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Date: MAR 28 2016
Refer To: ADESH-16-034
LAUR: 16-21912
Locates Action No.: n/a

John Kieling, Bureau Chief
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2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505-6303

Subject: Submittal of the Completion Report for Regional Aquifer Well R-58

Dear Mr. Kieling:

Enclosed please find two hard copies with electronic files of the Completion Report for Regional Aquifer Well R-58.

If you have any questions, please contact Steve Paris at (505) 606-0915 (smparis@lanl.gov) or Hai Shen at (505) 665-5046 (hai.shen.@em.doe.gov).

Sincerely,

Bruce Robinson, Program Director
Environmental Remediation Program
Los Alamos National Laboratory

Sincerely,

David S. Rhodes, Director
Environmental Management
Los Alamos Field Office

BR/DR/SP:sm

Enclosures: Two hard copies with electronic files – Completion Report for Regional Aquifer Well R-58

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LA-UR-16-21912
April 2016
EP2016-0032

Completion Report for Regional Aquifer Well R-58

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Associate Directorate for Environmental Management

EP2016-0032

Completion Report for Regional Aquifer Well R-58

April 2016

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for Randall Erickson	[signature]	Associate Director	Associate Directorate for Environmental Management	3/22/16

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EXECUTIVE SUMMARY

This well completion report describes the drilling, well construction, development, aquifer testing, and dedicated sampling system installation for regional aquifer monitoring well R-58, located within Technical Area 16 (TA-16) at Los Alamos National Laboratory (LANL or the Laboratory), Los Alamos, New Mexico. The R-58 monitoring well is being installed to augment the existing network to better define RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) contamination flow paths downgradient of potential contaminant breakthrough locations for S-Site and Fishladder Canyons. The primary purpose of well R-58 is to increase the overall detection efficiency of the TA-16 monitoring network for the high- and medium-priority sources at TA-16, as required by the New Mexico Environment Department's (NMED's) approval with modifications for the regional aquifer well R-58 drilling work plan.

The R-58 monitoring well borehole was drilled using dual-rotary air-drilling methods. Fluid additives used included potable water and foam. Foam-assisted drilling was used only to a depth of 1178 ft below ground surface (bgs). R-58 was drilled to a total depth of 1378.4 ft bgs.

The following geologic formations were encountered at R-58: Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, Otowi Member of the Bandelier Tuff, Guaje Pumice Bed of the Otowi Member, the Puye Formation, and the Tschicoma Formation younger dacite breccia.

Well R-58 was completed as a single-screen well, allowing evaluation of water quality and water levels within the regional aquifer. The screened interval is set between 1257 ft and 1277.3 ft bgs within dacite breccia. The static depth to water after well installation was measured at 1238.3 ft bgs.

The well was completed in accordance with an NMED-approved well design. The well was developed and the regional aquifer groundwater met target water-quality parameters. Aquifer testing indicates that regional aquifer monitoring well R-58 will perform effectively in meeting the planned objectives. A sampling system and transducer were placed above the screened interval, and groundwater sampling at R-58 will be performed as part of the annual Interim Facility-Wide Groundwater Monitoring Plan.

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Acronyms and Abbreviations

ADEM	Associate Directorate for Environmental Management
amsl	above mean sea level
ASTM	American Society for Testing and Materials
bgs	below ground surface
Consent Order	Compliance Order on Consent
DO	dissolved oxygen
DTW	depth to water
EES	Earth and Environmental Sciences (Laboratory group)
Eh	oxidation-reduction potential
EPA	Environmental Protection Agency (U.S.)
EPC-CP	Environmental Protection and Compliance Division–Environmental Compliance Programs
ESH	Environment, Safety, and Health (Laboratory directorate)
F	filtered
FD	field duplicate
FTP	field trip blank
gpd	gallons per day

gpm	gallons per minute
hp	horsepower
I.D.	inside diameter
LANL	Los Alamos National Laboratory
NAD	North American Datum
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxidation-reduction potential
PVC	polyvinyl chloride
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
SOP	standard operating procedure
SVOC	semivolatile organic compound
TA	technical area
TD	total depth
TOC	total organic carbon
UF	unfiltered
VOC	volatile organic compound
WCSF	waste characterization strategy form

1.0 INTRODUCTION

This completion report summarizes borehole drilling, well construction, well development, aquifer testing, and dedicated sampling system installation for regional aquifer monitoring well R-58. The report is written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005 (revised 2012), Compliance Order on Consent (the Consent Order). The R-58 monitoring well borehole was drilled in accordance with the New Mexico Environment Department– (NMED-) approved drilling work plan (LANL 2012, 212117; NMED 2012, 521741) between September 2 and 17, 2015, and completed between September 28 and November 5, 2015, at Los Alamos National Laboratory (LANL or the Laboratory) for the Associate Directorate for Environmental Management (ADEM).

Well R-58 is located within the Laboratory's Technical Area 16 (TA-16) in Los Alamos County, New Mexico (Figure 1.0-1). Well R-58 was installed to augment the existing network to better define RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine) contamination flow paths downgradient of potential contaminant breakthrough locations for S-Site and Fishladder Canyons. Secondary objectives were to identify and establish water levels in perched-intermediate aquifers, if present, and to collect samples of drill cuttings for lithologic description.

The R-58 borehole was drilled to a total depth (TD) of 1378.4 ft below ground surface (bgs). During drilling, cuttings samples were collected at 5-ft intervals from ground surface to TD. A monitoring well was installed with a screened interval between 1257 and 1277.3 ft bgs within dacite breccia. The depth to water (DTW) of 1238.3 ft bgs was recorded on November 6, 2015, after well installation.

Post-installation activities included well development, aquifer testing, surface completion, conducting a geodetic survey, and sampling system installation. Future activities will include site restoration and waste management.

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the ADEM Records Processing Facility. This report contains brief descriptions of activities and supporting figures, tables, and appendixes associated with the R-58 project.

2.0 ADMINISTRATIVE PLANNING

The following documents were prepared to guide activities associated with the drilling, installation, and development of regional aquifer well R-58:

- "Drilling Work Plan for Regional Aquifer Well R-58" (LANL 2012, 212117);
- "Field Implementation Plan for Regional Aquifer Well R-58" (TerranearPMC 2015, 601274);
- "IWD [Integrated Work Document] for Drilling and Installation of LANL Well R-58" (TerranearPMC 2015, 601273);
- "Storm Water Pollution Prevention Plan, Regional Wells (R-Wells) Drilling, Los Alamos National Laboratory, Revision 1" (LANL 2014, 601293); and
- "Waste Characterization Strategy Form for R-47, R-58, R-63i, CdV-9-1i," (LANL 2013, 244887).

3.0 DRILLING ACTIVITIES

This section describes the drilling approach and provides a chronological summary of field activities conducted at monitoring well R-58.

3.1 Drilling Approach

The drilling method, equipment and drill-casing sizes for the R-58 monitoring well were selected to retain the ability to investigate and case/seal off any perched groundwater encountered above the regional aquifer. Further, the drilling approach ensured that a sufficiently sized drill casing was used to meet the required 2-in.-minimum annular thickness of the filter pack around a 5.88-in.–outside diameter (O.D.) well screen.

Dual-rotary drilling methods using a Foremost DR-24HD drill rig were employed to drill the R-58 borehole. The drill rig was equipped with conventional drilling rods, tricone bits, downhole hammer bits, deck-mounted air compressor, and general drilling equipment. Auxiliary equipment included two Ingersoll Rand skid-mounted air compressors. Three sizes of A53 grade B flush-welded mild carbon-steel casing (16-in.-O.D., and 12-in.-and 10-in.–inside diameter [I.D.]) were used for the R-58 project.

The dual-rotary drilling technique at R-58 used filtered compressed air and fluid-assisted air to evacuate cuttings from the borehole during drilling. Drilling fluids, other than air, used in the borehole (all within the vadose zone) included potable water and a mixture of potable water with Baroid Quik Foam foaming agent. The fluids were used to cool the bit and help lift cuttings from the borehole. Use of the foaming agent was terminated at 1178 ft bgs, roughly 100 ft above the expected top of the regional aquifer. No additives, other than potable water, were used for drilling below 1178 ft bgs. The actual depth to water, however, was determined to be 1238 ft bgs. Total amounts of drilling fluids introduced into the borehole are presented in Table 3.1-1.

3.2 Chronological Drilling Activities for the R-58 Well

The DR-24HD drill rig, drilling equipment, and supplies were mobilized to the R-58 drill site from August 28 to September 1, 2015. The equipment and tooling were decontaminated before mobilization to the site. On September 2, following on-site equipment inspections, drilling of the monitoring well borehole began at 0235 h using dual-rotary methods with a 15-in. tricone bit and 16-in. drill casing.

The 16-in. surface casing was advanced to 96.2 ft bgs in Unit 4 of the Tshirege Member of the Bandelier Tuff on September 2. Open-hole drilling commenced the same day using a 15-in. tricone bit. Drilling proceeded through the Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, and the Otowi Member of the Bandelier Tuff to 676 ft bgs. The 16-in. casing shoe was cut on September 4 at 91.2 ft bgs.

Between September 4 and September 6, a 12-in. casing string was installed in the open borehole to a depth of 610 ft bgs (66 ft of slough was encountered in the borehole). Beginning on September 6, a 12-in. underreaming hammer bit was used to advance the 12-in. casing through the Otowi Member of the Bandelier Tuff, the Guaje Pumice Bed of the Otowi Member, and the Puye Formation to 1027.4 ft bgs. The 12-in. casing shoe was successfully cut on September 8 at 1022.4 ft bgs.

Between September 12 and September 14, a 10-in. casing string was installed to a depth of 1027.4 ft bgs. The 10-in. casing string and an underreaming hammer bit were advanced through the Puye Formation and the dacite breccia to a TD of 1378.4 ft bgs on September 17 at 1814 h. After reaching TD, the 10-in. casing was pulled back 2 ft, water levels were recorded in the borehole, and the

10-in. casing was pushed back to 1378 ft bgs. On September 18, a Laboratory natural gamma log was recorded. The casing shoe was cut on September 19 at 1371.9 ft bgs.

During drilling from September 2 to 8 and September 12 to 17, field crews worked 24-h shifts, 7 d/wk. All associated activities proceeded normally without incident or delay.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities for monitoring well R-58. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-58 monitoring well borehole at 5-ft intervals from ground surface to the TD of 1378.4 ft bgs. At each interval, approximately 500 mL of bulk cuttings were collected by the site geologist from the drilling discharge cyclone, placed in resealable plastic bags, labeled, and archived in core boxes. Whole rock, +35, and +10 sieve-size fractions were also processed, placed in chip trays, and archived for each 5-ft interval. Radiological control technicians screened the cuttings before they were removed from the site. All screening measurements were within the range of background values. The cuttings samples were delivered to the Laboratory's archive at the conclusion of drilling activities.

The stratigraphy at well R-58 is summarized in section 5.1, and a detailed lithologic log is presented in Appendix A.

4.2 Water Sampling

Four groundwater-screening samples were collected during development from the pump's discharge line for total organic carbon (TOC) analysis. Two samples were collected during aquifer testing and analyzed for TOC, alkalinity, anions, and metals.

Table 4.2-1 presents a summary of screening samples collected during the R-58 monitoring well installation. The TOC results and field water-quality parameters are presented in Appendix B.

Groundwater characterization samples will be collected from the completed well in accordance with the Consent Order. For the first year, the samples will be analyzed for a full suite of constituents in accordance with the requirements of the Interim Facility-Wide Groundwater Monitoring Plan. The analytical results will be included in the appropriate periodic monitoring report issued by the Laboratory. After the first year, the analytical suite and sample frequency at R-58 will be evaluated and presented in the annual Interim Facility-Wide Groundwater Monitoring Plan.

5.0 GEOLOGY AND HYDROGEOLOGY

The geologic and hydrogeologic features encountered at R-58 are summarized below. The Laboratory's geology task leader and project site geologist examined cuttings and the natural gamma log to determine geologic contacts and hydrogeologic conditions. Drilling observations and water-level measurements were used to identify groundwater encountered at R-58.

5.1 Stratigraphy

Rock units for the R-58 borehole are presented below in order of youngest to oldest in stratigraphic occurrence. Lithologic descriptions are based on binocular microscope analysis of drill cuttings collected from the discharge hose. Figure 5.1-1 illustrates the stratigraphy at R-58. A detailed lithologic log for R-58 is presented in Appendix A.

Unit 4, Tshirege Member of the Bandelier Tuff, Qbt 4 (0–110 ft bgs)

Unit 4 of the Tshirege Member of the Bandelier Tuff was encountered from 0 to 110 ft bgs. Unit 4 contains large glassy pumice fragments in outcrop that decrease with depth and become devitrified.

Unit 3t, Tshirege Member of the Bandelier Tuff, Qbt 3t (110–130 ft bgs)

The upper part of Unit 3 is further subdivided into Unit 3t (transition) in the western part of the Laboratory. Unit 3t of the Tshirege Member of the Bandelier Tuff was encountered from 110 ft to 130 ft bgs. Unit 3t is moderately to strongly welded crystal-rich tuff.

Unit 3, Tshirege Member of the Bandelier Tuff, Qbt 3 (130–260 ft bgs)

Unit 3 of the Tshirege Member of the Bandelier Tuff was encountered from 130 ft to 260 ft bgs. Unit 3 is a poorly to moderately welded devitrified ash-flow tuff (i.e., ignimbrite) that is crystal-rich, slightly pumiceous and lithic-poor and exhibits a matrix of fine ash.

Unit 2, Tshirege Member of the Bandelier Tuff, Qbt 2 (260–355 ft bgs)

Unit 2 of the Tshirege Member of the Bandelier Tuff was encountered from 260 ft to 355 ft bgs. Unit 2 represents a moderately to strongly welded devitrified rhyolitic ash-flow tuff (i.e., ignimbrite) that is composed of abundant quartz and sanidine crystals. Cuttings typically contain abundant fragments of indurated tuff and numerous free quartz and sanidine crystals.

Unit 1v, Tshirege Member of the Bandelier Tuff, Qbt 1v (355–400 ft bgs)

Unit 1v of the Tshirege Member of the Bandelier Tuff was encountered from 355 ft to 400 ft bgs. Unit 1v is a poorly to moderately welded, devitrified rhyolitic ash-flow tuff that is pumiceous, generally lithic-poor and crystal-bearing to locally crystal-rich. Abundant ash matrix is rarely preserved in cuttings. Cuttings commonly contain numerous fragments of indurated crystal-rich tuff with devitrified pumice. Abundant free quartz and sanidine crystals dominate cuttings in many intervals and minor small (generally less than 10 mm in diameter) volcanic lithic inclusions also occur in cuttings.

Unit 1g, Tshirege Member of the Bandelier Tuff, Qbt 1g (400–480 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff was encountered from 400 ft to 480 ft bgs. Unit 1g is a poorly welded vitric rhyolitic ash-flow tuff that is poorly to moderately indurated, strongly pumiceous, and crystal-bearing. White to pale orange, lustrous, glassy pumice lapilli are characteristic of Unit 1g. Cuttings contain abundant free quartz and sanidine crystals and glassy pumices.

Cerro Toledo Interval, Qct (480–615 ft bgs)

The Cerro Toledo interval was encountered from 480 ft to 615 ft bgs. The Cerro Toledo interval is a sequence of poorly consolidated tuffaceous and volcaniclastic sediments that occurs intermediately between the Tshirege and Otowi Members of the Bandelier Tuff. Sediments are largely stained with orange oxidation on grain surfaces.

Otowi Member of the Bandelier Tuff, Qbo (615–866 ft bgs)

The Otowi Member of the Bandelier Tuff was encountered from 615 ft to 866 ft bgs. The Otowi Member is composed of poorly welded vitric rhyolitic ash-flow tuffs that are pumiceous and crystal- and lithic-bearing. Drill cuttings contain pale orange to white pumices, volcanic lithic clasts, and quartz and sanidine crystals. Lithic fragments are commonly subangular to subrounded and generally of intermediate volcanic composition, including porphyritic dacites.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (866–889 ft bgs)

The Guaje Pumice Bed represents an air-fall tephra deposit of rhyolitic pumice that forms the base of the Otowi Member. The Guaje deposit was encountered from 866 ft to 889 ft bgs. Drill cuttings in this interval contain abundant lustrous vitric pumice lapilli (up to 15 mm in diameter) with trace occurrences of small volcanic lithic fragments. The deposit is poorly consolidated.

Puye Formation, Tpf (889–1187 ft bgs)

Puye Formation volcaniclastic sediments were encountered from 889 ft to 1187 ft bgs. The Puye Formation consists of alluvial fan deposits eroded from volcanic rocks in the nearby Jemez Mountains. Cuttings from this interval consist of grey, red, and purple dacitic and rhyolitic gravels, volcaniclastic sands, and minor devitrified pumice clasts. Cuttings are generally angular to subangular.

Tschicoma Formation Younger Dacite Flow Breccia, Tvt 2 (1187–1378.4 ft bgs)

The interval from 1187 ft to TD at 1378.4 ft bgs contains abundant reddish-brown oxidized/altered dacite that contains quartz and hornblende crystals. The size, angularity, and oxidation of cuttings suggest a flow breccia. Angular grey dacite clasts are mostly massive with minor vesicular clasts.

5.2 Groundwater

Drilling at R-58 proceeded without any indications of groundwater until 1240 ft bgs as noted by the drilling crew. The borehole was then advanced to the TD of 1378.4 ft bgs. The water level was 1240.2 ft bgs on September 18, 2015, before well installation. The DTW in the completed well was 1238.3 ft bgs on November 6.

During development, the average pumping rate was approximately 18 gallons per minute (gpm) with varying pump placement throughout the screened interval.

6.0 BOREHOLE LOGGING

A natural gamma ray log was recorded on September 18, 2015, inside the 10-in. casing from surface to 1378.4 ft bgs after the borehole was advanced to TD. Logging was conducted with Laboratory logging equipment and staff (Appendix C). A summary of the geophysical logging run is presented in Table 6.0-1.

7.0 WELL INSTALLATION R-58 MONITORING WELL

The R-58 well was installed between September 28 and November 5, 2015.

7.1 Well Design

The R-58 well was designed in accordance with requirements in the Consent Order, and NMED approved the final well design before the well was installed (Appendix D). The well was designed with a screened interval between 1257 ft and 1277 ft bgs to monitor the groundwater quality near the top of the regional aquifer within the dacite breccia.

7.2 Well Construction

From September 24 to October 2, 2015, the stainless-steel well casing, screens, and tremie pipe were decontaminated, and the workover rig and initial well construction materials were mobilized to the site.

The R-58 monitoring well was constructed of 5.0-in.-I.D./5.56-in.-O.D. type A304 passivated stainless-steel beveled casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. The screened section utilized two 10-ft lengths of 5.0-in.-I.D. rod-based 0.040-in. slot wire-wrapped screens to make up the 20-ft-long screen interval. All individual casing and screen sections were welded together using compatible stainless-steel welding rods. A 2-in. steel tremie pipe was used to deliver backfill and annular fill materials downhole during well construction. A short length of 16-in. (5.0-ft casing and shoe, from 91.2 ft to 96.2 ft bgs), 12-in. (5.0-ft casing and shoe, from 1022.4 ft to 1027.4 ft bgs), and 10-in. drill casing (6.1-ft casing and shoe, from 1371.9 ft to 1378.0 ft bgs) remain in the borehole. The 16-in. and 12-in. casing stubs were entombed in the upper bentonite seal, and the 10-in. casing stub was encased in slough and bentonite backfill at the bottom of the borehole.

A 10.4-ft-long stainless-steel sump was placed below the bottom of the well screen. The well casing was started into the borehole on September 28 at 0930 h. The well casing was hung by wireline with the bottom at 1287.7 ft bgs. Stainless-steel centralizers (two sets of four) were welded to the well casing approximately 2.0 ft above and below the screened interval. Figure 7.2-1 presents an as-built schematic showing construction details for the completed well.

The installation of annular materials began on October 9 after the bottom of the borehole was measured at 1374.1 ft bgs (approximately 4.3 ft of slough had accumulated in the borehole). The bentonite backfill was installed between October 9 and 11 from 1282.5 ft to 1374.1 ft bgs using 70.0 ft^3 of 3/8-in. bentonite chips and coated pellets. A summary of calculated volumes and annular materials used is presented in Table 7.2-1.

The filter pack was installed between October 11 and 16 from 1252.4 ft to 1282.5 ft bgs using 38.0 ft^3 of 10/20 silica sand. The actual volume of filter pack sand was 168% greater than the calculated volume and is likely the result of an oversized borehole caused by sloughing in the unconsolidated dacite breccia. The filter pack was surged to promote compaction. The fine sand collar was installed above the filter pack from 1250.3 ft to 1252.4 ft bgs using 2.5 ft^3 of 20/40 silica sand.

From October 17 to November 4, the bentonite seal was installed from 60.2 ft to 1250.3 ft bgs using 1152.9 ft^3 of 3/8-in. bentonite chips. On November 4, a cement seal was installed from 3.0 ft to 60.2 ft bgs. The top of the cement seal was verified on November 5 at 1000 h. The cement seal used 109.6 ft^3 of Portland Type I/II/V cement. This volume exceeded the calculated volume of 70.9 ft^3 by 55% and is likely the result of cement loss to the near-surface formations.

Operationally, well construction proceeded smoothly 12h/d, 7d/wk from September 28 to October 26 and 24 h/d, 7 d/wk from October 27 to November 4.

8.0 POST-INSTALLATION ACTIVITIES

Following well installation at R-58, the well was developed and aquifer pumping tests were conducted. The wellhead and surface pad were constructed, a geodetic survey was performed, and a dedicated sampling system was installed. Site restoration activities will be completed following the final disposition of contained drill cuttings and groundwater, per the NMED-approved waste-disposal decision trees for land application of drill cuttings and groundwater.

8.1 Well Development

The well was developed between November 6 and 13, 2015. Initially, the screened interval was swabbed and bailed to remove formation fines in the filter pack and well sump. Bailing continued until water clarity visibly improved. Final development was then performed with a submersible pump.

The swabbing tool employed was a 4.5-in.-O.D., 1-in.-thick nylon disc attached to a weighted steel rod. The wireline-conveyed tool was drawn repeatedly across the screened interval, causing a surging action across the screen and filter pack. The bailing tool was a 4.0-in.-O.D. by 21.0-ft-long carbon-steel bailer with a total capacity of 12 gal. The tool was repeatedly lowered by wireline, filled, withdrawn from the well, and emptied into the cuttings pit. Approximately 550 gal. of groundwater was removed during bailing activities.

After bailing, a 10-horsepower (hp), 4-in. Berkeley submersible pump was installed in the well for the final stage of well development. The screened interval was pumped from top to bottom and from bottom to top in 2-ft increments between November 9 and 11. Purging continued from November 11 to 13 with the pump intake set below the bottom of the well screen. Approximately 39,090 gal. of groundwater was purged with the submersible pump during well development.

Total Volumes of Introduced and Purged Water

During drilling, approximately 3645 gal. of potable water was added below the top of the regional aquifer at approximately 1240 ft bgs. Approximately 16,135 gal. was added during installation of the annular seals. In total, approximately 19,780 gal. of potable water was introduced to the borehole below 1240 ft bgs during project activities.

Approximately 39,640 gal. of groundwater was purged at R-58 during well development activities. Another 25,626 gal. was purged during aquifer testing. The total amount of groundwater purged during post-installation activities was 65,266 gal.

8.1.1 Well Development Field Parameters

During the pumping stage of well development, turbidity, temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and specific conductance in microSiemens per centimeter were measured. The required TOC and turbidity values for adequate well development are less than 2.0 ppm and less than 5 nephelometric turbidity units (NTU), respectively.

Field parameters were measured by collecting aliquots of groundwater from the discharge pipe with the use of a flow-through cell. The final parameters at the end of well development were pH of 8.04, temperature of 19.52ºC, specific conductance of 107 µS/cm, and turbidity of 5.0 NTU. Table B-2.2-1 in Appendix B shows field parameters and purge volumes measured during well development.

During 21-h aquifer test, the turbidity values ranged from 4 to 17.6 NTU, with the final recorded value of 5.8 NTU.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-58 between November 14 and 19, 2015. On November 14, the aquifer test pump assembly was installed and the well was pumped to fill the drop pipe for subsequent testing. Two short-duration tests with short-duration recovery periods were performed on November 16. A 21-h pump test with the pump intake at 1267.2 ft bgs, followed by a 24-h recovery period completed the testing of the screened interval. The test was scheduled for 24 h but was started late because of inclement weather and a Laboratory delayed start. The average pumping rate for the 21-h test was approximately 18.8 gpm.

A 10-hp pump was used for the aquifer tests. A total of approximately 25,626 gal. of groundwater was purged during aquifer testing. Turbidity, temperature, pH, DO, ORP, and specific conductance were measured during the aquifer test. Measured parameters are presented in Appendix B. The R-58 aquifer test results and analysis are presented in Appendix E.

8.3 Dedicated Sampling System Installation

The dedicated sampling system for R-58 was installed between January 9 and 15, 2016. The pumping system utilizes an environmentally retrofitted 4-in. 5-hp Grundfos submersible pump set in a shroud near the top of the screened interval. The pump column is constructed of 1-in. threaded/coupled passivated stainless-steel pipe. One 1-in. stainless-steel check valve was installed at the top of the lowermost pipe joint above the pump shroud to provide redundancy to the built-in check valve in the top of the pump body. A weep valve was installed at the bottom of the uppermost pipe joint to protect the pump column from freezing. To measure water levels in the well, two 1-in.-I.D. schedule 80 polyvinyl chloride (PVC) pipes were installed to sufficient depth to set a dedicated transducer and to provide access for manual water-level measurements. The PVC transducer tubes are equipped with 9-in. sections of 0.010-in. slot screen with a threaded end cap on the bottom of each tube. An In-Situ Level Troll 500 30-psig transducer was installed in one of the PVC tubes to monitor the water level in the well’s screened interval.

Sampling system details for R-58 are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes for the well. Figure 8.3-1c presents a performance curve for the submersible pump installed.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 10 in. thick, was installed at the R-58 wellhead. The concrete pad was slightly elevated above the ground surface and crowned to promote runoff. The pad will provide long-term structural integrity for the well. A brass survey pin was embedded in the northwest corner of the pad. A 16-in.-O.D. steel protective casing with a locking lid was installed around the stainless-steel well riser. A total of four removable bollards, painted yellow for visibility, were set at the outside edges of the pad to protect the well from traffic. Details of the wellhead completion are presented in Figure 8.3-1a.

8.5 Geodetic Survey

A New Mexico licensed professional land surveyor conducted a geodetic survey on January 5, 2016 (Table 8.5-1). The survey data conform to Laboratory Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA-D802, “Geospatial Positioning Accuracy Standard for A/E/C and Facility Management.” All coordinates are expressed relative to the New Mexico State Plane Coordinate System Central Zone (North American Datum [NAD] 83); elevation is expressed in feet above mean sea level (amsl) using the National Geodetic Vertical Datum of 1929. Survey points include ground surface elevation near the concrete pad, the top of the brass pin in the concrete pad, the top of the well casing, and the top of the protective casing for the R-58 monitoring well.

8.6 Waste Management and Site Restoration

Waste generated from the R-58 project included drilling fluids, purged groundwater, drill cuttings, decontamination water, and contact waste. A summary of the waste characterization samples collected during drilling, construction, and development of the R-58 well is presented in Table 8.6-1.

All waste streams produced during drilling and development activities were sampled in accordance with “Waste Characterization Strategy Form for R-47, R-58, R-63i, CdV-9-1i” (LANL 2013, 244887).

Fluids produced during drilling, well development, and aquifer testing are expected to be land-applied after a review of associated analytical results per the waste characterization strategy form (WCSF) and the ENV-RCRA-QP-010.2, Land Application of Groundwater. If it is determined the drilling fluids are nonhazardous but cannot meet the criteria for land application, they will be evaluated for treatment and disposal at one of the Laboratory’s wastewater treatment facilities. If analytical data indicate the drilling fluids are hazardous/nonradioactive or mixed low-level waste, the drilling fluids will be disposed of at an authorized facility.

Cuttings produced during drilling are anticipated to be land-applied after a review of associated analytical results per the WCSF and ENV-RCRA-QP-011.2, Land Application of Drill Cuttings. If the drill cuttings do not meet the criteria for land application, they will be disposed of at an authorized facility.

Decontamination fluid used for cleaning equipment is containerized. The fluid waste was sampled and will be disposed of at an authorized facility. Characterization of contact waste will be based upon acceptable knowledge, pending analyses of the waste samples collected from the drill cuttings, purge water, and decontamination fluid.

Site restoration activities will include removing drilling fluids and cuttings from the pit and managing the fluids and cuttings as described above, removing the polyethylene liner, removing the containment area berms, and backfilling and regrading the containment area, as appropriate.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Drilling, sampling, and well construction at R-58 were performed as specified in "Drilling Work Plan for Regional Aquifer Well R-58" (LANL 2013, 239226).

10.0 ACKNOWLEDGMENTS

Boart Longyear drilled and installed the R-58 monitoring well.

David C. Schafer designed, implemented, and analyzed the aquifer tests.

TerranearPMC provided oversight on all preparatory and field-related activities.

11.0 REFERENCES AND MAP DATA SOURCES

11.1 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 or ESH ID. This information is also included in text citations. ER IDs were assigned by the Environmental Programs Directorate's Records Processing Facility (IDs through 599999), and ESH IDs are assigned by the Environment, Safety, and Health (ESH) Directorate (IDs 600000 and above). IDs are used to locate documents in the Laboratory's Electronic Document Management System and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the ESH 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), December 2012. "Drilling Work Plan for Regional Aquifer Well R-58," Los Alamos National Laboratory document LA-UR-12-26784, Los Alamos, New Mexico. (LANL 2012, 212117)

LANL (Los Alamos National Laboratory), April 2013. "Drilling Work Plan for Well CdV-9-1(i)," Los Alamos National Laboratory document LA-UR-13-20779, Los Alamos, New Mexico. (LANL 2013, 239226)

LANL (Los Alamos National Laboratory), July 10, 2013. "Waste Characterization Strategy Form for R-47, R-58, R-63i, CdV-9-1i," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2013, 244887)

LANL (Los Alamos National Laboratory), June 26, 2014. "Storm Water Pollution Prevention Plan, Regional Wells (R-Wells) Drilling, Los Alamos National Laboratory, Revision 1," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2014, 601293)

NMED (New Mexico Environment Department), December 31, 2012. "Approval with Modifications, Drilling Work Plan for Regional Aquifer Well R-58," New Mexico Environment Department letter to P. Maggiore (DOE-LASO) and J.D. Mousseau (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2012, 521741)

TerranearPMC, August 2015. “Field Implementation Plan for Regional Aquifer Well R-58,” plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2015, 601274)

TerranearPMC, August 25, 2015. “IWD [Integrated Work Document] for Drilling and Installation of LANL Well R-58,” Los Alamos, New Mexico. (TerranearPMC 2015, 601273)

11.2 Map Data Sources

Point Feature Locations of the Environmental Restoration Project Database; Los Alamos National Laboratory, Waste and Environmental Services Division, EP2008-0109; 12 April 2010.

Hypsography, 100 and 20 Foot Contour Interval; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program; 1991.

Surface Drainages, 1991; Los Alamos National Laboratory, ENV Environmental Remediation and Surveillance Program, ER2002-0591; 1:24,000 Scale Data; Unknown publication date.

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 28 May 2009.

Dirt 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 Division; 4 December 2009.

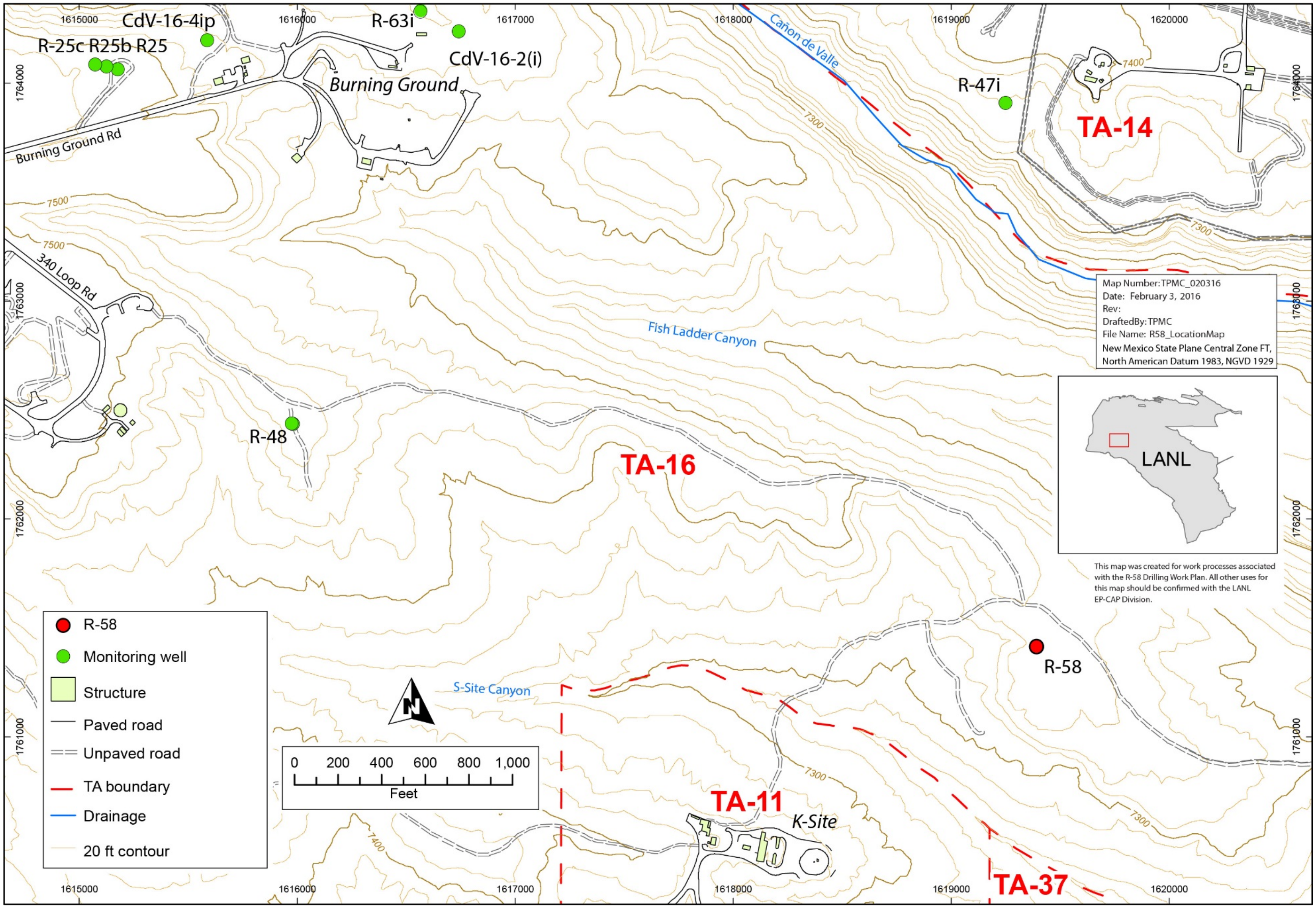

Figure 1.0-1 Location of monitoring well R-58

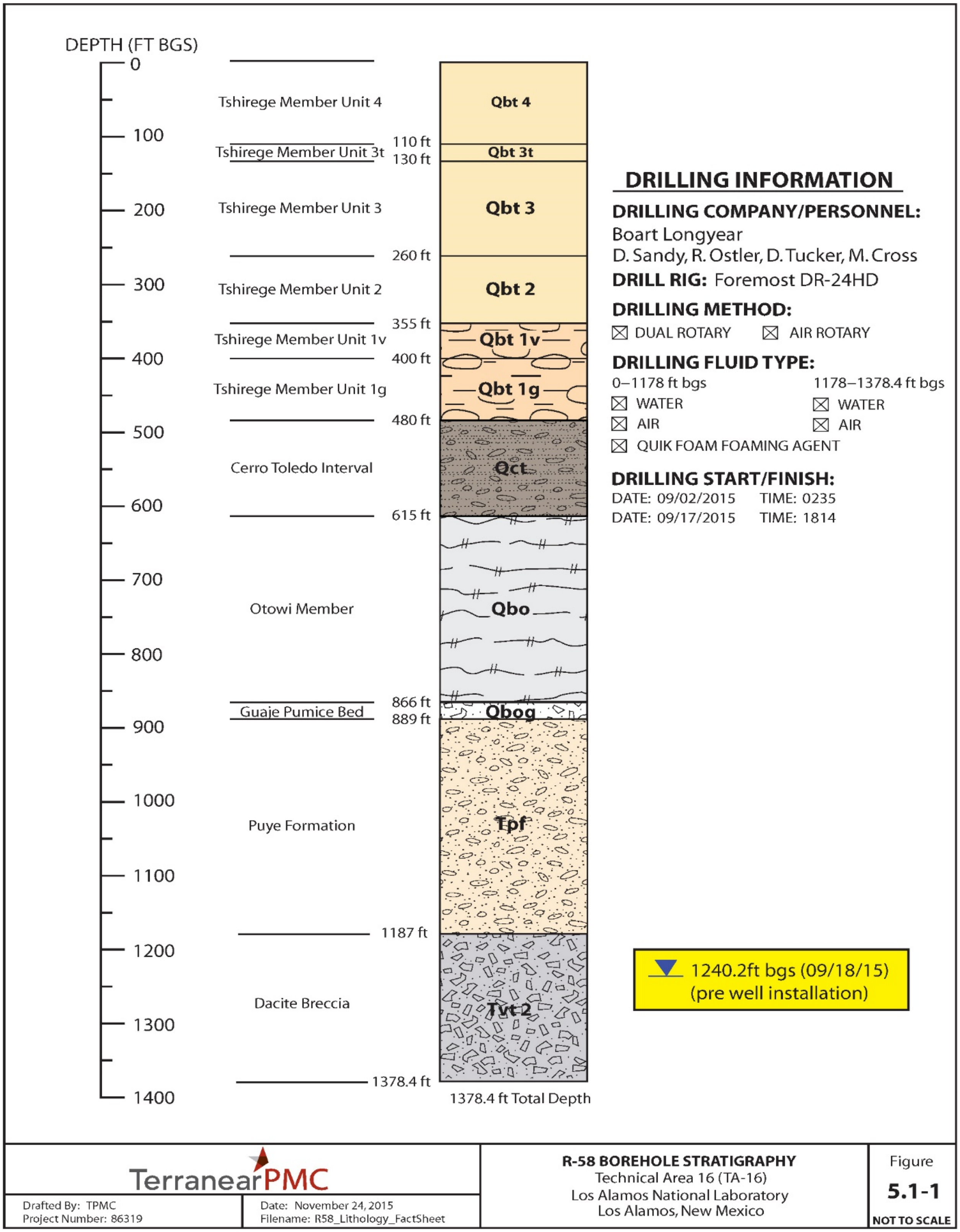

Figure 5.1-1 Monitoring well R-58 borehole stratigraphy

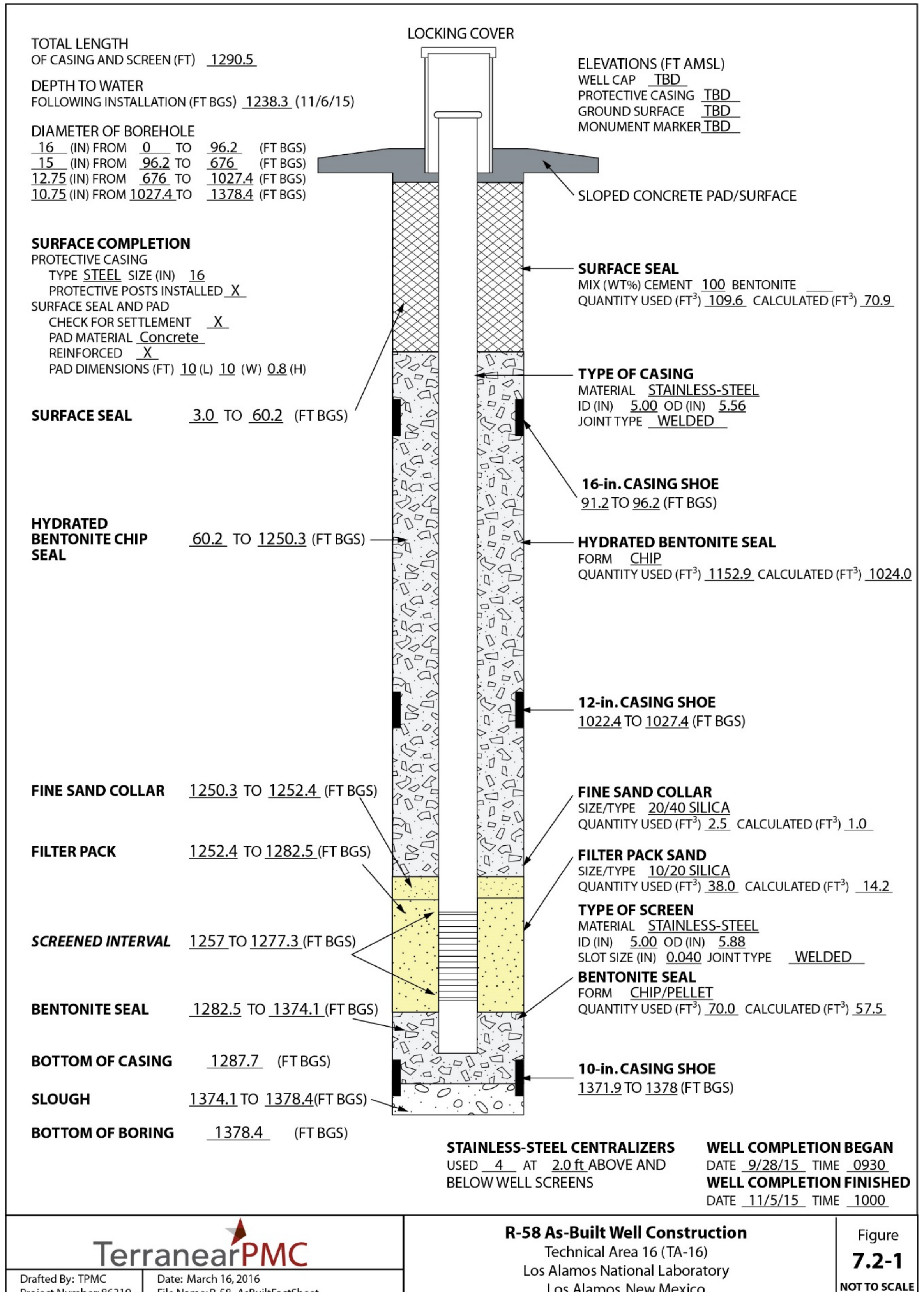

Figure 7.2-1 Monitoring well R-58 as-built well construction diagram

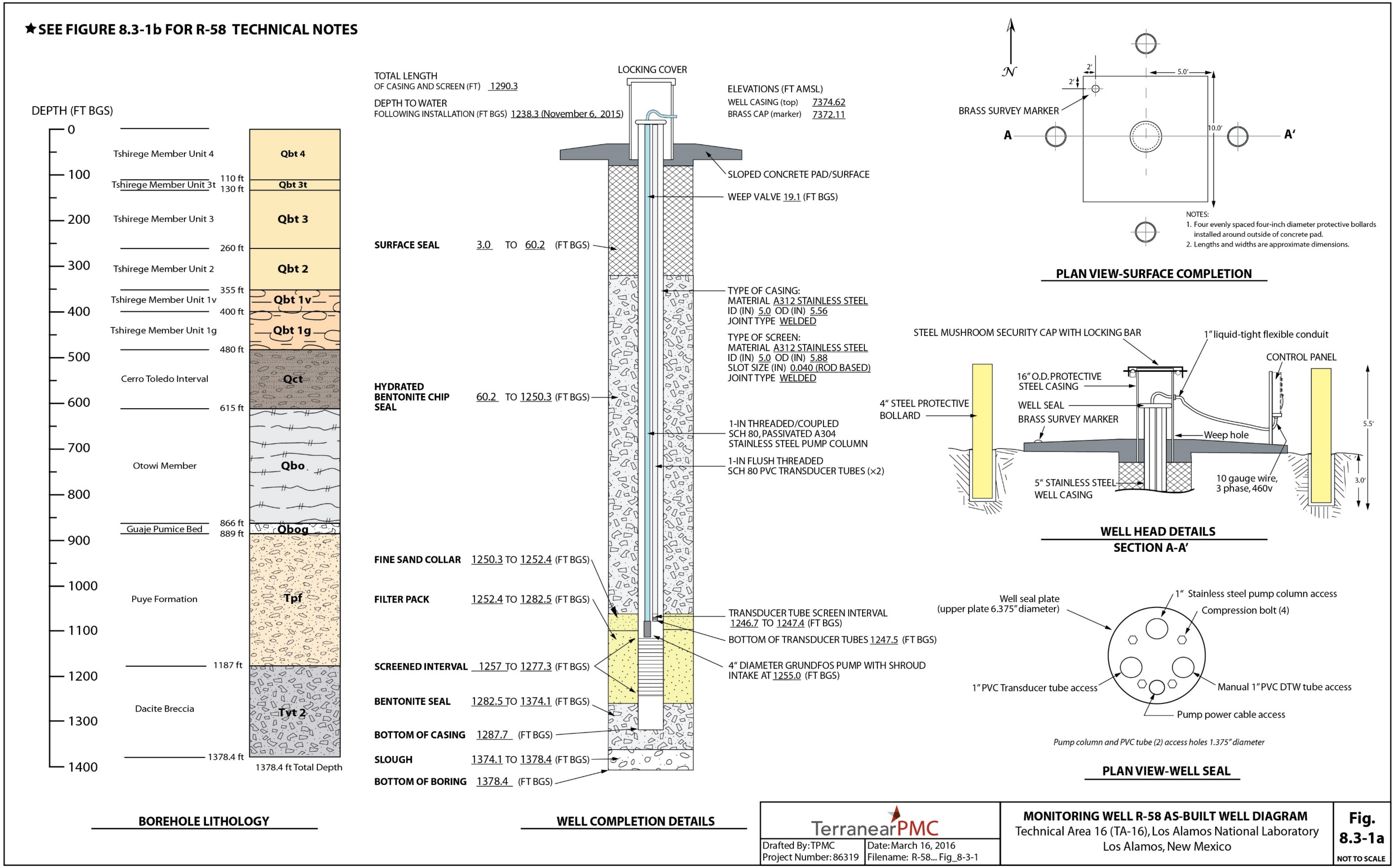

Figure 8.3-1a Monitoring well R-58 as-built diagram with borehole lithology and technical well completion details

R-58 TECHNICAL NOTES:

SURVEY INFORMATION*

Brass Marker

Northing:	1761298.75 ft
Easting:	1619435.65 ft
Elevation:	7372.11 ft AMSL

Well Casing (top of stainless steel)

Northing:	1761295.35 ft
Easting:	1619437.86 ft
Elevation:	7374.62 ft AMSL

BOREHOLE GEOPHYSICAL LOGS

LANL natural gamma log

DRILLING INFORMATION

Drilling Company
Boart Longyear

Drill Rig
Foremost DR-24HD

Drilling Methods
Dual Rotary
Fluid-assisted air rotary, Foam-assisted air rotary

Drilling Fluids
Air, potable water, AQF-2 Foam (to 1178 ft bgs)

MILESTONE DATES

Drilling

Start:	09/02/2015
Finished:	09/17/2015

Well Completion

Start:	09/28/2015
Finished:	11/05/2015

Well Development

Start:	11/06/2015
Finished:	11/13/2015

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Total Volume Purged: 39,640 gal.

Parameter Measurements (Final)

pH:	8.04
Temperature:	19.52°C
Specific Conductance:	107 µS/cm
Turbidity:	5.0 NTU

AQUIFER TESTING

Constant Rate Pumping Test

Water Produced:	25,626 gal.
Average Flow Rate:	18.8 gpm
Performed on:	11/14–19/2015

DEDICATED SAMPLING SYSTEM

Pump (Shrouded)
Make: Grundfos
Model: 10S50-930CBM
S/N: P115450003
Environmental retrofit
Top of pump intake 1252.6 ft bgs
Base of shroud 1255.0 ft bgs

Motor
Make: Franklin Electric
Model: 2343278602
5 hp, 3-phase, 460V

Pump Shroud
Pumps of Oklahoma custom 4.6-in. O.D. schd. 5
A304 stainless steel with schd. 40 pipe connections

Pump Column
1-in. threaded/coupled schd. 80, pickled and
passivated A304 stainless steel tubing
Weep valve installed at 19.1 ft bgs
Check valve installed at 1222.5 ft bgs

Transducer Tubes
2 × 1-in. flush threaded schd. 80 PVC tubing,
0.010-in. slot screens at 1246.7-1247.4 ft bgs

Transducer
Make: In-Situ, Inc.
Model: Level TROLL 500
30 psig range (vented)
S/N: 431623

NOTES:
* Coordinates based on New Mexico State Plane Grid Coordinates, Central Zone (NAD83);
Elevation expressed in feet amsl using the National Geodetic Vertical Datum of 1929.

TerranearPMC		R-58 TECHNICAL NOTES Technical Area 16 (TA-16) Los Alamos National Laboratory Los Alamos, New Mexico	Fig. 8.3-1b NOT TO SCALE
Drafted By: TPMC Project Number: 86319	Date: February 3, 2016 Filename: R-58_TechnicalNotes_Fig8.3-1b		

Figure 8.3-1b As-built technical notes for monitoring well R-58

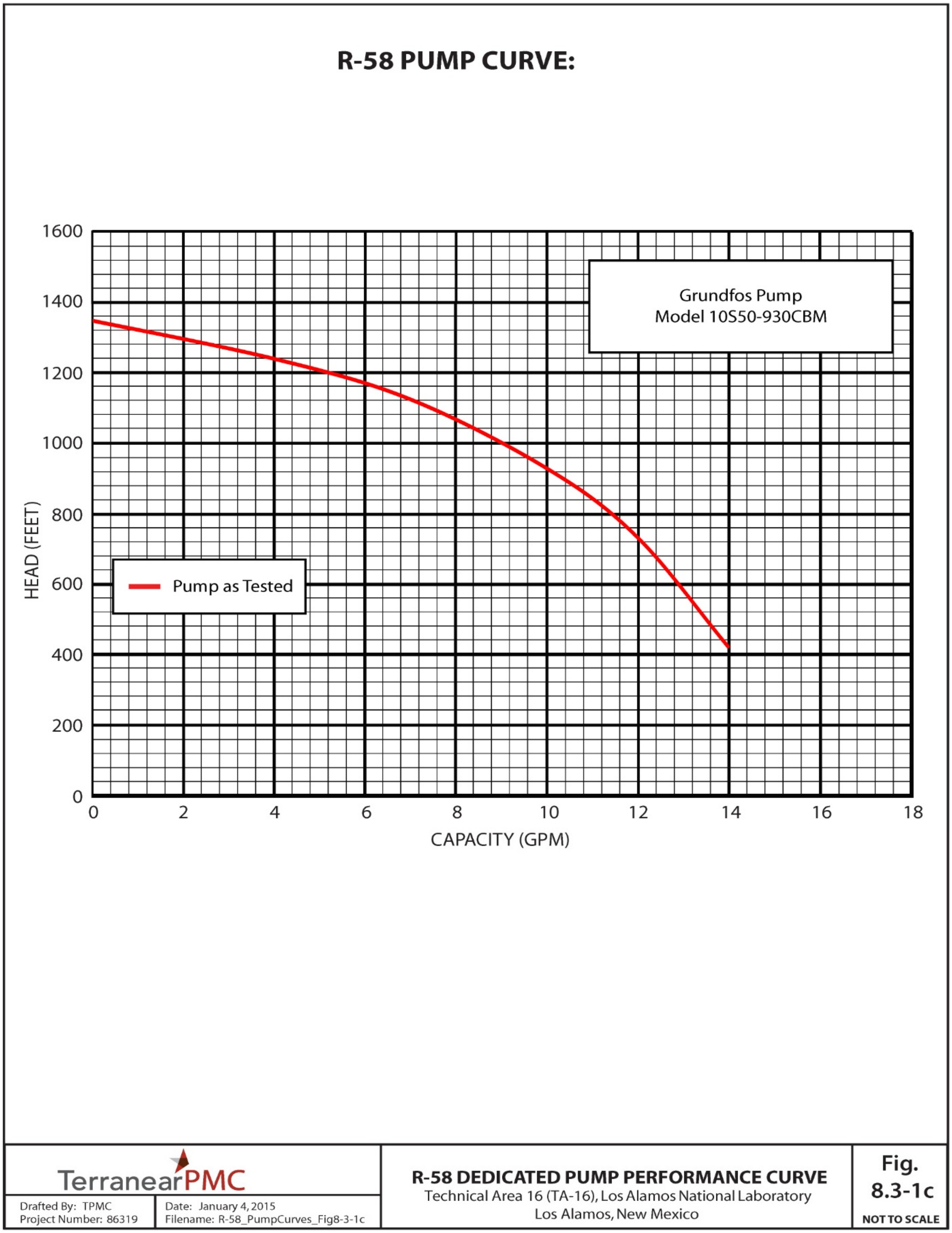

Figure 8.3-1c Pump curve for monitoring well R-58

Table 3.1-1
Fluid Quantities Used during R-58 Drilling and Well Construction

Date	Depth Interval (ft bgs)	Water (gal.)	Cumulative Water (gal.)	Quick Foam (gal.)	Cumulative Quick Foam (gal.)
Drilling					
9/1/15	0–36	555	555	0	0
9/2/15	36–296	2546	3101	15.75	15.75
9/3/15	296–676	3881	6982	40	55.75
9/6/15	600a–851	3350	10,332	16	71.75
9/7/15	851–1027	3860	14,192	25	96.75
9/14/15	1022[a]–1121	2385	16,577	12.75	109.5
9/15/15	1121–1178	1350	17,927	6	115.5
9/16/15	1178–1278	1985	19,912	n/a[b]	n/a
9/17/15	1278–1378.4	2800	22,712	n/a	n/a
Well Construction					
10/9/15	1374.1–1355	1488	1488	n/a	n/a
10/10/15	1355–1321	2265	3753	n/a	n/a
10/11/15	1321–1283	2888	6641	n/a	n/a
10/12/15	1283–1270	1381	8022	n/a	n/a
10/13/15	1270–1261	1079	9101	n/a	n/a
10/14/15	1261–1257	589	9690	n/a	n/a
10/15/15	1257–1255	1265	10,955	n/a	n/a
10/16/15	1255–1252	319	11,274	n/a	n/a
10/17/15	1252–1241	2034	13,308	n/a	n/a
10/18/15	1241–1220	2827	16,135	n/a	n/a
10/19/15	1220–1188	3600	19,735	n/a	n/a
10/21/15	1188–1165	1514	21,249	n/a	n/a
10/22/15	1165–1101	2978	24,227	n/a	n/a
10/23/15	1101–1032	3324	27,551	n/a	n/a
10/24/15	1032–1028	384	27,935	n/a	n/a
10/28/15	1028–1007	79	28,014	n/a	n/a
10/29/15	1007–936	541	28,555	n/a	n/a
10/30/15	936–859	337	28,892	n/a	n/a
10/31/15	859-651	679	29,571	n/a	n/a
11/1/15	651–472	665	30,236	n/a	n/a
11/2/15	472–223	900	31,136	n/a	n/a
11/3/15	223–60	459	31,595	n/a	n/a
11/4/15	60–3	550	32,145	n/a	n/a
Total Water Volume (gal.)					
R-58	54,857				

[a] Drilled out slough.

[b] n/a = Not applicable.

Table 4.2-1
Summary of Groundwater Screening Samples Collected during Well Development and Aquifer Testing at Well R-58

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Well Development					
R-58	CACV-15-104376	11/10/15	1277.3	Groundwater, Pumped	TOC
R-58	CACV-15-104377	11/11/15	1277.3	Groundwater, Pumped	TOC
R-58	CACV-15-104378	11/12/15	1277.3	Groundwater, Pumped	TOC
R-58	CACV-15-104379	11/13/15	1277.3	Groundwater, Pumped	TOC
Aquifer Testing					
R-58	CACV-15-104381	11/18/15	1254.0	Groundwater, Pumped	TOC, Alkalinity
R-58	CACV-15-104382	11/18/15	1254.0	Groundwater, Pumped	Anions, Metals

Table 6.0-1
R-58 Geophysical Logging Run

Date	Logging Interval	Description
9/18/15	0–1378.4 ft bgs	Laboratory natural gamma ray log run through 10-in. casing to TD at 1378.4 ft bgs

Table 7.2-1
R-58 Monitoring Well Annular Fill Materials

Material	Calculated Volume	Actual Volume
Upper surface seal: cement slurry	70.6 ft^3	109.6 ft^3
Upper bentonite seal: bentonite chips	1024.0 ft^3	1152.9 ft^3
Fine sand collar: 20/40 silica sand	1.0 ft^3	2.5 ft^3
Filter pack: 10/20 silica sand	14.2 ft^3	38.0 ft^3
Backfill: bentonite pellets/chips	57.5 ft^3	70.0 ft^3

Table 8.5-1
R-58 Survey Coordinates

Identification	Northing	Easting	Elevation
R-58 brass pin embedded in pad	1761298.75	1619435.65	7372.11
R-58 ground surface near pad	1761300.82	1619432.36	7372.02
R-58 top of stainless-steel well casing	1761295.36	1619437.86	7374.62
R-58 top of 16-in. protective casing	1761294.89	1619437.96	7375.61

Note: All coordinates are expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83); elevation is expressed in ft amsl using the National Geodetic Vertical Datum of 1929.

Table 8.6-1
Summary of Waste Samples Collected during
Drilling, Development and Sample System Installation at R-58

Location ID	Sample ID	Date Collected	Description	Sample Type
R-58	WST16-15-104049	9/2/15	Drill fluids VOC[a]/SVOC[b] initial sample–UF[c]	Liquid
R-58	WST16-15-104052	9/2/15	Drill fluids VOC/SVOC initial sample–UF FD[d]	Liquid
R-58	WST16-15-104055	9/2/15	Drill fluids VOC/SVOC initial sample–UF FTB[e]	Liquid
R-58	WST16-15-104050	9/6/15	Drill fluids VOC/SVOC midpoint sample–UF	Liquid
R-58	WST16-15-104053	9/6/15	Drill fluids VOC/SVOC midpoint sample–UF FD	Liquid
R-58	WST16-15-104056	9/6/15	Drill fluids VOC/SVOC midpoint sample–UF FTB	Liquid
R-58	WST16-15-104051	9/17/15	Drill fluids VOC/SVOC final sample–UF	Liquid
R-58	WST16-15-104054	9/17/15	Drill fluids VOC/SVOC final sample–UF FD	Liquid
R-58	WST16-15-104057	9/17/15	Drill fluids VOC/SVOC final sample–UF FTB	Liquid
R-58	WST16-16-105652	10/15/15	Drill fluids non-VOC sample–UF	Liquid
R-58	WST16-16-105651	10/15/15	Drill fluids non-VOC sample–F[f]	Liquid
R-58	WST16-15-104058	9/2/15	Drill cuttings VOC initial sample	Solid
R-58	WST16-15-104061	9/2/15	Drill cuttings VOC initial sample–FTB	Solid
R-58	WST16-15-104059	9/6/15	Drill cuttings VOC midpoint sample	Solid
R-58	WST16-15-104062	9/6/15	Drill cuttings VOC midpoint sample–FTB	Solid
R-58	WST16-15-104060	9/17/15	Drill cuttings VOC final sample	Solid
R-58	WST16-15-104063	9/17/15	Drill cuttings VOC final sample–FTB	Solid
R-58	WST16-16-105650	10/15/15	Drill cuttings non-VOC sample	Solid
R-58	WST16-16-110082	1/26/16	New Mexico Special Waste sample	Solid
R-58	WST16-16-110083	1/26/16	New Mexico Special Waste sample–FTB	Solid
R-58	WST16-16-109653	12/16/15	Decontamination fluids sample–F	Liquid
R-58	WST16-16-109654	12/16/15	Decontamination fluids sample–UF	Liquid
R-58	WST16-16-109655	12/16/15	Decontamination fluids sample–FD	Liquid
R-58	WST16-16-109656	12/16/15	Decontamination fluids sample–FTB	Liquid
R-58	WST16-16-109657	12/16/15	Development fluids sample–F	Liquid
R-58	WST16-16-109658	12/16/15	Development fluids sample–UF	Liquid
R-58	WST16-16-109659	12/16/15	Development fluids sample–FD	Liquid
R-58	WST16-16-109660	12/16/15	Development fluids sample–FTB	Liquid

[a] VOC = Volatile organic compound.
[b] SVOC = Semivolatile organic compound.
[c] UF = Unfiltered sample.
[d] FD = Field duplicate.
[e] FTB = Field trip blank.
[f] F = Filtered sample.

Appendix A

Borehole R-58 Lithologic Log

BOREHOLE IDENTIFICATION (ID): R-58	**TECHNICAL AREA (TA):** 16		
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME:** 9/02/15; 0235		**END DATE/TIME:** 9/17/15; 1814
DRILLING METHOD: Rotary and Dual Rotary	**MACHINE**: Foremost DR24 HD		**SAMPLING METHOD:** Grab
GROUND ELEVATION: 7372.02 ft amsl			**TOTAL DEPTH:** 1378.4 ft
DRILLERS: M. Cross, R. Ostler, D. Sandy, D. Tucker	**SITE GEOLOGISTS:** T. Sower, J. Jordan, E. Tow, L. Anderson		

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
0–15	**UNIT 4 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Rhyolitic Tuff—very pale orange (10YR 8/2) to orange-brown (10YR 7/4) poorly welded, crystal- and lithic-rich tuff. 0–15 ft WR/+10F/+35F: 55–65% quartz and sanidine crystals; 30%–40% powdered ash-flow tuff and welded tuff fragments; 5% rhyolitic and dacitic lithic clasts.	Qbt 4	Note: Drill cuttings for descriptive analysis were collected at 5-ft intervals from ground surface to borehole total depth (TD) at 1378.4 ft bgs. Unit 4 of the Tshirege Member of the Bandelier Tuff (Qbt 4), encountered from 0 to 110 ft below ground surface (bgs), is 110 ft thick.
15–25	Rhyolitic Tuff—very pale orange (10YR 8/2) to orange-brown (10YR 7/4) poorly welded, crystal- and lithic-rich tuff. 15–25 ft WR: 85% powdered ash flow tuff and welded tuff fragments; 10% rhyolitic and dacitic lithic clasts; 5% quartz and sanidine crystals. +10F: 70%–95% crystal-bearing ash-flow tuff fragments; 5%–30% dacitic and rhyolitic lithic clasts. +35F: 70%–75% quartz and sanidine crystals; 20%–25% tuff fragments; 5% dacitic lithic clasts.	Qbt 4	
25–95	Rhyolitic Tuff— Light gray (N7) to dark gray (N3) poorly welded, crystal- and lithic-rich tuff. 25%–95 ft WR: 60% powdered ash-flow tuff and welded tuff fragments; 30% rhyolitic and dacitic lithic clasts; 10% quartz and sanidine crystals. +10F: 60%–70% dacitic and rhyolitic lithic clasts; 30%–40% crystal-bearing ash-flow tuff fragments. +35F: 85%–90% quartz and sanidine crystals; 5%–10% tuff fragments; 5%–10% dacitic lithic clasts.	Qbt 4	
95–105	Rhyolitic Tuff— Light gray (N7) to dark gray (N3) poorly welded, crystal- and lithic-rich tuff. 95%–105 ft WR: 85% powdered ash flow tuff and welded tuff fragments; 10% rhyolitic and dacitic lithic clasts; 5% quartz and sanidine crystals. +10F: 50%–60% crystal-bearing ash-flow tuff fragments; 40%–50% dacitic and rhyolitic lithic clasts. +35F: 60%–70% quartz and sanidine crystals; 25%–35% tuff fragments; 5% dacitic lithic clasts.		

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
105–110	Rhyolitic Tuff— Light gray (N7) to dark gray (N3) poorly welded, crystal- and lithic-rich tuff. 25–95 ft WR: 60% powdered ash flow tuff and welded tuff fragments; 30% rhyolitic and dacitic lithic clasts; 10% quartz and sanidine crystals. +10F: 60%–70% dacitic and rhyolitic lithic clasts; 30%–40% crystal-bearing ash flow tuff fragments. +35F: 85%–90% quartz and sanidine crystals; 5%–10% tuff fragments; 5%–10% dacitic lithic clasts.	Qbt 4	The Qbt 4/Qbt 3t contact, estimated at 110 ft bgs, is based on natural gamma logging and drilling noted in harder rock.
110–130	**UNIT 3t OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Rhyolitic Tuff— Light gray (N7) to medium light gray (N6) poorly welded, crystal- and lithic-rich tuff. 25–95 ft WR: 60% powdered ash flow tuff and welded tuff fragments; 30% rhyolitic and dacitic lithic clasts; 10% quartz and sanidine crystals. +10F: 60%–70% dacitic and rhyolitic lithic clasts; 30%–40% crystal-bearing ash-flow tuff fragments. +35F: 85–90% quartz and sanidine crystals; 5%–10% tuff fragments; 5%–10% dacitic lithic clasts.	Qbt 3t	Unit 3t of the Tshirege Member of the Bandelier Tuff (Qbt 3t), encountered from 110 to 130 ft bgs, is approximately 20 ft thick. The Qbt 3t/Qbt 3 contact, estimated at 130 ft bgs, is based on increase in crystals in cuttings.
130–155	**UNIT 3 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Rhyolitic Tuff—light gray (N7) to medium dark gray (N4) poorly welded, crystal- and lithic-rich tuff. 130–155 ft WR/+10F/+35: 40%–70% tuff fragments; 30%–60% quartz and sanidine crystals; <10% gray rhyolitic and dacitic lithic clasts.	Qbt 3	Unit 3 of the Tshirege Member of the Bandelier Tuff (Qbt 3), encountered from 130 to 260 ft bgs, is approximately 130 ft thick.
155–200	Rhyolitic Tuff—light gray (N7) to medium dark gray (N4) poorly welded, crystal- and lithic-rich tuff. 155–200 ft WR/+10F: 60–80% tuff fragments; 20%–40% quartz and sanidine crystals; <10% gray rhyolitic and dacitic lithic clasts. +35F: 80%–95% quartz and sanidine crystals; 5%–20% tuff fragments; <5% dacitic lithic clasts.	Qbt 3	
200–215	Rhyolitic Tuff—light gray (N7) to pale yellowish brown (10TR 6/2) poorly welded, crystal-rich tuff. 200–215 ft WR: 60%–80% quartz and sanidine crystals; 20–40% tuff fragments; <5% gray rhyolitic and dacitic lithic clasts. +10F: 50%–60% quartz and sanidine crystals; 40%–50% tuff fragments; <5% gray rhyolitic and dacitic lithic clasts. +35F: 95%–100% quartz and sanidine crystals; <5% tuff fragments; <5% dacitic lithic clasts.	Qbt 3	

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
215–230	Rhyolitic Tuff—light gray (N7 to pale yellowish brown (10TR 6/2) poorly welded, crystal- and lithic-rich tuff. 155–200 ft WR/+10F: 60%–80% tuff fragments; 20%–40% quartz and sanidine crystals; <10% gray rhyolitic and dacitic lithic clasts. +35F: 80%–95% quartz and sanidine crystals; 5%–20% tuff fragments; <5% dacitic lithic clasts.	Qbt 3	
230–260	Rhyolitic Tuff—light gray (N7) to pale yellowish brown (10TR 6/2) very poorly welded, crystal-rich tuff. 230–260 ft WR/+10: 70%–80% tuff fragments; 20%–30% quartz and sanidine crystals. +35F: 60%–70% tuff fragments; 30%–40% quartz and sanidine crystals	Qbt 3	The Qbt 3/Qbt 2 contact, estimated at 260 ft bgs, is based on decrease in crystals in cuttings.
260–300	**UNIT 2 OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—gray (N6) to light brown (5YR 5/6), strongly welded, crystal-bearing tuff. 260–300 ft WR/+10/+35: 60%–70% welded tuff fragments; 30%–40% quartz and sanidine crystals.	Qbt 2	Unit 2 of the Tshirege Member of the Bandelier Tuff (Qbt 2), encountered from 260 to 355 ft bgs, is approximately 95 ft thick.
300–310	Rhyolitic Tuff—gray (N6) to pale yellowish brown (10YR 6/2), strongly welded, crystal-bearing tuff. 300–310 ft WR/+35: 50%–60% quartz and sanidine crystals; 40%–50% tuff fragments. +10F: Insufficient returns to sieve.	Qbt 2	Note: Poor recovery in +10
310–315	Rhyolitic Tuff—gray (N6) to light brown (5YR 5/6), strongly welded, crystal-bearing tuff. 260–300 ft WR/+10/+35: 60%–70% welded tuff fragments; 30%–40% quartz and sanidine crystals.	Qbt 2	
315–355	Rhyolitic Tuff—gray (N6) to pale reddish brown (10R 7/2), moderately welded, crystal-rich tuff 315–355 ft WR: 70%–80% tuff fragments; 20%–30% quartz and sanidine crystals. +10F: 70%–80% crystal-bearing tuff fragments; 20%–30% quartz and sanidine crystals. +35F: 70%–90% quartz and sanidine crystals; 5%–30% welded tuff fragments; <5% white to orange devitrified pumice clasts.	Qbt 2	The Qbt 2/Qbt 1v contact, estimated at 355 ft bgs, is based on increase in crystals in cuttings.

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
355–400	**UNIT 1v OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—light gray (N7) to pale brown (5YR 5/2), poorly welded, crystal-rich tuff, with abundant light gray (N7) dacitic lithics. 355–400 ft WR/+10: 50%–60% light gray lithic fragments; 30%–40% crystal-rich tuff fragments; 10% quartz and sanidine crystals. +35F: 85%–95% quartz and sanidine crystals; 5%–10% lithics; <5% tuff fragments.	Qbt 1v	Unit 1v of the Tshirege Member of the Bandelier Tuff (Qbt 1v), encountered from 355 to 400 ft bgs, is approximately 45 ft thick. The Qbt 1v/Qbt 1g contact, estimated at 400 ft bgs, is based on natural gamma logging and the presence of glassy pumice fragments.
400–405	**UNIT 1g OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—light gray (N7), poorly welded, crystal-rich tuff, with abundant light gray (N7) rhyolitic and dacitic lithics. 400–405 ft WR: 50%–60% quartz and sanidine crystals; 20%–30%.light gray lithic fragments; 20%–30% pumice and tuff fragments. +10F: 80%–90% light gray dacite lithic fragments; <10% pumice and tuff fragments; <10% euhedral quartz and sanidine crystals. +35F: 85%–95% quartz and sanidine crystals; 5%–10% dacite lithics; <5% tuff fragments and pumice.	Qbt 1g	Unit 1g of the Tshirege Member of the Bandelier Tuff (Qbt 1g), encountered from 400 to 480 ft bgs, is approximately 80 ft thick.
405–465	Rhyolitic Tuff—light gray (N7), poorly welded, crystal-rich tuff, with abundant light gray (N7) rhyolitic and dacitic lithics. 405–465 ft WR/+10F: 80%–90% light gray dacite lithic fragments; <10% pumice and tuff fragments; <10% euhedral quartz and sanidine crystals. +35F: 75%–85% quartz and sanidine crystals; 15%–20% dacite lithics; <5% tuff fragments and pumice.	Qbt 1g	
465–480	Rhyolitic Tuff—light gray (N7), poorly welded, crystal-rich tuff, with abundant light gray (N7) rhyolitic and dacitic lithics. 465–480 ft WR/+10F: 90% light gray dacite lithic fragments; 5% pumice and tuff fragments; <5% euhedral quartz and sanidine crystals. +35F: 75%–85% quartz and sanidine crystals; 15%–20% dacite lithics; <5% tuff fragments and pumice.	Qbt 1g	The Qbt 1g/Qct contact, estimated at 480 ft bgs, is based on color change and increase abundance of pumice in cuttings.

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
480–500	**CERRO TOLEDO INTERVAL** Pumiceous Sediments—sand to gravel size angular to subangular white pumice clasts with minor quartz, obsidian, and volcaniclastic sediments. 480–500 ft WR/+10F: 60%–80% pumice clasts with orange surface alteration up to 15 mm; 20%–40% gray dacite and varicolored rhyolite clasts up to 15 mm; trace quartz grains. +35F: 50%–70% quartz and sanidine grains; 20%–30% pumice clasts; 10%–20% dacite and rhyolite grains; trace obsidian fragments.	Qct	The Cerro Toledo interval (Qct), encountered from 480 to 615 ft bgs, is approximately 135 ft thick.
500–510	Pumiceous Sediments—sand to gravel size angular to subangular white pumice clasts with minor quartz, obsidian, and volcaniclastic sediments. 500–510 ft WR/+10F: 50%–60% pumice clasts with orange surface alteration up to 15 mm; 40%–50% gray dacite and varicolored rhyolite clasts up to 15 mm; trace quartz grains. +35F: 20%–40% pumice clasts; 20%–40% dacite and rhyolite grains; 20%–40% quartz and sanidine grains; trace obsidian fragments.	Qct	
510–520	Pumiceous Sediments—sand to gravel size angular to subangular white pumice clasts with minor quartz, obsidian, and volcaniclastic sediments. 510–520 ft WR/+10F: 50%–60% pumice clasts with orange surface alteration up to 15 mm; 40%–50% gray dacite and varicolored rhyolite clasts up to 15 mm; trace quartz grains. +35F: 50%–70% quartz and sanidine grains; 20%–30% pumice clasts; 10%–20% dacite and rhyolite grains; trace obsidian fragments.	Qct	
520–555	Pumiceous Sediments—sand to gravel size angular to subangular white pumice clasts with minor quartz, obsidian, and volcaniclastic sediments. 520–555 ft WR/+10F: 50%–60% pumice clasts with orange surface alteration up to 15 mm; 40%–50% gray dacite and varicolored rhyolite clasts up to 15 mm; trace quartz grains. +35F: 20%–40% pumice clasts; 20%–40% dacite and rhyolite grains; 20%–40% quartz and sanidine grains; trace obsidian fragments.	Qct	

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
555–615	Pumiceous Sediments—sand to gravel size angular to subangular white pumice clasts with minor quartz, obsidian, and volcaniclastic sediments. 555–645 ft WR/+10F: 50%–70% gray dacite and varicolored rhyolite clasts up to 15 mm; 30%–50% pumice clasts with orange surface alteration up to 15 mm; trace quartz grains. +35F: 20–40% pumice clasts; 20%–40% dacite and rhyolite grains; 20%–40% quartz and sanidine grains; trace obsidian fragments.	Qct	The Qct/Qbo contact, estimated at 615 ft bgs, is based on color change and decreased abundance of pumice in cuttings and presence of varied volcanoclastic grains in cuttings.
615–635	**OTOWI MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—white (N9), poorly welded, pumice- and lithic-rich tuff. 615–635 ft WR/+10F: 98%–99% rhyolite and dacite lithic fragments; <2% quartz grains; trace white pumice. +35F: 60%–90% lithic fragments; 10%–40% quartz grains; trace pumice.	Qbo	The Otowi Member of the Bandelier Tuff (Qbo), encountered from 615 to 866 ft bgs, is approximately 251 ft thick.
635–680	Rhyolitic Tuff—white (N9), poorly welded, pumice- and lithic-rich tuff. 635–680 ft WR/+10F: 80%–95% rhyolite and dacite lithic fragments; 5–20% orange or white pumice; trace quartz grains. +35F: 70%–90% lithic fragments; 5%–25% quartz grains; 5%–10% pumice.	Qbo	Note: 650–655 ft poor recovery in +35F
680–690	Rhyolitic Tuff—white (N9), poorly welded, pumice- and lithic-rich tuff. 680–690 ft WR/+10F: 60%–80% rhyolite and dacite lithic fragments; 20%–40% orange or white pumice; trace quartz grains. +35F: 50%–80% lithic fragments; 20%–30% quartz grains; 10%–20% pumice.	Qbo	
690–700	Rhyolitic Tuff—white (N9), poorly welded, pumice- and lithic-rich tuff. 690–700 ft WR/+10F: 40%–60% rhyolite and dacite lithic fragments; 40%–60% orange or white pumice; trace quartz grains. +35F: 40%–60% lithic fragments; 30%–50% pumice; 10%–20% quartz grains.	Qbo	
700–730	Rhyolitic Tuff—white (N9), poorly welded, pumice- and lithic-rich tuff. 700–730 ft WR/+10F: 60%–80% rhyolite and dacite lithic fragments; 20%–40% orange or white pumice; trace quartz grains. +35F: 50%–80% lithic fragments; 20%–30% quartz grains; 10%–20% pumice.	Qbo	

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
730–800	Rhyolitic Tuff—white (N9), poorly welded, pumice- and lithic-rich tuff. 730–800 ft WR/+10F: 50%–70% rhyolite and dacite lithic fragments; 30%–50% white pumice; trace quartz grains. +35F: 50%–70% lithic fragments; 20%–40% pumice; 20%–30% quartz grains.	Qbo	
800–815	Rhyolitic Tuff—white (N9), poorly welded, pumice- and lithic-rich tuff. 800–815 ft WR/+10F: 60%–80% rhyolite and dacite lithic fragments; 20%–40% white pumice; trace quartz grains. +35F: 50%–70% lithic fragments; 20%–40% pumice; 10%–20% quartz grains.	Qbo	
815–866	Rhyolitic Tuff—white (N9), poorly welded, pumice- and lithic-rich tuff. 815–866 ft WR/+10F: 50%–70% rhyolite and dacite lithic fragments; 30%–50% white pumice; trace quartz grains. +35F: 50%–70% lithic fragments; 20%–40% pumice; 20%–30% quartz grains.	Qbo	The Qbo/Qbog contact, estimated at 866 ft bgs, is based on increased abundance of pumice in cuttings, and natural gamma logging.
866–889	**GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF** Rhyolitic Tuff—white (N9), poorly welded, pumice- and lithic-rich tuff. 866–889 ft WR/+10F: 30%–70% rhyolite and dacite lithic fragments; 30%–70% white pumice; trace quartz grains. +35F: 30%–70% lithic fragments; 20%–50% pumice; 10%–30% quartz grains.	Qbog	The Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (Qbog), encountered from 866 to 889 ft bgs, is approximately 23 ft thick. The Qbog/Tpf contact, estimated at 889 ft bgs, is based on natural gamma logging and decreased abundance of pumice in cuttings.
889–975	**PUYE FORMATION** Volcaniclastic Sediments—sand to gravel size dacitic and rhyolitic sediments. 889–975 ft WR/ +10F: 100% subangular grains of dacite and rhyolite up to 20 mm. +35F: 98%–100% dacite and rhyolite grains; <2% quartz and sanidine grains.	Tpf	The Puye Formation (Tpf), encountered from 889 to 1187 ft bgs, is at least 298 ft thick.
975–1030	Volcaniclastic Sediments—clay to gravel size dacitic and rhyolitic sediments. 975–1030 ft WR/ +10F: 100% subangular grains of dacite and rhyolite up to 20 mm with silt and clay coating. +35F: 98%–100% dacite and rhyolite grains; <2% quartz and sanidine grains.	Tpf	
1030–1080	Volcaniclastic Sediments—sand to gravel size dacitic and rhyolitic sediments. 1030–1080 ft WR/ +10F: 100% subangular grains of dacite and rhyolite up to 20 mm. +35F: 98%–100% dacite and rhyolite grains; <2% quartz and sanidine grains.	Tpf	

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
1080–1095	Volcaniclastic Sediments—clay to gravel size dacitic and rhyolitic sediments. 1080–1095 ft WR/ +10F: 100% subangular grains of dacite and rhyolite up to 20 mm with clay coating. +35F: 98%–100% dacite and rhyolite grains; <2% quartz and sanidine grains.	Tpf	
1095–1135	Volcaniclastic Sediments—sand to gravel size dacitic and rhyolitic sediments. 1095–1135 ft WR/ +10F: 100% subangular grains of dacite and rhyolite up to 20 mm. +35F: 98%–100% dacite and rhyolite grains; <2% quartz and sanidine grains	Tpf	
1135–1187	Volcaniclastic Sediments—clay to gravel size dacitic and rhyolitic sediments. 1080–1095 ft WR/ +10F: 98%–100% subangular grains of dacite and rhyolite up to 20 mm with clay coating; <2% pumice clasts. +35F: 98%–100% dacite and rhyolite grains; <2% quartz and sanidine grains.	Tpf	Note: 1175 to 1185 ft bgs is finer grained than above. The Tpf/Tvt 2 contact, estimated at 1187 ft bgs, is based on color change of fragments and abrupt slowing of penetration rate during drilling.
1187–1205	**TSCHICOMA FORMATION, younger dacite flow breccia** Dacite breccia—Grey (N4 to N6) to maroon (5R 4/2) quartz and hornblende-bearing volcanic deposits 1187–1205 ft WR/+10F: 100% angular fragments of dacite with minor oxidation and variable alteration. +35F: 99%–100% angular fragments of dacite with minor oxidation and variable alteration; trace quartz, plagioclase, and hornblende crystals.	Tvt 2	The dacite breccia (Tvt 2), encountered from 1187 to 1378.4 ft bgs, is at least 191.4 ft thick.
1205–1230	Dacite breccia—Grey (N4 to N6) to maroon (5R 4/2) quartz and hornblende-bearing volcanic deposits 1205–1230 ft WR/+10F: 100% angular fragments of dacite with very minor oxidation and variable alteration. +35F: 99%–100% angular fragments of dacite with minor oxidation and variable alteration; trace quartz, plagioclase, and hornblende crystals.	Tvt 2	Note: Less oxidized than above
1230–1295	Dacite breccia—Grey (N4 to N6) to maroon (5R 4/2) quartz and hornblende-bearing volcanic deposits 1230–1295 ft WR/+10F: 100% angular fragments of dacite with moderate oxidation and variable alteration. +35F: 99%–100% angular fragments of dacite with minor oxidation and variable alteration; trace quartz, plagioclase, and hornblende crystals.	Tvt 2	Note: More oxidized than above

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
1295–1340	Dacite Breccia—Grey (N4 to N6) to maroon (5R 4/2) quartz and hornblende-bearing volcanic deposits 1295–1340 ft WR/+10F: 100% angular fragments of dacite with major oxidation and variable alteration. +35F: 99%–100% angular fragments of dacite with minor oxidation and variable alteration; trace quartz, plagioclase, and hornblende crystals.	Tvt 2	Note: Strongly oxidized in this interval.
1340–1378.4	Dacite Breccia—Grey (N4 to N6) to maroon (5R 4/2) quartz and hornblende-bearing volcanic deposits 1340–1378 ft WR/+10F: 100% angular fragments of dacite with moderate oxidation and variable alteration. +35F: 99%–100% angular fragments of dacite with minor oxidation and variable alteration; trace	Tvt 2	

Borehole Lithologic Log (continued)

ABBREVIATIONS

5YR 8/4 = Munsell rock color notation where hue (e.g., 5YR), value (e.g., 8), and chroma (e.g., 4) are expressed. Hue indicates soil color's relation to red, yellow, green, blue, and purple. Value indicates soil color's lightness. Chroma indicates soil color's strength.

% = estimated percent by volume of a given sample constituent

amsl = above mean sea level

bgs = below ground surface

Qbt 4 = Unit 4 of the Tshirege Member of the Bandelier Tuff

Qbt 3t = Unit 3t (transition) of the Tshirege Member of the Bandelier Tuff

Qbt 3 = Unit 3 of the Tshirege Member of the Bandelier Tuff

Qbt 2 = Unit 2 of the Tshirege Member of the Bandelier Tuff

Qbt 1v = Unit 1v (vapor phase) of the Tshirege Member of the Bandelier Tuff

Qbt 1g = Unit 1g (glassy) of the Tshirege Member of the Bandelier Tuff

Qct = Cerro Toledo interval

Qbo = Otowi Member of Bandelier Tuff

Qbog = Guaje Pumice Bed

Tpf = Puye Formation

Tvt 2 = Dacite breccia

+10F = plus No. 10 sieve sample fraction

+35F = plus No. 35 sieve sample fraction

WR = whole rock (unsieved sample)

1 mm = 0.039 in

1 in = 25.4 mm

Appendix B

Screening Groundwater Analytical Results for Well R-58

B-1.0 SCREENING GROUNDWATER ANALYSES AT R-58

R-58 is a regional aquifer monitoring well with one well screen drilled from 1257 ft to 1277.3 ft below ground surface (bgs) in dacite breccia. This appendix presents screening analytical results for samples collected during well development and aquifer testing at R-58.

Laboratory Analyses

Four groundwater samples were collected during development and two groundwater samples were collected during aquifer testing. Los Alamos National Laboratory's (LANL's or the Laboratory's) Earth and Environmental Sciences Group 14 (EES-14) analyzed the development samples for total organic carbon (TOC) and the aquifer test samples for TOC, alkalinity, anions, and metals. Table B-1.0-1 lists the samples submitted for TOC analyses from R-58.

Field Analyses

Additionally, groundwater samples were collected from a flow-through cell at regular intervals during well development and aquifer testing and measured for pH, conductivity, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), and turbidity.

B-2.0 SCREENING ANALYTICAL RESULTS

This section presents the TOC concentrations and field parameters measured during well development and aquifer testing.

B-2.1 Total Organic Carbon

TOC concentrations were at the target concentration of 2.0 mgC/L in four groundwater samples collected during well development at well R-58 (Table B-2.1-1). Table B-2.1-1 also presents the U.S. Environmental Protection Agency (EPA) method by which the samples were analyzed.

B-2.2 Field Parameters

Field parameters measured during well development and aquifer testing are summarized in Table B-2.2-1. Well development was initially conducted for 8 d. Aquifer testing was then conducted for 6 d. These activities were conducted consecutively and the field parameters are summarized below.

During well development and aquifer testing, pH varied from 7.98 to 8.66 and temperature ranged from 14.32°C to 19.72°C. DO concentrations varied from −9.83 to 9.79 mg/L. Specific conductance ranged from 94 μS/cm to 119 μS/cm, and turbidity values varied from 0 to 117 nephelometric turbidity units (NTU). Corrected oxidation-reduction potential (Eh) values, determined from field ORP measurements, varied from 257.8 mV to 594.2 mV. One temperature-dependent correction factor was used to calculate Eh values from field ORP measurements: 208.9 mV at 15°C. Figure B-2.2-1 shows the field parameters measured over the course of well development and aquifer testing.

The final parameters measured at the end of the aquifer testing period were pH of 8.19, temperature of 16.93°C, DO of 8.53 mg/L, specific conductance of 97 μS/cm, and turbidity of 5.8 NTU.

B-3.0 SUMMARY OF SCREENING ANALYTICAL RESULTS

TOC concentration was below the target level of 2.0 mgC/L and turbidity was 5.8 NTU at the end of aquifer testing. R-58 will be sampled quarterly for 1 yr, and the data collected will be assessed and incorporated into the Interim Facility-Wide Groundwater Monitoring Plan. Data from ongoing sampling at R-58 will be analyzed and presented in the appropriate Laboratory periodic monitoring report.

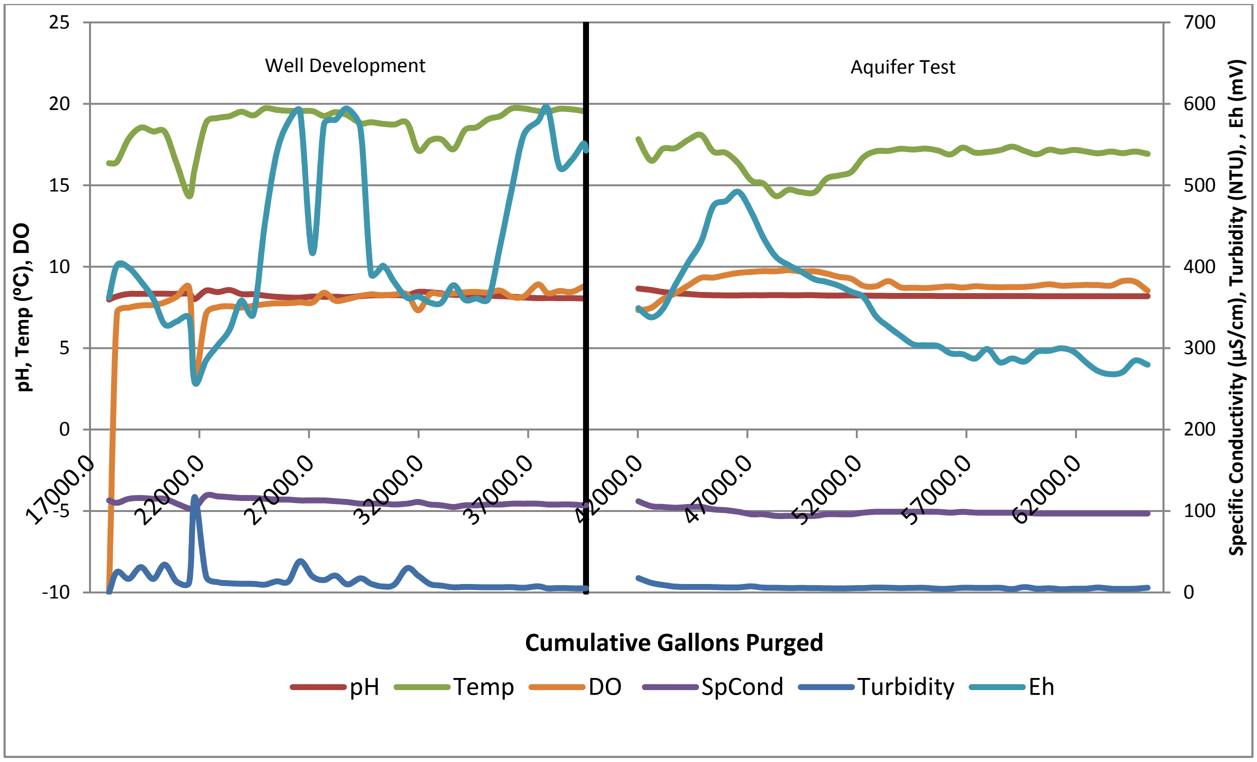

Figure B-2.2-1 Field parameters versus volume purged during R-58 well development and aquifer testing

Table B-1.0-1
Summary of Groundwater Screening Samples Collected during Well Development and Aquifer Testing at Well R-58

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Well Development					
R-58	CACV-15-104376	11/10/15	1277.3	Groundwater, Pumped	TOC
R-58	CACV-15-104377	11/11/15	1277.3	Groundwater, Pumped	TOC
R-58	CACV-15-104378	11/12/15	1277.3	Groundwater, Pumped	TOC
R-58	CACV-15-104379	11/13/15	1277.3	Groundwater, Pumped	TOC
Aquifer Testing					
R-58	CACV-15-104381	11/18/15	1254.0	Groundwater, Pumped	TOC, Alkalinity
R-58	CACV-15-104382	11/18/15	1254.0	Groundwater, Pumped	Anions, Metals

Table B-2.1-1
TOC Results

Sample ID	EPA Method	TOC Concentration (mgC/L)
CACV-15-104376	SW-846:9060	2.0
CACV-15-104377	SW-846:9060	2.0
CACV-15-104378	SW-846:9060	2.0
CACV-15-104379	SW-846:9060	2.0
CACV-15-104381	SW-846:9060	1.0

Table B-2.2-1
Purge Volumes and Field Parameters during Well Development and Aquifer Testing at R-58

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development									
11/6/15	n/r*; bailing							50	50.0
11/7/15	n/r; bailing							325	375.0
11/8/15	n/r; bailing							175	550.0
11/9/15	n/r; pumping through screen							81.8	631.8
11/10/15	n/r; pumping through screen							10757.5	11389.3
11/11/15	7.98	16.35	-9.83	153.4	362.3	113	0.0	6485.6	17874.9
	8.18	16.44	7.15	192.7	401.6	110	25.2	362.0	18236.9
	8.33	17.87	7.48	189.8	398.7	115	16.7	540.0	18776.9
	8.33	18.54	7.62	173.1	382.0	116	31.1	550.0	19326.9
	8.34	18.30	7.65	151.8	360.7	115	16.6	566.0	19892.9
	8.34	18.28	7.81	120.1	329.0	115	34.2	523.0	20415.9
	8.33	16.31	8.16	123.8	332.7	109	13.0	551.0	20966.9
	8.33	14.32	8.71	128	336.9	103	12.4	565.3	21532.2
11/12/15	8.01	16.01	3.17	48.9	257.8	103	117.2	251.6	21783.8
	8.53	18.84	7.09	76.1	285.0	119	19.8	520.0	22303.8
	8.44	19.13	7.51	94.6	303.5	118	12.7	530.0	22833.8
	8.57	19.24	7.57	113.6	322.5	117	11.3	540.0	23373.8
	8.32	19.51	7.49	149.5	358.4	116	10.7	540.0	23913.8
	8.31	19.29	7.60	132.9	341.8	116	10.5	550.0	24463.8
	8.22	19.72	7.70	243.7	452.6	115	9.6	520.0	24983.8
	8.15	19.63	7.75	330.7	539.6	114	13.7	541	25524.8
	8.11	19.57	7.76	368.7	577.6	114	13.4	532	26056.8
	8.10	19.56	7.81	382.0	590.9	113	38.4	532	26588.8
	8.17	19.55	7.80	207.7	416.6	113	19.7	569	27157.8
	8.15	19.26	8.40	366.0	574.9	113	15.2	527	27684.8
	8.16	19.49	7.91	371.4	580.3	112	20.7	521	28205.8
	8.13	19.30	8.01	385.2	594.1	111	9.9	543	28748.8
	8.19	18.81	8.21	360.1	569.0	109	17.4	601	29349.8
	8.24	18.87	8.30	182.2	391.1	109	10.6	482	29831.8
	8.25	18.77	8.25	192.3	401.2	109	7.3	542	30373.8
	8.26	18.73	8.29	172.1	381.0	108	9.7	520	30893.8
	8.25	18.83	8.30	152.9	361.8	109	29.9	581.4	31475.2

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
11/13/15	8.45	17.13	7.32	154.5	363.4	111	20.6	509.6	31984.8
	8.43	17.75	8.31	147.0	355.9	108	10.3	537	32521.8
	8.36	17.82	8.31	146.8	355.7	107	8.4	517	33038.8
	8.27	17.21	8.36	168.4	377.3	105	6.3	553	33591.8
	8.27	18.39	8.43	150.4	359.3	107	6.8	522	34113.8
	8.25	18.56	8.45	152.2	361.1	107	6.6	527	34640.8
	8.22	19.06	8.41	151.5	360.4	108	6.3	544	35184.8
	8.19	19.25	8.53	217.6	426.5	108	6.4	544	35728.8
	8.16	19.71	8.15	285.2	494.1	109	6.5	515	36243.8
	8.11	19.71	8.17	352.5	561.4	109	5.7	551	36794.8
	8.07	19.56	8.91	369.8	578.7	109	7.5	657	37451.8
	8.08	19.51	8.37	385.3	594.2	108	5.1	442	37893.8
	8.07	19.69	8.51	313.3	522.2	108	5.4	533	38426.8
	8.07	19.66	8.45	322.1	531.0	108	5.1	556	38982.8
	8.05	19.56	8.77	342.1	551.0	107	5.0	532	39514.8
	8.04	19.52	8.77	333.7	542.6	107	5.0	125.1	39639.9
Aquifer Pump Test									
11/14/15	n/r, pumping, fill discharge lines							178.8	39818.7
11/16/15	n/r, pumping, mini-tests							1671.7	41490.4
11/17/15 to 11/18/15	8.66	17.83	7.33	140.3	349.2	112	17.6	539.7	42030.1
	8.57	16.51	7.47	128.9	337.8	106	11.8	575	42605.1
	8.45	17.24	8.01	139.3	348.2	105	9.2	542	43147.1
	8.37	17.28	8.36	168.3	377.2	104	7.2	560	43707.1
	8.32	17.82	8.88	197.8	406.7	105	6.7	633	44340.1
	8.27	18.08	9.32	222.4	431.3	105	6.7	559	44899.1
	8.25	17.07	9.33	265.5	474.4	102	6.6	548	45447.1
	8.24	16.99	9.49	271.8	480.7	101	6.2	575	46022.1
	8.24	16.33	9.62	283.0	491.9	99	6.2	575	46597.1
	8.25	15.29	9.68	258.1	467.0	96	7.5	587	47184.1
	8.25	15.10	9.73	226.5	435.4	96	5.9	553	47737.1
	8.26	14.33	9.72	203.2	412.1	94	5.7	571	48308.1
	8.25	14.72	9.79	193.2	402.1	94	5.4	570	48878.1
	8.25	14.58	9.71	185.2	394.1	94	5.5	562	49440.1
	8.25	14.57	9.71	175.6	384.5	94	5.4	635	50075.1
	8.23	15.40	9.58	172.5	381.4	96	5.2	531	50606.1

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
	8.23	15.60	9.38	167.7	376.6	96	4.9	569	51175.1
	8.24	15.82	9.26	160.4	369.3	96	5.2	567	51742.1
	8.23	16.73	8.82	153.6	362.5	98	5.4	566	52308.1
	8.22	17.09	8.80	130.2	339.1	99	6.0	565	52873.1
	8.21	17.11	9.11	117.4	326.3	99	5.8	567	53440.1
	8.21	17.24	8.73	106.0	314.9	99	5.4	568	54008.1
	8.21	17.19	8.71	95.7	304.6	99	5.6	566	54574.1
	8.21	17.25	8.69	94.6	303.5	99	5.6	565	55139.1
	8.20	17.13	8.74	93.6	302.5	99	4.5	565	55704.1
	8.20	16.89	8.79	84.8	293.7	98	4.7	562	56266.1
	8.20	17.31	8.72	83.6	292.5	99	5.8	563	56829.1
	8.20	17.00	8.80	78.3	287.2	98	5.6	563	57392.1
	8.20	17.04	8.76	90.0	298.9	98	5.5	564	57956.1
	8.20	17.15	8.74	73.7	282.6	98	5.7	566	58522.1
	8.20	17.37	8.75	78.5	287.4	98	4.1	565	59087.1
	8.20	17.11	8.76	74.6	283.5	98	6.6	565	59652.1
	8.19	16.90	8.83	86.6	295.5	97	4.6	562	60214.1
	8.19	17.18	8.92	87.8	296.7	97	5.1	560	60774.1
	8.19	17.06	8.83	90.9	299.8	97	4.0	561	61335.1
	8.19	17.17	8.85	86.7	295.6	97	4.6	561	61896.1
	8.19	17.07	8.88	73.6	282.5	97	4.6	560	62456.1
	8.19	16.96	8.87	62.8	271.7	97	6.0	560	63016.1
	8.19	17.07	8.84	59.1	268.0	97	4.6	578	63594.1
	8.19	16.97	9.12	61.7	270.6	97	4.3	534	64128.1
	8.19	17.07	9.08	75.9	284.8	97	4.6	563	64691.1
	8.19	16.93	8.53	70.8	279.7	97	5.8	574.3	65265.4

Note: One temperature-dependent correction factor was used to calculate Eh values from field ORP measurements: 208.9 mV at 15°C.

*n/r = Not recorded.

Appendix C

Geophysical Logs
(on CD included with this document)

Appendix D

Final Well Design and
New Mexico Environment Department Approval

From: Everett, Mark Capen
Sent: Monday, September 21, 2015 2:17 PM
To: Michael Dale (Michael.Dale@state.nm.us); Wear, Benjamin, NMENV; Jerzy Kulis (jerzy.kulis@state.nm.us)
Cc: Rodriguez, Cheryl L; Shen, Hai; Paris, Steven M; Swickley, Stephani Fuller
Subject: R-58 proposed well design
Attachments: R-58 Well Design Justification_final.doc

Michael,

Attached, please find our proposed design for well R-58. Let me know if you have questions, otherwise please respond to this e-mail with your concurrence.

Thanks,

Mark Everett, PG
ER-ES LANL
(505) 667-5931 (o)
(505) 231-6002 (c)

Proposed Well Design for Regional Aquifer Well R-58

R-58 Well Objectives

Regional aquifer well R-58 is being installed to satisfy a recommendation made in the Technical Area 16 Well Network Evaluation and Recommendations and approved with modifications by the New Mexico Environment Department (NMED) Hazardous Waste Bureau. This assessment recommended installing one new regional groundwater monitoring well downgradient of potential contaminant breakthrough locations for S-Site Canyon and Fishladder Canyon. In consultation with NMED, the final location was moved east of the originally proposed location to the location shown on Figure 1 (Figure 1). The primary purpose of R-58 is to increase the overall detection efficiency of the TA-16 monitoring network for the high- and medium- priority sources at TA-16. Water-level data from this location will also constrain the shape of the regional water table and groundwater flow directions in this area.

R-58 Recommended Well Design

It is recommended that R-58 be installed as a single-screen well with a 20-ft stainless steel, 40-slot, wire-wrapped well screen. The top of the well screen would be set 17 ft below the regional water table. The primary filter pack will consist of 10/20 sand extending 5 ft above and 5 ft below the screen openings. A 2-ft secondary filter pack (transition sand) consisting of 20/40 sand will be placed above the primary filter pack. The 17 ft of submergence to the top of the well screen allows for a 5-ft filter pack and 2-ft transition sand resulting in 10 ft of additional submergence beneath the water table allowing for potential drawdown during development. The proposed well design is shown in Figure 2. This well design is based on the objectives stated above and on the information summarized below.

R-58 Well Design Considerations

At a total depth (TD) of 1378 ft, the R-58 borehole contained 16-in drill casing from 0 to 95 ft, 12-in drill casing from 0–1027 ft, and 10-in drill casing from 0-1378 ft. Preliminary lithological logs indicate that the geologic contacts are, in descending stratigraphic order: Qbt 4 (0-110 ft), Qbt 3t (110-130 ft), Qbt 3 (130-260? ft), Qbt 2 (260?-355? ft), Qbt 1v (355?-400 ft), Qbt 1g (400-480? ft), Qct (480?-615? ft), Qbof (615? ft- 866 ft), Qbog (866-889 ft), and Tpf (889-1378 ft). The proposed well screen will be in the Puye Formation. Well cuttings indicate that the Puye Formation at R-58 consists of poorly sorted and subangular to subrounded dacitic sands and gravels.

Characterization within the regional aquifer included the collection of cuttings at 5-ft intervals. In addition, a cased-hole gamma log was collected on 09/18/15 from 0-1378 ft. Based on drillers' observations of water production and multiple water-level measurements, the regional water-table surface occurs at a depth of approximately 1240 ft.

The proposed well screen targets the 1257 to 1277 ft interval with the goal of monitoring near the water table for potential contaminant travel pathways. Sediments making up the Puye Formation in this interval are primarily sands and gravels. The grain-size distribution appears to have good porosity and permeability characteristics. A 10-ft well screen was evaluated as a means to monitor a more discrete zone of groundwater near the top of the regional aquifer. However, the longer 20-ft screen was chosen because the longer screen provides greater assurance that preferential pathways in the stratigraphically complex aquifer will be adequately captured by water entering the well screen.

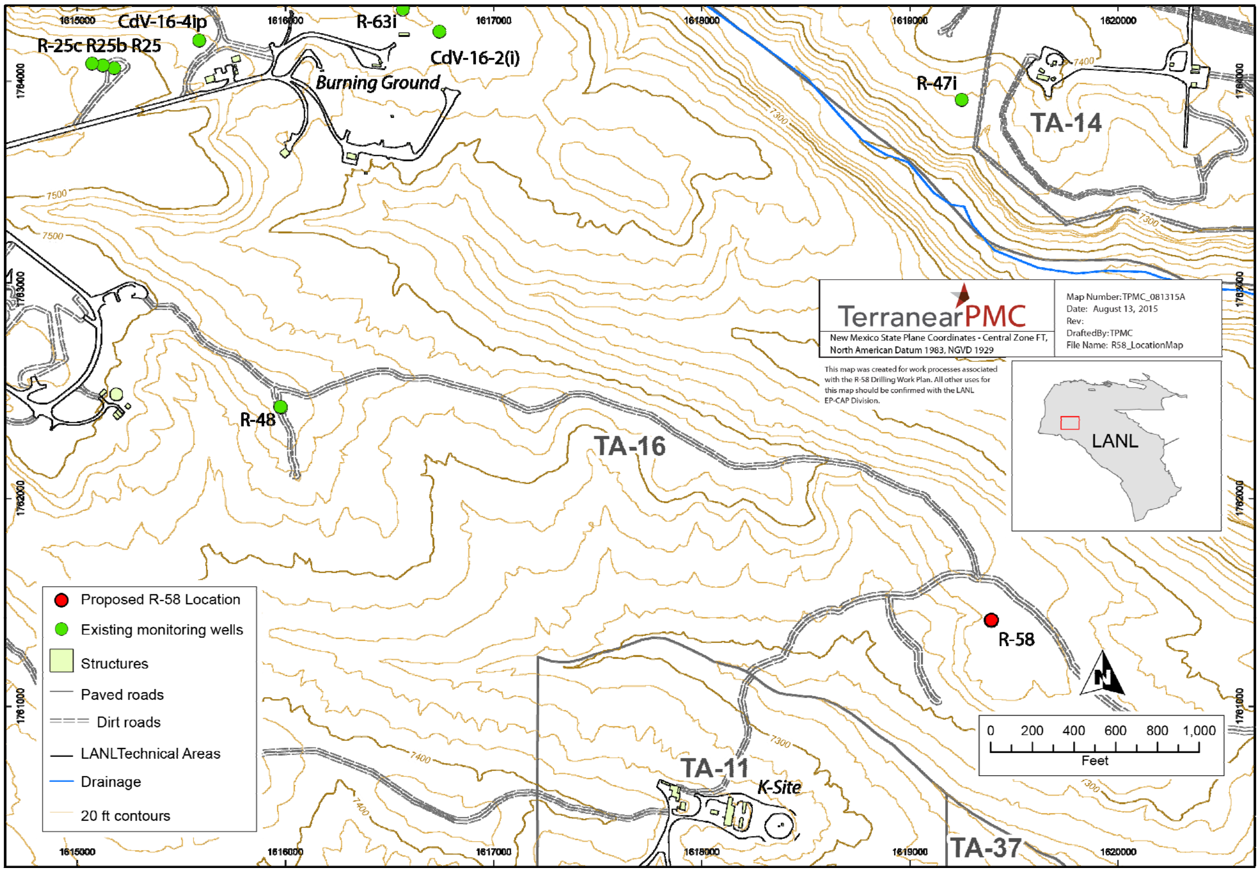

Figure 1. Map of well R-58 location

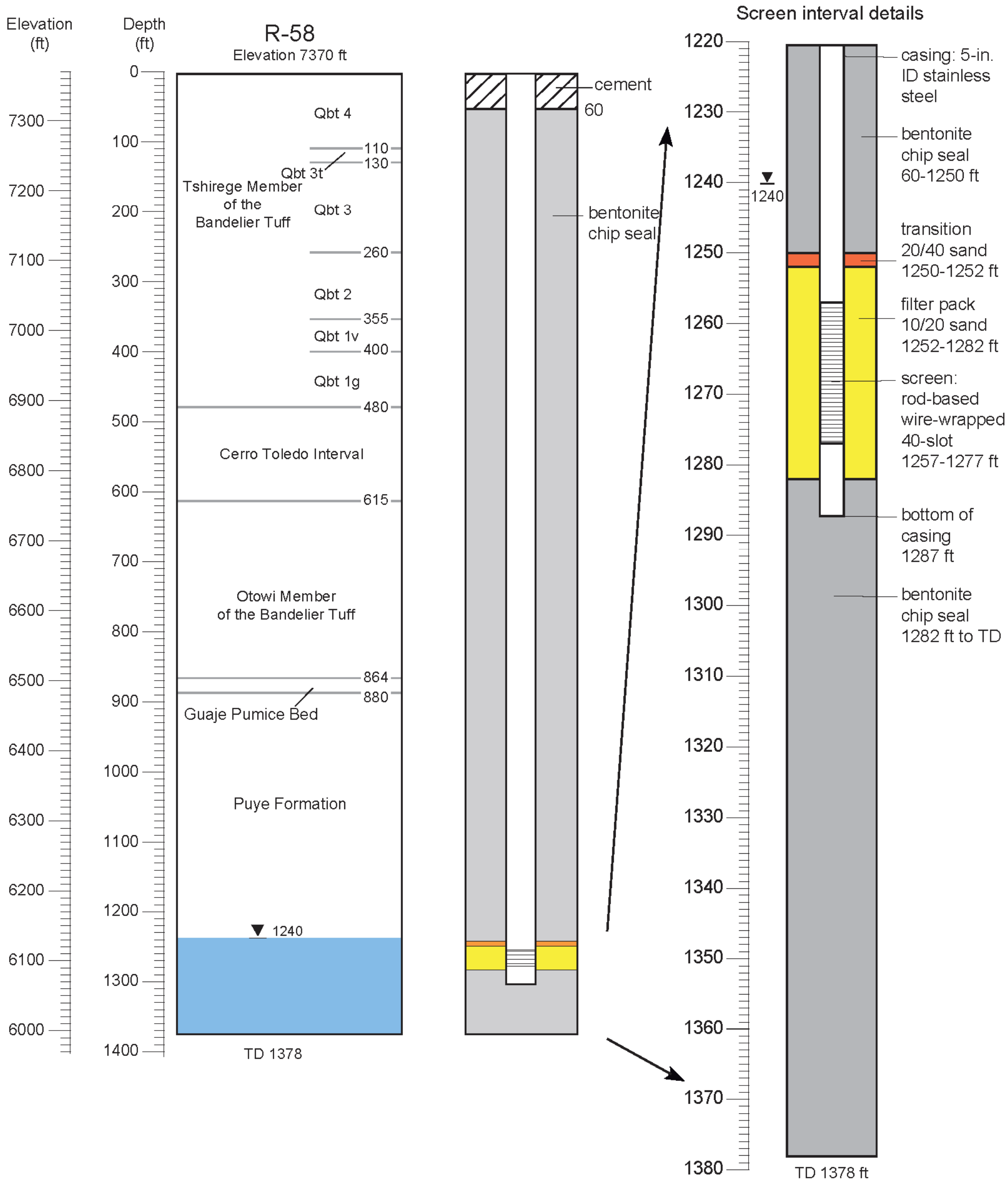

Figure 2. Proposed well design for R-58

From: Dale, Michael, NMENV <Michael.Dale@state.nm.us>
Sent: Monday, September 21, 2015 2:48 PM
To: Everett, Mark Capen
Cc: Rodriguez, Cheryl L; Shen, Hai; Paris, Steven M; Swickley, Stephani Fuller; Wear, Benjamin, NMENV; Kulis, Jerzy, NMENV; Cobrain, Dave, NMENV; Fellenz, David, NMENV; Yanicak, Stephen M; Green, Megan, NMENV; Granzow, Kim P
Subject: RE: R-58 proposed well design

Mark,

New Mexico Environment Department (NMED) hereby approves the installation of the regional-aquifer well R-58 as proposed in your e-mail, with attachments, that was received today, September 21, 2015 at 2:16 PM. This approval is based on information available to NMED at the time of the approval. LANL must provide the results of groundwater sampling, any modifications to the well design as proposed in the above-mentioned e-mail, and any additional information relevant to the installation of the well as soon as such data or information become available. Please call if you have any questions concerning this approval.

Thank you,

Michael R. Dale
New Mexico Environment Department
1183 Diamond Drive, Suite B
Los Alamos, NM 87544
LANL MS M894
Cell Phone: (505) 231-5423
Office Phone (505) 476-3078

From: Everett, Mark Capen [meverett@lanl.gov]
Sent: Monday, September 21, 2015 2:16 PM
To: Dale, Michael, NMENV; Wear, Benjamin, NMENV; Kulis, Jerzy, NMENV
Cc: Rodriguez, Cheryl L; Shen, Hai; Paris, Steven M; Swickley, Stephani Fuller
Subject: R-58 proposed well design

Michael,

Attached, please find our proposed design for well R-58. Let me know if you have questions, otherwise please respond to this e-mail with your concurrence.

Thanks,

Mark Everett, PG
ER-ES LANL
(505) 667-5931 (o)
(505) 231-6002 (c)

Appendix E

Aquifer Testing Report

E-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted during November 2015 at well R-58, a regional aquifer well located at Technical Area 16 (TA-16) at Los Alamos National Laboratory (LANL or the Laboratory) in Los Alamos, New Mexico. The tests at R-58 were conducted to characterize the saturated materials and to quantify the hydraulic properties of the screened interval. Testing consisted of brief trial pumping, background water-level data collection, and a 21-h constant-rate pumping test. (The planned 24-h pumping test was truncated to 21-h because a snowstorm overnight limited site accessibility for several hours, delaying the scheduled start.)

As in most of the R-well pumping tests conducted on the Pajarito Plateau, an inflatable packer system was installed in R-58 to try to eliminate casing storage effects on the test data. This setup was largely effective at eliminating storage effects and allowing the capture of some usable early data. However, there was evidence that minor air/gas buildup may have occurred beneath the inflatable packer or within the filter pack beneath the bentonite seal. The water pumped from R-58 during testing was slightly aerated, suggesting the presence of air/gas in the formation water. It appeared that some of the earliest data (1 to 2 s) may have reflected storage effects.

In addition, leaky (worn) coupling joints in the drop pipe string allowed water to flow from the drop pipe into the annular space between the well casing and drop pipe, above the inflatable packer, throughout the testing. During nonpumping periods, this allowed drainage of portions of the drop pipe leaving voids (vacuum) beneath a few of the check valves. For example, when the pump was removed from the well following testing, drop pipe voids approximately 6 ft in length were observed at two separate locations in the drop pipe string and a third area showing approximately 35 ft of empty drop pipe was noted. Because of these voids, whenever the pump was started, the pumping head was artificially low, essentially equal to the distance between the pumping water level and the lowest remaining void in the drop pipe, plus friction loss. This reduced head resulted in a brief transient period of increased discharge rate until the void was filled. This phenomenon had the effect of corrupting most of the early drawdown data collected while the voids were being refilled immediately following pump startup.

Conceptual Hydrogeology

R-58 is completed within highly permeable dacite breccia. The well screen is 20.3 ft long, extending from 1257.0 to 1277.3 ft below ground surface (bgs). The static water level measured on November 14, 2015, before testing, was 1241.04 ft below the top of the 5-in. stainless-steel casing (1238.44 ft bgs). The casing elevation was 7374.62 ft above mean sea level (amsl), making the groundwater elevation 6133.58 ft amsl. The brass cap elevation at the well was surveyed at 7372.11 ft amsl, placing the water level 1238.53 ft below the brass cap.

Dacite breccia extended from above the static water level to a depth of at least 1378.4 ft bgs where the pilot hole was terminated during drilling. The presence of the water table within the permeable formation implied locally unconfined conditions. The depth of the pilot hole implied a minimum aquifer thickness of 140 ft at this location. Testing showed the formation to be highly permeable both in the screened interval and beyond it (above and/or below). Also, during the drilling of the pilot hole, it was possible to air lift water steadily from a depth of 1378 ft suggesting great permeability at the bottom of the drilled zone.

R-58 Testing

R-58 was tested from November 14 to 19, 2015. On November 14, the pump was installed and operated long enough to fill the drop pipe to prepare for subsequent testing.

After background data had been collected for a couple of days, trial testing of R-58 (trial 1) began at 8:00 a.m. on November 16 at a discharge rate of 18.6 gallons per minute (gpm) and continued for 30 min. Following 30 min of recovery, a second trial test (trial 2) was performed at 9:00 a.m. for 60 min at a discharge rate of 18.6 gpm. Following shutdown, recovery/background data were recorded for 1500 min until the start of the 21-h pumping test at 11:00 a.m. on November 17.

Originally, the pumping test was scheduled for 24 h, beginning at 8:00 a.m. on November 17. However, a snowfall overnight triggered a Laboratory late start and it was not possible to mobilize to the site until just before 11:00 a.m. Once the crew was on site, the pumping test began at 11:00 a.m. at a rate of 18.8 gpm and continued until 8:00 a.m. on November 18. Then recovery data were recorded for 1440 min until 8:00 a.m. on November 19 when the pump was pulled from the well.

E-2.0 BACKGROUND DATA

The background water-level data collected in conjunction with running the pumping tests allow the analyst to see what water-level fluctuations occur naturally in the aquifer and help distinguish between water-level changes caused by conducting the pumping test and changes associated with other causes.

Background water-level fluctuations have several causes, among them barometric pressure changes, operation of other wells in the aquifer, Earth tides, and long-term trends related to weather patterns. The background data hydrographs from the monitored wells were compared with barometric pressure data from the area to determine if a correlation existed.

Previous pumping tests on the Plateau have demonstrated a barometric efficiency for most wells of between 90% and 100%. Barometric efficiency is defined as the ratio of water-level change divided by barometric pressure change, expressed as a percentage. In the initial pumping tests conducted on the early R-wells, downhole pressure was monitored using a vented pressure transducer. This equipment measures the difference between the total pressure applied to the transducer and the barometric pressure, this difference being the true height of water above the transducer.

Subsequent pumping tests, including R-58, have utilized nonvented transducers. These devices simply record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated “apparent” hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When monitored using a vented transducer, an increase in barometric pressure of 1 unit causes a decrease in recorded downhole pressure of 0.9 unit because the water level is forced downward 0.9 unit by the barometric pressure change. However, using a nonvented transducer, the total measured pressure increases by 0.1 unit (the combination of the barometric pressure increase and the water-level decrease). Thus, the resulting apparent hydrograph changes by a factor of 100 minus the barometric efficiency, and in the same direction as the barometric pressure change, rather than in the opposite direction.

Barometric pressure data were obtained from TA-54 tower site from the Waste and Environmental Protection and Compliance Division–Environmental Compliance Programs (EPC-CP). The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead brass cap elevation is at 7372.11 ft amsl. The static water level in R-58 was 1238.53 ft below the brass cap, making the water-table elevation 6133.58 ft amsl. Therefore, the measured barometric pressure data from TA-54 had to be adjusted to reflect the pressure at the elevation of the water table within R-58.

The following formula was used to adjust the measured barometric pressure data:

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R}\left(\frac{E_{R-58} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R-58}}{T_{WELL}} \right) \right]$$ **Equation E-1**

Where, P_{WT} = barometric pressure at the water table inside R-58

P_{TA54} = barometric pressure measured at TA-54

g = acceleration of gravity, in m/sec^2 (9.80665 m/sec^2)

R = gas constant, in J/Kg/degree Kelvin (287.04 J/Kg/degree Kelvin)

E_{R-58} = brass cap elevation at R-58 site, in feet (7372.11 ft)

E_{TA54} = elevation of barometric pressure measuring point at TA-54, in feet (6548 ft)

E_{WT} = elevation of the water level in R-58, in feet (6133.58 ft)

T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 35.0 degrees Fahrenheit, or 274.8 degrees Kelvin)

T_{WELL} = air column temperature inside R-58, in degrees Kelvin (assigned a value of 62.5 degrees Fahrenheit, or 290.1 degrees Kelvin)

This formula is an adaptation of an equation EPC-CP provided. It can be derived from the ideal gas law and standard physics principles. An inherent assumption in the derivation of the equation is that the air temperature between TA-54 and the well is temporally and spatially constant and that the temperature of the air column in the well is similarly constant.

The corrected barometric pressure data reflecting pressure conditions at the water table were compared with the water-level hydrograph to discern the correlation between the two and determine whether water-level corrections would be needed before data analysis.

E-3.0 IMPORTANCE OF EARLY DATA

When pumping or recovery first begins, the vertical extent of the cone of depression is limited to approximately the well screen length, the filter pack length, or the aquifer thickness in relatively thin permeable strata. For many pumping tests on the Plateau, the early pumping period is the only time the effective height of the cone of depression is known with certainty because soon after startup the cone of depression expands vertically through permeable materials above and/or below the screened interval. Thus, the early data often offer the best opportunity to obtain hydraulic conductivity information because conductivity would equal the earliest-time transmissivity divided by the well screen length.

Unfortunately, in many pumping tests, casing-storage effects dominate the early-time data, potentially hindering the effort to determine the transmissivity of the screened interval. The duration of casing-storage effects can be estimated using the following equation (Schafer 1978, 098240).

$$t_c = \frac{0.6\left(D^2 - d^2\right)}{\frac{Q}{s}}$$

Equation E-2

Where, t_c = duration of casing storage effect, in minutes

D = inside diameter of well casing, in inches

d = outside diameter of drop pipe, in inches

Q = discharge rate, in gallons per minute

s = drawdown observed in pumped well at time t_c, in feet

The calculated casing storage time is quite conservative. Often, the data show that significant effects of casing storage have dissipated after about half the computed time.

For wells screened across the water table or wells in which the filter pack can drain during pumping, there can be an additional storage contribution from the filter pack. The following equation provides an estimate of the storage duration accounting for both casing and filter pack storage.

$$t_c = \frac{0.6\left[\left(D^2 - d^2\right) + S_y\left(D_B^2 - D_C^2\right)\right]}{\frac{Q}{s}}$$

Equation E-3

Where, S_y = short term specific yield of filter media (typically 0.2)

D_B = diameter of borehole, in inches

D_C = outside diameter of well casing, in inches

This equation was derived from Equation E-2 on a proportional basis by increasing the computed time in direct proportion to the additional volume of water expected to drain from the filter pack. (To prove this, note that the left-hand term within the brackets is directly proportional to the annular area [and volume] between the casing and drop pipe, while the right-hand term is proportional to the area [and volume] between the borehole and the casing, corrected for the drainable porosity of the filter pack. Thus, the summed term within the brackets accounts for all of the volume [casing water and drained filter pack water] appropriately.)

In some instances, it is possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval before conducting the test. As discussed in Section E-1.0 this effort was largely successful in the testing performed on R-58. However, effervescence in the formation water appeared to cause some air buildup within the well imparting a very brief storage effect to some of the test data.

E-4.0 TIME-DRAWDOWN METHODS

Time-drawdown data can be analyzed using a variety of methods. Among them is the Theis method (1934-1935, 098241). The Theis equation describes drawdown around a well as follows:

$$s = \frac{114.6Q}{T} W(u)$$ **Equation E-4**

where,

$$W(u) = \int_u^\infty \frac{e^{-x}}{x} dx$$ **Equation E-5**

and

$$u = \frac{1.87r^2 S}{Tt}$$ **Equation E-6**

and where, s = drawdown, in feet

Q = discharge rate, in gallons per minute

T = transmissivity, in gallons per day per foot

S = storage coefficient (dimensionless)

t = pumping time, in days

r = distance from center of pumpage, in feet

To use the Theis method of analysis, the time-drawdown data are plotted on log-log graph paper. Then, Theis curve matching is performed using the Theis type curve—a plot of the Theis well function $W(u)$ versus $1/u$. Curve matching is accomplished by overlaying the type curve on the data plot and, while keeping the coordinate axes of the two plots parallel, shifting the data plot to align with the type curve, effecting a match position. An arbitrary point, referred to as the match point, is selected from the overlapping parts of the plots. Match-point coordinates are recorded from the two graphs, yielding four values: $W(u)$: $1/u$, s, and t. Using these match-point values, transmissivity and storage coefficient are computed as follows:

$$T = \frac{114.6Q}{s} W(u)$$ **Equation E-7**

$$S = \frac{Tut}{2693r^2}$$ **Equation E-8**

where, T = transmissivity, in gallons per day per foot

S = storage coefficient

Q = discharge rate, in gallons per minute

$W(u)$ = match-point value

s = match-point value, in feet

u = match-point value

t = match-point value, in minutes

An alternative solution method applicable to time-drawdown data is the Cooper-Jacob method (1946, 098236), a simplification of the Theis equation that is mathematically equivalent to the Theis equation for most pumped well data. The Cooper-Jacob equation describes drawdown around a pumping well as follows:

$$s = \frac{264Q}{T} \log \frac{0.3Tt}{r^2 S}$$

Equation E-9

The Cooper-Jacob equation is a simplified approximation of the Theis equation and is valid whenever the u value is less than about 0.05. For small radius values (e.g., corresponding to borehole radii), u is less than 0.05 at very early pumping times and therefore is less than 0.05 for most or all measured drawdown values. Thus, for the pumped well, the Cooper-Jacob equation usually can be considered a valid approximation of the Theis equation. An exception occurs when the transmissivity of the aquifer is very low. In that case, some of the early pumped well drawdown data may not be well approximated by the Cooper-Jacob equation.

According to the Cooper-Jacob method, the time-drawdown data are plotted on a semilog graph, with time plotted on the logarithmic scale. Then a straight line of best fit is constructed through the data points and transmissivity is calculated using:

$$T = \frac{264Q}{\Delta s}$$

Equation E-10

Where, T = transmissivity, in gallons per day per foot

Q = discharge rate, in gallons per minute

Δs = change in head over one log cycle of the graph, in feet

Because many of the test wells completed on the Plateau are severely partially penetrating, an alternate solution considered for assessing aquifer conditions is the Hantush equation for partially penetrating wells (Hantush 1961, 098237; Hantush 1961, 106003). The Hantush equation is as follows:

Equation E-11

$$s = \frac{Q}{4\pi T}\left[W(u) + \frac{2b^2}{\pi^2 (l-d)(l'-d')} \sum_{n=1}^{\infty} \frac{1}{n^2}\left(\sin\frac{n\pi l}{b} - \sin\frac{n\pi d}{b}\right)\left(\sin\frac{n\pi l'}{b} - \sin\frac{n\pi d'}{b}\right) W\left(u, \sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b}\right)\right]$$

Where, in consistent units, s, Q, T, t, r, S, and u are as previously defined and

b = aquifer thickness

d = distance from top of aquifer to top of well screen in pumped well

l = distance from top of aquifer to bottom of well screen in pumped well

d' = distance from top of aquifer to top of well screen in observation well

l' = distance from top of aquifer to bottom of well screen in observation well

K_z = vertical hydraulic conductivity

K_r = horizontal hydraulic conductivity

In this equation, $W(u)$ is the Theis well function and $W(u,\beta)$ is the Hantush well function for leaky aquifers where:

$$\beta = \sqrt{\frac{K_z}{K_r}} \frac{n\pi r}{b} \qquad \textbf{Equation E-12}$$

Note that for single-well tests, $d = d'$ and $l = l'$.

E-5.0 RECOVERY METHODS

Recovery data were analyzed using the Theis recovery method. This is a semilog analysis method similar to the Cooper-Jacob procedure.

In this method, residual drawdown is plotted on a semilog graph versus the ratio t/t', where t is the time since pumping began and t' is the time since pumping stopped. A straight line of best fit is constructed through the data points and T is calculated from the slope of the line as follows:

$$T = \frac{264Q}{\Delta s} \qquad \textbf{Equation E-13}$$

The recovery data are particularly useful compared with time-drawdown data. Because the pump is not running, spurious data responses associated with dynamic discharge rate fluctuations are eliminated. The result is that the data set is generally “smoother” and easier to analyze.

Recovery data also can be analyzed using the Hantush equation for partial penetration. This approach is generally applied to the early data in a plot of recovery versus recovery time.

E-6.0 SPECIFIC CAPACITY METHOD

The specific capacity of the pumped well can be used to obtain a lower-bound value of hydraulic conductivity. The hydraulic conductivity is computed using formulas that are based on the assumption that the pumped well is 100% efficient. The resulting hydraulic conductivity is the value required to sustain the observed specific capacity. If the actual well is less than 100% efficient, it follows that the actual hydraulic conductivity would have to be greater than calculated to compensate for well inefficiency. Thus, because the efficiency is not known, the computed hydraulic conductivity value represents a lower bound. The actual conductivity is known to be greater than or equal to the computed value.

For fully penetrating wells, the Cooper-Jacob equation can be iterated to solve for the lower-bound hydraulic conductivity. However, the Cooper-Jacob equation (assuming full penetration) ignores the contribution to well yield from permeable sediments above and below the screened interval. To account for this contribution, it is necessary to use a computation algorithm that includes the effects of partial penetration. One such approach was introduced by Brons and Marting (1961, 098235) and augmented by Bradbury and Rothchild (1985, 098234).

Brons and Marting introduced a dimensionless drawdown correction factor, s_P, approximated by Bradbury and Rothschild as follows:

$$s_P = \frac{1-\frac{L}{b}}{\frac{L}{b}}\left[\ln\frac{b}{r_w} - 2.948 + 7.363\frac{L}{b} - 11.447\left(\frac{L}{b}\right)^2 + 4.675\left(\frac{L}{b}\right)^3\right]$$ **Equation E-14**

In this equation, L is the well screen length, in ft. Incorporating the dimensionless drawdown parameter, the conductivity is obtained by iterating the following formula:

$$K = \frac{264Q}{sb}\left(\log\frac{0.3Tt}{r_w^2 S} + \frac{2s_P}{\ln 10}\right)$$ **Equation E-15**

The Brons and Marting procedure can be applied to both partially penetrating and fully penetrating wells.

To apply this procedure, a storage coefficient value must be assigned. Storage coefficient values generally range from 10^{-5} to 10^{-3} for confined aquifers and 0.01 to 0.25 for unconfined aquifers (Driscoll 1986, 104226). Semiconfined conditions generally are associated with intermediate storage coefficient values between these ranges. For R-58, the test data and well log suggested unconfined conditions as well as highly permeable and coarse-grained formation material that would be associated with storage coefficient values at the upper end of the normal range. Therefore, calculations were performed for an assigned storage coefficient range of 0.10 to 0.25. The lower-bound transmissivity calculation result is not particularly sensitive to the choice of storage coefficient value, so a rough estimate is generally adequate to support the calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, b. For R-58, b was assigned a value of 140 ft, the approximate thickness of saturated formation penetrated by the borehole before backfilling and well completion. The calculation is not particularly sensitive to the assigned value of saturated thickness. It is only necessary to use a value well in excess of the screen length. Ignoring deeper sediments has little effect on the calculation results because sediments far from the screened interval have minimal effect on yield.

E-7.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-58 tests were plotted along with barometric pressure to determine the barometric effect on water levels.

Figure E-7.0-1 shows aquifer pressure data from R-58 during the test period along with barometric pressure data from TA-54 that have been corrected to equivalent barometric pressure in feet of water at the water table. The R-58 data are referred to in the figure as the “apparent hydrograph” because the measurements reflect the sum of water pressure and barometric pressure, having been recorded using a nonvented pressure transducer. The times of the pumping periods for the R-58 pumping tests are included on the figure for reference.

A comparison of the apparent hydrograph and barometric pressure curve showed little correlation between the two, suggesting a high barometric efficiency, likely close to 100%. Large changes in barometric pressure caused negligible change in the apparent hydrograph, meaning that the changes in water level were equal and opposite to changes in barometric pressure.

Note that following both the trial testing and the 21-h test, water levels recovered temporarily above the initial static water level by up to a few hundredths of a foot. This so-called "super recovery" is not well understood. It has been observed in other R-well pumping tests at the Laboratory reaching magnitudes of many feet at those locations. One possible explanation is that the depressurization of aquifer water caused by the pumping test allowed dissolved gas to come out of solution. Assuming this process could continue for a time following pump shutoff, the volume of gas created would have the same effect as injecting an equivalent volume of water, thus raising water levels temporarily. The occurrence of this phenomenon obscured the natural hydraulic response during recovery, rendering the middle and late recovery data unanalyzable.

E-8.0 WELL R-58 DATA ANALYSIS

This section presents the data obtained from the R-58 pumping tests and the results of the analytical interpretations. Data are presented for trial 1, trial 2, and the 21-h constant-rate test.

E-8.1 Well R-58 Trial 1

Figure E-8.1-1 shows a semilog plot of the drawdown data collected from trial 1 on R-58 at a discharge rate of 18.6 gpm. It appeared that a portion of the drop pipe had drained overnight and that initial operation of the pump was against substantially reduced head. This resulted in a greater pumping rate initially while the gap in the drop pipe was refilled.

Based on the estimated elevation of the void in the drop pipe, from observations made days later when the pump was pulled from the well, and the resulting pumping head, the hydraulic characteristics of the pump bowls implied an estimated initial discharge rate of approximately 29 gpm. This discharge rate persisted for approximately 0.2 min corresponding to a void volume of about 6 gal.—roughly the volume of 35 ft of 2-in. drop pipe. This agreed with the observation of an approximately 35-ft empty interval of drop pipe observed when the pump was pulled from the well following the test effort.

Once the void had been filled, the discharge rate declined to 18.6 gpm, resulting in the rise in water level observed after 0.2 min.

The early data revealed a calculated transmissivity of 10,500 gallons per day (gpd)/ft. Dividing this value by the screen length of 20.3 ft yielded an estimated hydraulic conductivity of 517 gpd/ft^2, or 69 ft/d. This value may be considered an estimate of the properties of the screened interval.

The late data from trial 1 were plotted on the expanded scale shown in Figure E-8.1-2. The transmissivity computed from the plot was 70,100 gpd/ft. As discussed below, this appeared to be an overestimate of transmissivity and suggested that the curve was artificially flattened because of delayed yield.

Figure E-8.1-3 shows recovery data recorded for 30 min following cessation of trial 1 pumping. The initial slope was steep, gradually flattening over time because of partial penetration effects (vertical growth of the cone of impression) and delayed yield. The early data were insufficient to support a transmissivity computation. The late data showed that water levels recovered above the static water level ("super" recovery) and were not analyzable.

E-8.2 Well R-58 Trial 2

Figure E-8.2-1 shows a semilog plot of the drawdown data collected from trial 2 at a discharge rate of 18.6 gpm. The early data showed exaggerated drawdown, likely a response to a brief period (just a few seconds) of elevated discharge rate resulting from a small void in the drop pipe caused by leakage of water through a coupling joint during the 30-min recovery period between trials 1 and 2.

The subsequent data were plotted on the expanded scale shown in Figure E-8.2-2. The transmissivity value calculated from the analysis was 15,900 gpd/ft. This value was substantially greater than that obtained from trial 1 and was not considered reliable. The transition from the greater antecedent discharge rate (before the data shown on the line of fit on the graph) to the lower rate caused the data trace to be artificially flat for a period of time. Before the sought slope could be restored, the effects of delayed yield and vertical growth of the cone of depression caused continued flattening of the curve. Thus, no portion of the curve could be relied on to provide a valid estimate of the transmissivity.

Late drawdown data from trial 2 were plotted on the graph in Figure E-8.2-3. The transmissivity determined from the line of fit on the graph was 87,000 gpd/ft. As described later, similar to the late-time transmissivity value obtained from trial 1, this appeared to be an overestimate of transmissivity and suggested that the curve was artificially flattened because of delayed yield.

Figure E-8.2-4 shows the recovery data collected following trial 2. The transmissivity computed from the early data was 10,700 gpd/ft corresponding to a screen interval hydraulic conductivity of 527 gpd/ft^2, or 70 ft/d.

Late data showed the expected flattening effect associated with delayed yield and vertical growth of the cone of impression. These data also showed “super” recovery and were not analyzable.

E-8.3 Well R-58 21-h Test

Figure E-8.3-1 shows a semilog plot of the drawdown data collected during the 21-h pumping test at a discharge rate of 18.8 gpm. Because of the Laboratory delayed start the morning of the test and the 11:00 a.m. starting time, the pumping event missed the dense data collection programmed in the transducer for 8:00 a.m. Thus, only 1-min data were available for analysis. As shown on the plot, the first recorded data point showed exaggerated drawdown caused by antecedent drainage of a portion of the drop pipe during the 2-d background monitoring period. Subsequent data showed a flat slope resulting from delayed yield and vertical growth of the cone of depression.

It appeared that delayed yield had subsided midway through the pumping period. The transmissivity value determined from the stabilized late-time slope was 43,400 gpd/ft. It was assumed that this represented the transmissivity of the hydraulically contiguous formation responding to pumping, although it was not possible to know what the corresponding aquifer thickness was.

After approximately 1100 min of pumping, the water level rose several hundredths of a foot as indicated on the plot. There was no corresponding change in discharge rate to explain this response. It was possible that a small, gradual lessening of the gas content in the formation near the well resulted in a permeability increase there. Of note was the fact that less gas was observed in the pumped water at the end of the pumping test compared to earlier on.

Figure E-8.3-2 shows recovery data recorded following cessation of pumping. Interpreting this plot was challenging. The transmissivity determined from the earliest slope (not shown) was less than that determined from the above analyses, suggesting the early slope was artificially steep. It was possible a tiny buildup of air/gas in the casing beneath the inflatable packer or within the filter pack behind the blank casing above the well screen may have occurred, resulting in a brief storage-like effect associated with compression of the gas as water levels recovered initially.

Because of this possibility, the line of fit was chosen to deliberately omit the first few data points. At the same time, the line of fit was constructed to utilize data corresponding to at least 0.1 to 0.2 min of recovery—a duration expected to be minimally affected by partial penetration and delayed yield effects, based on previous analyses. Selecting the line of fit was tricky because the data plot showed a continuous change in slope over time, with no distinct straight line segment.

The transmissivity value obtained from the line of fit shown in Figure E-8.3-2 was 10,600 gpd/ft corresponding to a screen interval hydraulic conductivity value of 522 gpd/ft^2, or 70 ft/d. There was some uncertainty in this value because of the early storage effect and the lack of a consistent straight line portion of the curve.

Late recovery data showed the expected flattening effect associated with delayed yield and vertical growth of the cone of impression as well as the “super” recovery observed previously and were not analyzable.

E-8.4 Combined Results

Table E-8.4-1 summarizes the results of the early-data analyses determining the hydraulic properties of the screened zone in R-58. The transmissivity values ranged from 10.500 to 10,700 gpd/ft, averaging 10,600 gpd/ft. The resulting screen interval hydraulic conductivity values averaged 522 gpd/ft^2, or 70 ft/d.

Early-time data from trial 1 drawdown, trial 2 drawdown and recovery, and the 21-h test recovery were plotted on the same graph for comparison purposes in Figure E-8.4-1. The displacement data were normalized by dividing the displacement by the corresponding discharge rate for each test and, thus, the vertical scale on the plot is s/Q, the ratio of drawdown to pumping rate. The trial 1 drawdown data were normalized using the initial rate of 29 gpm, which accounts for the deviation of the later data on that particular plot from the others.

The significant observation from Figure E-8.4-1 was the distinctly steeper slope at very early time from the 21-h test recovery data compared with the slope of the trial 2 recovery data. This seemed to reinforce the idea of a small amount of gas buildup in the well or filter pack during the 21-h test, causing a minor storage-like effect.

E-8.5 Well R-58 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound hydraulic conductivity value for the permeable zone penetrated by R-58. This was done to provide a frame of reference for evaluating the above analyses.

The total saturated thickness of dacite breccia was not known. In applying partial penetration analysis, however, it is only necessary to assign an aquifer thickness substantially greater than the well screen length because sediments far from the screened interval have negligible effect on yield. The aquifer thickness was arbitrarily assigned a value of 140 ft—the approximate thickness of saturated sediments penetrated during drilling of the borehole. The well screen length of 20.3 ft was used in the partial penetration calculations.

R-58 produced 18.8 gpm with 1.37 ft of drawdown for a specific capacity of 13.7 gpm/ft after 1440 min of pumping. In addition to specific capacity and pumping time, other input values used in the calculations included assigned storage coefficient values ranging from 0.10 to 0.25 and a borehole radius of 0.67 ft (inferred from the volume of filter pack required to backfill the screen zone).

Applying the Brons and Marting method to these inputs yielded the lower-bound hydraulic conductivity estimates shown in Figure E-8.5-1: approximately 76 ft/d. This was slightly contradictory to the pumping test hydraulic conductivity estimate of 70 ft/d. However, the discrepancy was less than 10%, within typical accuracy expectations of many pumping test analyses.

In some instances in fractured rock, the specific capacity of the well will be greater than that estimated using porous media theory. Because when the well bore intersects fractures, it responds hydraulically with an effective radius greater than the actual, leading to an elevated specific capacity and an overestimate of the lower-bound hydraulic conductivity. It was not known if this was a contributing factor to the result presented here, that is, it was not known whether the dacite breccia was consolidated or unconsolidated. The screen interval drilled rapidly, suggesting unconsolidated conditions, so this explanation may not apply to R-58. Nevertheless, the hydraulic conductivity values from the pumping test and specific capacity agreed reasonably well and, further, suggested an efficient well.

E-8.6 Packer Deflation

Water leaking through the drop pipe coupling joints flowed into the annular space between the drop pipe and well casing above the inflatable packer and remained there until the packer was deflated at the end of the 24-h recovery period. This can be seen in the head buildup that occurred when the packer was deflated.

Figure E-8.6-1 shows the head buildup above the static water level during the first 15 min following packer deflation. As shown on the graph, the greatest head measured was 34 ft above the static level. The actual maximum height of water buildup in the annulus was not known because the head data were measured at 1-min intervals—not sufficient frequency to capture the maximum head position. It was certain, however, that the initial head following packer deflation would have been greater than the first measurement shown on the graph.

It was not possible to extrapolate what the maximum head buildup might have been because the exact time of packer deflation was not known. When the packer was bled, the pressurized nitrogen gas escaped slowly so there was no way to know at what point the pressure had been reduced sufficiently to allow movement of trapped water downward past the packer. The only certainty was that the packer deflated between 0 and 1 min on the graph in Figure E-8.6-1. Note that the buildup level declined 90% from minute 1 to minute 2—rapid response because of the great aquifer permeability. This means that it is probable that the initial head might have been far greater than the 34-ft level shown on the graph.

E-9.0 SUMMARY

Pumping tests were conducted on R-58 to gain an understanding of the hydraulic characteristics of the aquifer and screen interval. Testing consisted of two brief trial tests and a 21-h test.

Several important observations and conclusions from the test pumping include the following.

1. A comparison of barometric pressure and R-58 water-level data showed a highly barometrically efficient screen zone. Large changes in barometric pressure caused almost no change in the apparent hydrograph obtained from the well using a non-vented pressure transducer.

2. Following each pumping event, R-58 showed “super recovery” in which water levels rose above the original static level temporarily by up to a few hundredths of a foot. The cause of this phenomenon is not understood but may be related to the release of dissolved gas from the

formation water in response to pumping. Similar responses have been observed in other R-well pumping tests, but with magnitudes of several feet or tens of feet.

3. Water produced from R-58 showed effervescence during most of the pumping period but cleared toward the end of the test. Possibly related, the drawdown declined by approximately 5% over the last few hours of pumping during the 21-h test, consistent with a permeability increase near the well, perhaps associated with gradual decline of gas content in the formation pores there.

4. There was some evidence of minor gas buildup, either within the well casing beneath the inflatable packer or within the filter pack beneath the bentonite seal, causing a brief storage-like effect on the earliest recovery data from the 21-h pumping test.

5. Leaky (worn) threaded joints in the drop pipe allowed drainage of water from the pipe during nonpumping periods. This resulted in elevated discharge rates briefly on startup rendering most of the early-time pumping data unanalyzable.

6. The estimated transmissivity of the screened interval was 10,600 gpd/ft, making the hydraulic conductivity of the screen interval 522 gpd/ft^2, or 70 ft/d.

7. The overall transmissivity of the hydraulically contiguous sediments responding to pumping was 43,400 gpd/ft. The corresponding thickness of sediments was not known.

8. The specific capacity of R-58 implied a lower-bound hydraulic conductivity of approximately 76 ft/d—slightly greater than, but in reasonable agreement with, the pumping test result. This could be either from a fracture flow component, if the formation is consolidated, or from the inherent accuracy limitations of the typical pumping test analysis methods. Drilling performance through the screen interval suggested the likelihood of unconsolidated formation conditions.

E-10.0 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 or ESH ID. This information is also included in text citations. ER IDs were assigned by the Environmental Programs Directorate's Records Processing Facility (IDs through 599999), and ESH IDs are assigned by the Environment, Safety, and Health (ESH) Directorate (IDs 600000 and above). IDs are used to locate documents in the Laboratory's Electronic Document Management System 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 ESH 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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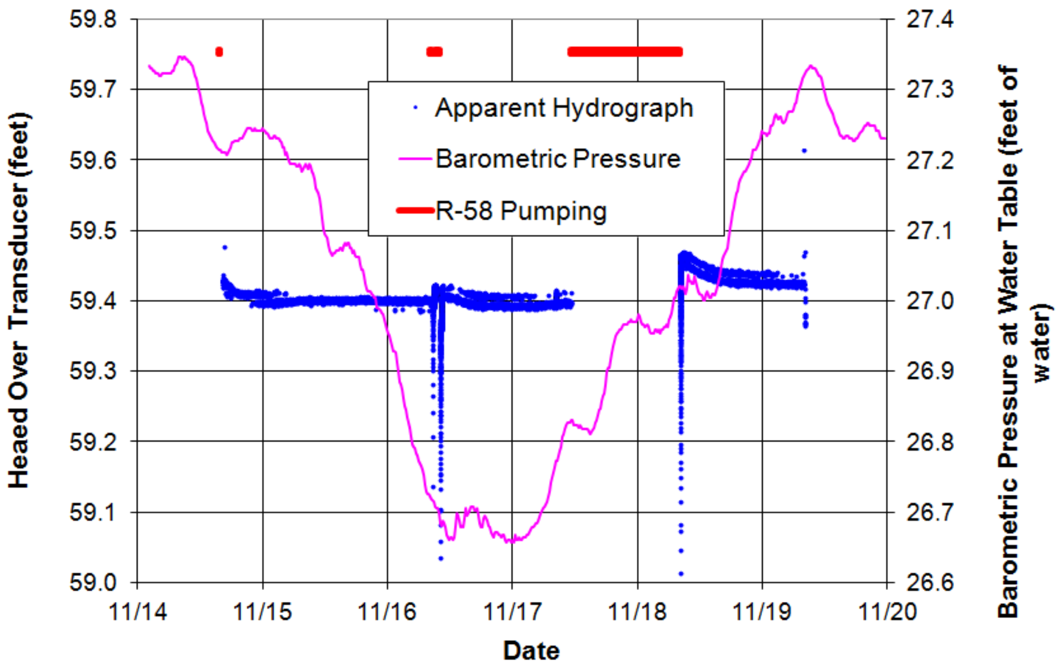

Figure E-7.0-1 Well R-58 apparent hydrograph

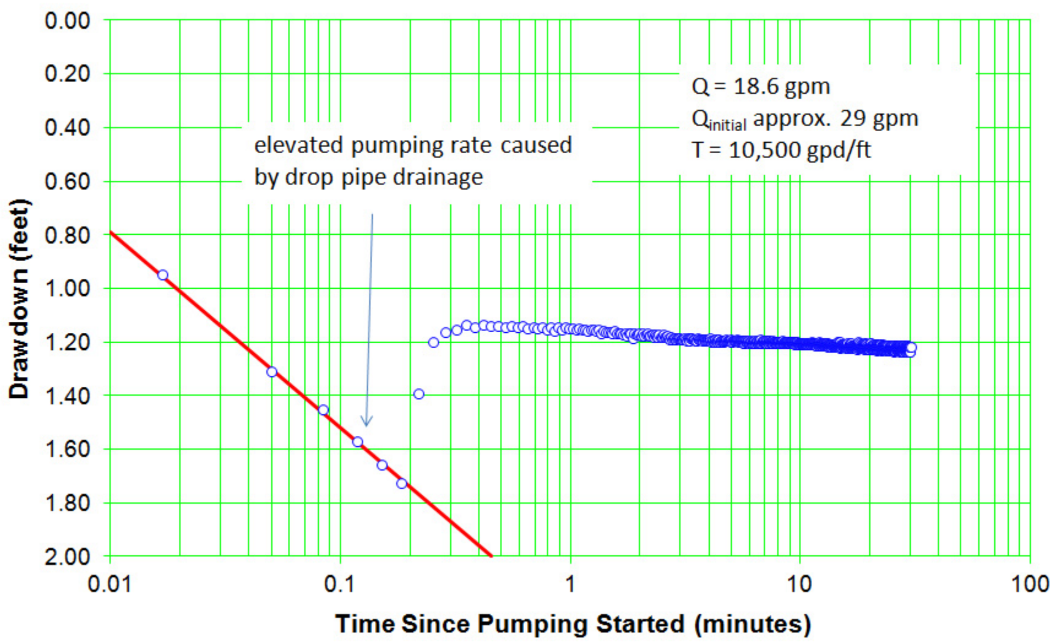

Figure E-8.1-1 Well R-58 trial 1 drawdown

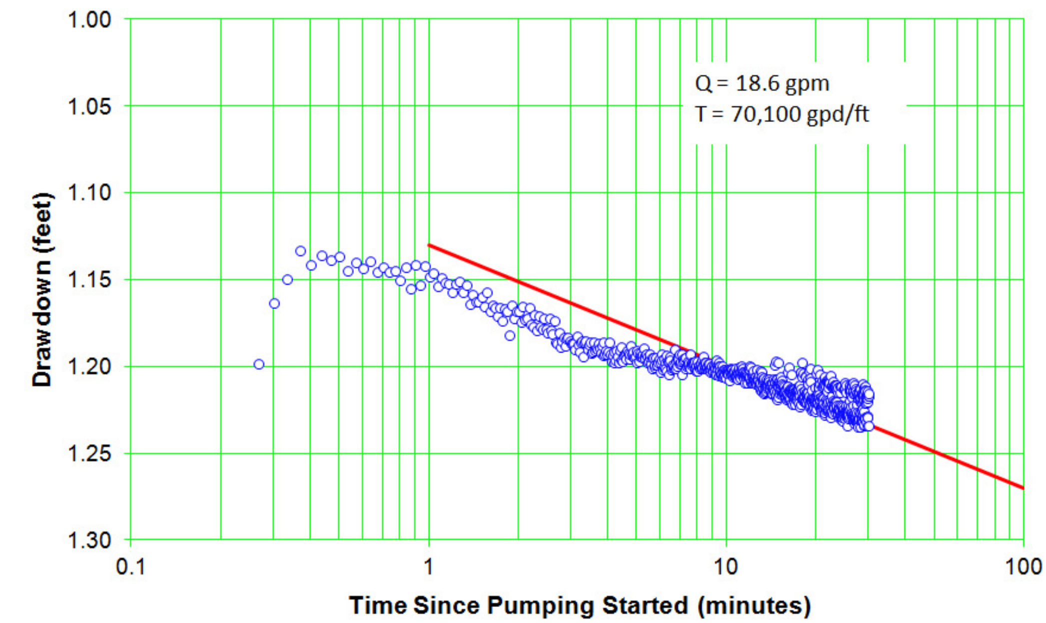

Figure E-8.1-2 Well R-58 trial 1 drawdown—expanded scale

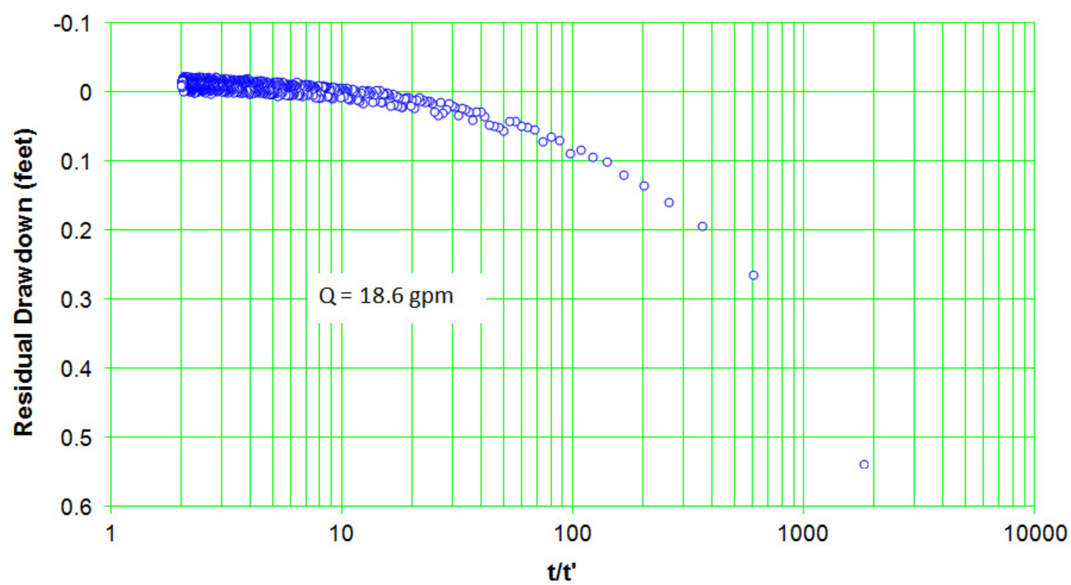

Figure E-8.1-3 Well R-58 trial 1 recovery

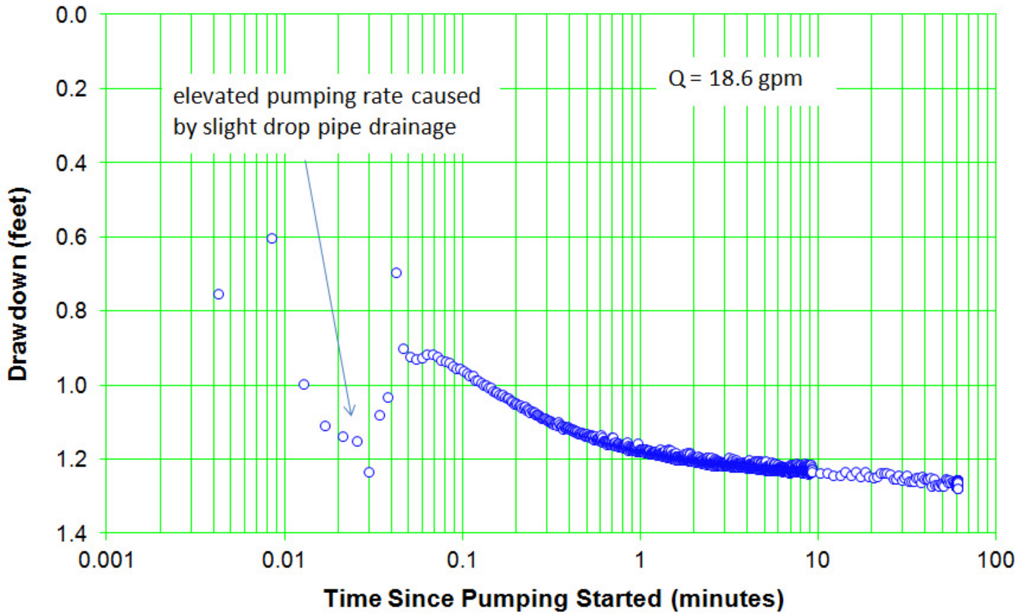

Figure E-8.2-1 Well R-58 trial 2 drawdown

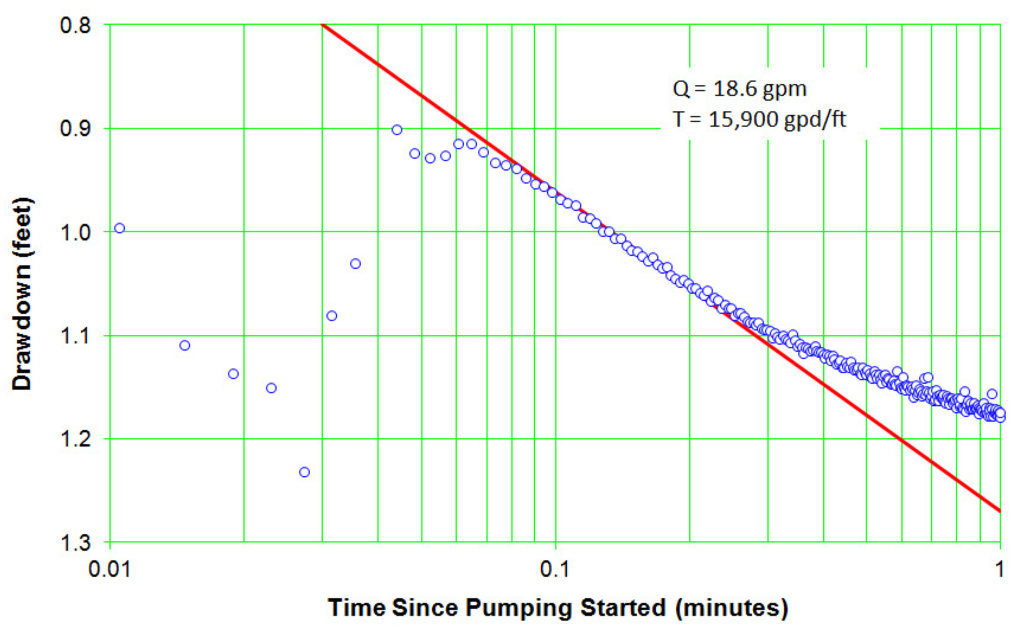

Figure E-8.2-2 Well R-58 trial 2 drawdown—expanded scale

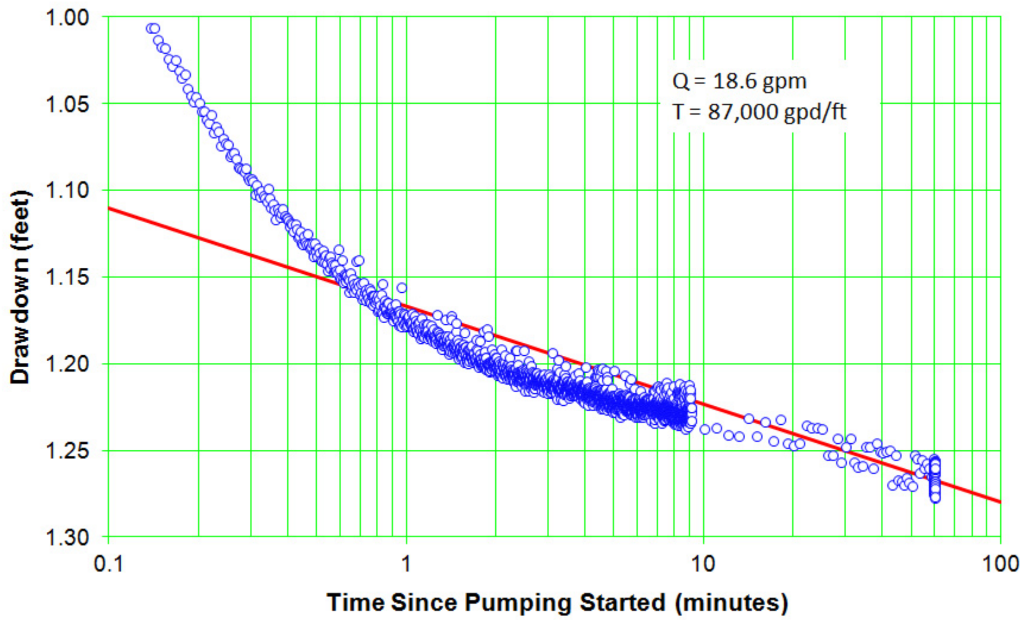

Figure E-8.2-3 Well R-58 trial 2 drawdown—late data

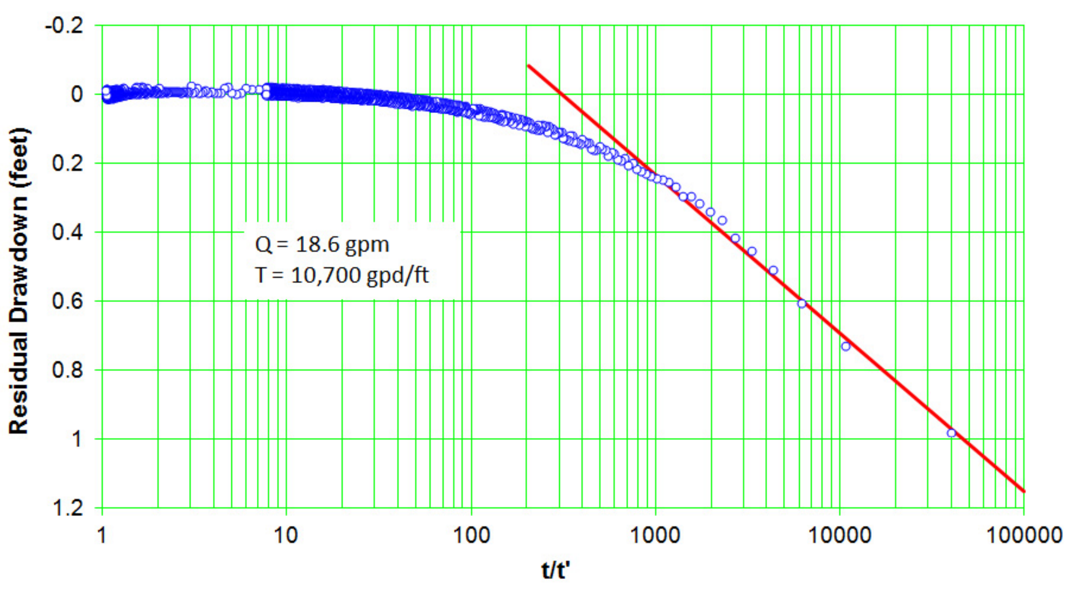

Figure E-8.2-4 Well R-58 trial 2 recovery

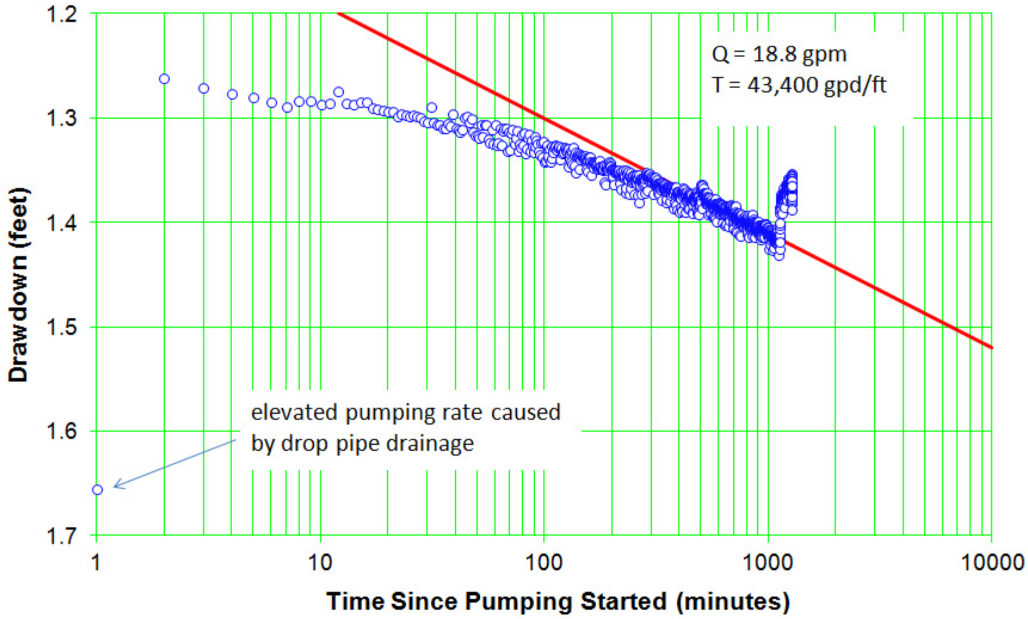

Figure E-8.3-1 Well R-58 drawdown

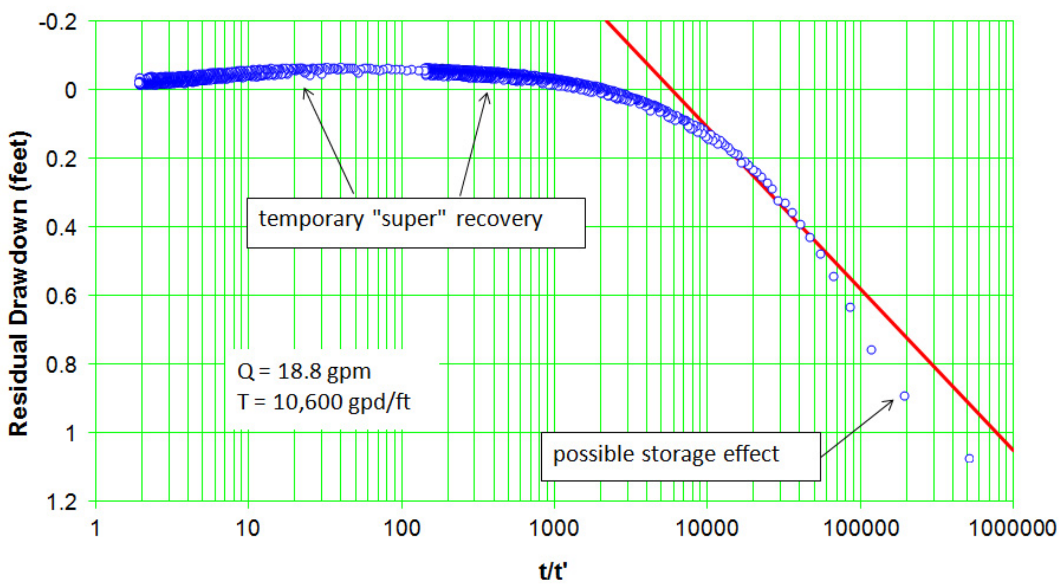

Figure E-8.3-2 Well R-58 recovery

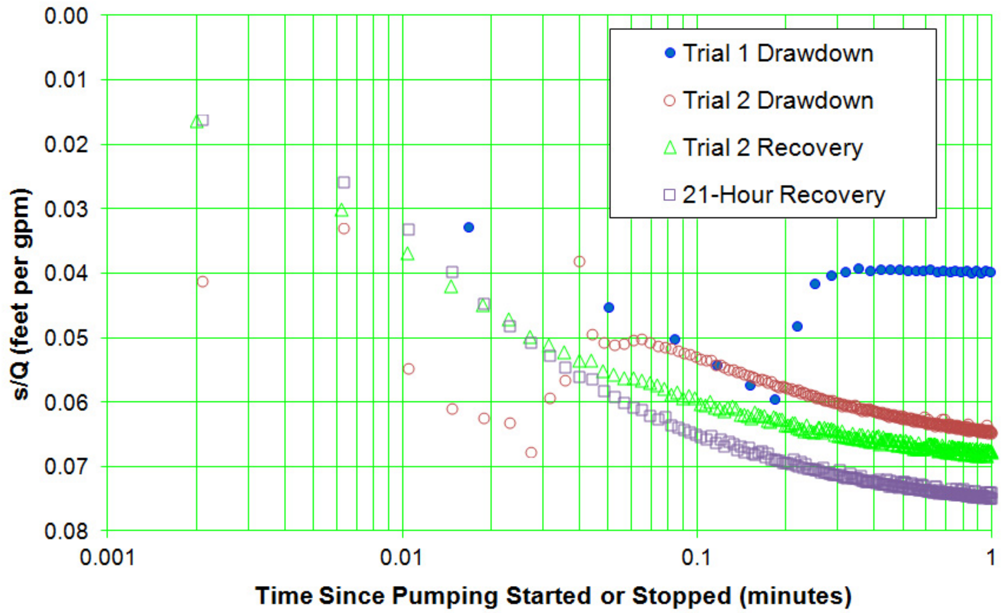

Figure E-8.4-1 Well R-58 combined early data

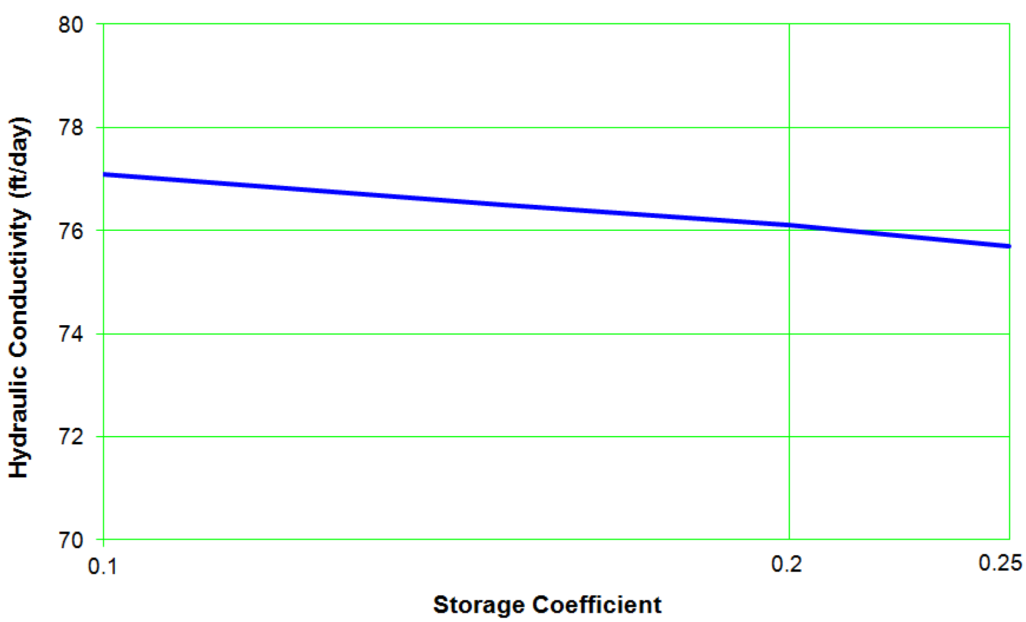

Figure E-8.5-1 Well R-58 lower bound-hydraulic conductivity

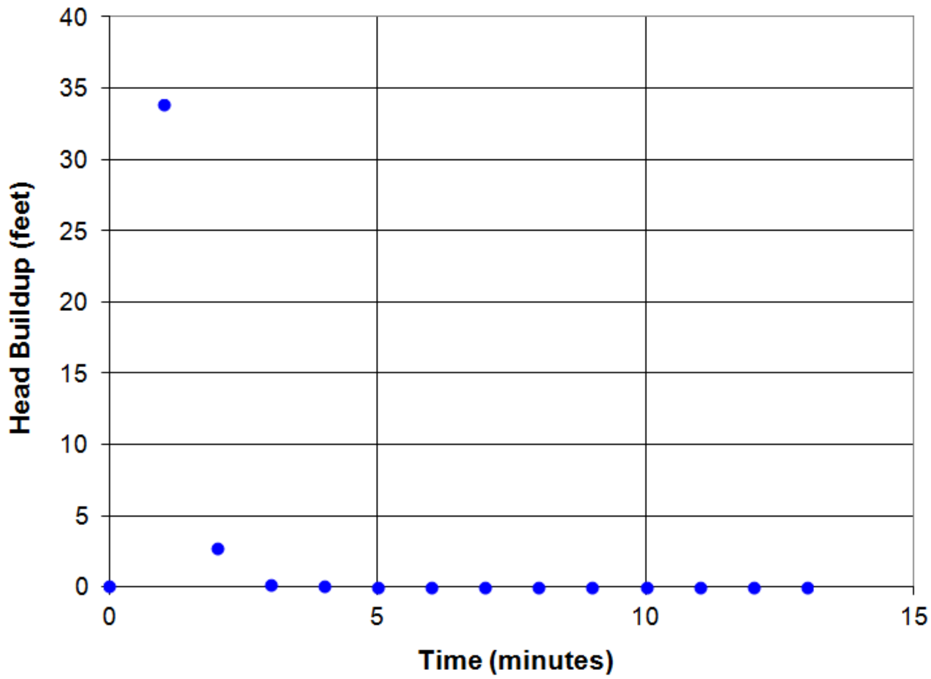

Figure E-8.6-1 Well R-58 packer deflation

Table E-8.5-1
Transmissivity and Hydraulic Conductivity Summary

Test	Method	T (gpd/ft)	K (gpd/ft^2)	K (ft/day)
Trial 1	Drawdown	10,500	517	69
Trial 2	Residual Drawdown	10,700	527	70
21-h Test	Residual Drawdown	10,600	522	70
Average	As Above	10,600	522	70