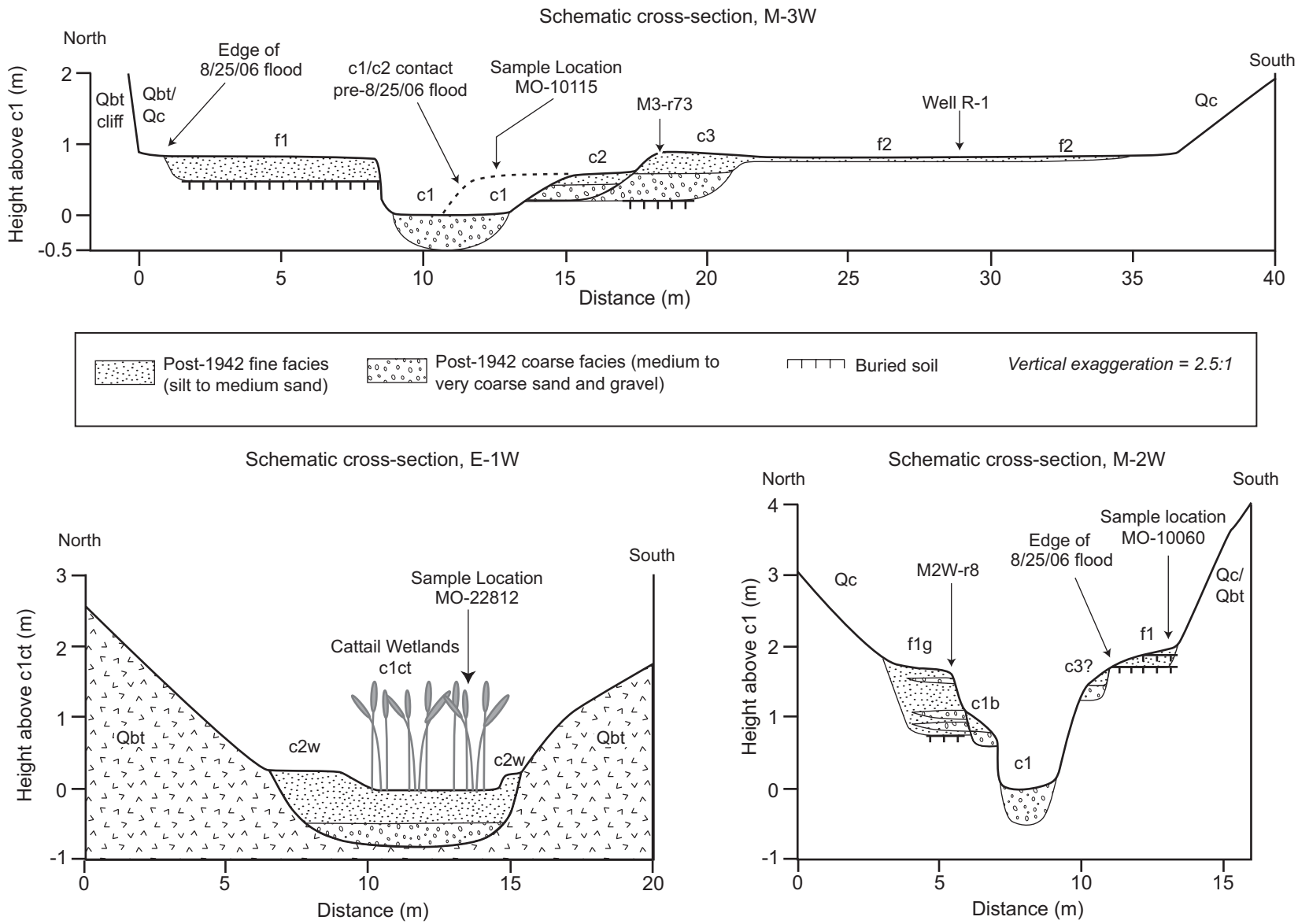


Figure 7.1-2. Schematic cross sections showing post-1942 coarse facies and fine facies sediment deposits in reaches E-1W, M-2W, and M-3W

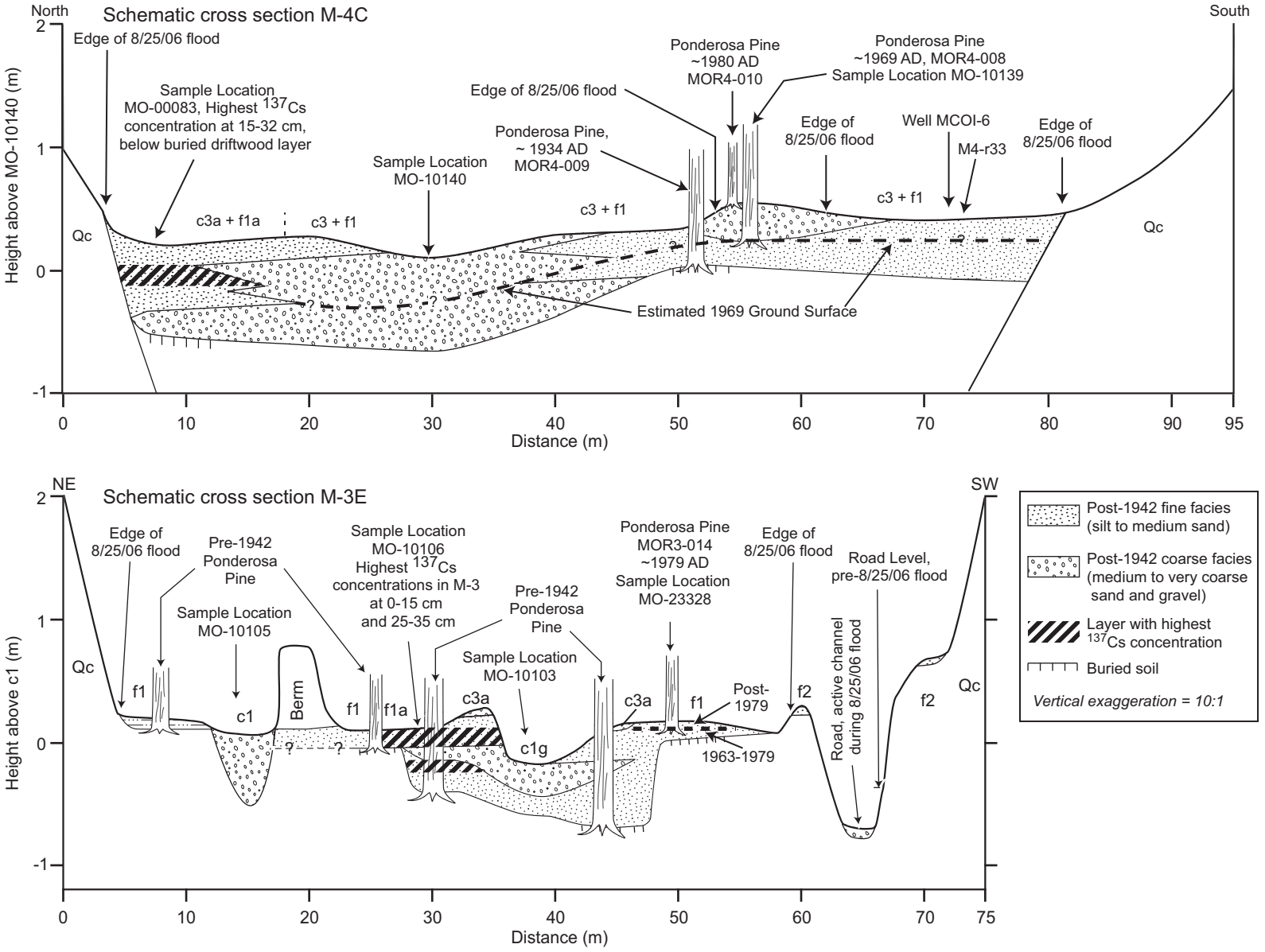


Figure 7.1-3. Schematic cross sections showing post-1942 coarse facies and fine facies sediment deposits in reaches M-3E and M-4C

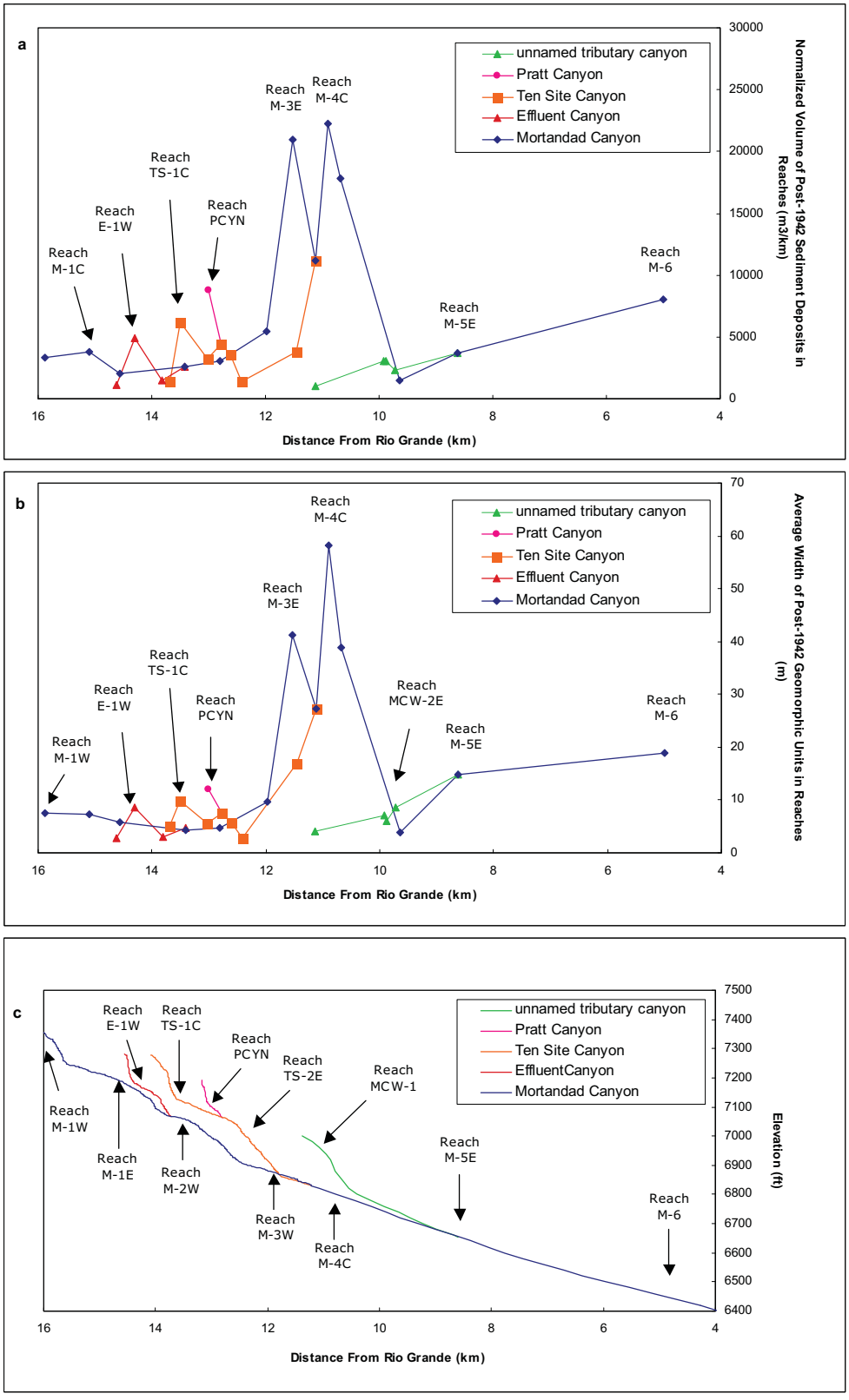


Figure 7.1-4. Longitudinal variations in normalized volume (a in units of m^3/km) and width, (b) of post-1942 sediment and geomorphic units, and stream profiles, and (c) in the Mortandad watershed

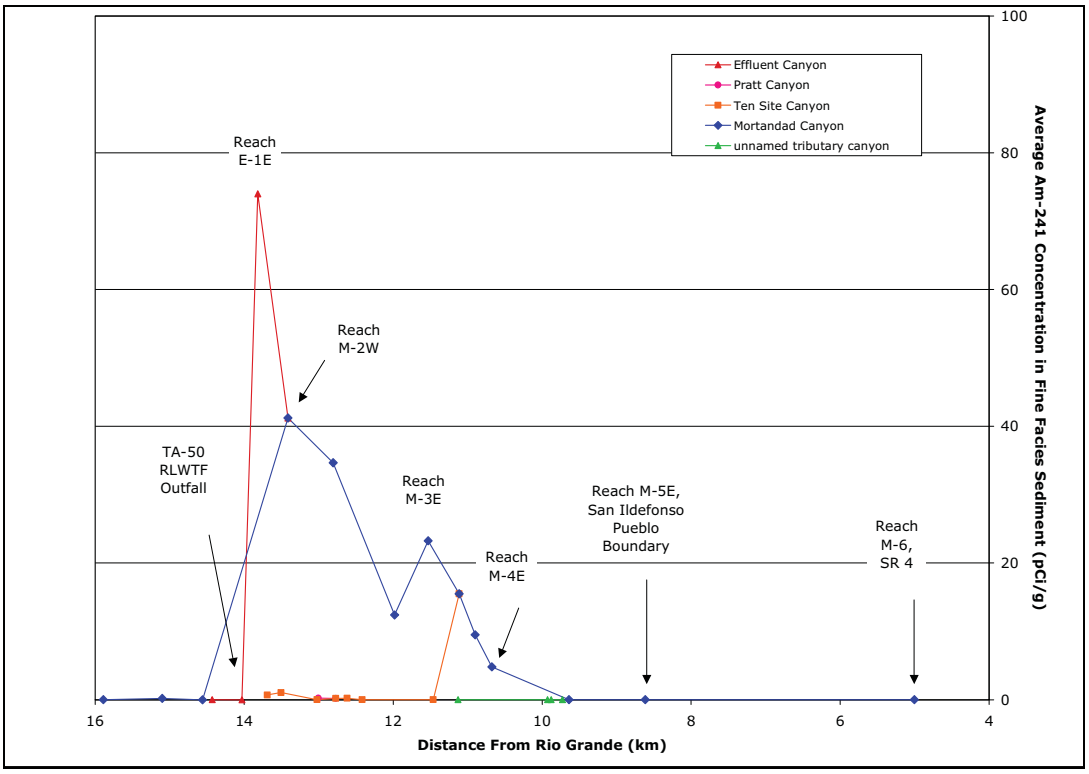


Figure 7.1-5. Estimated average concentrations of americium-241 in fine facies sediment in the Mortandad watershed

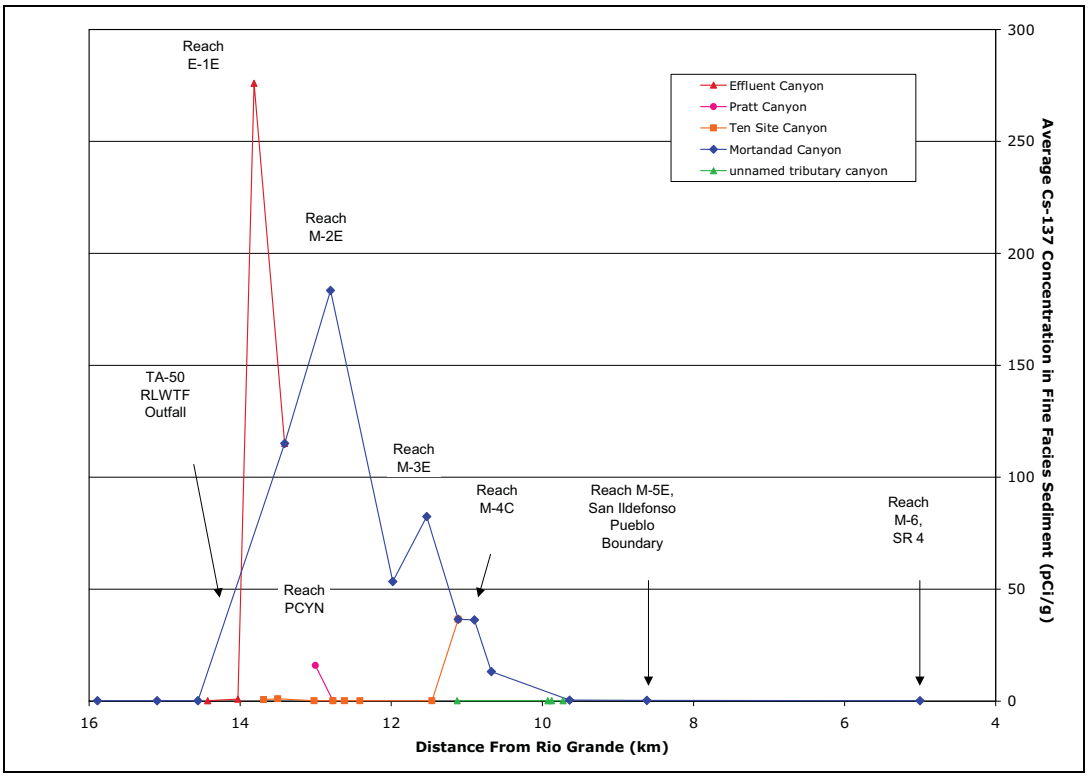


Figure 7.1-6. Estimated average concentrations of cesium-137 in fine facies sediment in the Mortandad watershed

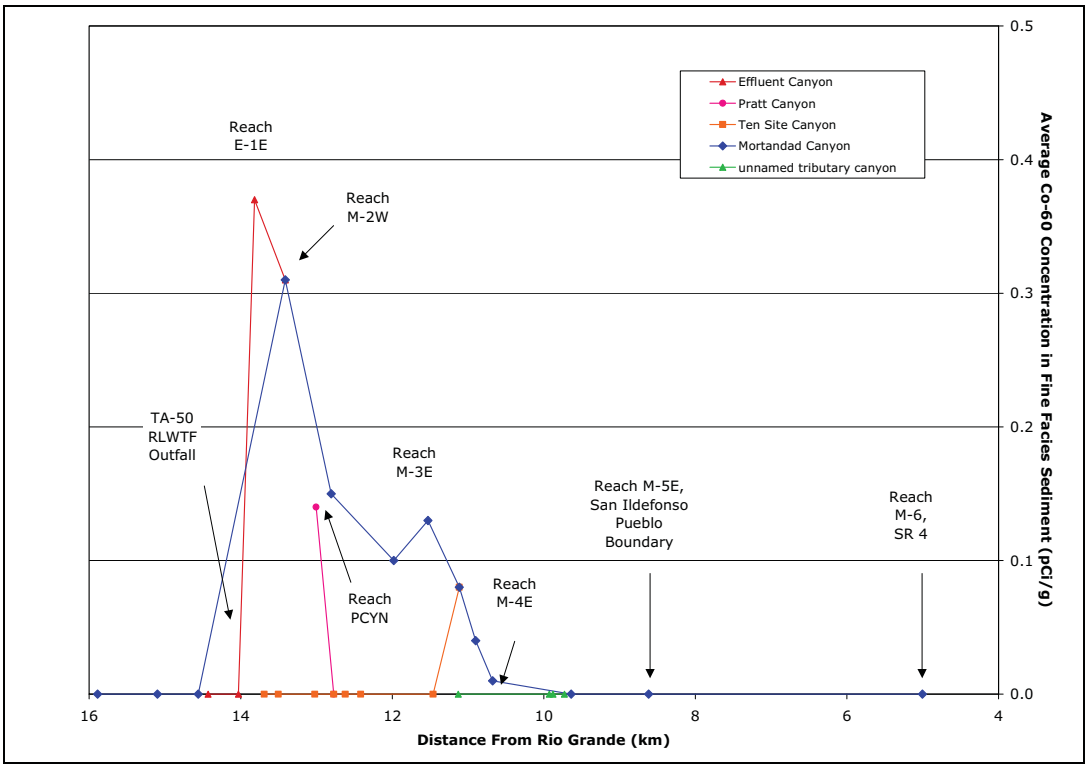


Figure 7.1-7. Estimated average concentrations of cobalt-60 in fine facies sediment in the Mortandad watershed

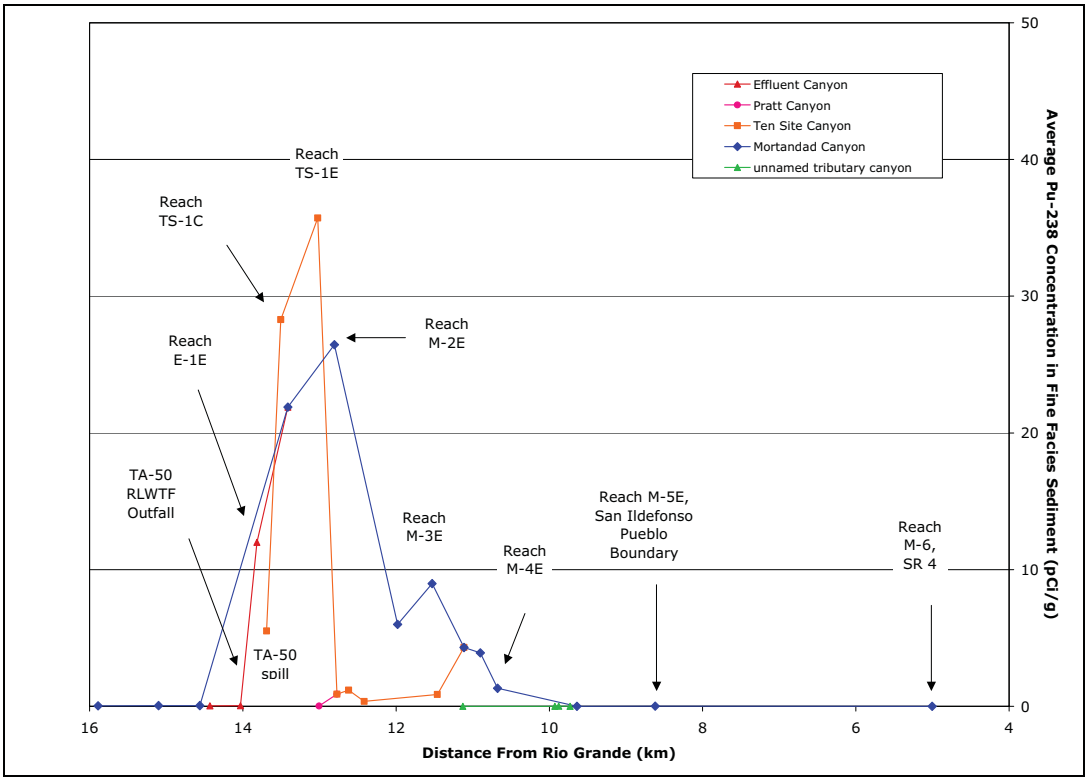


Figure 7.1-8. Estimated average concentrations of plutonium-238 in fine facies sediment in the Mortandad watershed

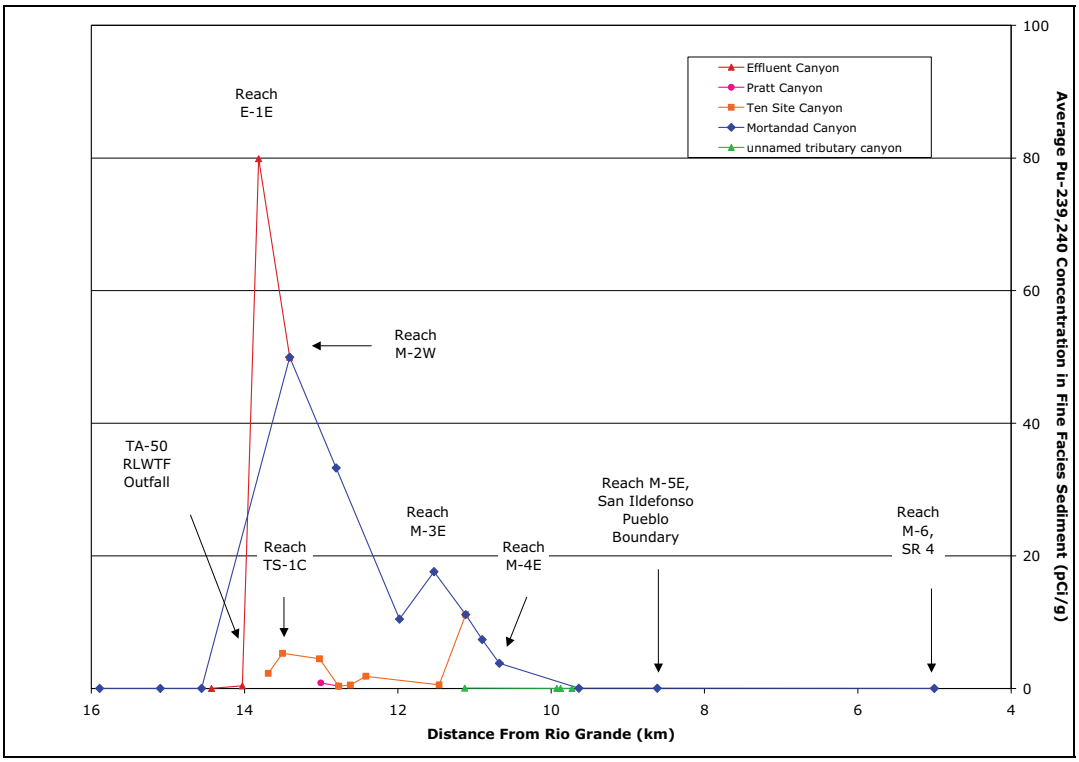


Figure 7.1-9. Estimated average concentrations of plutonium-239,240 in fine facies sediment in the Mortandad watershed

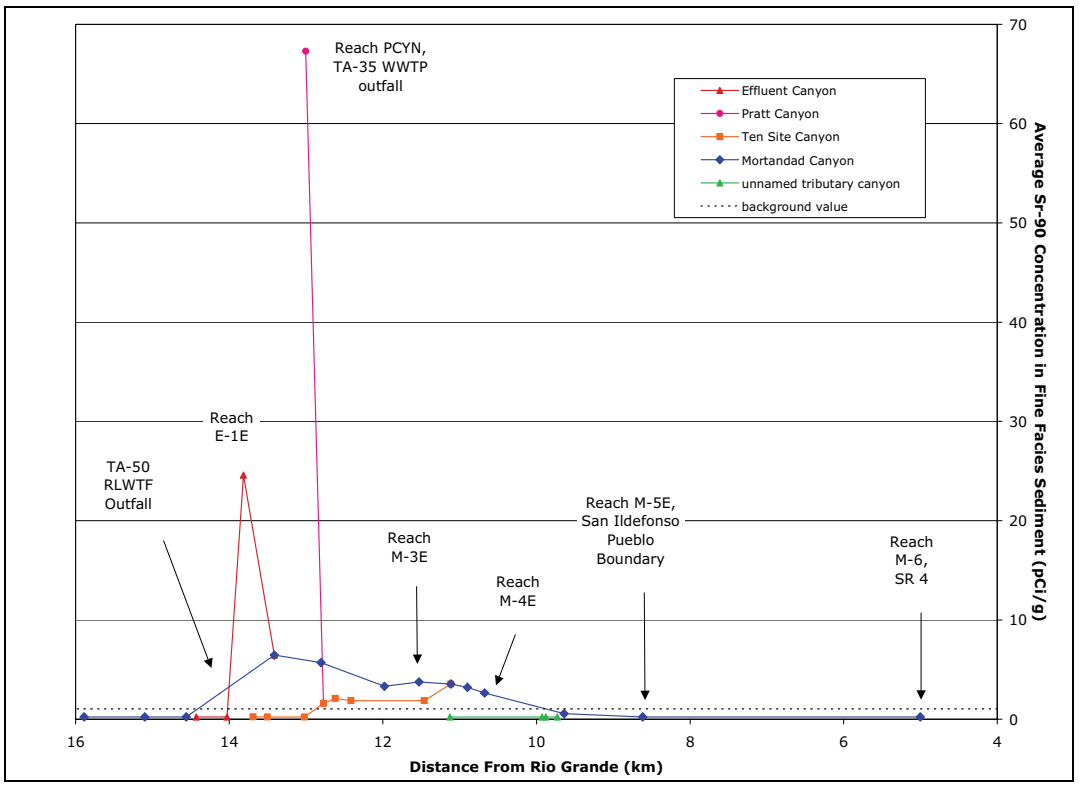


Figure 7.1-10. Estimated average concentrations of strontium-90 in fine facies sediment in the Mortandad watershed

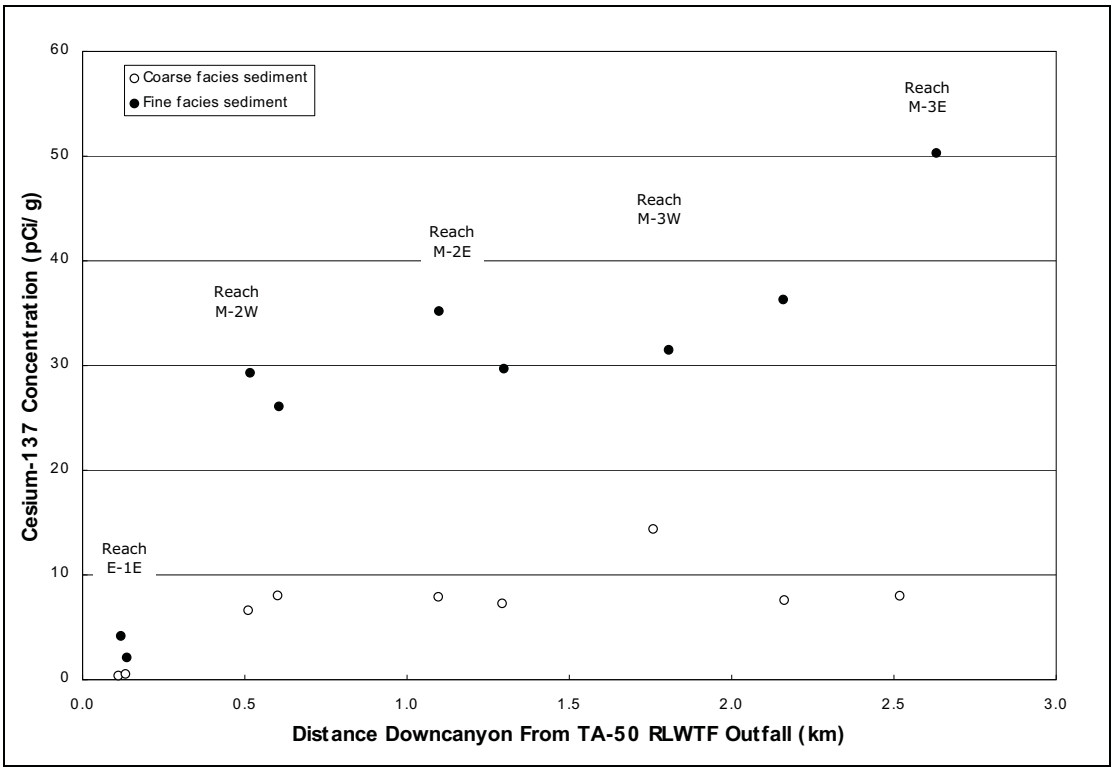
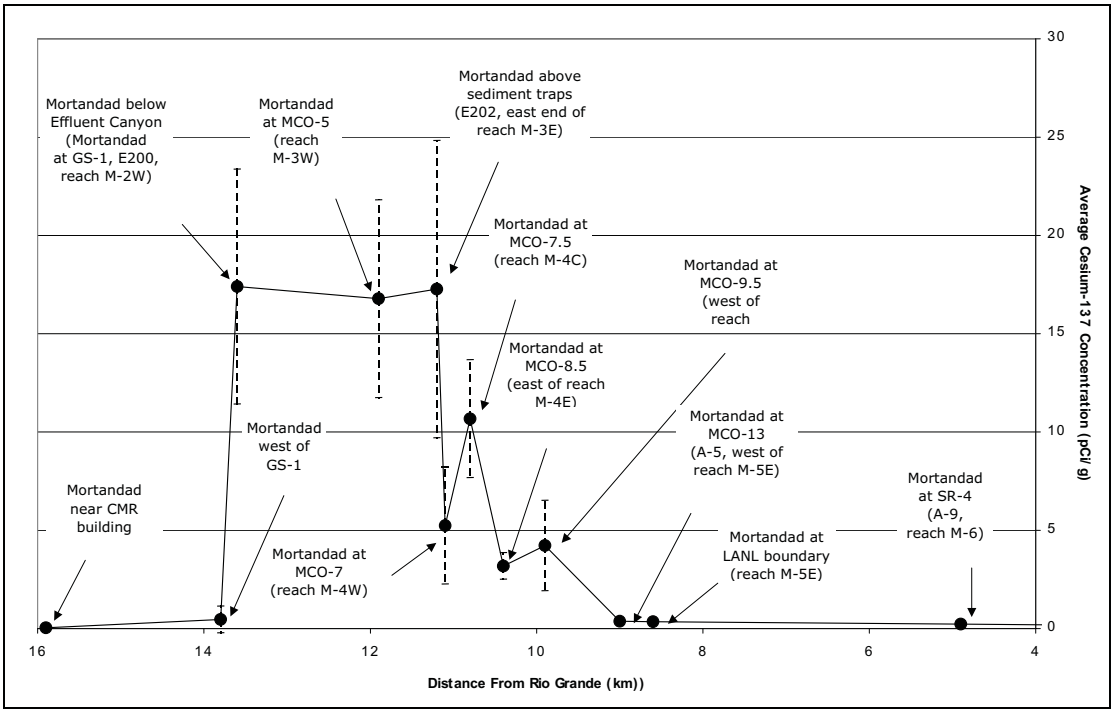


Figure 7.1-11. Cesium-137 concentrations in active channel sediment collected in Effluent and Mortandad Canyons in 2004



Notes: Error bars indicate 1 standard deviation of measurements. Previously used station names shown in parentheses, along with associated reaches.

Figure 7.1-12. Average cesium-137 concentrations at environmental surveillance stations in Mortandad Canyon, 1996–2005

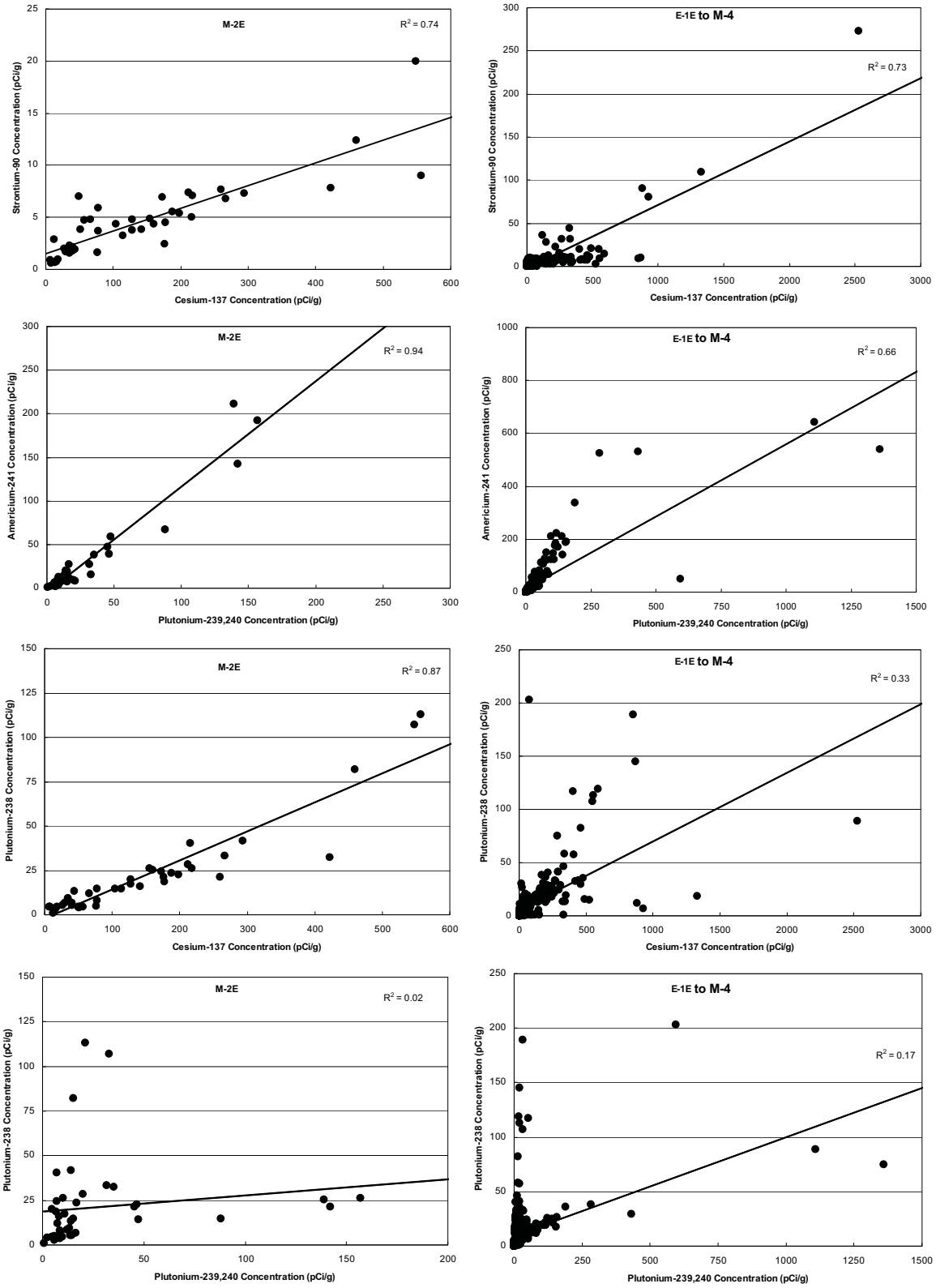


Figure 7.1-13. Scatter plots showing relations between pairs of radionuclides in sediment samples from reach M-2E and in entire data set from the TA-50 RLWTF outfall through reach M-4

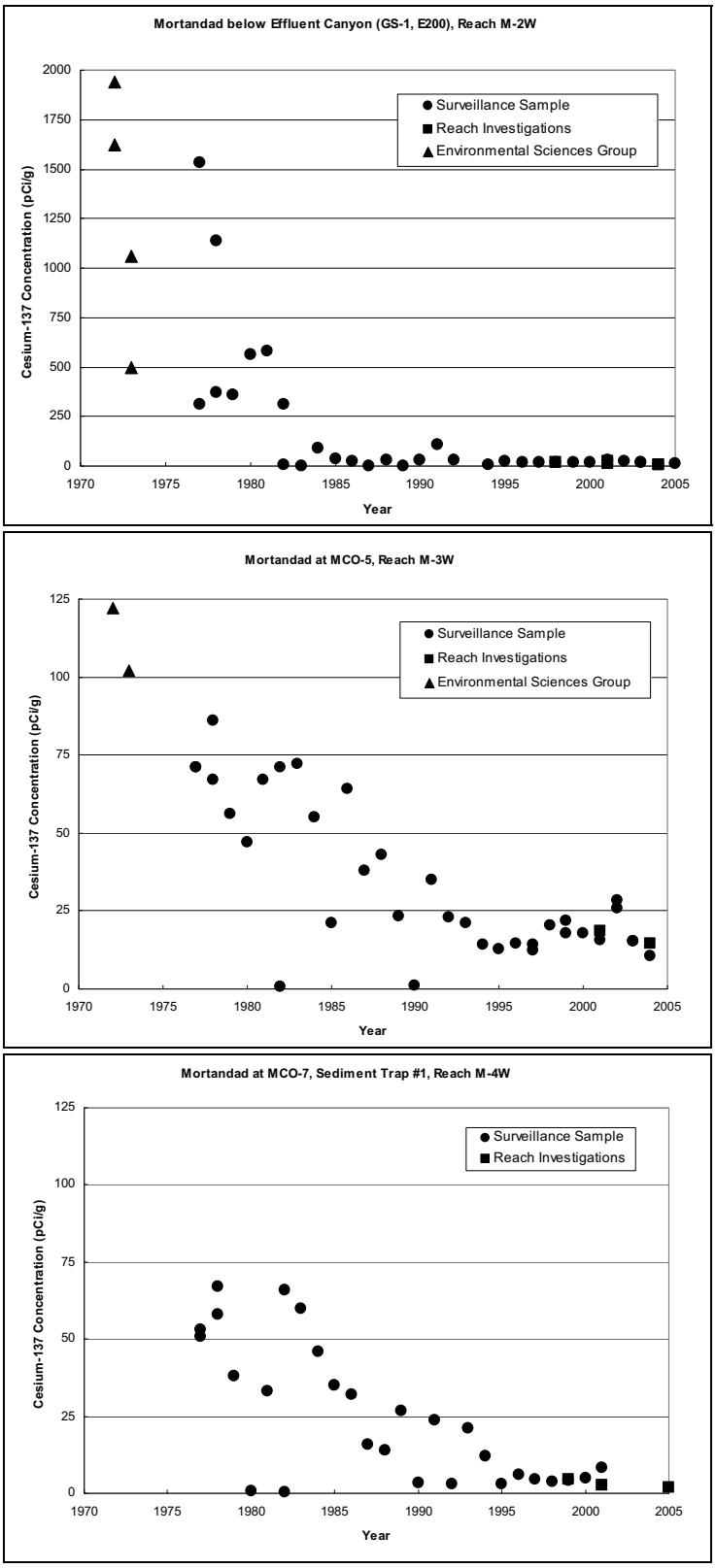


Figure 7.1-14. Time series of cesium-137 concentrations from active channel samples at environmental surveillance stations and from reach investigations

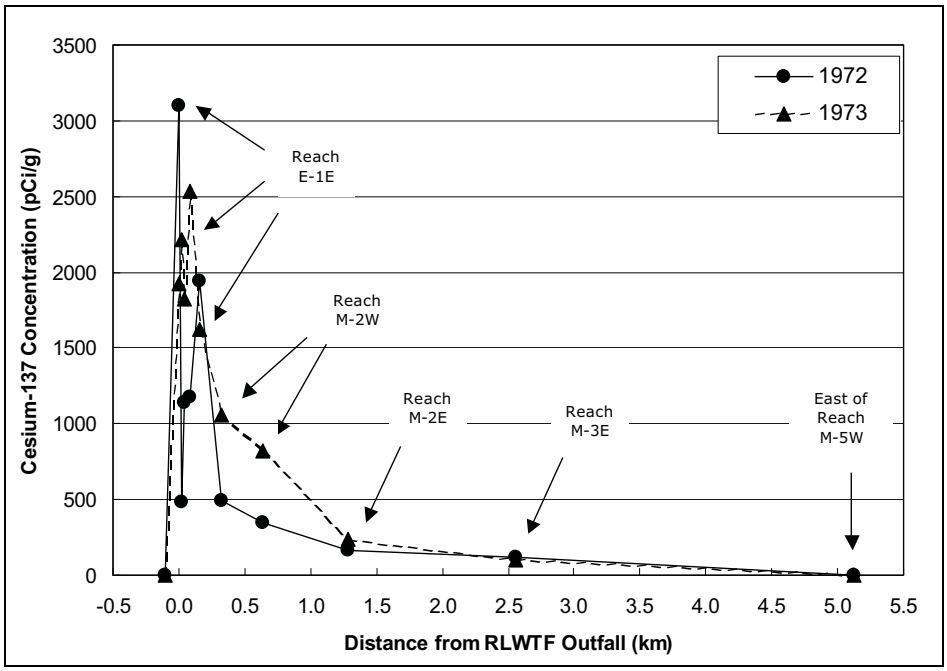


Figure 7.1-15. Cesium-137 concentrations from active channel samples collected in 1972 and 1973 plotted versus distance from TA-50 RLWTF outfall (data from Nyhan et al. 1978, 05726)

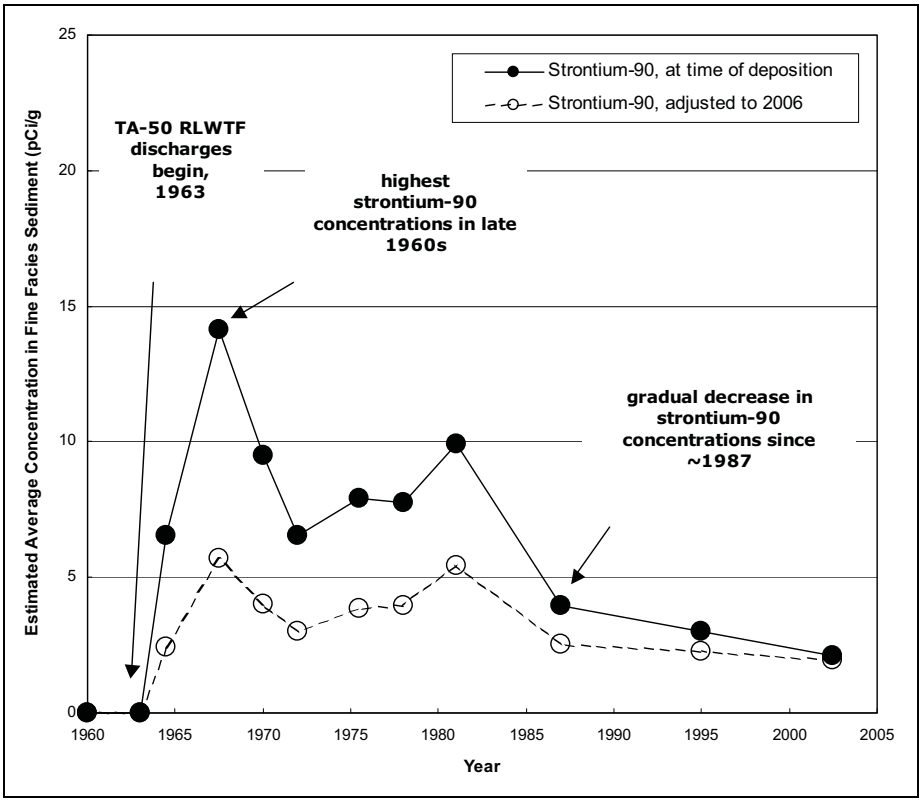


Figure 7.1-16. Reconstructed concentrations of americium-241, cesium-137, plutonium-238, plutonium-239,240, and strontium-90 in fine facies sediment in reaches M-3, M-4W, and M-4E, plotted against year

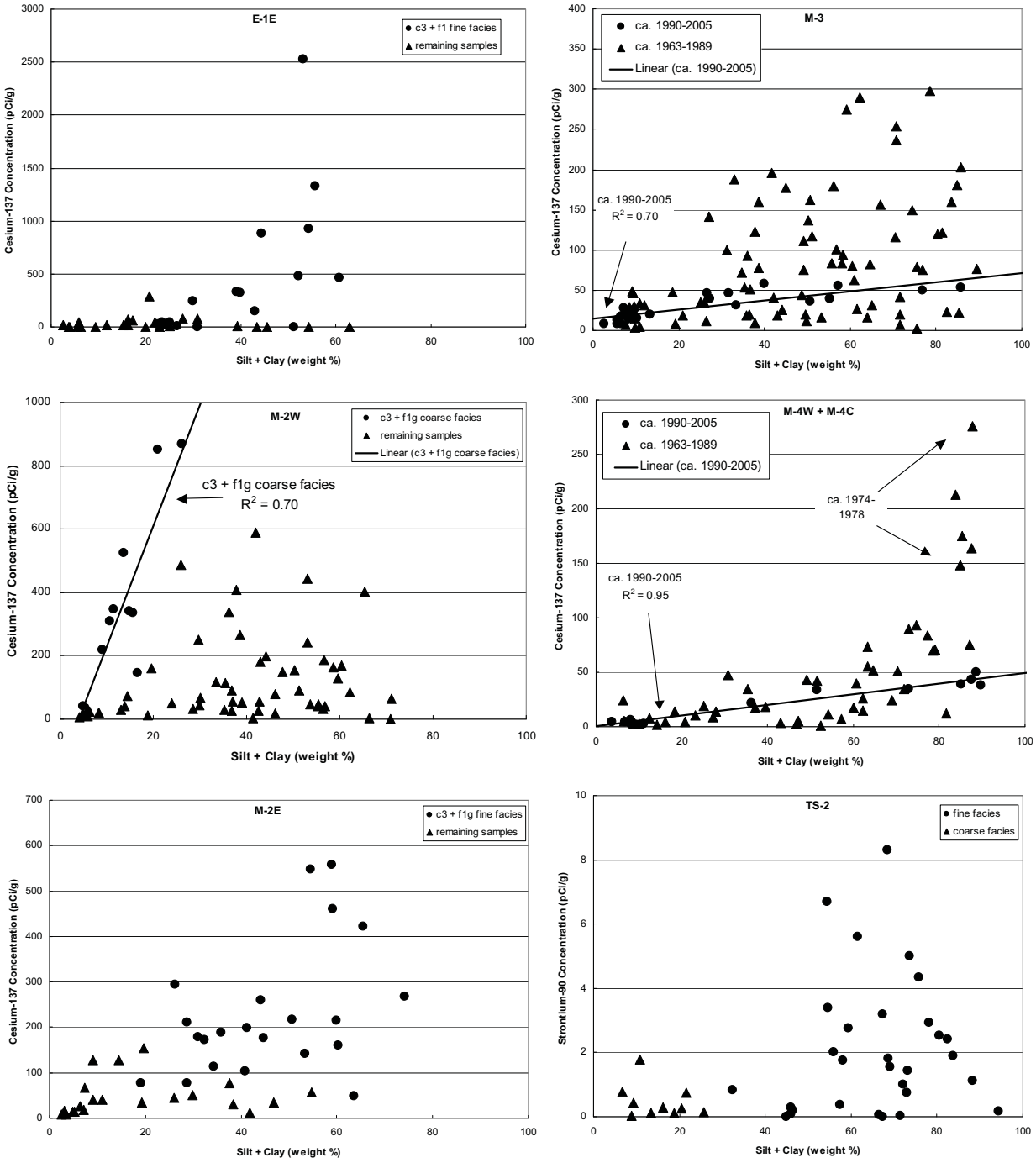


Figure 7.1-17. Scatter plots showing relations between radionuclide concentration and silt and clay content in reaches E-1E, M-2W, M-2E, M-3, M-4, and TS-2

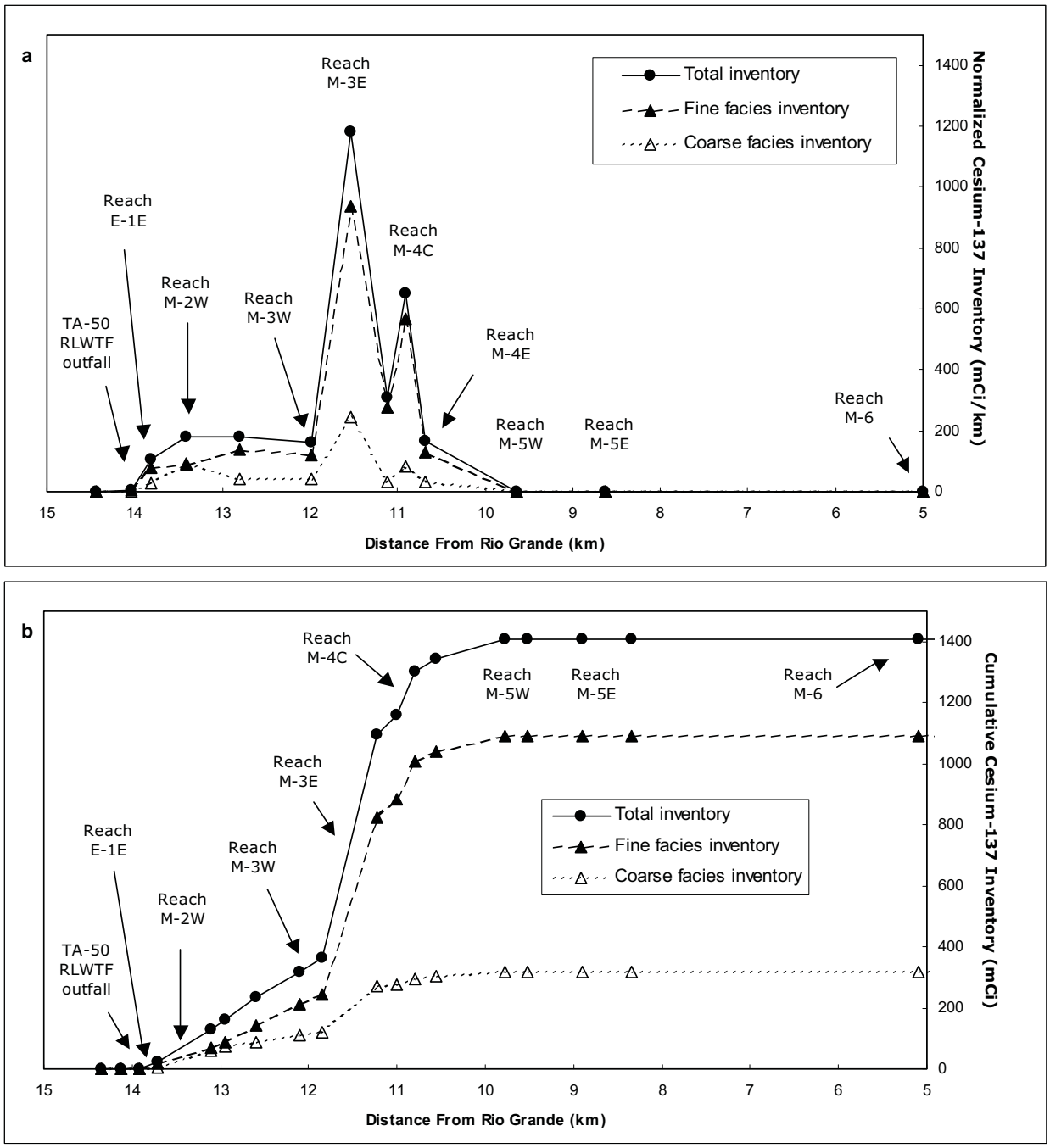


Figure 7.1-18. Estimated cesium-137 inventory in Effluent and Mortandad Canyons downstream from the TA-50 RLWTF outfall: (a) normalized inventory [mCi/km]; (b) cumulative inventory [mCi]

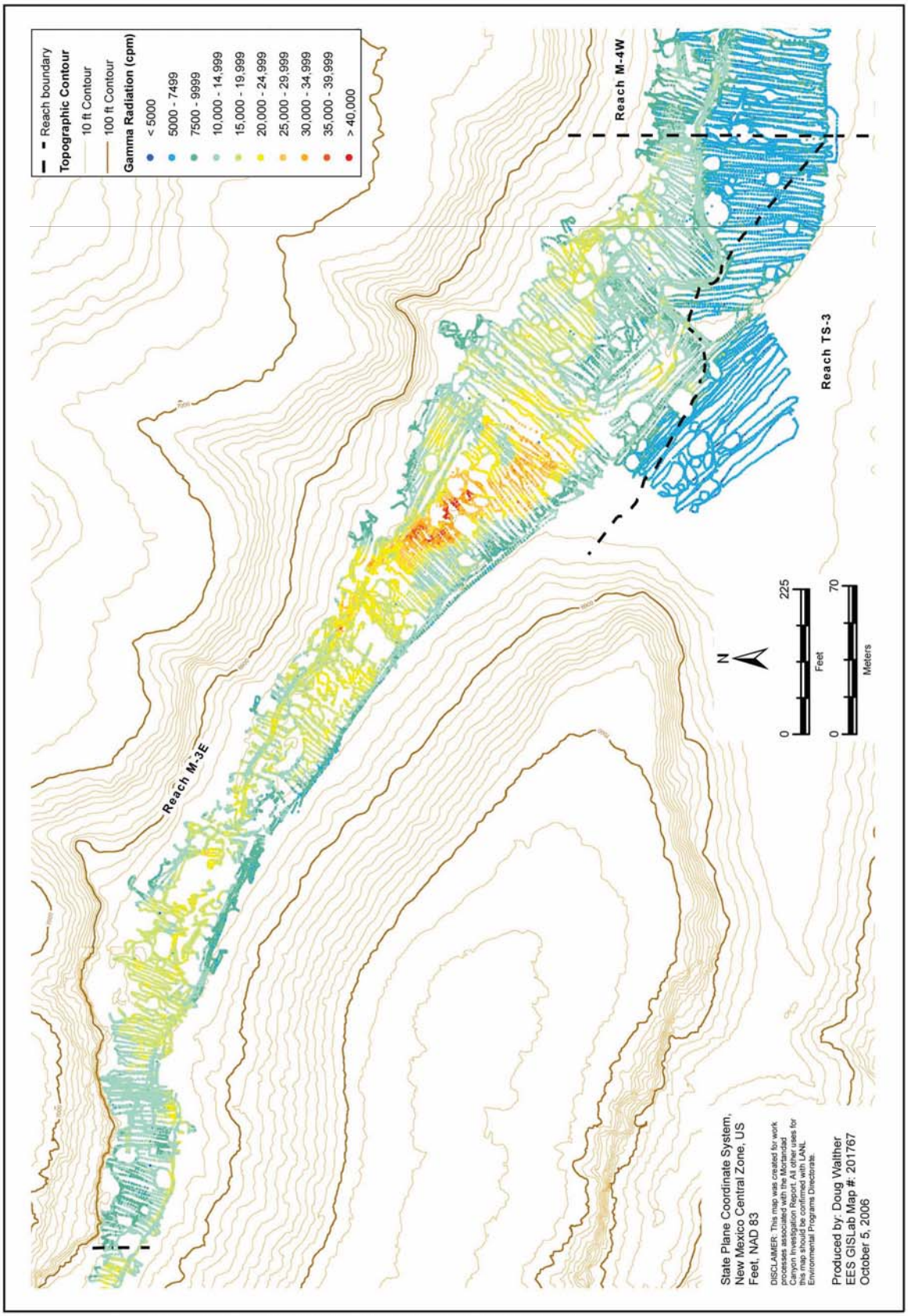
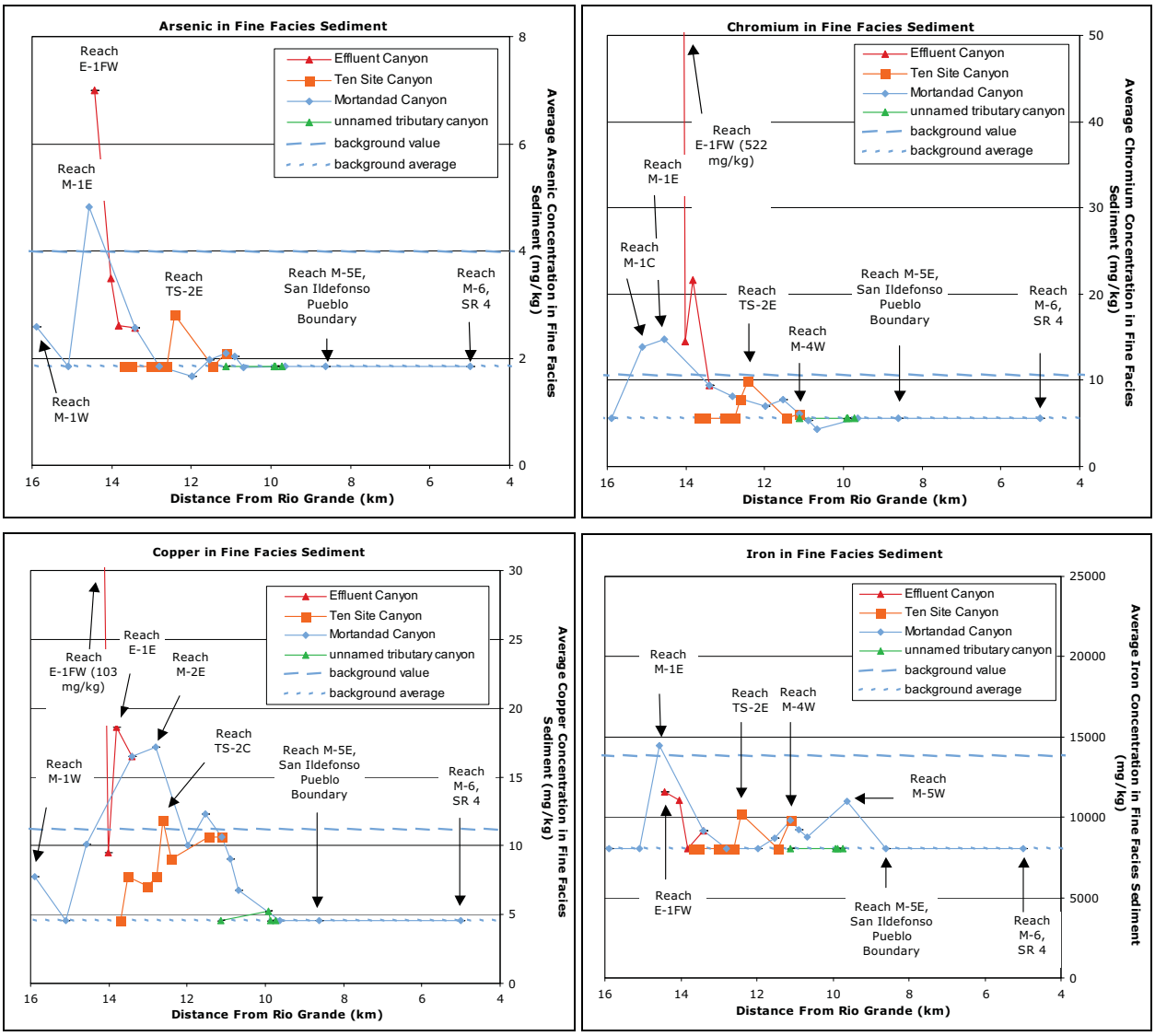
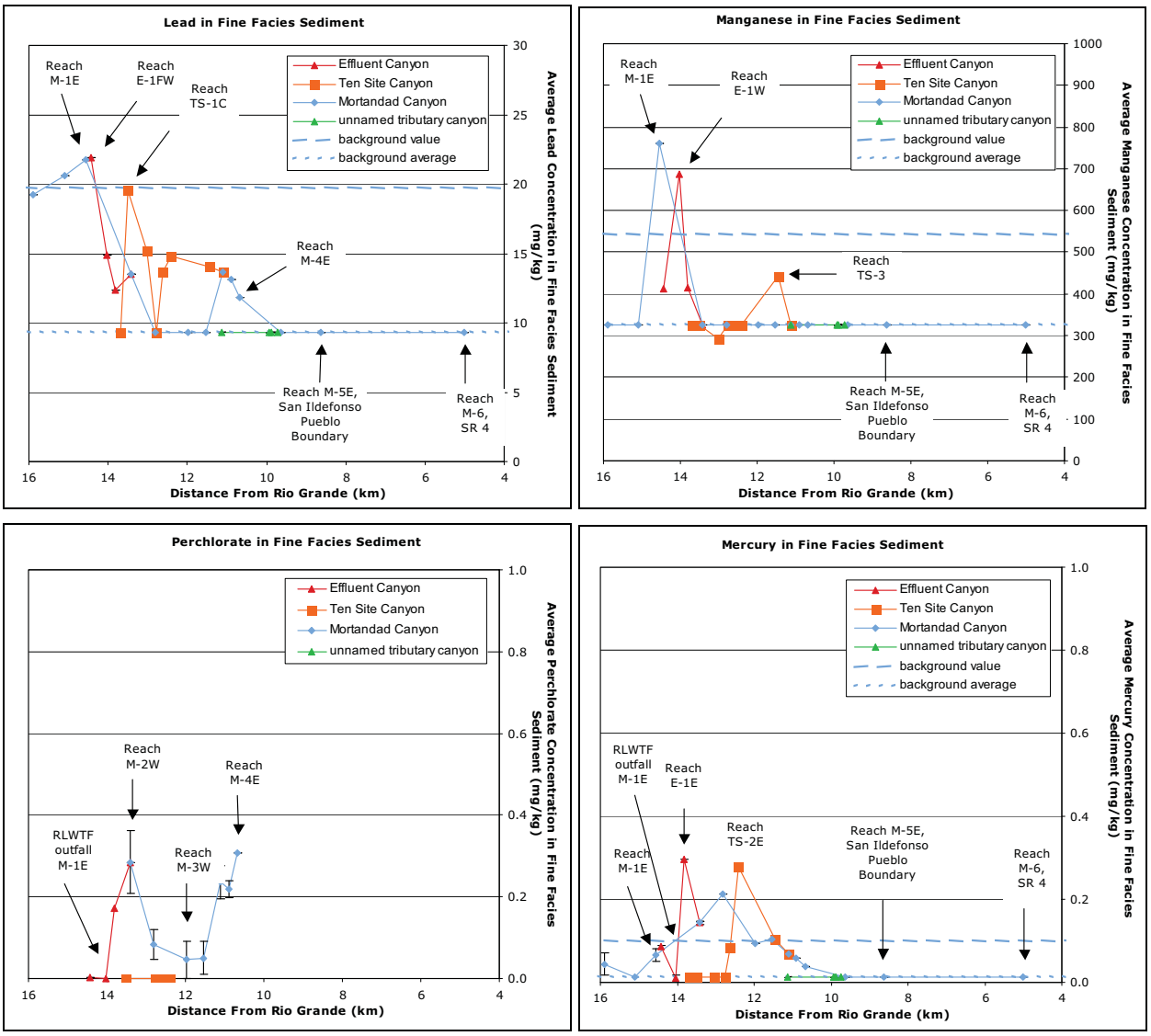


Figure 7.1-19. Results of gross-gamma radiation walkover survey in reach M-3E, in area of highest cesium-137 inventory in the Mortandad watershed, showing area of sediment deposition where floodwaters spread over canyon bottom



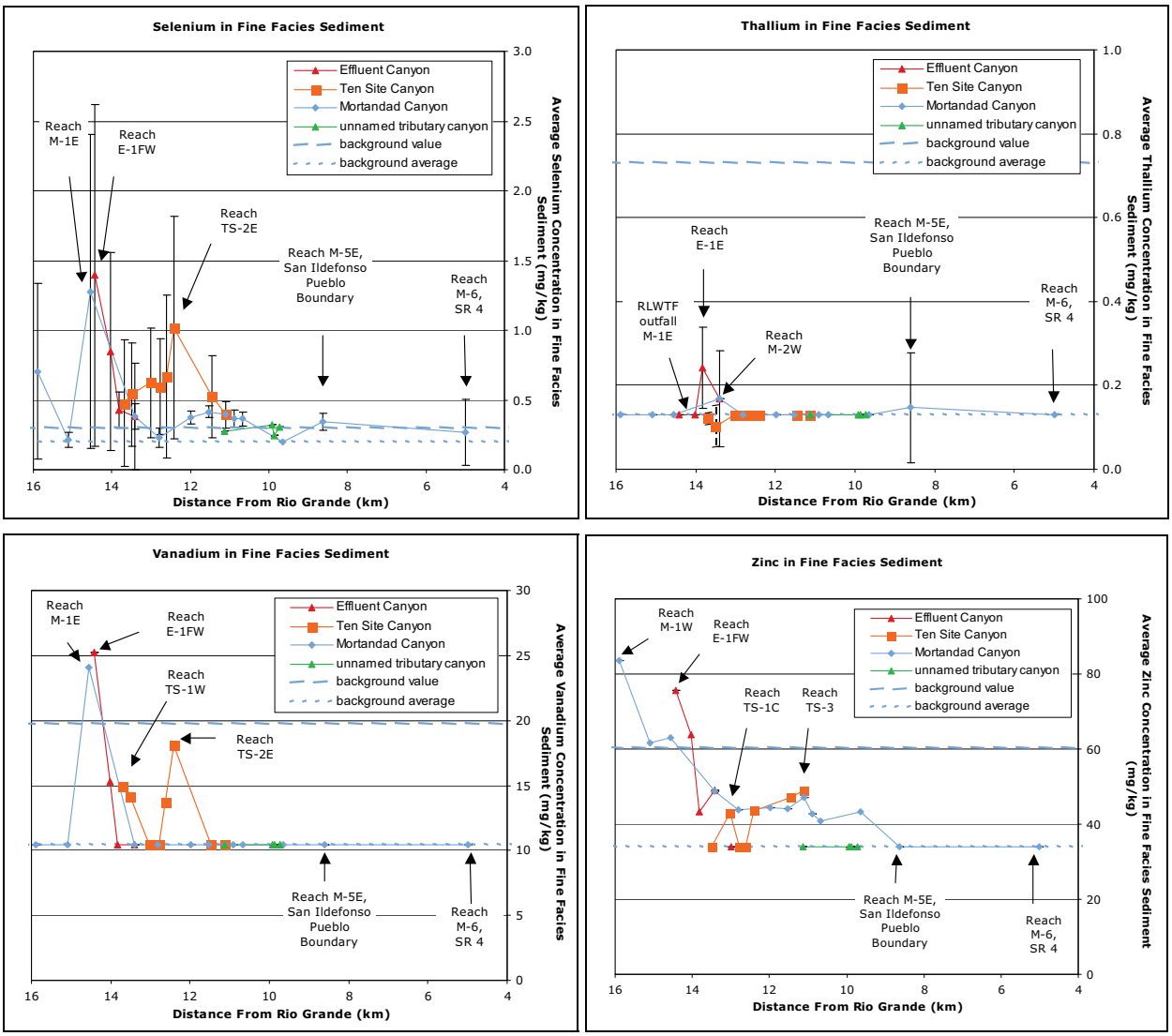
Note: Error bars indicate upper and lower bounds based on replacing nondetect values with either the detection limit or zero.

Figure 7.1-20. Estimated average concentrations of inorganic chemicals in fine facies sediment in the Mortandad watershed



Note: Error bars indicate upper and lower bounds based on replacing nondetect values with either the detection limit or zero.

Figure 7.1-20 (continued). Estimated average concentrations of inorganic chemicals in fine facies sediment in the Mortandad watershed



Note: Error bars indicate upper and lower bounds based on replacing nondetect values with either the detection limit or zero.

Figure 7.1-20 (continued). Estimated average concentrations of inorganic chemicals in fine facies sediment in the Mortandad watershed

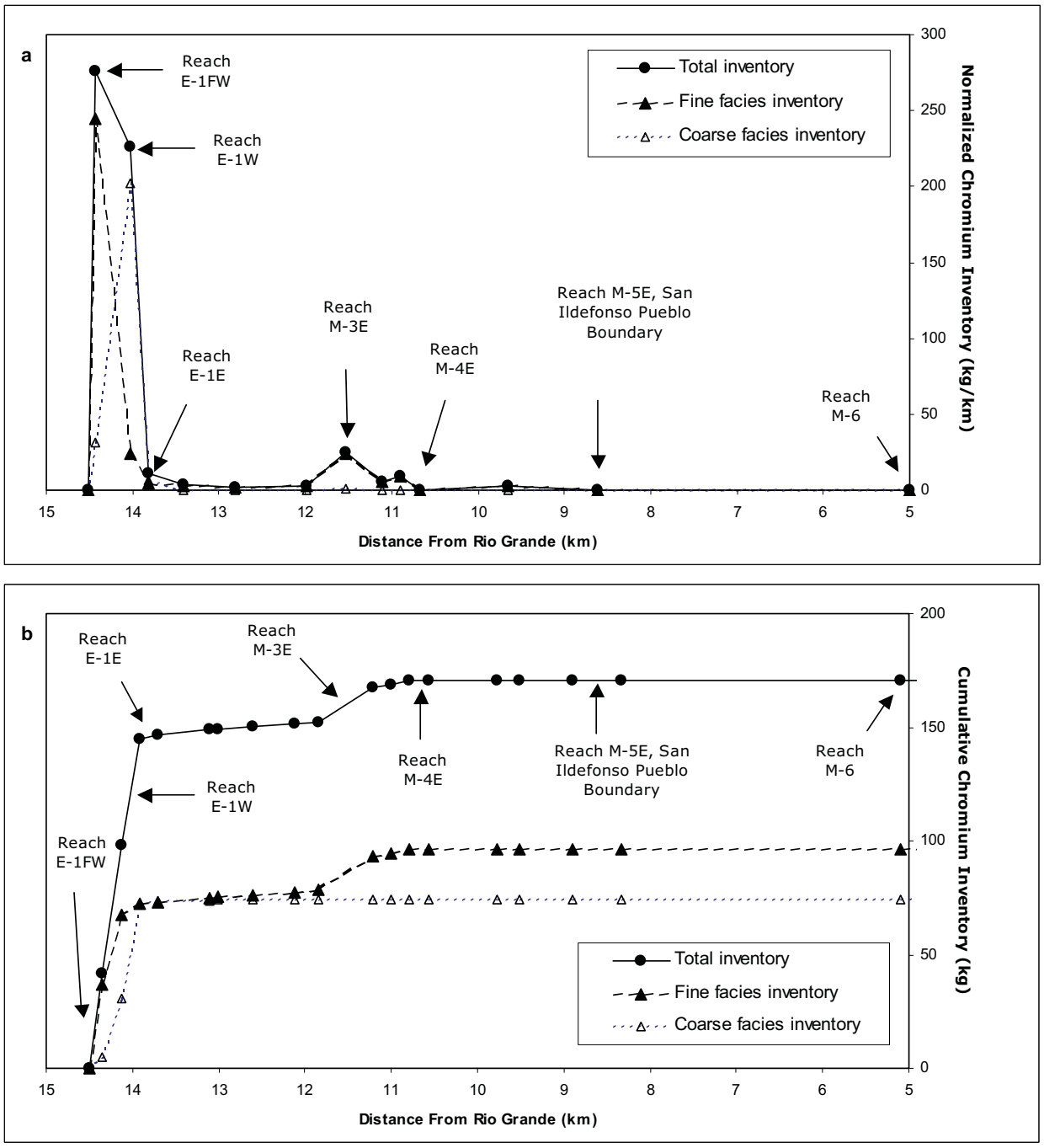


Figure 7.1-21. Estimated anthropogenic chromium inventory in Effluent and Mortandad Canyons downstream from the head of reach E-1FW: (a) normalized inventory [kg/km]; (b) cumulative inventory [kg]

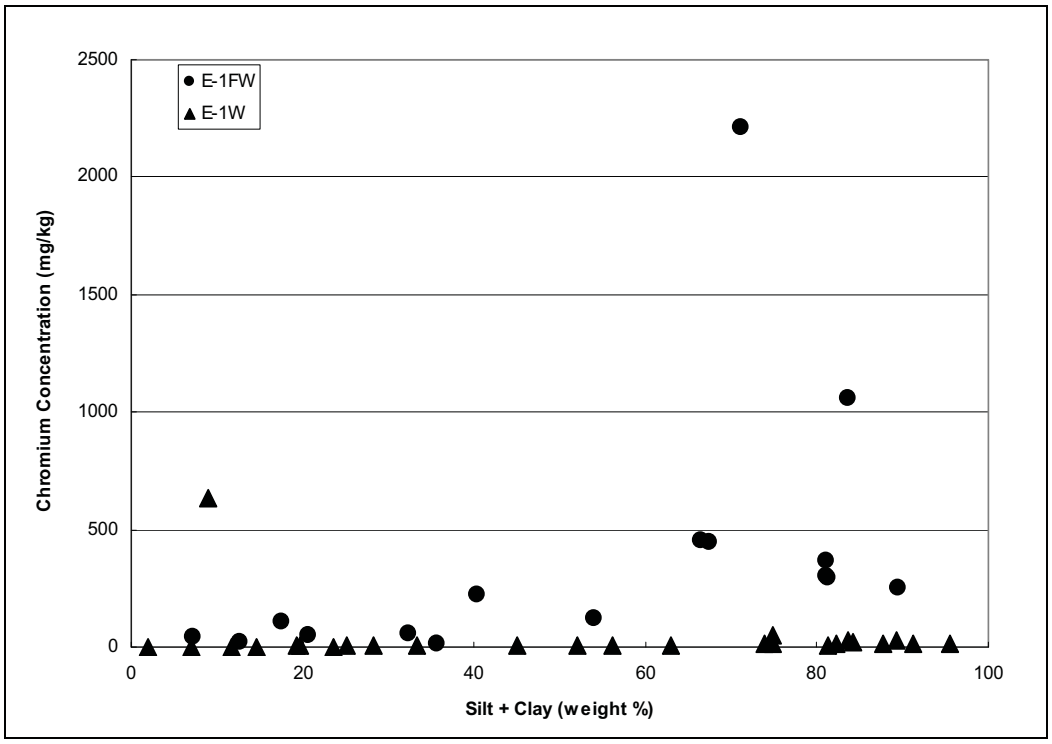


Figure 7.1-22. Scatter plot showing relations between chromium concentration and silt and clay content in reaches E-1FW and E-1W

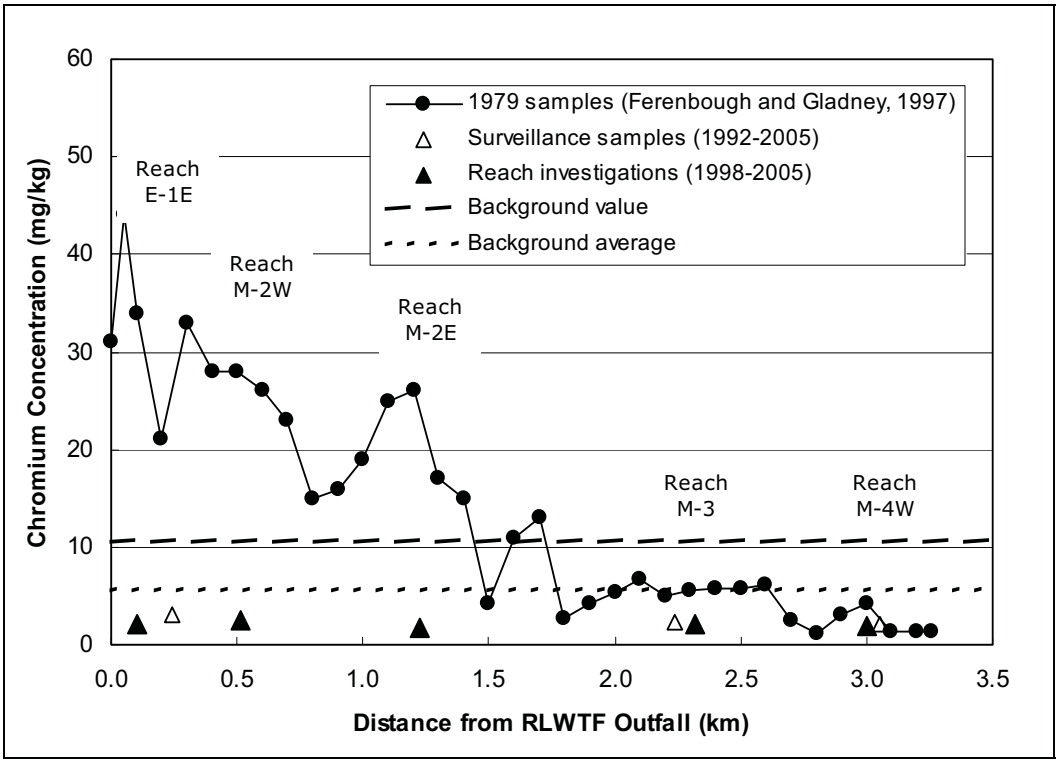
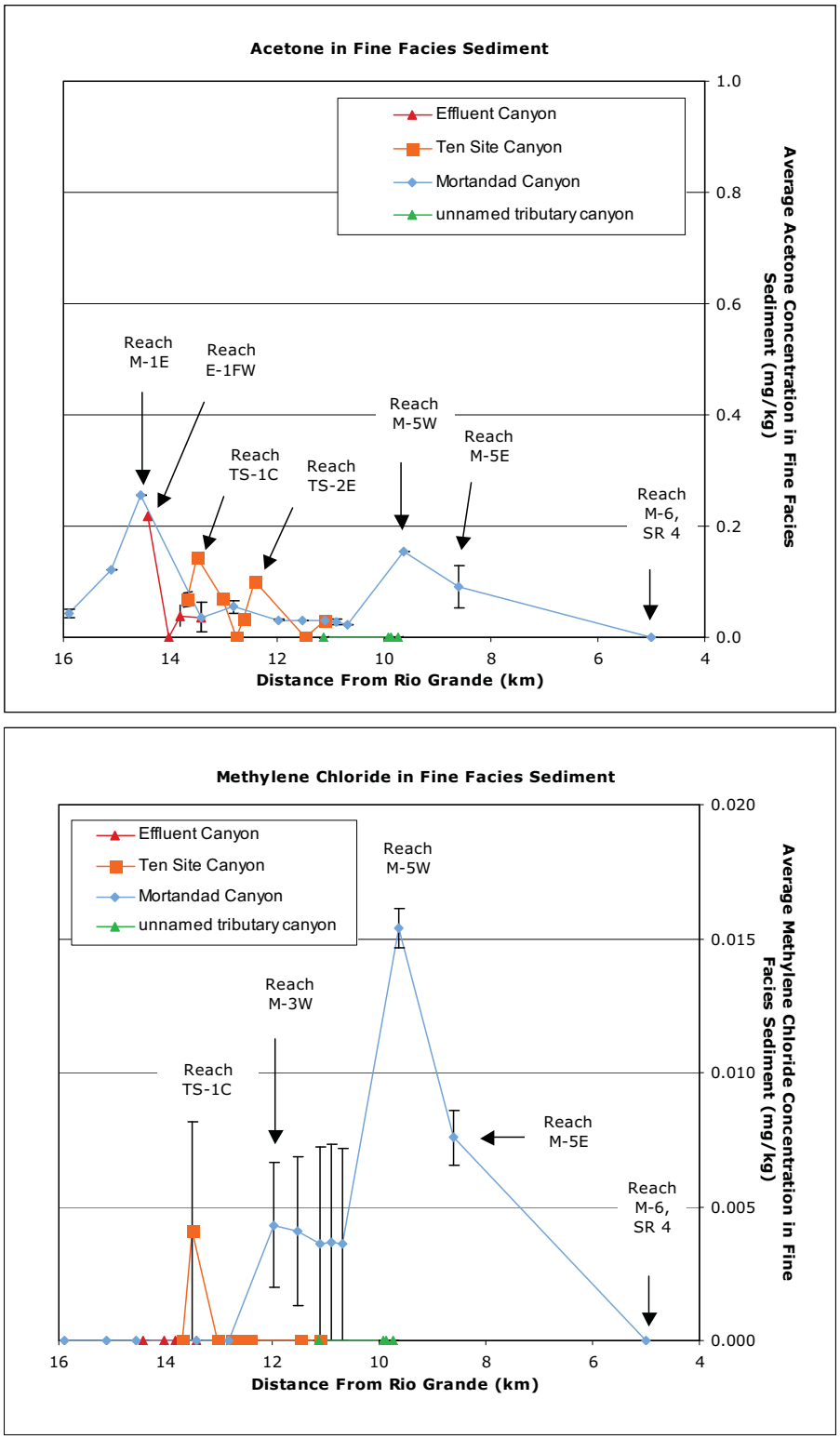
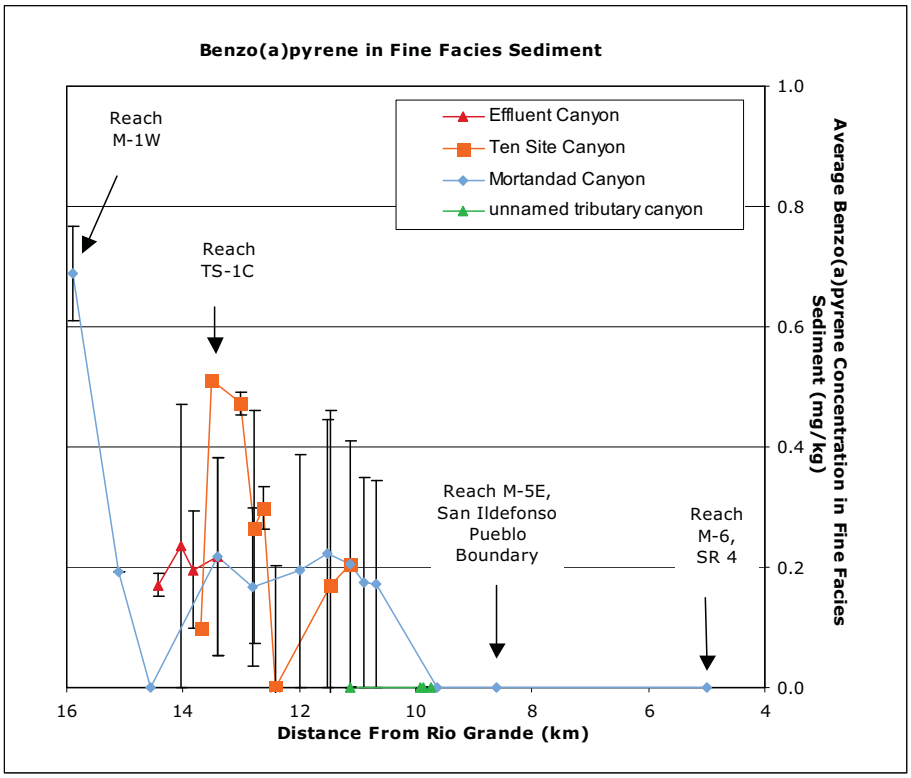


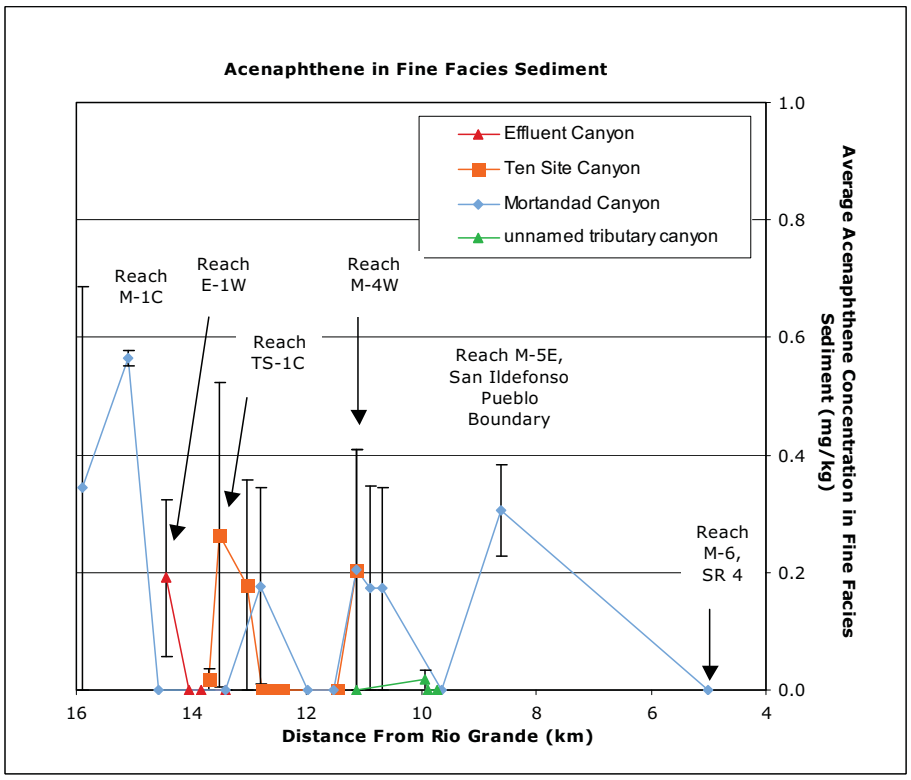
Figure 7.1-23. Chromium concentrations from active channel samples collected in 1979 (Ferenbaugh and Gladney 1997, 93715) and from later investigations plotted versus distance from TA-50 RLWTF outfall



Notes: Error bars indicate upper and lower bounds based on replacing nondetect values with either the detection limit or zero. A value of zero is shown where there are no detected results.

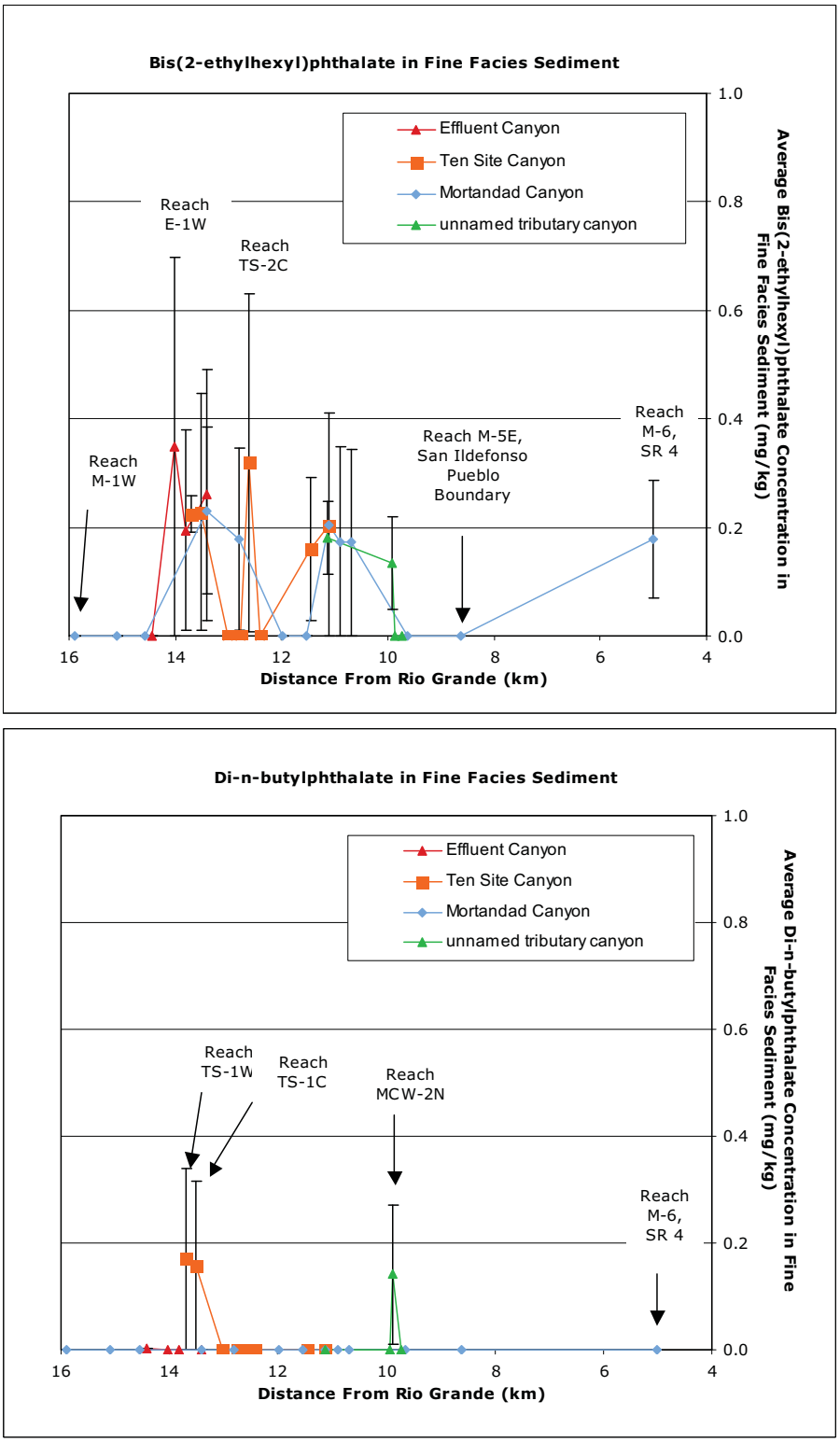
Figure 7.1-24. Estimated average concentrations of the PCBs Aroclor-1260 and Aroclor-1254 in fine facies sediment in the Mortandad watershed





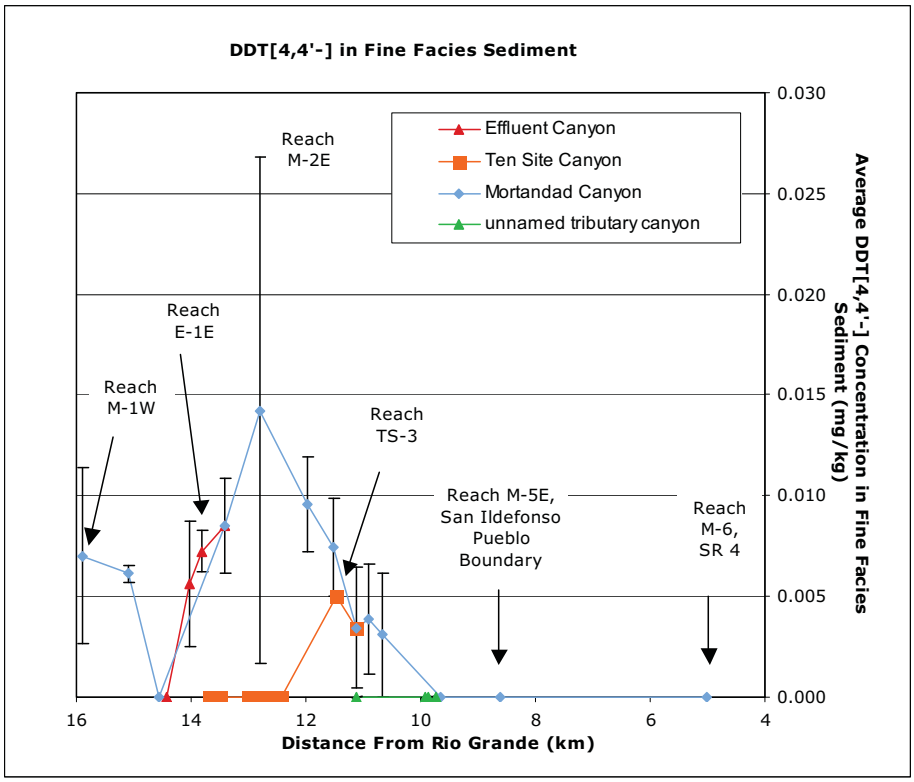
Notes: Error bars indicate upper and lower bounds based on replacing nondetect values with either the detection limit or zero. A value of zero is shown where there are no detected results.

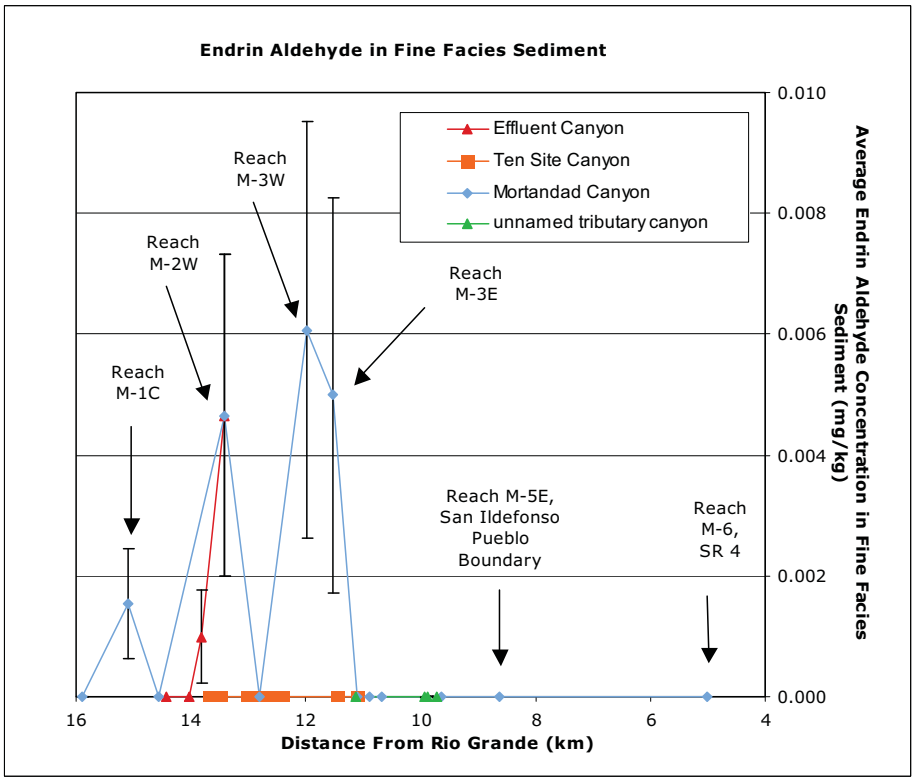
Figure 7.1-25. Estimated average concentrations of the PAHs benzo(a)pyrene and acenaphthene in fine facies sediment in the Mortandad watershed



Notes: Error bars indicate upper and lower bounds based on replacing nondetect values with either the detection limit or zero. A value of zero is shown where there are no detected results.

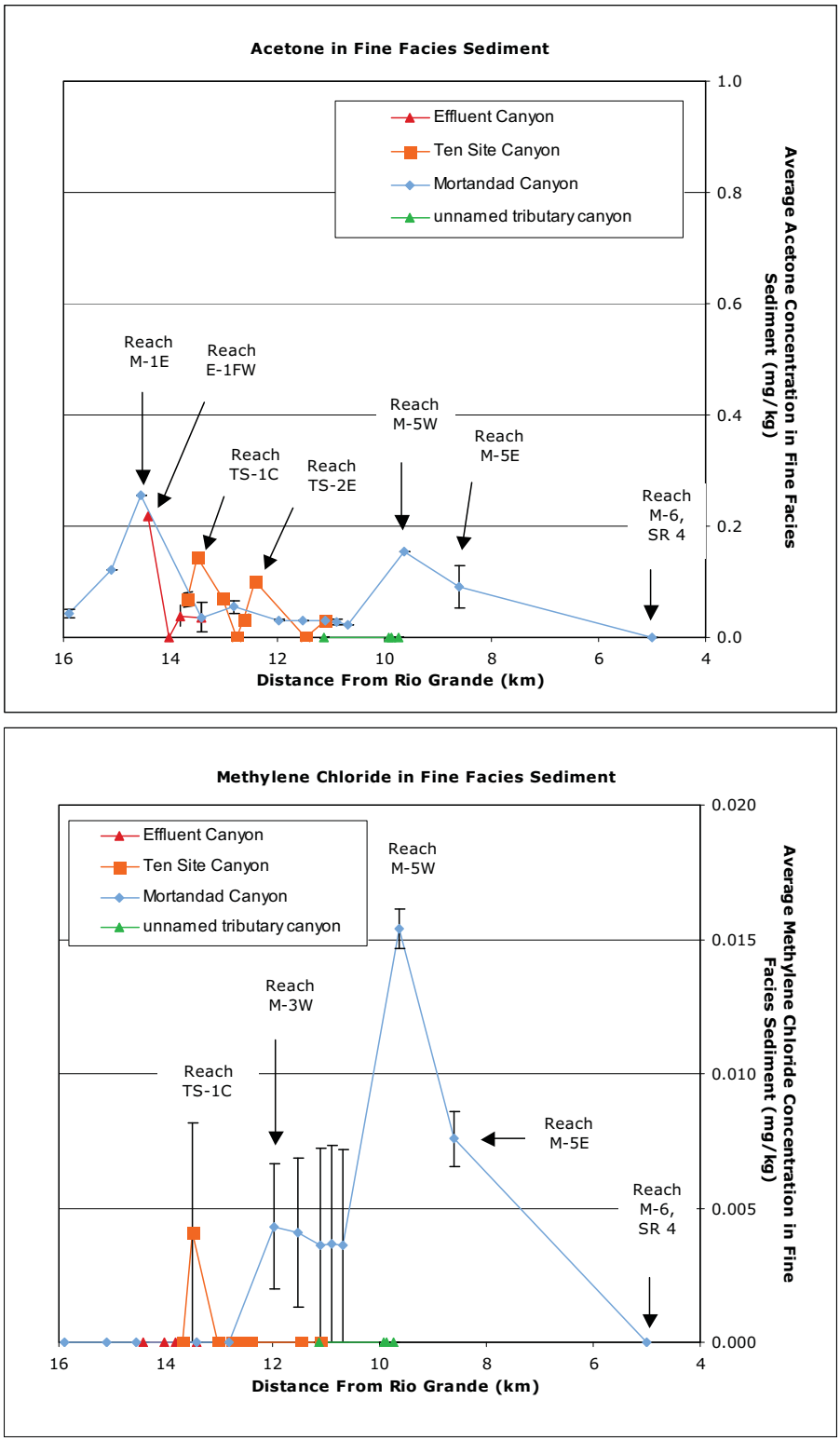
Figure 7.1-26. Estimated average concentrations of the SVOCs bis(2-ethylhexyl)phthalate and di-n-butylphthalate in fine facies sediment in the Mortandad watershed





Notes: Error bars indicate upper and lower bounds based on replacing nondetect values with either the detection limit or zero. A value of zero is shown where there are no detected results.

Figure 7.1-27. Estimated average concentrations of the pesticides DDT and endrin aldehyde in fine facies sediment in the Mortandad watershed



Notes: Error bars indicate upper and lower bounds based on replacing nondetect values with either the detection limit or zero. A value of zero is shown where there are no detected results.

Figure 7.1-28. Estimated average concentrations of the VOCs acetone and methylene chloride in fine facies sediment in the Mortandad watershed

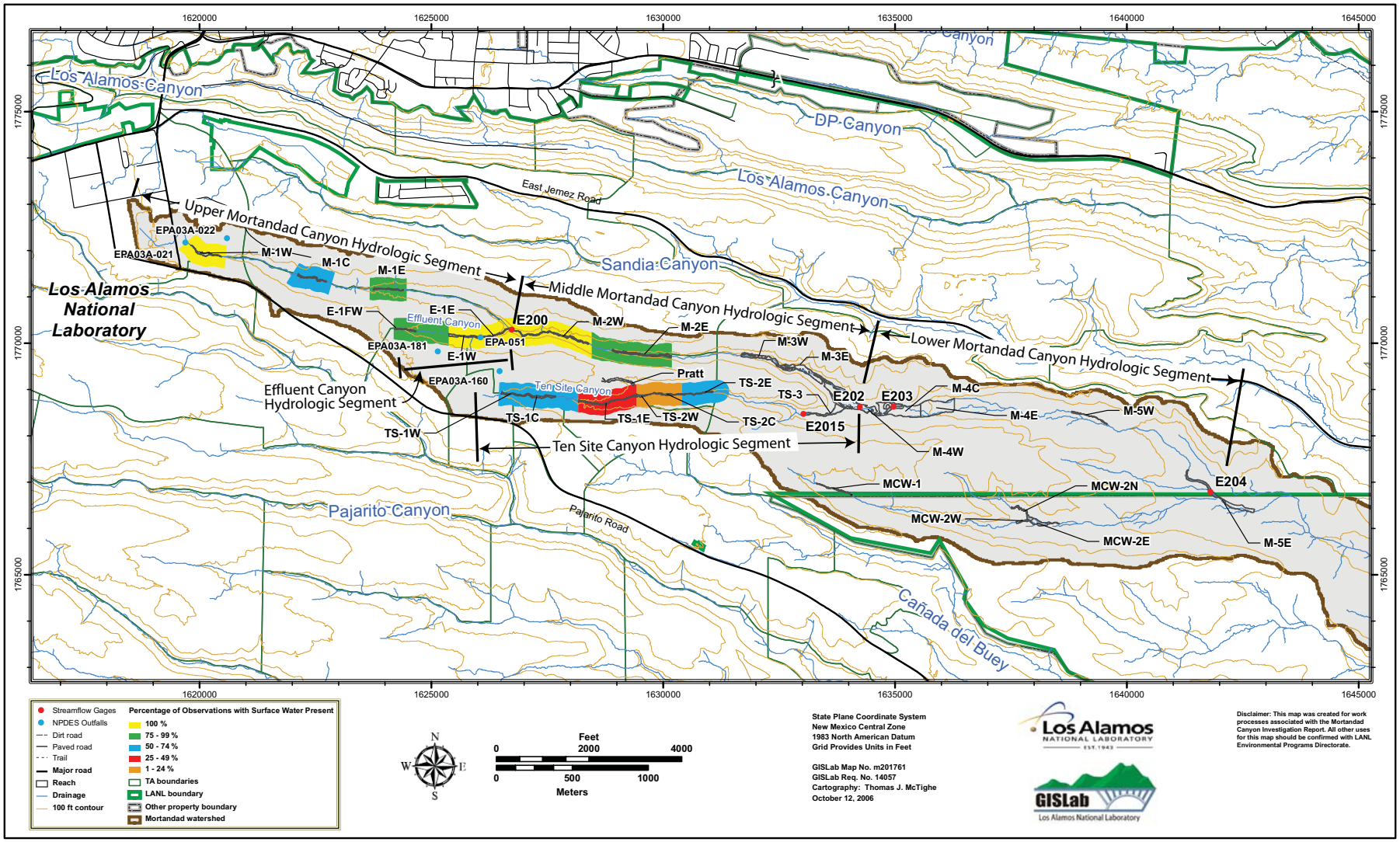


Figure 7.2-1. Mortandad watershed depicting different surface water occurrences, NPDES outfalls, and gaging stations

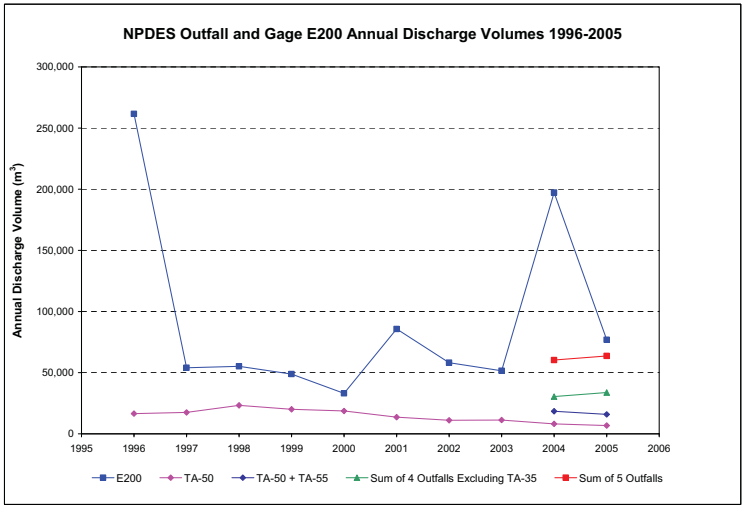


Figure 7.2-2. Comparison of NPDES outfall and gage E200 discharge volumes

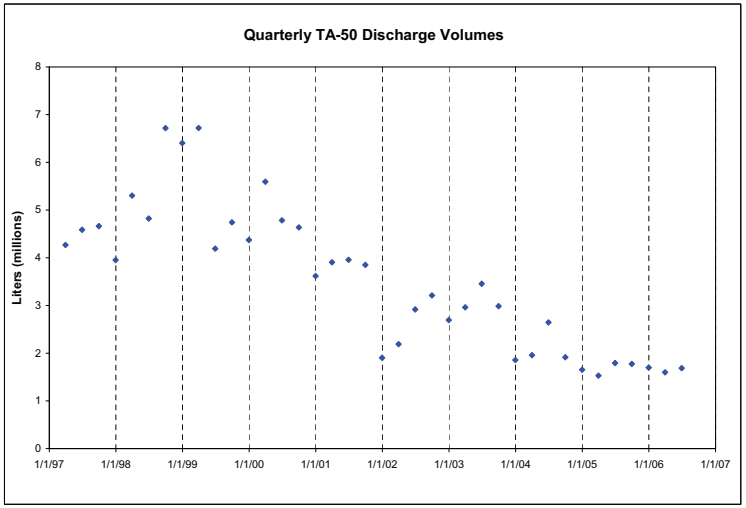


Figure 7.2-3. Seasonal variability in TA-50 RLWTF outfall discharges

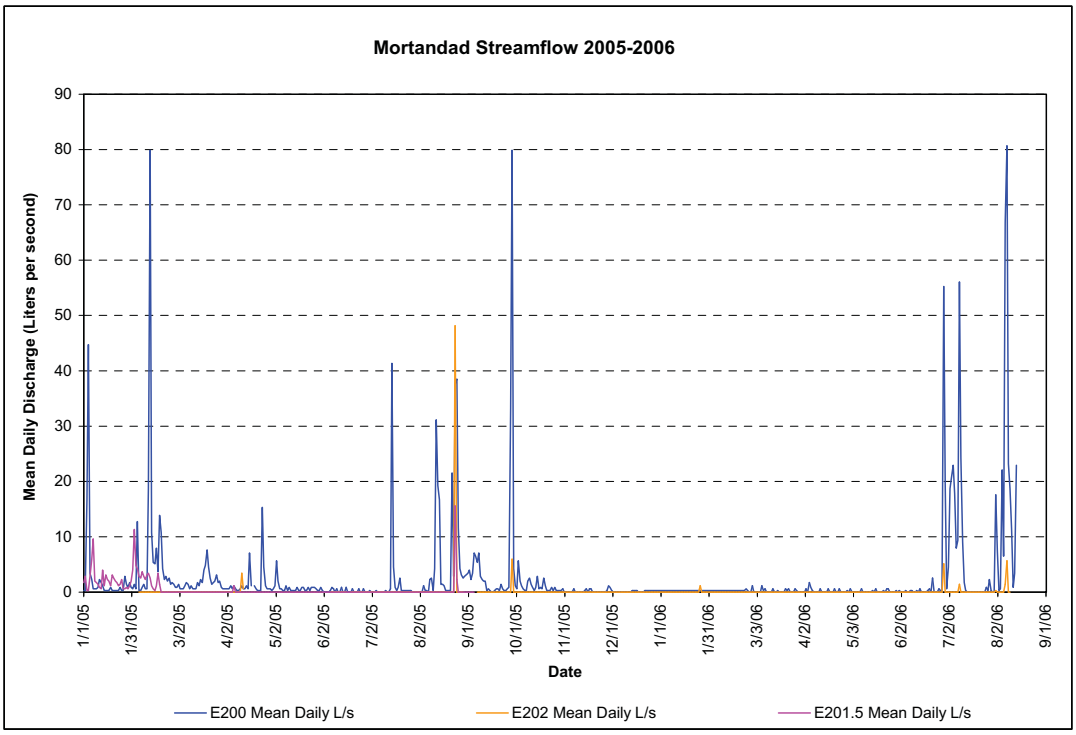


Figure 7.2-4. Mortandad Canyon streamflow during 2005–2006

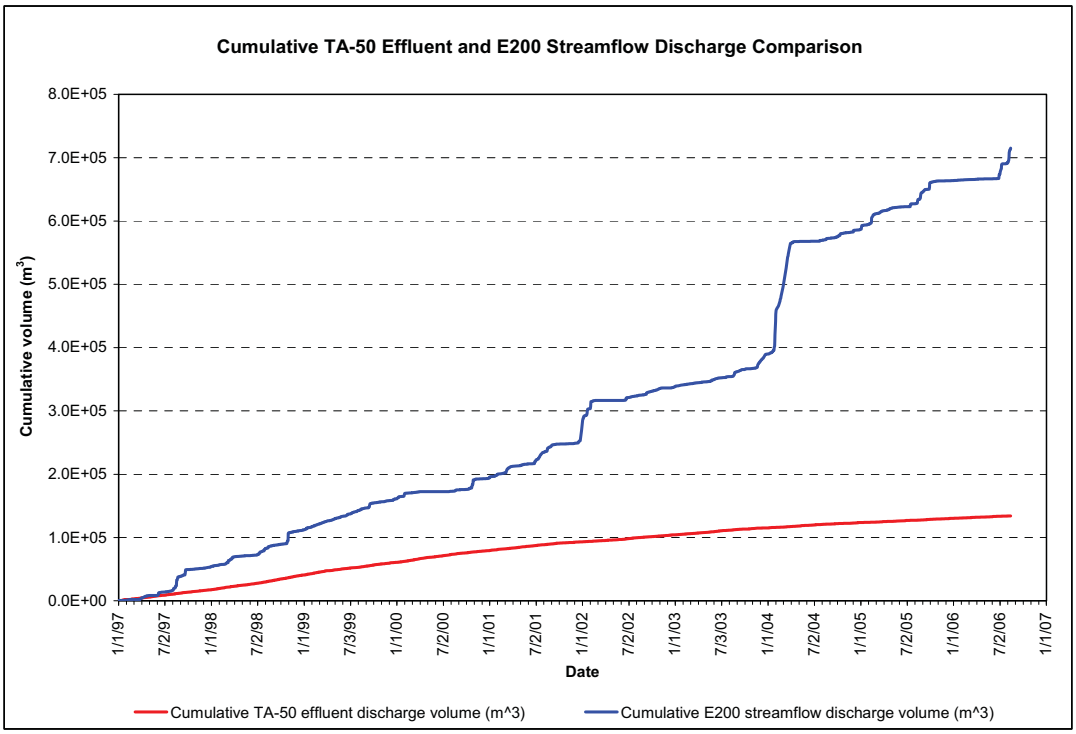
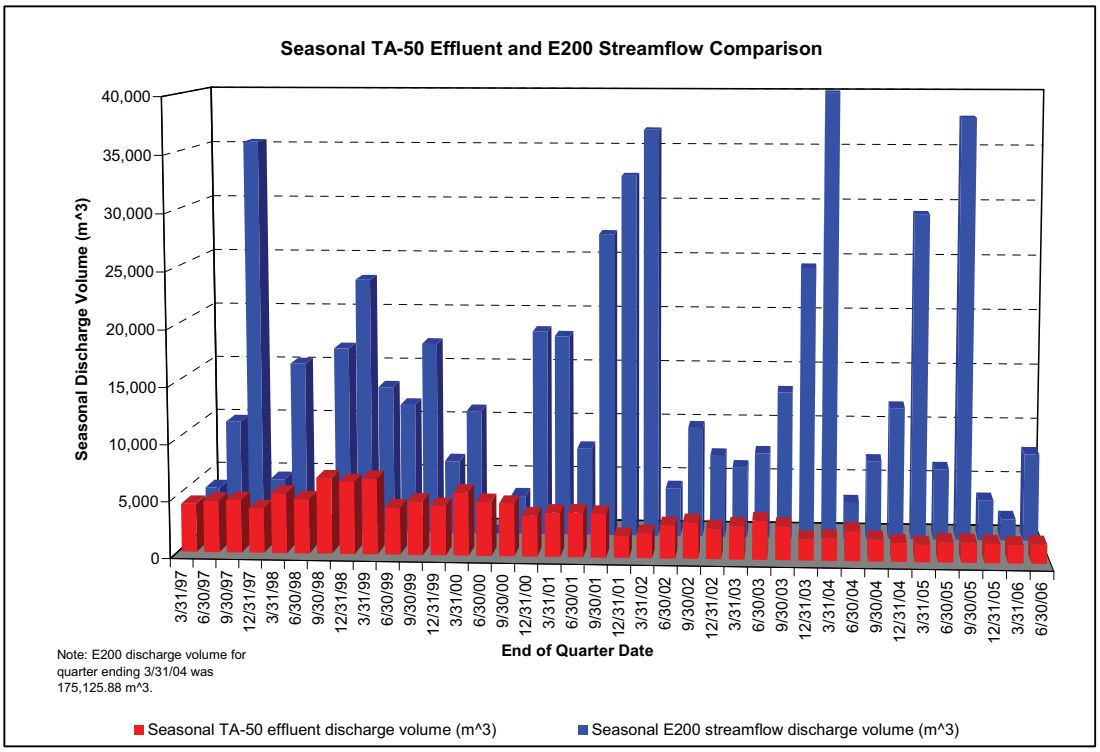


Figure 7.2-5. Comparison of cumulative TA-50 RLWTF outfall discharge and gage E200 streamflow volumes since 1997 using daily records



Note: Discharge volume for quarter ending 3/31/04 is off the chart at a volume exceeding 175,000 m^3.

Figure 7.2-6. Comparison of seasonal TA-50 RLWTF outfall discharge and gage E200 streamflow volumes since 1997

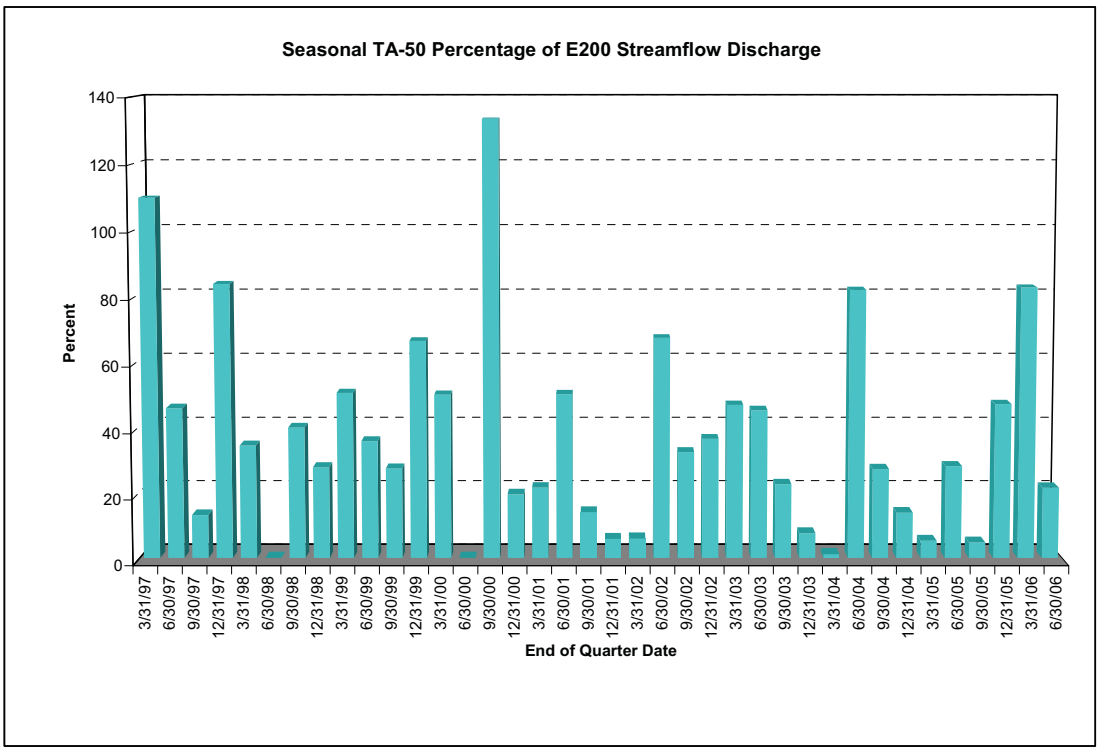


Figure 7.2-7. Seasonal TA-50 RLWTF outfall percentage of gage E200 total streamflow discharge

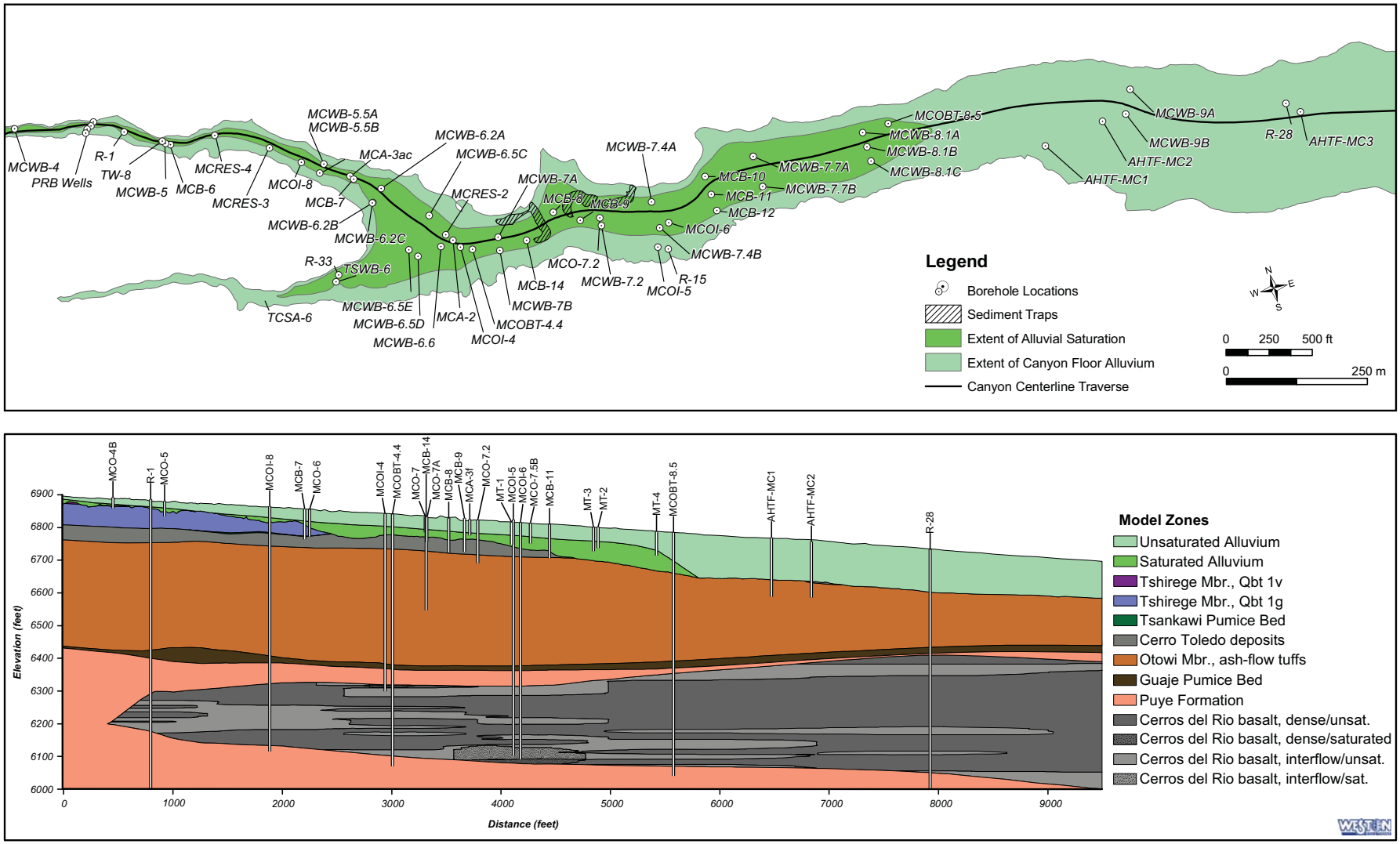


Figure 7.2-8. Map and cross section showing extent of alluvial groundwater in Mortandad Canyon

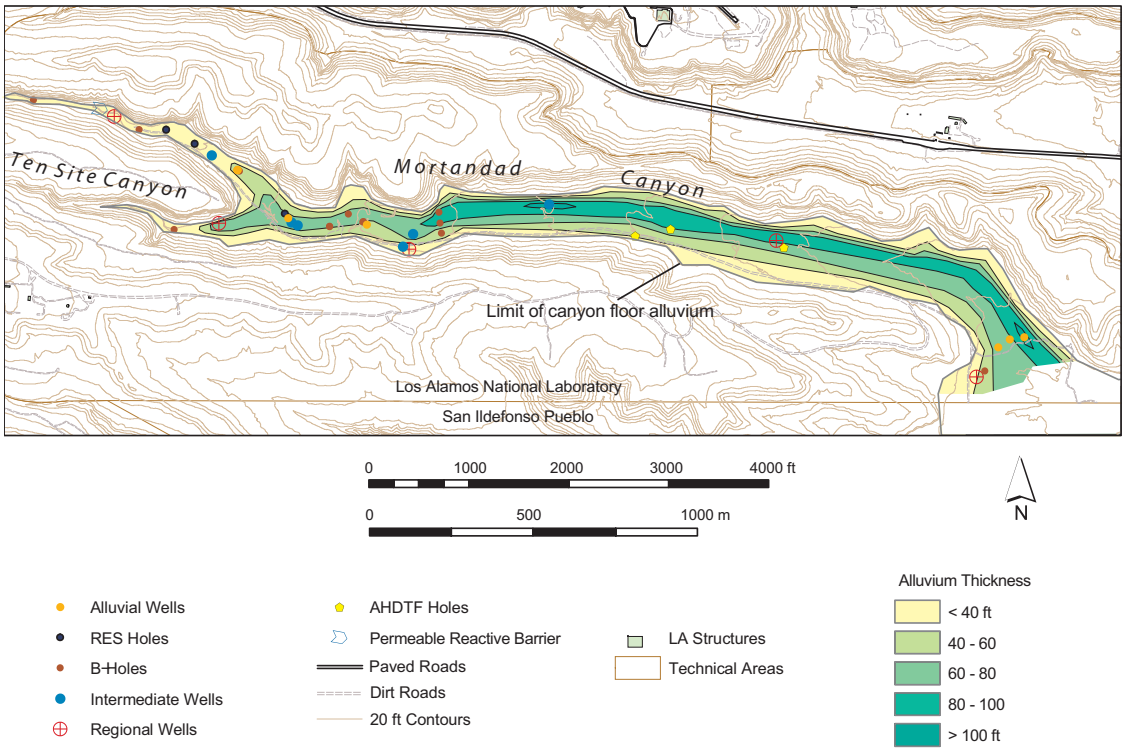
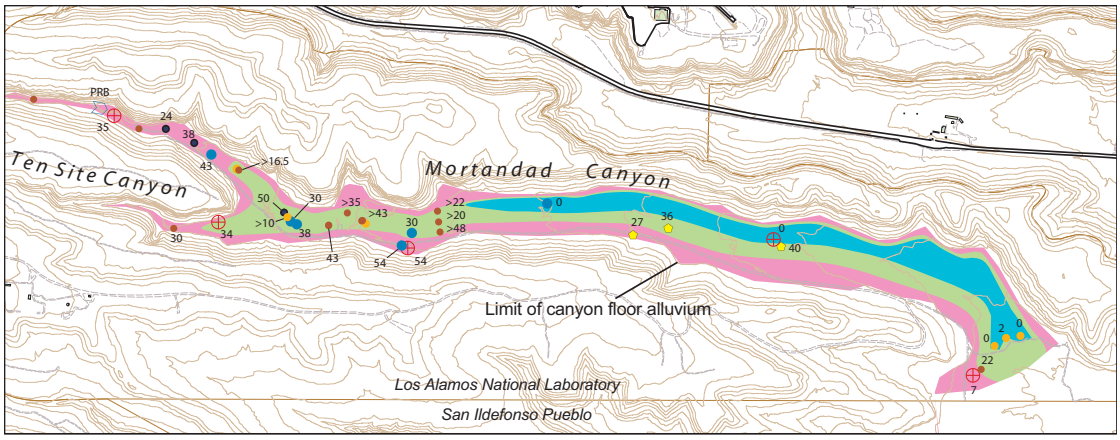


Figure 7.2-9. Map showing thickness of alluvium in Mortandad Canyon



Note: Numbers next to wells indicate thickness of Cerro Toledo interval in feet.

0 1000 2000 3000 4000 ft

0 500 1000 m

N

- Alluvial Wells
- RES Holes
- B-Holes
- Intermediate Wells
- Regional Wells
- AHDTF Holes
- Permeable Reactive Barrier
- Paved Roads
- Dirt Roads
- 20 ft Contours
- LA Structures
- Technical Areas

Bedrock Units Underlying Qal Beneath the Canyon Floor

- Tshirege Member, Qbt 1g
- Cerro Toledo Interval
- Otowi Member

Figure 7.2-10. Distribution of geologic bedrock units beneath alluvium in Mortandad Canyon

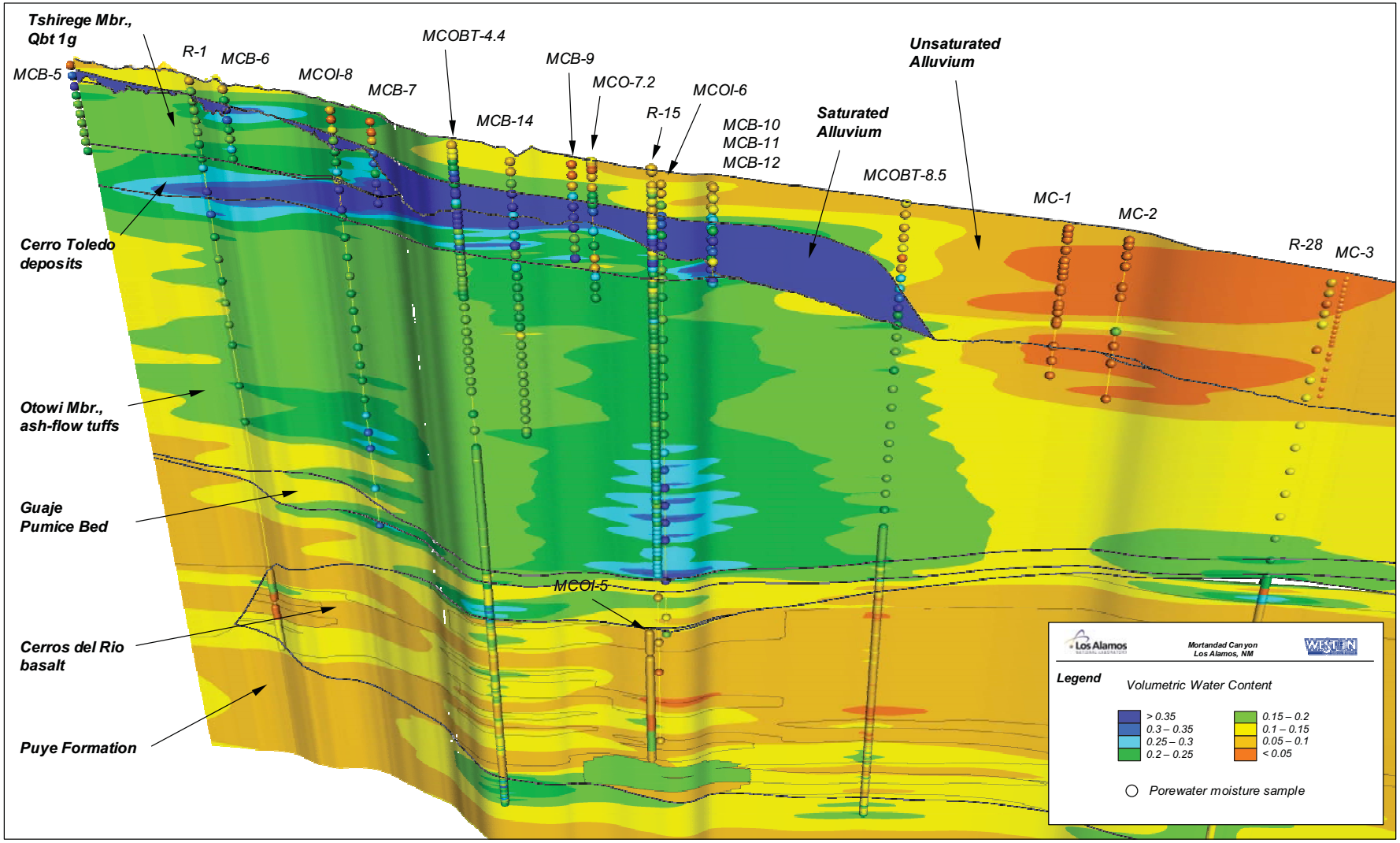


Figure 7.2-11. Cross section showing estimated volumetric moisture content based on borehole porewater measurements and saturated conditions occurring in alluvium and perched-intermediated groundwater

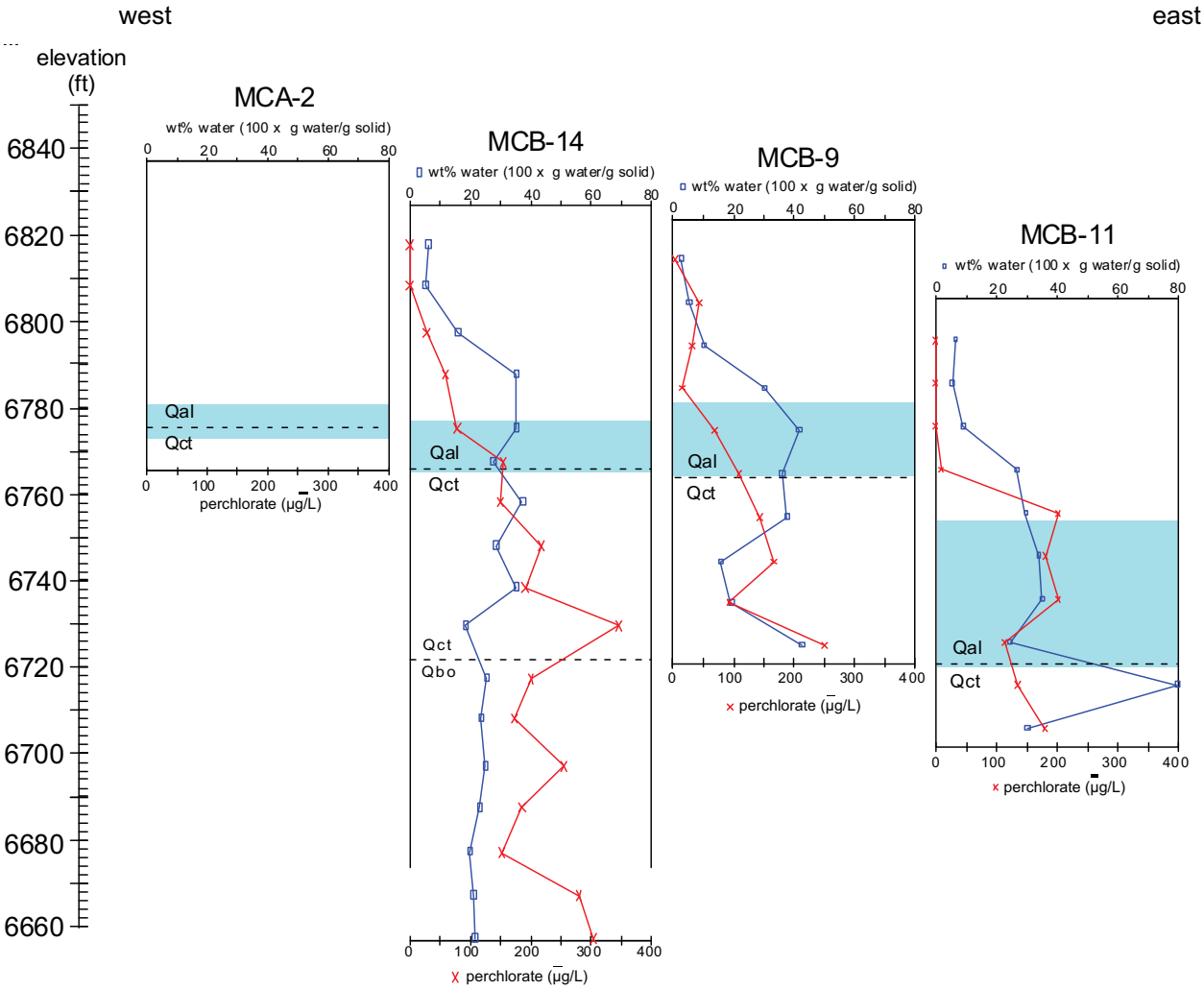
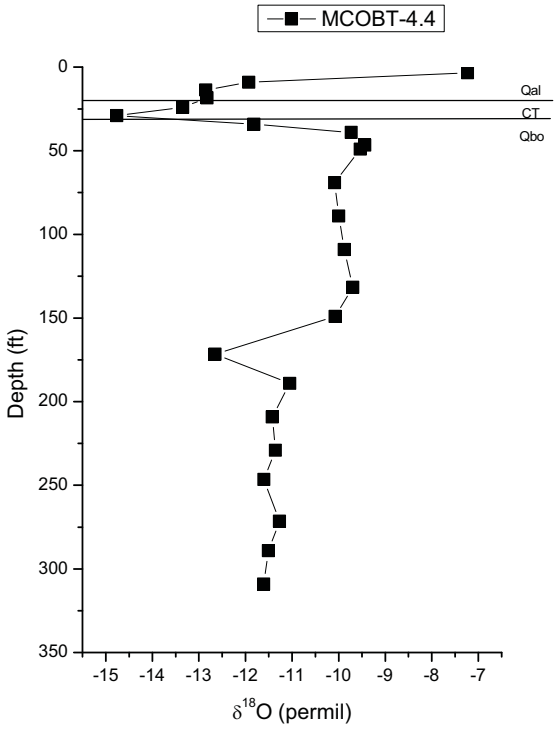


Figure 7.2-12. Comparison of alluvial groundwater occurrences (blue-shaded areas) with moisture and perchlorate profiles in wells MCA-2, MCB-9, MCB-11 and MCB-14



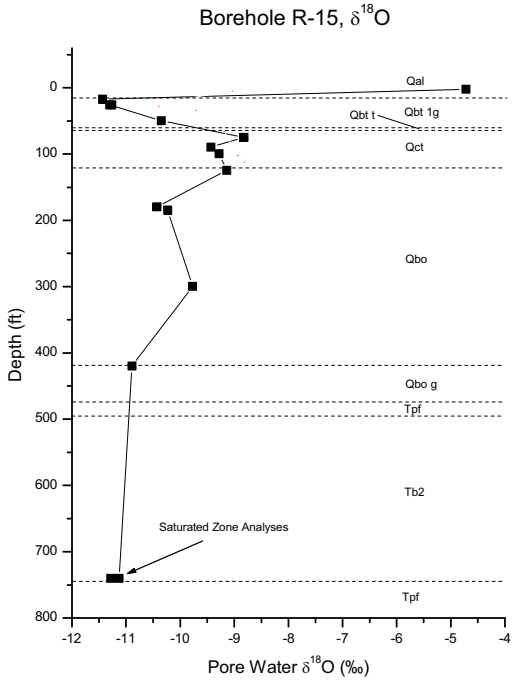


Figure 7.2-13. Oxygen isotope profiles for boreholes MCOBT-4.4, R-15 and MCOBT-8.5

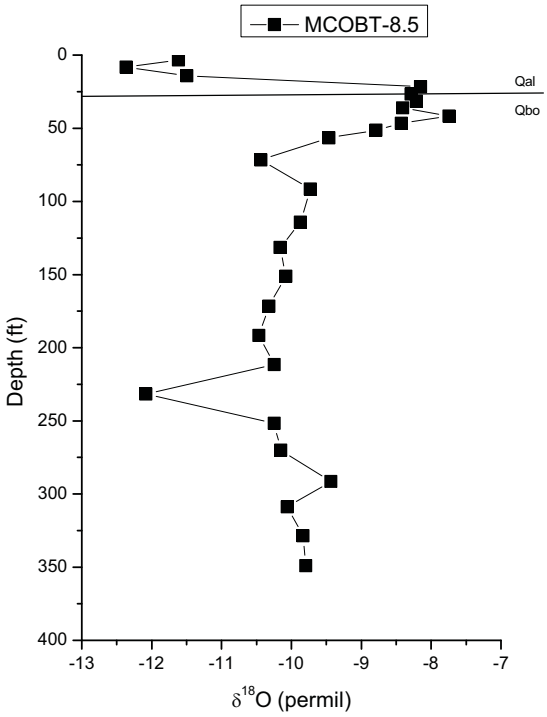


Figure 7.2-13 (continued). Oxygen isotope profiles for boreholes MCOBT-4.4, R-15 and MCOBT-8.5

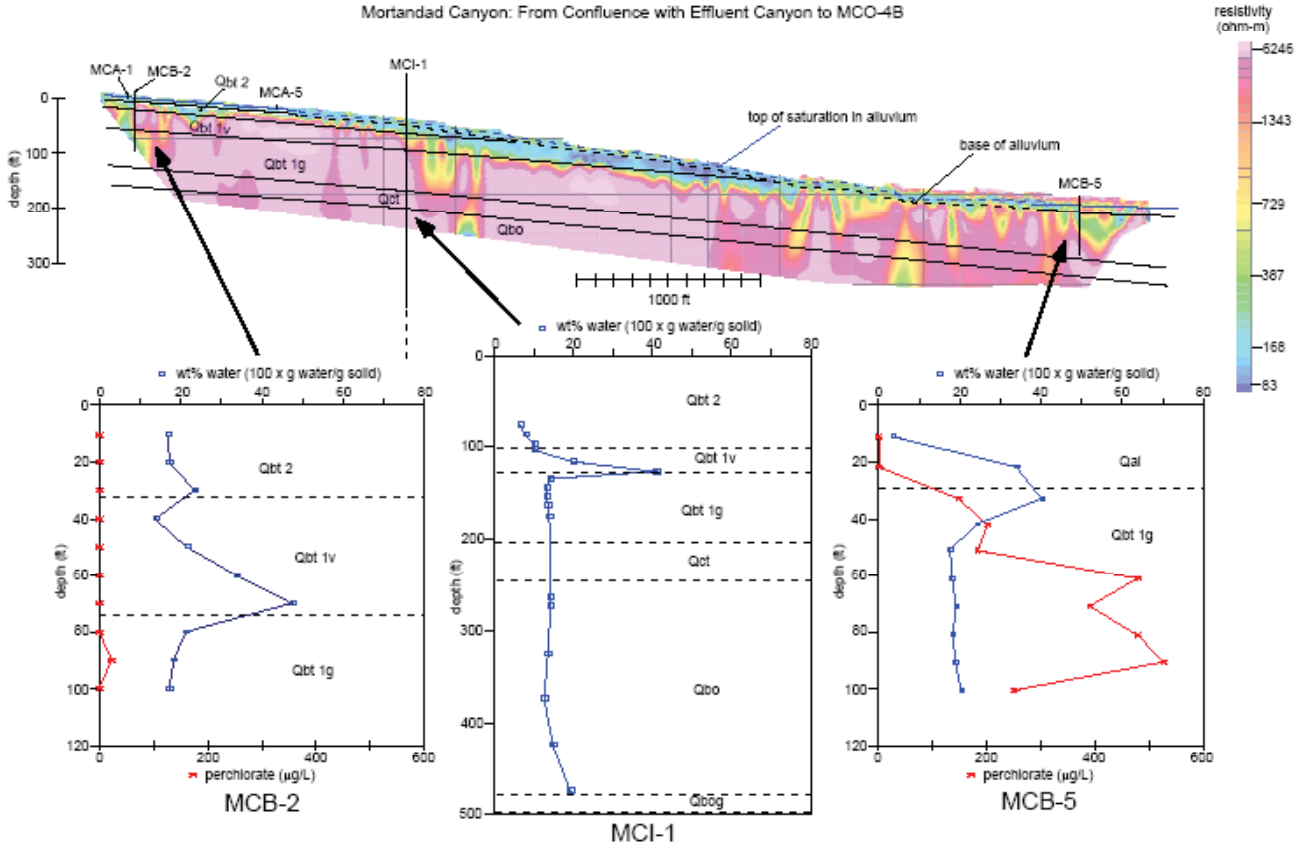


Figure 7.2-14. DC Resistivity profiles results compared to vadose-zone gravimetric moisture and porewater perchlorate concentrations for boreholes MCB-2, MCIO-I and MCB-5

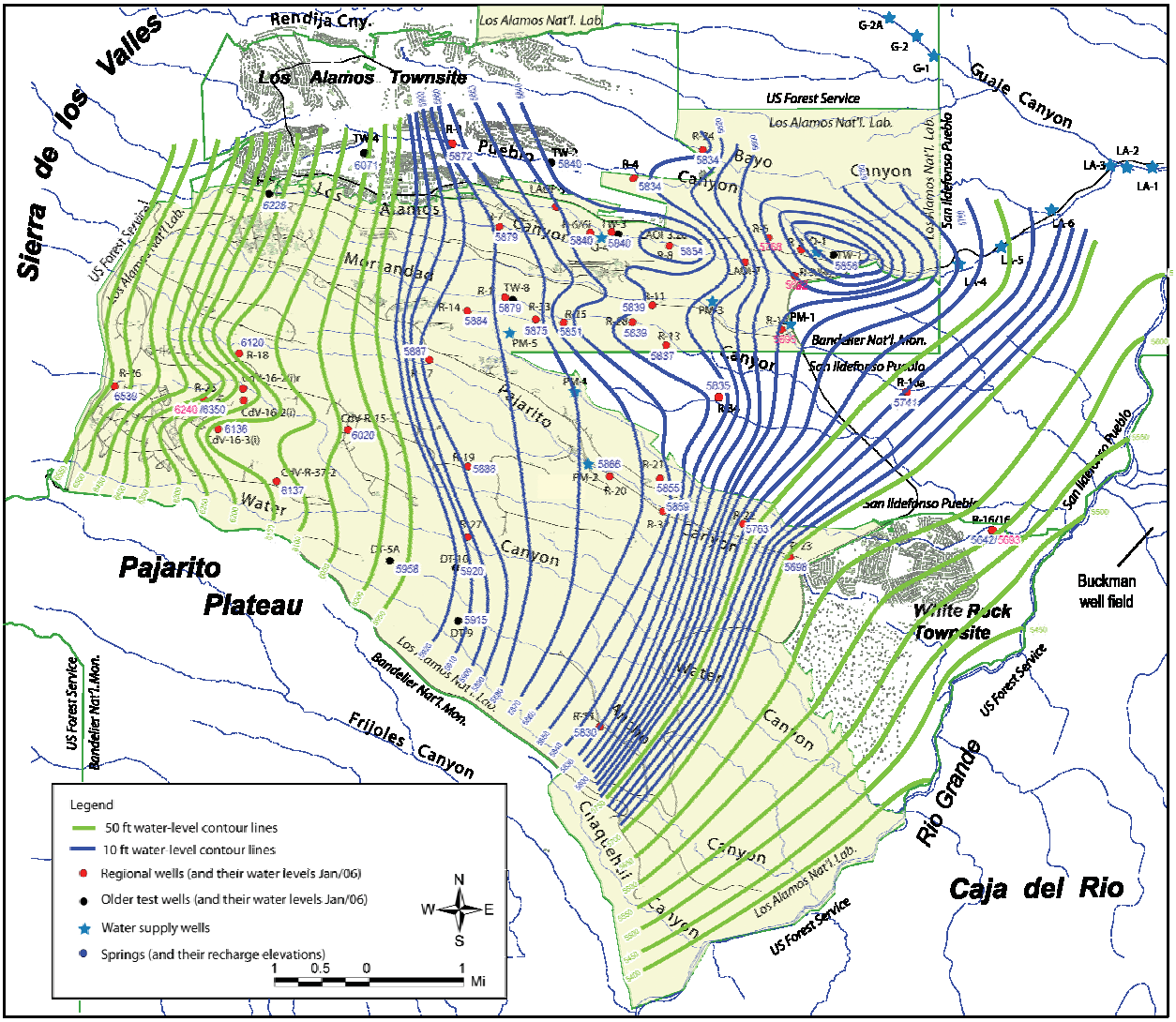
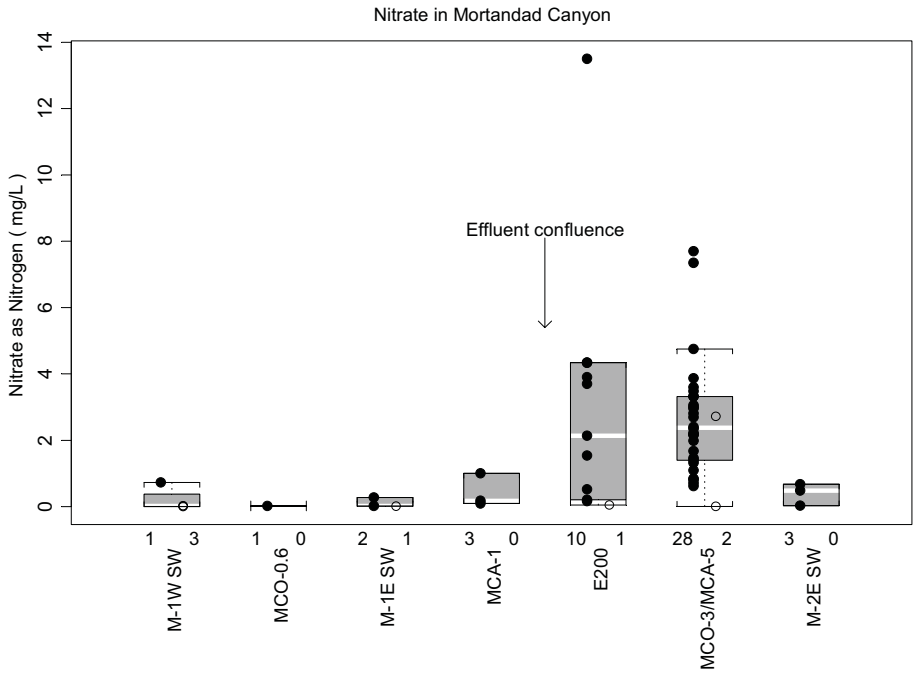
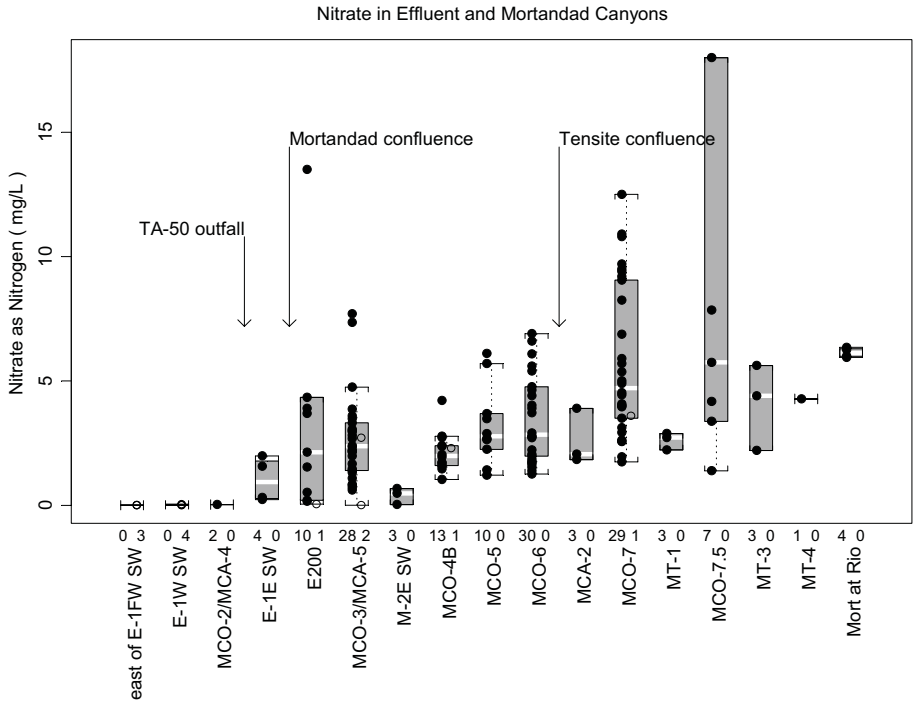


Figure 7.2-15. Water-table map based on January 2006 water-level data

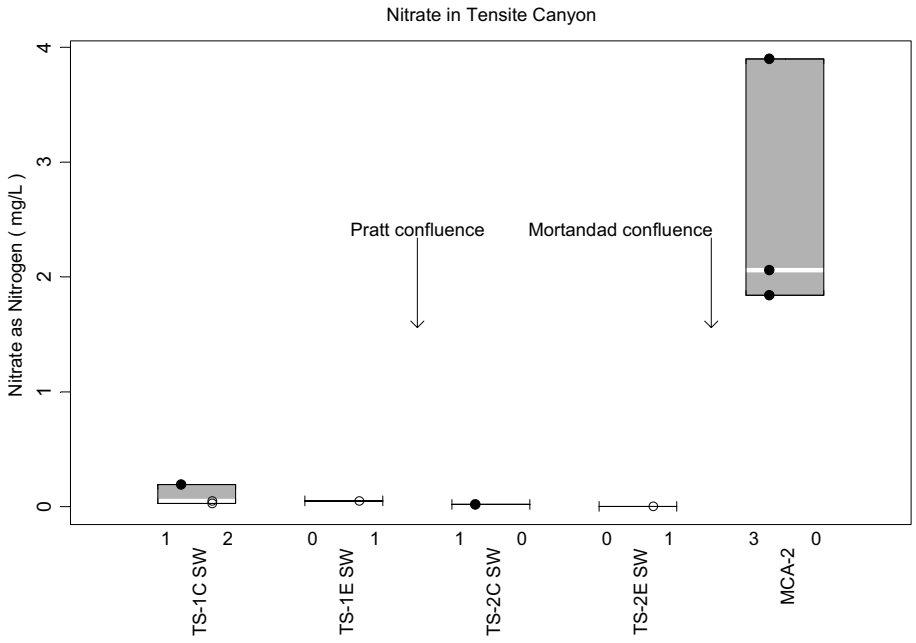


(a)



(b)

Figure 7.2-16. Box plots showing the spatial distribution of nitrate (as N) at surface water and alluvial groundwater locations in both filtered and non-filtered samples (a) the upper Mortandad Canyon hydrologic segment, (b) in Effluent Canyon and in Mortandad Canyon between the Effluent Canyon confluence and the Rio Grande, (c) in Ten Site Canyon to just past the Mortandad Canyon confluence



(c)

Figure 7.2-16 (continued). Box plots showing the spatial distribution of nitrate (as N) at surface water and alluvial groundwater locations in both filtered and non-filtered samples (a) the upper Mortandad Canyon hydrologic segment, (b) in Effluent Canyon and in Mortandad Canyon between the Effluent Canyon confluence and the Rio Grande, (c) in Ten Site Canyon to just past the Mortandad Canyon confluence

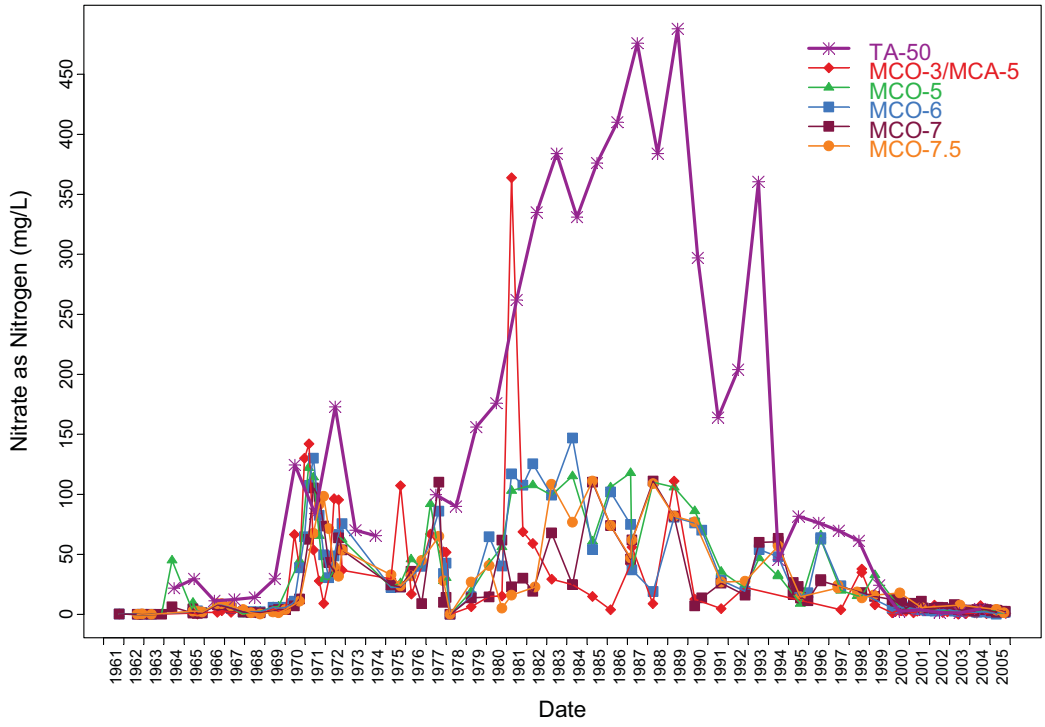


Figure 7.2-17. Comparison of nitrate concentrations (as N, mg/L) in TA-50 RLWTF effluent to those in down-gradient alluvial wells - history since 1960s

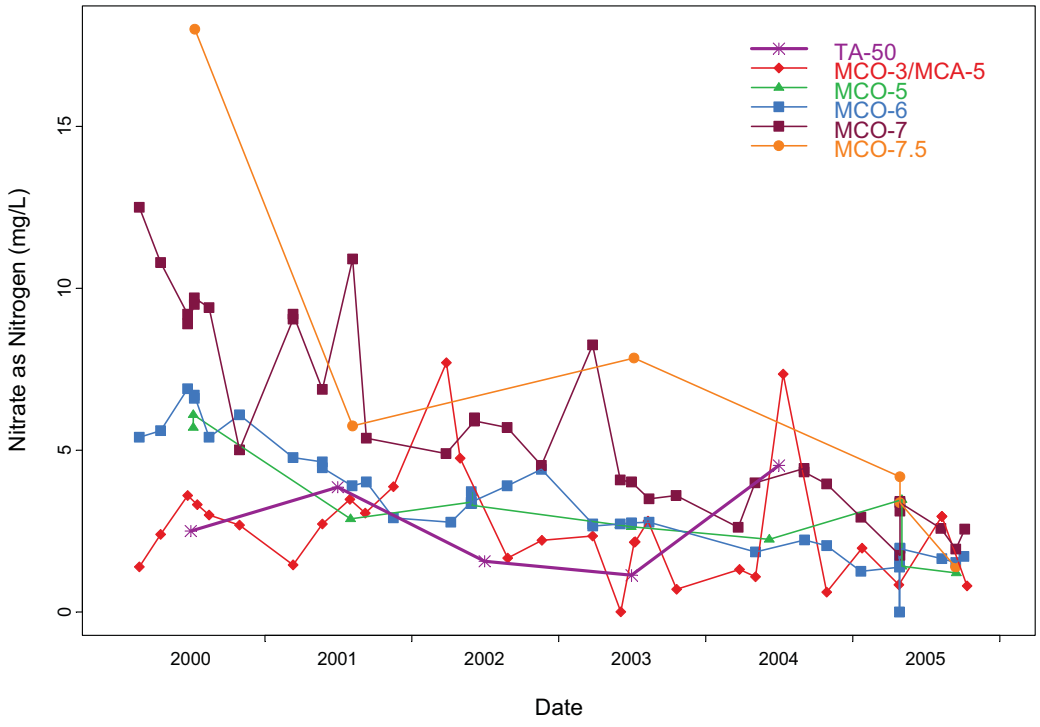


Figure 7.2-18. Comparison of nitrate concentrations (as N, mg/L) in TA-50 RLWTF effluent to those in down-gradient alluvial wells - history since 2000

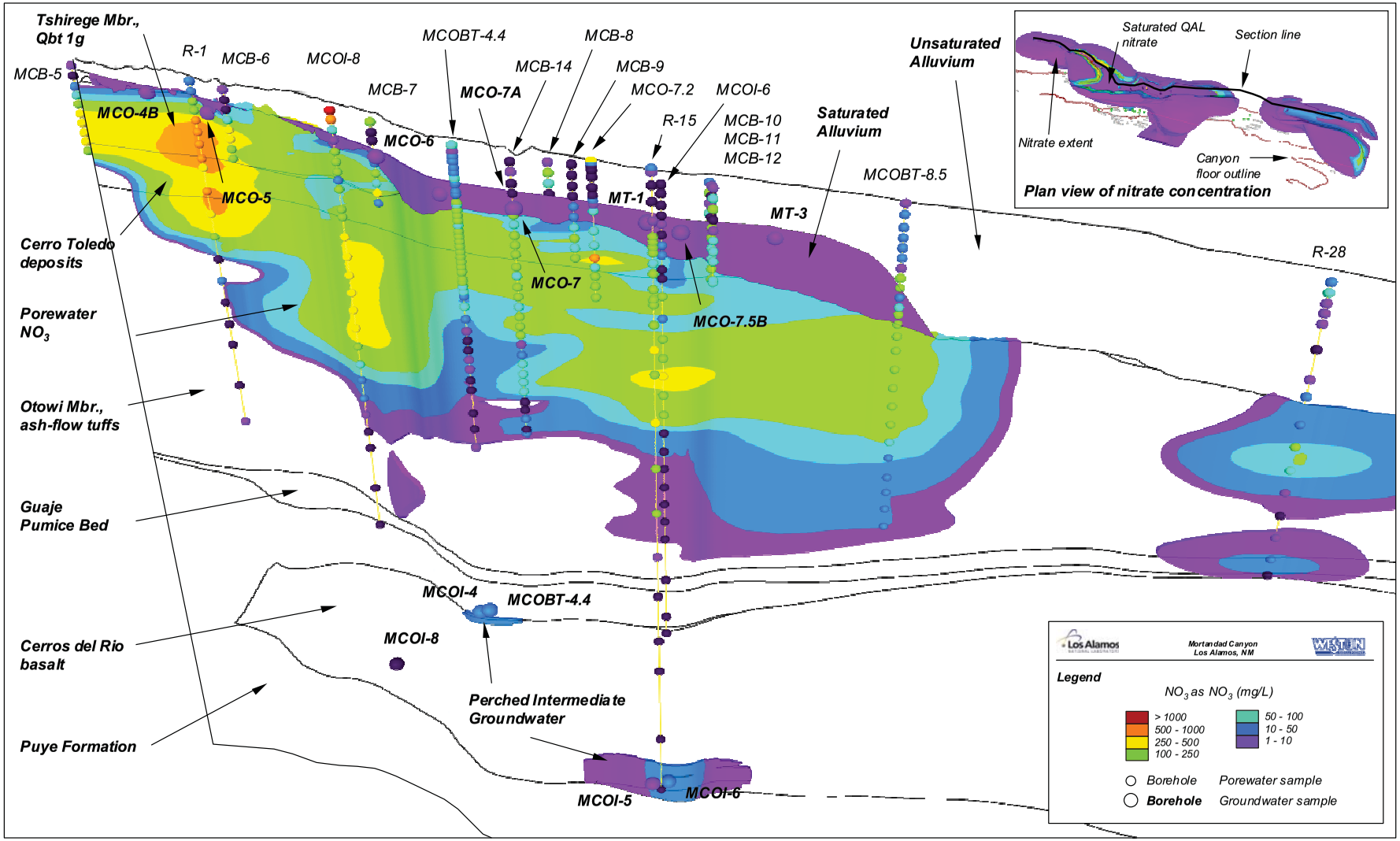


Figure 7.2-19. Cross section showing estimated nitrate concentrations (NO_3 as NO_3, mg/L) in Mortandad Canyon vadose-zone pore water and perched-intermediate groundwater

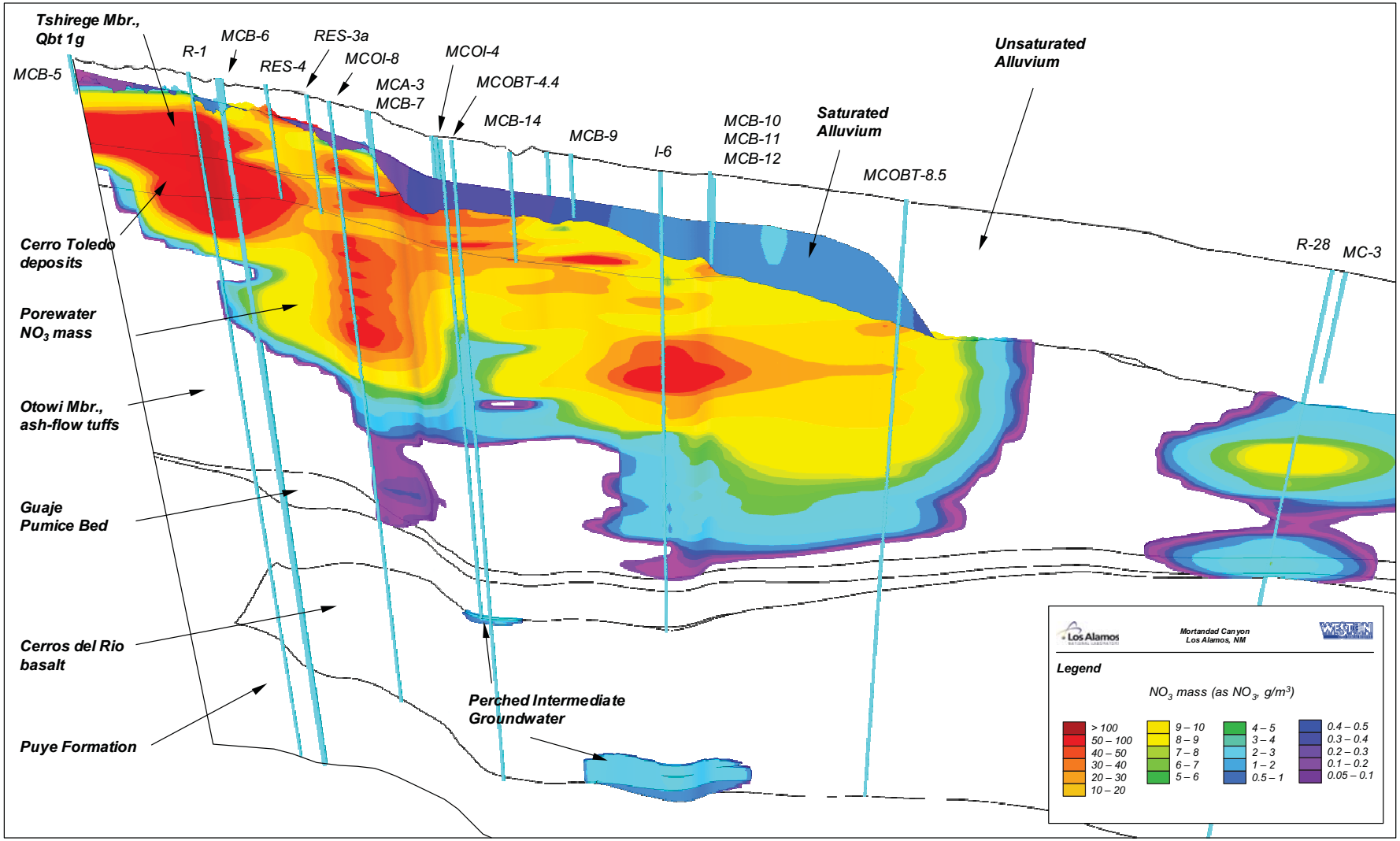


Figure 7.2-20. Cross section showing estimated nitrate mass (g NO_3 as NO_3/m^3 rock) distribution located within Mortandad Canyon vadose-zone pore water and perched-intermediate groundwater

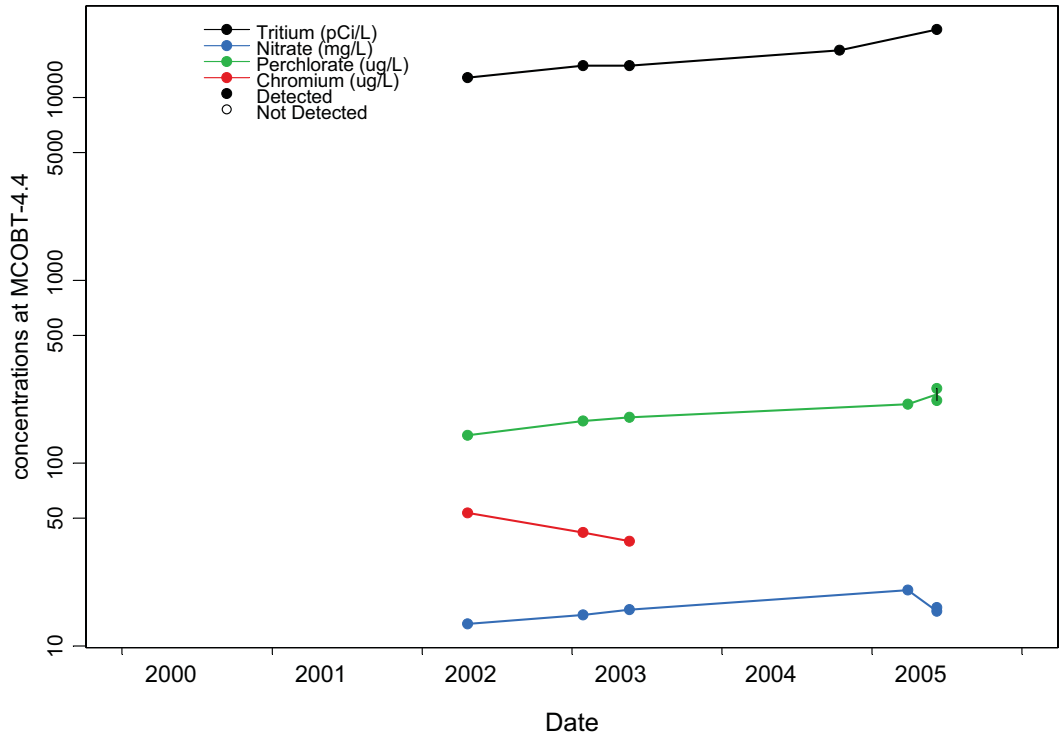


Figure 7.2-21. Concentrations of nitrate (as N), perchlorate, filtered chromium and tritium in perched-intermediate groundwater for period of record in well MCOBT-4.4

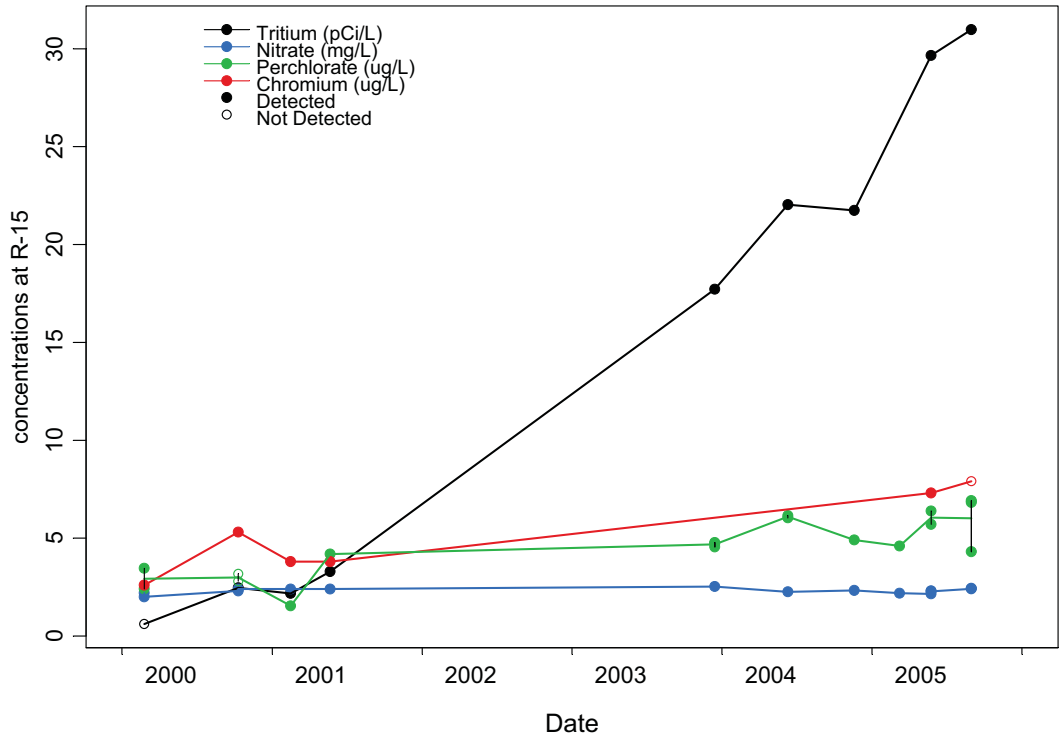


Figure 7.2-22. Concentrations of nitrate (as N), perchlorate, filtered chromium and tritium in regional groundwater for period of record in well R-15

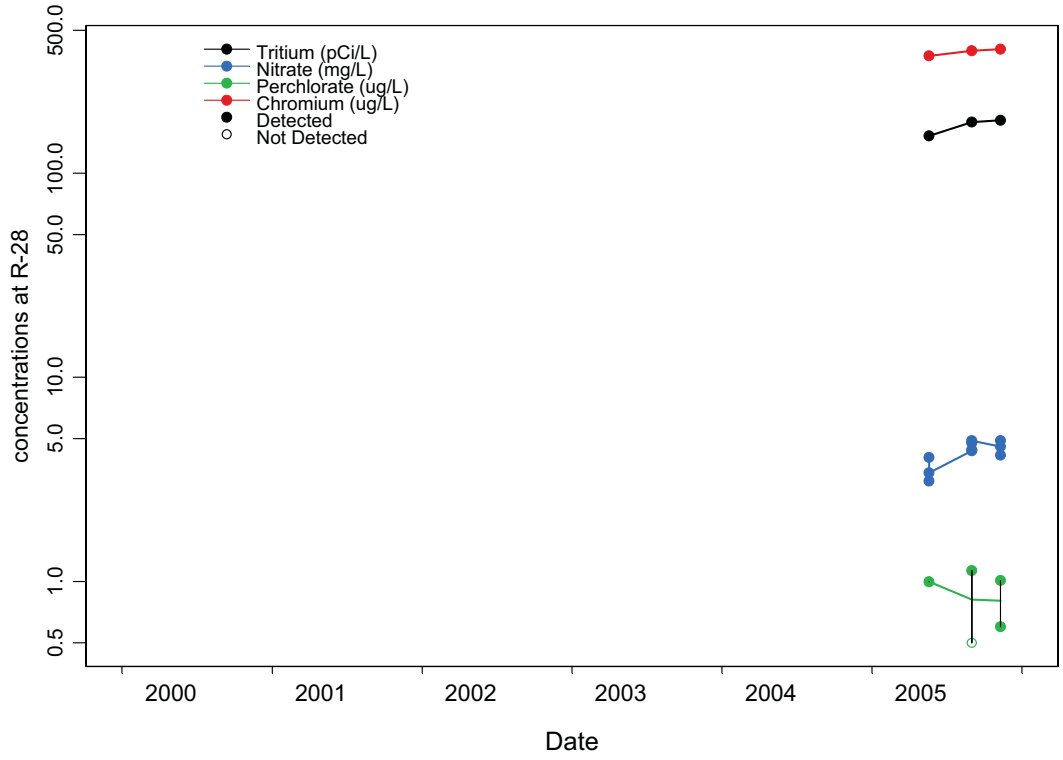
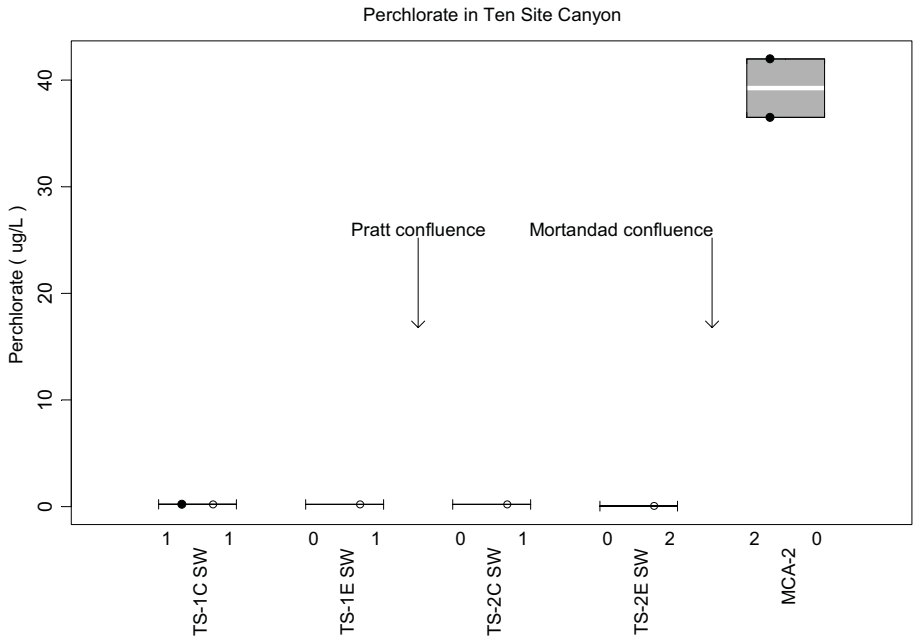
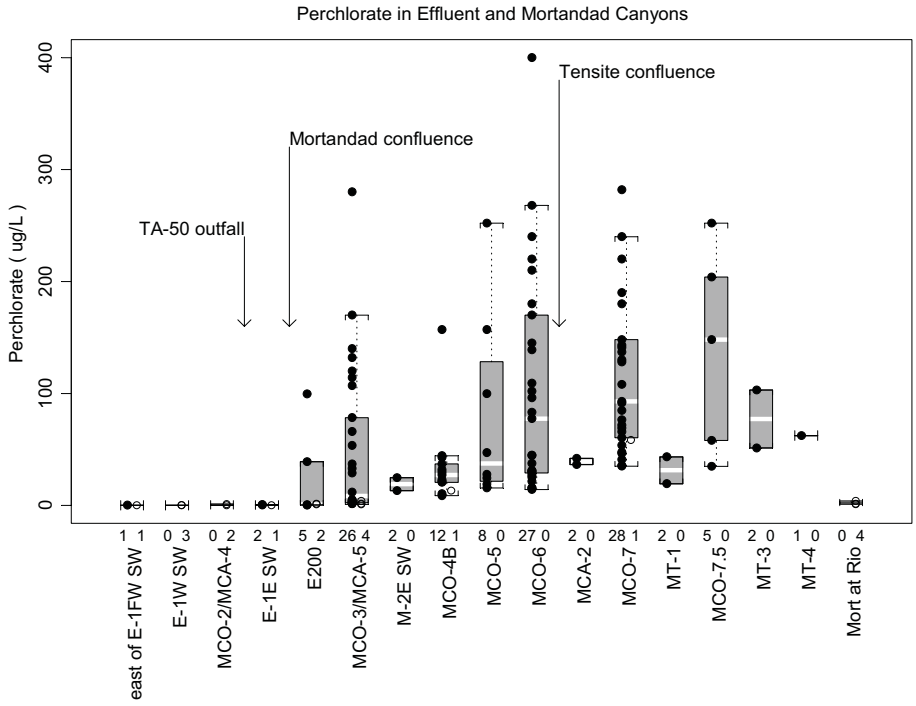


Figure 7.2-23. Concentrations of nitrate (as N), perchlorate, filtered chromium and tritium in regional groundwater for period of record in well R-28

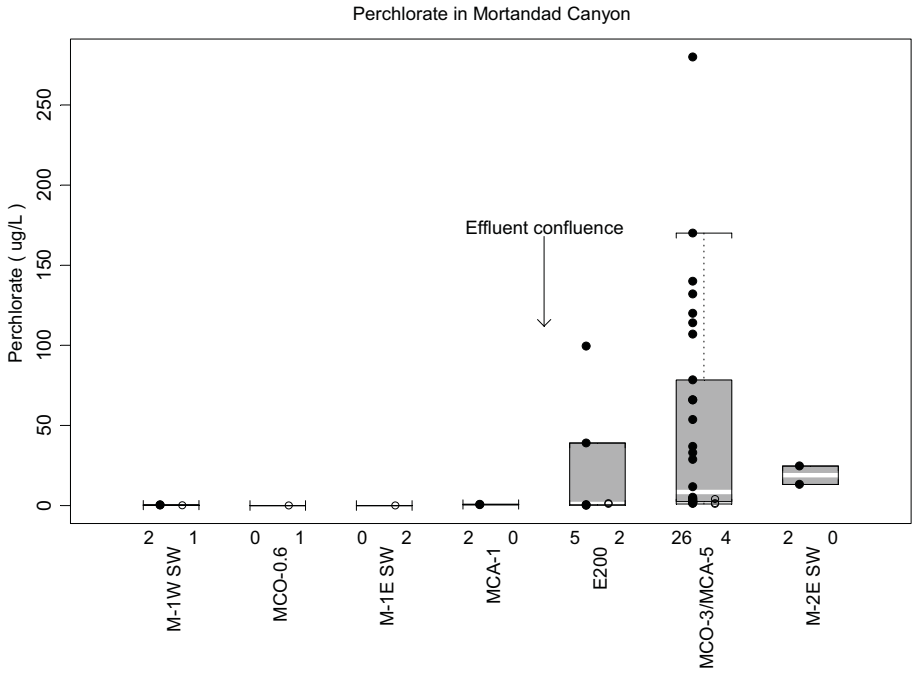


(a)



(b)

Figure 7.2-24. Box plots showing the spatial distribution of perchlorate (μg/L) at surface water and alluvial groundwater locations in both filtered and non-filtered samples (a) the upper Mortandad Canyon hydrologic segment, (b) in Effluent Canyon and in Mortandad Canyon between the Effluent Canyon confluence and the Rio Grande, (c) in Ten Site Canyon to just past the Mortandad Canyon confluence



(c)

Figure 7.2-24 (continued). Box plots showing the spatial distribution of perchlorate (µg/L) at surface water and alluvial groundwater locations in both filtered and non-filtered samples (a) the upper Mortandad Canyon hydrologic segment, (b) in Effluent Canyon and in Mortandad Canyon between the Effluent Canyon confluence and the Rio Grande, (c) in Ten Site Canyon to just past the Mortandad Canyon confluence

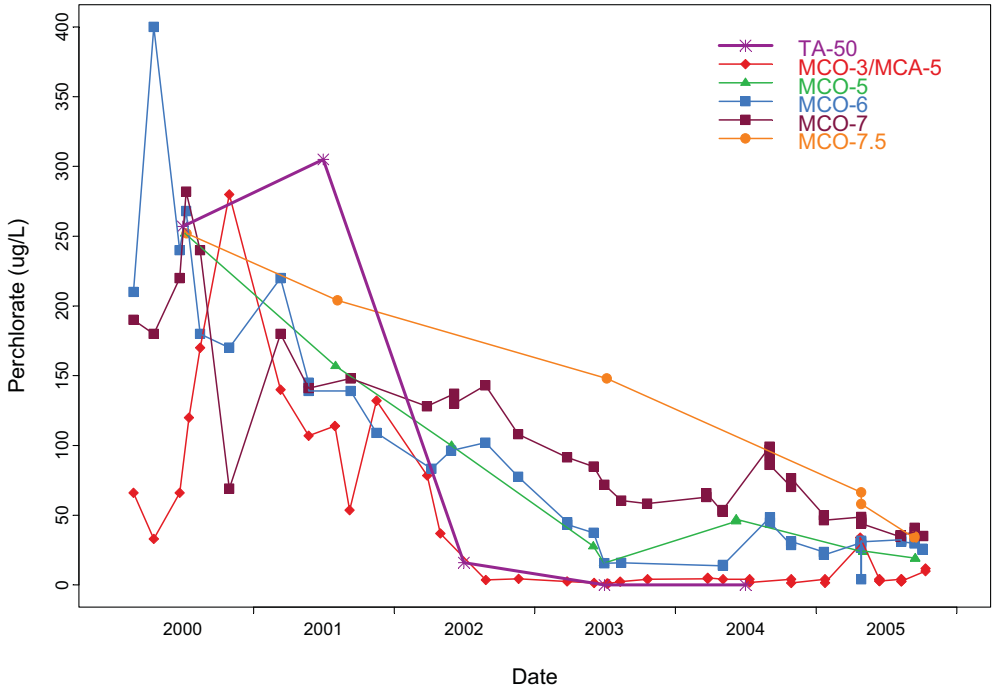


Figure 7.2-25. Comparison of perchlorate concentrations (µg/L) in TA-50 RLWTF effluent to those in down-gradient alluvial wells - history since 2000

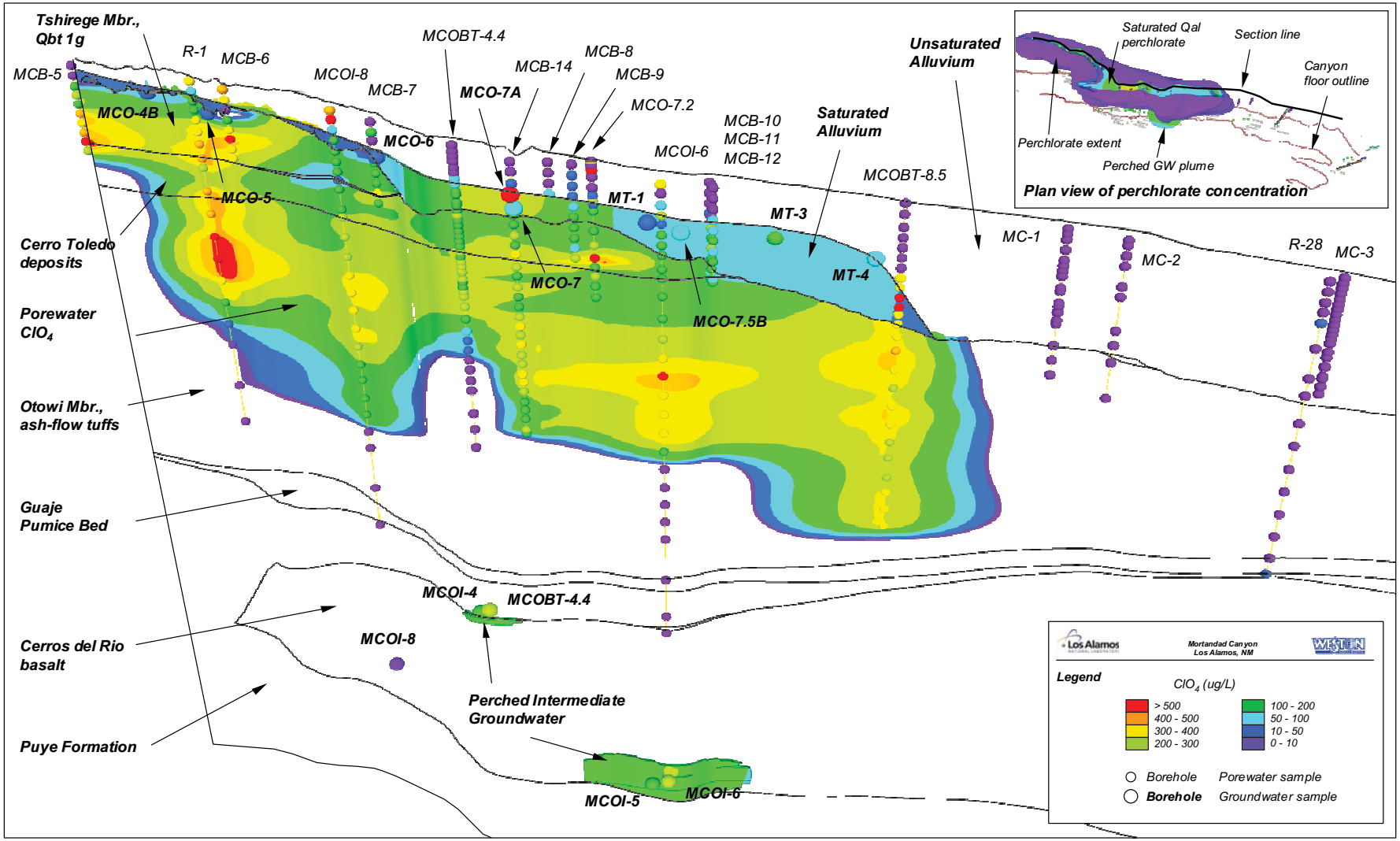


Figure 7.2-26. Cross section showing estimated perchlorate concentration (µg/L) in Mortandad Canyon vadose-zone pore water and perched-intermediate groundwater

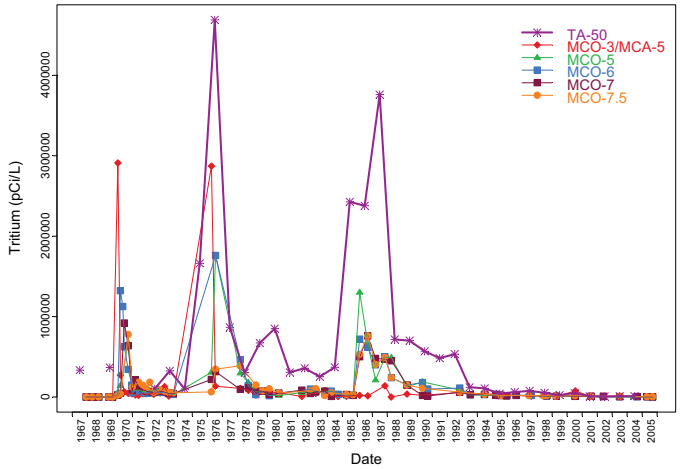


Figure 7.2-27. Comparison of tritium concentrations (pCi/L) in TA-50 RLWTF effluent to those in down-gradient alluvial wells - history since 1960s

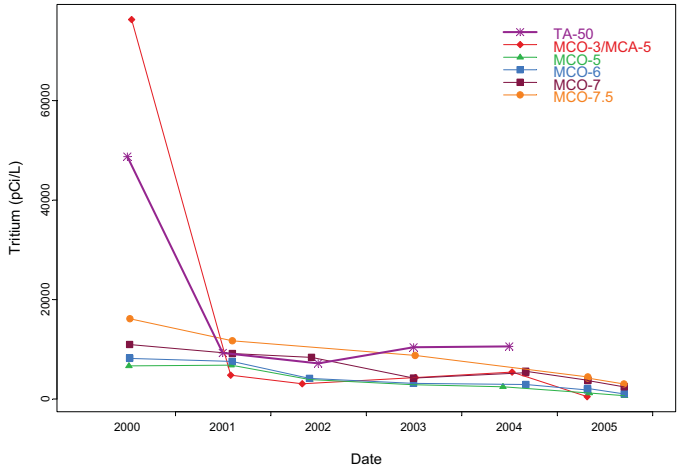


Figure 7.2-28. Comparison of tritium concentrations (pCi/L) in TA-50 RLWTF effluent to those in down-gradient alluvial wells - history since 2000

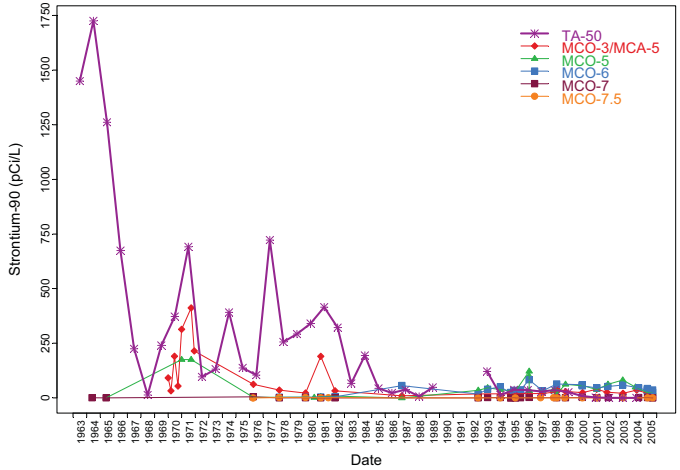


Figure 7.2-29. Comparison of strontium-90 concentrations (pCi/L) in TA-50 RLWTF effluent to those in down-gradient alluvial wells - history since 1960s

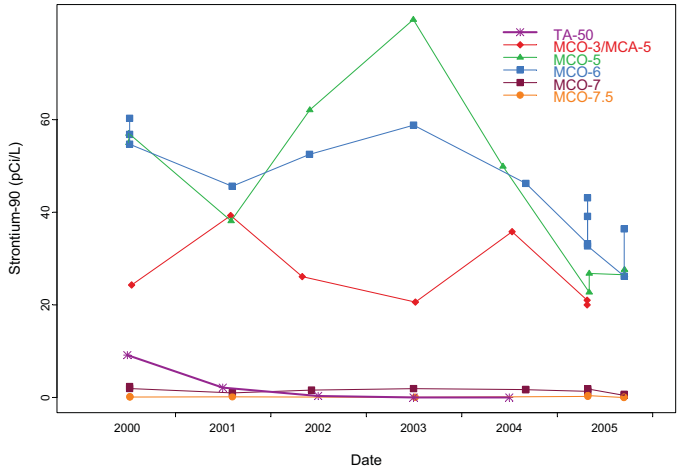


Figure 7.2-30. Comparison of strontium-90 concentrations (pCi/L) in TA-50 RLWTF effluent to those in down-gradient alluvial wells - history since 2000

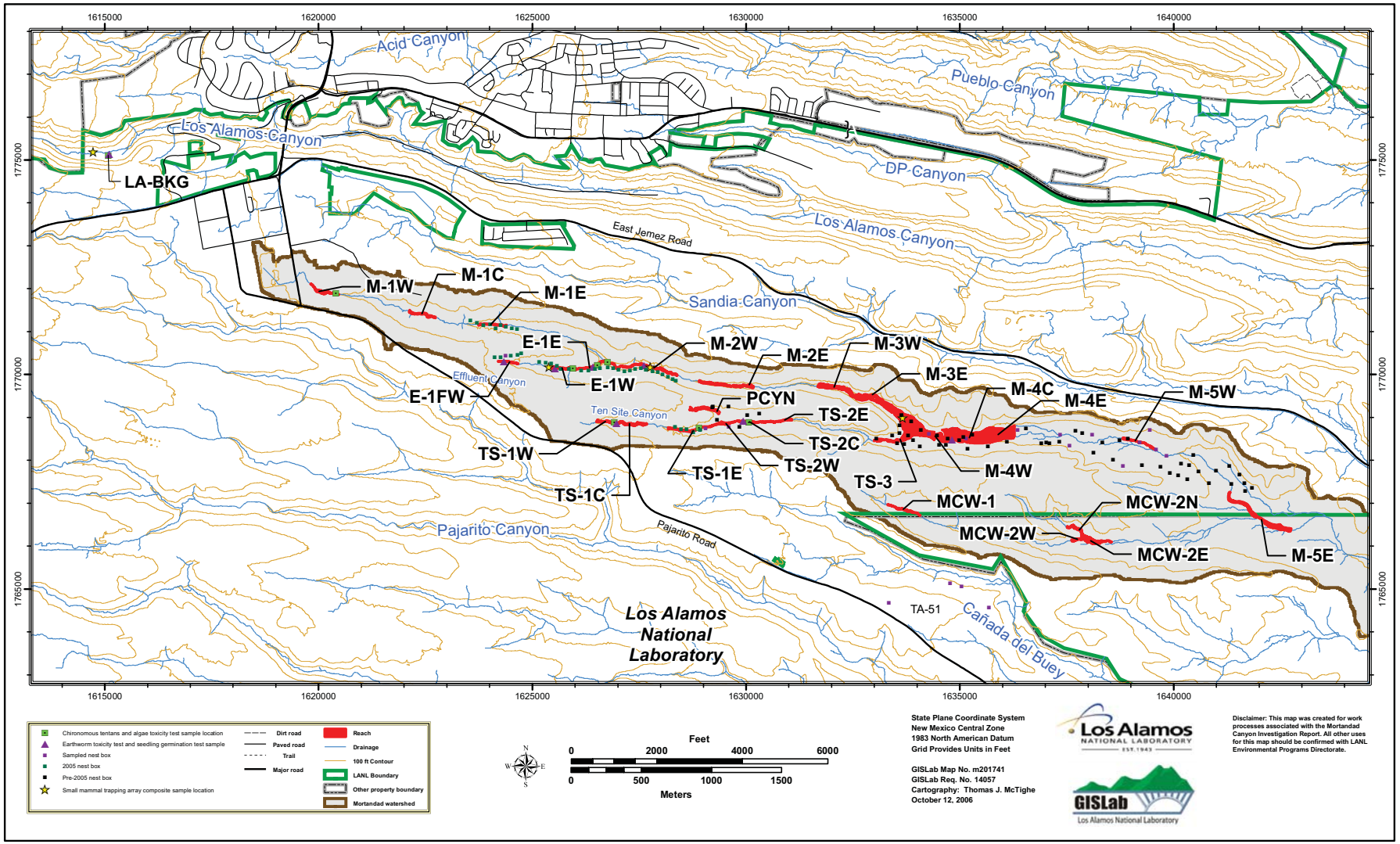


Figure 8.1-1. Map of reaches and sample locations

Key to Bird Species in Figures 8.1-2 to 8.1-11: ATFL = ash-throated flycatcher, HOFI = House Finch, HOWR = House wren, JUTI = juniper titmouse, MOBL = mountain bluebird, MOCH = mountain chickadee, PYNU = pygmy nuthatch, VGSW = violet-green swallow, WBNH = white-breasted nuthatch, WEBL = western bluebird

Key to Group Codes in Figures 8.1-2 to 8.1-11: M-# = reach # in Mortandad Canyon, TS-# = reach # in Ten Site Canyon, Mort = all of Mortandad Canyon, Cem = Cemetery, GC = Golf Course, CdB = Cañada del Buey, LA/P = Los Alamos and Pueblo Canyons, TA-35 = Technical Area 35, Other = boxes within nest box network but outside of areas listed above

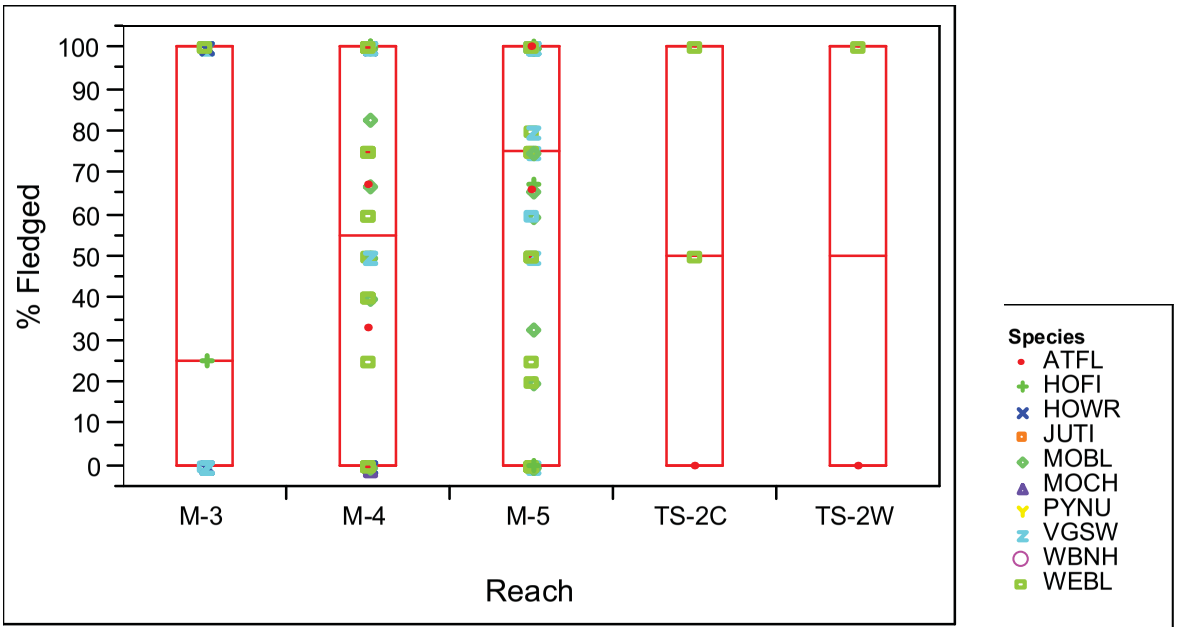


Figure 8.1-2. Box plots showing percent fledged by reach

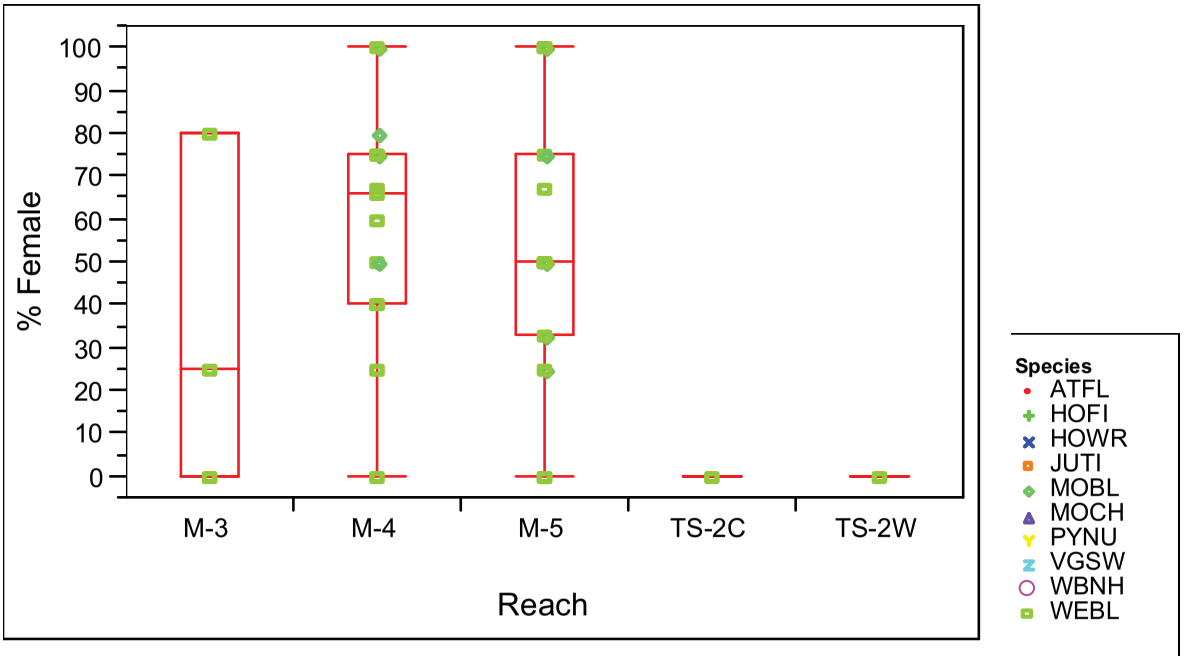


Figure 8.1-3. Box plots showing percent female by reach

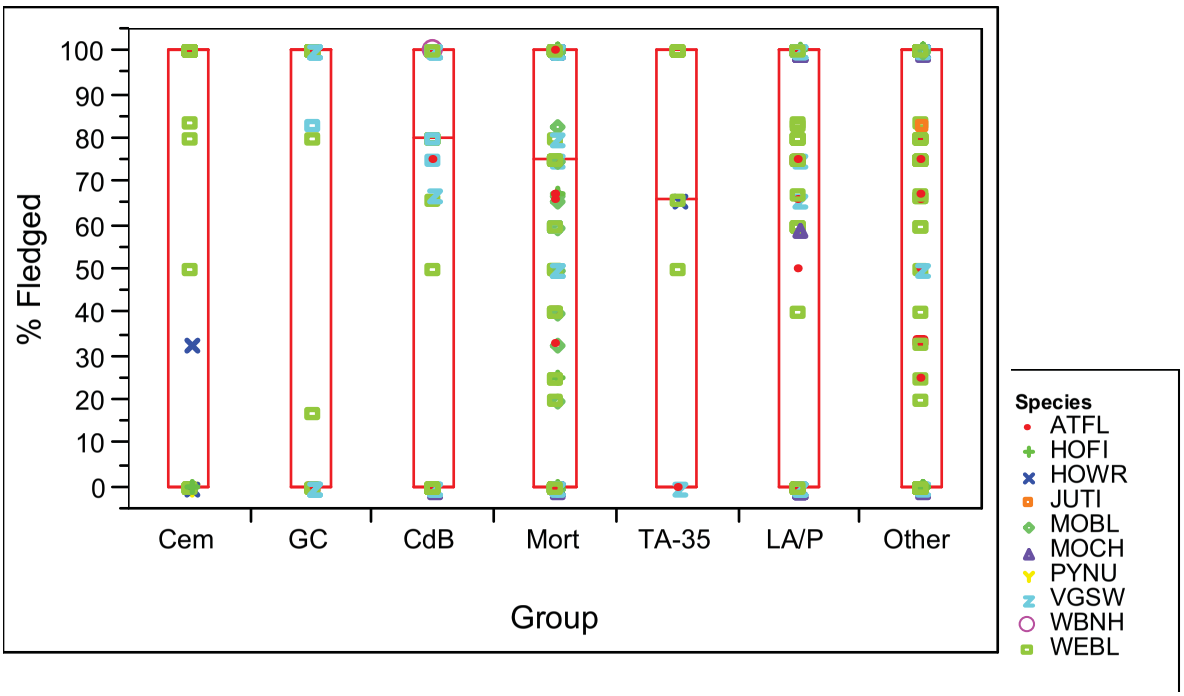


Figure 8.1-4. Box plots showing percent fledged by area (group)

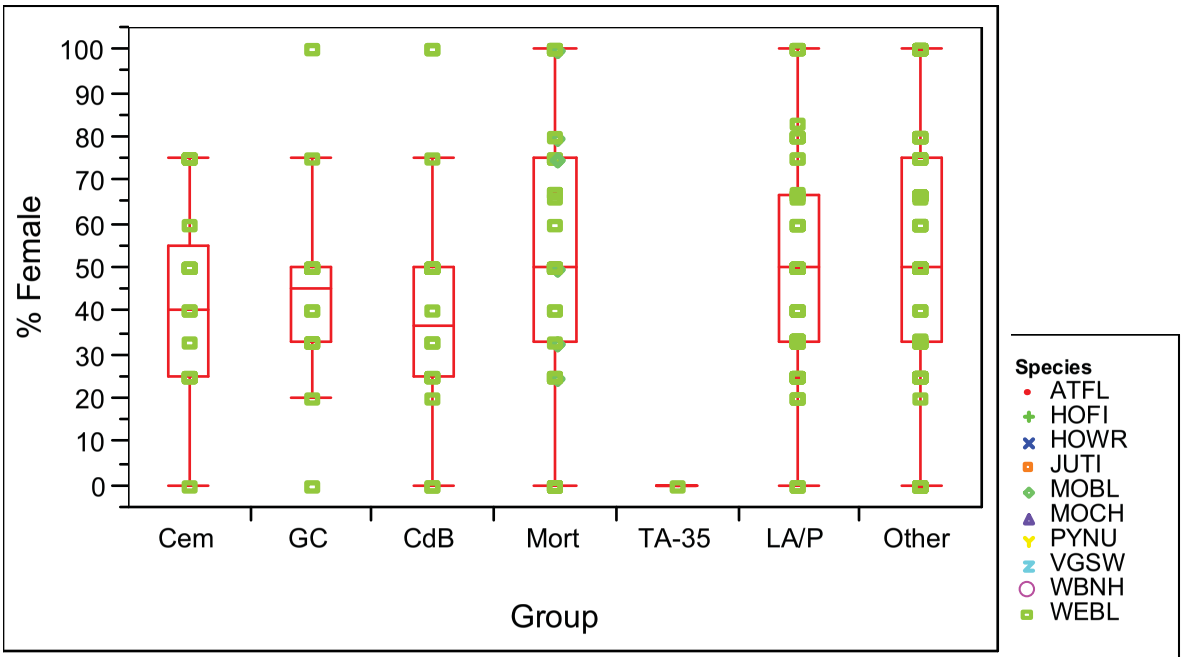


Figure 8.1-5. Box plots showing percent female by area (group)

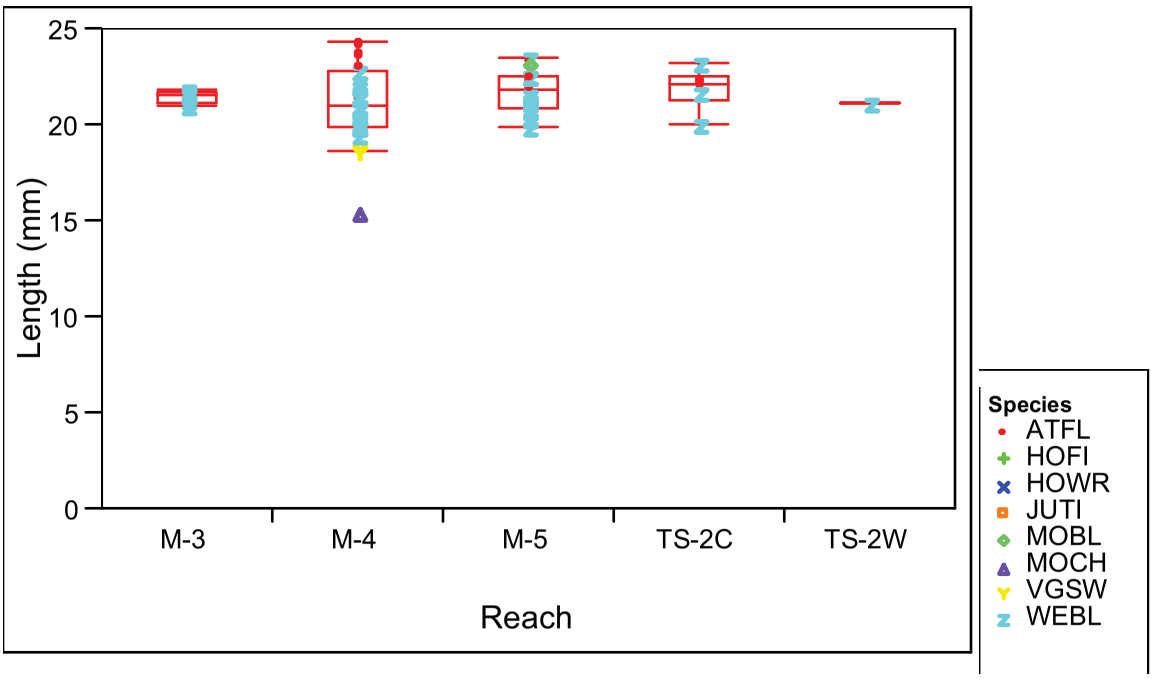


Figure 8.1-6. Box plots showing egg length by reach

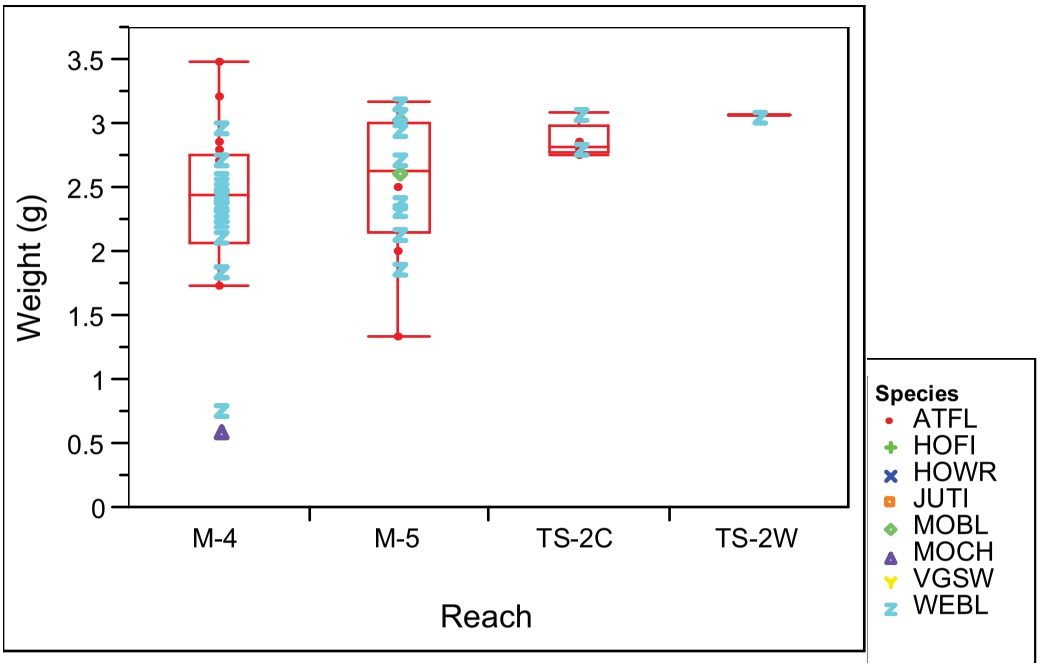


Figure 8.1-7. Box plots showing egg weight by reach

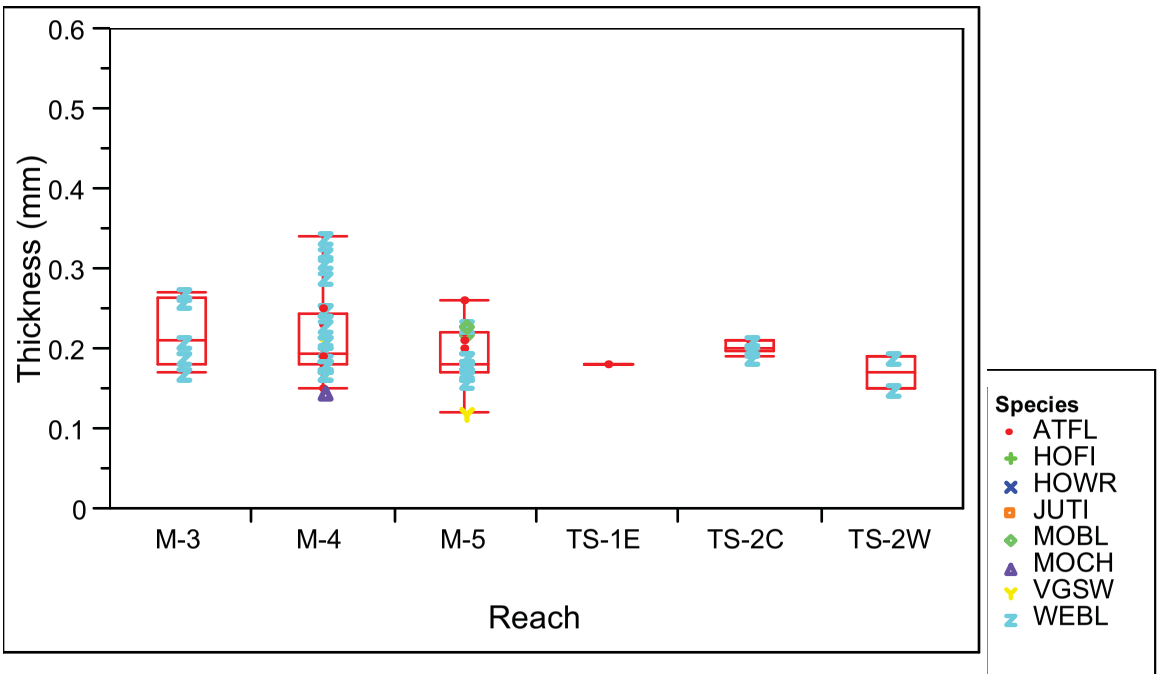


Figure 8.1-8. Box plots showing eggshell thickness by reach

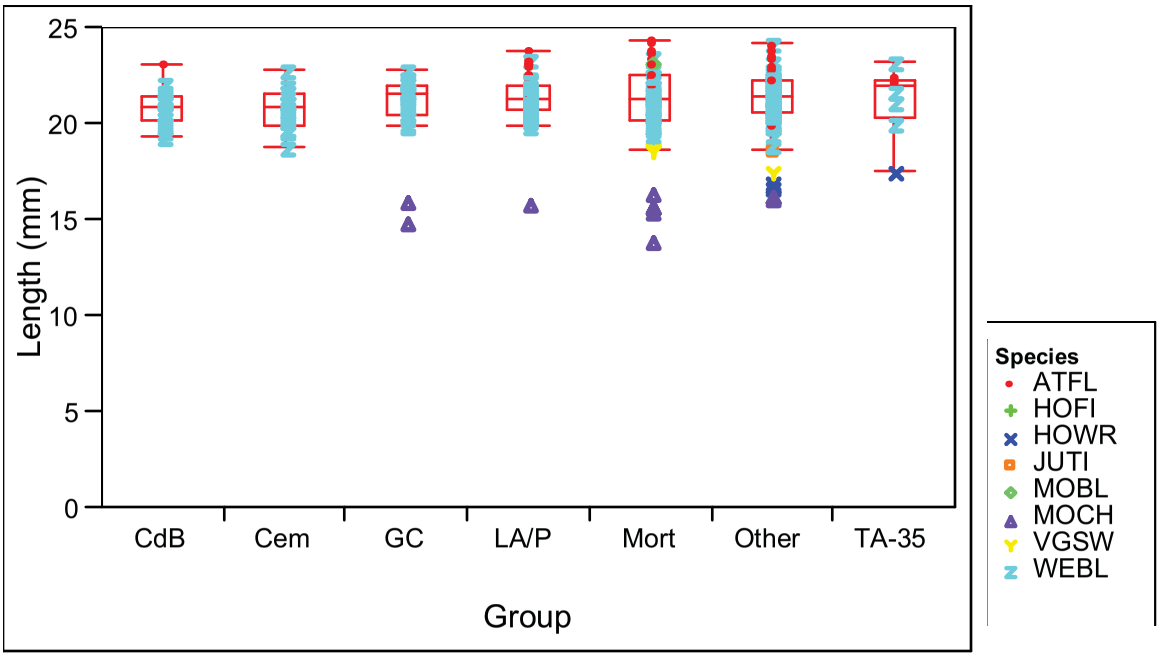


Figure 8.1-9. Box plots showing egg length by group

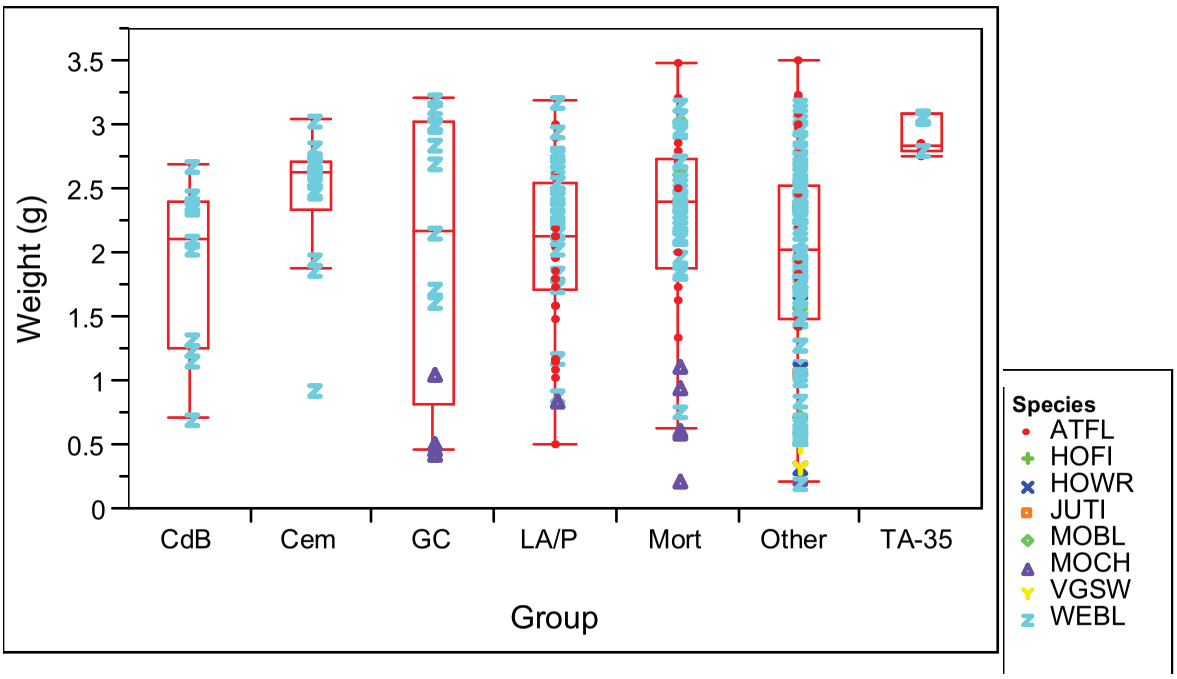


Figure 8.1-10. Box plots showing egg weight by group

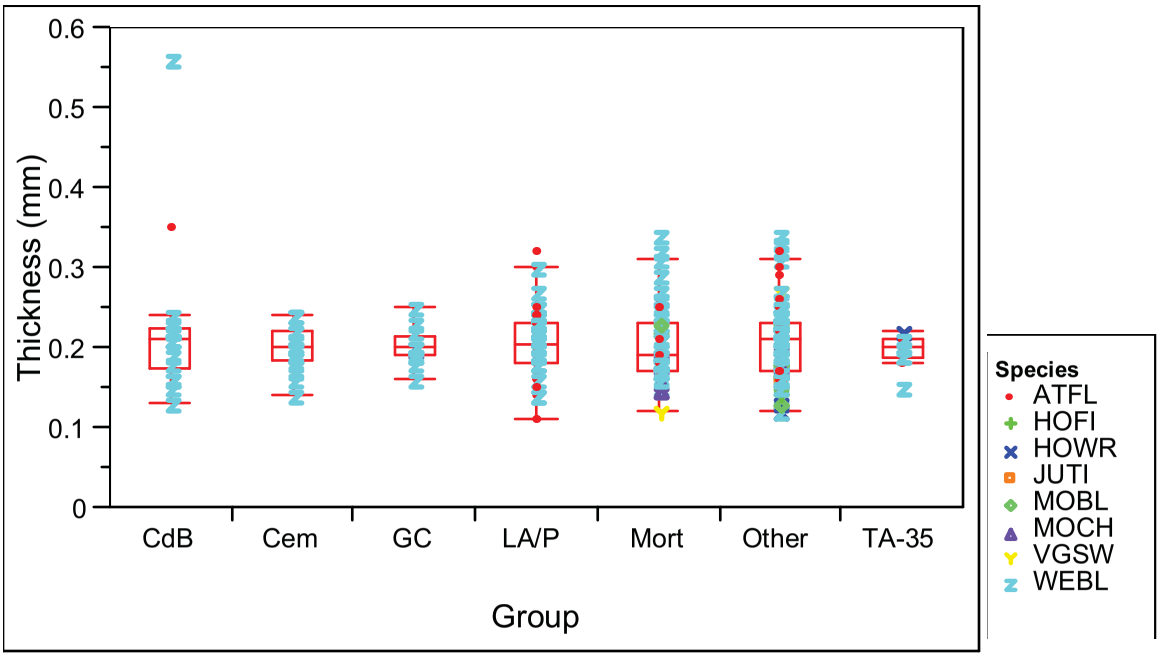


Figure 8.1-11. Box plots showing eggshell thickness by group.

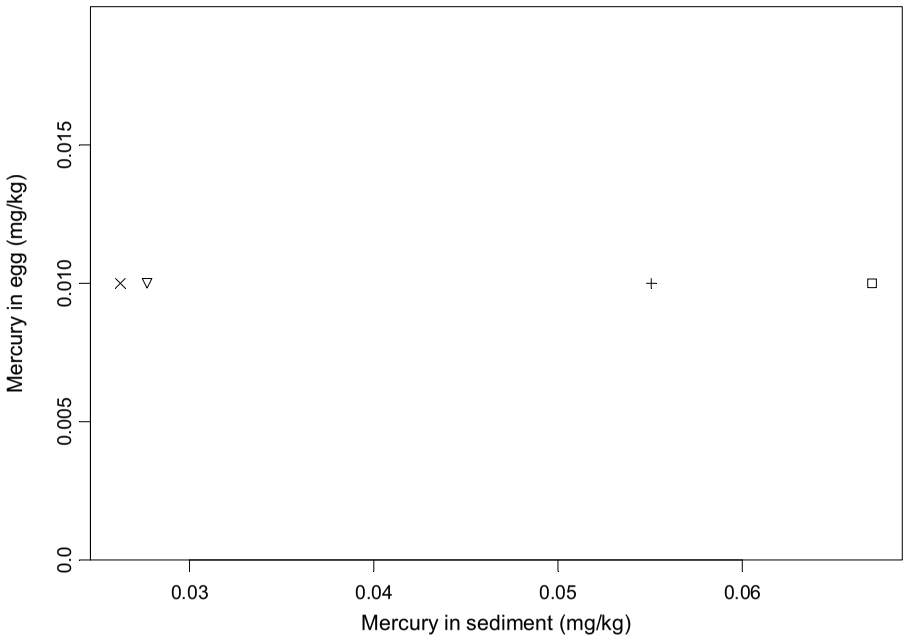


Figure 8.1-12. Concentration of mercury in egg contents

□ = E-1FW, + = M-4, × = M-5W,
△ = TS-1E, ▽ = TS-2W,

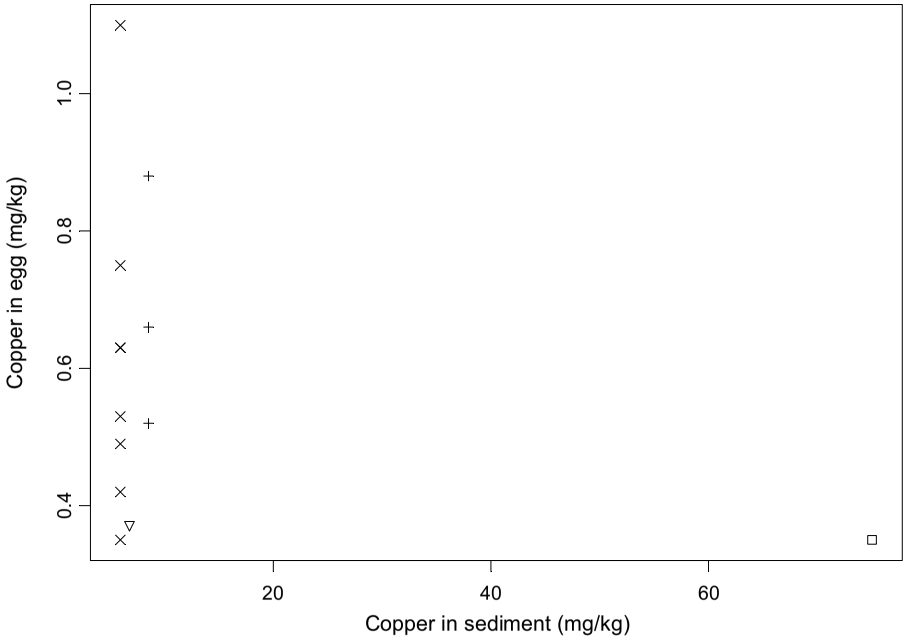


Figure 8.1-13. Concentration of copper in egg contents

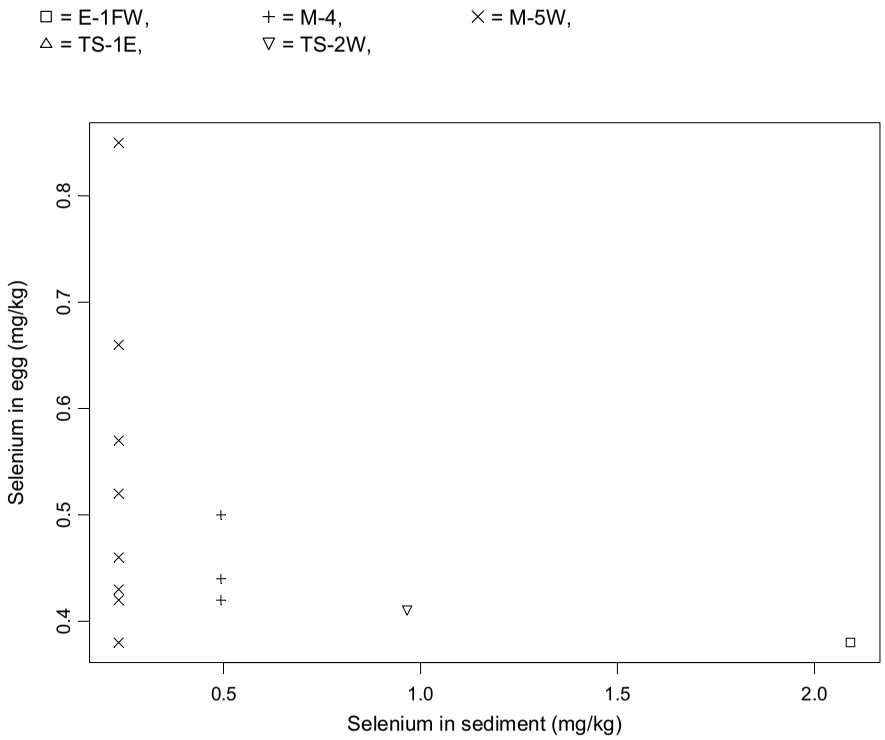


Figure 8.1-14. Concentration of selenium in egg contents

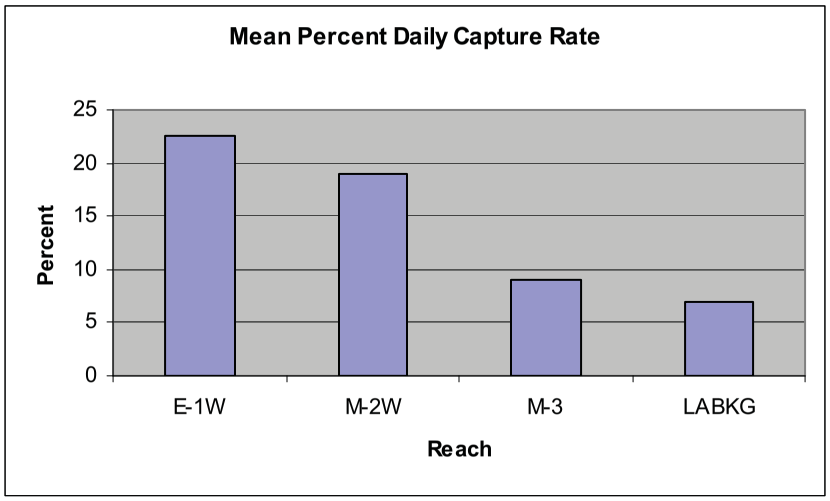


Figure 8.1-15. Mean percent daily capture rate for small mammals

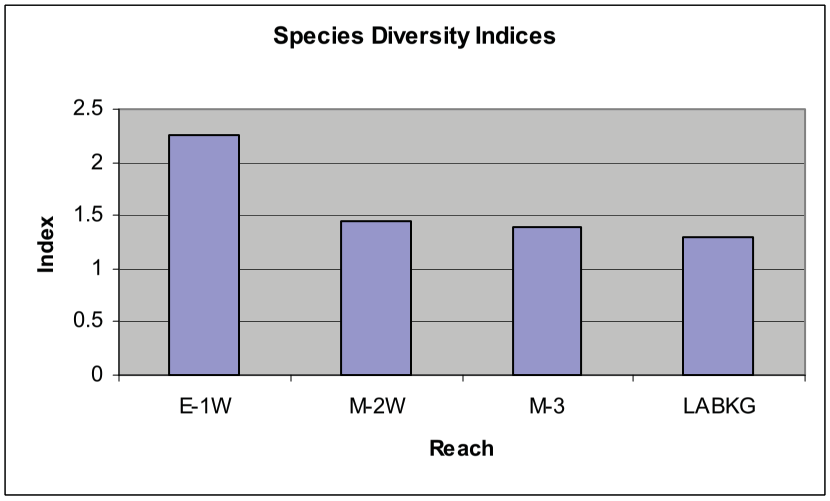


Figure 8.1-16. Small mammal species diversity

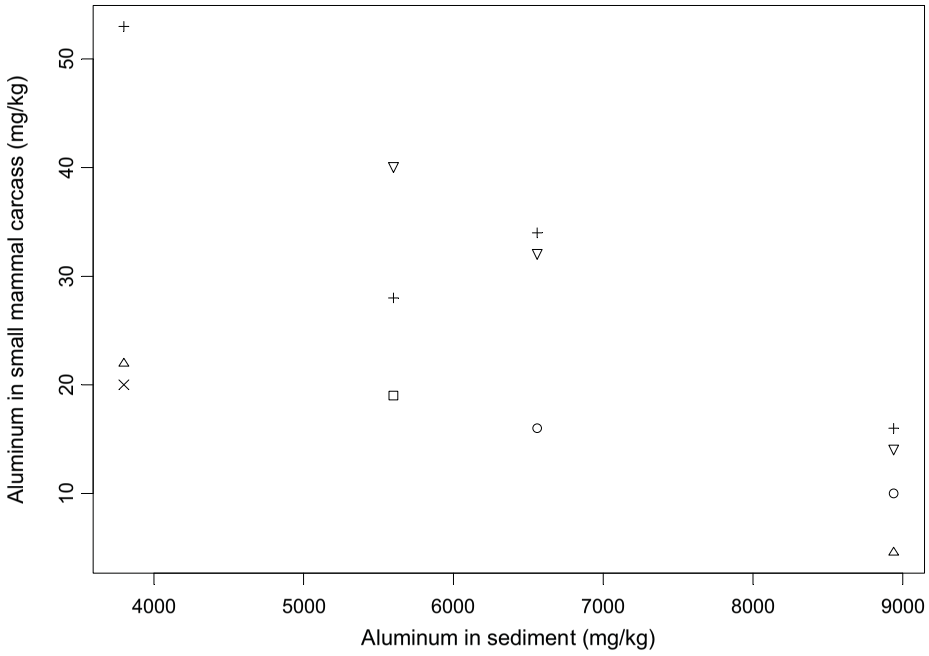


Figure 8.1-17. Aluminum in small mammal carcass versus sediment

○ = brush mouse, + = deer mouse, × = pinon mouse,
▽ = Mexican woodrat, △ = long tailed vole, □ = western harvest mouse.

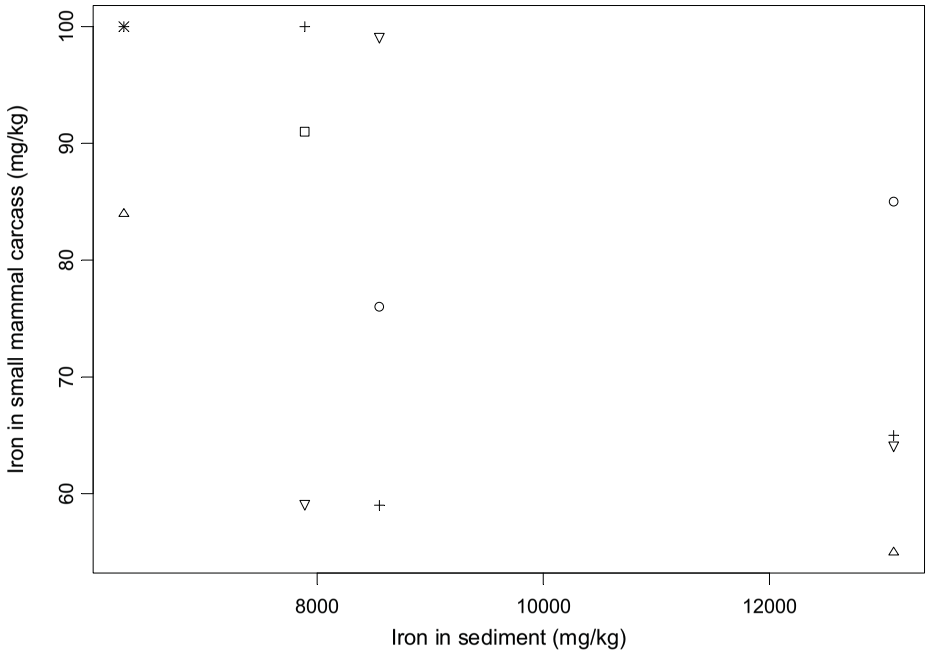


Figure 8.1-18. Iron in small mammal carcass versus sediment

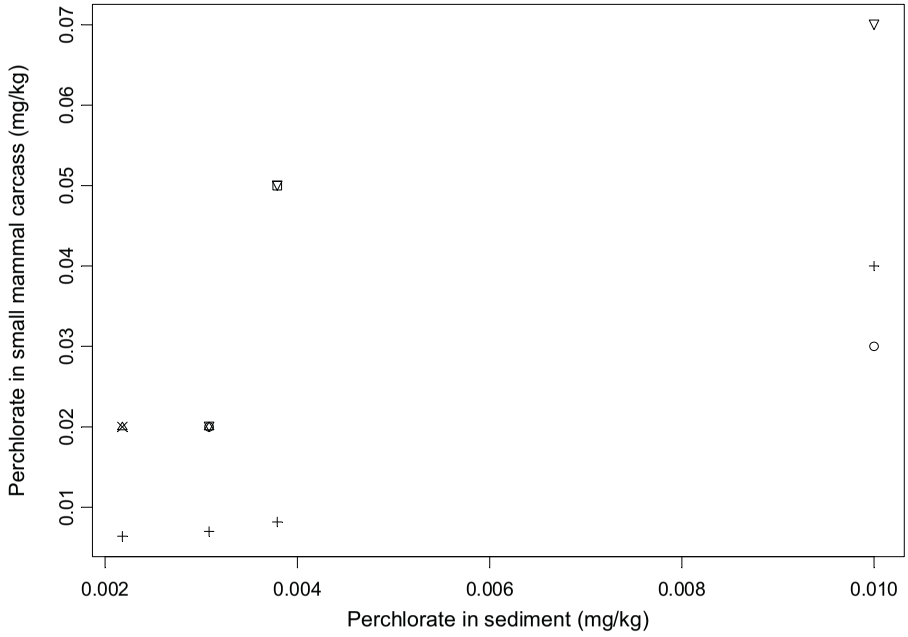
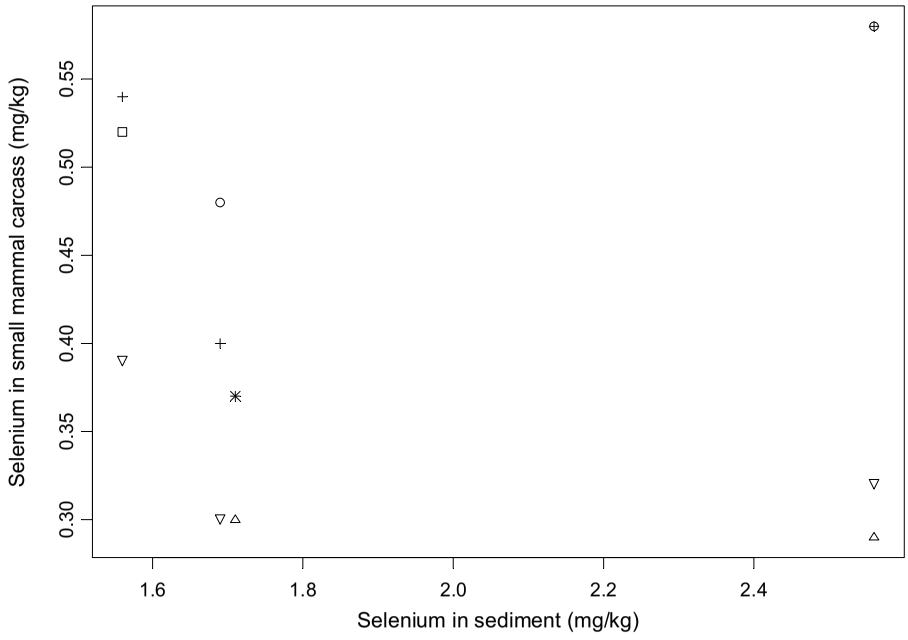


Figure 8.1-19. Perchlorate in small mammal carcass versus sediment

○ = brush mouse, + = deer mouse, × = pinon mouse,
▽ = Mexican woodrat, △ = long tailed vole, □ = western harvest mouse.



○ = brush mouse, + = deer mouse, × = pinon mouse,
▽ = Mexican woodrat, △ = long tailed vole, □ = western harvest mouse.

Figure 8.1-20. Selenium in small mammal carcass versus sediment

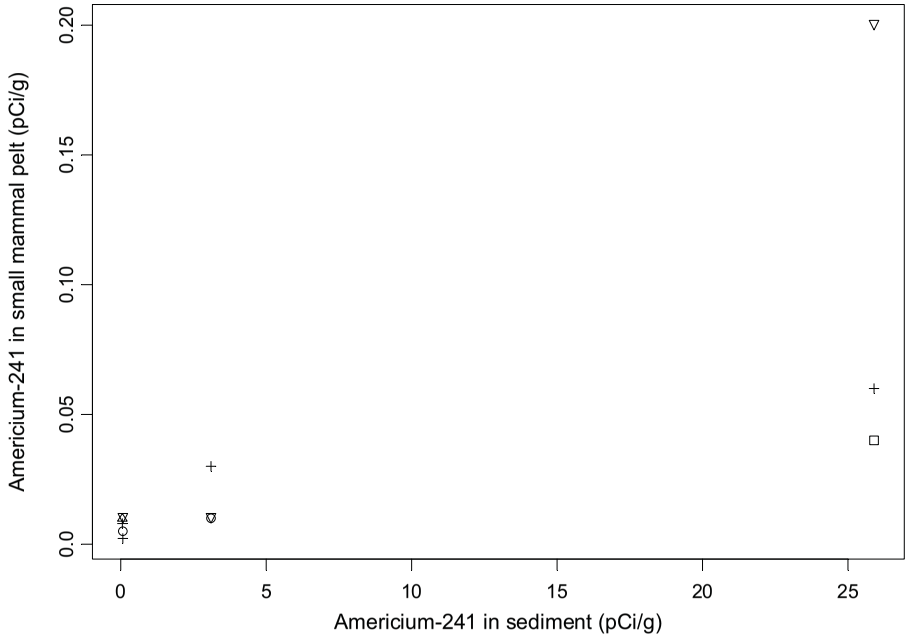
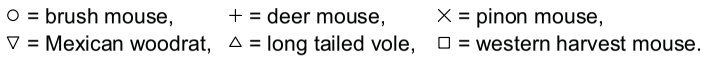


Figure 8.1-21. Concentration of americium-241 in small mammal pelt versus sediment concentration



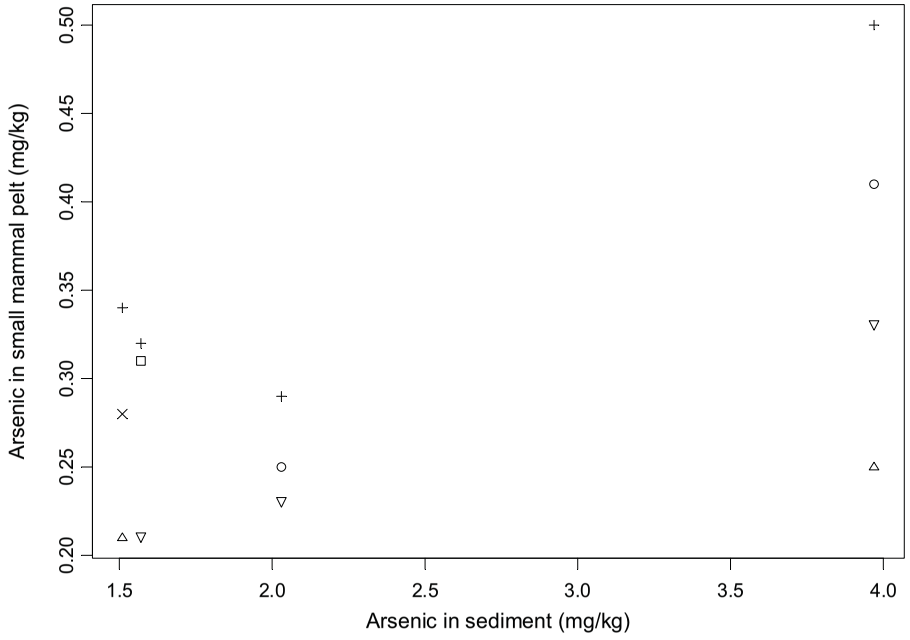


Figure 8.1-22. Concentration of arsenic in small mammal pelt versus sediment concentration

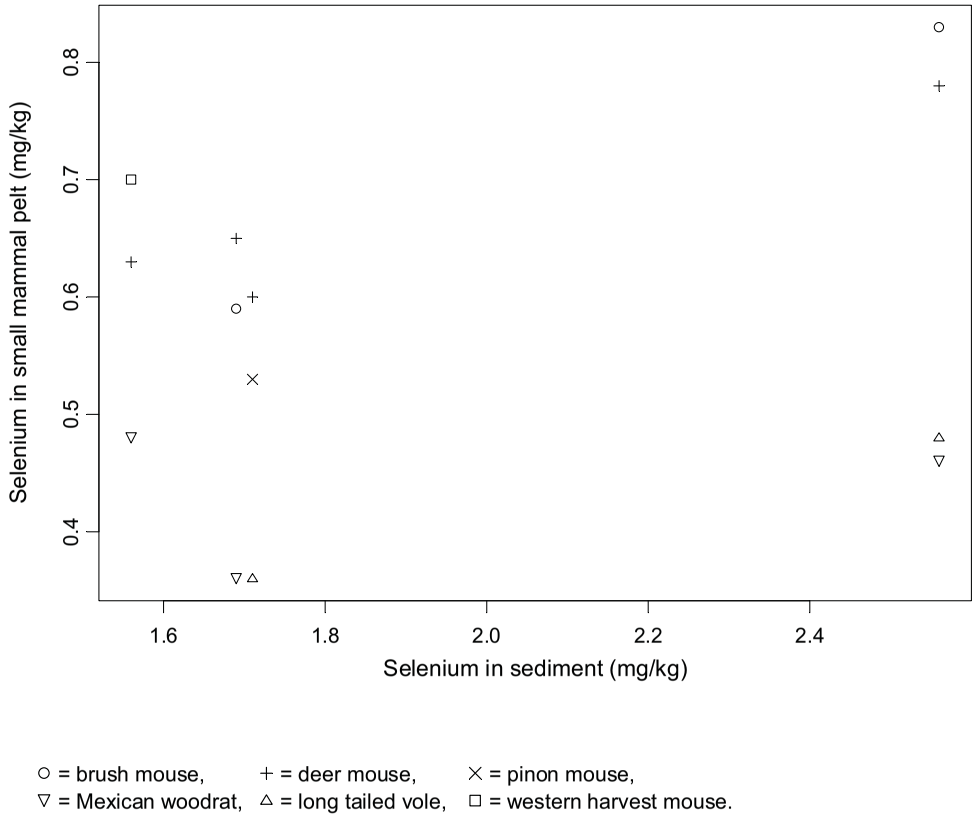


Figure 8.1-23. Concentration of selenium in small mammal pelt versus sediment concentration

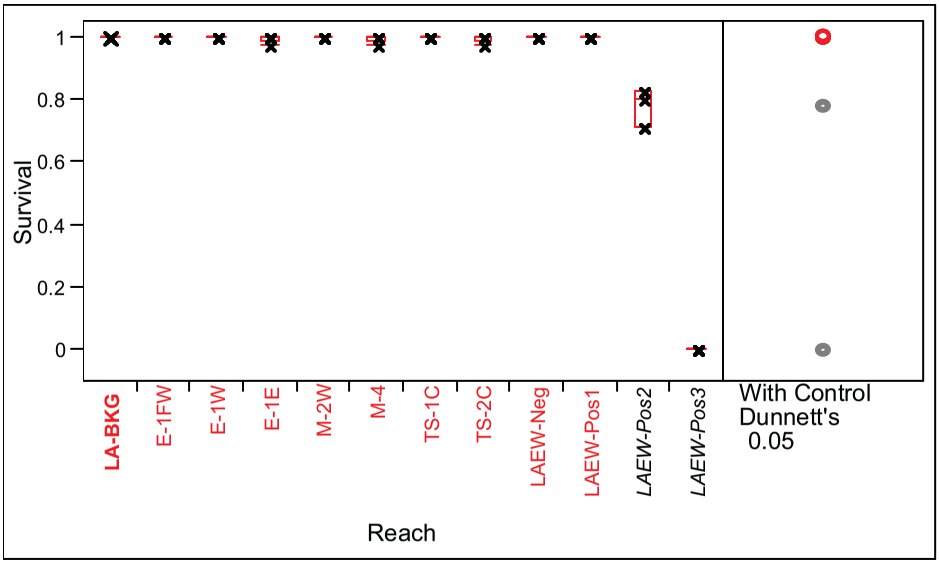


Figure 8.1-24. Survival of earthworms in toxicity test by reach

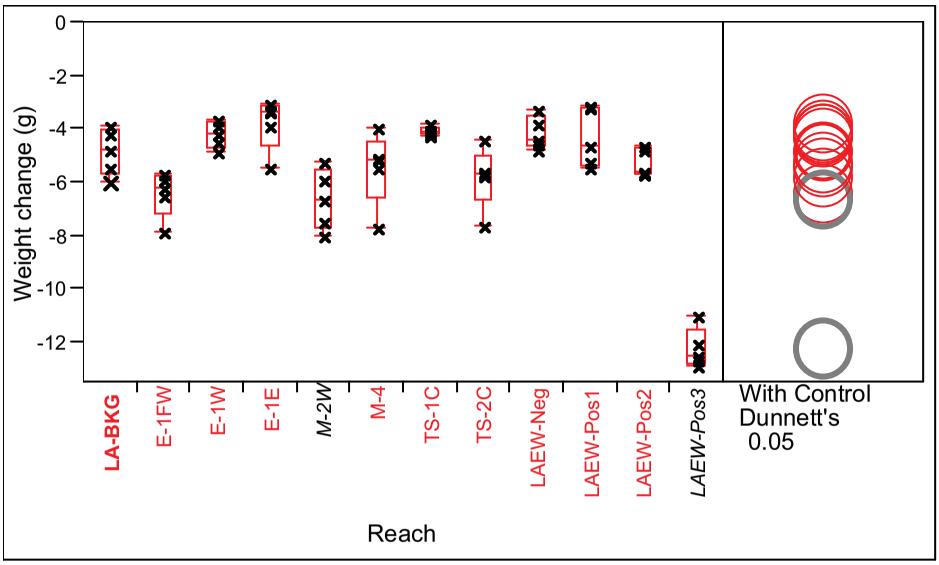
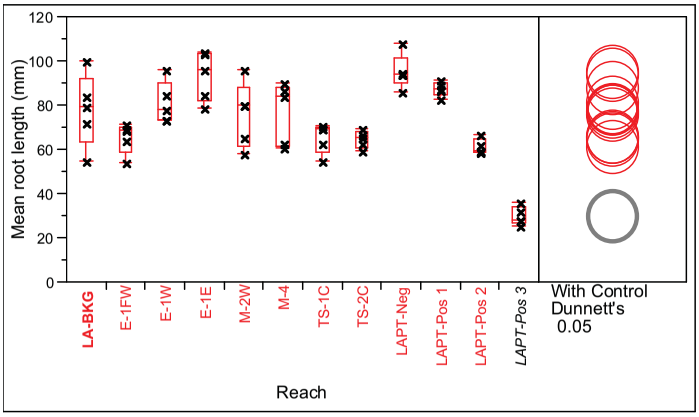
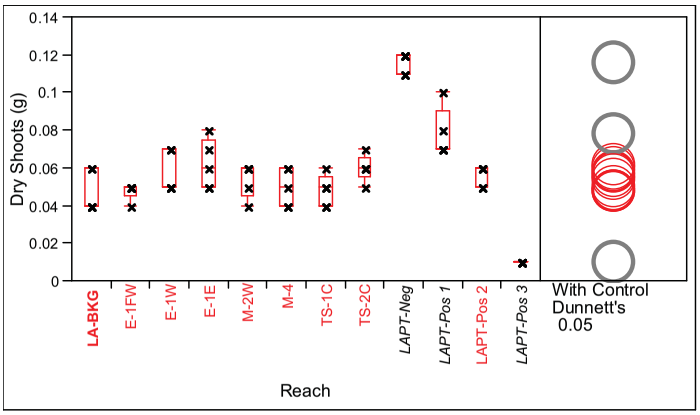


Figure 8.1-25. Weight change in earthworms during toxicity test by reach





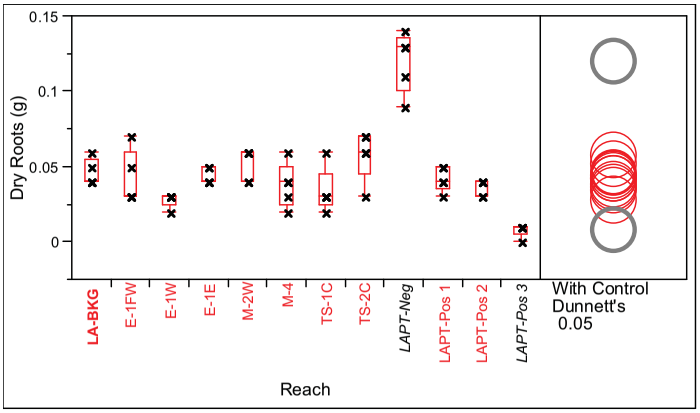


Figure 8.1-26. Plant Growth Parameters in toxicity test by reach

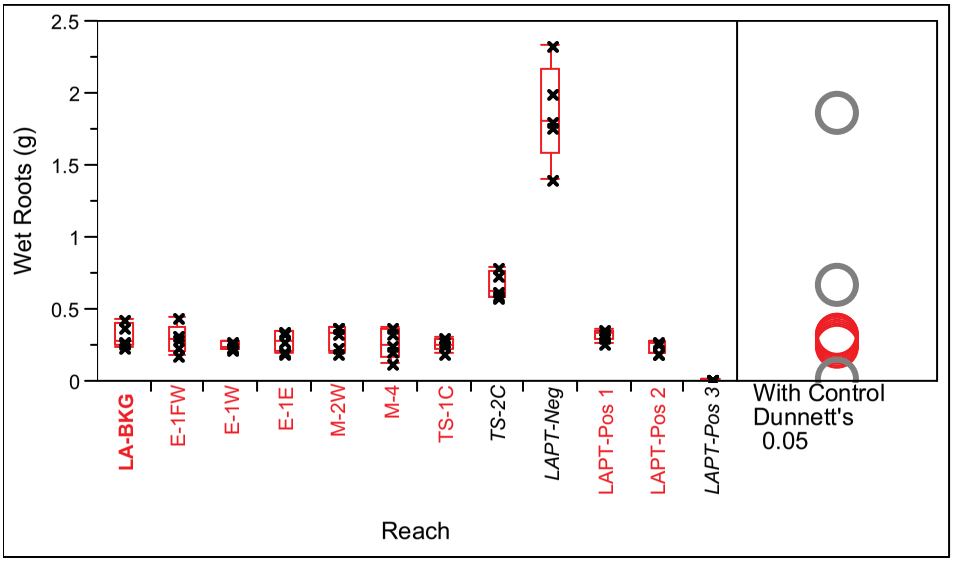


Figure 8.1-27. Wet root length by reach in plant toxicity test

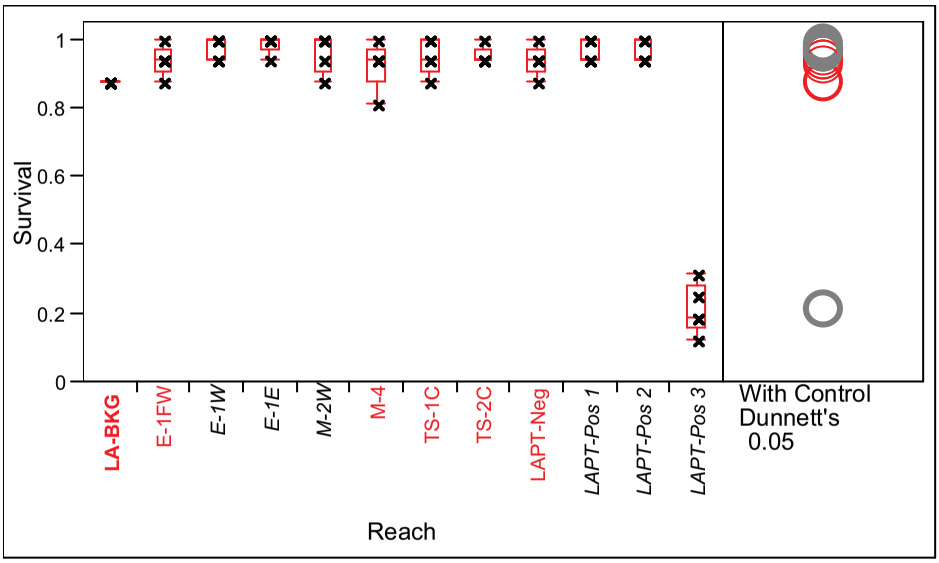


Figure 8.1-28. Fraction of Plants Surviving at end of Toxicity Test by reach

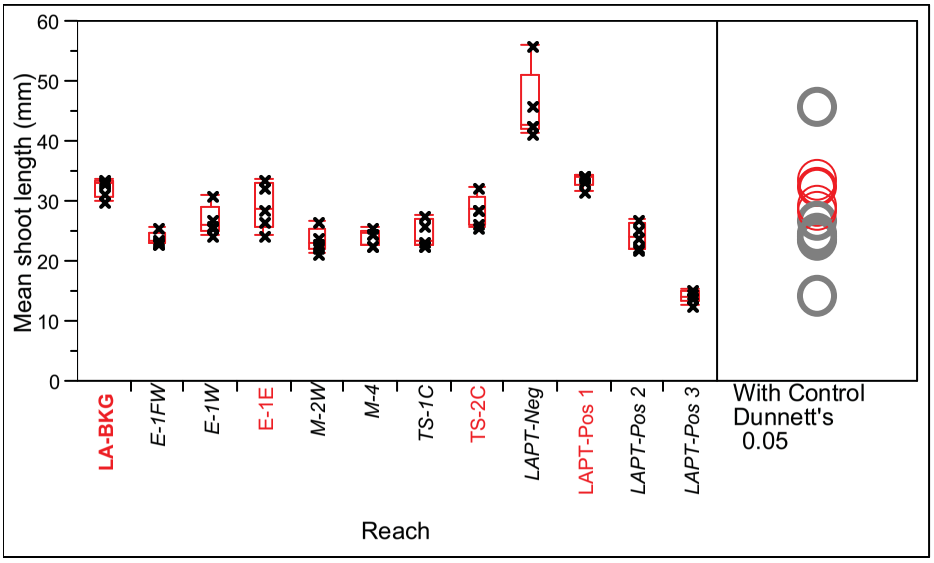


Figure 8.1-29. Mean shoot length of plants surviving at end of toxicity test by reach

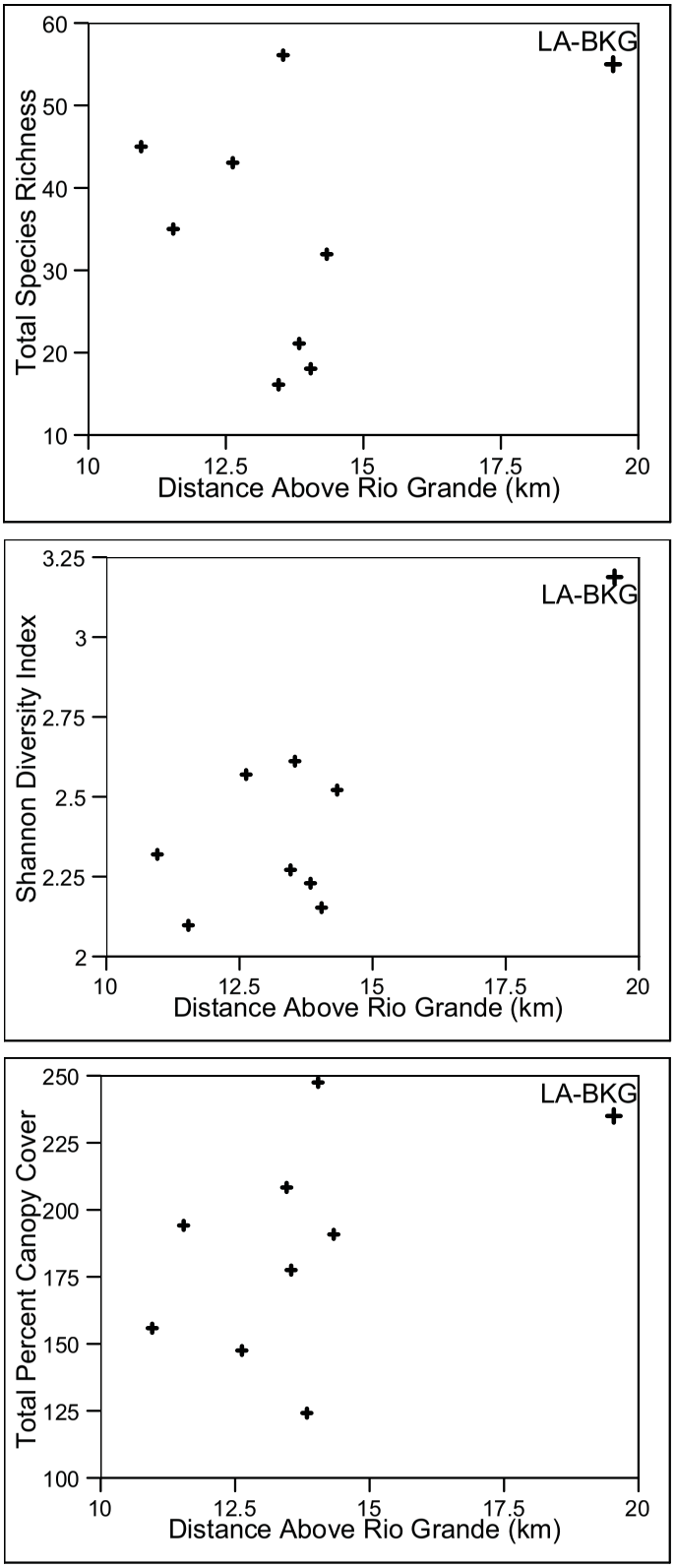


Figure 8.1-30. Scatter plots of plant field measures of diversity and cover versus distance from Rio Grande

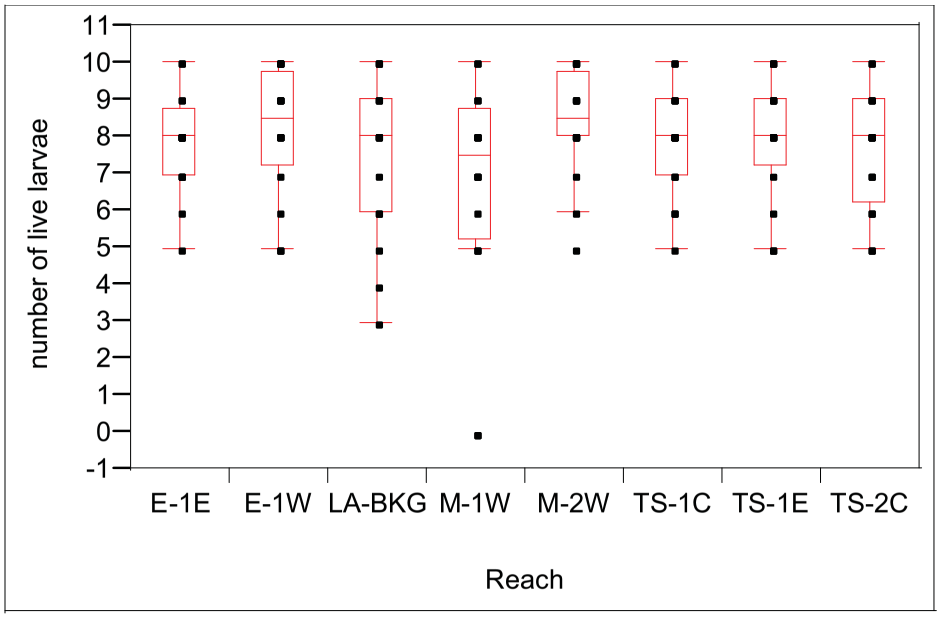


Figure 8.1-31. Number of live larvae at Conclusion of Chironomid Toxicity Test

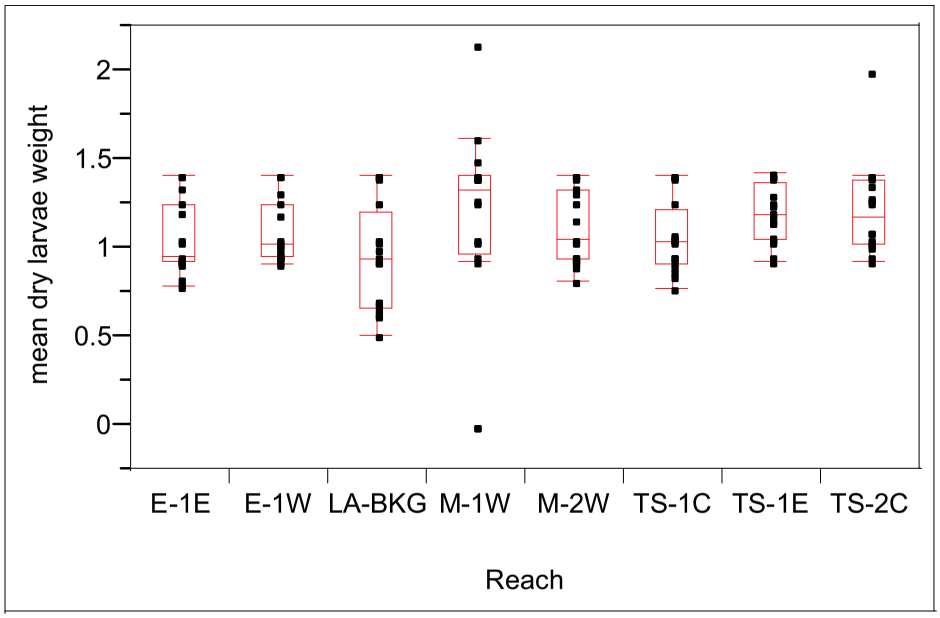


Figure 8.1-32. Box plot of mean dry larval weight (in mg) per Replicate after chironomid toxicity test

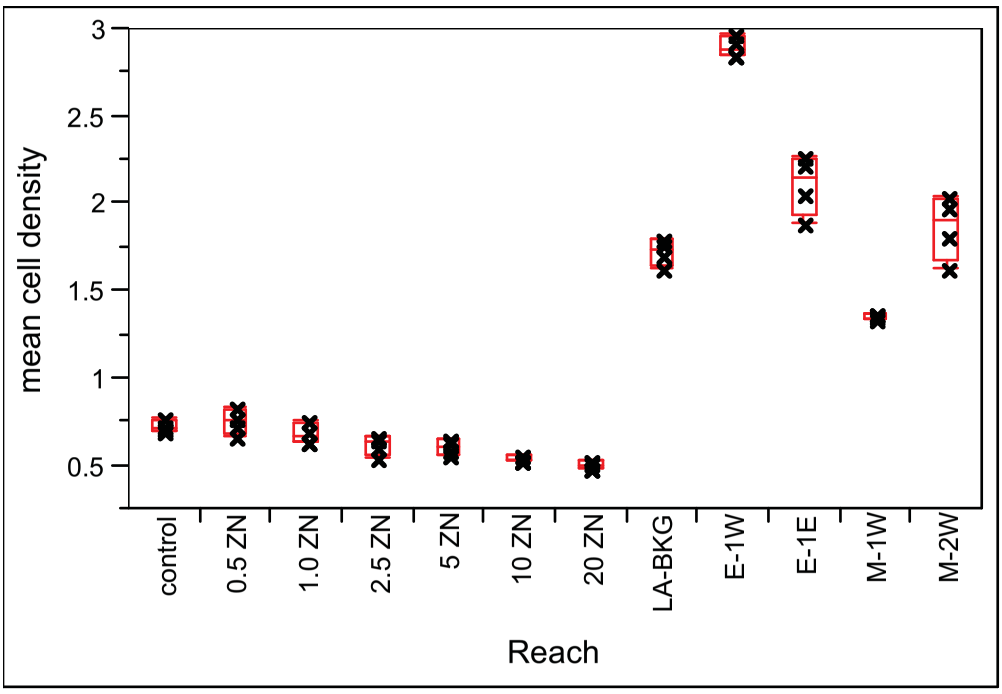


Figure 8.1-33. Box plot for mean algal cell density (in millions of cells/mL) at conclusion of July toxicity test

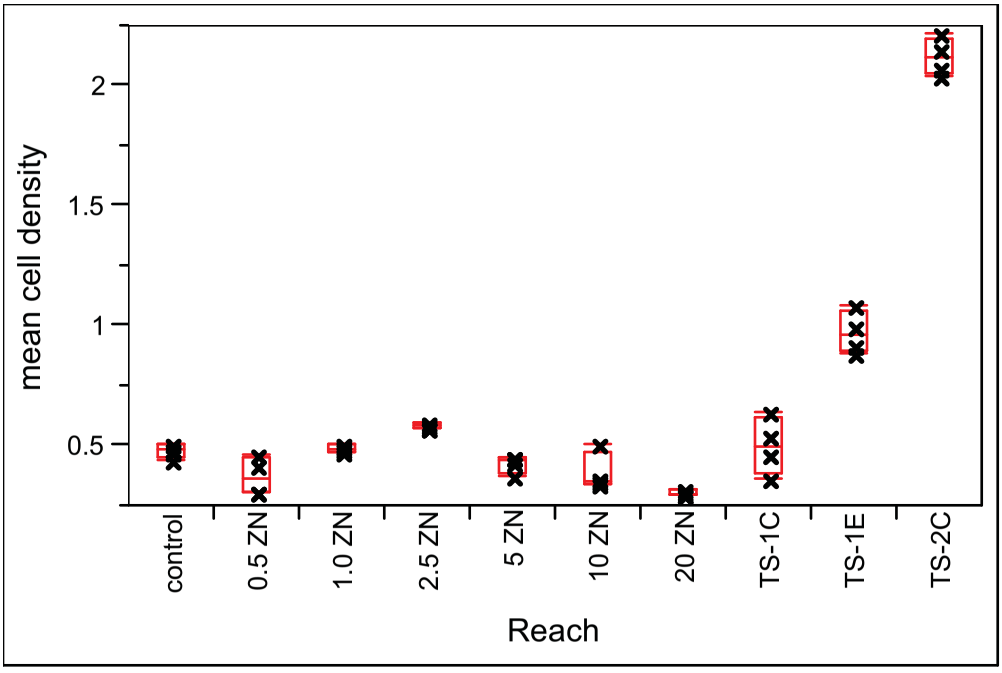


Figure 8.1-34. Box plot for mean algal cell density (in millions of cells/mL) at conclusion of August toxicity test

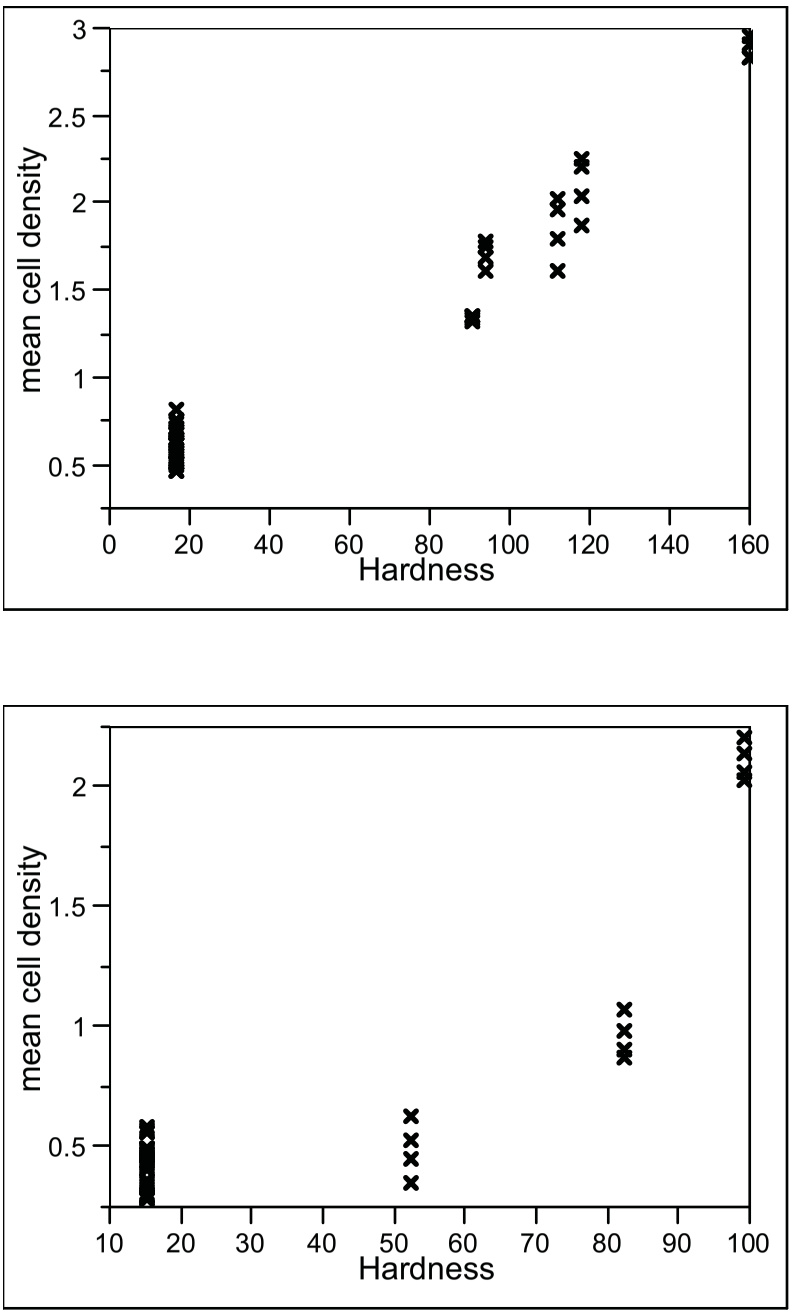


Figure 8.1-35. Bivariate fit of mean cell density (in millions of cells/mL) by hardness for July test (top panel) and August test (bottom panel)

Table 2.1-1
Annual Discharges Recorded for TA-50 RLWTF

Year	Discharge Volume (L)	^{241}Am (Ci)	^{137}Cs (Ci)	Gross Alpha (Ci)	Gross Beta/Gamma (Ci)	^{238}Pu (Ci)	^{239,240}Pu (Ci)	^{89}Sr (Ci)	^{90}Sr (Ci)	Total Tritium (Ci)	Total NO_3 as N (kg)
1963	2.74E+07	b	b	0.00371	0.1594	b	0.0016	0.1486	0.0397	b	b
1964	5.14E+07	b	b	0.0012	2.525	b	0.00194	0.06074	0.08865	b	1,126
1965	4.90E+07	b	b	0.00189	0.7084	b	0.00349	0.04229	0.06177	b	1,450
1966	5.28E+07	b	b	0.00209	0.3382	b	0.00162	0.02436	0.03558	b	596
1967	5.97E+07	b	b	0.00342	0.3091	b	0.00422	0.0535	0.0134	20	741
1968	6.03E+07	b	b	0.00257	0.2858	b	0.00259	0.0326	0.00082	b	858
1969	5.45E+07	b	b	0.0066	0.2893	b	0.00678	0.0546	0.0131	20	1,612
1970	5.32E+07	b	b	0.0033	0.1614	b	0.00498	0.0136	0.0198	b	6,618
1971	4.57E+07	b	b	0.00394	1.849	b	0.00691	0.01253	0.03159	b)	3,838
1972	5.71E+07	b	b	0.00513	0.3747	0.00769	0.00102	0.00352	0.0055	5.97	9,875
1973	5.37E+07	0.00136	0.2927	0.00424	0.9586	0.00839	0.00058	0.00455	0.0071	17.47	3,762
1974	4.06E+07	0.00166	0.156	b	0.181	0.0114	0.00039	0.00287	0.0159	4.05	2,660
1975	3.97E+07	0.00113	0.174	b	0.12	0.0148	0.00067	0.0017	0.00544	66.00	b
1976	3.99E+07	0.00114	0.193	b	0.0155	0.00748	0.00105	0.00092	0.00417	187.00	b
1977	4.21E+07	0.00193	0.142	b	0.0763	0.00257	0.00147	0.00226	0.0304	36.50	4,199
1978	4.05E+07	0.00173	0.317	b	0.0963	0.00405	0.00183	0.00264	0.0104	12.30	3,649
1979	4.86E+07	0.00468	0.17	b	0.0707	0.00055	0.00171	0.00607	0.0142	32.70	7,578
1980	5.28E+07	0.0057	0.132	b	b	0.0013	0.0082	0.0409	0.018	44.90	9,298
1981	5.53E+07	0.023	0.12	b	b	0.0029	0.055	0.042	0.023	17.00	14,496
1982	3.98E+07	0.0178	0.209	b	b	0.003	0.0166	0.0118	0.0128	14.20	13,320
1983	3.45E+07	0.038	b	b	b	0.011	0.042	0.057	0.0023	8.70	13,248
1984	3.50E+07	0.0082	b	b	b	0.0061	0.0081	0.26	0.0068	13.00	11,595
1985	2.86E+07	0.00542	b	b	b	0.00393	0.00575	0.00904	0.00125	69.40	10,754
1986	3.05E+07	0.00324	0.018	b	b	0.0015	0.00355	0.0092	0.00069	72.50	12,505

Table 2.1-1 (continued)

Year	Discharge Volume (L)	^{241}Am (Ci)	^{137}Cs (Ci)	Gross Alpha (Ci)	Gross Beta/Gamma (Ci)	^{238}Pu (Ci)	^{239,240}Pu (Ci)	^{89}Sr (Ci)	^{90}Sr (Ci)	Total Tritium (Ci)	Total NO_3 as N (kg)
1987	2.66E+07	0.0036	0.0081	b	b	0.0014	0.0032	0.064	0.001	100.00	12,662
1988	2.93E+07	0.0037	0.031	b	b	0.0011	0.0032	0.081	0.0002	21.00	11,251
1989	2.28E+07	0.0041	0.039	b	b	0.00051	0.002	0.018	0.0011	16.00	11,126
1990	2.11E+07	0.0027	0.0125	b	b	0.0002	0.0006	b	b	12.00	6,267
1991	2.19E+07	0.0011	0.067	b	b	0.0003	0.001	b	b	10.60	3,592
1992	1.99E+07	0.00027	0.0005	b	b	0.00032	0.00039	b	b	10.63	4,060
1993	2.17E+07	0.0112	0.00817	0.0124	0.0231	0.00058	0.00049	0.00263	0.00263	2.66	7,821
1994	2.08E+07	0.00306	0.00851	0.00523	0.0851	0.00281	0.00046	0.00196	0.000285	2.23	948
1995	1.76E+07	0.0034	0.00662	0.00531	0.02348	0.0034	0.0006	0.00012	0.000651	0.73	1,440
1996	1.65E+07	0.00199	0.0022	0.005036	0.010988	0.00225	0.00039	0.00066	0.0006	1.02	1,260
1997	1.75E+07	0.00256	0.00248	0.005713	0.009524	0.00134	0.0008	0.00083	0.0005	1.33	1,220
1998	2.32E+07	0.002	0.001	0.006272	0.018301	0.002	0.00091	0.002	0.00082	1.23	1,420
1999	2.00E+07	0.0011	0.0015	0.004977	0.011468	0.0024	0.0014	0.00036	0.00052	0.49	486
2000	1.86E+07	0.000041	0.0031	0.000219	0.002712	0.000063	0.000035	0.000332	0.00017	0.91	47
2001	1.36E+07	0.000056	0.000213	0.000248	0.006944	0.000074	0.000024	0.000039	0.000029	0.13	53
2002	1.10E+07	0.000114	0.000582	b	b	0.000073	0.000024	0.000004	0.000003	0.07898	17.31
2003	1.12E+07	0.000055	0.000614	b	b	0.000109	0.000043	0.0	0.0	0.1171	12.8
2004	8.17E+06	0.000013	0.000085	b	b	0.000018	0.000011	0.0	0.0	0.0865	36.7
2005	6.8E+06	0.00003	0.000039	b	b	0.000003	0.000002	0.0	0.0	0.0215	25.1
MinTotal	1.43E+09	0.156	2.12	0.0835	8.71	0.1056	0.1977	1.069	0.4709	823	197,498

Table 3.1-1
Sediment Investigation Reaches in the Mortandad Watershed

Subwatershed	Investigation Reach	Reach Abbreviation	Approximate Distance from Rio Grande to Midpoint of Reach (km)	Reach Length (km)	Year(s) of Sample Collection (Canyons Investigations)	Notes
Effluent Canyon	E-1 Far West	E-1FW	14.43	0.15	2004, 2005	Upcanyon of TA-55
	E-1 West	E-1W	14.03	0.21	1998, 2001, 2004, 2005	Downcanyon of TA-55
	E-1 East	E-1E	13.82	0.21	1998, 2001, 2004, 2005	Downcanyon of TA-50 outfall
Mortandad Canyon	M-1 West	M-1W	15.89	0.23	1998, 2004, 2005	Downcanyon of Diamond Drive
	M-1 Central	M-1C	15.10	0.20	2004	Upcanyon of TA-48
	M-1 East	M-1E	14.56	0.20	1998, 2004, 2005	Downcanyon of TA-48
	M-2 West	M-2W	13.41	0.60	1998, 2001, 2004, 2005	Downcanyon of Effluent Canyon
	M-2 East	M-2E	12.81	0.41	2001, 2004	Downcanyon of TA-35
	M-3 West[a]	M-3W	11.98	0.29	1999, 2001, 2004	Vicinity of permeable reactive barrier
	M-3 East[a]	M-3E	11.53	0.62	1999, 2001, 2004, 2005	Upcanyon of Ten Site Canyon; canyon floor widens
	M-4 West[b]	M-4W	11.12	0.21	1999, 2001, 2004, 2005	Downcanyon of Ten Site Canyon; includes sediment traps #1 and #2
	M-4 Central[b]	M-4C	10.90	0.22	1999, 2001, 2004, 2005	Downcanyon of sediment trap #2
	M-4 East[b]	M-4E	10.68	0.23	1999, 2001, 2004	Area where radionuclide concentrations are decreasing
	M-5 West	M-5W	9.64	0.25	2004	Midway between M-4 and M-5E
	M-5 East	M-5E	8.62	0.56	2000, 2001, 2004	Spans LANL-San Ildefonso Pueblo boundary
	M-6	M-6	5.00	0.20	2003, 2004, 2005	Upcanyon of SR 4

Table 3.1-1 (continued)

Subwatershed	Investigation Reach	Reach Abbreviation	Approximate Distance from Rio Grande to Midpoint of Reach (km)	Reach Length (km)	Year(s) of Sample Collection (Canyons Investigations)	Notes
Ten Site Canyon	TS-1 West	TS-1W	13.69	0.13	2004, 2005	Downcanyon of TA-50 and MDA C; steep and rocky
	TS-1 Central	TS-1C	13.50	0.24	1999, 2004, 2005	Canyon bottom widening and flattening
	TS-1 East	TS-1E	13.02	0.39	1999, 2004, 2005	Upcanyon of Pratt Canyon
	Pratt Canyon	PCYN	13.01	0.23	none	Sampled as part of TA-35 investigations in 1994, 1997, 1998, and 2005
	TS-2 West	TS-2W	12.77	0.11	1999, 2004, 2005	Downcanyon of Pratt Canyon
	TS-2 Central	TS-2C	12.62	0.20	1999, 2004, 2005	Downcanyon of TA-35 sewage lagoon outfall
	TS-2 East	TS-2E	12.42	0.21	1999, 2004, 2005	Downcanyon of TA-35 sand filter bed outfall
	TS-3	TS-3	11.46	0.31	2001, 2005	Upcanyon of Mortandad Canyon
Unnamed tributary canyon	MCW-1	MCW-1	11.13	0.25	2003, 2005	Upper part of unnamed tributary below TA-5
	MCW-2 North	MCW-2N	9.93	0.20	2003, 2005	Tributary below Far Point firing site (SWMU 05-001[c])
	MCW-2 West	MCW-2W	9.88	0.10	2003, 2005	Upcanyon of Far Point firing site tributary
	MCW-2 East	MCW-2E	9.73	0.20	2003, 2005	Downcanyon of Far Point firing site tributary

[a] In Section 6 and Appendix C tables, these 2 reaches are combined and reported as "M-3."

[b] In Section 6 and Appendix C tables, these 3 reaches are combined and reported as "M-4."

Table 3.2-1
Mortandad Canyon Surface and Groundwater Sampling Locations and Rationale

Location Name	Location and Rationale
Alluvial Groundwater Wells (West to East)	
MCO-0.6	Mortandad Canyon north of TA-48. Westernmost alluvial groundwater monitoring point in Mortandad Canyon. Provides samples of base line alluvial water upstream of the Mortandad and Effluent Canyons confluence and downstream of all potential contaminant sources in upper Mortandad Canyon.
MCA-1	Mortandad Canyon above confluence with Effluent Canyon. New well that provides samples of alluvial groundwater from the upper part of the Mortandad Canyon watershed above the influence of the TA-50 RLWTF outfall (NPDES outfall EPA03A-051).
MCA-4	Effluent Canyon. New well located downcanyon of release sites in Effluent Canyon and upcanyon of TA-50 RLWTF outfall. Provides continuity with historical groundwater quality data. Replacement for well MCO-2.
MCO-2	Effluent Canyon. Location is downcanyon of release sites in Effluent Canyon and upcanyon of TA-50 RLWTF outfall. Sampled when insufficient water was obtained from MCA-4.
MCA-5	Mortandad Canyon below confluence with Effluent Canyon. New well that provides samples of alluvial groundwater representing contributions from both Effluent Canyon and the upper part of the Mortandad Canyon watershed. First groundwater monitoring point below the TA-50 RLWTF outfall. Provides continuity with historical groundwater quality data. Replacement for well MCO-3.
MCO-4B	Mortandad Canyon near the east end of the narrow, deeply incised portion of the canyon. Provides samples of alluvial water upcanyon of the permeable reactive barrier and the major zone of infiltration where the canyon widens to the east. Provides continuity with historical groundwater quality data.
MCO-5	Mortandad Canyon near TW-8. Provides samples of alluvial water where the canyon widens eastward and alluvium thickens. First groundwater monitoring point downcanyon of the permeable reactive barrier. Provides continuity with historical groundwater quality data.
MCO-6	Mortandad Canyon above confluence with Ten Site Canyon. Location provides samples of alluvial groundwater from the upper part of the Mortandad Canyon watershed above the influence of release sites in the Ten Site Canyon watershed. Provides continuity with historical groundwater quality data.
MCA-2	Confluence of Mortandad and Ten Site canyons. New well that provides samples of alluvial groundwater that may a source of intermediate-perched groundwater encountered at MCI-4 and MCOBT-4.4. Equivalent to well MCO-6.8 in the “Work Plan for Mortandad Canyon” (LANL 1997, 56835).
MCO-7	Mortandad Canyon below confluence with Ten Site Canyon. Location provides samples of alluvial groundwater representing contributions from both Ten Site Canyon and the upper and middle parts of the Mortandad Canyon watershed. Located west of sediment traps. Provides continuity with historical groundwater quality data.
TSCA-6	Ten Site Canyon. New well located downcanyon of historic release sites at TA-35. Formerly called MCA-6. The TSCA-6 alluvial well was installed in the MCB-15 core hole after backfilling the deep borehole to the level of alluvial saturation.
MCO-7.2	Mortandad Canyon east of sediment traps. New well installed to determine if suballuvium groundwater occurs within Cerro Toledo deposits in this part of Mortandad Canyon. This well is dry although alluvial groundwater was present in overlying alluvium during drilling.

Table 3.2-1 (continued)

Location Name	Location and Rationale
MT-1	Mortandad Canyon downcanyon of sediment traps. Provides continuity with historical groundwater quality data. Alternative water sampling well for alluvial groundwater near MCO-7.2.
MCO-7.5	Mortandad Canyon downcanyon of sediment traps. Located near the eastern extent of persistent alluvial groundwater saturation. Provides continuity with historical groundwater quality data.
MT-2	Mortandad Canyon in area of intermittent alluvial saturation.
MT-3	Mortandad Canyon in area of intermittent alluvial saturation.
MT-4	Mortandad Canyon in area of intermittent alluvial saturation.
MCA-7,-8,-9	Mortandad Canyon near eastern Laboratory boundary. Transect of new wells installed to determine if saturation occurs near the Laboratory boundary. MCA-7 (dry) was plugged and abandoned. Alluvial wells (dry) were installed in MCA-8 and MCA-9. Meets the requirement to install wells MC-13A and -13B in the "Work Plan for Mortandad Canyon" (LANL 1997, 56835).
Surface Water (West to East)	
Reach M-1W Surface Water (MO-24789)	Mortandad Canyon east of Diamond Drive. Provides base line information for surface water in uppermost part of Mortandad Canyon watershed.
Reach M-1E Surface Water (MO-24790)	Mortandad Canyon north of TA-48. Provides samples of surface water upstream of the Mortandad and Effluent Canyons confluence and downstream of all potential contaminant sources in upper Mortandad Canyon.
Reach E-1FW Surface Water (MO-24786)	Uppermost Effluent Canyon. Provides samples surface water downstream of outfalls on the east end of TA-48.
Reach E-1W Surface Water (MO-24787)	Middle Effluent Canyon. Provides samples surface water upstream of TA-50 RLWTF outfall (NPDES outfall EPA03A-051).
Reach E-1E Surface Water (MO-24788)	Effluent Canyon about 130 m (425 ft) downstream of the TA-50 RLWTF outfall. Provides samples of surface water downstream of all Effluent Canyon contaminant sources.
Reach M-2W Surface Water (MO-24808)	Below confluence of Mortandad and Effluent Canyons at the E200 gaging station. Provides samples combined Mortandad and Effluent Canyons surface water.
Reach M-2E Surface Water (MO-24791)	Mortandad Canyon about 970 m (3180 ft) downcanyon of the Effluent Canyon confluence. Provides samples of surface water near the terminus of surface water flow supported by the TA-50 RLWTF outfall.

Table 3.2-1 (continued)

Location Name	Location and Rationale
Reach TS-1W Surface Water (MO-24792)	Ten Site Canyon headwaters above TA-35.
Reach TS-2E Surface Water (MO-24793)	Ten Site Canyon downcanyon of TA-35 where surface water occurs in persistent bedrock pools.
Perched Intermediate Groundwater (West to East)	
MCOI-1	Bench south of Mortandad Canyon about 425 m (1400 ft) east of the confluence with Effluent Canyon. New borehole to investigate western extent of intermediate-perched groundwater. Borehole was moist but did not produce flowing water. Well installed but does not produce water.
MCOI-8	Mortandad Canyon between TW-8 and MCOBT-4.4. New well to investigate possible saturation was encountered in the lower part of Cerros del Rio basalts. Water level in well generally coincides with top of sump.
MCOI-4	Confluence of Mortandad and Ten Site canyons. New well completed in a thin zone of intermediate-perched groundwater that occurs in Puye Formation sedimentary deposits on top of Cerros del Rio basalts.
MCOBT-4.4	Confluence of Mortandad and Ten Site canyons. Well completed in 2001 within a thin zone of perched groundwater occurs in Puye Formation sedimentary deposits on top of Cerros del Rio basalt.
MCOI-5	Mortandad Canyon on the R-15 well pad on the south side of the canyon. New well completed in an intermediate perched groundwater that occurs in the lower part of Cerros del Rio basalts.
MCOI-6	Mortandad Canyon north of R-15 near the canyon axis. New well completed in an intermediate-perched groundwater occurs in the lower part of Cerros del Rio basalt.
MCOI-10	Mesa top south of Mortandad Canyon, south of well R-15. New borehole to investigate southern extent of intermediate perched groundwater in the Cerros del Rio basalt. Borehole was dry and backfilled.
MCOBT-8.5	Mortandad Canyon about 440 m (1450 ft) downcanyon of R-15; located near the stream channel. New borehole to investigate eastern extent of intermediate-perched groundwater in the Cerros del Rio basalt. Borehole was dry and backfilled.
Regional Groundwater (West to East)	
R-1	Mortandad Canyon in area transitioning from narrow slot canyon to the west and a broad open canyon to the east. Westernmost well for monitoring regional groundwater in Mortandad Canyon. Completed as a single screen well. R-1 is a replacement well for TW-8.
TW-8	Mortandad Canyon in area transitioning from narrow slot canyon to the west and a broad open canyon to the east.
R-14	Upper Ten Site Canyon. Location provides samples of regional groundwater downstream of historic release sites at TA-35. Well has two screens in the regional aquifer.
R-33	Lower Ten Site Canyon near confluence with Mortandad Canyon. Location provides samples of regional groundwater near confluence. Well has two screens in the regional aquifer.

Table 3.2-1 (continued)

Location Name	Location and Rationale
R-15	Mortandad Canyon. Location provides samples of regional groundwater in part of canyon where infiltration of contaminated alluvial water is expected to affect deep groundwater systems. Completed as a single screen well.
R-28	Mortandad Canyon. Location provides samples of regional groundwater downgradient of where infiltration of contaminated alluvial water is expected to affect deep groundwater systems. Completed as a single screen well.
R-13	Mortandad Canyon near the eastern Laboratory boundary. Location provides samples of regional groundwater moving off-site. Completed as a single screen well.
R-34	Cedro Canyon. Well installed at the request of San Ildefonso Pueblo to monitor groundwater on San Ildefonso lands downgradient of Mortandad Canyon. Completed as a single screen well.

Note: Gray shading indicates new wells required by the "Work Plan for Mortandad Canyon" (LANL 1997, 56835) and "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613).

Table 3.2-2a
Period of Record for Manual Water-Level Data in Mortandad Canyon Wells

Saturated Zone	Well	Period of Record
Alluvial	MCA-1	5/05–07/06
	MCA-2	5/05–07/06
	MCA-3ac[a]	11/04–07/06
	MCA-3b	11/04–07/06
	MCA-3def[b]	03/05–07/06
	MCA-4	04/05–07/06
	MCA-5	04/05–07/06
	TSCA-6	04/05–07/06
	TSWB-6	01/95–07/97; 02/00–07/06 (dry)
	MCA-8	09/04–07/06 (dry)
	MCA-9	01/04–07/06 (dry)
	MCO-0.6	03/99–09/02; 05/05–07/06
	MCO-4B	8/90; 8/97; 5/98 – 7/06
	MCO-5	10/60-12/69; 07/71-09/71; 2/74–11/74; 8/76–11/79; 10/80; 4/81; 4/82; 10/83; 2/91 9/91; 8/92–10/92; 12/93; 6/94; 8/95; 8/96–11/96; 8/97; 5/98; 3/99–11/99; 03/00–07/06
	MCO-6	08/61–09/71; 02/74–11/74; 08/76–1/79; 10/80; 04/81; 04/82; 02/91–09/91; 08/92; 12/93; 03/95– 08/95; 11/96; 08/97; 10/98–07/06
	MCO-7	10/60–12/69; 07/71–09/71; 02/74–11/74; 08/76–11/79; 10/80; 04/81; 04/82; 10/83; 02/91 –10/91; 07/92; 12/93; 06/94; 06/95–11/96; 03/99–07/06
	MCO-7.5	10/61–12/69; 07/7–09/71; 02/74–11/74; 08/76–11/79; 10/80; 04/81; 10/83; 02/91–09/91; 07/92; 06/94; 06/95–08/95; 08/96–11/96; 05/98–07/03; 04/05–07/06
	MCWB-5	01/95–09/95; 01/96; 08/98; 01/00; 12/05 –07/06
	MCWB-5.5A	01/95–09/95; 07/97; 01/00; 12/05–07/06
	MCWB-5.5B	01/95– 09/95; 07/97; 01/00; 12/05–07/06
	MCWB-6.2A	01/95–09/95; 11/96; 07/97; 01/00; 12/05–07/06
	MCWB-6.5C	01/95–09/95; 11/96; 07/97; 01/00; 12/05–07/06
	MCWB-6.5D	01/95–09-95; 11/96; 06/97; 08/98; 06/99–06/03; 12/05– 0706 (mostly dry)
	MCWB-6.5E	01/95–09/95; 11/96; 06/97–07/97; 08/98; 01/00; 12/05– 0706
	MCWB-7A	01/95–09/95; 11/96; 06/97–07/97; 01/00; 12/05-0306
	MCWB-7B	01/95–09/95; 11/96; 06/97–07/97; 07/01; 12/05
	MCWB-7.4A	01/95–09/95; 11/96; 06/97–07/97; 01/00; 12/05-0306
	MCWB-7.4B	01/95 09/95; 11/96; 06/97–07/97; 01/00; 07/01; 12/05– – 03/06
	MCWB-7.7A	01/95–09/95; 06/97; 08/98; 01/00; 12/05– 3/06
	MCWB-7.7B	01/95–9/95; 07/97; 08/98; 03/99–06-03; 10/05–03/06
	MT-1	11/88; 02/91; 05/98–08/98; 03/99–06/03; 04/05–07/06
	MT-2	11/88; 02/91; 05/98–08/98; 03/99–06/03; 04/05–07/06 (dry)
	MT-3	11/88; 02/91; 05/98–08/98; 03/99–06/03; 04/05–07/06
	MT-4	11/88; 02/91; 05/98–08/98; 03/99–06/03; 05/05–07/06

Table 3.2-2 (continued)

Saturated Zone	Well	Period of Record
Intermediate	MCOBT-4.4	04/02–05/03; 11/04; 03/05–07/06
	MCOI-1	01/05–06/06 (dry)
	MCOI-4	11/04–07/06
	MCOI-5	10/04–03/06
	MCOI-6	01/05–02/06
	MCOI-8	01/05 –06/06
Regional	R-1	12/03; 01/05– 2/06
	R-13	02/02–12/03; 06/04; 01/05–02/06
	R-14	None, Westbay well
	R-15	09/99 02/00; 02/01–05/01; 07/02; 12/03; 06/04–02/06
	R-28	12/03 –01/04; 01/05–02/06
	Test Well 8	10/92–01/94; 01/00; 06/01; 06/04–02/06
	R-33	None; manual measurements are not possible with well completion.
	R-34	08/04– 05/06

[a] Denotes a nest of two piezometers with two transducers.

[b] Denotes a nest of three piezometers with three transducers.

Table 3.2-2b
Period of Record for
Automated Water-Level Data in Mortandad Canyon Alluvial Wells

Saturated Zone	Well	Period of Record
Alluvial	MCA-1	05/05–07/06
	MCA-2	05/05 07/06
	MCA-3ac[a]	04/05–07/06
	MCA-3b	04/05–07/06
	MCA-3def[b]	MCA-3d 04/05–07/06; MCA-3e and MCA-3f 10/05-0706
	MCA-4	05/05 07/06
	MCA-5	05/05–07/06
	TSCA-6	10/05–07/06
	TSWB-6	02/00–12/05; 07/06 (dry)
	MCA-8	10/05–07/06
	MCA-9	08/05 –07/06
	MCO-0.6	05/05– 07/06
	MCO-4B	05/05–07/06
	MCO-5	10/92–12/93; 05/05– 07/06
	MCO-6	05/05–07/06
	MCO-7	05/05–07/06
	MCO-7.5	05/05–07/06
	MCWB-5	01/96–10/99; 01/00–05/01; 07/02–07/06
	MCWB-5.5A	07/97–07/06
	MCWB-5.5B	07/97–07/06
	MCWB-6.2A	07/97–07/06
	MCWB-6.5C	07/97–03/06
	MCWB-6.5D	12/05–03/06
	MCWB-6.5E	07/97–10/99; 01/00–07/06
	MCWB-7A	07/97–07/06
	MCWB-7B	07/97–12/00; 07/01–01/03
	MCWB-7.4A	07/97– 04/99; 01/00 03/06
	MCWB-7.4B	07/97–07/99; 07/01–03/06
	MCWB-7.7A	01/00– 03/06
	MCWB-7.7B	07/97–03/06
	MT-1	05/05–07/06
	MT-2	05/05–07/06 (dry)
	MT-3	05/05–07/06
	MT-4	05/05–07/06

Table 3.2-2 (continued)

Saturated Zone	Well	Period of Record
Intermediate	MCOBT-4.4	07/02–07/06
	MCOI-1	None
	MCOI-4	10/05–07/06
	MCOI-5	08/05–07/06
	MCOI-6	08/05–07/06
	MCOI-8	10/05–07/06
Regional	R-1	01/05–03/06
	R-13	01/05–05/06
	R-14	12/04–09/05; 11/05–06/06
	R-15	12/04–05/06
	R-28	01/05–05/06
	Test Well 8	06/93–11/93; 01/94–03/97; 01/00–08/03; 12/04-05/06
	R-33	No valid data
	R-34	01/05–02/05; 05/05–06/06

[a] Denotes a nest of two piezometers with two transducers.
[b] Denotes a nest of three piezometers with three transducers.

Table 3.2-3
Characterization and RES Boreholes Installed in Mortandad Canyon

Borehole	Depth	Purpose and Location
Characterization Boreholes		
MCB-1	32 m (105 ft)	Determine distribution of contaminants in the vadose zone above the TA-50 outfall in Effluent Canyon. Borehole plugged and abandoned.
MCB-2	31.9 (104.5 ft)	Determine distribution of contaminants and moisture flux in the vadose zone below the TA-50 outfall near the Mortandad and Effluent Canyons confluence. Borehole is instrumented with water content and matric potential sensors.
MCB-3	NA	Determine distribution of contaminants in the vadose zone beneath the narrow slot portion of Mortandad Canyon between the confluence with Effluent Canyon and TW-8. Could not be drilled because there is no access to this portion of Mortandad Canyon.
MCB-4	NA	Determine distribution of contaminants in the vadose zone beneath the narrow slot portion of Mortandad Canyon between the confluence with Effluent Canyon and TW-8. Could not be drilled because there is no access to this portion of Mortandad Canyon.
MCB-5	31.7 m (104 ft)	Determine distribution of contaminants and moisture flux in the vadose zone beneath the narrow slot portion of Mortandad Canyon between the confluence with Effluent Canyon and TW-8. Borehole is about 205 m (670 ft) west of the permeable reactive barrier and represents westernmost access to slot portion of Mortandad Canyon. Borehole is instrumented with a vector probe.
MCB-6	27 m (89 ft)	Determine distribution of contaminants and moisture flux in the vadose zone in area where Mortandad Canyon begins to widen eastward. The borehole is about 140 m (460 ft) east of the permeable reactive barrier. Borehole is instrumented with a vector probe.
MCB-7	30.8 m (101 ft)	Determine distribution of contaminants and moisture flux in the vadose zone in Mortandad Canyon about 200 m (650 ft) upcanyon of the confluence with Ten Site Canyon. Borehole is instrumented with water content and matric potential sensors.
MCB-8	31.9 m (104.5 ft)	Determine distribution of contaminants and moisture flux in the vadose zone in the Mortandad Canyon sediment traps. Borehole is instrumented with water content and matric potential sensors.
MCB-9	31.2 m (102.5 ft)	Determine distribution of contaminants and moisture flux in the vadose zone adjacent to easternmost sediment trap in Mortandad Canyon. Borehole is instrumented with a vector probe.
MCB-10	31.7 m (104 ft)	Determine distribution of contaminants in the vadose zone near eastern limit of alluvial saturation in Mortandad Canyon. Northern borehole in north-south transect across canyon that includes MCB-11 and MCB-12. Borehole plugged and abandoned.
MCB-11	31.7 m (104 ft)	Determine distribution of contaminants and moisture flux in the vadose zone near eastern limit of alluvial saturation in Mortandad Canyon. Middle borehole in north-south transect across canyon that includes MCB-10 and MCB-12. Borehole is instrumented with water content and matric potential sensors.
MCB-12	31.9 m (104.5 ft)	Determine distribution of contaminants in the vadose zone near eastern limit of alluvial saturation in Mortandad Canyon. Southern borehole in north-south transect across canyon that includes MCB-10 and MCB-11. Borehole plugged and abandoned.
MCB-13	NA	Determine distribution of contaminants in the vadose zone in Mortandad Canyon east of persistent alluvial groundwater. Could not be drilled because this portion of Mortandad Canyon is a protected archeological zone.
MCB-14	86.6 m (284 ft)	Determine distribution of contaminants and moisture flux in the vadose zone adjacent to the westernmost Mortandad Canyon sediment trap. Borehole is instrumented with a vector probe.

Table 3.2-3 (continued)

Borehole	Depth	Purpose and Location
MCB-15	47.1 m (154.5 ft)	Determine distribution of contaminants in the vadose zone in lower Ten Site Canyon. Borehole was drilled to total depth and partially backfilled before installing alluvial well TSCO-6.
MCB-16	30.5 m (100 ft)	Determine distribution of contaminants and moisture flux in the vadose zone near the eastern Laboratory. The borehole was drilled about 32 m (105 ft) northeast of R-13. Borehole is instrumented with water content and matric potential sensors.
RES Boreholes		
MCRES-2	61 m (200.2 ft)	Borehole drilled to collect moisture data, soil properties, and borehole geophysics at the confluence of Mortandad Ten Site canyons where surface-based resistivity survey indicates electrically resistive bedrock at depth. Borehole is instrumented with a vector probe. Paired with data collected from MCOBT-4.4 to evaluate lateral changes in resistivity structure in bedrock units beneath Mortandad Canyon.
MCRES-3	61 m (200 ft)	Borehole drilled to collect moisture data, soil properties, and borehole geophysics in Mortandad Canyon east of TW-8 where surface-based resistivity survey indicates resistive bedrock at depth. MCRES-3 is paired with MCRES-4 to evaluate lateral changes in resistivity structure in bedrock units beneath Mortandad Canyon. Borehole plugged and abandoned.
MCRES-4	68.6 m (225 ft)	Borehole drilled to collect moisture data, soil properties, and borehole geophysics in Mortandad Canyon east of TW-8 where surface-based resistivity survey indicates conductive bedrock at depth. MCRES-4 is paired with MCRES-3 to evaluate lateral changes in resistivity structure in bedrock units beneath Mortandad Canyon. Borehole is instrumented with water content and matric potential sensors.
R-28	45.6 (150 ft)	Core collected from the upper 45.6 m (150 ft) of the corehole drilled at the R-28 regional well site were analyzed for moisture data and soil properties. The data were collected to determine if data from a surface-based resistivity survey can be used to predict changes in moisture content with depth. The corehole was plugged and abandoned.

Table 3.4-1
Deviations from Plans for Alluvial Wells,
Characterization Boreholes, Resistivity Boreholes, and Intermediate Wells

Planned	Actual Disposition
Alluvial wells A-3a to A-3f to be drilled along the canyon axis between MCO-8 and MCW-8.1A,B,C	Archeological site restrictions required moving the drilling location . MCA-3 actually installed as two sets of three nested piezometers each. The set MCA-3a,b,c was installed in Mortandad Canyon upcanyon of the confluence with Ten Site Canyon, ~25 ft upcanyon of MCB-7. The set MCA-3d,e,f was installed south of sediment trap #3 and near MCB-9.
Alluvial well MCA-6 to be installed singly in lower Ten Site Canyon	Hole was extended to 154.5-ft depth to accomplish the goals of MCB-15 before the lower interval was plugged to 21.3-ft depth to allow construction of alluvial well MCA-6.
Transect of alluvial wells MCA-7, MCA-8, and MCA-9 proposed across Mortandad Canyon near R-13	All three alluvial explorations were dry to total depth. MCA-8 and MCA-9 were completed as alluvial wells; MCA-7 was plugged and abandoned.
Characterization borehole MCB-3 to be drilled in Mortandad Canyon between MCA-5 and MCO-4	MCB-3 was not drilled because this stretch of Mortandad Canyon is too narrow and heavily vegetated for drilling activity.
Characterization borehole MCB-4 to be drilled in Mortandad Canyon between MCA-5 and MCO-4, immediately north of R-14	MCB-4 was not drilled because this stretch of Mortandad Canyon is too narrow and heavily vegetated for drilling activity.
Characterization borehole MCB-8 to be drilled in Mortandad Canyon between sediment traps #1 and #2	MCB-8 was moved to a location south of sediment trap #1.
Characterization borehole MCB-9 to be drilled in Mortandad Canyon within sediment trap #1	MCB-9 was moved to a location south of sediment trap #3.
Characterization boreholes MCB-10, MCB-11, and MCB-12 to be drilled in Mortandad Canyon in a cluster downcanyon of the sediment traps	Characterization boreholes MCB-10, MCB-11, and MCB-12 were drilled in a north-to-south transect across Mortandad Canyon downcanyon of sediment trap #3.
Characterization borehole MCB-13 to be drilled between MCO-8 and MCW-8.1A,B,C	MCB-13 was not drilled because of archeological site restrictions.
Characterization borehole MCB-14 to be drilled in accessible portion of lower Ten Site Canyon west of MCOI-3	MCB-14 was moved to a location next to sediment trap #1.
Characterization borehole MCB-15 to be installed singly in lower Mortandad Canyon.	MCB-15 was backfilled to 21.3-ft depth and completed as alluvial well MCA-6.
Intermediate well MCOI -3 to be installed in lower Ten Site Canyon with one screen in Cerros del Rio basalt. Projected depth 770 ft. Core to be collected to refusal (~560 ft).	MCOI-3 was not drilled; the objectives set out for MCOI -3 were obtained by drilling R-33 in this locality.
Intermediate well MCOI -5 to be installed near R-15, with one screen in Cerros del Rio basalt. Projected depth 760 ft. Core to be collected to refusal (~500 ft).	Intermediate well MCOI-5 located and completed as planned. Total depth drilled 717 ft. No core was collected because of available core (0–420 ft and 740–751.5 ft) from adjacent R-15 borehole.
Intermediate well MCOI -10 to be installed on the north flank of the mesa south of R-15, on the Qbt 2 bench above the canyon bottom, with one screen in the Cerros del Rio basalt. Projected depth 1000 ft. Core to be collected from 300 to 800 ft depth.	MCOI-10 was moved farther south to the mesa top because of limited space on the Qbt 2 bench. No well was installed at MCOI-10 because the borehole was dry throughout; the hole was plugged and abandoned. Total depth drilled 1050 ft. Core was collected from 300 to 727.3-ft depth.

Table 4.2-1
Summary of Water Samples Taken, 2000–2005, Mortandad Canyon

Location Name	Sampling Performed for the Work Plan for Mortandad Canyon and the Mortandad Canyon Groundwater Work Plan, Revision 1					
	2000	2001	2002	2003	2004	2005
Alluvial Wells (West to East)						
MCO-0.6						Dry √
MCA-1	n/a*	n/a	n/a	n/a	n/a	√ √
MCA-4	n/a	n/a	n/a	n/a	n/a	Dry √
MCO-2	√					Dry Dry
MCA-5	n/a	n/a	n/a	n/a	n/a	√ Dry
MCO-4B		√		√	√ √	√ √ √ √
MCO-5	√	√	√	√	√	√ √
MCO-6	√√√√√	√√√√√	√√√√	√√√√	√√√	√ √ √ √
MCA-2	n/a	n/a	n/a	n/a	n/a	√ √
MCO-7	√√√√√	√√√√	√√√√	√√√√√	√√√√	√ √ √ √ √
TSCA-6	n/a	n/a	n/a	n/a	n/a	Dry Dry
MT-1						√ √
MCO-7.5	√	√		√		√ √
MT-2						Dry Dry
MT-3			√			√ √
MT-4						Dry √
Surface Water (West to East)						
Reach M-1W Surface Water (MO-24789)	n/a	n/a	n/a	n/a	n/a	√ √ √
Reach M-1E Surface Water (MO-24790)	n/a	n/a	n/a	n/a	n/a	√ √
Reach E-1FW Surface Water (MO-24786)	n/a	n/a	n/a	n/a	n/a	√ √
Reach E-1W Surface Water (MO-24787)	n/a	n/a	n/a	n/a	n/a	√ √ √
Reach E-1E Surface Water (MO-24788)	n/a	n/a	n/a	n/a	n/a	√ √ √
Reach M-2W Surface Water (MO-24808)	n/a	n/a	n/a	n/a	n/a	√ √
Reach M-2E Surface Water (MO-24791)	n/a	n/a	n/a	n/a	n/a	√ √
Reach TS-1W Surface Water (MO-24792)	n/a	n/a	n/a	n/a	n/a	√ √ √ √
Reach TS-2E Surface Water (MO-24793)	n/a	n/a	n/a	n/a	n/a	√ √

Table 4.2-1 (continued)

Location Name	Sampling Performed for the Work Plan for Mortandad Canyon and the Mortandad Canyon Groundwater Work Plan, Revision 1					
	2000	2001	2002	2003	2004	2005
Perched-Intermediate Groundwater (West to East)[smr1]						
MCOI-1	n/a	n/a	n/a	n/a	n/a	Dry
MCOI-8	n/a	n/a	n/a	n/a	n/a	√ Dry
MCOI-4	n/a	n/a	n/a	n/a	n/a	√ √
MCOBT-4.4	n/a			√ √	√	√ √
MCOI-5	n/a	n/a	n/a	n/a	n/a	√ √
MCOI-6	n/a	n/a	n/a	n/a	n/a	√ √
Regional Groundwater (west to east)						
R-1	n/a	n/a	n/a	√		√ √ √
TW-8	√ √ √	√ √ √ √ √	√ √ √	√	√	√ √
R-14	n/a	n/a	n/a		√ √ √	√ √
R-33	n/a	n/a	n/a	n/a	n/a	√ √
R-15	√ √	√ √		√	√ √	√ √ √
R-28	n/a	n/a	n/a	n/a	n/a	√ √ √
R-13	n/a	n/a	√ √ √	√ √ √	√	√ √ √
R-34	n/a	n/a	n/a	n/a		√ √
PM-5	√ √ √ √ √	√√√√√√√√√	√√√√√√√√√	√√√√√√√	√√√√√	√ √ √ √ √

Notes: Gray shading highlights sample locations required under the "Mortandad Canyon Groundwater Work Plan, Revision 1" (LANL 2004, 82613).
Multiple checks (√) represent number of sampling events in a year. Underlined checks (√) represent samples collected as part of two rounds of snapshot sampling. Underlined Dry (Dry) indicates sample location was dry during the snapshot sampling. Checks without underlining (√) represent samples collected as part of routine surveillance monitoring.

*n/a = Not applicable, well not installed or surface water station not established.

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Table 6.2-1
Mortandad Sediment Inorganic COPCs

Reach	Aluminum	Ammonia	Antimony	Arsenic	Barium	Beryllium	Boron	Bromide	Cadmium	Calcium	Chloride	Chromium[a]	Chromium hexavalent ion	Cobalt	Copper	Cyanide (Total)	Fluoride	Iron	Lead
LANL sediment BV[b]	**15400**	**#N/A**	**0.83**	**3.98**	**127**	**1.31**	**#N/A**	**#N/A**	**0.4**	**4420**	**17.1**	**10.5**	**#N/A**	**4.73**	**11.2**	**0.82**	**#N/A**	**13800**	19.7
Residential SSL[c]	**77800**	**#N/A**	**31.3**	**3.9**	**15600**	**156**	**15600**	**#N/A**	**39**	**#N/A**	**#N/A**	**2100**	**234**	**1520**	**3130**	**1220**	**3670**	**23500**	400
M-1W	—[d]	4.67	11 (U)	**4.4**	—	—	—	—	0.93 (U)	—	—	—	—	—	13.3	0.93 (U)	—	—	25.8
M-1C	—	—	—	—	132	—	—	—	—	—	—	16.8	—	—	—	—	—	—	24
M-1E	26000	—	—	**8.4**	270	1.4	29	—	0.79 (U)	—	—	18.8	—	7.7	14	—	—	21000	30
E-1FW	21300 (J+)	—	—	**16.6**	233	—	—	—	0.85	4820	—	**2210**	1.99	4.78	383	—	3.73	18300	56.8 (J)
E-1W	19000	3.22	1.41 (U)	**11**	350	2.4	—	8.31	1.75 (U)	5800	185	636	—	12	20	1.2 (U)	7.59	**25000**	34.6 (J-)
E-1E	—	—	—	**6.1**	130	—	—	12.4	2.2 (J+)	51000	88.7	140	—	6	120	—	3.9	—	50
M-2W	—	3.05	13 (U)	**4.3**	130	—	—	3.83	0.8	22000	39.2	22	—	—	47	—	70.6	14000	58
M-2E	—	—	—	—	—	—	—	1.12	0.508 (U)	12000	52.7	14	—	—	35	—	13.3	—	—
M-3	—	—	—	**4**	—	—	—	0.944	0.53 (U)	5460	35.8	17.5	—	—	29	—	3.62	13900	—
TS-1W	—	—	11.2 (UJ)	—	131	—	—	—	1	—	—	—	—	4.84	—	—	—	—	—
TS-1C	—	3.84	11.2 (UJ)	—	153	—	—	—	1.7	—	—	—	—	5.9 (J)	14.5	—	—	**28800 (J+)**	39.1
TS-1E	—	4.65	—	—	—	—	—	—	0.59 (U)	—	—	—	—	6.77	119	—	—	—	24.7
TS-2W	—	—	—	—	—	—	—	—	0.67 (U)	—	—	—	—	—	18.8	—	6.2	—	—
TS-2C	—	4.45	—	—	—	—	—	—	0.59 (U)	—	—	22.3	—	—	48.1	—	2.23	—	29.2
TS-2E	16100	—	—	**4.43**	—	—	—	—	0.75	—	126	26.8	—	5.5 (J)	67	—	1.8	13900 (J+)	26.3
TS-3	—	—	—	—	—	—	—	—	0.51 (U)	—	—	—	—	—	19	—	—	—	20
M-4	—	—	1.9 (J-)	**4.6**	146	—	—	—	0.75 (U)	5180	—	14.5 (J)	—	5.1	37.2	—	1.48	15100	22.6
MCW-1	—	—	—	—	—	—	—	—	0.582 (U)	—	—	—	—	—	—	—	—	—	21.4
MCW-2N	—	—	—	—	—	—	—	—	0.532 (U)	—	—	—	—	—	—	—	—	—	—
MCW-2W	—	—	—	—	—	—	—	—	0.5 (U)	—	—	—	—	—	11.5	1.37	—	—	—
MCW-2E	—	—	—	—	—	—	—	—	0.53 (U)	—	—	—	—	—	—	—	—	—	—
M-5W	—	—	—	—	143	—	—	—	—	—	—	—	—	—	—	—	—	14100	—
M-5E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
M-6	—	—	—	—	—	—	—	—	0.51 (U)	—	—	—	—	—	—	—	—	—	—

Table 6.2-1 (continued)

Reach	Magnesium	Manganese	Mercury	Nickel	Nitrate	Nitrate-Nitrite as N	Nitrite	Oxalate	Perchlorate[c]	Phosphorus, Orthophosphate (Expressed as PO4)	Selenium	Silver	Sodium	Sulfate	Thallium	Total Phosphorus	Uranium[e]	Vanadium	Zinc
LANL sediment BV[b]	2370	543	0.1	9.38	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.3	1	1470	58.2	0.73	#N/A	2.22	19.7	60.2
Residential SSL[a]	#N/A	3590	100000	1560	100000	#N/A	7820	#N/A	55	#N/A	391	391	#N/A	#N/A	5.16	#N/A	16	78.2	23500
M-1W	—	—	0.19 (U)	28.8	—	—	—	—	—	—	2.22 (U)	3.7 (U)	—	—	—	—	—	—	137
M-1C	—	—	—	—	—	—	—	—	—	—	0.35	—	—	—	—	—	—	—	71.8
M-1E	3400	1640	0.16 (U)	11	—	—	—	—	—	—	10.7 (U)	3.2 (U)	—	—	—	—	—	37	94
E-1FW	3310	1040	0.22	10.9	—	—	—	—	0.00323	—	11.5 (U)	—	—	—	—	101	—	53.1	169
E-1W	2700	2500 (J-)	0.24 (U)	11	—	—	—	46.5	—	—	5.25 (U)	4.8 (U)	—	232	—	293	4.32	30	110
E-1E	—	1700	2.7	46	—	0.21 (J)	—	25.8	0.0011 (J)	—	2.28 (U)	3.3	—	204	1.6	154	4.14 (J+)	—	78 (J-)
M-2W	—	—	0.69	—	—	0.7	—	19.3	0.959	—	1.6 (U)	2.8 (U)	1700	181	0.8 (J)	101	—	—	100
M-2E	—	—	1.1	—	—	—	—	15.8	0.141 (J)	—	0.59	2.7	—	99.9	—	—	—	—	60.6
M-3	—	—	0.43	—	—	—	—	12.8	0.162 (J+)	—	1.6 (U)	—	—	96.2	—	—	—	—	88.8
TS-1W	—	—	—	—	—	—	—	—	—	—	1.63 (U)	1.4 (U)	—	—	1 (U)	—	—	23	—
TS-1C	—	—	—	58.9	—	—	—	—	—	—	3 (U)	1.4 (U)	—	—	1 (U)	93.3	—	25.9	94
TS-1E	—	661	—	—	—	—	—	—	—	—	1.8 (U)	—	—	—	—	—	—	—	—
TS-2W	—	—	—	—	1.9	—	0.26	—	—	3.8 (J)	2.02 (U)	—	—	—	—	—	—	—	—
TS-2C	—	—	0.86	—	1.5	—	0.32	—	—	2.4 (J)	1.8 (U)	42.8	—	—	—	99.4	—	22	61
TS-2E	—	—	1.36	—	0.7	—	0.11 (J)	—	—	3.4 (J)	9.94 (U)	33.9	—	827	—	—	—	27.1	90.4
TS-3	—	570	0.19	—	—	—	—	—	—	—	1.76 (U)	4.4	—	—	—	—	—	—	63
M-4	—	—	0.32	—	—	0.3 (J)	—	—	0.627 (J-)	—	2.26 (U)	7	—	—	—	127	—	—	73.6
MCW-1	—	—	—	—	—	—	—	—	—	—	0.582 (U)	—	—	—	—	—	—	—	—
MCW-2N	—	—	—	—	—	—	—	—	—	—	0.55 (U)	—	—	—	—	—	—	—	—
MCW-2W	—	—	—	—	—	—	—	—	—	—	0.55 (U)	—	—	—	—	—	—	—	—
MCW-2E	—	—	—	—	—	—	—	—	—	—	0.52 (U)	—	—	—	—	—	—	—	—
M-5W	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	72.9
M-5E	—	—	—	—	—	—	—	—	—	—	0.56 (J-)	—	—	—	1 (U)	—	—	—	—
M-6	—	—	—	—	—	—	—	—	—	—	0.603 (U)	—	—	—	—	—	—	—	—

Notes: Values are in mg/kg. Values are maximum values > BV; if no BV, value is maximum detected value. Values in bold exceed the residential SSL. Grey shading indicates a screening value was exceeded for that chemical.

[a] EPA region 6 residential HHMSSL (Human Health Medium-Specific Screening Levels), EPA 2005, 91002.

[b] LANL (1998, 59730).

[c] Residential SSLs are NMED values (NMED 2006, 92513) unless otherwise noted.

[d] — = Not detected, not detected > BV, or not analyzed.

[e] EPA region 9 residential PRG (Preliminary Remediation Goals), EPA 2004, 93663.

Table 6.2-2
Mortandad Sediment Organic COPCs

Reach	Acenaphthene	Acetone	Anthracene	Aroclor-1254	Aroclor-1260	Aroclors (Mixed)[a]	Benzene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene[b]	Benzo(k)fluoranthene	Benzoic Acid[a]	BHC[alpha-]	BHC[beta-]	BHC[delta-]	BHC[gamma-]	Bis(2-ethylhexyl)phthalate	Bromodichloromethane	Bromomethane	Butanone[2-]	Butylbenzylphthalate[a,c]	Carbazole[a]	Carbon Tetrachloride
Residential SSL[d]	**3730**	**28100**	**22000**	**1.12**	**1.12**	**2.22**	**10.3**	**6.21**	**0.621**	**6.21**	**2290**	**62.1**	**100000**	**0.902**	**3.16**	**#N/A**	**4.37**	**347**	**14.4**	**8.51**	**31800**	**240**	**240**	**3.47**
M-1W	0.42	0.087 (J)	0.74	—[e]	0.063	—	—	2.71	**2.11**	2.51	1.18	0.2	—	0.018	0.003	—	0.0075	—	—	—	—	—	—	—
M-1C	1.7	0.19 (J)	0.32	—	0.14	—	—	0.38	0.45	0.3	0.18	0.19	—	0.021 (J+)	0.0048 (J-)	—	0.0091 (J+)	—	—	—	0.021 (J)	—	—	—
M-1E	—	0.44 (J)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.036 (J)	—	—	—
E-1FW	0.33	0.47 (J)	0.3 (J+)	0.16	0.03	—	—	0.44 (J+)	0.5 (J+)	0.49 (J+)	0.29 (J+)	0.27 (J+)	—	—	—	—	—	—	—	0.002 (J)	0.025 (J)	—	—	—
E-1W	—	—	—	—	0.02	—	—	0.23	0.26	0.48	0.25	—	—	—	—	—	—	0.04 (J)	—	—	—	—	—	—
E-1E	—	0.1	0.04 (J)	0.13 (J-)	0.11	0.053	—	0.1	0.25	0.42 (J)	0.12	0.13	5.7 (J)	0.0073 (J)	—	—	—	0.16 (J-)	—	—	0.027	—	—	—
M-2W	—	0.034 (J)	0.01 (J)	0.15 (J)	0.21 (J)	—	—	0.37 (J-)	0.37 (J-)	0.37 (J-)	0.07	0.37 (J-)	0.13 (J)	—	—	—	—	0.4 (J)	—	—	0.02 (J+)	—	—	—
M-2E	0.088 (J-)	0.085 (J)	0.15 (J-)	0.053	0.054	—	—	0.22 (J-)	0.16 (J-)	0.11 (J)	—	0.069 (J)	—	—	0.0023 (J)	—	—	0.091 (J)	—	—	—	—	—	—
M-3	—	0.046	—	—	0.39	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TS-1W	0.041 (J)	0.13 (J)	0.04 (J)	0.57	**1.37**	1.52	—	0.44 (J)	**0.67 (J)**	0.87 (J)	0.25 (J)	0.27 (J)	0.13 (J)	—	—	—	—	0.55	—	—	—	—	—	0.002 (J)
TS-1C	0.51 (J)	0.21 (J)	0.9 (J)	0.01 (J)	**1.3**	—	0.00069 (J)	1.86 (J)	**2.04**	2.53 (J)	1.35 (J)	1.13 (J)	0.14 (J)	—	—	—	—	0.16 (J)	—	—	0.038 (J)	0.51 (J)	—	—
TS-1E	0.06	0.13 (J)	0.11 (J)	0.03 (J)	0.19 (J)	—	—	0.72 (J-)	**0.85 (J)**	1.6 (J)	0.58	0.25 (J-)	—	—	—	—	—	—	—	—	0.02 (J)	—	—	—
TS-2W	—	—	0.045	—	0.1	—	—	0.33	0.38	0.36	0.26	0.16	—	—	—	—	—	—	—	—	0.019 (J)	—	—	—
TS-2C	—	0.16 (J)	0.01 (J)	0.069 (J)	0.16	—	—	0.11 (J+)	0.17 (J-)	0.37 (J)	0.12 (J-)	—	—	—	—	—	—	0.15 (J)	—	—	0.026 (J)	—	—	—
TS-2E	—	0.14	—	—	0.31	—	0.0008 (J)	—	—	—	0.082	—	—	—	—	—	—	—	—	—	0.014 (J)	—	—	—
TS-3	—	—	—	—	0.076	—	—	0.059 (J)	0.084 (J)	0.09 (J)	—	0.079 (J)	0.14 (J)	0.007	—	—	—	0.094 (J)	—	—	—	—	—	—
M-4	0.29 (J)	0.087 (J+)	0.38 (J)	0.01	0.12	—	—	0.58 (J-)	0.59 (J)	0.6 (J)	0.73 (J-)	0.2 (J)	0.18 (J)	—	—	—	—	0.41 (J)	0.004 (J)	—	0.014 (J)	—	0.23 (J)	—
MCW-1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.191 (J)	—	—	—	—	—	—
MCW-2N	0.0108 (J)	—	—	—	—	—	—	—	—	—	—	—	0.402 (J)	—	—	—	—	0.17 (J)	—	—	—	—	—	—
MCW-2E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
M-5W	—	0.23 (J)	—	—	—	—	—	—	—	—	—	—	—	0.049	0.0076	0.0034	0.017	—	—	—	0.03 (J)	—	—	—
M-5E	1.8 (J+)	0.16 (J)	—	—	—	—	0.00057 (J)	—	—	—	—	—	—	—	—	—	—	—	—	—	0.024 (J)	—	—	—
M-6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.207 (J)	—	—	—	—	—	—

Table 6.2-2 (continued)

Reach	Chlordane[alpha-][f]	Chlordane[gamma-][f]	Chloroform	Chloromethane	Chlorophenol[2-]	Chlorophenyl-phenyl[4-] Ether	Chrysene	DDD[4,4'-]	DDE[4,4'-]	DDT[4,4'-]	Dibenz(a,h)anthracene	Dibenzofuran	Dichlorobenzene[1,2-][b]	Dichlorobenzidine[3,3'-]	Dichloroethene[1,1-]	Dichloroethene[cis-1,2-]	Dieldrin	Diethylphthalate	Di-n-butylphthalate	Endosulfan Sulfate	Endrin Aldehyde	Fluoranthene	Fluorene	Heptachlor Epoxide[a]	Hexachlorobutadiene
Residential SSL[d]	**16.2**	**16.2**	**4**	**21.8**	**166**	**#N/A**	**615**	**24.4**	**17.2**	**17.2**	**0.621**	**142**	**37.4**	**10.8**	**206**	**76.5**	**0.304**	**48900**	**6110**	**18.3**	**18.3**	**2290**	**2660**	**0.53**	**12.2**
M-1W	0.002 (J)	0.0024	—	—	—	—	2.22	0.0038	—	0.013 (J)	—	—	—	—	—	—	0.0033 (J)	—	—	—	—	7.78	0.031	—	—
M-1C	—	—	—	—	—	—	0.56	0.0031 (J+)	0.0036 (J+)	0.016 (J+)	—	—	—	—	—	—	—	—	—	—	0.0032 (J+)	1.5	0.23	—	—
M-1E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
E-1FW	—	—	—	—	—	—	0.59 (J+)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.5 (J+)	0.22 (J+)	—	—
E-1W	—	—	—	—	—	—	0.23	—	—	0.0096 (J-)	—	—	—	—	—	—	—	—	—	—	—	0.7 (J)	—	—	—
E-1E	0.0095	0.014	0.0013 (J-)	—	—	—	0.25	—	0.0062 (J)	0.078 (J)	—	—	—	—	—	—	—	—	—	—	0.0035 (J)	0.63	—	0.0027 (J)	—
M-2W	—	—	—	—	—	—	0.37 (J-)	—	—	0.035 (J)	—	—	—	—	—	—	—	—	—	—	0.014 (J)	0.37 (J-)	—	—	—
M-2E	—	—	—	—	—	—	0.21 (J-)	—	—	0.01 (J)	—	—	—	—	—	—	0.0045 (J)	—	—	0.0034 (J)	—	0.59 (J-)	0.089 (J-)	—	—
M-3	—	—	—	—	—	—	—	—	—	0.028	—	—	—	—	—	—	—	—	—	—	0.011 (J+)	0.15 (J)	—	—	—
TS-1W	—	—	—	—	—	—	0.72 (J)	—	—	—	—	—	—	—	—	—	—	—	2.6 (J)	—	—	1 (J)	—	—	—
TS-1C	—	—	—	—	—	—	1.64 (J)	—	—	—	0.18 (J)	0.26 (J)	—	—	—	—	—	0.1 (J)	3 (J)	—	—	3.18 (J)	0.47 (J)	—	—
TS-1E	—	—	—	—	—	—	0.91 (J)	—	—	—	—	0.14 (J)	—	—	—	—	—	—	—	—	—	1.7 (J+)	—	—	—
TS-2W	—	—	—	—	—	—	0.53	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.88 (J)	—	—	—
TS-2C	—	—	—	—	—	—	0.18 (J+)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.36 (J-)	—	—	—
TS-2E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TS-3	—	—	—	—	—	—	0.087 (J)	—	—	0.0095 (J)	—	—	—	—	—	—	—	—	—	—	—	0.35 (J)	—	—	—
M-4	—	—	—	0.002 (J)	—	—	0.59 (J)	—	—	0.015 (J-)	—	—	—	0.7	—	0.001 (J)	—	—	—	—	—	1.5	0.24 (J)	—	—
MCW-1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCW-2N	—	—	—	—	0.024 (J)	0.0904 (J)	—	—	—	—	—	0.0251 (J)	—	—	—	—	—	—	0.0406 (J)	—	—	—	0.0195 (J)	—	0.02 (J)
MCW-2E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
M-5W	—	—	—	—	—	—	—	0.0067	0.0022	0.019 (J)	—	—	—	—	0.0012 (J)	—	—	—	—	—	—	—	—	—	—
M-5E	—	—	—	—	—	—	—	—	—	—	—	—	0.0013 (J)	—	0.0016 (J)	—	—	—	—	—	—	—	—	—	—
M-6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 6.2-2 (continued)

Reach	Hexanone[2-]	Indeno(1,2,3-cd)pyrene	Isopropylbenzene	Isopropyltoluene[4-][g]	Methoxychlor[4,4'-][a]	Methyl-2-pentanone[4-]	Methylene Chloride	Methylnaphthalene[2-][h]	Naphthalene	Nitroaniline[2-][a]	Nitroaniline[4-][a]	Nitrophenol[2-]	Nitrosodiphenylamine[N-]	Phenanthrene	Pyrene	Tetrachloroethene	Toluene[b]	Trichloroethane[1,1,1-][b]	Trichloroethene	Trichlorofluoromethane	Trichlorophenol[2,4,6-]	Trimethylbenzene[1,2,4-]	Xylene (Total)[b]	Xylene[1,2-][b]	Xylene[1,3-][b]
Residential SSL[d]	**31800**	**6.21**	**271**	**271**	**305.515**	**5510**	**182**	**79.5**	**79.5**	**180**	**180**	**166**	**993**	**1830**	**2290**	**12.5**	**252**	**563**	**0.638**	**588**	**6.11**	**58**	**82**	**99.5**	**82**
M-1W	—	1.23	—	—	0.1	—	—	—	—	—	—	—	—	3.38 (J)	5.2	0.00067 (J)	—	—	—	—	—	—	—	—	—
M-1C	—	0.22	—	0.0065 (J)	0.14	—	—	—	1	—	—	—	—	1.1	0.86	0.00086 (J)	—	—	—	—	—	—	—	—	—
M-1E	—	—	—	0.039 (J)	—	—	—	—	—	—	—	—	—	—	—	0.0011 (J-)	0.028	—	0.00023 (J)	—	—	—	—	—	—
E-1FW	—	0.34 (J+)	0.024	0.57 (J-)	—	0.014 (J)	—	0.0082 (J)	1.2 (J+)	—	—	—	—	0.94 (J-)	1 (J+)	0.0011 (J-)	0.075 (J-)	—	—	—	—	—	0.0014 (J)	—	—
E-1W	—	—	—	—	—	—	—	—	—	—	—	—	—	0.4 (J)	0.57	—	—	—	—	—	—	—	—	—	—
E-1E	—	0.13	—	0.016 (J)	—	—	—	—	—	—	—	—	—	0.34	0.65	—	—	—	—	0.002 (J)	—	—	—	—	—
M-2W	—	0.06	—	0.032	—	—	—	—	—	—	—	—	—	0.37 (J-)	0.37 (J-)	—	—	—	—	0.0034 (J)	—	—	—	—	—
M-2E	—	—	—	—	0.034 (J)	—	—	—	0.08 (J-)	—	—	—	—	0.56 (J-)	0.55 (J-)	—	—	0.03 (J+)	—	0.0027 (J)	—	—	—	—	—
M-3	—	—	—	0.026 (J)	—	—	0.0083	—	—	—	—	—	—	0.11 (J)	—	—	0.023 (J)	—	—	—	—	—	—	—	—
TS-1W	0.014	0.23 (J)	—	0.014	—	—	0.002 (J)	—	—	0.25 (J)	0.24 (J)	—	—	0.35 (J)	1.2 (J)	—	0.022 (J)	—	—	—	—	—	—	—	—
TS-1C	0.0033 (J)	1.45 (J)	0.00074 (J)	0.026 (J)	—	0.008 (J)	—	0.081 (J)	0.18 (J)	—	—	—	—	3.1 (J)	3.52 (J)	—	0.016 (J-)	—	0.00035 (J)	—	—	—	—	—	—
TS-1E	—	0.52 (J+)	—	0.0082 (J)	—	—	—	0.13 (J)	—	—	—	—	—	0.81 (J)	2.2 (J-)	0.02 (J)	0.018 (J)	0.01	0.0003 (J)	—	—	0.00078 (J)	—	—	—
TS-2W	—	0.28	—	—	—	—	—	—	—	—	—	—	—	0.29	0.63 (J)	0.02	—	0.01	0.0011 (J)	—	—	0.00086 (J)	—	—	—
TS-2C	—	0.12 (J-)	—	0.0038 (J)	—	—	—	—	—	—	—	—	—	0.097 (J+)	0.66 (J)	0.01	0.0073 (J)	0.0055 (J-)	0.00028 (J)	—	—	0.001 (J)	—	—	—
TS-2E	—	—	—	—	—	0.0043 (J+)	—	—	—	—	—	—	—	—	—	—	0.00096 (J)	—	—	0.00037 (J)	—	—	—	—	—	—
TS-3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.38 (J)	—	—	—	—	—	—	—	—	—	—
M-4	—	0.29 (J)	—	—	—	—	0.0067	—	0.002 (J)	—	—	—	—	1.5	1.4	0.006 (J)	0.014	—	—	0.0088 (J)	—	0.003 (J)	—	0.002 (J)	0.005 (J)
MCW-1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCW-2N	—	—	—	0.0025 (J)	—	—	—	0.0274 (J)	—	—	—	0.0818 (J)	0.0801 (J)	—	—	—	—	—	—	—	0.052 (J)	—	—	—	—
MCW-2E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.0028 (J)	—	—	—	—	—	—	—	—
M-5W	—	—	—	—	0.23	—	0.034 (J)	—	—	—	—	—	—	—	—	0.0017 (J)	—	0.00072 (J)	0.0048 (J)	—	—	—	—	—	—
M-5E	—	—	—	0.0019 (J)	—	—	0.01 (J)	—	—	—	—	—	—	—	—	0.024 (J)	—	0.0014 (J)	0.013 (J)	—	—	0.00074 (J)	—	—	—
M-6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Notes: All values are in mg/kg. All values are maximum detected values. Values in bold exceed the residential SSL. Grey shading indicates a screening value was exceeded for that chemical.

[a] EPA region 6 residential HHMSSL (EPA 2005, 91002).

[b] Pyrene residential SSL is used as a surrogate

[c] SSL based on the soil saturation concentration; not a risk-based value.

[d] Residential SSLs are NMED values (NMED 2006, 92513) unless otherwise noted.

[e] — = Not detected or not analyzed.

[f] Chlordane residential SSL is used as a surrogate.

[g] Isopropylbenzene residential SSL is used as a surrogate.

[h] Naphthalene residential SSL is used as a surrogate.

Table 6.2-3
Mortandad Sediment Radionuclide COPCs

Reach	Americium-241	Cesium-134	Cesium-137	Cobalt-60	Europium-152	Plutonium-238	Plutonium-239	Ruthenium-106	Sodium-22	Strontium-90	Thorium-228	Thorium-230	Thorium-232	Tritium	Uranium-234	Uranium-235	Uranium-238
LANL sediment BV[a]	**0.04**	**#N/A**	**0.9**	**#N/A**	**#N/A**	**0.006**	**0.068**	**#N/A**	**#N/A**	**1.04**	**2.28**	**2.29**	**2.33**	**0.093**	**2.59**	**0.2**	**2.29**
Residential SAL[b]	**30**	**2.4**	**5.6**	**1.3**	**2.9**	**37**	**33**	**20**	**1.6**	**5.7**	**2.3**	**5**	**5**	**750**	**170**	**17**	**86**
M-1W	—[c]	—	—	—	—	0.04	—	—	—	—	—	—	—	0.13	—	—	—
M-1C	1	0.07	—	—	—	0.1	—	—	—	—	—	—	3.48	—	—	—	—
M-1E	—	—	—	—	—	0.048	—	—	—	—	—	—	—	—	—	—	—
E-1FW	—	0.083	—	—	—	0.102	—	—	—	—	—	—	—	—	—	—	—
E-1W	0.28	—	2.14	—	—	0.417	30.1	—	—	—	—	—	—	—	—	—	2.65
E-1E	**642**	0.196	**2530**	**5.22**	—	**88.7 (J-)**	**1360 (J-)**	—	0.49	**273 (J-)**	—	—	—	105.0239	16.04	0.683	7.125
M-2W	**524**	0.24	**870**	**2.45**	—	**203**	**596**	—	0.151	**35.9 (J-)**	—	—	—	7.153747	14.7	0.8	10.7
M-2E	**211**	0.114	**557**	0.5	—	**113**	**157**	—	—	**20**	—	—	—	0.518	—	—	—
M-3	**223**	0.177	**298**	**1.47**	—	**40.9 (J+)**	**123 (J+)**	0.8	—	**8.6 (J-)**	—	—	—	0.3211111	—	0.45	—
TS-1W	4.172 (J-)	0.072	3.585	1.2991	—	**67.817 (J-)**	19.51	—	—	3.11 (J-)	—	—	—	1.264033 (J)	2.735	—	3.049
TS-1C	2.3	—	3.1869	—	—	**314.079**	**35.198 (J-)**	—	—	—	**15.2**	**28.511**	**13.557**	0.3034217 (J)	—	0.255	3.006
TS-1E	—	—	—	—	—	**338.335 (J-)**	**37.916**	—	—	—	—	—	—	—	—	—	—
TS-2W	0.493	0.086	—	—	—	2.087	0.665	—	—	**6.7**	—	—	—	0.143	—	—	—
TS-2C	0.302	0.099	—	—	—	1.98	0.896	—	—	5.61	—	—	—	0.134	—	0.22	—
TS-2E	—	0.082	—	—	—	1.351	5.237	—	—	**8.3**	—	—	—	—	—	—	2.37
TS-3	—	—	1.22	—	—	1.55	0.77	—	—	3.1	—	—	—	0.297	—	—	—
M-4	**112**	0.194	**276**	0.445	0.338	32.2 (J+)	**64.5 (J+)**	—	—	**9.64**	—	—	—	0.2781174	—	0.285	—
MCW-1	—	—	—	—	—	—	0.0741	—	—	—	—	2.44	—	—	—	—	—
MCW-2N	—	—	—	—	—	0.0229	—	—	—	—	—	—	—	—	—	—	—
M-5W	—	—	0.92	—	—	—	0.11	—	—	1.68	—	—	—	—	—	0.24	—
M-5E	—	0.1	0.93	—	—	0.09	0.13	—	—	—	—	—	—	—	—	0.27	—

Notes: Values are in pCi/g. Values are maximum detected values > BV; if no BV, value is maximum detected value. Values in bold exceed the residential SSL. Grey shading indicates a screening value was exceeded for that chemical.

[a] LANL 1998, 59730

[b] LANL 2005, 88493.

[c] — = Not detected, not detected > BV, or not analyzed.

Table 6.3-1
Mortandad Filtered Water Inorganic COPCs

Location ID	Media Code[a]	Aluminum	Ammonia	Ammonia as Nitrogen	Antimony	Arsenic	Barium	Beryllium	Boron	Bromide	Cadmium	Calcium	Cerium	Chloride	Chromium	Chromium hexavalent ion	Cobalt	Copper	Cyanide (Total)	Dysprosium	Erbium
Acute Aquatic Life[b]		**750**	—[c]	—	—	**340**	—	—	—	—	**2**	—	—	—	**570**	—	—	**13.4**	—	—	—
Human Health Persistent[b]		—	—	—	**640**	**9**	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Livestock Watering[b]		**5000**	—	—	—	**200**	—	—	**5000**	—	**50**	—	—	—	**1000**	—	**1000**	**500**	—	—	—
MO-24786	WS	263	—	—	—	7.8	210 (J)	—	25.5	—	0.1	29300 (J)	10.3	130000	36.4	—	14.2 (J)	**29.2**	2.86	0.4	0.3
MO-24787	WS	**1400**	—	—	—	—	114	—	44.4	—	—	24000	4.2	39100	7.4	—	1.6	—	—	0.3	—
MO-24788	WS	**924 (J)**	—	—	0.82	—	32.1	—	107	—	—	18000	2.6	39000	2.5	—	2	12.2	—	0.2	—
MO-24789	WS	**12500**	—	—	1.2	—	98.8	—	32.8	—	0.26	12900	19.6	224000 (J)	7.8	—	4.1	12.4	8.64	1.2	0.6
MO-24790	WS	**4230 (J)**	—	—	—	—	132	—	26.7	—	—	21300	10.7	47400	4	—	7.4	3.5	—	0.6	0.3
MO-24791	WS	230	—	—	0.61	—	44.8	—	59	—	—	33400	—	109000	2.3	—	—	3.9	—	—	—
MO-24792	WS	**1620**	—	—	—	—	95.3	—	46	—	—	25100 (J)	0.8	48800	1.3	—	1.9	3.1	10	—	—
MO-24793	WS	389	—	—	—	—	146	—	30	—	—	40400	3.8	14200	1.7	—	2.4	8.3	—	0.2	—
Mortandad at GS-1	WS	**1021**	—	—	1	2.4	38.5	0.11	65.99	—	1.02	46800	—	20600	7.19	—	0.87	**30.3**	—	—	—
Mortandad at Rio Grande (A-11)	WS	142 (J-)	—	—	—	—	61.1	—	572	—	0.07	31200	—	63400	—	—	12.8	**22.1 (J+)**	—	—	—
Mortandad below Effluent Canyon	WS	**2790 (J)**	—	—	0.56	—	39	—	104	—	0.11	32600	—	34600	2.39 (J-)	—	—	12.9	—	—	—
NM Groundwater Standards[d]		—	—	—	—	**100**	**1000**	—	—	—	**10**	—	—	**250000**	**50**	—	—	**1000**	**200**	—	—
EPA MCLs[e]		—	—	—	**6**	**10**	**2000**	**4**	—	—	**5**	—	—	—	**100**	**100**	—	**1300**	**200**[f]	—	—
EPA region 6 tap water screening levels[g]		**36500**	**208.6**	**208.6**	—	—	—	—	**7300**	—	—	—	—	—	—	—	**730**	—	—	—	—
MCA-1	WGA	5770	—	—	—	—	84.6	0.37	33.7	—	0.1	19500	10.4	38000	4.6	—	—	3.1	—	0.6	0.3
MCA-2	WGA	895 (J+)	—	—	—	—	185	—	82.7	40	—	25400 (J)	1.4	58700	1.1	—	—	—	—	0.2	0.4
MCA-4	WGA	1410 (J+)	—	—	—	**16.6**	121	—	32.1	—	0.28	21100 (J)	—	—	43	—	10.6	5.4	—	—	—
MCA-5	WGA	1400	—	—	0.64	—	25.5	0.13	38.8	—	—	25900	3.1	46900	3.7	—	1.4	5.9	—	0.3	—
MCO-0.6	WGA	1040 (J+)	—	—	—	—	214	—	20.9	200	—	22800 (J)	30.3	**303000**	6	—	14.3	4.1	—	1.4	0.8
MCO-2	WGA	111	—	—	—	**17**	155	2	37.99	—	—	28660	—	4590	13	—	—	—	—	—	—
MCO-3	WGA	951	—	100 (J+)	0.69	—	35.9	—	90	—	0.24	45200	—	22600	3.98	—	2.2	33	—	—	—
MCO-4B	WGA	1490 (J-)	—	**310**	—	—	113	—	79.8	—	—	53800	1.6	64400	2.1	—	—	2.21	—	0.2	0.2
MCO-5	WGA	323	—	—	—	2.43	135	—	110	—	0.28	56100	0.4	59400	1.8	—	—	2.13	—	—	0.2
MCO-6	WGA	113	—	—	0.75 (J)	2.6 (JN-)	117	0.04 (J)	137	—	0.15	47500	—	53100	1.79 (J)	—	4.9	2.9	—	—	0.2
MCO-7	WGA	385	—	—	—	1.29	224	0.03 (J)	96.3	100	0.2	33800	0.3	51300	1.89 (J)	—	0.34 (J)	3.2	2.85 (J)	0.2	0.5
MCO-7.5	WGA	2270	—	—	—	0.75	174	0.02	87.9	120	0.16	30400	2.9	31000	4	—	2.3	0.92	3.79	0.4	0.9
MT-1	WGA	1920	—	—	—	—	198	—	49.5	40	—	23300	2.5	**40000 (J)**	2.4	—	—	—	—	0.4	0.8
MT-3	WGA	156	—	—	—	—	150	1.3	83.1	100	—	20600	—	39600	5.2	—	1.2	9.8	—	0.4	1.2
MT-4	WGA	110	—	—	—	—	97.1	—	52.7	120	—	16000	—	34000	1.6	—	—	—	—	0.2	0.6
MCOBT-4.4	WGI	—	—	—	—	—	13.6	—	47.4	—	0.18	32400	—	17300	**53.5**	—	0.92	2.28	—	—	—
MCOI-4	WGI	—	—	—	—	—	19.4	—	31.7	400	0.14	36500	—	20700	29.4	—	—	30.5	4.04	—	—
MCOI-5	WGI	—	—	—	2.7	—	26.9	—	23.7	150	—	20100 (J)	—	6700	3.5	—	4	4.3	—	—	—
MCOI-6	WGI	—	—	—	—	—	33.1	—	32.5	290	—	48100	—	24000	**57.2**	—	—	7.6	3.89	—	—
PM-5	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5.3	—	—	—	—	—
R-1	WGR	—	—	—	—	—	17.9	—	13.9	170	0.11	12200	—	1970	5.6	—	1.6	—	—	—	—
R-13	WGR	40.5	40 (J)	—	—	—	29.3	—	21.5	—	—	14700	—	5950	3.76	—	1.6	—	—	—	—
R-14	WGR	29.3 (J-)	—	80 (J-)	—	8.24 (JN-)	48.6	—	21.1	40	—	12300	—	2050	3.02	—	—	2.79	—	—	—
R-15	WGR	—	160	—	0.16 (J)	7.2	30.2	0.02 (J)	19 (J)	110	—	14200	—	4900	7.3	—	—	—	—	—	—
R-28	WGR	—	—	—	—	—	56.2	—	25.5	180	—	35700	—	24400	**404**	—	—	—	—	—	—
R-33	WGR	—	—	—	—	—	34.8	—	13.5	—	0.1	12000	—	2190	8.2	—	1.7	—	—	—	—
Test Well 8	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.3	—	—	—	—	—

Table 6.3-1 (continued)

Location ID	Media Code[a]	Europium	Fluoride	Gadolinium	Holmium	Iron	Lanthanum	Lead	Lutetium	Magnesium	Manganese	Molybdenum	Neodymium	Nickel	Nitrate as Nitrogen	Nitrate-Nitrite as N	Nitrite	Perchlorate	Phosphorus, Orthophosphate (Expressed as PO4)	Potassium
Acute Aquatic Life[b]		—	—	—	—	—	—	**64.6**	—	—	—	—	—	**467**	—	—	—	—	—	—
Human Health Persistent[b]		—	—	—	—	—	—	—	—	—	—	—	—	**4600**	—	—	—	—	—	—
Livestock Watering[b]		—	—	—	—	—	—	**100**	—	—	—	—	—	—	**132000**	**132000**	**132000**	—	—	—
MO-24786	WS	—	90	0.7	—	5730 (J)	3.1	1.1	—	5140 (J)	816	87	3.2	13 (J)	—	—	—	0.15 (J-)	—	3590 (J)
MO-24787	WS	—	750	0.4	—	4510	2.1	0.78	—	5920	958	45.1	1.8	1.7	—	—	—	—	—	13200
MO-24788	WS	—	530	0.3	—	560 (J)	1.7	0.63	—	3660	13.4	34.3	1.4	14	—	1570	—	0.38 (J)	—	12300
MO-24789	WS	—	270 (J+)	1.8	0.2	7280	8.2	8.1	—	2310	42.3	117	8.3	5.6	—	—	—	0.42	—	7040
MO-24790	WS	—	180 (J+)	0.9	—	2280 (J)	4.5	1.6	—	4490	1850	4.8	4.3	7.6	—	10 (J-, JN-)	—	—	—	6400
MO-24791	WS	—	590	—	—	103	0.3	—	—	2040	—	32.1	0.4	2.8	—	670	—	24.7	—	7310
MO-24792	WS	—	60	—	—	852	0.4	—	—	3150	449	12.6	0.4	1.7	—	—	—	0.22 (J)	—	7310
MO-24793	WS	—	300 (J+)	0.3	—	548	1	0.58	—	5610	875	36.7	1.1	8.4	—	—	—	—	—	4800
Mortandad at GS-1	WS	—	890	—	—	584	—	1.47	—	3660	7	97	—	13	—	4340	—	—	—	8610
Mortandad at Rio Grande (A-11)	WS	—	1120	—	—	75.9	—	0.54	—	7370	33.7	2.09	—	3.31	—	6350	—	—	—	15900
Mortandad below Effluent Canyon	WS	—	540	—	—	1540 (J)	—	1.5	—	4620 (J-)	16.9	37.5	—	6.45	—	13500 (J-)	—	0.48 (J)	—	8100
NM Groundwater Standards[d]		—	**1600**	—	—	**1000**	—	**50**	—	—	**200**	—	—	—	—	—	—	—	—	—
EPA MCLs[e]		—	**4000**	—	—	—	—	**15**	—	—	—	—	—	**100**	**10000**	**10000**	**1000**	—	—	—
EPA region 6 tap water screening levels[g]		—	—	—	—	—	—	—	—	—	—	**183**	—	—	—	—	—	**25.55**[h]	—	—
MCA-1	WGA	—	160	0.9	—	**3270**	5.1	1.1	—	4970	62.4	1.2	4.7	2.8	—	170	—	0.75 (J)	—	4430
MCA-2	WGA	—	1450	0.2	—	409	0.7	—	—	4520	3.8 (J)	93.3	0.7	3.9 (JN-)	—	3900	—	**44.3**	—	20700
MCA-4	WGA	—	—	—	—	**9060**	—	3.4	—	4530	**1510 (J)**	**611**	—	10.7	—	—	—	—	—	8340
MCA-5	WGA	—	440	0.3	—	726	1.8	—	—	2320	6.2	27.8	1.7	—	—	**595000**	—	**34**	—	6520
MCO-0.6	WGA	0.2	210	2.2	0.3	**8820**	8.4	1.9	—	4990	**2040 (J)**	—	9.2	16.7	—	20	—	—	—	12100
MCO-2	WGA	—	870	—	—	**15328**	—	—	—	6800	**2266**	**400.99**	—	—	—	20	—	—	—	3870
MCO-3	WGA	—	900	—	—	499 (J)	—	0.15 (JN-)	—	2960	1.07 (JN-)	77	—	7.04	—	**530000**	—	**170**	—	8170
MCO-4B	WGA	—	1070	0.2	—	611	1.1	0.08	—	4020	3.8	72.9	1	7.17	—	**73100**	—	**44.3 (J+)**	—	13600
MCO-5	WGA	—	1180	—	—	136	0.5	0.13	—	4680	0.3	81.3	0.5	9.19 (J)	—	6100	—	24.4 (J)	—	16000
MCO-6	WGA	—	1440	—	—	32.8	0.2	0.2 (J)	—	4410	7.3	89.7	0.2	12.5	—	6900	—	**400**	—	17700
MCO-7	WGA	—	**2130**	—	—	173	—	0.82	—	7410	1.6	92.1	—	10.6	—	**12500**	—	**240**	—	19300
MCO-7.5	WGA	—	**1770**	0.3	—	**1020**	1.3	1.1	0.3	7210	7.6	108	1.2	8.08	—	**18000**	—	**66.3**	—	16600
MT-1	WGA	—	**1960**	0.3	—	1000	1.1	0.76	0.3	5680	7.5	99.8	1	2.8	—	2730	—	**49.2**	—	17700
MT-3	WGA	—	1560	—	0.2	92.5	—	—	0.5	5190	—	81.4	—	3.9	—	4400 (J)	—	**106**	—	9570
MT-4	WGA	—	1330	—	—	—	—	—	0.3	4040	—	56.6	—	4.6	—	4280	—	**62.9**	—	5740
MCOBT-4.4	WGI	—	420	—	—	—	—	—	—	5590	—	0.96	—	2.25	—	**15800**	—	**256**	—	690
MCOI-4	WGI	—	230	—	—	28.5	—	—	—	5720	15.9	1.4	—	5.1	—	**14200**	—	**159**	—	840
MCOI-5	WGI	—	370	—	—	69.8	—	—	—	3780	157 (J)	8.1	—	62.2 (J)	2930	4220	360	**104**	—	740
MCOI-6	WGI	—	560	—	—	—	—	—	—	9650	25.1	2.5	—	5.9 (J+)	—	**16400**	—	**246 (J)**	—	740
PM-5	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-1	WGR	—	260 (J+)	—	—	78.8	—	—	—	4220	4.2	2.4	—	1.1	—	250	—	0.33	40 (J)	1790
R-13	WGR	—	480	—	—	147	—	—	—	3710	7.55	1.12	—	—	—	810	—	0.41 (J)	—	1440
R-14	WGR	—	390	—	—	**4500**	—	0.08	—	3520	**588 (J)**	5.53	—	2 (JN-)	50 (J)	90 (J-)	—	0.18	370 (J)	2290
R-15	WGR	—	220	—	—	210	—	0.22 (J)	—	3880	18	—	—	1.89 (J)	—	2430	—	6.92	—	1900
R-28	WGR	—	350	—	—	—	—	—	—	9010	3.5	0.87	—	7.4	—	4760	—	1.13 (J)	—	1660
R-33	WGR	—	240	—	—	263	—	—	—	4080	6	10.9	—	**168**	—	430	—	0.38 (J+)	—	2280
Test Well 8	WGR	—	160	0.9	—	**3270**	5.1	1.1	—	4970	62.4	1.2	4.7	2.8	—	170	—	0.75 (J)	—	4430

Table 6.3-1 (continued)

Location ID	Media Code[a]	Praseodymium	Samarium	Selenium	Silver	Sodium	Strontium	Sulfate	Terbium	Thallium	Thulium	Tin	Titanium	Total Phosphate as Phosphorus	Total Phosphorus	Uranium	Vanadium	Ytterbium	Zinc
Acute Aquatic Life[b]		—	—	—	**3.2**	—	—	—	—	—	—	—	—	—	—	—	—	—	**117.2**
Human Health Persistent[b]		—	—	**4200**	—	—	—	—	—	**6.3**	—	—	—	—	—	—	—	—	**26000**
Livestock Watering[b]		—	—	**50**	—	—	—	—	—	—	—	—	—	—	—	—	**100**	—	**25000**
MO-24786	WS	0.8	0.7	—	—	64100 (J)	158 (J)	11100 (J+)	—	0.6	—	3.7 (J)	—	—	—	0.37	4.1	0.2	12.4
MO-24787	WS	0.5	0.4	9.7 (JN-)	—	47700	121	14000	—	—	—	—	—	730	450	0.27	3.5	—	11.7
MO-24788	WS	0.4	0.3	—	—	82700	67.6	13700	—	0.42	—	—	—	220	—	0.53	2.3	—	9
MO-24789	WS	2.1	1.6	—	—	178000	58.9	6870	0.2	—	—	—	—	—	—	0.44	20.4	0.5	76.1
MO-24790	WS	1.1	0.8	—	—	37100	125	3590	—	—	—	—	—	—	—	0.28	3.6	0.3	13.8
MO-24791	WS	—	—	—	—	60000	80.8	15000	—	—	—	—	—	—	—	0.66	1.2	—	2.6
MO-24792	WS	—	—	—	—	41800	125	6360	—	0.88	—	—	—	—	—	0.24	—	—	15.4
MO-24793	WS	0.3	0.3	—	0.26	12000	183	6540	—	—	—	—	—	—	—	0.77	3.9	—	4.6
Mortandad at GS-1	WS	—	—	1.6	0.05 (J)	77310	74.3	40700	—	0.26	—	39.99	0.17	210	—	3.78	4.5 (J+)	—	**265**
Mortandad at Rio Grande (A-11)	WS	—	—	—	—	92700	123	34900	—	—	—	—	6.36 (J)	4080	4850	0.5	7.89	—	39.7
Mortandad below Effluent Canyon	WS	—	—	—	—	96400	95	70800	—	0.19	—	—	—	—	150	—	4.73	—	14.8
NM Groundwater Standards[d]		—	—	**50**	**50**	—	—	**600000**	—	—	—	—	—	—	—	—	—	—	**10000**
EPA MCLs[e]		—	—	**50**	—	—	—	—	—	**2**	—	—	—	—	—	—	—	—	—
EPA region 6 tap water screening levels[g]		—	—	—	—	—	**21900**	—	—	—	—	**21900**	—	—	—	**7.3**[i]	**36.5**	—	—
MCA-1	WGA	1.3	0.9	—	—	33600	116	27900	—	—	—	—	—	60	—	0.21	—	0.3	11.3
MCA-2	WGA	0.2	0.2	—	—	70000 (J)	143	23200	—	—	—	—	—	280	—	1.7	2.8	0.7	—
MCA-4	WGA	—	—	—	—	102000 (J)	128	—	—	0.97	—	—	—	—	—	1.2	14.8	—	—
MCA-5	WGA	0.4	0.3	—	—	58300	57.8	24000	—	0.46	—	—	—	—	120	—	—	—	5.5
MCO-0.6	WGA	2.3	1.9	—	—	273000 (J)	163	12700	0.3	—	—	—	—	80	—	4.1	12.5	0.7	25.1
MCO-2	WGA	—	—	—	8.99	36050	152.99	—	—	—	—	—	—	430	—	—	—	—	—
MCO-3	WGA	—	—	—	—	92090	97.6	89100	—	0.39	—	—	0.25	200	100	0.69	1.41	—	7.96 (J+)
MCO-4B	WGA	0.3	0.2	—	—	80700	173	45600	—	0.3	—	—	—	120	60	0.66	2.3	0.3	7.66 (J-)
MCO-5	WGA	—	—	5.24	—	77400	202	76000	—	0.24	—	—	—	180	90	1.21	1.6	0.3	9.92 (J+)
MCO-6	WGA	—	—	6.1	0.02 (J)	71300	189	83000	—	1.01	—	—	—	150	100 (J+)	1.62	1.1	0.4	14.7 (J+)
MCO-7	WGA	—	—	7.3	0.01	79300	161	77000	—	0.44	—	—	—	410	280	**28.5**	3.3	0.8	8.8
MCO-7.5	WGA	0.3	0.3	1.2	—	84900	140	36000	—	—	—	—	—	140	290 (J-)	1.6	4	1.7	19.6
MT-1	WGA	0.3	0.2	—	—	67900	154	30600	—	—	—	—	—	210	—	0.56	3.6	1.3	10.6
MT-3	WGA	—	—	—	—	90900	136	36600	—	—	0.3	4.5	—	160	110	1.2	3.1	2.4	34.8
MT-4	WGA	—	—	—	—	86700	105	27200	—	0.8	—	—	—	200	—	1.5	2.5	1.3	—
MCOBT-4.4	WGI	—	—	—	—	21700	157	27500	—	0.08	—	—	—	—	60	0.28	0.98	—	2.01
MCOI-4	WGI	—	—	—	—	24300	177	31800	—	—	—	—	—	100	—	0.23	1.5	—	141
MCOI-5	WGI	—	—	—	—	13900	92.4	14100	—	0.48	—	—	—	—	—	0.15	1.4	—	145
MCOI-6	WGI	—	—	—	—	21600	218	39500	—	0.6	—	—	—	180 (J+)	—	0.5	1.4	—	74.2
PM-5	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-1	WGR	—	—	—	—	12900	55.4	3650	—	0.64	—	—	—	—	—	0.84	8.4	—	7.6
R-13	WGR	—	—	—	—	11100	55.1	3140	—	0.03	—	—	—	90 (J+)	40 (J+)	0.5	4.81	—	5.78
R-14	WGR	—	—	—	—	15000	98.4	1920	—	0.45	—	—	—	—	790	0.63	6.75	—	6.4
R-15	WGR	—	—	0.95 (J)	—	11300	63.7	6640	—	0.96	—	—	—	140	60	0.45	6.4 (J)	—	7.09 (J)
R-28	WGR	—	—	6.8	—	14200	140	39400	—	0.52	—	—	—	60	—	1.1	5.4	—	11

Table 6.3-1 (continued)

Location ID	Media Code[a]	Praseodymium	Samarium	Selenium	Silver	Sodium	Strontium	Sulfate	Terbium	Thallium	Thulium	Tin	Titanium	Total Phosphate as Phosphorus	Total Phosphorus	Uranium	Vanadium	Ytterbium	Zinc
R-33	WGR	—	—	—	1.8 (NJ)	12000	52.6	2790	—	0.78	—	—	—	—	—	0.96	6.1	—	38.6
Test Well 8	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Notes: All values in ug/L. All surface waters associated with these locations are ephemeral. Bolded concentrations exceed a standard and/or screening level. Grey shading indicates a standard and/or screening value was exceeded for that chemical.

[a] Media code definitions are provided in Table C-2-4.

[b] 20.6.4 NMAC.

[c] — = Not detected or not analyzed.

[d] 20.6.2 NMAC.

[e] EPA 2005, 91002.

[f] EPA MCL for free cyanide.

[g] EPA 2005, 91002 only listed for chemicals without a standard or MCL.

[h] Perchlorate-revised value.

[i] EPA region 9 PRG (EPA 2004, 93663).

Table 6.3-2
Mortandad Unfiltered Water Inorganic COPCs

Location ID	Media Code[a]	Aluminum	Ammonia	Ammonia as Nitrogen	Antimony	Arsenic	Barium	Beryllium	Boron	Bromide	Cadmium	Calcium	Cerium	Chloride	Chromium	Chromium hexavalent ion	Cobalt	Copper	Cyanide (Total)	Dysprosium	Erbium	Europium
Acute Aquatic Life[b]		—[c]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Livestock Watering[b]		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wildlife Habitat[b]		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24786	WS	1090	—	—	—	7.6	201	—	26.3	190	0.16	28600	13.9	135000	46.3	—	11.1	45.3	—	0.6	0.3	—
MO-24787	WS	3350	131	—	—	6.6 (J)	148	0.41 (J)	26.6	120	0.13	27300	9.8	53300	7.5	—	1	3.5 (J)	—	0.6	0.3	—
MO-24788	WS	3310	66	—	0.67	—	46.4	0.19 (J)	94.4	130	0.12 (J)	23700	4.4	66100	4.6 (J)	—	—	23.5	—	0.3	—	—
MO-24789	WS	43700	99	—	1 (J)	6.5 (J)	198	2.1	37.3	40	0.49 (J)	13500	33.6	226000 (J)	27.5	—	2.7	55.4	—	2	1	0.3
MO-24790	WS	7400	—	—	—	—	138	—	27.2	120	0.12	21500	11.5	47700 (J)	6.8	—	5.6	4.4	—	0.6	0.3	—
MO-24791	WS	941	—	—	0.56	—	42.9	—	58.1	20	—	32600	2.1	58900	2.4	—	—	4.2	—	0.2	—	—
MO-24792	WS	37700	—	—	—	7.5	349	3.5	57.7	—	1.2	34400 (J)	8.4	48400	20.8	—	11.4	25	2.72 (J)	0.5	0.2	—
MO-24793	WS	2360	—	—	—	—	149	—	30.5	100	0.15	40700	4.6	242000	2.1	—	2.1	10.2	—	0.3	—	—
MO-24794	WS	1170	—	—	—	—	114	0.12 (J)	—	—	—	26000	—	11500	—	—	—	4.7 (J)	—	—	—	—
MO-24795	WS	590	—	—	—	—	172	0.18 (J)	—	—	0.56 (J)	27600	—	9920	1.4 (J)	—	1.4 (J)	32.5	2.79 (J)	—	—	—
MO-24808	WS	809	80	—	—	—	48.8	0.14 (J)	—	—	0.11 (J)	25200	—	23900	1.4 (J)	—	—	9.2 (J)	—	—	—	—
Mortandad at GS-1	WS	1010	—	160	—	2.59	42.29	0.13	—	—	0.25	47400	—	—	8.69	—	1.39	18.79	10.00	—	—	—
Mortandad below Effluent Canyon	WS	4410	—	—	—	—	44.9	—	30.4	—	—	15000	—	34000	—	—	—	4.7	—	—	—	—
NM Groundwater Standards[d]		—	—	—	—	**100**	**1000**	—	—	—	**10**	—	—	**250000**	**50**	—	—	**1000**	**200**	—	—	—
EPA MCLs[f]		—	—	—	**6**	**10**	**2000**	**4**	—	—	**5**	—	—	—	**100**	**100**	—	**1300**	**200**[e]	—	—	—
EPA region 6 tap water screening levels[g]		**36500**	**208.6**	**208.6**	—	—	—	—	**7300**	—	—	—	—	—	—	—	**730**	—	—	—	—	—
MCA-1	WGA	8740	—	—	—	—	89.3	0.56	34.2	60	0.11	19600	13.6	37700	6.5	—	—	—	—	0.8	0.4	—
MCA-2	WGA	3120 (J+)	—	—	—	—	196	0.1	75.5	50	—	25600 (J)	5	53700	2.2	—	—	—	—	0.4	0.4	—
MCA-4	WGA	24700 (J+)	—	—	0.84	**19.4**	216	2.2	37	—	0.75	22800 (J)	—	—	**101**	—	10.5	26.1	—	—	—	—
MCA-5	WGA	4370	—	—	0.53	—	31	0.18	41.2	40	—	26200	4.4	53600	5.6	—	—	7.1	—	0.4	0.2	—
MCO-0.6	WGA	3880 (J+)	—	—	—	—	234	—	21.1	200	0.13	23600 (J)	36.2	**299000**	12.9	—	14.5	10.9	—	1.6	0.9	0.3
MCO-2	WGA	128.99	—	—	—	**15**	155	—	35.99	—	—	—	—	—	17	—	—	—	10	—	—	—
MCO-3	WGA	1570	—	—	0.6	2.73 (JN-)	36.2	—	90.99	—	0.59	46400	—	—	4.77	—	—	32.8	2	—	—	—
MCO-4B	WGA	1810	—	—	—	4.31	117	—	82	30	—	36200	1.9	66800	2.5	—	—	2.12	—	0.3	0.2	—
MCO-5	WGA	521	—	—	—	2.31	135	0.03	110	80	0.31	44300	1.6	50700	1.6	—	2.46	2.93	—	0.2	0.2	—
MCO-6	WGA	103 (J+)	—	—	—	1.5	115	0.04 (J)	103	30	0.39	42600	—	60700	3.9 (J)	—	3.15	4.9	—	—	0.2	—
MCO-7	WGA	2300	—	—	—	2.94	208	0.04 (J)	152	110	0.28 (J+)	24200	0.5	52000	1.89 (J)	—	0.4 (J)	4.3	—	0.2	0.5	—
MCO-7.5	WGA	3230	—	—	—	0.92	172	0.15 (J)	81.7	100	—	29200	3.6	38300	2.9	—	0.51	2.4	—	0.5	0.9	—
MT-1	WGA	2100	—	—	—	—	223	0.24	49.5	70	0.13	24200	12.4	44800	2.8	—	—	—	—	1	0.8	—
MT-3	WGA	602	—	—	—	—	148	—	78.5	100	—	20400	0.8	39800	2.1	—	—	5	—	0.5	1.3	—
MT-4	WGA	173	—	—	—	—	98	—	52.2	130	—	16100	0.2	34400	1.9	—	—	—	—	0.2	0.6	—

Table 6.3-2 (continued)

Location ID	Media Code[a]	Aluminum	Ammonia	Ammonia as Nitrogen	Antimony	Arsenic	Barium	Beryllium	Boron	Bromide	Cadmium	Calcium	Cerium	Chloride	Chromium	Chromium hexavalent ion	Cobalt	Copper	Cyanide (Total)	Dysprosium	Erbium	Europium
MCOBT-4.4	WGI	23.6	—	—	—	0.4	15	—	50.9	130	—	38000	—	17300	**53.6**	—	4.82	2.8	2.27 (J)	—	—	—
MCOI-4	WGI	499 (J)	—	—	—	0.9	21.7	—	30	380	—	35600	0.7	20300	**135 (J)**	—	1.3	97.1	—	—	—	—
MCOI-5	WGI	3410	—	—	**7.1**	—	51.2	0.15	23.5	130	—	20800 (J)	5.9	6690	**770**	—	9	211	—	0.3	—	—
MCOI-6	WGI	7	—	—	—	1.2	33.2	—	31.5	290	—	47600	—	24100	**59**	—	—	14.5	—	—	—	—
MCOI-8	WGI	9.3	—	—	—	0.6	63	—	66	200	—	25300	—	13200	**—**	—	—	1.7	—	—	—	—
PM-5	WGR	44.7	—	—	—	1	32.5	—	67 (J)	—	—	12300	—	2850	5.9	5.5	—	—	50	—	—	—
R-1	WGR	23	—	—	—	1	17.3	—	14	170	0.14	11700	—	2250	5.9	—	—	4.8	—	—	—	—
R-13	WGR	7	—	—	—	3.56 (JN-)	310	—	63	20	—	14200	—	2520	5.9	—	—	2.34	2.36	—	—	—
R-14	WGR	37	—	80	—	7.3	75	—	27	100	—	13800	0.3	1970	7.7	—	5.2	7.56 (J)	—	—	—	—
R-15	WGR	56.5 (JN-)	110	—	—	4.91 (JN-)	34	0.05 (J)	20 (J)	21000	—	14700	0.2	5220	9.2	—	—	1.91	6.56	—	—	—
R-28	WGR	10	—	—	—	1	370	—	77	160	—	36500	—	29200	**416**	—	8.6	4.3	3.95	—	—	—
R-33	WGR	14	—	—	—	0.9	35.6	—	14.3	30	—	12000	0.3	2240	12.3	—	—	3.5	—	—	—	—
Test Well 8	WGR	88.3	—	—	0.45	0.4	8.51	—	28.4	20	—	11800	—	2060	7.92	2.3	—	1.7	6	—	—	—

Table 6.3-2 (continued)

Location ID	Media Code[a]	Fluoride	Gadolinium	Holmium	Iron	Iron (ferrous)	Lanthanum	Lead	Lithium	Lutetium	Magnesium	Manganese	Mercury	Molybdenum	Neodymium	Nickel	Nitrate	Nitrate as Nitrogen	Nitrate-Nitrite as N	Nitrite	Perchlorate
Acute Aquatic Life[b]		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Livestock Watering[b]		—	—	—	—	—	—	—	—	—	—	—	**10**	—	—	—	**132000**	**132000**	**132000**	**132000**	—
Wildlife Habitat[b]		—	—	—	—	—	—	—	—	—	—	—	**0.77**	—	—	—	—	—	—	—	—
MO-24786	WS	340	0.9	—	4200	—	4.2	3.1	—	—	5060	873	—	93.5	4.3	11.2	—	—	—	—	—
MO-24787	WS	760 (J)	0.8	—	6250	—	4	1.8	—	—	6860	1080	—	63.9	3.6	2.5	—	—	—	—	—
MO-24788	WS	620	0.5	—	2080	—	2.8	2.3	—	—	4070	74	—	34.8	2.4	13	—	720	1990	—	0.68
MO-24789	WS	720	3.1	0.4	25700	—	14.6	27	—	—	6060	115	0.07 (J)	121	14.8	13.6	—	—	730	—	—
MO-24790	WS	500	0.9	—	4230	—	4.9	3.1	—	—	4670	2010	—	4.8	4.8	7.7	—	270	—	—	—
MO-24791	WS	620	0.3	—	467	—	1.4	—	—	—	2050	5.9	—	30.9	1.3	3	—	30	—	—	—
MO-24792	WS	220	0.7	—	37800	—	3.7	33.6	—	—	8200	1690	—	15.5	3.4	17.1	—	190	—	—	—
MO-24793	WS	310	0.4	—	1120	—	1.9	1.7	—	—	5670	887	—	36.6	1.8	8.3	—	—	—	—	—
MO-24794	WS	322	—	—	679	—	—	1.2 (J)	—	—	4490	88.4	—	—	—	3 (J)	—	—	—	—	—
MO-24795	WS	430	—	—	493	—	—	1.6 (J)	—	—	4380	426	—	—	—	8.8	—	—	19.6 (J)	—	—
MO-24808	WS	—	—	—	472	—	—	0.55 (J)	—	—	3870	108	—	—	—	5.8	—	—	—	—	0.14 (J)
Mortandad at GS-1	WS	—	—	—	644	—	—	0.52	—	—	2660	16	0.07	—	—	14.39	—	4340	3900	—	99.5
Mortandad below Effluent Canyon	WS	310 (J+)	—	—	2460	—	—	2.7	—	—	3290	29.1	—	—	—	—	—	—	160 (J-)	—	0.5
NM Groundwater Standards[d]		**1600**	—	—	**1000**	—	—	**50**	—	—	—	**200**	**2**	—	—	—	—	—	—	—	—
EPA MCLs[f]		**4000**	—	—	—	—	—	**15**	—	—	—	—	**2**	—	—	**100**	**10000**	**10000**	**10000**	**1000**	—
EPA region 6 tap water screening levels[g]		—	—	—	—	—	—	—	**730**	—	—	—	—	**183**	—	—	—	—	—	—	**25.55**[h]
MCA-1	WGA	170	1.2	—	**5070**	—	6.5	2.9	—	—	5170	50.1	—	1.3	6.1	3.1	—	1000	—	**3960**	—
MCA-2	WGA	1430	0.5	—	**1490**	—	2.2	1.6	—	—	4750	21.7 (J)	—	94.2	2.1	3.4	—	1840	—	—	—
MCA-4	WGA	—	—	—	**26500**	—	—	**20.8**	—	—	7210	**1670 (J)**	—	**600**	—	20.4	—	—	—	—	—
MCA-5	WGA	410	0.5	—	**2370**	—	2.6	—	—	—	2650	10.7 (J)	0.05	27	2.3	—	—	840	—	—	—
MCO-0.6	WGA	220	2.6	0.3	**11900**	—	10.4	4.3	—	—	5520	**2140 (J)**	—	—	11.1	19.1	—	—	—	—	—
MCO-2	WGA	—	—	—	**16041**	—	—	—	—	—	—	**2375**	—	**354.99**	—	—	—	30	—	—	—
MCO-3	WGA	—	—	—	815 (J)	—	—	0.58	—	—	2750	6.19	0.03	74.5	—	7.03	—	3320	—	—	**280**
MCO-4B	WGA	980	0.3	—	735	—	1.2	0.13	—	—	2850	4.8	—	76.9	1.2	7.31	—	1710	—	—	**157**
MCO-5	WGA	**1680**	0.3	—	242	—	1.3	0.51	—	—	3830	8.1	—	83.1	1.1	8.9	—	3470	5700	—	**252**
MCO-6	WGA	1310	—	—	38.7	—	0.2	0.29 (J)	—	—	3910	2.32	—	89.9 (J)	0.3	22.79	—	1380	6600	—	**268**
MCO-7	WGA	1400	—	—	**1140**	—	0.3	1.32	—	—	5660	17.6	0.24	83.3	0.2	10	—	1750	9500	—	**282**
MCO-7.5	WGA	**1780**	0.4	0.2	**1460**	—	1.5	1.01	—	0.3	7180	26.4	—	93.9	1.4	8.6	—	4170	**18000**	20	**252**
MT-1	WGA	**1960**	1.2	0.2	**1180**	—	5	1.7	—	0.3	6060	45.6	—	100	4.8	5.3	—	2890	—	—	—
MT-3	WGA	**1960**	—	0.2	351	—	0.3	—	—	0.5	5120	6.5	—	79.7	0.3	3.9	—	5620	—	—	—
MT-4	WGA	1350	—	—	—	—	—	—	—	0.3	4030	—	—	57.3	—	4.9	—	—	—	—	—

Table 6.3-2 (continued)

Location ID	Media Code[a]	Fluoride	Gadolinium	Holmium	Iron	Iron (ferrous)	Lanthanum	Lead	Lithium	Lutetium	Magnesium	Manganese	Mercury	Molybdenum	Neodymium	Nickel	Nitrate	Nitrate as Nitrogen	Nitrate-Nitrite as N	Nitrite	Perchlorate
MCOBT-4.4	WGI	350	—	—	**—**	—	—	—	39	—	6030	1.6	—	0.98	—	3.73	**89500**	**20200**	**16200**	—	**210**
MCOI-4	WGI	220	—	—	**1150 (J)**	—	0.3	4.8	27	—	5620	23.3	—	4.3	0.3	35.8 (J)	**—**	**11220**	**13200**	—	**140**
MCOI-5	WGI	310	0.3	—	**6980**	—	2.6	13.8	—	—	4560	**231 (J)**	—	20.8	2.4	**414**	**—**	**—**	3070	—	—
MCOI-6	WGI	580	—	—	107	—	—	1.3	34	—	9560	29	—	2	—	7.3	**—**	**16710**	**15000**	580	**160**
MCOI-8	WGI	**1730**	—	—	30	—	—	—	49	—	5950	**940**	—	150	—	27	**—**	**—**	**—**	—	—
PM-5	WGR	330	—	—	**—**	—	—	0.35	—	—	4870	1.81	—	2.31	—	0.23	**—**	350	340	—	1.29
R-1	WGR	180	—	—	74.5	—	—	0.3	37	—	4060	**—**	—	2.8	—	1	1460	330	240	—	0.34
R-13	WGR	450	—	—	140	—	—	0.1	24	—	3520	7.66	—	1.11	—	—	3320	750	790	—	0.4
R-14	WGR	340	—	—	**6850**	910	—	0.4	27	—	3480	**586**	0.08	5.6	—	2.2 (JN-)	760	170	70 (J-)	190	0.19
R-15	WGR	270	—	—	520	—	—	0.65 (J)	25	—	4250	24	—	**—**	—	2.79 (J)	**10700**	2410	2530	—	6.15
R-28	WGR	330	—	—	24.8	—	—	—	48	—	9220	17	—	0.9	—	8.1	**20200**	4570	4890	—	1.13 (J)
R-33	WGR	250	—	—	402	—	—	—	21	—	4090	4.9	—	1.5	—	32	**—**	350	310	—	—
Test Well 8	WGR	870	—	—	**1210**	—	—	7	21	—	4310	9.52	—	2.01	—	1.8 (JN-)	670	350	340	—	3.26

Table 6.3-2 (continued)

Location ID	Media Code[a]	Phosphorus, Orthophosphate (Expressed as PO4)	Potassium	Praseodymium	Samarium	Selenium	Silver	Sodium	Strontium	Sulfate	Sulfide, Total	Terbium	Thallium	Thulium	Tin	Titanium	Total Phosphate as Phosphorus	Total Phosphorus	Uranium	Vanadium	Ytterbium	Zinc
Acute Aquatic Life[b]		—	—	—	—	**20**	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Livestock Watering[b]		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wildlife Habitat[b]		—	—	—	—	**5**	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24786	WS	—	3710	1.1	0.8	—	—	61100	152	10900	—	—	—	—	—	—	—	—	0.46	8.3	0.3	16.8
MO-24787	WS	20	14100	1	0.7	—	—	48300	117	14000	—	—	—	—	—	—	—	941	0.51	6.2	0.3	18.3
MO-24788	WS	160	13500	0.7	0.5	—	—	76200	72.2	23300	—	—	—	—	—	—	—	270	0.67	3.2	—	29.1
MO-24789	WS	400	10100	3.8	2.9	—	—	173000	64.3	32200	—	0.4	—	—	—	—	—	401	0.72	48.3	0.8	271
MO-24790	WS	560	6630	1.2	0.9	—	—	38800	126	14600	—	—	—	—	—	—	—	—	0.34	7.6	0.3	21.3
MO-24791	WS	200	7020	0.3	0.3	—	—	61100	79	17700	—	—	—	—	—	—	—	—	0.73	1.4	—	4.1
MO-24792	WS	10	14500	0.9	0.7	—	0.39	43800 (J)	185	11300	—	—	0.73	—	4.5	—	—	174	2.9	36.4	0.2	213
MO-24793	WS	50	4840	0.5	0.4	—	0.32	12000	184	6940	—	—	—	—	—	—	—	—	0.77	4.4	—	8.6
MO-24794	WS	—	4760	—	—	—	—	20100	—	8400	—	—	—	—	—	—	—	—	—	3.3 (J)	—	10.4
MO-24795	WS	—	2760	—	—	—	5.4	16700	—	5320	—	—	—	—	—	—	—	—	—	2.5 (J)	—	22.1
MO-24808	WS	—	9590	—	—	—	—	39900	—	10000	—	—	—	—	—	—	—	149	—	2.1 (J)	—	17.1
Mortandad at GS-1	WS	220	9160	—	—	2	0.11	79100	—	—	—	—	0.21	—	—	—	220	—	3.8	5.8	—	—
Mortandad below Effluent Canyon	WS	—	7630	—	—	2.55	—	38000	63.1	10600	—	—	—	—	—	—	—	170	—	—	—	14.9
NM Groundwater Standards[d]		—	—	—	—	**50**	**50**	—	—	**600000**	—	—	—	—	—	—	—	—	—	—	—	**10000**
EPA MCLs[f]		—	—	—	—	**50**	—	—	—	—	—	—	**2**	—	—	—	—	—	—	—	—	—
EPA region 6 tap water screening levels[g]		—	—	—	—	—	—	—	**21900**	—	—	—	—	—	—	—	—	—	**7.3[i]**	**36.5**	—	—
MCA-1	WGA	—	4640	1.6	1.2	—	—	33600	117	28700	—	—	—	—	—	—	—	—	0.26	8.7	0.4	18.2
MCA-2	WGA	310	21000	0.6	0.5	7.7	—	69600 (J)	145	23200	—	—	—	—	—	—	—	—	1.8	4	0.7	—
MCA-4	WGA	—	11100	—	—	—	0.31	97400 (J)	143	—	—	—	—	—	—	—	—	—	3	34.7	—	64.9
MCA-5	WGA	250	6910	0.6	0.5	—	—	58500	58.7	25800	—	—	—	—	—	—	—	—	—	—	0.2	10.6
MCO-0.6	WGA	—	12700	2.8	2.3	—	—	277000 (J)	169	12800	—	0.3	—	—	—	—	—	—	4.3	15.5	0.8	32.4
MCO-2	WGA	430	—	—	—	2	8	—	153.99	1300	—	—	—	—	—	—	—	—	—	—	—	—
MCO-3	WGA	210	6980	—	—	—	—	68100	97.7	18700	—	—	0.24	—	—	—	—	—	0.71	2.01	—	15.1
MCO-4B	WGA	150	12700	0.3	0.3	—	—	67800	179	19800	—	—	—	—	—	—	—	—	0.66	2.2	0.3	5.8
MCO-5	WGA	220	16000	0.3	0.3	—	—	65400	203	33800	—	—	0.14	—	—	—	90	—	1.82 (J)	1.4	0.3	9.13 (J+)
MCO-6	WGA	200	16700	—	—	2.79	0.01 (J)	75000	184	19800	—	—	0.73	—	—	—	—	—	1.7 (J)	1.89 (J)	0.4	3.9
MCO-7	WGA	280	19100	—	—	0.95 (J)	0.1	75500	158	25900	—	—	—	—	—	—	270	—	2.18	3.1	0.9	12
MCO-7.5	WGA	600	13300	0.4	0.3	1.29	0.02	83900	138	33400	—	—	—	—	—	—	—	—	1.69	4.2	1.7	12.7
MT-1	WGA	340	18800	1.5	1.1	—	—	70200	165	32200	—	0.2	—	—	—	—	—	—	0.52	3.9	1.3	13.8
MT-3	WGA	240	9560	—	—	—	—	89300	134	37400	—	—	—	0.3	—	—	—	—	1.2	1.5	2.5	6
MT-4	WGA	—	5780	—	—	—	—	86700	105	27100	—	—	—	—	—	—	—	—	1.5	2.8	1.3	—

Table 6.3-2 (continued)

Location ID	Media Code[a]	Phosphorus, Orthophosphate (Expressed as PO4)	Potassium	Praseodymium	Samarium	Selenium	Silver	Sodium	Strontium	Sulfate	Sulfide, Total	Terbium	Thallium	Thulium	Tin	Titanium	Total Phosphate as Phosphorus	Total Phosphorus	Uranium	Vanadium	Ytterbium	Zinc
MCOBT-4.4	WGI	100	710	—	—	—	—	23200	170	27300	—	—	—	—	—	1	—	—	0.28	1	—	9
MCOI-4	WGI	90	830	—	—	—	—	22600	173	31700	—	—	—	—	—	—	—	—	0.12	1.9	—	137
MCOI-5	WGI	—	1240	0.6	0.5	—	—	14100	108	14200	—	—	—	—	—	—	210	—	0.26	8.6	—	382
MCOI-6	WGI	200	740	—	—	—	—	21600	215	39500	—	—	—	—	—	2	—	—	0.47	1.3	—	90.8
MCOI-8	WGI	140	4790	—	—	—	—	45400	170	23500	—	—	—	—	—	—	—	—	1.6	—	—	50
PM-5	WGR	—	2310	—	—	—	—	13500	59.3	2760	—	—	—	—	—	—	30	40	0.55	11	—	12.2
R-1	WGR	120	1840	—	—	—	—	12800	53	3700	2	—	—	—	—	—	—	—	0.83	8.7	—	11
R-13	WGR	50	1400	—	—	2.98	—	11700	53.8	3360	—	—	0.27	—	—	—	—	—	0.49	6	—	38
R-14	WGR	580	2300 (J)	—	—	10.1 (J+)	—	15700	102	1890	30	—	0.03 (JN-)	—	1	—	—	1020	0.63	6.45 (J)	—	13
R-15	WGR	70	2000	—	—	2.9	—	12100	65	7590	—	—	1.51	—	—	—	—	70	0.46	7.34	—	3.59 (J)
R-28	WGR	20	1740 (J)	—	—	6.3 (J)	0.61	15600	143	43200	5	—	—	—	—	2	90	—	1.1 (J)	7	—	52
R-33	WGR	70	2170	—	—	6.2	—	12100	53.2	2800	—	—	—	—	—	—	—	—	1	6.1	—	63.2
Test Well 8	WGR	90	2060	—	—	—	—	10800	54.3	2150	—	—	0.45	—	—	—	—	60	0.84	5.3	—	460

All values in ug/L. Bolded concentrations exceed a standard and/or screening level. Grey shading indicates a standard and/or screening value was exceeded for that chemical. All surface waters associated with these locations are ephemeral.

[a] Media code definitions are provided in Table C-2-4.

[b] 20.6.4 NMAC.

[c] — = Not detected or not analyzed.

[d] 20.6.2 NMAC.

[e] EPA MCL for free cyanide.

[f] EPA 2005, 91002.

[g] EPA 2005, 91002 only listed for chemicals without a standard or MCL.

[h] Perchlorate-revised value.

[i] EPA region 9 PRG (EPA 2004, 93663).

Table 6.3-3
Mortandad Unfiltered Water Organic COPCs

Location ID	Media Code[a]	Acenaphthene	Acenaphthylene	Acetone	Anthracene	Aroclor-1260	Benzene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzoic Acid	Bis(2-ethylhexyl)phthalate	Butanone[2-]	Carbazole	Carbon Disulfide	Chloromethane	Chloronaphthalene [2-]	Chrysene	DDD[4,4'-]	DDE[4,4'-]	DDT[4,4'-]	Dichlorobenzene [1,2-]
Acute Aquatic Life[b]		—[c]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	**1.1**	**1.1**	**1.1**	—
Human Health Persistent[b]		—	—	—	—	**0.00064**	—	—	—	—	—	—	—	—	—	—	—	—	**0.0022**	**0.0022**	**0.0022**	—
Wildlife Habitat[b]		—	—	—	—	**0.014**	—	—	—	—	—	—	—	—	—	—	—	—	**0.001**	**0.001**	**0.001**	—
MO-24786	WS	—	—	2.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24787	WS	—	—	2.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24788	WS	—	—	2	—	—	—	—	—	—	14.2	—	—	—	—	—	—	—	—	—	—	—
MO-24790	WS	—	—	3.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24792	WS	—	—	2.4	—	**1.1 (J-)**	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24793	WS	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24808	WS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mortandad below Effluent Canyon	WS	—	—	75.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NM Groundwater Standards[d]		—	—	—	—	**1**	**10**	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
EPA MCLs[e]		—	—	—	—	—	**5**	—	—	—	—	**6**	—	—	—	—	—	—	—	—	—	**600**
EPA region 6 tap water screening levels[f]		**365**	—	**5475**	**1825**	—	—	**0.92**	**0.92**	**9.2**	**146000**	—	**7065**	**33.62**	**1043**	**21.3**	**487**	**92**	**2.77**	**1.95**	**1.95**	—
MCA-1	WGA	—	—	—	—	—	—	—	—	—	—	—	1.4	—	—	—	—	—	—	—	—	—
MCA-2	WGA	—	—	—	—	—	—	—	—	—	—	3.2	—	—	—	—	—	—	—	—	—	—
MCA-5	WGA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCO-0.6	WGA	—	—	5.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.26
MCO-3	WGA	—	—	—	—	—	—	—	—	—	—	0.25	—	—	—	—	—	—	—	—	—	—
MCO-4B	WGA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.3	—	—	—	—	—	—
MCO-5	WGA	—	—	—	—	—	0.45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCO-6	WGA	—	—	—	—	—	—	—	—	—	—	3.1	—	—	—	—	—	—	—	—	—	—
MCO-7	WGA	—	—	—	—	—	—	—	—	—	—	3.2	—	—	—	—	—	—	—	—	—	—
MT-1	WGA	—	—	2.4	—	—	—	—	—	—	—	**7**	—	—	—	—	—	—	—	—	—	—
MT-3	WGA	0.71	0.6	3.4	0.64	—	—	—	0.44	0.66	—	0.59	—	0.68	—	—	0.68	0.8	—	—	—	—
MCOBT-4.4	WGI	—	—	5.3	—	—	—	—	—	—	—	1.6 (J)	—	—	—	—	—	—	—	—	0.03 (J)	—
MCOI-4	WGI	—	—	3.5	—	—	—	—	—	—	—	—	—	—	4.2 (J)	3.4 (J)	—	—	—	—	—	—
MCOI-5	WGI	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCOI-6	WGI	—	—	—	—	—	—	—	—	—	—	4.6	3.7	—	—	—	—	—	—	—	—	—
PM-5	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.00792	—	—	—
R-1	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-13	WGR	—	—	71.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.01	—	—
R-14	WGR	—	0.25 (J)	4.2	0.3 (J)	—	—	0.42 (J)	—	—	—	—	—	—	—	—	—	0.38 (J)	—	—	—	—
R-15	WGR	—	—	19 (J)	—	—	—	—	—	—	—	**9.3 (J)**	—	—	—	—	—	—	—	—	—	—
R-28	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.1	—	—	—	—	—	—
R-33	WGR	—	—	—	—	—	—	—	—	—	—	**8.2**	—	—	—	—	—	—	—	—	—	—
Test Well 8	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 6.3-3 (continued)

Location ID	Media Code[a]	Dichlorobenzene[1,3-]	Dichlorobenzene[1,4-]	Dichlorobenzidine[3,3'-]	Diethylphthalate	Dioxane[1,4-]	Endrin	Fluoranthene	Fluorene	Isopropylbenzene	Methyl-2-pentanone[4-]	Methylene Chloride	Methylnaphthalene[2-]	Naphthalene	Nitroaniline[4-]	Octachlorodibenzofuran [1,2,3,4,6,7,8,9-]	Phenanthrene	Pyrene	Toluene	Xylene (Total)	Xylene[1,2-]	Xylene[1,3-]+Xylene[1,4-]
Acute Aquatic Life[b]		—	—	—	—	—	**0.086**	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Human Health Persistent[b]		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wildlife Habitat[b]		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24786	WS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24787	WS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24788	WS	—	—	—	—	—	—	—	—	—	1.9	—	—	—	—	—	—	—	—	—	—	—
MO-24790	WS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24792	WS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24793	WS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MO-24808	WS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mortandad below Effluent Canyon	WS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.85	—	—	—	—
NM Groundwater Standards[d]		—	—	—	—	—	—	—	—	—	—	**100**	**30**	**30**	—	—	—	—	**750**	**620**	—	—
EPA MCLs[e]		—	**75**	—	—	—	**2**	—	—	—	—	—	—	—	—	—	—	—	**1000**	—	—	—
EPA region 6 tap water screening levels[f]		**14.5**	—	**1.49**	**29200**	**61.12**	—	**1460**	**243**	**658**	—	—	—	—	—	—	—	**183**	—	—	**1431**	—
MCA-1	WGA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCA-2	WGA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCA-5	WGA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.38	—	—	—
MCO-0.6	WGA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCO-3	WGA	0.65	0.39	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCO-4B	WGA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCO-5	WGA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.84E-05	—	—	0.83	0.64	0.19	0.45
MCO-6	WGA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCO-7	WGA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MT-1	WGA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MT-3	WGA	—	—	**14.1 (J+)**	—	—	—	0.73	0.74	—	—	—	0.6	0.64	—	—	0.75	0.66	0.34	—	—	—
MCOBT-4.4	WGI	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCOI-4	WGI	—	—	—	—	53.3 (J)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MCOI-5	WGI	—	—	—	—	—	—	—	—	—	—	—	—	—	17.6 (J+)	—	—	—	8.5	—	—	—
MCOI-6	WGI	—	—	—	—	52.2 (J)	—	—	—	—	5.8 (J)	—	—	—	—	—	—	—	31.2	—	—	—
PM-5	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-1	WGR	—	—	—	7.44 (J+)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R-13	WGR	—	0.32 (J)	—	—	—	0.0084	—	—	—	—	—	—	—	—	—	—	—	2.8	—	—	—
R-14	WGR	—	—	—	—	—	—	0.33 (J)	0.3 (J)	0.3	—	—	—	—	—	—	0.43 (J)	0.36 (J+)	—	—	—	—
R-15	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.69 (J)	—	—	—
R-28	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	29.1	—	—	—

Table 6.3-3 (continued)

Location ID	Media Code[a]	Dichlorobenzene[1,3-]	Dichlorobenzene[1,4-]	Dichlorobenzidine[3,3'-]	Diethylphthalate	Dioxane[1,4-]	Endrin	Fluoranthene	Fluorene	Isopropylbenzene	Methyl-2-pentanone[4-]	Methylene Chloride	Methylnaphthalene[2-]	Naphthalene	Nitroaniline[4-]	Octachlorodibenzofuran [1,2,3,4,6,7,8,9-]	Phenanthrene	Pyrene	Toluene	Xylene (Total)	Xylene[1,2-]	Xylene[1,3-]+Xylene[1,4-]
R-33	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Test Well 8	WGR	—	—	—	—	—	—	—	—	—	—	1.1	—	0.37	—	—	—	—	0.3	—	—	—

Notes: All values in ug/L. Bolded concentrations exceed a standard and/or screening level. Grey shading indicates a standard and/or screening value was exceeded for that chemical. All surface waters associated with these locations are ephemeral.

[a] Media code definitions are provided in Table C-2-4.

[b] 20.6.4 NMAC

[c] — = Not detected or not analyzed.

[d] 20.6.2 NMAC

[e] EPA 2005, 91002.

[f] EPA 2005, 91002 only listed for chemicals without a standard or MCL.

Table 6.3-4
Mortandad Filtered Water Radionuclide COPCs

Location ID	Media Code[a]	Americium-241	Cesium-137	Gross Alpha	Gross Beta	Gross Gamma	Plutonium-238	Plutonium-239/240[b]	Potassium-40	Radium-226	Sodium-22	Strontium-90	Uranium-234	Uranium-235/236[c]	Uranium-238
Derived Concentration Guide (DCG) 100 mrem/yr[d]		**30**	**3000**	**—[e]**	—	—	**40**	**30**	**7000**	**100**	**10000**	**1000**	**500**	**600**	**600**
MO-24786	WS	—	—	—	5.5 (J)	—	—	—	—	—	—	—	0.14 (J)	—	0.12 (J)
MO-24787	WS	—	—	—	16 (J)	—	—	—	—	—	—	0.44	0.09 (J)	—	0.07 (J)
MO-24788	WS	4.07	22.8	7.98	48.1	—	1.5	2.56	—	0.41 (J)	—	4.37	0.42	—	0.36
MO-24789	WS	—	—	—	6.22 (J)	—	—	—	—	1.45 (J)	—	—	0.16 (J)	—	0.14 (J)
MO-24790	WS	—	—	1.94 (J)	8.42	—	—	—	—	0.37 (J)	—	0.6 (J)	0.13 (J)	—	0.08 (J)
MO-24791	WS	0.64	—	4.24 (J)	109	—	0.2	0.39	—	—	—	41.4	0.58	—	0.19
MO-24792	WS	0.04 (J)	—	—	25.7	—	0.23	0.07 (J)	—	—	—	9.1	0.13 (J)	—	0.1 (J)
MO-24793	WS	—	—	—	44.9	—	—	—	—	—	—	19.1	0.24 (J)	—	0.26
Mortandad at GS-1	WS	0.6	—	—	—	—	1.51	0.82	—	—	—	45.29	3.51	0.07	1.08
Mortandad below Effluent Canyon	WS	1.62	9.67 (J)	4.68 (J)	28.8	—	0.44	0.75	—	0.61 (J)	—	3.2	0.17 (J)	—	0.07 (J)
EPA MCLs[f]		—	—	**15**	—	—	—	—	—	—	—	—	—	—	—
Derived Concentration Guide (DCG) 4 mrem/yr		**1.2**	**120**	—	—	—	**1.6**	**1.2**	**280**	**4**	**400**	**40**	**20**	**24**	**24**
MCA-1	WGA	—	—	2.35	6.03 (J)	—	—	—	—	1.94	—	0.42 (J)	0.11 (J)	—	0.09 (J)
MCA-2	WGA	0.1 (J)	—	3.67 (J)	47.4	—	—	—	70.8 (J)	1.66	—	10.4	0.99	0.06 (J)	0.66
MCA-5	WGA	1.19	—	3.11 (J)	59.6	—	0.78	0.76	—	1.41	—	21	0.47	0.03 (J)	0.17
MCO-0.6	WGA	—	—	5.16 (J, J-)	14.5 (J)	—	—	—	—	—	—	0.45 (J)	1.2	—	1.38
MCO-4B	WGA	0.17	—	3.73 (J)	112	—	0.11 (J)	0.2	—	—	—	39.6 (J)	0.54	—	0.17 (J)
MCO-5	WGA	0.11	—	1.89 (J)	95.9	—	0.05	—	—	—	—	**57**	0.42 (J)	0.04	0.41
MCO-6	WGA	0.08 (J)	—	3.06 (J)	112	—	0.02	—	—	1.42	5.84	**56.79**	1.4	0.06 (J)	0.5
MCO-7	WGA	0.12	—	—	31.5	—	0.03	—	—	2.19 (J)	—	1.92	0.77	0.08 (J)	0.65
MCO-7.5	WGA	0.21	—	2.53 (J)	25	—	—	0.07 (J)	—	0.72 (J)	—	—	0.5	0.06 (J)	0.45
MT-1	WGA	0.12	—	1.25 (J)	30.4	—	—	0.04 (J)	—	1.37 (J)	—	0.41 (J)	0.65	—	0.48
MT-3	WGA	0.23	—	2.89 (J)	28.8	—	—	—	—	—	—	—	0.57	0.08 (J)	0.47
MT-4	WGA	0.08 (J)	—	2.46 (J)	15.5	—	—	—	—	—	—	—	0.69	0.06 (J)	0.62
MCOBT-4.4	WGI	—	—	—	—	—	—	—	44.4	—	—	—	0.25	—	0.15
MCOI-4	WGI	—	—	—	3.35 (J)	—	—	—	—	—	—	—	0.11 (J)	—	—
MCOI-5	WGI	—	—	—	—	—	—	—	—	—	—	—	0.11 (J)	—	0.06 (J)
MCOI-6	WGI	—	—	2.11 (J)	14.7 (J)	—	—	—	—	3.04	—	—	0.4	0.06 (J)	0.19
R-1	WGR	—	—	—	3.63 (J)	—	—	—	—	—	—	—	0.63	—	0.23
R-13	WGR	—	—	—	—	—	—	—	—	—	—	—	0.33	—	0.14
R-15	WGR	—	—	—	3.42 (J)	137	—	—	—	—	—	1.51	0.34	0.04	0.18 (J)
R-28	WGR	—	—	—	9.29 (J)	—	—	—	—	—	—	—	0.89	0.07 (J)	0.39
R-33	WGR	—	—	—	4.96 (J)	—	—	—	—	—	—	—	0.65	—	0.32

Note: All values in pCi/L. Bolded concentrations exceed a standard and/or screening level. Grey shading indicates a standard and/or screening value was exceeded for that chemical.
[a] Media code definitions are provided in Table C-2-4.
[b] Plutonium-239 DCG.
[c] Uranium-235 DCG.
[d] No applicable NM standards; all surface waters are ephemeral.
[e] — = Not detected or not analyzed.
[f] EPA 2005, 91002.

Table 6.3-5
Mortandad Unfiltered Water Radionuclide COPCs

Location ID	Media Code[a]	Americium-241	Cesium-137	Gross Alpha	Gross Alpha/Beta	Gross Beta	Gross Gamma	Plutonium-238	Plutonium-239/240[b]	Potassium-40	Radium-226	Sodium-22	Strontium-90	Technetium-99	Thorium-228	Thorium-230	Thorium-232	Tritium	Uranium-234	Uranium-235/236[c]	Uranium-238
Livestock Watering[d]		—[e]	—	**15**	—	—	—	—	—	—	**30**	—	—	—	—	—	—	**20000**	—	—	—
Derived Concentration Guide (DCG) 100 mrem/yr[f]		**30**	**3000**	—	—	—	—	**40**	**30**	**7000**	—	**10000**	**1000**	**100000**	**400**	**300**	**50**	—	**500**	**600**	**600**
MO-24786	WS	—	—	—	—	5 (J)	—	—	—	—	—	—	0.36 (J)	—	—	—	—	117.18	0.19 (J)	—	0.16 (J)
MO-24787	WS	—	—	—	—	16.1	—	—	—	—	0.76	—	0.58 (J)	—	—	—	—	365 (J)	0.19 (J)	—	0.16 (J)
MO-24788	WS	8.64 (J)	35.6	**18.4 (J)**	12.3	52.7 (J)	—	3.15 (J)	4.85 (J)	63.6 (J)	—	—	3.97 (J)	—	—	—	—	1090	0.56 (J+)	—	0.24 (J+)
MO-24789	WS	—	—	4.87 (J)	7.44	13.1	—	0.13 (J)	0.08	—	0.43	—	0.44 (J)	—	—	—	—	87.8	0.42	—	0.4
MO-24790	WS	—	—	2.2 (J)	—	9.26	—	—	—	—	—	—	0.5 (J)	—	—	—	—	86.84	0.12 (J)	—	0.12 (J)
MO-24791	WS	0.98 (J)	6.15 (J)	7.22	—	119	—	0.28 (J)	0.5	—	—	—	43.9 (J)	9.87	—	—	—	590.7	0.52	—	0.18
MO-24792	WS	0.2	—	7.41 (J,J-)	7.73	43.9	—	1.79	0.79	—	—	—	6.63	—	—	—	—	72.8	0.24	—	0.22
MO-24793	WS	—	—	**81.2**	—	59.2	—	0.07 (J)	—	—	—	—	21.3	—	—	—	—	167.31	0.22 (J)	—	0.26
MO-24794	WS	—	—	—	3.1	—	—	0.12	—	—	—	—	—	—	—	—	—	—	0.26	—	0.29
MO-24795	WS	—	—	—	6.15	—	—	0.06	—	—	—	—	—	—	—	—	—	—	0.15	—	0.13
MO-24808	WS	1.88	—	—	4.59	—	—	0.75	0.81	—	—	—	—	—	—	—	—	—	0.36	—	0.19
Mortandad at GS-1	WS	6.54 (J+)	31.39	**39.9**	—	92.9 (J)	262	5	6.75	—	—	8.96	47.7	—	—	—	—	**52633.41**	3.43	0.07	1.12
Mortandad at Rio Grande (A-11)	WS	0.03	—	—	—	15.3	—	—	—	—	1.36	—	0.3 (J)	—	—	—	—	5.97	0.35	—	0.17
Mortandad below Effluent Canyon	WS	15	42.6	**49.3**	—	80.3	—	6.75	4.73	—	0.7 (J)	12.8	11.5	—	0.12 (J)	0.07	0.1 (J)	12900	2.93	0.17	0.25
EPA MCLs[g]		—	—	**15**	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Derived Concentration Guide (DCG) 4 mrem/yr[g]		**1.2**	**120**	—	—	—	—	**1.6**	**1.2**	**280**	**4**	**400**	**40**	**4000**	**16**	**12**	**2**	**80000**	**20**	**24**	**24**
MCA-1	WGA	—	—	3.66 (J)	—	10.5	—	—	—	—	—	—	—	—	—	—	—	109.83	0.17 (J)	—	0.2 (J)
MCA-2	WGA	0.07 (J)	—	3.63 (J)	—	51.4	—	—	—	—	1.63	—	9.53	12.6 (J)	—	—	—	3649.59	0.94	0.06 (J)	0.66
MCA-5	WGA	**2.44 (J)**	7.53 (J)	8.91 (J)	—	80.2 (J)	—	**1.75 (J)**	**1.96 (J)**	—	1.35 (J)	—	20 (J)	15.6 (J)	—	—	—	491 (J)	0.49 (J)	—	0.26 (J)
MCO-0.6	WGA	—	—	7.86 (J,J-)	—	19.7 (J)	—	—	—	—	—	—	0.38 (J)	—	—	—	—	222 (J)	1.43	0.09 (J)	1.53
MCO-2	WGA	—	—	—	—	—	—	—	—	—	—	—	0.67	—	—	—	—	—	0.14	—	0.15
MCO-3	WGA	**3.98**	8.08	12.4	—	161 (J)	—	**2.19**	**1.78**	**649**	0.52 (JN+)	24.6	39.3	—	—	—	0.05 (J)	76300	4.27	0.17 (J)	1.17
MCO-4B	WGA	0.7	—	7.11 (J-)	—	262 (J)	—	0.14	0.27	—	1.28 (J)	—	**79.1**	6.25 (J)	—	—	—	2790	3.24	0.21	0.91
MCO-5	WGA	1.06	—	11.9 (J-)	—	251 (J)	—	0.17	0.29	63.1 (J)	0.99 (J)	26.2	**81.6**	7.43 (J)	—	0.05 (J)	—	6820	2.66	0.14 (J)	0.8
MCO-6	WGA	0.97	—	6.28 (J-)	—	152 (J)	—	0.01	0.03 (J)	—	1.55 (J)	18.5	**60.29**	10.7 (J)	—	0.03 (J)	—	8260.29	2.48	0.16	0.88
MCO-7	WGA	0.98	16.5	3.39 (J-)	—	54.2	—	—	0.02	—	1.59 (J)	12.4	2.32	18 (J)	—	0.04 (J)	—	10971.14	0.85	0.04 (J)	0.69
MCO-7.5	WGA	0.32	—	2.8 (J)	—	43.3 (J)	—	0.23	0.32	—	2.27	8.34 (J)	0.42 (J)	23.1	0.12 (J)	0.16 (JN+)	0.05 (J)	16137.42	0.51	0.05 (J)	0.55
Mort PRB Apatite Cell 10	WGA	0.12 (J)	—	—	—	—	—	—	—	—	—	—	1.48	—	—	—	—	—	—	—	—
Mort PRB Apatite Cell 4	WGA	—	—	—	—	—	—	0.05 (J)	—	—	—	—	14.4	—	—	—	—	—	—	—	—
Mort PRB Apatite Cell 8	WGA	0.4	—	—	—	—	—	0.21	0.22	—	—	—	36.9	—	—	—	—	—	—	—	—
Mort PRB Bio Cell 3	WGA	0.66	—	—	—	—	—	0.08 (J)	0.06 (J)	—	—	—	**45.9**	—	—	—	—	—	—	—	—
Mort PRB Bio Cell 7	WGA	0.21	—	—	—	—	—	0.1 (J)	0.05 (J)	—	—	—	34.6	—	—	—	—	—	—	—	—

Table 6.3-5 (continued)

Location ID	Media Code[a]	Americium-241	Cesium-137	Gross Alpha	Gross Alpha/Beta	Gross Beta	Gross Gamma	Plutonium-238	Plutonium-239/240[b]	Potassium-40	Radium-226	Sodium-22	Strontium-90	Technetium-99	Thorium-228	Thorium-230	Thorium-232	Tritium	Uranium-234	Uranium-235/236[c]	Uranium-238
Mort PRB Bio Cell 9	WGA	0.34	—	—	—	—	—	0.23	0.13	—	—	—	**48.5**	—	—	—	—	—	—	—	—
Mort PRB Gravel Cell 11	WGA	0.34	—	—	—	—	—	0.27	0.23	—	—	—	**60.9**	—	—	—	—	—	—	—	—
Mort PRB Gravel Cell 12	WGA	0.12 (J)	—	—	—	—	—	0.1	0.05 (J)	—	—	—	**67.7**	—	—	—	—	—	—	—	—
Mort PRB Gravel Cell 6	WGA	0.24	—	—	—	—	—	0.13	0.08 (J)	—	—	—	**62**	—	—	—	—	—	—	—	—
Mort PRB Limestone Cell 13	WGA	0.35	—	—	—	—	—	0.1	0.24	—	—	—	**53.4**	—	—	—	—	—	—	—	—
Mort PRB Limestone Cell 14	WGA	0.19	—	—	—	—	—	0.07 (J)	—	—	—	—	**49.3**	—	—	—	—	—	—	—	—
Mort PRB Limestone Cell 5	WGA	0.67	—	—	—	—	—	0.19	0.43	—	—	—	**47**	—	—	—	—	—	—	—	—
MT-1	WGA	0.11 (J)	—	6.38	—	33.1 (J)	—	0.07 (J)	0.1 (J)	—	1.54 (J)	—	0.58 (J)	16	—	—	—	3610	0.94 (J)	0.05 (J)	0.81 (J)
MT-3	WGA	0.2 (J)	—	2.06 (J)	—	29.8 (J)	—	—	—	—	—	—	—	17.4	—	—	—	6287.01	0.45	—	0.39
MT-4	WGA	0.08 (J)	—	—	—	17	—	—	—	—	—	—	—	20.2	—	—	—	4720	0.7	0.04 (J)	0.62
PRB-MW-01	WGA	**3.09**	—	—	—	—	—	1.41	**1.57**	—	—	—	**90.5**	—	—	—	—	—	—	—	—
PRB-MW-02	WGA	0.74	—	—	—	—	—	0.33	0.88	—	—	—	**78.9**	—	—	—	—	—	—	—	—
MCOBT-4.4	WGI	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	23500	0.4	0.06	0.36
MCOI-4	WGI	—	—	—	—	2.03 (J)	—	—	—	—	3.28	—	—	5.76 (J)	—	—	—	12900	0.13 (J)	—	—
MCOI-5	WGI	—	—	—	—	—	—	—	—	—	—	—	—	4.72 (J)	—	—	—	4480	0.19 (J)	—	0.13 (J)
MCOI-6	WGI	—	—	—	—	10.2 (J)	—	—	—	—	0.73 (J)	—	—	7.86 (J)	—	—	—	13100	0.41	—	0.21
MCOI-8	WGI	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	136.37	—	—	—
PM-5	WGR	0.15	—	—	—	4.01 (J)	—	—	—	—	0.56 (J)	—	—	—	—	0.2 (J)	—	2.36	0.39	0.04 (J)	0.21
R-1	WGR	—	—	14.5	—	3.75 (J)	—	—	—	—	—	—	—	—	—	—	—	—	0.67	0.06 (J)	0.28
R-13	WGR	—	—	0.64 (J)	—	2.58	—	—	—	—	0.44 (J)	—	—	—	—	—	—	—	0.31	0.06 (J)	0.15
R-14	WGR	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.55	0.33	0.08 (J)	0.2
R-15	WGR	—	—	—	—	3.1	240	—	—	195	0.92 (J)	—	—	—	—	—	—	30.97	0.31	0.07	0.18
R-28	WGR	—	—	—	—	12.4 (J)	—	—	—	—	—	—	—	—	—	—	—	181.36	0.85	0.08 (J)	0.39
R-33	WGR	—	—	—	—	4.51 (J)	—	—	—	—	0.7 (J)	—	—	—	—	—	—	137.29	0.62	0.05 (J)	0.33
Test Well 8	WGR	—	—	—	—	3.01	—	—	—	—	3.99	—	—	—	—	—	—	6.06	0.41	—	0.22

Notes: All values in pCi/L. Bolded concentrations exceed a standard and/or screening level. Grey shading indicates a standard and/or screening value was exceeded for that chemical.

[a] Media code definitions are provided in Table C-2-4.

[b] Plutonium-239 DCG.

[c] Uranium-235 DCG.

[d] 20.6.4 NMAC.

[e] — = Not detected or not analyzed.

[f] Only listed for chemicals without a NM standard.

[g] EPA 2005, 91002.

Table 6.4-1
Mortandad Core Inorganic COPCs

Borehole	Media Code[a]	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium[b]	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vanadium	Zinc
QAL (ALLH) LANL BV[c]		**29200**	**0.83**	**8.17**	**295**	**1.83**	**0.4**	**6120**	**19.3**	**8.64**	**14.7**	**21500**	**22.3**	**4610**	**671**	**0.1**	**#N/A**	**15.4**	**1.52**	**1**	**0.73**	**39.6**	**48.8**
QBT2 LANL BV		**7340**	**0.5**	**2.79**	**46**	**1.21**	**1.63**	**2200**	**7.14**	**3.14**	**4.66**	**14500**	**11.2**	**1690**	**482**	**0.1**	**#N/A**	**6.58**	**0.3**	**1**	**1.1**	**17**	**63.5**
QBT1V LANL BV		**8170**	**0.5**	**1.81**	**26.5**	**1.7**	**0.4**	**3700**	**2.24**	**1.78**	**3.26**	**9900**	**18.4**	**780**	**408**	**0.1**	**#N/A**	**2**	**0.3**	**1**	**1.24**	**4.48**	**84.6**
QBT 1G, QCT, QBO, QBOF LANL BV		**3560**	**0.5**	**0.56**	**25.7**	**1.44**	**0.4**	**1900**	**2.6**	**8.89**	**3.96**	**3700**	**13.5**	**739**	**189**	**0.1**	**#N/A**	**2**	**0.3**	**1**	**1.22**	**4.59**	**40**
Residential SSL		**77800**	**31.3**	**3.9**	**15600**	**156**	**39**	**#N/A**	**2100**	**1520**	**3130**	**23500**	**400**	**#N/A**	**3590**	**100000**	**391**	**1560**	**391**	**391**	**5.16**	**78.2**	**23500**
B-1	QBT1V	—[d]	—	—	—	—	0.53 (U)	—	—	—	—	—	—	—	—	—	—	—	0.67	—	—	—	—
B-1	QBT2	—	—	—	—	1.76	—	—	—	—	—	—	—	—	—	—	—	—	1.08	—	—	—	64.4
B-2	QBT1G	9440	—	0.88	—	1.71	—	—	14	—	—	5040	—	—	264 (J)	—	—	—	—	—	—	—	—
B-2	QBT1V	25500	—	3.82	338	5.51	—	—	—	—	4.36 (J+)	11000	60	—	670 (J)	—	—	—	0.69 (U)	—	1.63	—	98.2
B-2	QBT2	—	—	—	—	—	—	—	—	—	—	—	11.4	—	497 (J)	—	—	—	—	—	—	—	65.5
B-5	QAL	—	—	—	—	—	0.61 (U)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-5	QBT1G	—	—	0.57 (U)	—	—	0.58 (U)	—	—	—	—	4090 (J)	—	—	—	—	—	—	0.58 (U)	—	—	—	—
B-6	QAL	—	—	—	—	—	0.6 (U)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	70.6
B-6	QBT1G	—	—	0.8 (U)	—	—	0.62 (U)	—	—	—	—	—	—	—	—	—	—	—	0.62 (U)	—	—	—	—
B-7	QAL	—	—	—	—	—	0.58 (U)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-7	QBT1G	42000	0.53 (U)	2.7 (U)	634	3.89	0.66 (U)	—	6.6	—	9.41	13200	29.6	1310	—	—	—	13.5	0.66 (U)	—	—	8.65	101
B-7	QCT	14600	—	1.39	70	4.41	0.63 (U)	—	5.23	—	4.41	6880	17.8	1630	—	—	—	3.91	0.56 (J)	—	—	7.3	120
B-8	QAL	—	—	—	—	—	0.56 (U)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-8	QCT	37200	—	1.9	166	3.59	0.77 (U)	—	7.15	—	7.67	10700	26.3	1710 (J+)	364	—	—	18.2	1.03	—	—	9.66	65.4
B-9	QAL	36000	—	—	—	3.18	0.61 (U)	—	—	—	—	—	37.9	—	—	—	—	—	—	—	0.82	—	86.2
B-9	QCT	14900	—	0.95	56.6	1.76	0.62 (U)	—	3.47	—	—	12500	—	905 (J)	216 (J)	—	—	3.43	1.13	—	—	9.81	44
B-10	QAL	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	57.9
B-10	QCT	17300	—	2.42 (J)	73	2.49	—	—	5.74	—	5.19	12500	14.2	1540 (J+)	474	—	—	4.43	1.2	—	—	9.12	62.5
B-11	QAL	—	—	—	—	—	0.63 (U)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	65.6
B-11	QCT	23300	0.52 (UJ)	1.23	81.8	1.5	0.65 (U)	—	4.27	—	—	10600	—	1000	246	—	—	4.21	0.65 (U)	—	—	7.19	—
B-12	QCT	28000 (J+)	—	3.52	178	6.66	—	2420	11.2 (J)	—	5.9	14100 (J+)	114	4270	918 (J-)	—	—	6 (J)	0.74	—	—	21.7	245 (J)
B-14	QAL	62600	—	—	365	4.18	0.72 (U)	—	—	—	17	—	31.9	—	—	—	—	25.4	—	—	—	—	94.8
B-14	QBOF	7850 (J)	—	1.35 (J)	85.1 (J-)	—	0.58 (U)	—	71.7 (J-)	—	8.19 (J)	10900	—	1390 (J-)	217 (J-)	—	—	3.56	1.19	—	—	6.83	—
B-14	QCT	11400	—	0.84 (U)	43.4	—	0.62 (U)	—	4.09 (J)	—	4.33	5860	—	1230 (J)	—	—	—	2.8	0.62	—	—	9.63 (J)	—
B-15	QAL	—	—	—	—	—	0.53 (U)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B-15	QBO	—	—	—	30.5	—	0.55 (U)	—	3.07	—	—	6690 (J+)	—	—	198	—	—	—	0.55 (U)	—	—	5.25	49.7
B-15	QBT1G	—	—	0.6 (U)	—	—	0.6 (U)	—	—	—	—	—	—	—	—	—	—	—	0.57 (U)	—	—	—	—
B-15	QCT	17300 (J+)	—	1.36 (U)	66.9	5.71	0.58 (U)	—	9.98	—	5.95	10100 (J+)	—	2470 (J+)	237	—	—	5.4	0.84 (U)	—	—	13	63.8
B-16	QBO	—	—	—	49	—	—	—	6.48	—	—	4000	—	—	230	—	—	—	0.66	—	—	—	—

Table 6.4-1 (continued)

Borehole	Media Code[a]	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium[b]	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vanadium	Zinc
R-14	QBO	—	—	—	—	—	0.528 (U)	—	—	—	—	3830	—	—	—	—	—	—	0.528 (U)	—	—	—	—
R-14	QBT1G	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.531 (U)	—	—	—	—
R-14	QBT1V	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.499 (U)	—	—	—	—
R-14	QBT2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.523 (U)	—	—	—	—
R-14	QCT	3660	—	—	—	—	0.489 (U)	—	2.76	—	—	—	—	—	—	—	—	—	0.489 (U)	—	—	—	—
R-15	QBO	8820	1.3 (J-)	1.4 (J)	156	—	0.6 (U)	10200	9.6	21.2	35.1	**28000**	—	16700	545 (J+)	0.12 (U)	0.83 (J)	75.6	1.3	2.4 (U)	—	28.1	46.2
R-15	QBT1G	27500	0.68 (UJ)	2.8	192	4.8	—	2040	6.4	—	15.4	9390	31.2	1300	479 (J-)	—	—	9.1 (J)	0.79 (U)	—	—	11.8	80.2
R-15	QCT	23800	0.72 (UJ)	2.1 (J)	72.5	2.9	—	2190	442	—	46.1	8110	16.6	1840	348 (J-)	—	—	218	0.83 (U)	—	—	10 (J)	46.4

Notes: All values in mg/kg. Values are maximum values > BV. Values in bold exceed the residential SSL. Grey shading indicates a screening value was exceeded for that chemical.

[a] Media code definitions are provided in Table C-2-4.

[b] EPA region 6 residential HHMSSL (EPA 2005, 91002).

[c] LANL (1998, 59730).

[d] — = Not detected > BV or not analyzed.

Table 6.4-2
Mortandad Core Radionuclide COPCs

Borehole	Media Code[a]	Americium-241	Cesium-134	Plutonium-238	Plutonium-239	Tritium	Uranium-234	Uranium-235	Uranium-238
QAL (ALLH) LANL BV[b]		**0.013**	**#N/A**	**0.023**	**0.054**	**#N/A**	**2.59**	**0.2**	**2.29**
QBT2 LANL BV		**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**1.98**	**0.09**	**1.93**
QBT1V LANL BV		**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**3.12**	**0.14**	**3.05**
QBT 1G, QCT, QBO, QBOF LANL BV		**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**4**	**0.18**	**3.9**
Residential SSL[c]		**30**	**2.4**	**37**	**33**	**750**	**170**	**17**	**86**
B-1	QBT2	-[d]	-	-	-	-	2.24	0.1	2.26
B-2	QBT1V	-	-	-	-	-	-	0.19	3.22
B-2	QBT2	-	-	-	-	-	-	0.13	1.94
B-5	QAL	0.79	-	0.19	0.78	-	3.08	-	3.16
B-5	QBT1G	-	-	-	0.07	13.39	-	-	-
B-6	QAL	0.06	-	-	-	-	-	-	-
B-6	QBT1G	-	-	-	-	9.28	-	-	-
B-7	QAL	1.07	-	0.18	1.11	0.84	-	-	-
B-7	QBT1G	-	-	-	-	8.72	-	0.2	-
B-7	QCT	-	-	-	-	3.31	-	-	-
B-8	QCT	-	-	-	-	1.06	-	-	-
B-9	QAL	-	-	0.07	-	1.02	-	-	-
B-9	QCT	-	-	-	-	7.5	-	-	-
B-10	QAL	-	-	-	-	29.44	-	-	2.65
B-10	QCT	-	-	-	-	4.16	-	-	-
B-11	QAL	-	-	-	-	5.9	-	-	-
B-11	QCT	-	-	-	-	3.64	-	-	-
B-12	QAL	-	-	-	-	1.75	-	-	-
B-12	QCT	-	-	-	-	6.81	-	-	-
B-14	QAL	0.03	-	-	0.06	7.92	-	-	-
B-14	QBOF	-	-	-	-	5.66	-	-	-
B-14	QCT	-	0.13	0.12	-	5.71	-	-	-
B-15	QBT1G	-	-	-	-	-	-	-	3.94
B-16	QAL	-	-	-	-	-	-	-	2.42
I-6	QAL	-	-	-	-	1.85	-	-	-
I-6	QBO	-	-	-	-	8.33	-	-	-
I-6	QCT	-	-	-	-	0.97	-	-	-
I-8	QAL	-	-	-	-	1.23	-	-	-
I-8	QBO	-	-	-	-	9.18	-	-	-

Table 6.4-2 (continued)

Borehole	Media Code[a]	Americium-241	Cesium-134	Plutonium-238	Plutonium-239	Tritium	Uranium-234	Uranium-235	Uranium-238
QAL (ALLH) LANL BV[b]		**0.013**	**#N/A**	**0.023**	**0.054**	**#N/A**	**2.59**	**0.2**	**2.29**
QBT2 LANL BV		**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**1.98**	**0.09**	**1.93**
QBT1V LANL BV		**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**3.12**	**0.14**	**3.05**
QBT 1G, QCT, QBO, QBOF LANL BV		**#N/A**	**#N/A**	**#N/A**	**#N/A**	**#N/A**	**4**	**0.18**	**3.9**
Residential SSL[c]		**30**	**2.4**	**37**	**33**	**750**	**170**	**17**	**86**
I-8	QBT1G	-	-	-	-	3.33	-	-	-
I-8	QCT	-	-	-	-	5.65	-	-	-
R-1	QAL	0.486	-	0.0812	0.503	0.604	-	-	-
R-1	QBO	-	-	-	-	10.3	-	0.233	-
R-1	QBT1G	-	-	-	-	29.6	-	0.242	-
R-1	QCT	-	-	-	-	10.8	-	-	-
R-14	QBT1V	-	-	-	-	-	-	0.157	-
R-15	QAL	-	-	-	-	0.12	-	-	-
R-15	QBO	-	-	-	-	26.5	-	-	-
R-15	QBT1G	-	-	-	-	14.6	-	-	-
R-15	QCT	-	-	-	-	12.5	-	-	-
R-28	QAL	-	-	-	-	0.0591	-	-	-
R-28	QBO	-	-	-	-	-	-	0.424	-
R-28	QBOG[e]	-	-	-	-	-	3.58	0.184	3.77
R-28	QCT	-	-	-	-	-	-	0.268	-

Notes: All values in pCi/g. Values are maximum detected values > BV; if no BV, value is maximum detected value. No values exceed the residential SSL.

[a] Media code definitions are provided in Table C-2-4.

[b] LANL 1998, 59730.

[c] LANL 2005, 88493.

[d] — = Not detected (if no BV), not detected > BV, or not analyzed.

[e] No background values have been developed for QBOG.

Table 6.5-1
Mortandad COPC Summary

Analyte	Sediment	Water	Core
Aluminum	x[a]	**x**[b]	x
Ammonia	x	x	—[c]
Ammonia as Nitrogen	—	**x**	—
Antimony	x	**x**	x
Arsenic	**x**	**x**	x
Barium	x	x	x
Beryllium	x	x	x
Boron	x	x	—
Bromide	x	x	—
Cadmium	x	x	x
Calcium	x	x	x
Cerium	—	x	—
Chloride	x	**x**	—
Chromium	**x**	**x**	x
Chromium hexavalent ion	x	x	—
Cobalt	x	x	x
Copper	x	**x**	x
Cyanide (Total)	x	x	—
Dysprosium	—	x	—
Erbium	—	x	—
Europium	—	x	—
Fluoride	x	**x**	—
Gadolinium	—	x	—
Holmium	—	x	—
Iron	**x**	**x**	**x**
Iron (ferrous)	—	x	—
Lanthanum	—	x	—
Lead	x	**x**	x
Lithium	—	x	—
Lutetium	—	x	—
Magnesium	x	x	x
Manganese	x	**x**	x
Mercury	x	x	x
Molybdenum	—	**x**	x
Neodymium	—	x	—
Nickel	x	**x**	x
Nitrate	x	**x**	—
Nitrate as Nitrogen	—	**x**	—
Nitrate-Nitrite as N	x	**x**	—

Table 6.5-1 (continued)

Analyte	Sediment	Water	Core
Nitrite	x	**x**	—
Oxalate	x	—	—
Perchlorate	x	**x**	—
Phosphorus, Orthophosphate (Expressed as PO_4)	x	x	—
Potassium	—	x	—
Praseodymium	—	x	—
Samarium	—	x	—
Selenium	x	x	x
Silver	x	x	x
Sodium	x	x	—
Strontium	—	x	—
Sulfate	x	x	—
Sulfide, Total	—	x	—
Terbium	—	x	—
Thallium	x	x	x
Thulium	—	x	—
Tin	—	x	—
Titanium	—	x	—
Total Phosphate as Phosphorus	—	x	—
Total Phosphorus	x	x	—
Uranium	x	**x**	—
Vanadium	x	x	x
Ytterbium	—	x	—
Zinc	x	**x**	x
Acenaphthene	x	x	—
Acenaphthylene	—	x	—
Acetone	x	x	—
Anthracene	x	x	—
Aroclor-1254	x	—	—
Aroclor-1260	**x**	**x**	—
Aroclors (Mixed)	x	—	—
Benzene	x	x	—
Benzo(a)anthracene	x	x	—
Benzo(a)pyrene	**x**	—	—
Benzo(b)fluoranthene	x	x	—
Benzo(g,h,i)perylene	x	—	—
Benzo(k)fluoranthene	x	x	—
Benzoic Acid	x	x	—
BHC[alpha-]	x	—	—
BHC[beta-]	x	—	—

Table 6.5-1 (continued)

Analyte	Sediment	Water	Core
BHC[delta-]	x	—	—
BHC[gamma-]	x	—	—
Bis(2-ethylhexyl)phthalate	x	**x**	—
Bromodichloromethane	x	—	—
Bromomethane	x	—	—
Butanone[2-]	x	x	—
Butylbenzylphthalate	x	—	—
Carbazole	x	x	—
Carbon Disulfide	—	x	—
Carbon Tetrachloride	x	—	—
Chlordane[alpha-]	x	—	—
Chlordane[gamma-]	x	—	—
Chloroform	x	—	—
Chloromethane	x	x	—
Chloronaphthalene[2-]	—	x	—
Chlorophenol[2-]	x	—	—
Chlorophenyl-phenyl[4-] Ether	x	—	—
Chrysene	x	x	—
DDD[4,4'-]	x	x	—
DDE[4,4'-]	x	x	—
DDT[4,4'-]	x	x	—
Dibenz(a,h)anthracene	x	—	—
Dibenzofuran	x	—	—
Dichlorobenzene[1,2-]	x	x	—
Dichlorobenzene[1,3-]	—	x	—
Dichlorobenzene[1,4-]	—	x	—
Dichlorobenzidine[3,3'-]	x	**x**	—
Dichloroethene[1,1-]	x	—	—
Dichloroethene[cis-1,2-]	x	—	—
Dieldrin	x	—	—
Diethylphthalate	x	x	—
Dioxane[1,4-]	—	x	—
Di-n-butylphthalate	x	—	—
Endosulfan Sulfate	x	—	—
Endrin	—	x	—
Endrin Aldehyde	x	—	—
Fluoranthene	x	x	—
Fluorene	x	x	—
Heptachlor Epoxide	x	—	—
Hexachlorobutadiene	x	—	—

Table 6.5-1 (continued)

Analyte	Sediment	Water	Core
Hexanone[2-]	x	—	—
Indeno(1,2,3-cd)pyrene	x	—	—
Isopropylbenzene	x	x	—
Isopropyltoluene[4-]	x	—	—
Methoxychlor[4,4'-]	x	—	—
Methyl-2-pentanone[4-]	x	x	—
Methylene Chloride	x	x	—
Methylnaphthalene[2-]	x	x	—
Naphthalene	x	x	—
Nitroaniline[2-]	x	—	—
Nitroaniline[4-]	x	x	—
Nitrophenol[2-]	x	—	—
Nitrosodiphenylamine[N-]	x	—	—
Octachlorodibenzofuran[1,2,3,4,6,7,8,9-]	—	x	—
Phenanthrene	x	x	—
Pyrene	x	x	—
Tetrachloroethene	x	—	—
Toluene	x	x	—
Trichloroethane[1,1,1-]	x	—	—
Trichloroethene	x	—	—
Trichlorofluoromethane	x	—	—
Trichlorophenol[2,4,6-]	x	—	—
Trimethylbenzene[1,2,4-]	x	—	—
Xylene (Total)	x	x	—
Xylene[1,2-]	x	x	—
Xylene[1,3-]	x	—	—
Xylene[1,3-]+Xylene[1,4-]	—	x	—
Americium-241	**x**	**x**	x
Cesium-134	x	—	x
Cesium-137	**x**	x	—
Cobalt-60	**x**	—	—
Europium-152	x	—	—
Plutonium-238	**x**	**x**	x
Plutonium-239/240	**x**	**x**	x
Potassium-40	—	**x**	—
Radium-226	—	x	—
Ruthenium-106	x	—	—
Sodium-22	x	x	—
Strontium-90	**x**	**x**	—
Technetium-99	—	x	—

Table 6.5-1 (continued)

Analyte	Sediment	Water	Core
Thorium-228	**x**	x	—
Thorium-230	**x**	x	—
Thorium-232	**x**	x	—
Tritium	x	**x**	x
Uranium-234	x	x	x
Uranium-235/236	x	x	x
Uranium-238	x	x	x

[a] x = Analyte is a COPC for given medium.

[b] Bold x = Analyte exceeded residential SSL, SAL, or standard.

[c] — = Analyte is not a COPC for given medium.

Table 7.1.1
Summary of Estimated Inventory of Radionuclides in Post-1942 Sediments in the Mortandad Watershed

Area	Distance From Rio Grande (km)	Americium-241		Cesium-137		Cobalt-60		Plutonium-238		Plutonium-239,240		Strontium-90	
		Inventory (mCi)	Percent of Total Inventory	Inventory (mCi)	Percent of Total Inventory	Inventory (mCi)	Percent of Total Inventory	Inventory (mCi)	Percent of Total Inventory	Inventory (mCi)	Percent of Total Inventory	Inventory (mCi)	Percent of Total Inventory
Effluent Canyon	13.71–14.70	11	3%	23	2%	0.1	3%	3	1%	17	4%	1.7	1%
Mortandad Canyon between Effluent Canyon and Reach M-3E	11.84–13.71	81	19%	340	24%	0.8	29%	55	21%	87	22%	16	10%
Mortandad Canyon Reach M-3E	11.22–11.84	230	55%	732	52%	1.5	52%	85	32%	192	50%	36	23%
Pratt Canyon	12.83–13.12	0.2	0%	10	1%	0	3%	0.0	0%	0.5	0%	62	39%
Ten Site Canyon	11.22–13.75	2.3	1%	2.0	0%	0.0	0%	87	33%	16	4%	5	3%
Mortandad Canyon Reach M-4	10.56–11.22	75	18%	246	17%	0.4	12%	27	10%	57	15%	24	15%
Mortandad Canyon between Reach M-4 and East End of Reach M-5E	8.90–10.56	21	5%	66	5%	0.1	2%	7	3%	18	5%	13	8%
Total	n/a*	420	100%	1420	100%	3	100%	263	100%	387	100%	157	100%

Note: Inventory does not include estimates in reaches where these analytes are not COPCs or for parts of Mortandad Canyon upcanyon of Effluent Canyon or downcanyon of M-5E, or for the unnamed tributary canyon that heads in TA-5

*n/a = Not applicable.

Table 7.2-1
Recent Annual Discharge Volumes for NPDES Outfalls in the Mortandad Watershed

Outfall	Key Facility	Annual Total Discharge (m^3)	
		2004	2005
051	WMO: RLWTF (TA-50, 21)	8170	6796
03A-021	CMR Building (TA-03)	4490	3483
03A-022	Sigma Complex (TA-03)	7461	14,403
03A-160	Nonkey (TA-35)	29,844	29,844
03A-181	Plutonium Facility Complex (TA-55)	10,306	9087
	Sum of Mortandad Outfall Discharges	60,271	63,613

Sources: LANL 2004, 94068; LANL 2005, 94073.

Table 7.2-2
Days with Recorded Flow for Streamflow Gaging Stations in the Mortandad Watershed

Gage	E200	E202	E2015	E203	E204
Period of Record[a]	10/1/1995 8/14/2005	10/1/1996 8/19/2006	11/17/1999 9/30/2005	10/1/1996 9/30/2005	10/1/1993 9/30/2005
Days with Recorded Flow	2798	436	212	0	0
Total Days of Record[b]	3710	3069	1919	3288	4383
% of Days with Recorded Flow	75.4%	14.2%	11.1%	0.0%	0.0%

Source: WQH database.

[a] Water year data are provisional.

[b] Excludes days when equipment malfunction resulted in no record.

Table 7.2-3
Seasonal TA-50 RLWTF Outfall Percentage of E200 Flow

Year	Jan–Mar	Apr–Jun	Jul–Sep	Oct–Dec	Annual Average
1997	109.7%	45.9%	13.2%	83.7%	63.1%
1998	34.5%	Not available[a]	40.0%	27.8%	34.1%
1999	50.6%	35.8%	27.5%	66.4%	45.1%
2000	50.0%	Not available[b]	na[b]	19.6%	34.8%
2001	21.6%	50.2%	14.1%	5.9%	22.9%
2002	6.0%	67.4%	32.5%	36.6%	35.6%
2003	46.9%	45.3%	22.6%	7.6%	30.6%
2004	1.1%	81.9%	27.4%	13.9%	31.1%
2005	5.2%	28.2%	4.7%	47.2%	21.3%
2006	82.6%	21.5%			
Mean	40.8%	47.0%	22.7%	34.3%	35.4%
Median	40.7%	45.6%	25.0%	27.8%	34.1%

[a] E200 gage malfunctioned from 5/23/1998 to 6/3/2000; summary data not valid.

[b] E200 gage malfunctioned from 4/5/2000 to 7/24/2000; summary data not valid.

Table 7.2-4
Average Volumetric Water Content for Mortandad Boreholes by Unit

Borehole	Average 0–6 m (0–20 ft)	Alluvium >6m (>20 ft)	Qbt 2 >6 m (>20 ft)	Qbt 1	Qct	Qbo
MCB-1	16		10	10		
MCB-2	17		24	25		
MCB-5	4	37		19		
R-1	12			21	48	22
MCB-6	10	30		23		
MCI-8	6	12		22	32	24
MCB-7	1	31				
MCOBT-4.4	14	30			36	19
MCB-14	6	28			30	20
MCB-8	14	12			19	
MCB-9	3	29			28	
MCI-6	7	28			16	29
R-15	8			16	36	19
MCB-10	15	24			39	
MCB-11	6	26			55	
MCB-12	10	22			31	
MCOBT-8.5	10	15				21
R-28	6	8				16
MCB-16	7	21				12
MCB-15	5	30		20	17	16
MCI-1			8	17		15
MCI-10				9		9

Notes: Blank cells indicate unit is not present; 0–20 ft average is independent of stratigraphic unit. Qbt 2 is Tshirege Member unit Qbt 2. Qbt 1 is Tshirege Member unit Qbt 1 (includes subunits 1v and 1g). Qct is the Cerro Toledo interval, and Qbo is the Otowi Member of the Bandelier Tuff.

Table 7.2-5
Estimated Nitrate and Perchlorate Masses by Strata Based on earthVision Models

Model Zone	NO_3 (as N, kg)	% NO_3	CLO_4 (kg)	% CLO_4
Unsaturated Alluvium	6379	2.9	10	0.8
Saturated Alluvium	230	0.1	35	2.8
QBT3	0	0.0	0	0.0
QBT2	12	0.0	0	0.0
QBT1V	7986	3.6	8	0.7
QBT1G	41609	18.8	150	12.1
QBTT	1087	0.5	4	0.3
QCT	39667	17.9	171	13.8
QBOF	123370	55.8	839	67.7
QBOG	131	0.1	0	0.0
TPF	41	0.0	0	0.0
TPF2	2	0.0	0	0.0
TPF3	0	0.0	0	0.0
TT	0	0.0	0	0.0
Saturated TB4 (Dense)	57	0.0	1	0.1
Saturated TB4 (Interflow)	325	0.1	20	1.6
Unsaturated TB4 (Dense)	91	0.0	0	0.0
Unsaturated TB4 (Interflow)	2	0.0	0	0.0
Total Porewater	220377	99.7	1,183	95.5
Perched Intermediate	382	0.2	22	1.8
Alluvial Saturation	230	0.1	35	2.8
Grand Total	**220,989**	**100.0**	**1,239**	**100.0**

Table 8.1-1
Field Studies in Mortandad Canyon Watershed As Implemented

Assay Type	Reach	Rationale for Reach Selection Based on HQ
Soil COPECs		
Earthworm toxicity, plant toxicity, sediment characterization	E-1FW	Plant: high chromium, vanadium (+ other inorganic chemicals) Worm: high chromium, high copper
	E-1W	Plant: high chromium, vanadium Worm: high chromium
	E-1E	Plant: high chromium, high silver Worm: high chromium, high mercury, high Am-241, high Pu-239
	TS-1C	Plant: high selenium, vanadium Worm: di-n-butyl phthalate
	TS-2C	Plant: high silver, high vanadium Worm: moderate chromium, moderate mercury
	M-2W	Plant: lower inorganic chemicals Worm: moderate chromium, moderate mercury, high Am-241, Pu-238, and Pu-239 High perchlorate
	M-4	Plant: high silver, lower other inorganic chemicals Worm: lower chromium, lower mercury Moderate perchlorate
	LA-BKG	Background location
General small mammal trapping, sediment characterization	E-1W	Moderate arsenic and manganese
	M-2W	High thallium, Aroclor-1260 for potential risk to Mexican spotted owl High perchlorate
	M-3	Low arsenic, no other small mammal COPECs Low perchlorate
	LA-BKG	Background location
Shrew trapping, sediment characterization	E-1W	100% wet, high arsenic, high thallium
	LA-BKG	Background location
Plant diversity	E-1FW	Correlate to plant toxicity
	E-1W	Correlate to mammal trapping and plant toxicity
	E-1E	Correlate to plant toxicity
	TS-1C	Correlate to plant toxicity
	TS-2C	Correlate to plant toxicity
	M-2W	Correlate to mammal trapping and plant toxicity High perchlorate
	M-3	Correlate to mammal trapping and plant toxicity
	M-4	Correlate to plant toxicity
	LA-BKG	Background location
Additional nest boxes	E-1FW	Robin: moderate copper, vanadium, PCBs Swallow: no COPECs
	E-1W	Robin: high vanadium, lower zinc Swallow: High aluminum, moderate vanadium, lower copper and zinc Kestrel: no COPECs

Table 8.1-1 (continued)

Assay Type	Reach	Rationale for Reach Selection Based on HQ
	E-1E (bench above reach)	Robin: high mercury, moderate copper, lead Swallow: low zinc Kestrel: no COPECs but total hazard index (HI)=2 and Cs-137 HQ=0.8
	TS-1C	Swallow: high vanadium, zinc Kestrel: no COPECs but total HI=1.2 Robin: highest organic HQ (di-n-butyl phthalate)
	M-1E	Robin: high vanadium Swallow: high aluminum and vanadium, lower zinc Kestrel: no COPECs
	M-2W (bench above reach)	Robin: lower lead, mercury, zinc, PCBs Swallow: low zinc Kestrel: no COPECs but total HI=1.2 High perchlorate
	M-2E (bench above reach)	Robin: moderate mercury Swallow: low zinc Kestrel: no COPECs Moderate perchlorate
	TS-1E	Add to existing network in area of higher contamination
Sediment/Water COPECs		
Aquatic Toxicity and rapid bioassessment protocol	E-1W	High barium, PCBs, DDT for aquatic community
	E-1E	No aquatic community COPECs
	M-1W	Chlordane and DDT COPECs for aquatic community
	M-2W	No aquatic community COPECs Low perchlorate
	TS-1C	High PCBs and anthracene for aquatic community
	TS-1E	High PCBs, anthracene, and copper for aquatic community
	TS-2C	High silver for aquatic community Moderate PCBs and dibenz(a,h)anthracene for aquatic community
	LA-BKG	Background location. Collect sediment and water for toxicity testing, not used for rapid bioassessment protocol
Algal toxicity tests	M-1W	Included to collocate with aquatic toxicity tests
	M-2W	sampled at gaging station E200; location with high HQs for algae for radium-226 and americium-241
	E-1W	Just downcanyon from gaging station E196, location with high HQs for algae for radium-226
	E-1E	Upcanyon of high HQ at gaging station E200 for algae for radium-226 and americium-241
	TS-1C	Included to collocate with aquatic toxicity tests
	TS-1E	Included to collocate with aquatic toxicity tests
	TS-2C	Included to collocate with aquatic toxicity tests
	LA-BKG	Background location

Table 8.1-2
Number of Each Species Collected for Analysis in Each Reach in the Mortandad Watershed

Reach	M-3E	M-2W	E-1W	LA-BKG
Deer Mouse (*Peromyscus maniculatus*)	23	10	8	18
Mexican Wood rat (*Neotoma mexicana*)	4	4	2	0
Brush Mouse (*Peromyscus boylii*)	0	17	7	0
Long-tailed Vole (*Microtus longicaudus*)	0	0	1	5
Pinyon Mouse (*Peromyscus truei*)	0	0	0	2
Western Harvest Mouse (*Reithrodontomys megalotis*)	10	0	0	0
Montane Shrew (*Sorex spp*)	0	0	4	6

Table 8.1-3
Samples Collected from Nest Boxes

Reach/Location	Number of Egg Samples	Number of Insect Samples
E-1FW	1	1
TS-1E	0	1
TS-2W	1	1
M-4	2	2
M-4E	1	1
M-4W	1	1
M-5W	9	3
TA-51	1	0
Cañada del Buey	3	1
Guaje Pines Cemetery	7	2
Los Alamos golf course	6	1

Table 8.1-4
Estimate of Risk to Mexican Spotted Owl Through Ingestion of Small Mammals

COPEC	Maximum Detected Concentration in Carcass (mg/kg)	Carcass wt (kg)	Max Concentration in Pelt (mg/kg)	Pelt wt (kg)	Calculated Whole Animal Concentration (mg/kg)	Avian Soil TRV (mg/kg/d)	Owl Food Ingestion Rate (kg/d)	ESL for Food (in mg/kg)	HQ
Mercury (inorganic)	0.02	0.1025	0.07	0.0193	0.03	0.019	0.102	0.186	0.15
Mercury (methyl)*	0.02	0.1025	0.07	0.0193	0.03	0.0064	0.102	0.063	0.45
Selenium	0.58	0.1025	0.83	0.0193	0.62	0.44	0.102	4.31	0.14

*Not analyzed; bounding case of 100% methyl mercury

Table 8.1-5
Estimate of Risk to Southwestern Willow Flycatcher Through Ingestion of Nest Box Insects by Reach

COPEC	Avian sediment TRV (mg COPEC/kg bird/day)	SWF food ingestion rate (kgfresh food/kg bird/d)	Food ESL (in mg/kg or pCi/g)	Detected Concentration in Insect Tissue in E-1FW Nest Boxes (mg/kg fresh insect)	HQ for E-1FW	Detected Concentration in Insect Tissue in TS-1E Nest Boxes (mg/kg fresh insect)	HQ for TS-1E	Mean Detected Concentration in Insect Tissue in M-4 Nest Boxes (mg/kg fresh insect)	HQ for M-4	Mean Detected Concentration in Insect Tissue in M-5W nest boxes (mg/kg fresh insect)	HQ for M-5W	Detected Concentration in Insect Tissue in Cañada del Buey Nest Boxes (mg/kg fresh insect)	HQ for Canada del Buey	Detected Concentration in Insect Tissue in Pueblo Nest Boxes (mg/kg fresh insect)	HQ for Pueblo	Mean Detected Concentration in Insect Tissue in Rendija Nest Boxes (mg/kg fresh insect)	HQ for Rendija
Aluminum	pH dependent	0.79	n/a	51	n/a	250	n/a	118	n/a	141	n/a	130	n/a	70	n/a	145	n/a
Barium	73.5	0.79	93	5.3	0.057	120	1.29	6.4	0.07	6.3	0.07	5.6	0.060	4.3	0.046	17.5	0.188
Cadmium	1.47	0.79	1.9	0.33	0.1774	0.63	0.34	0.11	0.06	0.13	0.07	0.72	0.3871	0.13	0.0699	0.205	0.1102
Copper	2.98	0.79	3.8	41	10.87	70	18.56	35	9.28	12.6	3.34	28	7.42	28	7.42	48	12.73
Mercury (inorganic)	0.019	0.79	0.024	ND*	0.000	ND	0.00	ND	0.00	0.02	0.83	0.02	0.83	0.02	0.83	ND	0.000
Mercury (methyl)	0.0064	0.79	0.01	ND	0.000	ND	0.00	ND	0.00	0.02	2.47	0.02	2.47	0.02	2.47	ND	0.000
Selenium	0.44	0.79	0.6	0.19	0.341	0.31	0.56	0.425	0.76	0.29	0.52	0.13	0.23	0.13	0.233	0.165	0.296
Silver	5.44	0.79	6.9	0.02	0.00291	0.17	0.02	0.071	0.01	0.014	0.0020	0.19	0.02760	0.02	0.00291	0.055	0.00799
Vanadium	0.344	0.79	0.44	ND	0.000	ND	0.00	ND	0.00	0.36	0.83	0.31	0.712	ND	0.000	0.615	1.413
Zinc	37.7	0.79	48	100	2.096	210	4.40	99.65	2.09	73.7	1.54	100	2.096	120	2.515	125	2.620

*ND = Analyte not detected.

Table 8.1-6
Estimate of Risk to the Insectivorous Robin Using Estimated Concentrations of COPECs in Earthworms

COPEC	Basis of Estimated Worm Tissue Concentration	Avian Soil TRV (mg COPEC/ kg bw/day)	Robin Food Ingestion Rate for Regression (kgfresh food/kg bird/d)	Robin Food Ingestion Rate for ESL TF (kg dry food/kg bw/d)	Food ESL (in mg/kg)	Concentration in Soil LA-BKG	HQ for LA-BKG	Concentration in Earthworm Toxicity Test Soil - Reach E-1FW	HQ for E-1FW	Concentration in Earthworm Toxicity Test Soil - Reach E-1W	HQ for E-1W	Concentration in Toxicity Test Soil - Reach E-1E	HQ for E-1E	Concentration in Earthworm Toxicity Test Soil - Reach M-2W	HQ for M-2W	Concentration in Earthworm Toxicity Test Soil - Reach M-4	HQ for M-4	Concentration in Earthworm Toxicity Test Soil - Reach TS-1C	HQ for TS-1C	Concentration in Earthworm Toxicity Test Soil - Reach TS-2C	HQ for TS-2C
Copper	regression	2.98	0.897	na[a]	3.322185	4.2	0.65	90.9	2.80	12.2	0.85	4.2	0.27	12.4	0.86	20	1.05	3.69	0.64	6.94	0.72
Lead	regression	1.63	0.897	na	1.817168	9.6	0.15	27.3	0.97	17.8	0.531	9.56	0.49	11.1	0.22	19	0.59	5.76	-0.028	10.7	0.20
Mercury (inorganic)	regression	0.019	0.897	na	0.021182	0.01	1.200	0.09	2.9	0.04	1.826	0.01	42	0.04	1.8	0.21	5.4	0.008	1.2	0.02	1.4
Mercury (methyl)	regression	0.0064	0.897	na	0.007135	0.01	3.6	0.09	8.5	0.04	5.4	0.01	126	0.04	5.4	0.21	16	0.008	3.4	0.02	4.2
Selenium	ESL TF	0.44	na	0.35	1.257143	ND[b]	0	ND	0	ND	0	0.75	0.28	ND	0	ND	0	ND	0	ND	0
Silver	regression	5.44	0.897	na	6.06466	ND	0	0.15	0.014	0.11	0.013	0.1	0.15	0.11	0.013	0.3	0.019	0.04	0.01	0.78	0.036
Vanadium	ESL TF	0.344	na	0.35	0.982857	11	0.48	30	1.3	20.5	0.88	11.3	0.36	11.9	0.51	19.1	0.82	11.9	0.51	13.3	0.57
Zinc	ESL TF	37.7	na	0.35	107.7143	30	1.1	75	2.6	75	2.6	30	0.003	79.5	2.8	55.9	2.0	45.9	1.6	46.5	1.6
Aroclor-1254	ESL TF	0.1	na	0.35	0.285714	ND	0	0.04	0.95	ND	0	0.0017	1.23	0.0059	0.140	0.01	0.24	0.01	0.24	0.01	0.24

[a] na = Not applicable to model used for this COPEC.

[b] ND = Analyte not detected.

Table 8.1-7
Estimate of Risk to Small Mammals (shrew) from Estimated COPEC Concentrations in Earthworms

COPEC	Basis of Concentration	Maximum Detected Concentration Detected in Earthworm Toxicity Test Soil	Estimated Concentration in Earthworm Tissue (mg/kg fresh wt)	Mammalian Soil TRV (mg COPEC/kg bird/day)	Shrew Food Ingestion Rate (kg fresh food/kg bw/d) or if ESL TF Used (kg dry food/kg bw/d)	Food ESL (in mg/kg or pCi/g)	HQ
Arsenic	ESL TF	5.6	1.32	1.04	0.198	5.3	0.25
Cadmium	Regression	0.66	2.25	0.77	0.508	1.5	1.48
Manganese	Regression	614	30.95	44	0.508	86.6	0.36
Thallium	ESL TF	0.87	0.87	0.0071	0.198	0.036	24
Vanadium	ESL TF	29.7	1.25	4.16	0.198	21.0	0.06
Chrysene	ESL TF	0.62	0.15	0.17	0.198	0.86	0.17

Table 8.1-8
Estimate of Risk to Shrews from Estimated Thallium Concentrations in Earthworms by Reach

Reach	Concentration in Earthworm Tox Test Composite Soil	Estimated Concentration in Earthworm Tissue (mg/kg fresh wt)	Mammalian Soil TRV (mg COPEC/kg bird/day)	Shrew Food Ingestion Rate (kgfresh food/kg bw/d) or if ESL TF Used (kg dry food/kg bw/d)	Food ESL (in mg/kg or pCi/g)	HQ
TS-1C	0.16	0.16	0.0071	0.198	0.036	4
E-1E	0.87	0.87	0.0071	0.198	0.036	24
M-4	0.52	0.52	0.0071	0.198	0.036	15
E-1FW	0.15	0.15	0.0071	0.198	0.036	4
E-1W	0.2	0.20	0.0071	0.198	0.036	6
M-2W	0.14	0.14	0.0071	0.198	0.036	4
TS-2C	0.13	0.13	0.0071	0.198	0.036	4
LA-BKG	0.1	0.10	0.0071	0.198	0.036	3

Table 8.1-9
Plant and Earthworm HQs for Study Design COPECs in Soil from Laboratory Toxicity Tests

		HQ of Soil Sample from Toxicity Test for Receptor at Left							
Plant COPEC	**Plant ESL**	**LA-BKG**	**E-1FW**	**E-1W**	**E-1E**	**M-2W**	**M-4**	**TS-1C**	**TS-2C**
Barium	110	0.39	0.93	1.1	0.81	0.52	1.1	0.26	0.70
Chromium	2.4	2.2	218	8.4	20	3.24	5.7	1.7	2.8
Copper	10	0.42	9.1	1.2	0.03	1.2	2.0	0.37	0.69
Manganese	50	3.1	5.9	11	12	7.5	9.4	5.1	5.5
Selenium	0.1	ND[a]	ND	ND	7.50	ND	ND	ND	ND
Silver	0.05	ND	3.0	2.2	2.0	2.2	6.0	0.80	15.60
Thallium	0.1	1.0	1.5	2.0	8.7	1.4	5.2	1.6	1.3
Vanadium	0.025	440	1200	820	452	476	764	476	532
Zinc	10	3.0	7.5	7.5	3.0	8.0	5.6	4.6	4.7
Acenapthene	0.25	ND	ND	ND	ND	ND	ND	ND	ND
Endrin aldehyde	0.0034	ND	ND	ND	ND	ND	ND	ND	ND
Plant HI		450	1446	853	507	500	799	490	563
Worm COPEC	**Worm ESL**	**LA-BKG**	**E-1FW**	**E-1W**	**E-1E**	**M-2W**	**M-4**	**TS-1C**	**TS-2C**
Chromium	2.3	2.3	228	8.78	21	3.4	6.0	1.8	2.9
Copper	13	0.32	7.0	0.94	0.021	0.95	1.5	0.28	0.53
Mercury	0.05	0.20	1.8	0.80	0.20	0.80	4.2	0.16	0.40
Amercium-241	44	NA[b]	ND	0.01	0.73	NA	0.23	0.00	0.01
Plutonium-238	44	ND	ND	ND	0.48	0.14	0.43	0.13	0.03
Plutonium-239	47	ND	0.0011	0.01	1.8	0.20	0.29	0.02	0.01
Worm HI		2.8	237	11	25	5.5	13	2.4	3.9

[a] ND = Not detected.

[b] NA = Not analyzed.

Table 8.1-10
Summary of Field Plant Survey Results

Reach	Approximate Distance Above Rio Grande (km)	Total Species Richness	Shannon Diversity Index (All Species)	Total Percent Canopy Cover
LA-BKG	19.5	55	3.19	235.25
E-1E	13.8	21	2.23	124.25
E-1FW	14.3	32	2.52	190.75
E-1W	14.0	18	2.15	247.25
M-2W	13.4	16	2.27	208.25
M-3	11.5	35	2.10	194.25
M-4	10.9	45	2.32	155.50
TS-1C	13.5	56	2.61	177.75
TS-2C	12.6	43	2.57	147.75

Table 8.1-11
Detected Radionuclide Concentrations in Algal Toxicity Test Samples

Reach	Sample ID	Radionuclide	Result (pCi/L)	HQ Based on Algae ESL
TS-1C	CAMO-05-61178	Americium-241	0.2	0.03
M-2W	CAMO-05-61170	Americium-241	1.88	0.32
E-1E	CAMO-05-61174	Americium-241	5.29	0.91
M-1W	CAMO-05-61176	Radium-226	0.43	4.3

Table 8.1-12
Estimate Risk to the Occult Myotis Little Brown Bat
from Ingestion of COPECs in the Tissues of Insects Collected from Nest Boxes

COPEC	Maximum Detected Concentration in Insect Tissue in Nest Box (mg/kg fresh insect)	Mammalian Sediment TRV (mg COPEC/kg bw/day)	Bat Food Ingestion Rate (kgfresh food/kg bird/d)	Food ESL (in mg/kg or pCi/g)	HQ
Aluminum	250	pH dependent	0.410	n/a*	n/a
Arsenic	1.4	1.04	0.410	3	0.55

*n/a = Not applicable.

Table 8.1-13
Estimate of Risk to the Red Fox from Ingestion of COPECs in the Tissues of Small Mammals

COPEC	Measured Whole Animal Concentration	Mammalian TRV (mg/kg/d)	Fox Food Ingestion Rate (kg food fresh weight/kg bird/d)	ESL (in mg/kg)	HQ
Aroclor-1260	0.32	13.8	0.14	98	0.003

Table 8.1-14
Lines of Evidence and Rationale for the Mexican Spotted Owl (AE1)

Line of Evidence	Weight of Evidence Criteria	Result
(1) Modeled exposure and literature toxicity information to calculate spatially weighted HQ values using ECORSK.9 (includes consideration of nesting and foraging habitat based on vegetation class coverage)	Medium	Total mean adjusted HI across watershed for owl equals 1.6, indicating a slight potential fro risk (mostly associated with non-canyons contaminants). Mean adjusted HI for reach with known owl nest is 0.2, indicating no potential for risk to owl.
(2) Modeled and measured concentrations in prey species (small mammals)—compare prey COPEC concentrations across gradient and determine division of contaminants between carcass and pelt	Medium	Dose of COPEC ingested had HQ<1.0 for all COPECs when compared to TRV, indicating that the risk through food ingestion was much lower than that predicted by the ESL screening.
(3) Analysis of owl pellets	Low	Results of pellet analysis confirmed that the small mammal prey species captured and used for tissue analysis are the species consumed by the owl, supporting the use of these species in the food chain modeling
(4) Comparison of concentrations in 2005 sediment samples to ESLs	Low	Screening of 2005 sediment data against ESLs resulted in addtion of bis (2ethylhexyl) phthalate as a new COPEC for this receptor

Table 8.1-15
Lines of Evidence and Rationale for Avian and Mammalian Aerial Insectivores (AE6)

Line of Evidence	Weight of Evidence Criteria	Result	Aerial Insectivore Receptors
(1) Nest box study—determine nest success rate by bluebirds along a gradient of COPEC concentrations in the Mortandad Canyon watershed; need to account for other factors known to influence nest success (food, predators, etc.)	Medium (new boxes) High (established boxes)	Percent fledged and percent female nestlings were not different between Mortandad watershed reaches or between Mortandad watershed and other canyons, indicating no effect on population (measured as nest success)	Southwestern willow flycatcher/Violet-green swallow
(2) Nest box study—determine eggshell thickness for bluebirds along a gradient of COPEC concentrations in Mortandad, Effluent, and Ten Site Canyons; need to account for other factors known to influence eggshell thickness (amount of calcium in diet, etc.)	Medium	Egg size (length and weight), and eggshell thickness were not different between Mortandad reaches or between Mortandad and other canyons, indicating no effect on nest success	Southwestern willow flycatcher/Violet-green swallow
(3) Nest box study—compare COPEC concentrations in eggs within Mortandad Canyon watershed and also compare concentrations with “reference” locations	Medium-low	Concentrations of metals in eggs did not correlate with concentrations of metals in soil, indicating soil is not a source of bioaccumulation into eggs	Southwestern willow flycatcher/Violet-green swallow
(4) Compare the measured concentrations of COPECs in insects with the TRV	Medium	Potential dose through food to Southwestern willow flycatcher and little myotis bat modeled based on measured COPEC concentrations in nest box insects. Copper, mercury, vanadium, and zinc had 1.0<HQ<10 for flycatcher using mean concentrations. Bat had no COPECs with HQ>1.0 using maximum detected concentrations.	Southwestern willow flycatcher/Violet-green swallow Occult little myotis bat
(5) Comparison of concentrations in 2005 sediment and water samples to ESLs	Low	Only new COPEC to swallow or flycatcher from screening of 2005 sediment samples is bis (2 ethylhexyl) phthalate. No new COPECs for bat. Some existing study design COPECs are now COPECs in additional reaches	Southwestern willow flycatcher/Violet-green swallow Occult little myotis bat
(6) Modeled exposure and literature toxicity information to calculate spatially weighted HQ values using ECORSK.9 (includes consideration of nesting and foraging habitat based on vegetation class coverage)—could be based on a frequency of HQ values greater than 1 for the watershed	Medium	The mean adjusted total HI for the SWF was 6.2, based on mercury, di-n-butyl phthalate, boron, and bis (2ethylhexyl) phthtalate. These values indicate a potential for risk to the flycatcher.	Southwestern willow flycatcher

Table 8.1-16
Lines of Evidence and Rationale for Avian Ground Invertevores (AE2)

Line of Evidence	Weight of Evidence Criteria	Result
(1) Nest box Study-Compare the measured concentrations of COPECs in insects with the TRV for the robin with the invertevore diet	Medium	Substituted calculations with earthworms for this measure
(2) Nest box study—determine nest success rate by bluebirds along a gradient of COPEC concentrations in the Mortandad Canyon watershed; need to account for other factors known to influence nest success (food, predators, etc.)	Medium (new boxes) High (established boxes)	Percent fledged and percent female nestlings were not different between Mortandad watershed reaches or between Mortandad watershed and other canyons, indicating no effect on population (measured as nest success)
(3) Nest box study—determine eggshell thickness for bluebirds along a gradient of COPEC concentrations in Mortandad, Effluent, and Ten Site Canyons; need to account for other factors known to influence eggshell thickness (amount of calcium in diet, etc.)	Medium	Egg size (length and weight), and eggshell thickness were not different between Mortandad watershed reaches or between Mortandad watershed and other canyons, indicating no effect on nest success
(4) Nest box study—compare COPEC concentrations in eggs within Mortandad Canyon watershed and also compare concentrations with "reference" locations	Medium-low	Concentrations of metals in eggs did not correlate with concentrations of metals in soil, indicating soil is not a source of bioaccumulation into eggs
(5) Modeled and measured concentrations in food (earthworm bioaccumulation test)—determine if exposure concentrations differ within the watershed in relation to sediment concentrations; design used a gradient in COPEC concentrations with the Mortandad Canyon watershed and also compared concentrations with "reference" locations	Medium	HQs based on modeled doses from estimated concentrations in earthworms indicated that some COPECs (mercury, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, and Aroclor-1254) may have potential for ecological risk to avian ground invertevores
(6) Modeled exposure and literature toxicity information to calculate spatially weighted HQ values using ECORSK.9 (includes consideration of nesting and foraging habitat based on vegetation class coverage) for bluebird populations in the watershed; will be based on a frequency of HQ values greater than 1 for the watershed (or assessment population area)	Medium	Western bluebird served as a surrogate for the robin representing avian invertevores in the model. The mean adjusted total HI for the bluebird is 1.2, too low for population level effects.
(7) Field surveys of avian ground invertevore abundance and diversity in the Mortandad Canyon watershed; and also compare abundance/diversity with "reference" locations	Low	Field surveys of Upper Mortandad and Ten Site Canyon had similar diversity indices and most species in both areas were invertevores, no population level effects seen
(8) Comparison of concentrations in 2005 sediment samples to ESLs	Low	Only new COPEC from screening of 2005 sediment samples is bis(2-ethylhexyl)phthalate. Some existing study design COPECs are now COPECs in additional reaches.

Table 8.1-17
Lines of Evidence and Rationale for Mammalian Invertevores and Omnivores (AE3)

Line of Evidence	Weight of Evidence Criteria	Result
(1) Field surveys to determine small mammal reproduction status along gradient of COPEC concentrations in the Mortandad Canyon watershed and also compare reproduction rates with "reference" locations	Medium high	No differences seen in relative population abundance, gender, or body weight between reaches
(2) Modeled and measured concentrations in food (earthworms)—could determine if exposure concentrations differ within the watershed in relation to sediment concentrations; design could use a gradient in COPEC concentrations with the Mortandad Canyon watershed and also compare concentrations with "reference" location	Medium	Modeling of potential risk through food to the shrew or mouse using estimated concentrations in earthworms showed only thallium with an HQ elevated enough to indicate potential for population-level effects. Thallium has a very low TRV and high default TF in model
(3) Modeled exposure and literature toxicity information to calculate spatially weighted HQ values using ECORSK.9 (includes consideration of nesting and foraging habitat based on vegetation class coverage) for deer mouse and shrew populations in the watershed—could be based on a frequency of HQ values greater than 1 for the watershed	Medium	Mean HI exceeded 1 in only 8% of sites across watershed. Dominant COPEC in this model is also thallium
(4) Comparison of concentrations in 2005 sediment samples to ESLs	Low	Screening of 2005 sediment sample data did not show any new COPECs for these receptors

Table 8.1-18
Lines of Evidence and Rationale for Detritivores (AE4)

Line of Evidence	Weight of Evidence Criteria	Result
(1) Toxicity test (earthworm mortality) along gradient of COPEC concentrations in the Los Alamos and Pueblo watershed—compare mortality rates with "reference" locations	High	No differences in earthworm mortality seen between reaches, indicating no effect along COPEC gradient. Weight loss differed between reaches, but did not correlate with COPEC concentration.
(2) The concentration of COPECs in earthworms	Contributor to other AEs	Not measured due to laboratory error
(3) Comparison of concentrations in 2005 sediment samples to ESLs	Low	Screening of 2005 sediment data indicates that hexavalent chromium would be a study design COPEC for this receptor. Existing studies included reaches with this COPEC.

Table 8.1-19
Lines of Evidence and Rationale for Plants (AE5)

Line of Evidence	Weight of Evidence Criteria	Result
1) Toxicity test (seedling germination) along gradient of COPEC concentrations in the Los Alamos and Pueblo watershed and also compare germination rates with "reference" locations	High	No differences in mortality, dry root mass, dry shoot mass, or mean root length. Some differences in wet root length and mean shoot length between reaches, but effect did not match with COPEC concentration
2) Abundance and diversity of plants along gradient of COPEC concentrations in the Mortandad watershed and also compare plant abundance/diversity with "reference" locations	Medium	Plant survey showed differences between reaches, but not attributable to COPEC gradient. Differences attributable to climate factors, and species in all reaches increased since previous survey during dry year.
(3) Comparison of concentrations in 2005 sediment samples to ESLs	Low	Screening of 2005 sediment data indicates that hexavalent chromium would be a study design COPEC for this receptor. Existing studies included reaches with this COPEC.

Table 8.1-20
Lines of Evidence and Rationale for the Aquatic Community (AE7)

Line of Evidence	Weight of Evidence Criteria	Result
(1) Estimates of growth and mortality of aquatic invertebrates based on toxicity tests using *Chironomus tentans* compared with the reference location	High	No significant differences in larval survival or mean dry weight of larvae between reaches, indicating no effect of COPECs on larval survival and growth.
(2) A rapid bioassessment characterization to evaluate habitat ratings at selected locations based on watershed features, riparian vegetation, in-stream features, aquatic vegetation, and benthic substrate; assessment will also include measures of abundance and diversity of aquatic invertebrates through Hess sampling and dip net capture	Medium	Physical aspects of habitat similar between reaches; all rated as marginal using index scores. Chironomids made up majority of biomass in all reaches, supporting their use as toxicity indicator organism.
(3) Comparison of concentrations in 2005 sediment and water samples to ESLs	Low	Screening of 2005 sediment data indicated iron should be a new COPEC for this receptor. Screening of water data also indicated iron should be a new COPEC, and cobalt would be a COPEC at one water location
(4) Algae toxicity test	High	Differences seen between water samples from different reaches attributable to differences in water hardness. Algal cell growth in all samples except TS-1C exceeded negative and positive laboratory control sample growth. Results indicate no impairment of algal cell growth due to COPECs in water.

Table 8.2-1
Identifying Sediment COPCs, Non-carcinogens

Reach	Aluminum	Antimony	Barium	Beryllium	Boron	Cadmium	Chromium hexavalent ion	Cobalt	Copper	Cyanide (Total)	Fluoride	Iron	Lead	Manganese	Mercury[a]	Nickel	Nitrate	Nitrite	Perchlorate[a]	Selenium	Silver	Thallium	Uranium[b]	Vanadium	Zinc	Acenaphthene	Acetone	Anthracene	Aroclor-1254	Aroclor-1260	Benzo(g,h,i)perylene[c]	Benzoic Acid[a]	Bromomethane	Butanone[2-]
Residential SSL	**77800**	**31.3**	**15600**	**156**	**15600**	**39**	**234**	**1520**	**3130**	**1220**	**3670**	**23500**	**400**	**3590**	**23**	**1560**	**100000**	**7820**	**55**	**391**	**391**	**5.16**	**16**	**78.2**	**23500**	**3730**	**28100**	**22000**	**1.12**	**1.12**	**2290**	**100000**	**8.51**	**31800**
M-1W	-	0.35	-	-	-	0.02	-	-	<0.01	<0.01	-	-	0.06	-	<0.01	0.02	-	-	-	<0.01	<0.01	-	-	-	<0.01	<0.01	<0.01	<0.01	-	0.05	<0.01	-	-	-
M-1C	-	-	<0.01	-	-	-	-	-	-	-	-	-	0.06	-	-	-	-	-	-	<0.01	-	-	-	-	<0.01	<0.01	<0.01	<0.01	-	0.13	<0.01	-	-	<0.01
M-1E	**0.33**	-	0.02	<0.01	<0.01	0.02	-	<0.01	<0.01	-	-	**0.89**	0.08	**0.46**	<0.01	<0.01	-	-	-	0.03	<0.01	-	-	**0.47**	<0.01	-	<0.01	-	-	-	-	-	-	<0.01
E-1FW	**0.27**	-	0.01	-	-	0.02	<0.01	<0.01	**0.12**	-	<0.01	**0.78**	**0.14**	**0.29**	<0.01	<0.01	-	-	<0.01	0.03	-	-	-	**0.68**	<0.01	<0.01	<0.01	<0.01	**0.14**	0.03	<0.01	-	<0.01	<0.01
E-1W	**0.24**	0.05	0.02	0.02	-	0.04	-	<0.01	<0.01	<0.01	<0.01	**1.06**	0.09	**0.70**	0.01	<0.01	-	-	-	0.01	0.01	-	**0.27**	**0.38**	<0.01	-	-	-	-	0.02	<0.01	-	-	-
E-1E	-	-	<0.01	-	-	0.06	-	<0.01	0.04	-	<0.01	-	**0.13**	**0.47**	**0.12**	0.03	-	-	<0.01	<0.01	<0.01	**0.31**	**0.26**	-	<0.01	-	<0.01	<0.01	**0.12**	0.10	<0.01	<0.01	-	<0.01
M-2W	-	**0.42**	<0.01	-	-	0.02	-	-	0.02	-	0.02	**0.60**	**0.15**	-	0.03	-	-	-	0.02	<0.01	<0.01	**0.16**	-	-	<0.01	-	<0.01	<0.01	**0.13**	**0.19**	<0.01	<0.01	-	<0.01
M-2E	-	-	-	-	-	0.01	-	-	0.01	-	<0.01	-	-	-	0.05	-	-	-	<0.01	<0.01	<0.01	-	-	-	<0.01	<0.01	<0.01	<0.01	0.04	0.04	-	-	-	-
M-3	-	-	-	-	-	0.01	-	-	<0.01	-	<0.01	0.59	-	-	0.02	-	-	-	<0.01	<0.01	-	-	-	-	<0.01	-	<0.01	-	-	0.35	-	-	-	-
TS-1W	-	**0.36**	<0.01	-	-	0.03	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	**0.19**	-	**0.29**	-	<0.01	<0.01	<0.01	**0.51**	**1.22**	<0.01	<0.01	-	-
TS-1C	-	**0.36**	<0.01	-	-	0.04	-	<0.01	<0.01	-	-	**1.23**	0.10	-	-	0.04	-	-	-	<0.01	<0.01	**0.19**	-	**0.33**	<0.01	<0.01	<0.01	<0.01	<0.01	**1.16**	<0.01	<0.01	-	<0.01
TS-1E	-	-	-	-	-	0.02	-	<0.01	0.04	-	-	-	0.06	0.18	-	-	-	-	-	<0.01	-	-	-	-	-	<0.01	<0.01	<0.01	0.03	0.17	<0.01	-	-	<0.01
TS-2W	-	-	-	-	-	0.02	-	-	<0.01	-	<0.01	-	-	-	-	<0.01	<0.01	-	<0.01	-	-	-	-	-	-	-	-	<0.01	-	0.09	<0.01	-	-	<0.01
TS-2C	-	-	-	-	-	0.02	-	-	0.02	-	<0.01	-	0.07	-	0.04	-	<0.01	<0.01	-	<0.01	0.11	-	-	0.28	<0.01	-	<0.01	<0.01	0.05	0.14	<0.01	-	-	<0.01
TS-2E	**0.21**	-	-	-	-	0.02	-	<0.01	0.02	-	<0.01	**0.59**	0.07	-	0.06	-	<0.01	<0.01	-	0.03	0.09	-	-	**0.35**	<0.01	-	<0.01	-	-	**0.28**	<0.01	-	-	<0.01
TS-3	-	-	-	-	-	0.01	-	-	<0.01	-	-	-	0.05	0.16	<0.01	-	-	-	-	<0.01	0.01	-	-	-	<0.01	-	-	-	-	0.06	-	<0.01	-	-
M-4	-	0.06	<0.01	-	-	0.02	-	<0.01	0.01	-	<0.01	0.64	0.06	-	0.01	-	-	-	0.01	<0.01	0.02	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	<0.01	<0.01	-	<0.01
MCW-1	-	-	-	-	-	0.01	-	-	-	-	-	-	0.05	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MCW-2N	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	<0.01	-	-	-	-	-	<0.01	-	-
MCW-2W	-	-	-	-	-	0.01	-	-	<0.01	<0.01	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MCW-2E	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M-5W	-	-	<0.01	-	-	-	-	-	-	-	-	0.60	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	<0.01	-	-	-	-	-	-	<0.01
M-5E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	0.19	-	-	-	<0.01	<0.01	-	-	-	-	-	-	<0.01
M-6	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 8.2-1 (continued)

Reach	Butylbenzylphthalate[a,d]	Chlorophenol[2-]	Dibenzofuran	Dichlorobenzene[1,2-][d]	Dichloroethene[1,1-]	Dichloroethene[cis-1,2-]	Diethylphthalate	Di-n-butylphthalate	Endosulfan Sulfate	Endrin Aldehyde	Fluoranthene	Fluorene	Hexachlorobutadiene	Hexanone[2-]	Isopropylbenzene	Isopropyltoluene[4-][c]	Methoxychlor[4,4'-][a]	Methyl-2-pentanone[4-]	Methylnaphthalene[2-][c]	Naphthalene[a]	Nitroaniline[2-][a]	Nitroaniline[4-][a]	Nitrophenol[2-]	Phenanthrene	Pyrene	Toluene[d]	Trichloroethane[1,1,1-][d]	Trichlorofluoromethane	Trichlorophenol[2,4,6-]	Trimethylbenzene[1,2,4-]	Xylene (Total)[d]	Xylene[1,2-][d]	Xylene[1,3-][d]	SOFnc
Residential SSL	**240**	**166**	**142**	**37.4**	**206**	**76.5**	**48900**	**6110**	**18.3**	**18.3**	**2290**	**2660**	**12.2**	**31800**	**271**	**271**	**306**	**5510**	**79.5**	**79.5**	**180**	**180**	**166**	**1830**	**2290**	**252**	**563**	**588**	**6.11**	**58**	**82**	**99.5**	**82**	
M-1W	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	-	-	-	-	<0.01	-	-	-	-	-	-	<0.01	<0.01	-	-	-	-	-	-	-	-	0.55
M-1C	-	-	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	0.01	-	-	-	<0.01	<0.01	-	-	-	-	-	-	-	-	0.21
M-1E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	**2.34**
E-1FW	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	-	-	<0.01	<0.01	-	<0.01	<0.01	0.02	-	-	-	<0.01	<0.01	<0.01	-	-	-	-	<0.01	-	-	**2.58**
E-1W	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	-	-	-	-	-	-	-	-	**2.96**
E-1E	-	-	-	-	-	-	-	-	-	<0.01	<0.01	-	-	-	-	<0.01	-	-	-	-	-	-	-	<0.01	<0.01	-	-	<0.01	-	-	-	-	-	**1.66**
M-2W	-	-	-	-	-	-	-	-	-	<0.01	<0.01	-	-	-	-	<0.01	-	-	-	-	-	-	-	<0.01	<0.01	-	-	<0.01	-	-	-	-	-	**1.76**
M-2E	-	-	-	-	-	-	-	-	<0.01	-	<0.01	<0.01	-	-	-	-	<0.01	-	-	<0.01	-	-	-	<0.01	<0.01	-	<0.01	<0.01	-	-	-	-	-	0.18
M-3	-	-	-	-	-	-	-	-	-	<0.01	<0.01	-	-	-	-	<0.01	-	-	-	-	-	-	-	<0.01	-	<0.01	-	-	-	-	-	-	-	0.99
TS-1W	-	-	-	-	-	-	-	<0.01	-	-	<0.01	-	-	<0.01	-	<0.01	-	-	-	-	<0.01	<0.01	-	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	**2.63**
TS-1C	<0.01	-	<0.01	-	-	-	<0.01	<0.01	-	-	<0.01	<0.01	-	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	-	-	-	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	**3.50**
TS-1E	-	-	<0.01	-	-	-	-	-	-	-	<0.01	-	-	-	-	<0.01	-	-	<0.01	-	-	-	-	<0.01	<0.01	<0.01	<0.01	-	-	<0.01	-	-	-	0.51
TS-2W	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	-	<0.01	-	-	<0.01	-	-	-	0.12
TS-2C	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	<0.01	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	<0.01	-	-	<0.01	-	-	-	0.74
TS-2E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	<0.01	-	<0.01	-	-	-	-	-	**1.71**
TS-3	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	0.32
M-4	-	-	-	-	-	<0.01	-	-	-	-	<0.01	<0.01	-	-	-	-	-	-	-	<0.01	-	-	-	<0.01	<0.01	<0.01	-	<0.01	-	<0.01	-	<0.01	<0.01	0.97
MCW-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07
MCW-2N	-	<0.01	<0.01	-	-	-	-	<0.01	-	-	-	<0.01	<0.01	-	-	<0.01	-	-	<0.01	-	-	-	<0.01	-	-	-	-	-	<0.01	-	-	-	-	0.03
MCW-2W	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
MCW-2E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	0.01
M-5W	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	0.61
M-5E	-	-	-	<0.01	<0.01	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	<0.01	-	-	-	0.20
M-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01

Notes: Residential SSL values are in mg/kg. Ratios in bold and gray shading show where the SOFnc>1 and the ratio is >0.1.

[a] EPA Region 6 residential SSL (EPA 2005, 91002).

[b] EPA Region 9 residential SSL (epa.gov/region09/waste/sfund/prg/files/04prgtable.pdf).

[c] Pyrene used as surrogate for benzo(g,h,i)perylene. Isopropyltoluene uses isopropylbenzene SSL as surrogate and 2-methylnaphthalene uses naphthalene as surrogate.

[d] Screening value is based on saturation, not risk based.

Table 8.2-2
Identifying Sediment COPCs, Carcinogens

Reach	Arsenic	Chromium*	Aroclor-1254	Aroclor-1260	Aroclors (Mixed)*	Benzene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	BHC[alpha-]	BHC[beta-]	BHC[gamma-]	Bis(2-ethylhexyl)phthalate	Bromodichloromethane	Carbazole*	Carbon Tetrachloride	Chloroform	Chloromethane	Chrysene	DDD[4,4'-]	DDE[4,4'-]	DDT[4,4'-]	Dibenz(a,h)anthracene	Dichlorobenzene[1,4-]	Dichlorobenzidine[3,3'-]	Dieldrin	Heptachlor Epoxide*	Hexachlorobenzene	Indeno(1,2,3-cd)pyrene	Methylene Chloride	Nitrosodiphenylamine[N-]	Tetrachloroethene	Trichloroethene	SOFca
Residential SSL	**3.9**	**2100**	**2.22**	**2.22**	**2.22**	**10.3**	**6.21**	**0.62**	**6.21**	**62.1**	**0.9**	**3.16**	**4.37**	**347**	**14.4**	**240**	**0.97**	**4**	**21.8**	**615**	**24.4**	**17.2**	**17.2**	**0.62**	**39.5**	**10.8**	**0.3**	**0.53**	**3.04**	**6.21**	**182**	**993**	**12.5**	**0.64**	
M-1W	**1.13**	-	-	0.03	-	-	**0.44**	**3.40**	**0.40**	<0.01	0.01	<0.01	<0.01	-	-	-	-	-	-	<0.01	<0.01	-	<0.01	-	-	-	0.01	-	-	**0.20**	-	-	<0.01	-	**5.62**
M-1C	-	<0.01	-	0.06	-	-	0.06	0.72	0.05	<0.01	0.02	<0.01	<0.01	-	-	-	-	-	-	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-	0.04	-	-	<0.01	-	0.97
M-1E	**2.15**	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	<0.01	**2.16**
E-1FW	**4.26**	**1.05**	0.07	0.01	-	-	0.07	**0.81**	0.08	<0.01	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	0.05	-	-	<0.01	-	**6.41**
E-1W	**2.82**	**0.30**	-	<0.01	-	-	0.04	**0.42**	0.08	-	-	-	-	<0.01	-	-	-	-	-	<0.01	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	**3.67**
E-1E	**1.56**	0.07	0.06	0.05	0.02	-	0.02	**0.40**	0.07	<0.01	<0.01	-	-	<0.01	-	-	-	<0.01	-	<0.01	-	<0.01	<0.01	-	-	-	-	<0.01	-	0.02	-	-	-	-	**2.29**
M-2W	**1.10**	0.01	0.07	0.09	-	-	0.06	**0.60**	0.06	<0.01	-	-	-	<0.01	-	-	-	-	-	<0.01	-	-	<0.01	-	-	-	-	-	-	<0.01	-	-	-	-	**2.01**
M-2E	-	<0.01	0.02	0.02	-	-	0.04	0.26	0.02	<0.01	-	<0.01	-	<0.01	-	-	-	-	-	<0.01	-	-	<0.01	-	-	-	0.01	-	-	-	-	-	-	-	0.38
M-3	**1.03**	<0.01	-	**0.18**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	<0.01	-	-	-	**1.21**
TS-1W	-	-	**0.26**	**0.62**	**0.68**	-	0.07	**1.08**	**0.14**	<0.01	-	-	-	<0.01	-	-	<0.01	-	-	<0.01	-	-	-	-	-	-	-	-	-	0.04	<0.01	-	-	-	**2.89**
TS-1C	-	-	<0.01	**0.59**	-	<0.01	**0.30**	**3.29**	**0.41**	0.02	-	-	-	<0.01	-	-	-	-	-	<0.01	-	-	-	**0.29**	-	-	-	-	-	**0.23**	-	-	-	<0.01	**5.13**
TS-1E	-	-	0.01	0.09	-	-	**0.12**	**1.37**	**0.26**	<0.01	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	0.08	-	-	<0.01	<0.01	**1.93**
TS-2W	-	-	-	0.05	-	-	0.05	0.61	0.06	<0.01	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	0.05	-	-	<0.01	<0.01	0.82
TS-2C	-	0.01	0.03	0.07	-	-	0.02	0.27	0.06	-	-	-	-	<0.01	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	0.02	-	-	<0.01	<0.01	0.48
TS-2E	**1.14**	0.01	-	**0.14**	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1.29**
TS-3	-	-	-	0.03	-	-	<0.01	0.13	0.01	<0.01	<0.01	-	-	<0.01	-	-	-	-	-	<0.01	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	0.19
M-4	**1.18**	<0.01	<0.01	0.05	-	-	0.09	**0.95**	0.10	<0.01	-	-	-	<0.01	<0.01	<0.01	-	-	<0.01	<0.01	-	-	<0.01	-	-	0.06	-	-	-	0.05	<0.01	-	<0.01	-	**2.50**
MCW-1	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
MCW-2N	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	0.00
MCW-2W	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.00
MCW-2E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
M-5W	-	-	-	-	-	-	-	-	-	-	0.04	<0.01	<0.01	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	-	-	-	-	-	-	-	<0.01	-	<0.01	<0.01	0.06
M-5E	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	<0.01	0.02	0.02
M-6	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00

Notes: Residential SSL values are in mg/kg. Ratios in bold and gray shading show where the SOFnc>1 and the ratio is >0.1.
*EPA Region 6 residential SSL (EPA 2005, 91002), multiplied by 10 to account for target risk level of 1E-5.

Table 8.2-3
Identifying Sediment COPCs, Radionuclides

Reach	Americium-241	Cesium-134	Cesium-137	Cobalt-60	Europium-152	Plutonium-238	Plutonium-239	Ruthenium-106	Sodium-22	Strontium-90	Thorium-228	Thorium-230	Thorium-232	Tritium	Uranium-234	Uranium-235	Uranium-238	SOFrad
Residential SAL*	**30**	**2.4**	**5.6**	**1.3**	**2.9**	**37**	**33**	**20**	**1.6**	**5.7**	**2.3**	**5**	**5**	**750**	**170**	**17**	**86**	
M-1W	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	<0.01	-	-	-	<0.01
M-1C	0.03	0.03	-	-	-	<0.01	-	-	-	-	-	-	0.7	-	-	-	-	0.76
M-1E	<0.01	-	-	-	-	<0.01	0.16	-	-	-	-	-	-	-	-	-	-	0.17
E-1FW	-	0.03	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	0.04
E-1W	0.01	-	**0.38**	-	-	0.01	**0.91**	-	-	-	-	-	-	-	-	-	0.03	**1.35**
E-1E	**21.4**	0.08	**452**	**4.02**	-	**2.4**	**41.2**	-	**0.31**	**47.9**	-	-	-	**0.14**	0.09	0.04	0.08	**569**
M-2W	**17.5**	0.1	**155**	**1.88**	-	**5.49**	**18.1**	-	0.09	**6.3**	-	-	-	0.01	0.09	0.05	**0.12**	**205**
M-2E	**7.03**	0.05	**99.5**	**0.38**	-	**3.05**	**4.76**	-	-	**3.51**	-	-	-	<0.01	-	-	-	**118**
M-3	**7.43**	0.07	**53.2**	**1.13**	-	**1.11**	**3.73**	0.04	-	**1.51**	-	-	-	<0.01	-	0.03	-	**68.3**
TS-1W	**0.14**	0.03	**0.64**	**0.99**	-	**1.83**	**0.59**	-	-	**0.55**	-	-	-	<0.01	0.02	-	0.04	**4.82**
TS-1C	0.08	-	**0.57**	-	-	**8.49**	**1.07**	-	-	-	**6.61**	**5.7**	**2.71**	<0.01	-	0.01	0.03	**25.3**
TS-1E	-	-	-	-	-	**9.14**	**1.15**	-	-	-	-	-	-	-	-	-	-	**10.3**
TS-2W	0.02	0.03	-	-	-	0.06	0.02	-	-	**1.18**	-	-	-	<0.01	-	-	-	**1.30**
TS-2C	0.01	0.04	-	-	-	0.05	0.03	-	-	**0.98**	-	-	-	<0.01	-	0.01	-	**1.13**
TS-2E	-	0.03	-	-	-	0.04	**0.16**	-	-	**1.46**	-	-	-	-	-	-	0.03	**1.71**
TS-3	-	-	0.22	-	-	0.04	0.02	-	-	0.54	-	-	-	<0.01	-	-	-	0.83
M-4	**3.73**	0.08	**49.3**	**0.34**	**0.12**	**0.87**	**1.95**	-	-	**1.69**	-	-	-	<0.01	-	0.02	-	**58.1**
MCW-1	-	-	-	-	-	-	<0.01	-	-	-	-	0.49	-	-	-	-	-	<0.01
MCW-2N	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	<0.01
M-5W	-	-	0.16	-	-	-	<0.01	-	-	0.29	-	-	-	-	-	0.01	-	0.48
M-5E	-	0.04	0.17	-	-	<0.01	<0.01	-	-	-	-	-	-	-	-	0.02	-	0.23

Note: Ratios in bold and gray shading show where the SOFrad>1 and the ratio is >0.1.
*LANL (2005, 88493).

Table 8.2-4
Identifying Surface Water COPCs, Non-carcinogens

Location ID	Reach	Media Code	Field Preparation	Aluminum	Antimony	Barium	Beryllium	Boron	Cadmium	Cobalt	Copper	Cyanide (Total)	Fluoride	Iron	Lead[a]	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium	Thallium	Vanadium	Zinc	Perchlorate	Uranium[b]	Acetone	Butanone[2-]	Methyl-2-pentanone[4-]	Pyrene	Benzoic Acid	SOFnc
Tap Water Screening Level				**36500**	**14.6**	**7300**	**73**	**7300**	**18.3**	**730**	**1460**	**730**	**2190**	**11000**	**15**	**5110**	**11**	**183**	**730**	**183**	**183**	**21900**	**2.41**	**36.5**	**11000**	**25.6**	**7.3**	**5480**	**7060**	**1990**	**183**	**146000**	
MO-24786	east of E-1FW	WS	Filtered	<0.01	-	0.03	-	<0.01	<0.01	0.02	0.02	<0.01	0.04	**0.52**	0.07	**0.16**	<0.01	**0.48**	0.02	<0.01	-	-	<0.01	**0.25**	0.05	**0.11**	<0.01	-	-	-	-	-	**1.80**
MO-24786	east of E-1FW	WS	Unfiltered	0.03	-	0.03	-	<0.01	<0.01	0.02	0.03	-	**0.16**	**0.38**	**0.21**	**0.17**	-	**0.51**	0.02	-	-	-	<0.01	-	0.06	**0.23**	<0.01	<0.01	-	-	-	-	**1.86**
MO-24787	E-1W	WS	Filtered	0.04	-	0.02	-	<0.01	-	<0.01	-	-	**0.34**	**0.41**	0.05	**0.19**	<0.01	**0.25**	<0.01	-	0.05	-	<0.01	-	0.04	0.10	<0.01	-	-	-	-	-	**1.50**
MO-24787	E-1W	WS	Unfiltered	0.09	-	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	-	**0.35**	**0.57**	**0.12**	**0.21**	-	**0.35**	<0.01	-	-	-	<0.01	-	0.07	**0.17**	<0.01	<0.01	-	-	-	-	**1.98**
MO-24788	E-1E	WS	Filtered	0.03	0.06	<0.01	-	0.01	-	<0.01	<0.01	-	0.24	0.05	0.04	<0.01	<0.01	0.19	0.02	0.01	-	-	<0.01	0.17	0.07	0.06	<0.01	-	-	-	-	-	0.98
MO-24788	E-1E	WS	Unfiltered	0.09	0.05	<0.01	<0.01	0.01	<0.01	-	0.02	-	**0.28**	**0.19**	**0.15**	0.01	-	**0.19**	0.02	0.03	-	-	<0.01	-	0.09	0.09	<0.01	<0.01	<0.01	-	<0.01	-	**1.24**
MO-24789	M-1W	WS	Filtered	**0.34**	0.08	0.01	-	<0.01	0.01	<0.01	<0.01	0.01	**0.12**	**0.66**	**0.54**	<0.01	<0.01	**0.64**	<0.01	0.02	-	-	<0.01	-	0.06	**0.56**	<0.01	-	-	-	-	-	**3.11**
MO-24789	M-1W	WS	Unfiltered	**1.20**	0.07	0.03	0.03	<0.01	0.03	<0.01	0.04	-	**0.33**	**2.34**	**1.80**	0.02	<0.01	**0.66**	0.02	-	-	-	<0.01	-	0.10	**1.32**	0.02	-	-	-	-	-	**8.02**
MO-24790	M-1E	WS	Filtered	**0.12**	-	0.02	-	<0.01	-	0.01	<0.01	-	0.08	**0.21**	**0.11**	**0.36**	<0.01	0.03	0.01	-	-	-	<0.01	-	0.04	0.10	<0.01	-	-	-	-	-	**1.09**
MO-24790	M-1E	WS	Unfiltered	**0.20**	-	0.02	-	<0.01	<0.01	<0.01	<0.01	-	**0.23**	**0.38**	**0.21**	**0.39**	-	0.03	0.01	-	-	-	<0.01	-	0.05	**0.21**	<0.01	<0.01	-	-	-	-	**1.76**
MO-24808	M-2W	WS	Unfiltered	0.02	-	<0.01	<0.01	-	<0.01	-	<0.01	-	-	0.04	0.04	0.02	-	-	<0.01	<0.01	-	-	-	-	-	0.06	<0.01	-	-	-	-	-	0.22
Mortandad at GS-1	M-2W	WS	Filtered	0.03	0.07	<0.01	<0.01	<0.01	0.06	<0.01	0.02	-	**0.41**	0.05	0.10	<0.01	<0.01	**0.53**	0.02	-	<0.01	<0.01	<0.01	**0.11**	**0.52**	**0.12**	0.02	-	-	-	-	-	**2.08**
Mortandad at GS-1	M-2W	WS	Unfiltered	0.03	-	<0.01	<0.01	-	0.01	<0.01	0.01	0.01	-	0.06	0.03	<0.01	<0.01	-	0.02	**3.89**	0.01	<0.01	-	0.09	**0.52**	**0.16**	-	-	-	-	-	-	**4.87**
Mortandad below Effluent Canyon	M-2W	WS	Filtered	0.08	0.04	<0.01	-	0.01	<0.01	-	<0.01	-	**0.25**	**0.14**	0.10	<0.01	<0.01	**0.20**	<0.01	0.02	-	-	<0.01	0.08	-	**0.13**	<0.01	-	-	-	-	-	**1.09**
Mortandad below Effluent Canyon	M-2W	WS	Unfiltered	0.12	-	<0.01	-	<0.01	-	-	<0.01	-	0.14	0.22	0.18	<0.01	-	-	-	0.02	0.01	-	<0.01	-	-	-	<0.01	0.01	-	-	<0.01	0.74
MO-24791	M-2E	WS	Filtered	<0.01	0.04	<0.01	-	<0.01	-	-	<0.01	-	**0.27**	<0.01	-	-	<0.01	**0.18**	<0.01	**0.97**	-	-	<0.01	-	0.09	0.03	<0.01	-	-	-	-	-	**1.62**
MO-24791	M-2E	WS	Unfiltered	0.03	0.04	<0.01	-	<0.01	-	-	<0.01	-	0.28	0.04	-	<0.01	-	0.17	<0.01	-	-	-	<0.01	-	0.10	0.04	<0.01	-	-	-	-	-	0.72
MO-24792	TS-1C	WS	Filtered	0.04	-	0.01	-	<0.01	-	<0.01	<0.01	0.01	0.03	0.08	-	0.09	<0.01	0.07	<0.01	<0.01	-	-	<0.01	0.37	0.03	-	<0.01	-	-	-	-	-	0.76
MO-24792	TS-1C	WS	Unfiltered	**1.03**	-	0.05	0.05	<0.01	0.07	0.02	0.02	<0.01	**0.10**	**3.44**	**2.24**	**0.33**	-	0.08	0.02	-	-	<0.01	<0.01	**0.30**	**0.40**	**1.00**	0.02	<0.01	-	-	-	-	**9.18**
MO-24793	TS-2E	WS	Filtered	0.01	-	0.02	-	<0.01	-	<0.01	<0.01	-	0.14	0.05	0.04	0.17	<0.01	0.20	0.01	-	-	<0.01	<0.01	-	0.11	0.11	<0.01	-	-	-	-	-	0.88
MO-24793	TS-2E	WS	Unfiltered	0.06	-	0.02	-	<0.01	<0.01	<0.01	<0.01	-	**0.14**	**0.10**	**0.11**	**0.17**	-	**0.20**	0.01	-	-	<0.01	<0.01	-	**0.11**	**0.12**	<0.01	<0.01	-	-	-	-	**1.09**
MO-24794	TS-1E	WS	Unfiltered	0.03	-	0.02	<0.01	-	-	-	<0.01	-	0.15	0.06	0.08	0.02	-	-	<0.01	-	-	-	-	-	-	0.09	<0.01	-	-	-	-	-	0.45
MO-24795	TS-2C	WS	Unfiltered	0.02	-	0.02	<0.01	-	0.03	<0.01	0.02	<0.01	0.20	0.04	0.11	0.08	-	-	0.01	-	-	0.03	-	-	-	0.07	<0.01	-	-	-	-	-	0.64
Mortandad at Rio Grande (A-11)	none	WS	Filtered	<0.01	-	<0.01	-	0.08	<0.01	0.02	0.02	-	**0.51**	<0.01	0.04	<0.01	<0.01	0.01	<0.01	-	-	-	<0.01	-	0.07	**0.22**	<0.01	-	-	-	-	-	1.00

Notes: All values in ug/L. Ratios in bold and gray shading show where the SOFnc>1 and the ratio is >0.1.

[a] EPA Region 6 screening value (EPA 2005, 91002).

[b] EPA Region 9 screening value (epa.gov/region09/waste/sfund/prg/files/04prgtable.pdf).

Table 8.2-5
Identifying Surface Water COPCs, Carcinogens

Location ID	Reach	Media Code	Field Preparation	Arsenic	Chromium[a]	Aroclor-1260	SOFca
Tap Water Screening Level[b]				**0.44**	**1100**	**0.33**	
MO-24786	east of E-1FW	WS	Filtered	**17.6**	0.03	-	**17.7**
MO-24786	east of E-1FW	WS	Unfiltered	**17.2**	0.04	-	**17.2**
MO-24787	E-1W	WS	Filtered	-	<0.01	-	-
MO-24787	E-1W	WS	Unfiltered	**14.9**	<0.01	-	**14.9**
MO-24788	E-1E	WS	Filtered	-	<0.01	-	-
MO-24788	E-1E	WS	Unfiltered	-	<0.01	-	-
MO-24789	M-1W	WS	Filtered	-	<0.01	-	-
MO-24789	M-1W	WS	Unfiltered	**14.7**	0.03	-	**14.7**
MO-24790	M-1E	WS	Filtered	-	<0.01	-	-
MO-24790	M-1E	WS	Unfiltered	-	<0.01	-	-
Mortandad at GS-1	M-2W	WS	Filtered	**5.43**	<0.01	-	**5.4**
Mortandad at GS-1	M-2W	WS	Unfiltered	**5.86**	<0.01	-	**5.9**
Mortandad below Effluent Canyon	M-2W	WS	Filtered	-	<0.01	-	-
Mortandad below Effluent Canyon	M-2W	WS	Unfiltered	-	<0.01	-	-
MO-24791	M-2E	WS	Filtered	-	-	-	-
MO-24791	M-2E	WS	Unfiltered	-	<0.01	-	-
MO-24792	TS-1C	WS	Filtered	-	<0.01	-	-
MO-24792	TS-1C	WS	Unfiltered	**17.0**	<0.01	**3.31**	**20.3**
MO-24793	TS-2E	WS	Filtered	-	0.02	-	0.0
MO-24793	TS-2E	WS	Unfiltered	-	<0.01	-	-
MO-24794	TS-1E	WS	Unfiltered	-	<0.01	-	-
MO-24795	TS-2C	WS	Unfiltered	-	-	-	-
MO-24808	M-2W	WS	Unfiltered	-	<0.01	-	-
Mortandad at Rio Grande (A-11)	none	WS	Filtered	-	-	-	-

Notes: All values in ug/L. Ratios in bold and gray shading show where the SOFca>1 and the ratio is >0.1.

[a] Used hexavalent chromium screening value.

[b] EPA Region 6 screening value (EPA 2005, 91002).

Table 8.2-6
Identifying Surface Water COPCs, Radionuclides

Location ID	Reach	Media code	Field Preparation	Americium-241	Cesium-137	Plutonium-238	Plutonium-239	Plutonium-239/240[a]	Potassium-40	Radium-226	Sodium-22	Strontium-90	Technetium-99	Thorium-228	Thorium-230	Thorium-232	Tritium	Uranium-234	Uranium-235	Uranium-235/236[b]	Uranium-238	SOFrad
Tap Water Screening Level [c]				**1.2**	**120**	**1.6**	**1.2**	**1.2**	**280**	**4**	**400**	**40**	**4000**	**16**	**12**	**2**	**80000**	**20**	**24**	**24**	**24**	
MO-24786	east of E-1FW	WS	Unfiltered	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	<0.01	<0.01	-	-	<0.01	0.03
MO-24786	east of E-1FW	WS	Filtered	-	-	-	<0.01	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	<0.01	0.01
MO-24787	E-1W	WS	Unfiltered	-	-	-	-	-	-	0.19	-	0.01	-	-	-	-	<0.01	<0.01	-	-	<0.01	0.23
MO-24787	E-1W	WS	Filtered	-	-	-	<0.01	-	-	-	-	0.01	-	-	-	-	-	<0.01	-	-	<0.01	0.02
MO-24788	E-1E	WS	Unfiltered	**7.2**	**0.30**	**1.97**	**1.78**	**4.04**	**0.23**	-	-	0.10	-	-	-	-	0.014	0.03	-	-	<0.01	**15.7**
MO-24788	E-1E	WS	Filtered	**3.39**	**0.19**	**0.94**	<0.01	**2.13**	-	**0.10**	-	**0.11**	-	-	-	-	-	0.02	-	-	0.02	**6.90**
MO-24789	M-1W	WS	Unfiltered	-	-	0.08	0.07	-	-	0.11	-	0.01	-	-	-	-	<0.01	0.02	-	-	0.02	0.31
MO-24789	M-1W	WS	Filtered	-	-	-	<0.01	-	-	0.36	-	-	-	-	-	-	-	<0.01	-	-	<0.01	0.38
MO-24790	M-1E	WS	Unfiltered	-	-	-	-	-	-	-	-	0.01	-	-	-	-	<0.01	<0.01	-	-	<0.01	0.02
MO-24790	M-1E	WS	Filtered	-	-	-	<0.01	-	-	0.09	-	0.02	-	-	-	-	-	<0.01	-	-	<0.01	0.12
MO-24808	M-2W	WS	Unfiltered	**1.57**	-	**0.47**	**0.68**	-	-	-	-	-	-	-	-	-	-	0.02	-	-	<0.01	**2.74**
Mortandad at GS-1	M-2W	WS	Unfiltered	**5.45**	**0.26**	**3.13**	-	**5.63**	-	-	0.02	**1.19**	-	-	-	-	**0.658**	**0.17**	-	<0.01	0.05	**16.6**
Mortandad at GS-1	M-2W	WS	Filtered	**0.5**	-	**0.94**	-	**0.68**	-	-	-	**1.13**	-	-	-	-	-	**0.18**	-	<0.01	0.05	**3.48**
Mortandad below Effluent Canyon	M-2W	WS	Unfiltered	**12.5**	**0.36**	**4.22**	-	**3.94**	-	**0.18**	0.03	**0.29**	-	<0.01	<0.01	0.05	**0.161**	**0.15**	-	<0.01	0.01	**21.9**
Mortandad below Effluent Canyon	M-2W	WS	Filtered	**1.35**	0.08	**0.28**	-	**0.63**	-	**0.15**	-	0.08	-	-	-	-	-	<0.01	-	-	<0.01	**2.57**
MO-24791	M-2E	WS	Unfiltered	**0.82**	0.05	**0.18**	-	**0.42**	-	-	-	**1.10**	<0.01	-	-	-	<0.01	0.03	-	-	<0.01	**2.60**
MO-24791	M-2E	WS	Filtered	**0.53**	-	**0.13**	<0.01	**0.33**	-	-	-	**1.04**	-	-	-	-	-	0.03	-	-	<0.01	**2.06**
MO-24792	TS-1C	WS	Unfiltered	**0.17**	-	**1.12**	**0.66**	**0.32**	-	-	-	**0.17**	-	-	-	-	<0.01	0.01	-	-	<0.01	**2.45**
MO-24792	TS-1C	WS	Filtered	0.03	-	0.14	-	0.06	-	-	-	0.23	<0.01	<0.01	-	<0.01	<0.01	<0.01	-	-	<0.01	0.47
MO-24793	TS-2E	WS	Unfiltered	-	-	0.04	-	-	-	-	-	0.53	-	-	-	-	<0.01	0.01	-	-	0.01	0.60
MO-24793	TS-2E	WS	Filtered	-	-	-	<0.01	-	-	-	-	0.48	-	-	-	-	-	0.01	-	-	0.01	0.50
MO-24794	TS-1E	WS	Unfiltered	-	-	0.08	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	0.01	0.10
MO-24795	TS-2C	WS	Unfiltered	-	-	0.04	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	<0.01	0.05
Mortandad at Rio Grande (A-11)	none	WS	Unfiltered	0.03	-	-	-	-	-	0.34	-	<0.01	-	-	-	-	<0.01	0.02	-	-	<0.01	0.40
Rio Grande at Mortandad	none	WS	Unfiltered	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.01	-	-	-	-	<0.01
Rio Grande at Mortandad	none	WS	Filtered	-	-	-	-	-	-	-	-	<0.01	-	-	<0.01	-	-	0.03	-	-	0.01	0.06

Note: Ratios in bold and gray shading show where the SOFrad>1 and the ratio is >0.1.

[a] Plutonium-239 DCG.

[b] Uranium-235 DCG.

[c] DCG (Derived Concentration Guide) based on committed effective dose equivalent of 4 mrem/yr, all values in pCi/L.

Table 8.2-7
Reaches Evaluated for Water, Sediment, and Multimedia Exposure

Endpoint	Reach	Water	Sediment	Multimedia
Carcinogen	M-1W	x	x	yes
	M-1E		x	
	E-1FW	x	x	yes
	E-1W	x	x	yes
	E-1E		x	
	M-2W	x	x	
	M-3		x	
	TS-1W		x	
	TS-1C	x	x	yes
	TS-1E		x	
	TS-2E		x	
	M-4		x	
Non-carcinogen	M-1W	x		
	M-1E	x	x	yes
	E-1FW	x	x	yes
	E-1W	x	x	yes
	E-1E	x	x	yes
	M-2W	x	x	yes
	M-2E	x		
	TS-1W		x	
	TS-1C	x	x	yes
	TS-2E	x	x	yes
Radionuclide	E-1W		x	
	E-1E	x	x	yes
	M-2W	x	x	yes
	M-2E	x	x	yes
	M-3		x	
	TS-1W		x	
	TS-1C	x	x	yes
	TS-1E		x	
	TS-2W		x	
	TS-2C		x	
	TS-2E		x	
	M-4		x	

Table 8.2-8
Site-Specific Exposure Scenarios and Complete Exposure Pathways

	Exposure Scenarios	
Exposure Pathways	**Trail User**	**Residential**
Incidental ingestion of soil	**X**	**X**
Inhalation of dust	**X**	**X**
Dermal contact with soil	**X**	**X**
Ingestion of fruits and vegetables	—*	**X**
Ingestion of meat	—	—
Ingestion of groundwater	—	—
Dermal contact with groundwater	—	—
Ingestion of surface water	**X**	—
Dermal contact with surface water	**X**	—
External irradiation	**X**	**X**

* — = Incomplete pathway.

Table 8.2-9
Media-Specific Risk-Based Screening Levels (MSSL) for the Trail User Scenario

Medium	COPC	CAS ID	Units	Endpoint	Target Adverse-Effect Level	Recreational MSSL	Reference
Sediment	Aluminum	7429-90-5	mg/kg	nc	HQ=1	100000	LANL (2004, 87800)
Sediment	Antimony	7440-36-0	mg/kg	nc	HQ=1	317	LANL (2004, 87800)
Sediment	Aroclor-1254	11097-69-1	mg/kg	ca	1E-5 risk	10.5	LANL (2004, 87800)
Sediment	Aroclor-1254-nc	11097-69-1	mg/kg	nc	HQ=1	6.65	LANL (2004, 87800)
Sediment	Aroclor-1260	11096-82-5	mg/kg	ca	1E-5 risk	10.5	LANL (2004, 87800)
Sediment	Aroclors (Mixed)	1336-36-3	mg/kg	ca	1E-5 risk	10.5	LANL (2004, 87800)
Sediment	Arsenic	7440-38-2	mg/kg	ca	1E-5 risk	27.7	LANL (2004, 87800)
Sediment	Arsenic-nc	7440-38-2	mg/kg	nc	HQ=1	183	LANL (2004, 87800)
Sediment	Benzo(a)anthracene	56-55-3	mg/kg	ca	1E-5 risk	30.1	LANL (2004, 87800)
Sediment	Benzo(a)pyrene	50-32-8	mg/kg	ca	1E-5 risk	3.01	LANL (2004, 87800)
Sediment	Benzo(b)fluoranthene	205-99-2	mg/kg	ca	1E-5 risk	30.1	LANL (2004, 87800)
Sediment	Chromium	7440-47-3	mg/kg	ca	1E-5 risk	100000	LANL (2004, 87800)
Sediment	Chromium-nc	7440-47-3	mg/kg	nc	HQ=1	14300	LANL (2004, 87800)
Sediment	Copper	7440-50-8	mg/kg	nc	HQ=1	31700	LANL (2004, 87800)
Sediment	Indeno(1,2,3-cd)pyrene	193-39-5	mg/kg	ca	1E-5 risk	30.1	LANL (2004, 87800)
Sediment	Iron	7439-89-6	mg/kg	nc	HQ=1	100000	LANL (2004, 87800)
Sediment	Lead	7439-92-1	mg/kg	nc	HQ=1	560	LANL (2004, 87800)
Sediment	Manganese	7439-96-5	mg/kg	nc	HQ=1	15800	LANL (2004, 87800)
Sediment	Mercury	7487-94-7	mg/kg	nc	HQ=1	238	LANL (2004, 87800)
Sediment	Thallium	7440-28-0	mg/kg	nc	HQ=1	52.3	LANL (2004, 87800)
Sediment	Uranium	7440-61-1	mg/kg	nc	HQ=1	2380	LANL (2004, 87800)
Sediment	Vanadium	7440-62-2	mg/kg	nc	HQ=1	5550	LANL (2004, 87800)
Sediment	Americium-241	86954-36-1	pCi/g	rad	15 mrem/yr	280	LANL (2005, 88493)
Sediment	Cesium-137	10045-97-3	pCi/g	rad	15 mrem/yr	210	LANL (2005, 88493)
Sediment	Cobalt-60	10198-40-0	pCi/g	rad	15 mrem/yr	46	LANL (2005, 88493)
Sediment	Europium-152	14683-23-9	pCi/g	rad	15 mrem/yr	100	LANL (2005, 88493)
Sediment	Plutonium-238	13981-16-3	pCi/g	rad	15 mrem/yr	330	LANL (2005, 88493)
Sediment	Plutonium-239	15117-48-3	pCi/g	rad	15 mrem/yr	300	LANL (2005, 88493)
Sediment	Sodium-22	13966-32-0	pCi/g	rad	15 mrem/yr	58	LANL (2005, 88493)
Sediment	Strontium-90	10098-97-2	pCi/g	rad	15 mrem/yr	5600	LANL (2005, 88493)
Sediment	Thorium-228	14274-82-9	pCi/g	rad	15 mrem/yr	77	LANL (2005, 88493)
Sediment	Thorium-230	14269-63-7	pCi/g	rad	15 mrem/yr	150	LANL (2005, 88493)
Sediment	Thorium-232	7440-29-1	pCi/g	rad	15 mrem/yr	40	LANL (2005, 88493)
Sediment	Tritium	10028-17-8	pCi/g	rad	15 mrem/yr	5100000	LANL (2005, 88493)
Sediment	Uranium-238	7440-61-1	pCi/g	rad	15 mrem/yr	2100	LANL (2005, 88493)

Table 8.2-9 (continued)

Medium	COPC	CAS ID	Units	Endpoint	Target Adverse-Effect Level	Recreational MSSL	Reference
Surface water	Arsenic	7440-38-2	ug/L	ca	1E-5 risk	98.3	LANL (2004, 87390)
Surface water	Arsenic-nc	7440-38-2	ug/L	nc	HQ=1	1900	LANL (2004, 87390)
Surface water	Aroclor-1260	11096-82-5	ug/L	ca	1E-5 risk	74.5	LANL (2004, 87390)*
Surface water	Lead	7439-92-1	ug/L	nc	HQ=1	65	LANL (2005, 88493)
Surface water	Mercury	7439-97-6	ug/L	nc	HQ=1	1660	LANL (2004, 87390)*
Surface water	Aluminum	7429-90-5	ug/L	nc	HQ=1	6320000	LANL (2004, 87390)*
Surface water	Barium	7440-39-3	ug/L	nc	HQ=1	388000	LANL (2004, 87390)
Surface water	Fluoride	7782-41-4	ug/L	nc	HQ=1	379000	LANL (2004, 87390)
Surface water	Iron	7439-89-6	ug/L	nc	HQ=1	1900000	LANL (2004, 87390)
Surface water	Manganese	7439-96-5	ug/L	nc	HQ=1	706000	LANL (2004, 87390)
Surface water	Molybdenum	7439-98-7	ug/L	nc	HQ=1	31600	LANL (2004, 87390)
Surface water	Thallium	7440-28-0	ug/L	nc	HQ=1	506	LANL (2004, 87390)
Surface water	Vanadium	7440-62-2	ug/L	nc	HQ=1	32000	LANL (2005, 88493)
Surface water	Perchlorate	14797-73-0	ug/L	nc	HQ=1	632	LANL (2004, 87390)
Surface water	Uranium	7440-61-1	ug/L	nc	HQ=1	19000	LANL (2004, 87390)
Surface water	Americium-241	86954-36-1	pCi/L	rad	4 mrem/yr	275	LANL (2004, 87390)
Surface water	Cesium-137	10045-97-3	pCi/L	rad	4 mrem/yr	20000	LANL (2004, 87390)*
Surface water	Plutonium-238	13981-16-3	pCi/L	rad	4 mrem/yr	313	LANL (2004, 87390)*
Surface water	Plutonium-239	15117-48-3	pCi/L	rad	4 mrem/yr	282	LANL (2004, 87390)
Surface water	Plutonium-239/240	15117-48-3	pCi/L	rad	4 mrem/yr	282	LANL (2004, 87390)
Surface water	Potassium-40	13966-00-2	pCi/L	rad	4 mrem/yr	53800	LANL (2004, 87390)*
Surface water	Radium-226	13982-63-3	pCi/L	rad	4 mrem/yr	758	LANL (2004, 87390)*
Surface water	Strontium-90	10098-97-2	pCi/L	rad	4 mrem/yr	6540	LANL (2004, 87390)
Surface water	Tritium	10028-17-8	pCi/L	rad	4 mrem/yr	15600000	LANL (2004, 87390)*
Surface water	Uranium-234	13966-29-5	pCi/L	rad	4 mrem/yr	3530	LANL (2004, 87390)

*Additional documentation of this MSSL is provided in Appendix E.

Table 8.2-10
Toxicity Values that Differed Between Sources

Chemical	Chemical Abstract System ID	Parameter	Value	Source
Aroclor-1254	11097-69-1	SFi	3.50E-01	LANL (2004, 87800)
			No value	LANL (2004, 87390)
			2.00E+00	NMED (2006, 92513)
			2.00E+00	EPA (2005, 91002)
Barium	7440-39-3	RfDo	**7.00E-02**	LANL (2004, 87800)
			7.00E-02	LANL (2004, 87390)
			2.00E-01	NMED (2006, 92513)
			2.00E-01	EPA (2005, 91002)
		RfDi	**1.43E-04**	LANL (2004, 87800)
			7.00E-02	LANL (2004, 87390)
			2.00E-01	NMED (2006, 92513)
			2.00E-01	EPA (2005, 91002)
Copper	7440-50-8	RfDo	4.00E-02	LANL (2004, 87800)
			3.70E-02	LANL (2004, 87390)
			4.00E-02	NMED (2006, 92513)
			3.70E-02	EPA (2005, 91002)
Manganese	7439-96-5	RfDo	**2.00E-02**	LANL (2004, 87800)
			1.40E-01	LANL (2004, 87390)
			4.70E-02	NMED (2006, 92513)
			4.70E-02	EPA (2005, 91002)
Thallium	7440-28-0	RfDo	**6.60E-05**	LANL (2004, 87800)
			8.00E-05	LANL (2004, 87390)
			6.60E-05	NMED (2006, 92513)
			7.00E-05	EPA (2005, 91002)
Vanadium	7440-62-2	RfDo	7.00E-03	LANL (2004, 87800)
			7.00E-03	LANL (2004, 87390)
			1.00E-03	NMED (2006, 92513)
			1.00E-03	EPA (2005, 91002)

Notes: More protective values are in bold type. CSFi = inhalation cancer slope factor, RFDo = oral reference dose, RFDi = inhalation reference dose.

Table 8.2-11
Summary of Trail User Risk Assessment Results

Endpoint	Reach	Sediment	Surface Water	Multimedia Sum
Non-carcinogen HI	M-1W	0.016	0.446	0.46
	M-1E	0.397	0.055	0.45
	E-1FW	0.429	0.060	0.49
	E-1W	0.304	0.042	0.35
	E-1E	0.063	0.040	0.10
	M-2W	0.116	0.206	0.32
	M-2E		0.003	
	M-3	0.011		
	TS-1W	0.091		
	TS-1C	0.113	0.549	0.66
	TS-2E	0.184	0.030	0.21
	M-4	0.012		
Carcinogen risk	M-1W	5.5E-06	6.6E-07	6.2E-06
	M-1E	1.9E-06		
	E-1FW	3.5E-06	7.7E-07	4.3E-06
	E-1W	2.4E-06	6.7E-07	3.0E-06
	E-1E	1.6E-06		
	M-2W	2.0E-06	7.6E-07	2.8E-06
	M-3	8.6E-07		
	TS-1W	1.4E-06		
	TS-1C	2.7E-06	9.1E-07	3.6E-06
	TS-1E	2.3E-06		
	TS-2E	1.2E-06		
	M-4	7.8E-07		
Radionuclide dose (mrem/yr)	E-1W	1.60		
	E-1E	**43.7**	0.25	**44.0**
	M-2W	10.4	0.33	10.7
	M-2E	10.2	0.05	10.3
	M-3	9.08		
	TS-1W	0.43		
	TS-1C	3.39	0.04	3.43
	TS-1E	3.98		
	TS-2W	0.05		
	TS-2C	0.01		
	TS-2E	0.30		
	M-4	2.75		

Table 8.2-12
Risk Ratios based on Representative Concentrations for Sediment, Trail User Scenario

Non-carcinogen COPCs - Ratios															
Reach	Aluminum	Antimony	Aroclor-1254	Arsenic	Chromium	Copper	Iron	Lead	Manganese	Mercury	Thallium	Uranium	Vanadium	SOFnc	HI
MSSL	1E+05	317	6.65	183	14300	31700	1E+05	560	15800	238	52.3	2380	5550		
M-1W	-	-	-	0.014	-	-	-	-	-	-	-	-	-	0.01	0.01
M-1E	0.12	-	-	0.022	-	-	0.12	-	0.045	-	-	-	0.004	0.31	0.31
E-1FW	0.091	-	0.021	0.035	0.048	0.003	0.1	0.045	0.029	-	-	-	0.004	0.38	0.38
E-1W	0.059	-	-	0.018	0.003	-	0.087	-	0.041	-	-	0.001	0.002	0.21	0.21
E-1E	-	-	-	0.011	-	-	-	0.017	0.021	0.001	0.003	0.002	-	0.06	0.06
M-2W	-	9E-04	-	0.011	-	-	0.08	0.015	-	-	0.002	-	-	0.11	0.11
M-2E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M-3	-	-	-	0.011	-	-	-	-	-	-	-	-	-	0.01	0.01
TS-1W	-	-	-	-	-	-	-	-	-	-	0.002	-	0.002	0.00	0.005
TS-1C	-	0.002	-	-	-	-	0.11	-	-	-	0.002	-	0.003	0.12	0.12
TS-1E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TS-2W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TS-2C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TS-2E	0.066	-	-	0.012	-	-	0.087	-	-	-	-	-	0.003	0.17	0.17
M-4	-	-	-	0.011	-	-	-	-	-	-	-	-	-	0.01	0.01

Table 8.2-12 (continued)

Carcinogen COPCs - Ratios										
Reach	Aroclor-1254	Aroclor-1260	Arsenic	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Chromium	Indeno(1,2,3-cd)pyrene	SOFca	Carcinogenic risk
MSSL	10.5	10.5	27.7	30.1	3.01	30.1	1E+05	30.1		
M-1W	-	-	0.092	0.033	0.286	0.035	-	0.012	0.46	4.6E-06
M-1E	-	-	0.147	-	-	-	-	-	0.15	1.5E-06
E-1FW	0.013	-	0.23	-	0.05	-	0.007	-	0.30	3.0E-06
E-1W	-	-	0.117	-	0.086	-	4E-04	-	0.20	2.0E-06
E-1E	0.007	-	0.074	-	0.083	-	-	-	0.16	1.6E-06
M-2W	0.014	0.004	0.073	-	0.123	-	-	-	0.21	2.1E-06
M-2E	-	-	-	-	-	-	-	-	-	-
M-3	-	0.014	0.072	-	-	-	-	-	0.09	8.6E-07
TS-1W	0.054	-	-	-	0.034	-	-	-	0.09	8.8E-07
TS-1C	-	0.034	-	0.017	0.136	0.019	-	0.011	0.22	2.2E-06
TS-1E	-	-	-	0.016	0.137	0.023	-	-	0.18	1.8E-06
TS-2W	-	-	-	-	-	-	-	-	-	-
TS-2C	-	-	-	-	-	-	-	-	-	-
TS-2E	-	0.03	0.081	-	-	-	-	-	0.11	1.1E-06
M-4	-	-	0.073	-	-	-	-	-	0.07	7.3E-07

Table 8.2-12 (continued)

Radionuclide COPCs - Ratios														
Reach	Americium-241	Cesium-137	Cobalt-60	Plutonium-238	Plutonium-239	Sodium-22	Strontium-90	Thorium-228	Thorium-230	Thorium-232	Tritium	Uranium-238	SOFrad	Radionuclide dose (mrem/yr)
MSSL	280	210	46	330	300	58	5600	77	150	40	5E+06	2100		
M-1W	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M-1E	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E-1FW	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E-1W	-	0.005	-	-	0.1	-	-	-	-	-	-	-	0.11	1.58
E-1E	**0.38**	**2.58**	0.022	0.057	**0.37**	0.001	0.002	-	-	-	2E-07	-	**3.42**	**51.2**
M-2W	0.169	0.305	0.007	0.107	0.151	-	1E-03	-	-	-	-	7E-04	0.74	11.1
M-2E	0.086	0.467	0.004	0.049	0.076	-	6E-04	-	-	-	-	-	0.68	10.2
M-3	0.099	0.388	0.004	0.028	0.091	-	7E-04	-	-	-	-	-	0.61	9.16
TS-1W	0.003	0.003	-	0.014	0.006	-	1E-04	-	-	-	-	-	0.03	0.39
TS-1C	-	0.009	-	0.058	0.029	-	-	0.033	0.025	0.079	-	-	0.23	3.50
TS-1E	-	-	-	0.235	0.031	-	-	-	-	-	-	-	0.27	3.98
TS-2W	-	-	-	-	-	-	4E-04	-	-	-	-	-	0.00	0.007
TS-2C	-	-	-	-	-	-	4E-04	-	-	-	-	-	0.00	0.006
TS-2E	-	-	-	-	0.017	-	0.001	-	-	-	-	-	0.02	0.28
M-4	0.034	0.138	0.001	0.01	-	-	6E-04	-	-	-	-	-	0.18	2.76

Table 8.2-13
Risk Ratios based on Representative Concentrations for Surface Water, Trail User Scenario

Non-carcinogen COPCs – Ratios															
Reach	Aluminum	Arsenic-nc	Barium	Fluoride	Iron	Lead	Manganese	Mercury	Molybdenum	Perchlorate	Thallium	Uranium	Vanadium	SOFnc	HI
MSSL	6E+06	1900	4E+05	4E+05	2E+06	65	7E+05	1660	31600	632	506	19000	31700		
M-1W	0.007	0.003		0.002	0.014	0.415		4E-05	0.004				0.002	0.45	0.45
M-1E	0.001			0.001	0.002	0.048	0.003						2E-04	0.06	0.06
east of E-1FW		0.004		9E-04	0.002	0.048	0.001		0.003		4E-04		3E-04	0.06	0.06
E-1W		0.003		0.002	0.003	0.029	0.001		0.002				2E-04	0.04	0.04
E-1E				0.002	0.001	0.035			0.001		1E-03			0.04	0.04
M-2W	7E-04	0.004			0.001	0.042		5E-05	2E-04	0.157	1E-03		7E-05	0.21	0.21
M-2E				0.002					1E-03					0.00	0.00
TS-2E				8E-04	6E-04	0.026	0.001		0.001			4E-05	1E-04	0.03	0.03
TS-1C	0.006		9E-04	6E-04	0.02	0.517	0.002				0.001	2E-04	0.001	0.55	0.55

Table 8.2-13 (continued)

Reach	Carcinogen COPCs - Ratios				Radionuclide COPCs - Ratios										
	Aroclor-1260	Arsenic	SOFca	Carcinogenic risk	Americium-241	Cesium-137	Plutonium-238	Plutonium-239/240	Potassium-40	Radium-226	Strontium-90	Tritium	Uranium-234	SOFrad	Radionuclide dose (mrem/yr)
MSSL	74.5	98.3			275	20000	313	282	53800	758	6540	15600000	3530		
M-1W		0.066	0.07	6.6E-07											
M-1E															
east of E-1FW		0.077	0.08	7.7E-07											
E-1W		0.067	0.07	6.7E-07											
E-1E					0.0314	0.0018	0.0101	0.0172	0.0012	0.0003	0.0006			0.063	0.25
M-2W		0.076	0.08	7.6E-07	0.0463	0.0016	0.016	0.0147		0.0007	0.0017	0.002272	0.0004	0.084	0.33
M-2E					0.0036		0.0009	0.0018			0.0067			0.013	0.05
TS-2E															
TS-1C	0.015	0.076	0.09	9.1E-07			0.0057	0.0028			0.001			0.01	0.04

Table 8.2-14
Representative Concentrations for Sediment COPCs, Trail User Scenario (Surface Area Weighted)

Reach	COPC	UCL	Mean	Number of Samples	Number of Detects	Maximum Detect
E-1E	Americium-241	107.45	36.05	31	30	642
E-1E	Arsenic	2.0481	1.6772	32	31	6.1
E-1E	Cesium-137	542.15	186.79	31	31	2530
E-1E	Cobalt-60	0.9935	0.43307	31	16	4.35
E-1E	Lead	9.6317	8.3673	32	32	50
E-1E	Manganese	331.94	271.84	32	32	1700
E-1E	Mercury	0.259	0.1205	32	29	0.39
E-1E	Plutonium-238	18.892	9.4569	31	30	88.7
E-1E	Plutonium-239	110.5	34.177	31	30	1110
E-1E	Sodium-22	0.08	0.05088	31	3	0.49
E-1E	Strontium-90	13.809	8.2762	31	19	273
E-1E	Thallium	0.1497	0.09421	32	6	1.6
E-1E	Tritium	1.0007	0.5814	15	8	2.4
E-1E	Uranium	4.14	2.632	5	5	4.14
E-1FW	Aluminum	9126.9	8004	16	16	21300
E-1FW	Aroclor-1254	0.1398	0.11108	8	5	0.16
E-1FW	Arsenic	6.3618	5.6298	16	16	16.6
E-1FW	Benzo(a)pyrene	0.1519	0.12288	16	11	0.5
E-1FW	Chromium	690.81	452.91	16	16	2210
E-1FW	Copper	108.83	79.415	16	16	383
E-1FW	Iron	9955.6	9876.6	16	16	18300
E-1FW	Lead	24.925	24.078	16	16	56.8
E-1FW	Manganese	462.3	379.86	16	16	1040
E-1FW	Vanadium	21.66	19.888	16	16	53.1
E-1W	Aluminum	5897.9	7891.9	22	22	19000
E-1W	Arsenic	3.2493	3.3112	22	21	11
E-1W	Cesium-137	1.0536	0.81755	11	7	2.14
E-1W	Chromium	40.773	13.894	22	22	50
E-1W	Iron	8727.6	10751	22	22	25000
E-1W	Manganese	642.34	642.5	22	22	2500
E-1W	Plutonium-239	30.1	2.19368	8	7	30.1
E-1W	Uranium	3.3943	2.084	5	5	4.32
E-1W	Vanadium	12.018	14.894	22	22	30
M-1E	Aluminum	11961	12972	21	21	26000
M-1E	Arsenic	4.065	4.509	21	21	8.4
M-1E	Iron	11962	13660	21	21	21000
M-1E	Manganese	704.27	714.48	21	21	1640

Table 8.2-14 (continued)

Reach	COPC	UCL	Mean	Number of Samples	Number of Detects	Maximum Detect
M-1E	Vanadium	20.13	22.561	21	21	37
M-1W	Arsenic	2.5527	2.3785	16	14	4.4
M-1W	Benzo(a)anthracene	0.9801	0.62494	16	10	2.71
M-1W	Benzo(a)pyrene	0.8623	0.54029	16	8	2.11
M-1W	Benzo(b)fluoranthene	1.0678	0.56874	16	7	2.51
M-1W	Indeno(1,2,3-cd)pyrene	0.3636	0.19041	16	5	1.23
M-2E	Americium-241	23.982	17.323	36	34	211
M-2E	Cesium-137	98.113	81.947	36	36	557
M-2E	Cobalt-60	0.194	0.16677	36	20	0.47
M-2E	Plutonium-238	16.073	12.864	36	36	113
M-2E	Plutonium-239	22.737	17.567	36	36	157
M-2E	Strontium-90	3.1602	2.7663	36	35	20
M-2W	Americium-241	47.189	24.688	53	47	524
M-2W	Antimony	0.2853	0.25509	48	25	0.65
M-2W	Aroclor-1260	0.0432	0.02508	21	9	0.21
M-2W	Arsenic	2.0119	1.5455	54	51	4.3
M-2W	Cesium-137	64.061	54.577	53	53	850
M-2W	Cobalt-60	0.3364	0.26596	53	33	2.45
M-2W	Iron	7967.3	6170.9	54	54	14000
M-2W	Lead	8.5311	8.0198	54	54	18
M-2W	Plutonium-238	35.185	15.216	53	51	203
M-2W	Plutonium-239	45.28	24.119	53	53	596
M-2W	Strontium-90	5.38	3.0123	53	51	35.9
M-2W	Thallium	0.1009	0.08676	54	12	0.8
M-2W	Uranium-238	2.4555	1.3226	16	16	10.7
M-3	Americium-241	27.795	20.917	76	70	223
M-3	Aroclor-1260	0.148	0.0698	15	13	0.39
M-3	Arsenic	1.9829	1.8303	65	65	4
M-3	Cesium-137	81.557	72.188	76	76	298
M-3	Cobalt-60	0.1684	0.1276	74	43	1.47
M-3	Plutonium-238	9.3315	7.9833	76	74	40.9
M-3	Plutonium-239	27.153	18.154	76	76	123
M-3	Strontium-90	3.9094	3.5116	76	71	8.6
M-4	Americium-241	9.5695	7.723	65	59	112
M-4	Arsenic	2.0265	1.9372	63	62	4.6
M-4	Cesium-137	28.951	23.989	65	65	276
M-4	Cobalt-60	0.0586	0.0457	64	14	0.44
M-4	Plutonium-238	3.2719	2.6901	65	64	32.2
M-4	Strontium-90	3.443	2.8102	65	60	9.64

Table 8.2-14 (continued)

Reach	COPC	UCL	Mean	Number of Samples	Number of Detects	Maximum Detect
TS-1C	Antimony	0.4931	0.46543	19	3	0.63
TS-1C	Aroclor-1260	0.359	0.28663	19	18	1.3
TS-1C	Benzo(a)anthracene	0.5231	0.28428	19	11	1.86
TS-1C	Benzo(a)pyrene	0.4095	0.2689	19	13	2.04
TS-1C	Benzo(b)fluoranthene	0.5792	0.33632	19	8	2.53
TS-1C	Cesium-137	1.9247	0.83	4	3	2.19
TS-1C	Indeno(1,2,3-cd)pyrene	0.3339	0.16673	19	10	1.45
TS-1C	Iron	11007	9093.1	19	19	28800
TS-1C	Plutonium-238	19.058	12.1	18	18	314.07
TS-1C	Plutonium-239	8.6642	4.679	18	18	35.19
TS-1C	Thallium	0.1104	0.10289	19	8	0.18
TS-1C	Thorium-228	2.5368	1.6239	14	14	15.2
TS-1C	Thorium-230	3.7975	1.9887	14	14	28.51
TS-1C	Thorium-232	3.1583	1.5906	14	14	13.55
TS-1C	Vanadium	14.873	13.752	19	19	25.9
TS-1E	Benzo(a)anthracene	0.4958	0.32692	17	11	0.72
TS-1E	Benzo(a)pyrene	0.4122	0.38296	17	14	0.85
TS-1E	Benzo(b)fluoranthene	0.7002	0.46484	17	8	1.6
TS-1E	Plutonium-238	77.436	29.308	16	16	338.33
TS-1E	Plutonium-239	9.1811	3.8059	16	16	37.91
TS-1W	Americium-241	0.7702	0.495	8	5	1.53
TS-1W	Aroclor-1260	0.4671	0.29443	8	5	1.37
TS-1W	Benzo(a)pyrene	0.1028	0.07544	14	12	0.32
TS-1W	Benzo(b)fluoranthene	0.1073	0.0737	14	12	0.87
TS-1W	Cesium-137	0.6484	0.4896	8	8	1.15
TS-1W	Plutonium-238	4.6989	3.7253	14	14	14.3
TS-1W	Plutonium-239	1.6674	1.5374	14	14	4.06
TS-1W	Thallium	0.1206	0.10237	14	7	0.24
TS-1W	Vanadium	12.456	12.086	14	14	23
TS-2C	Strontium-90	2.2671	1.9972	28	24	5.61
TS-2E	Aluminum	6584.2	6043.1	14	14	16100
TS-2E	Aroclor-1260	0.31	0.06962	8	5	0.31
TS-2E	Arsenic	2.2453	2.1303	14	14	4.43
TS-2E	Iron	8703.9	8130.9	14	14	13900
TS-2E	Plutonium-239	5.23	2.59261	8	7	5.23
TS-2E	Strontium-90	14.533	5.0773	14	9	8.3 *
TS-2E	Vanadium	15.038	14.187	14	14	27.1
TS-2W	Strontium-90	2.4796	1.5442	26	10	6.7

*Used maximum detect as representative concentration; calculated UCL > maximum.

Table 8.2-15
Representative Concentrations for Surface Water COPCs, Trail User Scenario

Reach	COPC	UCL	Mean	Number of Samples	Number of Detects	Maximum Detect
E-1E	Americium-241	8.64	6.71333	3	3	8.64
E-1E	Cesium-137	35.6	27.7	2	2	35.6 *
E-1E	Fluoride	607.091	444	4	4	620
E-1E	Iron	2080	1246.33	3	3	2080
E-1E	Lead	2.3	1.49333	3	3	2.3
E-1E	Molybdenum	34.8	28.75	2	2	34.8 *
E-1E	Plutonium-238	3.15	2.53333	3	3	3.15
E-1E	Plutonium-239/240	4.85	3.89333	3	3	4.85
E-1E	Potassium-40	63.6	35.255	2	1	63.6 *
E-1E	Strontium-90	3.97	3.13	2	2	3.97 *
E-1W	Arsenic	6.6	3.9	4	1	6.6
E-1W	Fluoride	760	610.8	5	5	760
E-1W	Iron	6250	4262.5	4	4	6250
E-1W	Lead	1.9	1.69636	4	3	1.9
E-1W	Manganese	1035.14	589.5	4	4	1080
E-1W	Molybdenum	64.5	52.6667	3	3	64.5
E-1W	Vanadium	6.2	4.92673	4	3	6.2
east of E-1FW	Arsenic	7.6	5.3	2	1	7.6 *
east of E-1FW	Fluoride	349	211.667	3	3	349
east of E-1FW	Iron	4200	3965	2	2	4200 *
east of E-1FW	Lead	3.1	1.675	2	1	3.1 *
east of E-1FW	Manganese	873	634.5	2	2	873 *
east of E-1FW	Molybdenum	93.5	55.95	2	2	93.5 *
east of E-1FW	Vanadium	8.3	4.4	2	1	8.3 *
M-1E	Aluminum	7400	4655	2	2	7400 *
M-1E	Fluoride	500	291.667	3	3	500
M-1E	Iron	4230	3095	2	2	4230 *
M-1E	Lead	3.1	1.945	2	2	3.1 *
M-1E	Manganese	2010	1080.5	2	2	2010 *
M-1E	Vanadium	7.6	6.1	2	2	7.6 *
M-1W	Aluminum	43700	31033.3	3	3	43700
M-1W	Arsenic	6.5	4.16667	3	1	6.5
M-1W	Fluoride	672.121	399.5	4	4	720
M-1W	Iron	25700	17336.7	3	3	25700
M-1W	Lead	27	19.0333	3	3	27
M-1W	Mercury	0.07	0.04833	3	2	0.07
M-1W	Molybdenum	121	83.55	2	2	121 *

Table 8.2-15 (continued)

Reach	COPC	UCL	Mean	Number of Samples	Number of Detects	Maximum Detect
M-1W	Vanadium	48.3	35.0667	3	3	48.3
M-2E	Americium-241	0.985	0.89	2	2	0.985 *
M-2E	Fluoride	628	502	3	3	628
M-2E	Molybdenum	30.9	29.7	2	2	30.9 *
M-2E	Plutonium-238	0.287	0.2765	2	2	0.287 *
M-2E	Plutonium-239/240	0.508	0.482	2	2	0.508 *
M-2E	Strontium-90	43.9	41.65	2	2	43.9 *
M-2W	Aluminum	4410	1970.67	3	3	4410
M-2W	Americium-241	12.7148	6.35501	10	10	15.1
M-2W	Cesium-137	32.925	25.775	8	8	42.6
M-2W	Iron	2460	1118	3	3	2460
M-2W	Lead	2.7	1.26333	3	3	2.7
M-2W	Mercury	0.08	0.04513	10	1	0.08
M-2W	Perchlorate	99.5	14.1489	10	5	99.5
M-2W	Plutonium-238	5.00321	3.55384	10	10	7.57
M-2W	Plutonium-239/240	4.14226	2.98443	10	10	6.7543
M-2W	Radium-226	0.51154	0.373	8	2	0.709
M-2W	Strontium-90	11.2143	7.60309	8	7	14.5
M-2W	Tritium	35500	9888.1	8	8	35500
M-2W	Uranium-234	1.36323	0.73914	10	10	2.93
M-2W	Vanadium	2.1	2.28333	3	2	2.1
TS-1C	Aluminum	37700	20920	3	3	37700
TS-1C	Aroclor-1260	1.1	0.5725	2	1	1.1 *
TS-1C	Arsenic	7.5	6	3	1	7.5
TS-1C	Barium	349	191.967	3	3	349
TS-1C	Fluoride	226.522	151.5	4	4	228
TS-1C	Iron	37800	16486.7	3	3	37800
TS-1C	Lead	33.6	13.9333	3	3	33.6
TS-1C	Manganese	1690	598.167	3	3	1690
TS-1C	Plutonium-238	1.79	1.106	3	3	1.79
TS-1C	Plutonium-239/240	0.79	0.45333	3	3	0.79
TS-1C	Strontium-90	6.63	5.57	2	2	6.63 *
TS-1C	Thallium	0.73	0.47667	3	1	0.73
TS-1C	Vanadium	36.4	17.7667	3	2	36.4
TS-1C	Uranium	2.9	2.9	1	1	2.9 *
TS-1E	Fluoride	322	322	1	1	322 *
TS-2C	Fluoride	430	430	1	1	430 *
TS-2C	Lead	1.6	1.6	1	1	1.6 *

Table 8.2-15 (continued)

Reach	COPC	UCL	Mean	Number of Samples	Number of Detects	Maximum Detect
TS-2E	Fluoride	316	269.333	3	3	316
TS-2E	Iron	1120	908.5	2	2	1120 *
TS-2E	Lead	1.7	1.21	2	2	1.7 *
TS-2E	Manganese	887	462.75	2	2	887 *
TS-2E	Molybdenum	36.6	21.2	2	2	36.6 *
TS-2E	Uranium	0.77	0.77	1	1	0.77 *
TS-2E	Vanadium	4.4	4.05	2	2	4.4 *

*Maximum detect used as the representative concentration.