ESHID-601362

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Date: MAR 2 2 2016
Symbol: EPC-DO-16-063
LA-UR: 16-21509
Locates Action No.: U1501760

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

Dear Ms. Hunter:

Subject: Multiple Activities Work Plan for the Treatment and Land Application of Groundwater from Mortandad and Sandia Canyons, DP-1793 WP#3

On July 27, 2015, the New Mexico Environment Department (NMED) issued a Discharge Permit (DP-1793) to the U.S. Department of Energy and Los Alamos National Security, LLC (DOE/LANS) for the land application of treated groundwater from covered activities. Pursuant to Condition No. 3 of the above-referenced discharge permit, DOE/LANS are required to submit detailed, project-specific work plans for approval by NMED before any activities are undertaken.

Chromium (Cr) concentrations exceed the New Mexico Water Quality Control Commission (NMWQCC) Regulation 3103 groundwater standard of 50 µg/L in regional aquifer groundwater beneath Mortandad and Sandia Canyons within Los Alamos National Laboratory. The enclosed work plan is for the proposed discharge of treated groundwater from three Chromium Project activities: (1) pumping at extraction well CrEX-1 for hydraulic control of the plume, (2) development, aquifer testing, and on-going pumping to evaluate the optimum chromium mass removal pumping strategy at a new extraction well (CrEX-3, spring 2016) and injection capacity at new injection wells CrIN-1 through CrIN-5, and (3) routine monitoring well purging during sampling and five-day pumping at recently installed piezometers to confirm measured chromium concentrations.

The activities listed above will be conducted as specified in the NMED-approved Interim *Measures Work Plan for the Evaluation of Chromium Mass Removal* and *Work Plan for Chromium Plume Center Characterization.* Produced groundwater will be treated and discharged in accordance with the enclosed work plan and supporting information.

Please contact Robert S. Beers by telephone at (505) 667-7969 or by email at bbeers@lanl.gov if you have questions regarding this work plan.

Sincerely,

John P. McCann
Acting Division Leader
Environmental Protection & Compliance Division
Los Alamos National Security, LLC

Sincerely,

David S. Rhodes
Supervisor, Soil & Groundwater Remediation
Environmental Management
Los Alamos Field Office
U.S. Department of Energy

JPM:DSR:MTS:RSB/lm

Enclosures:

1) Multiple Activities Work Plan for the Treatment and Land Application of Groundwater from Mortandad and Sandia Canyons, DP-1793, WP #3
2) Interim Measures Work Plan for Chromium Plume Control and Work Plan for Chromium Plume Center Characterization
3) Topographical Map of the Project Site
4) Table 3.4-1 (Chromium Investigation Monitoring Group) from the Monitoring Year 2016 Interim Facility-Wide Groundwater Monitoring Plan
5) As-Built Specifications for Well and Piezometers
6) Water-Quality Data from CrEX-1, R-42, R-45, and R-50
7) Schematic of the IX Treatment System and Technical Specifications of the IX Vessels and Resin
8) 2016 Chromium Groundwater Project Land Application Layout
9) Sample Land-Application Zone Signage

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GROUND WATER
MAR 23 2016
BUREAU

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Chromium (Cr) concentrations exceed the New Mexico Water Quality Control Commission (NMWQCC) Regulation 3103 groundwater standard of 50 μg/L in regional aquifer groundwater beneath Mortandad and Sandia Canyons within Los Alamos National Laboratory. The enclosed work plan is for the proposed discharge of treated groundwater from three Chromium Project activities: (1) pumping at extraction well CrEX-1 for hydraulic control of the plume, (2) development, aquifer testing, and on-going pumping to evaluate the optimum chromium mass removal pumping strategy at a new extraction well (CrEX-3, spring 2016) and injection capacity at new injection wells CrIN-1 through CrIN-5, and (3) routine monitoring well purging during sampling and five-day pumping at recently installed piezometers to confirm measured chromium concentrations.

ENCLOSURE 1

Multiple Activities Work Plan for
the Treatment and Land Application of
Groundwater from Mortandad and Sandia Canyons,
DP-1793, WP #3

EPC-DO-16-063

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ENCLOSURE 1

Multiple Activities Work Plan for the Treatment and Land Application of Groundwater from Mortandad and Sandia Canyons, DP-1793 WP #3

Introduction. Chromium (Cr) concentrations exceed the New Mexico Water Quality Control Commission (NMWQCC) Regulation 3103 groundwater standard of 50 μg/L in regional aquifer groundwater beneath Mortandad and Sandia Canyons within Los Alamos National Laboratory (the Laboratory). Investigations have identified the probable Cr(VI) source as cooling-tower effluent released near the head of Sandia Canyon between 1956 and 1972. Hexavalent chromium was transported down the canyon in surface-water flow where it eventually infiltrated the vadose zone into the regional aquifer. Some Cr is present in the Sandia Canyon wetland and sediments as stable Cr(III). Hexavalent chromium is also still present in the vadose zone (including in perched-intermediate groundwater) beneath Sandia and Mortandad Canyons.

The Cr plume is approximately 1 mi by 0.5 mi in size and is estimated to be situated in the upper 75 ft of the aquifer. Several wells along the downgradient edge of the plume in the regional aquifer show increases in Cr concentrations, suggesting potential expansion of the plume. Because of these recent increases, the Laboratory proposed to conduct a plume control interim measures (IM) in accordance with Section VII.B.1 of the March 1, 2005, Compliance Order on Consent (Consent Order). The "Interim Measures Work Plan for Chromium Plume Control" (IMWP) was submitted on May 26, 2015 (Enclosure 2). The New Mexico Environment Department (NMED) approved the IMWP on October 15, 2015 (Enclosure 2). The IMWP establishes the technical foundation for the activities to control Cr plume migration in groundwater beneath Mortandad Canyon and provides the technical information to support a proposed configuration and operational mode for extraction and injection wells.

An additional work plan, the "Work Plan for Chromium Plume Center Characterization," was submitted to NMED on July 28, 2015 (Enclosure 2). It describes activities and studies to further refine the Laboratory's assessment of potential remedial strategies for Cr in the regional aquifer and vadose zone. NMED approved the work plan on October 15, 2015. The scope is largely centered on the installation of a new extraction well (CrEX-3) located within the plume centroid and testing (pumping) to evaluate the feasibility of efficient mass removal from the centroid.

This DP-1793 Work Plan (Work Plan #3) is for the proposed calendar year (CY) 2016 discharge of treated groundwater from three activities planned as part of the overall Chromium Project and more specifically for the IMWP and Interim Facility-Wide Groundwater Monitoring Plan (IFGMP) activities: (1) past (2015) and planned (2016) pumping at extraction well CrEX-1 for hydraulic control of the plume; (2) development, aquifer testing, and ongoing pumping to characterize the plume center at a new extraction well (CrEX-3) and injection capacity at new injection wells CrIN-1 through CrIN-5; and (3) routine purging during sampling of contaminant-affected monitoring wells under the IFGMP and 5-d pumping at recently installed piezometers to confirm measured Cr concentrations. Although generated from three different activities, due to similarities in water quality the groundwater will be treated and combined into six existing synthetically lined lagoons before land application.

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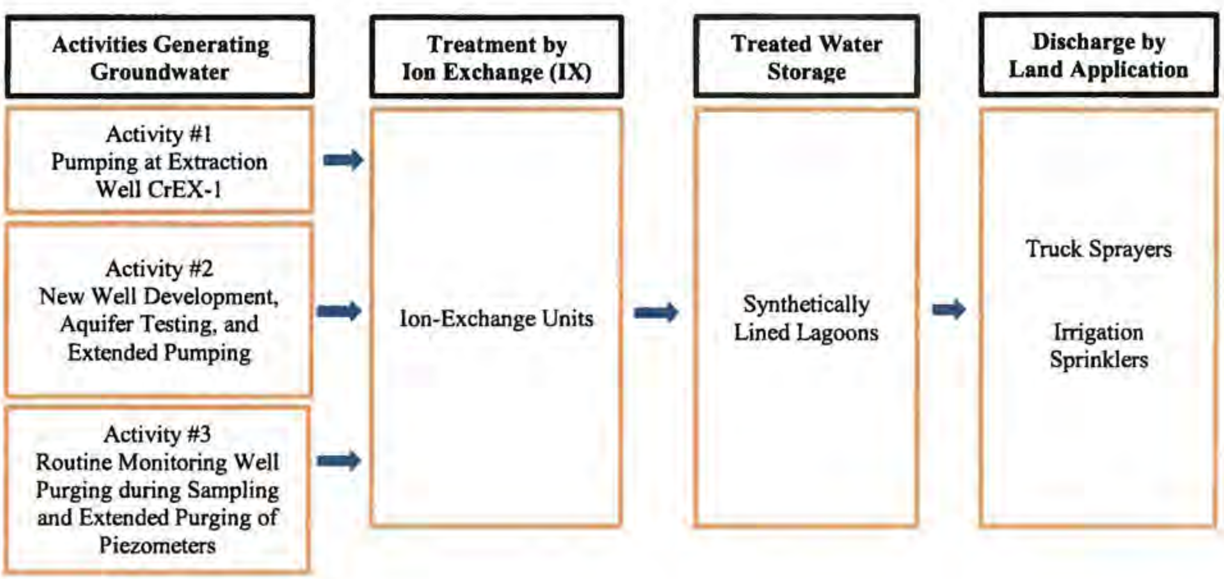
Multiple Activities Work Plan for the Treatment and Land Application of Groundwater from Mortandad and Sandia Canyons, DP-1793 WP #3

Groundwater produced during these three activities will be treated to less than 90% of the NMWQCC Cr groundwater standard of 50 μg/L, stored in the lined lagoons, and discharged by land application in accordance with Work Plan #3 and the NMED-issued Discharge Permit DP-1793 (July 27, 2015). Figure 1 shows the treatment, storage, and land-application flow diagram. This Work Plan is limited to land application in CY2016.

Volumes of water proposed for land application from the three activities planned in CY2016 are only estimates. Administrative controls will restrict the actual volume applied to less than the permitted volume of 350,000 gallons per day (gpd) total for all work plans submitted during this period.

Objectives. The activities proposed under this Work Plan address water generated from the Chromium Project focus on (1) assessing the potential for hydraulic control of Cr contamination in the regional aquifer via pumping with an extraction well, CrEX-1, located in Mortandad Canyon; (2) developing the well, aquifer testing, and extended pumping to evaluate optimum pumping rate(s) for Cr mass removal within the centroid of the groundwater plume at newly installed extraction well (spring 2016) CrEX-3 coupled with optimization of an injection strategy at newly installed injection wells CrIN-1 through CrIN-5 (spring and winter 2016); and (3) ongoing quarterly monitoring in groundwater monitoring wells in the area of the Cr plume and extended pumping at recently installed piezometers to confirm measured Cr concentrations.

Figure 1. Block Flow Diagram of Multiple Activities Treatment, Storage, and Land-Application Systems



ENCLOSURE 1

Multiple Activities Work Plan for the Treatment and Land Application of Groundwater from Mortandad and Sandia Canyons, DP-1793 WP #3

Proposed Activities.

Activity No. 1: Pumping at an Existing Extraction Well CrEX-1. Under the Chromium Project, pumping at an extraction well is conducted to evaluate (1) the characteristics of both the aquifer and the pumping-induced capture zone, and (2) the hydraulically controlled Cr migration within the aquifer. Approximately 49% of the water volume proposed for land application under this Work Plan is from pumping at extraction well CrEX-1 (26,780,000 gal.).

Activity No. 2: New Well Development, Aquifer Testing, and Extended Pumping. Following construction, new wells are pumped (developed) to remove introduced drilling and construction water and any naturally occurring fine-grained material to enhance hydraulic connection between the well and the aquifer. After development, both extraction and injection wells typically undergo aquifer testing to evaluate the hydraulic properties of the aquifer. Groundwater produced during an aquifer test is representative of water in the aquifer. After aquifer testing is completed, a dedicated pumping system or injection system will be installed, and ongoing pumping will be performed at the extraction well to evaluate aquifer and contaminant properties within the plume center. Approximately 51% the water volume proposed for land application under this Work Plan is from pumping at the new wells: extraction well CrEX-3 (17,568,000 gal.) and injection wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 (10,080,000 gal.).

Activity No. 3: Routine Monitoring Well Purging during Sampling and Extended Purging of Piezometers. The Laboratory conducts periodic sampling from groundwater wells to monitor the nature and extent and fate and transport of contaminants. Before a sample is collected from a groundwater monitoring well, it is necessary to purge the well to ensure the sample collected is representative of water in the aquifer. Typically, 3 casing volumes are purged from a monitoring well before a sample is collected. Accordingly, each monitoring well sampled by the Laboratory generates a volume of purge water after sampling. In addition, existing piezometers will be purged continuously for up to 5 d to collect additional data. Purge water is stored at the well site pending the availability of analytical data characterizing the quality of the water in storage. If the purge water in storage meets the requirements of the NMED-approved 2010 Los Alamos National Laboratory Drilling, Development, Rehabilitation, and Sampling Purge Water Decision Tree, then the purge water may be land-applied without treatment. Purge water with contaminant concentrations exceeding Decision-Tree limits must be treated before land application or dispositioned off-site. For the wells listed in this activity, treatment before land application is proposed. The volume of water (40,686 gal.) produced during Activity No. 3 represents less than 1/10 of 1% of the total water proposed for land application under this Work Plan.

Below are the sources of water to be treated and land-applied as a result of the above activities.

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Multiple Activities Work Plan for the Treatment and Land Application of Groundwater from Mortandad and Sandia Canyons, DP-1793 WP #3

Activity No. 1: Sources of Water from Pumping at Extraction Wells. Pumping at extraction well CrEX-1 will be conducted in CY2016 to continue to test feasibility of hydraulic control of Cr migration and to assess the potential for long-term removal of Cr from the regional aquifer. Groundwater generated from extraction well CrEX-1 in CY2015 and CY2016 is proposed for treatment and land application under this Work Plan.

- **CrEX-1 water generated in CY2015.** Pumping at extraction well CrEX-1 was conducted in CY2015 under the NMED-approved DP-1793 Work Plan #2 (October 29, 2015). While most of the produced water was treated and land-applied in CY2015, approximately 400,000 gal. of regional aquifer groundwater was treated and placed into the synthetically lined lagoons for storage. Table 1 provides information on the volume of water in storage from CY2015 pumping at CrEX-1.

- **CrEX-1 water generated in CY2016.** The U.S. Department of Energy (DOE) and Los Alamos National Security, LLC (LANS) propose to pump from extraction well CrEX-1 during CY2016 (approximately May 16—December 31) for an anticipated 229 d. Regional aquifer groundwater produced during the test will be treated and land-applied in accordance with this Work Plan. Table 1 provides information on the pumping rate (in gallons per minute [gpm]), duration (in days), and volume (in gpd).

Table 1. Sources and volumes of water from pumping at extraction well CrEX-1.

Well: CY Pumping	Pumping Rate (gpm)	Maximum Daily Volume Pumped (gpd)	Estimated Pumping Period (d)	Total Volume Treatment and Land Application (gal.)
CrEX-1: 2015 water in storage[1]	n/a[2]	n/a	n/a	400,000
CrEX-1: 2016 pumping	80	115,200	229[1]	26,380,800
Total volume from pumping at CrEX-1 extraction well				**26,780,800**

[1]Treated water stored in the six synthetically lined lagoons.
[2]n/a means not applicable. [3]Continous pumping is expected to begin May 16, 2016, and conclude by the end of December 2016.

Activity No. 2: Sources of Water from New Well Development, Aquifer Testing, and Extended Pumping

- **New Extraction Well (CrEX-3) Development, Aquifer Testing, and Extended Pumping Water Generated in CY2016.** DOE and LANS are scheduled to install CrEX-3 by May 2016. Once installed, this well will be developed and aquifer tested, followed by an extended period of pumping. It is anticipated that these activities will occur during CY2016 (May—December) over a period of approximately 244 d. Regional aquifer groundwater produced during the test will be treated and land-applied in accordance with this Work Plan. Table 2 provides information on the pumping rate, duration, and volume.

- **New Injection Wells Development and Aquifer Testing Water Generated in CY2016.** DOE and LANS propose to develop and aquifer test wells CrIN-1, CrIN-2, CrIN-3, CrIN-4, and CrIN-5 during CY2016 (May—December) for approximately 14 d each. Regional aquifer groundwater produced during the development and testing will be treated and land-applied in accordance with this Work Plan. Table 2 provides information on the pumping rate, duration, and volume.

Table 2. Sources and volumes of water from pumping during Activity #2.

Well: CY Pumping	Pumping Rate (gpm)	Maximum Daily Volume Pumped (gpd)	Estimated Pumping Period (d)	Total Volume Treatment and Land Application (gal.)
CrEX-3: pumping[1]	50	72,000	244[1]	17,568,000
CrIN-1	100	144,000	14	2,016,000
CrIN-2	100	144,000	14	2,016,000
CrIN-3	100	144,000	14	2,016,000
CrIN-4	100	144,000	14	2,016,000
CrIN-5	100	144,000	14	2,016,000
Total volume from pumping at extraction and injection wells				**27,648,000**

[1]Development pumping, followed by testing and extended pumping, is expected to begin May 1, 2016, and conclude by the end of December 2016. Produced water will be stored until this work plan is approved.

Activity No. 3: Sources of Water from Routine Monitoring Well Purging during Sampling.

- Groundwater monitoring wells at the Laboratory are routinely sampled in accordance with the NMED-approved IFGMP. Numerous monitoring wells in the Chromium Investigation monitoring group in Sandia and Mortandad Canyons are monitored quarterly. Six of these wells—R-28, R-42, R-43 screen 1 (S1), R-50 S1, R-62, and SCI-2 and five piezometers (CrPZ-1, CrPZ-2-S1, CrPZ-2-S2, CrPZ-3, and CrPZ-5)—have the potential to show concentrations above the NMWQCC Regulation 3103 groundwater standard of 50 μg/L for Cr (total), and therefore discharge may require treatment before disposition via land application. Groundwater produced from pumping at piezometer CrPZ-4 will not be managed under this Work Plan.

  Purge water from sampling at 10 locations (CrPZ-2-S1 and CrPZ-2-S2 are the same location) was placed into temporary storage. Table 3 lists the wells and associated volumes. Additional purge water will be generated during CY2016 sampling of these locations. Additionally, the five piezometers will be pumped continuously at up to 0.7 gpm for up to 5 d. Under this Work Plan, the routine monitoring well sample purge water will be treated by IX to less than 90% of the NMWQCC groundwater standard for Cr, temporarily stored in the six synthetically lined lagoons, and land-applied.

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Multiple Activities Work Plan for the Treatment and Land Application of Groundwater from Mortandad and Sandia Canyons, DP-1793 WP #3

Table 3. Sources and volumes of routine monitoring well purging during sampling.

Well	Source of Groundwater	Current Volume in Storage (gal.)	Additional Volume Expected (gal.)	Total Volume Treatment and Land Application (gal.)
R-28	Well purge water	260	825	1,085
R-42	Well purge water	210	630	840
R-43 S1	Well purge water	213	760	973
R-50 S1	Well purge water	224	775	999
R-62	Well purge water	184	553	737
SCI-2	Well purge water	81	96	177
CrPZ-1	Well purge water (sampling and 5-d pumping)	0	5,100	5,100
CrPZ-2-S1	Well purge water (sampling and 5-d pumping)	3,000	5,100	8,100
CrPZ-2-S2	Well purge water (sampling and 5-d pumping)	2,500	5,200	7,700
CrPZ-3	Well purge water (sampling and 5-d pumping)	2,600	5,100	7,700
CrPZ-5	Well purge water (sampling and 5-d pumping)	2,125	5,150	7,275
Total purge water from well sampling and pumping				**40,686**

Below is additional information, common to all three of activities identified above on the proposed discharge.

1. **Location**. Although Discharge Permit DP-1793 references 55 sections within the New Mexico State Plane Coordinate System at the Laboratory where treated groundwater may be discharged, the wells, piezometers, and proposed land-application sites referenced in this Work Plan are all located within the following four sections: (Township/Range/Section) T19N/R06E/S22, S23, S24, and S25. These four sections were selected because of their proximity to the Chromium Project sources referenced in this Work Plan.

   Enclosure 3 is a topographic map of the project site including the location of all site monitoring areas (SMAs), solid waste management units (SWMUs), National Pollution Discharge Elimination System (NPDES) outfalls, groundwater discharge permits, areas of concern (AOCs) identified in the 2005 NMED Consent Order, drinking water wells, surface impoundments, and surface drainage features in the vicinity of the Chromium Project.

2. **Groundwater Monitoring.** Groundwater monitoring is conducted quarterly within a group of monitoring wells contained in the Chromium Investigation monitoring group under the annual IFGMP. Annual submittal of the IFGMP is required under the Consent Order. The wells comprising the Chromium Investigation monitoring group are situated within Sandia and Mortandad Canyons. Sampling during CY2016 is being carried out in accordance with the NMED-approved IFGMP. The monitoring locations, analytical suites, and frequency of monitoring reflect the technical and regulatory status of each area and are updated annually in the IFGMP.

   The Chromium Investigation monitoring group focuses on the characterization and fate and transport of Cr contamination in intermediate-perched groundwater and within the regional aquifer. The distribution of wells in the monitoring group also addresses past releases from NPDES Outfall 051, which discharges from the Radioactive Liquid Waste Treatment Facility in the Mortandad Canyon watershed. The IFGMP for the Chromium Investigation Monitoring Group for 2016 (October 2015–September 2016) is provided as Enclosure 4. The plan lists the rationale for well selection, the applicable analytical suites, and the sampling frequency.

3. **Depth to Groundwater and Groundwater Flow Direction.** Groundwater may be present in the land application area within alluvial, perched-intermediate, and regional aquifers.

   Three alluvial groundwater monitoring wells are located in the vicinity of the land-application sites in Mortandad Canyon: MCO-9, MCO-12, and MCA-9 (see Enclosure 3). These alluvial groundwater wells are effective first indicators of whether infiltration from land application is occurring. The direction of alluvial groundwater flow, when present, is downcanyon to the southeast.

   The depth to perched-intermediate groundwater at well MCOI-5 in the vicinity of the proposed land-application sites in Mortandad Canyon is approximately 650 ft. Saturated intervals can be present above, within, and at the base of the basalts underlying the site, making determination of an overall aquifer flow direction difficult.

   The depth to regional groundwater beneath the proposed land-application sites in Mortandad Canyon is approximately 1000 ft. The direction of groundwater flow in the regional aquifer beneath the proposed land-application sites is also generally to the southeast.

   The Laboratory proposes to conduct monthly water-level measurements at Mortandad Canyon alluvial wells MCO-9, MCO-12, and MCA-9, both during and up to 3 mo following termination of land application.

If sufficient water is present, then a sample will be collected and analyzed for Cr, nitrate+nitrite (NO_3+ NO_2-N), total dissolved solids (TDS), chloride (Cl), and perchlorate (ClO_4) by an off-site, independent, National Environmental Laboratory Accreditation Program– (NELAP-) accredited analytical laboratory. The water level in a monitoring well must be within the screened interval to meet the criteria for sample collection.

4. **Well Specifications**. Enclosure 5 provides the as-built specifications for all wells and piezometers referenced in this Work Plan, with the exception of extraction well CrEX-3 and the injection wells, for which the proposed designs are included because they will be installed in 2016.

5. **Expected Contaminants**. The source of groundwater generated from all activities listed in this Work Plan is the intermediate and regional aquifer. By volume, approximately half the water proposed for treatment and land application is from pumping at extraction well CrEX-1 and approximately half from pumping at extraction well CrEX-3. Accordingly, the quality of groundwater from CrEX-1 and CrEX-3 best represent the quality of the discharge. Because CrEX-3 has not yet been drilled, water quality from monitoring well R-42 is presented as a worst-case proxy. For completeness, Table 4 presents maximum concentrations of key anthropogenic contaminants from all wells proposed for land application under this Work Plan.

   Enclosure 6 contains water-quality data from CrEX-1, R-42 (proxy for CrEX-3), R-45 (proxy for CrIN-1 and CrIN-2), and R-50 (proxy for CrIN-3, CrIN-4, and CrIN-5) for general inorganics, metals, polychlorinated biphenyls, volatile organic compounds, and semivolatile organic compounds. Table 4 below provides the maximum concentrations of Cr, NO_3+ NO_2-N, TDS, Cl, and ClO_4 detected in 2015 from all wells and piezometers listed in Tables 1, 2, and 3.

   Chromium is the only contaminant expected to exceed the NMWQCC Regulation 3103 groundwater standards at the above-referenced wells and piezometers. Nitrate (NO_3-N) concentrations are above background levels in some wells and may become elevated even further before anionic equilibrium is reached in the IX vessel because of sorption-site flooding. Treated water monitoring conducted under this Work Plan (see item 8 below) and operational monitoring conducted by the Laboratory using Hach methods for real-time field results will closely track NO_3-N and Cr concentrations in the treated water.

Table 4. Maximum concentrations of Cr, NO_3+ NO_2-N, TDS, Cl, and ClO_4 in wells and piezometers, 2015.

Well Type by Activity	Cr (µg/L)	NO_3+NO_2-N (mg/L)	TDS[2] (mg/L)	Cl (mg/L)	ClO_4 (µg/L)
Activity #1					
CrEX-1	181	3.4	280	30.4	0.80
Activity #2					
R-42 (proxy for CrEX-3	915	6.0	394	47.4	1.3
R-45 (proxy for CrIN-1 and CrIN-2)	37.8	3.5	187	4.9	0.6
R-50 (proxy for CrIN-3, CrIN-4, and CrIN-5)	126	2.0	187	9.5	0.6
Activity #3					
R-28	422	4.2	333	38.5	1.2
R-42	915	6.0	394	47.4	1.3
R-43 S1	146	6.0	211	8.6	1.0
R-50 S1	117	2.0	187	9.1	0.6
R-62	161	1.3	290	9.8	0.8
SCI-2	449	4.6	483	70	1.0
CrPZ-1	430.8	4.1	na[1]	37.3	2.1
CrPZ-2-S1	83.9	3.6	na	66.4	0.9
CrPZ-2-S2	35.0	1.0	na	7.7	0.4
CrPZ-3	338.9	5.8	na	22.5	1.2
CrPZ-5	89.3	3.1	na	19.4	0.4
NMWQCC GW Std[2]	**50**	**10**	**1000**	**250**	**13.8[3]**

[1]na means that no results are available for this constituent.
[2]NMWQCC Regulation 3103 standards for groundwater, except as noted.
[3]NMED Risk Assessment Guidance for Site Investigations and Remediation, Table A-1, Tap Water Soil Screening Levels.

In addition to the contaminants listed above, the recovery of NMED-approved groundwater tracers may occur in any of the wells listed in this Work Plan. In accordance with a Notice of Intent (NOI) to discharge submitted to the NMED (EPC-DO-16-047, March 4, 2016), DOE/LANS is conducting a tracer study in the Cr(VI)-contaminated regional aquifer beneath Mortandad Canyon to evaluate the solute transport characteristics of the aquifer, and to support the future assessment of potential remedial alternatives for the contaminated groundwater. Multiple nonreactive tracers and an alkaline (pH ~10) buffer solution will be deployed to the regional aquifer. The tracers include five different naphthalene sulfonates, deuterated water (D_2O), sodium bromide (NaBr), and sodium perrhenate ($NaReO_4$). For the alkaline buffer solution, sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) will be used in roughly equal molar proportions to produce a solution of approximately pH 10. Table 5 below lists all of the tracers and their deployment locations. None of the tracers deployed are NM WQCC Toxic Pollutants (20.6.2.7.WW NMAC) or Regulation 3103 contaminants (20.6.2.3103 NMAC).

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Table 5. Tracers Potentially Present in Groundwater Produced Under Work Plan #3

Deployment Location	Unit	Tracer(s)/ Solution	Notes
R-50 Screen #1	Regional Aquifer	Na-1,5 NDS[a]	Dilution test. Anticipated recovery: <2%. Involves injection of tracer and monitoring of migration of tracer away from the well.
CrPZ-2a	Regional Aquifer	Na-2,7 NDS $NaReO_4$	Injection point for cross-hole test.
CrPZ-2b	Regional Aquifer	Na-2 NS[b] D_2O	Injection point for cross-hole test
R-28	Regional Aquifer	Na-1 NS NaBr	Injection point for cross-hole test.
CrPZ-3 or R-42	Regional Aquifer	$NaHCO_3$ Na_2CO_3	Push-pull test to evaluate desorption of Cr(VI) from aquifer sediment surfaces caused by injection of alkaline solution. Test involves injection of alkaline water, followed by a wait period, then pumping at injection point to recover alkaline water and mobilized Cr(VI). Anticipated recovery: ~90%.
CrPZ-3 or R-42	Regional Aquifer	Na-2,6-NDS	Injection point for cross-hole test.

[a]NDS = Naphthalene disulfonate.

[b]NS = Naphthalene sulfonate.

Potential recoveries of the deployed tracers range from zero to 100% for all tracers at CrEX-3 over a 3-year period. Tracers will be monitored for their appearance in CrEX-1, in quarterly-sampled monitoring wells, and in any new wells that are installed in the vicinity of the tracer injections. Initial arrival of tracers isn't expected earlier than approximately 6 months, but monitoring will begin about 4 months after deployment. Peak tracer concentrations in CrEX-3 could range from <0.1 μg/L to 1 mg/L, with a possibility of tracer concentrations remaining below detection limits. All analytical data collected from monitoring for tracers at all locations will be reported to the NMED in the required discharge permit report submitted upon completion of this Work Plan.

6. **Raw Water Storage.** The type, quantity, and capacity of tanks storing untreated groundwater from all activities are listed in Table 6.

Table 6. Type, quantity, and capacity of storage tanks receiving untreated groundwater[1].

Well	Type of Storage	Quantity	Tank Capacity (gal.)
All sources listed in Tables 1, 2, 3	21,000-gal. metal storage tank	18	~378,000

[1]Water stored in poly tanks at individual well sites will be transferred to the tanks listed in Table 6 before treatment.

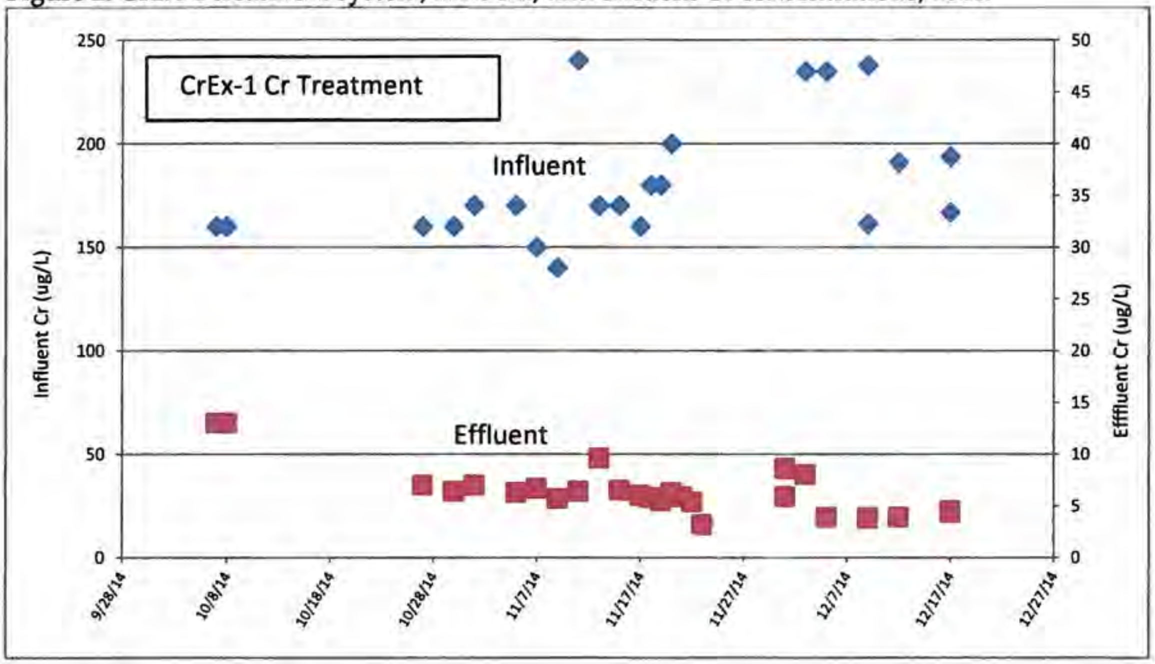
7. **Treatment System.** Groundwater produced from all activities referenced in this Work Plan will be treated by IX to reduce Cr concentrations to below 45 μg/L, 90% of the NMWQCC Regulation 3103 groundwater standard. The project has both a centralized IX unit staged at well R-28 and a smaller portable unit that may be used at the extraction and injection wells. Enclosure 7 provides a schematic of the IX treatment system and technical specifications of the IX vessels and resin. The large treatment system contains two treatment trains, and the portable unit contains one train. Each train is composed of both a first stage and a second stage IX unit. Sample collection ports are located at all stages of treatment. The treatment system design is based on an influent Cr concentration of up to 1,000 μg/L. Spare vessels will be staged on-site for replacement, as needed.

   Groundwater pumped from extraction and injection wells either will be (1) treated at the well site and then transferred across Mortandad Canyon in a single-wall, 4-in.-diameter high-density polyethylene pipeline to the synthetically lined lagoons for storage before land application or (2) transferred to the storage tanks at R-28 via a double-wall piping or by water truck, treated, and stored in the synthetically lined lagoons for storage before land application (see Enclosure 8). Groundwater produced from the wells and piezometers listed in Table 3 will be transported by truck to the treatment system located at well R-28; treated water will be comingled from the three activities covered by this Work Plan in the synthetically lined lagoons before land application.

   The performance and removal efficiency of the proposed IX treatment system was demonstrated previously during pumping tests conducted under NMED-issued temporary permissions in 2012, 2013, and 2014 and the NMED-approved DP-1793 Work Plan #2 in 2015. The proposed IX treatment system will remove Cr to concentrations below 45 μg/L, less than 90% of the NMWQCC groundwater standard of 50 μg/L. Figure 2 below shows Cr concentrations in the influent (untreated water) and effluent (treated water) from CrEX-1 during aquifer tests in 2014. Effluent concentrations did not exceed 13 μg/L, 26% of the 50 μg/L groundwater standard during the 45-d pumping of CrEX-1. Chromium removal during the 22 d of pumping at CrEX-1 in 2015 provided similar results to those presented in Figure 2.

   The IX vessels and resins will be sampled and characterized before shipment back to the vendor for regeneration. It is the responsibility of the vendor to manage the vessels and resins in accordance with all applicable federal, state, and local regulations.

Figure 2. CrEX-1 treatment system, influent, and effluent Cr concentrations, 2014.



8. **Sampling Plan.** To demonstrate compliance with the NMWQCC Regulation 3103 groundwater standards for Cr and NO_3-N, grab samples will be collected routinely and throughout the entirety of the pumping from the sample port downstream of the last IX treatment vessel at each treatment site. Treated water samples will be collected twice per week for analysis by an off-site, independent, NELAP-accredited analytical laboratory. Table 7 summarizes the proposed sampling plan.

Table 7. Proposed sampling plan for treated water from all Work Plan activities.

Parameter	Sample Type	Analytical Method	TAT[1]	Frequency	MDL[2]
NO_3-N	Grab, filtered	§20.6.2.3107.B	5 d	2 times/wk	0.033 mg/L
Total Cr	Grab, filtered	§20.6.2.3107.B	5 d	2 times /wk	2 μg/L

[1]TAT means the analytical turnaround time. [2]MDL means the method or instrument detection limit.

The following contingencies will be applied under this sampling plan.

- ✓ If Cr and NO_3-N concentrations collected under the above sampling plan are less than 45 μg/L or 9 mg/L, respectively, then treated groundwater will move directly from the treated water storage lagoon(s) to land application.

- ✓ If Cr and NO_3-N concentrations collected under the above sampling plan exceed 45 μg/L or 9 mg/L, respectively, then land application will stop immediately and a representative sample(s) from the lagoon(s) receiving treated water will be collected for Cr and NO_3-N analysis.

- ✓ If the contents of the sampled lagoon(s) do not meet the above-referenced criteria for land application, then it will be re-treated and reanalyzed to verify concentrations meet land-application criteria.

- ✓ If Cr concentrations in the effluent stream exceed the above-referenced criteria, then the upstream IX vessel will be replaced by the downstream vessel and a new downstream vessel will be installed.

Operational samples will be collected routinely and measured for Cr and NO_3-N using Hach methods for real-time field results to monitor the IX treatment system's performance.

9. **Treated Water Storage.** Treated groundwater from all sources will be stored in the existing six synthetically lined lagoons before land application. Enclosure 8 shows the location and types of pipelines transferring water from the IX treatment units to the treated water storage lagoons. Table 7 provides additional information on the capacity of these lagoons.

Table 7. Type, quantity, and capacity of storage lagoons receiving treated groundwater.

Location	Type of Storage (year installed)	Quantity	Capacity Each (gal.)	Total Capacity (gal.)
Mortandad Canyon	Synthetically lined lagoon (2013)	3	140,000+/-	420,000+/–
Mortandad Canyon	Synthetically lined lagoon (2014)	3	210,000+/-	630,000+/–

Three of the six synthetically lined lagoons proposed for use under this Work Plan were constructed in 2013 and approved by NMED Ground Water Quality Bureau (GWQB) for storing treated water during the 2013 and 2014 Chromium Project aquifer tests. Design criteria for these three lagoons were submitted to the NMED in the following document: Additional Information, Request for Temporary Permission to Discharge Treated Groundwater from a Pumping Test at Well R-28, DP-1793 (ENV-RCRA-13-0059). In April 2014, an inspection report (ENV-DO-14-0084) was submitted to NMED for the synthetically lined storage lagoons.

Three additional treated water storage lagoons were constructed in 2014 southeast of the three 2013 lagoons. The 2014 lagoons were constructed in accordance with the design criteria submitted to NMED in the Discharge Permit DP-1793 Amended Application on January 7, 2014 (ENV-DO-13-0343). Record drawings of the 2014 lagoons were submitted to the NMED in October 2014 (ENV-DO-14-0310).

10. **Land Application.** Treated groundwater from all activities and sources referenced in this Work Plan will be land-applied in accordance with requirements of Discharge Permit DP-1793 (July 2015) and the conditions listed below. The following three sections—Planning, Operational Controls, and Inspections—provide additional information on the land-application component of this Work Plan.

- **Planning.** Land application zones 1–4 identified in Enclosure 3 were selected and will be utilized based on the following criteria specified in Condition No. 4 of Discharge Permit DP-1793 and NMED's approval (as modified) of Work Plan #2:

  - ✓ Avoidance of watercourses, water bodies, and wetlands by observing a 20-ft no-spray buffer;
  - ✓ Avoidance of AOCs by observing a 20-ft no-spray buffer, with the exception of the following canyon-bottom AOCs: C-00-001 through C-00-019 and C-00-021;
  - ✓ Avoidance of SWMUs and SMAs by observing a 20-ft no-spray buffer;
  - ✓ Avoidance of cultural sites; and
  - ✓ Application on areas with average slopes <2% when groundcover is <50% and average slopes <5% when groundcover is >50%.

  Treated groundwater will be land-applied by (1) water trucks (3,000–10,000-gal. capacity) equipped with both standard rear-mounted dust control sprayers and multiple high-pressure water sprayers, and (2) by irrigation-type sprinklers. Zones 1–3 are unpaved roads and road shoulders; zone 4 is an irrigation site. Each type of land-application zone is discussed below.

  Water trucks will be filled with treated water from the six synthetically lined lagoons located near the well R-28 site (see Enclosure 8). A totalizing meter will record the volume of treated water loaded into each truck. Land application zones 1–3 consist of approximately 3 mi of unpaved road receiving treated water for dust suppression. As much as 30% of the treated water discharged will be land-applied for dust control.

  The unpaved roads in zones 1–3 will receive water for dust suppression. The frequency and volume of treated water land-applied for dust control will be based on field conditions. The Operations Manager will determine when an application of dust-suppression water is required.

  Maintaining a low-dust environment for field personnel is an important health and safety objective for the field superintendent. Enclosure 3 shows the location of unpaved roads. (Note: zone 2 will only receive water for dust suppression, while zones 1 and 3 will also receive sprayed water along the road shoulders.)

  The road shoulders in zones 1 and 3 have been identified as suitable terrain for the land application of treated water by high-pressure water sprayers. These areas meet the criteria of having >50% vegetation and have slopes that average <5% over the land application area. Additionally, these areas are relatively flat and heavily vegetated in the strip closest to the road that will be used for spraying. When deployed by the truck driver, the high-pressure sprayer can land-apply treated water up to 100 ft from the center of the road for zone 3.

Zone 1 will be limited to land application by the high-pressure sprayers to 25 ft on either side of the center line of the road. High-visibility markings such as stakes with flagging are placed 25 ft from the road center line to identify the appropriate spray distance. The frequency and volume of land application to the road shoulders in zones 1 and 3 will be directed by the Operations Manager based on the history of discharges to each zone and a field assessment of soil moisture. The Operations Manager objective is to achieve an equitable distribution of treated water across zones 1and 3. Enclosure 3 shows the location of road shoulder land-application zones 1 and 3.

Zone 4 is the area approved for receiving treated water by irrigation-type sprinklers. Treated groundwater from the six synthetically lined lagoons will be pumped to the irrigation sprinklers and the volume measured by a totalizing meter. Field personnel will supervise the land application and engage/disengage individual sprinklers units, as necessary. The Operations Manager will direct the frequency of use and volume discharge to each land-application zone based on previous use and soil-moisture conditions.

- **Operational Controls.** Condition No. 4 of Discharge Permit DP-1793 and NMED's approval (as modified) of Work Plan #2 establishes the following conditions for the land application of treated groundwater:
  - ✓ Do not land apply water within 20 ft of watercourses or water bodies.
  - ✓ Land application cannot result in water flowing from an approved land-application site.
  - ✓ Land application cannot create ponds or pools or standing water.
  - ✓ Land application must be conducted in a manner that maximizes infiltration and evaporation.
  - ✓ Land application is restricted to daylight hours and for a maximum of 10 h/d.
  - ✓ Land application must be supervised.
  - ✓ Land application cannot extend off Laboratory property without written permission from the land owner.
  - ✓ Land application will be stopped if leaks in the land-application system are detected.
  - ✓ Land application is prohibited while precipitation is occurring or when temperatures are below freezing.

To ensure compliance with the conditions listed above, the Laboratory will implement the following operational controls:

a. All field personnel involved with land application will complete training to the following standard operating procedure and regulatory documents:

   - ENV-RCRA-QP-010.3, Land Application of Groundwater
   - NMED-issued Discharge Permit DP-1793, LANL Groundwater Projects (July 27, 2015)
   - Multiple Activities Work Plan for the Treatment and Land Application of Groundwater From Mortandad and Sandia Canyons, DP-1793 WP#3
   - NMED-GWQB Approval of DP-1793 WP#3 (pending)

b. All field personnel will participate in pre-job briefings and morning tailgate talks to provide field personnel with the following critical information: daily weather reports, daily land-application activities, system maintenance and repairs scheduled, and daily inspection schedule.

c. Signs identifying the beginning and end of each land-application zone will be installed (e.g., ZONE 1), areas where land application is permitted (green signs designating "SPRAY") and not permitted (red signs designating "NO SPRAY"). Enclosure 9 provides an illustration of the signage. Note: high visibility markings are placed at the appropriate distance from the road to identify the usable land-application area.

d. Field personnel will maintain written records of the volume and date of treated water land-applied to each zone.

➢ **Inspections.** The following inspections will be conducted to ensure compliance with the land-application criteria specified in Condition No. 4 of Discharge Permit DP-1793 and this Work Plan:

   ✓ Daily inspection of dust-suppression sprayers, high-pressure sprayers, transfer pumps, transfer hoses, and all equipment associated with land application by water truck

   ✓ Daily inspection of transfer pumps, transfer hoses, fittings, couplings, and all components of the irrigation sprinkler system

   ✓ Daily inspection of the land-application zones for evidence of standing or flowing water

   ✓ Daily inspection of the six synthetically lined lagoons for minimum 2-ft freeboard

11. **Maximum Daily Discharge.** The maximum daily discharge under this and all other active work plans approved under DP-1793 will not exceed 350,000 gpd. Volumes will be documented in the land application logs and verified by the Operations Manager.

12. **Water Conservation and Reuse Options.** In lieu of using potable water for dust suppression, as much as 30% of the treated water discharged will be land-applied to approximately 3 mi of dirt road in Mortandad Canyon (Zones 1–3). Given the project's location, other reuse options—such as using treated water at Laboratory cooling towers—would require transporting the treated water by truck; the resulting environmental impact was deemed unacceptable because of the carbon dioxide emissions generated.

13. **Project Schedule.** Land application will commence following NMED approval of this Work Plan and will continue until December 31, 2016, or when field conditions prohibit land application (see item 10 above).

14. **Reporting.** In accordance with requirements B.8 and B.9 of Discharge Permit DP-1793 (July 27, 2015), DOE/LANS will submit to NMED annual monitoring reports by March 1 of each year and a final completion report within 60 d of completing discharges under this Work Plan.

ENCLOSURE 2

Interim Measures Work Plan
for Chromium Plume Control
and Work Plan for Chromium
Plume Center Characterization

EPC-DO-16-063

LA-UR-16-21509

U1501760

Date: MAR 2 2 2016

LA-UR-15-23126
May 2015
EP2015-0089

Interim Measures Work Plan for Chromium Plume Control

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Environmental Programs Directorate

EP2015-0089

Interim Measures Work Plan for Chromium Plume Control

May 2015

Responsible project manager:

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Printed Name	Signature	Title	Organization	Date

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Christine Gelles	David J Nickless for	Acting Manager	DOE-EM-LA	5/21/15
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Figures

Appendix

1.0 INTRODUCTION

This interim measures (IM) work plan (IMWP) for plume control describes proposed activities to control chromium plume migration in groundwater at the Los Alamos National Laboratory (LANL or the Laboratory) boundary. The Laboratory proposes to conduct the IM in accordance with Section VII.B.1 of the March 1, 2005, Compliance Order on Consent (the Consent Order). The IM is proposed to control chromium migration in groundwater while long-term corrective action remedies are being evaluated. The work proposed in this IMWP follows from the "Interim Measures Work Plan for the Evaluation of Chromium Mass Removal," submitted to the New Mexico Environment Department (NMED) in April 2013 (LANL 2013, 241096). That work plan was prepared in response to requirements in a letter from NMED dated January 25, 2013 (NMED 2013, 521862), which directed that the work plan assess the potential for active long-term removal of chromium from the regional aquifer by pumping with a pilot extraction test well. This plan describes the installation and operation of extraction and injection wells to control plume migration.

Investigations and conceptual models related to chromium contamination are summarized in a number of reports, including the "Investigation Report for Sandia Canyon" (LANL 2009, 107453) and the "Phase II Investigation Report for Sandia Canyon" (LANL 2012, 228624). Additional information presented in the "Summary Report for the 2013 Chromium Groundwater Aquifer Tests at R-42, R-28, and SCI-2" (LANL 2014, 255110) and other previously unreported testing results at the new chromium extraction well CrEX-1 inform the technical recommendations in this work plan. Figure 1.0-1 shows the current extent of the chromium plume defined by the 50-ppb New Mexico groundwater standard. Figure 1.0-1 also includes time-series plots for wells R-45 and R-50, located at the downgradient portion of the plume. Chromium concentrations at these downgradient plume-edge wells show interannual variability in chromium concentrations, but the overall trend shows a distinct overall increasing trend in chromium concentrations. These increasing trends are the reason the Laboratory is proposing the plume-control actions presented in this IMWP.

2.0 OBJECTIVES

The principle objective of the IM presented in this work plan is to achieve and maintain the 50-ppb downgradient chromium plume edge within the Laboratory boundary. The activities conducted under this work plan are being proposed to expedite control of plume migration.

The measures implemented under this work plan to achieve this objective have the metric of reduction of chromium concentrations at R-50 to the 50-ppb New Mexico groundwater standard or less over a period of approximately 3 yr. The method used to achieve this objective is to pump at an existing extraction well (CrEX-1) and to inject treated water into new injection wells located primarily along the downgradient portion of the plume. A secondary objective of hydraulically controlling plume migration in the eastern downgradient portion of the plume near well R-45 is expected to be met through injection in two wells located near R-45, as discussed in sections 3.1 and 3.2 of this plan. The pumping conducted for hydraulic control will also incidentally reduce the mass of chromium within the regional aquifer, but mass removal is not specifically an objective of this IM. Another objective is to obtain additional information of the aquifer properties (i.e., aquifer heterogeneity, hydraulic connections between pumping and observation wells) in the plume area by monitoring responses to pumping conducted for plume control.

3.0 APPROACH

To rapidly reduce off-site chromium transport in the regional aquifer, a pump and treat (P&T) and injection approach is proposed to achieve hydraulic control of off-site plume migration. Plume control would be implemented using a method of hydraulic capture that utilizes existing extraction well CrEX-1 and a configuration of injection wells to control migration of chromium contaminated groundwater (Figure 3.0-1). The time frame to achieve the 50-ppb New Mexico groundwater standard within the Laboratory boundary along the southern portion of the plume is modeled at less than 3 yr. Once achieved, it is anticipated that intermittent versus continual pumping will occur to maintain hydraulic control of the plume. This P&T and injection effort may be implemented intermittently but is intended to be of limited duration until a final remedy is proposed and approved by NMED. Updates to the estimations of plume response will be ongoing as data from pumping and injection are obtained.

Groundwater plumes are generally mitigated using one or a combination of three categorical approaches: monitored natural attenuation (MNA), P&T, or in situ strategies. MNA requires documentation that natural processes are occurring within the aquifer to reduce concentrations or toxicity of target contaminants. P&T can be conducted with the specific objective of achieving optimal removal of target contaminants from groundwater or to hydraulically control plume migration. In situ approaches generally involve the use of amendments directly within the aquifer either to favorably alter the geochemistry of the contaminants or to enhance naturally occurring biological processes that can favorably alter groundwater contaminants, in either case rendering them immobile or nontoxic.

All of the above-mentioned approaches other than hydraulic control, as proposed in this IMWP for plume control, would be expected to produce a much slower response at the advancing plume edge or have not yet been fully evaluated for technical feasibility in the groundwater setting beneath Mortandad Canyon. Groundwater modeling indicates that pumping to remove chromium within the plume centroid does not appreciably affect the concentration of chromium at the southern plume edge until after 10 yr or more, and thus does not meet the primary objective of this IMWP. Groundwater modeling of various scenarios shows that a combination of pumping and injection along the downgradient plume edge has a rapid effect on stabilizing the plume edge (as defined by the 50-ppb New Mexico groundwater standard) well within the Laboratory boundary in less than 3 yr of operation (Appendix A).

Disposition options, other than injection of treated groundwater via injection wells, were considered, including land application and piping and discharge of treated groundwater via an existing outfall that would release water into the same pathway that the chromium source initially followed. Relatively small volumes of treated groundwater may be land-applied in accordance with approved permits, largely for local dust suppression in the project area, but limitations on the amount of water that can be land-applied because of field logistics of distributing sufficient water on a continual basis would not result in sufficient extraction rates. Dispositioning treated water via a pipeline and existing outfall does not provide the significant benefit of rapid hydraulic control that injection wells provide and, therefore, does not support the objectives of this IMWP. However, the pipeline and outfall option for treated groundwater will likely be evaluated as a potential component of a final remedial solution to the plume.

Other, more complex approaches, including MNA and in situ strategies that may eventually be applied to address the chromium plume, are being evaluated under a separate work plan for plume-center characterization. A final evaluation of technologies, including ranking and cost benefit, will be provided in a corrective measures evaluation report for NMED.

3.1 Hydraulic Capture

The goal of hydraulic capture is to create and maintain a capture zone that will arrest plume migration. An initial area of capture was determined from the 7-wk pumping period conducted at CrEX-1 in fall 2014. Appendix A presents the pressure-response data obtained from surrounding monitoring wells and provides an initial estimate of the capture zone. However, to optimize hydraulic capture of chromium-contaminated groundwater moving within the aquifer, existing extraction well CrEX-1 will operate continuously. This is consistent with the initial purpose of CrEX-1 "to evaluate further the capture zone" and "to evaluate the potential to control chromium migration towards the Laboratory boundary via hydraulic control" (LANL 2014, 254824). An initial period of pumping at CrEX-1 (a minimum of 5–6 mo) at approximately 80–100 gallons per minute (gpm) will help further establish and determine the extent, orientation, and shape of the capture zone established by pumping. The shape of the capture zone is expected to be impacted by aquifer heterogeneity. Analysis of pressure-response data from surrounding monitoring wells and piezometers will help with spatial characterization of aquifer heterogeneity and spatial propagation of the zones of hydraulic influence and hydraulic capture. All monitoring wells within the Interim Facility-Wide Groundwater Monitoring Plan's (IFGMP's) Chromium Investigation monitoring group and newly installed regional aquifer piezometers installed in corehole borings will have dedicated transducers for continuous monitoring of pressure response associated with pumping at CrEX-1 (and Los Alamos County water-supply wells).

If extended pumping at CrEX-1 and use of injection wells does not establish a capture zone sufficient to arrest plume migration, installation, and operation of an additional extraction well will be considered. The location of an additional extraction would be determined from newly obtained data. Modeled estimations of the shape of the capture zone over 1-, 3-, and 5-yr pumping durations in CrEX-1 are presented in Appendix A (Figures A-6.0-1a, b, and c).

Pumped and treated water will be land-applied in accordance with an approved discharge permit pending issuance from the NMED Groundwater Quality Bureau because no other option is currently available for its disposition. The land-application permit will limit the period of application to months when the ground is not frozen to avoid runoff of applied water. After injection wells are installed and permitted (as discussed in section 3.2), reinjection will be the primary method of disposition and will allow for continuous pumping throughout the year, unconstrained by limitations of land application. The treatment and water management approach is described in section 3.5.

3.2 Injection Wells

Existing modeling analyses described in Appendix A suggest that the hydraulic capture of the contaminated groundwater at CrEX-1 will be substantially aided by siting the injection wells at the downgradient plume edge (Figure 3.0-1). Six injection wells are proposed to support plume control and provide operational flexibility during maintenance downtime. The priority injection well locations are those situated along the Laboratory boundary west and east of R-50 because of their specific role in helping to control chromium plume migration to the south (off-site). The next priority wells are those at the plume edge west of R-45 to help address what appears to be the advancement of the plume in that area, as manifested by the increasing chromium concentration at well R-45. The next priority well is the one situated at the plume edge west of R-44 to ensure the plume does not advance to the southeast in the R-44 area. A sixth injection well is currently planned in the centroid near R-42. This location was selected as a potential injection well location not only to provide an additional disposition location but also to test how injection of treated water may enhance diffusive processes between fine-grained, low-permeability zone that may contain higher concentrations of chromium and coarse-grained, high-porosity and permeability zones that have lower chromium concentrations because of dilution from high ambient groundwater flow or because of removal by pumping.

A typical injection well design is shown in Figure 3.2-1. Injection wells will be completed with screens in the upper portion of the regional aquifer. Data from existing monitoring wells and from the recent corehole drilling campaign indicate that contamination is dominantly within the upper 50 ft of the aquifer, so injection-well screens will be targeted for that interval. Specific hydraulic performance will vary between injection wells depending on the geology encountered, but the basic assumption is that injection wells will be able to accept injection rates comparable with the rates of extraction. Because of terrain constraints and the large number of cultural sites in the project area, angled drilling may be used to achieve target locations in the aquifer. Angled drilling would utilize existing monitoring well pads. Preliminary estimates indicate that the largest angle that will be drilled is approximately 23 degrees from vertical at chromium injection well CrIN-5.

3.3 Interim Measure Performance

Modeling results indicate the plume responds quickly to pumping at CrEX-1 and injection in the two injection wells west and east of R-50. The modeling analysis assumes that injection of treated water is distributed across the two injection wells at a rate equivalent to pumping at CrEX-1. Pumping at CrEx-1 in fall 2014 indicated the maximum sustainable pumping rate is approximately 80–100 gpm.

Figure 3.3-1 shows projections of the plume over 1-yr, 3-yr, and 5-yr time frames. The operational approach used for the model assumes that CrEX-1 is pumping at 80 gpm and injection is occurring at approximately 40 gpm in each of the wells west and east of R-50. The model indicates the plume edge will be well within the Laboratory boundary by the second year of full operation. Currently, existing downgradient portions of the plume not captured by pumping at CrEX-1 will continue to migrate but at concentrations increasingly below the 50-ppb New Mexico groundwater standard. Injection wells along the eastern portion of the plume, especially near R-45, are also expected to limit plume expansion to the east (Figure A-8.0-3 in Appendix A). Some uncertainty exists in the potential influence of injection on groundwater flow direction in that portion of the plume, but dilution of plume concentrations in that area as a result of injection would likely also result in decreases in chromium concentrations along that potential flow path. There are some uncertainties specifically with respect to how quickly the plume will respond to pumping because the model and the projections shown in Figure 3.3-1 do not yet represent the role that dual porosity may play with respect to the distribution of chromium within the aquifer. Seven weeks of pumping in CrEX-1 in fall 2014 showed steady concentrations of chromium, possibly indicating that chromium is primarily within coarse, permeable strata in this portion of the plume. Additional pumping at CrEX-1 will improve the understanding of whether dual porosity plays a role in the distribution of chromium in the aquifer in the CrEX-1 area.

Once downgradient plume control is achieved, it is anticipated that operations will become intermittent for operational efficiency but in a manner that still maintains plume control. It is anticipated that hydraulic control measures will continue until a final remedy is approved and implementation is underway.

3.4 Performance Monitoring

Existing monitoring wells within the Chromium Investigation monitoring group under the IFGMP (Figure 1.0-1) will continue to be sampled in accordance with the current approved IFGMP (LANL 2014, 256728). However, key wells for monitoring performance of the IM are R-50, screens 1 and 2; R-44, screens 1 and 2; and R-45, screens 1 and 2. These wells are situated along the downgradient edge of the plume and, therefore, are well suited for monitoring performance of the hydraulic containment strategy.

Although somewhat variable, the overall trend in chromium concentrations in R-45 and R-50 over the past few years has been increasing within the upper screens. The chromium concentration in these wells is expected to decline in response to the pumping and injection approach described here. Well R-44 is currently showing low and stable chromium concentrations that should remain the same or decline in response to pumping and injection. Figure A-8.0-4 in Appendix A shows estimations of the trend of chromium concentrations at R-50, screen 1, and R-45, screen 1, in response to pumping and injection. New piezometers installed in coreholes drilled in 2014 and 2015 within the plume area will be used along with existing monitoring wells to continuously monitor pressure responses associated with pumping and injection and may also be monitored periodically for changes in water quality.

3.5 Groundwater Treatment and Disposition

The treatment system will consist of extraction well CrEX-1 (and a possible additional extraction well), a treatment system, a spray irrigation system for potential land application, and ultimately up to six injection wells. Once fully operational, the system will run continuously with pumped groundwater being treated at the surface and delivered to injection wells via piping. The treatment unit is likely to be sited at the CrEX-1 location to minimize the distance that contaminated groundwater is conveyed before pumping begins. Two treatment trains, each consisting of two ion-exchange vessels, will operate in series to treat groundwater extracted from CrEX-1. The first vessel removes up to 99% of the chromium (and nitrate), and the second vessel is used for redundancy and polishing. A third treatment train is held in reserve as a spare. Water quality in the treatment stream will be monitored in accordance with an NMED-approved discharge permit to ensure that water land-applied or dispositioned via reinjection will meet the criteria set forth in the permit(s). When the injection wells are operational, a computer-control system will be in place to monitor and control flow rates, pressures, water levels, and injection rates into the wells to ensure the systems are operating as designed. Flow rate of injected water will be monitored, and pressure at each injection well will be maintained at a design level. Water levels in all injection wells will be monitored by a control system with system shutdown mechanisms in places. Each injection well will also be equipped with a submersible pump to allow each well to be periodically back-flushed for maintenance. The approved discharge permit will include contingencies for failures in any part of the treatment and discharge system.

4.0 SCHEDULE

Implementation of the IMWP scope currently depends on the Laboratory's receiving approval from NMED for the land application of treated water pumped from CrEX-1. It is currently anticipated that a discharge permit will be in place for land application sometime in June 2015 to allow the Laboratory to begin pumping at CrEX-1. Under that scenario, pumping could be conducted continuously from approximately July to approximately November 2015, at which time pumping and land application will terminate because the permit will not allow land application on frozen ground. Additional restrictions on initial operations at CrEX-1 are the limits established for allowed days of pumping under the existing New Mexico Office of the State Engineer (OSE) permit. Eighty-seven days of pumping remain on the existing OSE permit. Additionally, existing National Environmental Policy Act (NEPA) coverage provides for an additional 13 million gallons of pumping. Extending operation of CrEX-1 past these limits requires completion of the Environmental Assessment process under the NEPA, an OSE permit for change in point of diversion, and a discharge permit for land application of treated water. The process involved for all of these permits is underway.

Drilling and construction of injection wells is expected to begin in fall 2015. The goal is to have the pumping, treatment, and injection infrastructure in place for operation in 2016; however, operation of the injection wells depends upon receiving the discharge permit for injection wells, the application for which was submitted April 2015. Once the system is fully operational, pumping and injection will operate continuously while monitoring is conducted by the Laboratory to determine whether hydraulic capture meets the objective of achieving and maintaining the plume edge within the Laboratory boundary.

If the goal is met, an updated extraction and injection operational program to maintain hydraulic control will be implemented. The updated strategy will consider opportunities to minimize groundwater extraction while still controlling the migration of chromium.

5.0 MANAGEMENT OF INVESTIGATION-DERIVED WASTE

Investigation-derived waste will be managed in accordance with EP-DIR-SOP-10021, Characterization and Management of Environmental Programs Waste. This standard operating procedure incorporates the requirements of applicable U.S. Environmental Protection Agency and NMED regulations, U.S. Department of Energy orders, and Laboratory requirements. The primary waste streams include development water, drill cuttings, drilling fluid, decontamination fluids, and contact waste.

6.0 REFERENCES

The following list includes all documents cited in this plan. Parenthetical information following each reference provides the author(s), publication date, and ER ID 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), October 2009. "Investigation Report for Sandia Canyon," Los Alamos National Laboratory document LA-UR-09-6450, Los Alamos, New Mexico. (LANL 2009, 107453)

LANL (Los Alamos National Laboratory), September 2012. "Phase II Investigation Report for Sandia Canyon," Los Alamos National Laboratory document LA-UR-12-24593, Los Alamos, New Mexico. (LANL 2012, 228624)

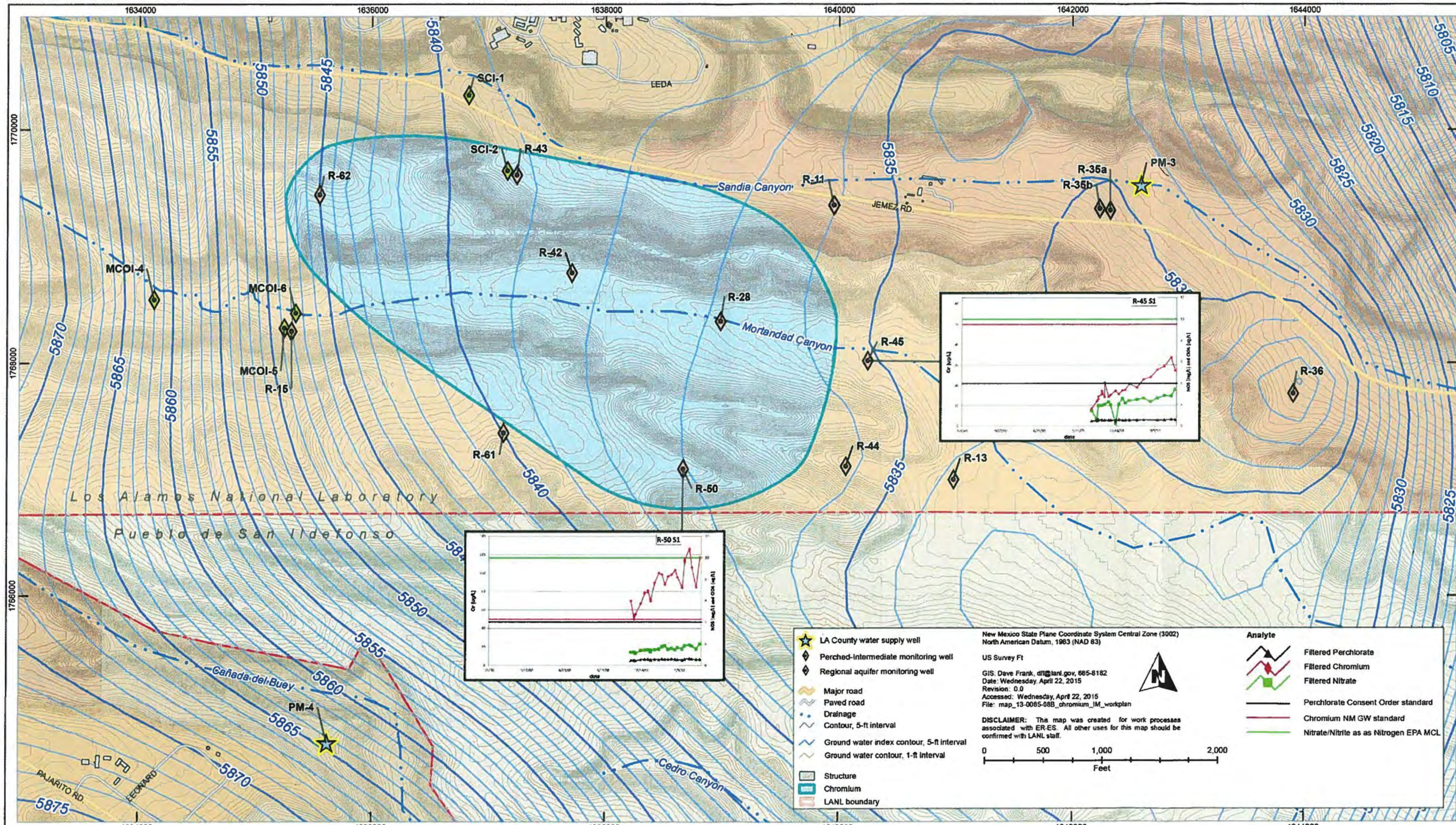
LANL (Los Alamos National Laboratory), April 2013. "Interim Measures Work Plan for the Evaluation of Chromium Mass Removal," Los Alamos National Laboratory document LA-UR-13-22534, Los Alamos, New Mexico. (LANL 2013, 241096)

LANL (Los Alamos National Laboratory), March 2014. "Summary Report for the 2013 Chromium Groundwater Aquifer Tests at R-42, R-28, and SCI-2," Los Alamos National Laboratory document LA-UR-14-21642, Los Alamos, New Mexico. (LANL 2014, 255110)

LANL (Los Alamos National Laboratory), March 2014. "Drilling Work Plan for Groundwater Extraction Well CrEX-1," Los Alamos National Laboratory document LA-UR-14-21478, Los Alamos, New Mexico. (LANL 2014, 254824)

LANL (Los Alamos National Laboratory), May 2014. "Interim Facility-Wide Groundwater Monitoring Plan for the 2015 Monitoring Year, October 2014–September 2015," Los Alamos National Laboratory document LA-UR-14-23327, Los Alamos, New Mexico. (LANL 2014, 256728)

NMED (New Mexico Environment Department), January 25, 2013. "Response, Proposal to Submit Interim Measures Work Plan for Chromium Contamination in Groundwater," 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 2013, 521862)



Notes: Shaded area represents the approximate plume edge at the 50-ppb level for chromium. The two time-series plots show increasing chromium concentrations at the downgradient portion of the plume.

Figure 1.0-1 Extent of chromium contamination in groundwater

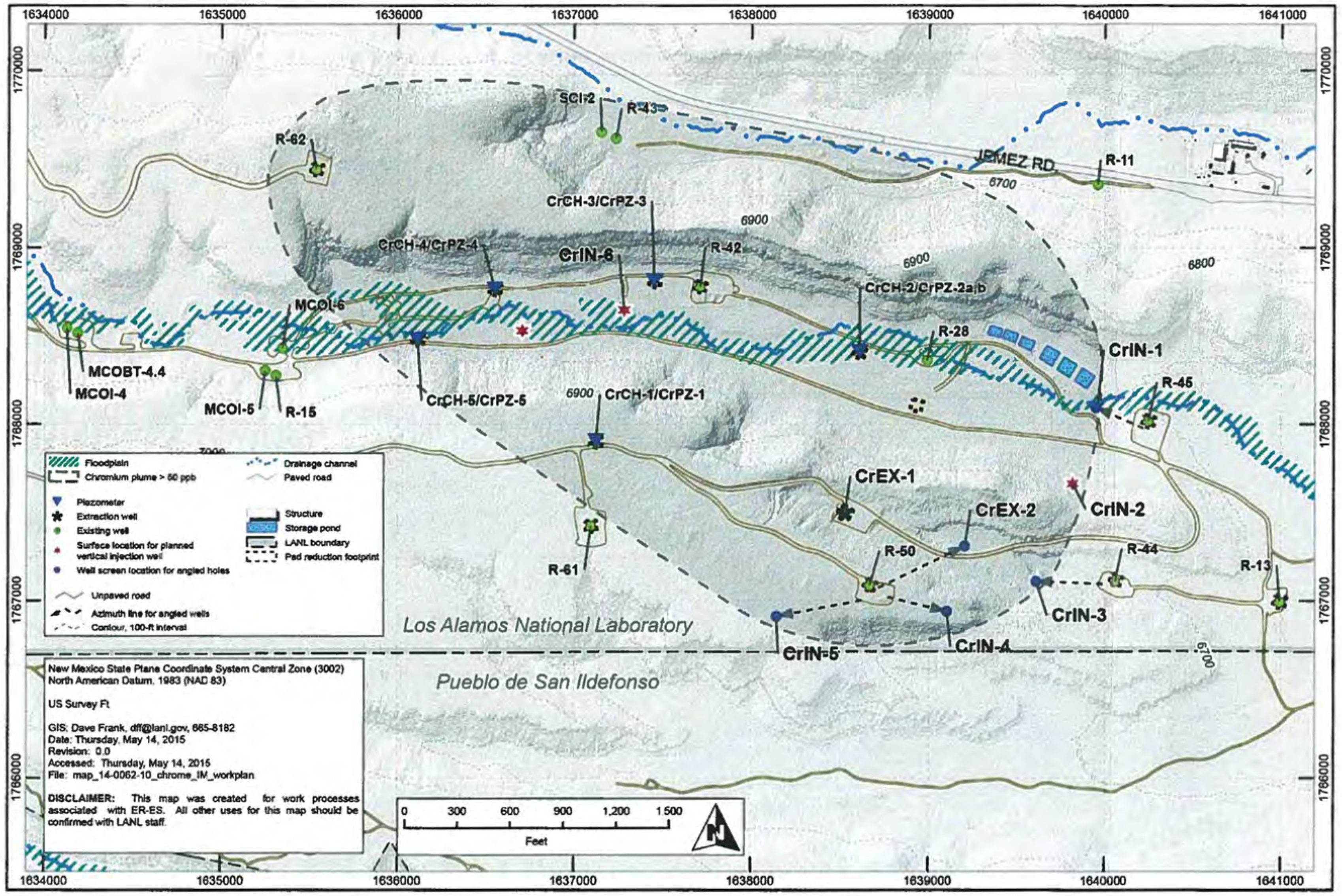


Figure 3.0-1 Location of the existing extraction well for hydraulic control and proposed locations for injection wells

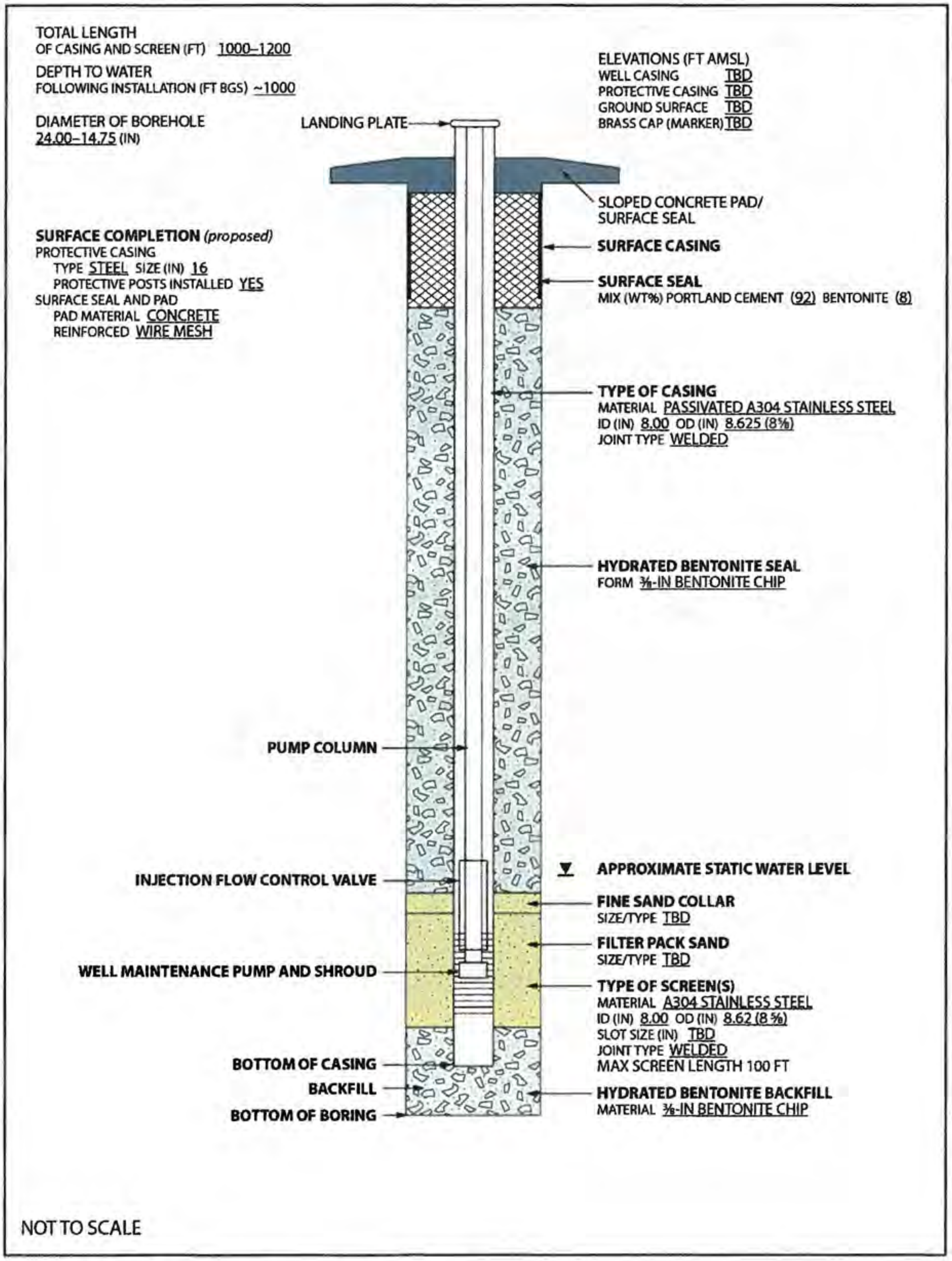
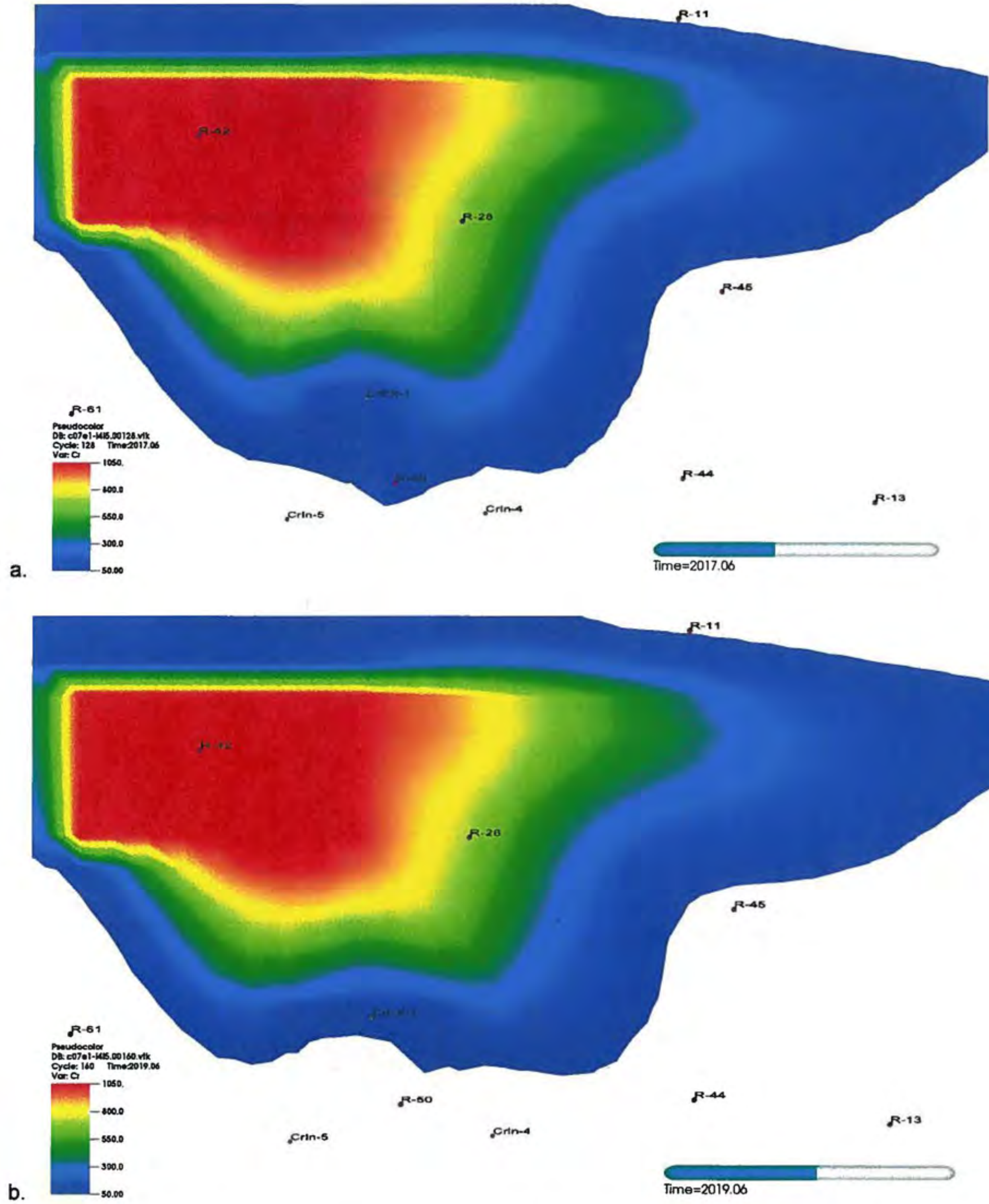
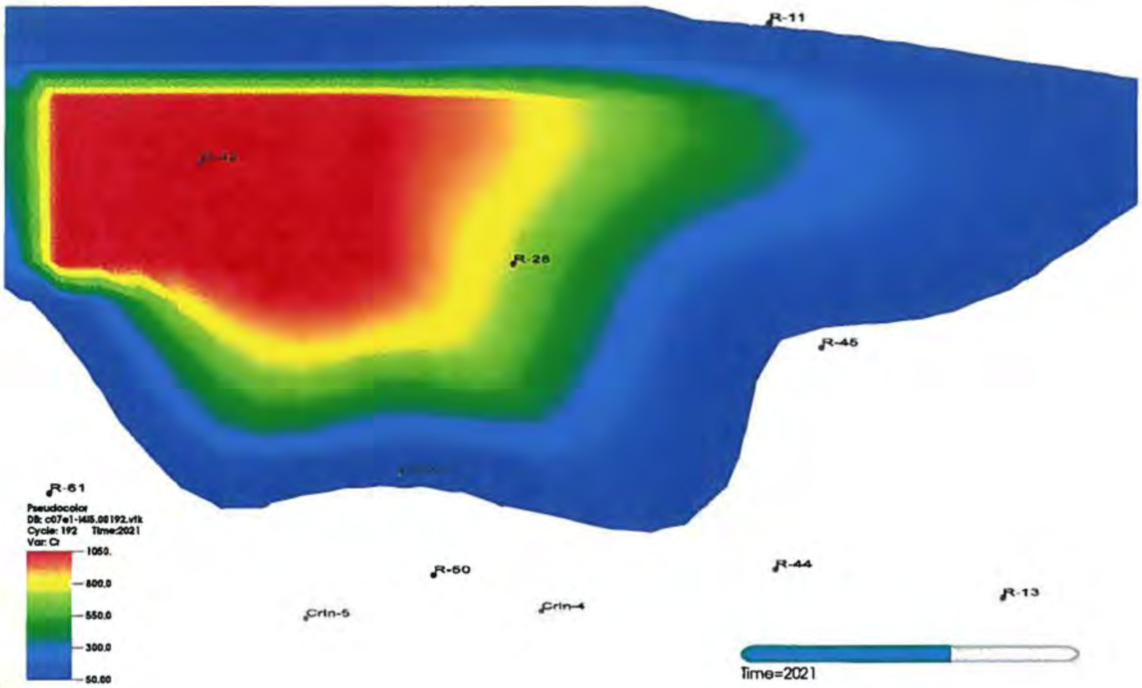


Figure 3.2-1 Generalized injection well design



Note: The modeled scenarios assume pumping at CrEX-1 at 80 gpm and injection in CrIN-1 and CrIN-2 at 40 gpm each.

Figure 3.3-1 Snapshot estimations of the extent of chromium at the 50-ppb level for (a) 1-yr, (b) 3-yr, and (c) 5-yr time frames after initiation of pumping and injection



c.

Note: The modeled scenarios assume pumping at CrEX-1 at 80 gpm and injection in CrIN-1 and CrIN-2 at 40 gpm each.

Figure 3.3-1 (continued) Snapshot estimations of the extent of chromium at the 50-ppb level for (a) 1-yr, (b) 3-yr, and (c) 5-yr time frames after initiation of pumping and injection

Appendix A

Modeling Analyses

A-1.0 INTRODUCTION

This appendix provides a detailed analysis of the hydraulic pressure data collected during the pumping test conducted at regional chromium extraction well CrEX-1 by Los Alamos National Laboratory (LANL or the Laboratory). Preliminary analyses were presented in the "Completion Report for Chromium Extraction Well 1" (hereafter, the CrEX-1 Completion Report) (LANL 2015, 600170). The appendix also provides a modeling analysis of potential capture zones (CZs) and plume responses under different pumping regimes and injection scenarios.

A-2.0 HYDROGEOLOGY

CrEX-1 was installed initially to test the concept of hydraulic capture of chromium-contaminated groundwater to arrest plume migration at the southern downgradient edge of the plume. The CrEX-1 borehole was drilled using fluid-assisted dual-rotary drilling methods and mud-rotary methods. Drilling fluid additives included potable water, a foaming agent and benonite-based drilling mud. The CrEX-1 screened intervals consist of a 50.0-ft screen from 990 to 1040 ft below ground surface (bgs) and a 20-ft-long screen from 1070 ft to 1090 ft bgs that is isolated from the upper screen with a packer. A 30-ft section of blank casing separates the two screens. CrEX-1 is completed in the Puye Formation ([Tpf] 809 ft to 1054 ft bgs); mixed Miocene deposits ([Tjpf and Tcar] 1054 ft to 1070 bgs); and Miocene pumiceous sediments ([Tjfp] 1070 ft to 1155 ft bgs). Since only the upper 50-ft screen was pumped, the aquifer test provides information about the properties of Puye Formation. Aquifer testing indicated CrEX-1 will perform effectively and will be capable of sustained pumping at approximately 80–100 gallons per minute (gpm) (LANL 2015, 600170).

On October 3, 2014, following well installation, well development, installation of the packer between the upper and lower screens, and aquifer testing, the depth to water was 997.2 ft bgs. The upper screen of CrEX-1 straddles the regional water table. This allows for effective interrogation of the upper most portion of the regional aquifer next to the regional water table where the highest contaminant concentrations are expected. As a result, the effective screen length is about 43 ft (from the water table to the bottom of the upper screen which is at 1040 ft bgs).

The pumping of CrEX-1 produces a maximum drawdown of about 6.2 m (~20 ft) within the pumped upper screen at a pumping rate of approximately 80 gpm. However, the well-specific capacity does not decline with the increase of the pumping rate (and the respective increase of the pumping drawdown; see below). This suggests that borehole skin effects cause a portion of the drawdown; as a result, the drawdown in the aquifer near the well is expected to be much lower than the one observed within the pumped borehole. Nevertheless, the pumping causes a decline in the regional water table, and it is expected that residual vadose-zone groundwater flow from the capillary fringe may impact the drawdowns observed in CrEx-1. Therefore, unconfined (phreatic) groundwater flow is occurring near the pumped well. However, the observed drawdowns are still small compared with the aquifer thickness (>100 ft), and therefore it is acceptable to use analytical solutions and numerical models that interpret the flow as confined.

Based upon the depth to water of 997.2 ft bgs measured at CrEX-1 on October 3, 2014, after installation, initial development and aquifer testing, the water-level elevation was approximately 5834.73 ft above mean sea level ([amsl] the top of well casing is at elevation 6831.91 ft and the water level in the well is 997.2 bgs).

A-3.0 CrEX-1 PUMPING TEST DATA

CrEX-1 was tested from October 1 to 4, 2014. Testing consisted of a five-step pumping test on October 1, and a 24-h constant-rate pumping test that was begun on October 3. The pumping rates during the five-step test and the 24-h pumping test were relatively steady. The water level declines and rebounds very fast in response to pumping. The initial recovery of water levels to elevations higher than the equilibrated static level during rebound when pumping stops could indicate groundwater recharge from the vadose zone, but there may be other explanations such as elastic deformations in the porous media. The water level also recovers relatively fast to the prepumping conditions after pumping stops, suggesting the aquifer at CrEX-1 has relatively high hydraulic conductivity and that borehole skin effects may be impacting the observed drawdowns within the pumping well. The aquifer testing was performed in the upper screen only. A 50-horsepower, 6-in.-diameter Grundfos submersible pump was used to perform the aquifer tests.

Five short-duration pumping intervals (steps) without recovery in between were conducted on October 1. The primary objective of the short-duration step tests was to assess the hydraulic behavior of the system and properly determine the optimal pumping rate for the 24-h test. The step tests demonstrated that the specific capacity of the well does not seem to depend on the pumping rate, which suggests the well is fully developed. During the step tests, the specific capacity varied between 100 and 120 m^2/d (5.5 and 6.6 gpm/ft). The pumping at the highest rate produced about 5 m (~16 ft) drawdown within the screen. However, the well-specific capacity does not decline with the increase of the pumping rate (LANL 2015, 600170, Appendix D). This suggests that borehole skin effects cause a portion of the drawdown. Nevertheless, the pumping causes a decline in the regional water table. Therefore, unconfined (phreatic) groundwater flow is occurring near the pumped well.

A 24-h aquifer test was completed on October 3. The test was conducted at a pumping rate of 517.6 m^3/d (94.9 gpm). The 24-h aquifer test analyses suggested a formation transmissivity on the order of 490 m^2/d (40,000 gallons per day/ft). This transmissivity value is very similar to the estimate obtained by a recent analysis of R-28 aquifer test conducted in 2014 (LANL 2014, 255110).

The saturated thickness corresponding to the transmissivity value is not known in order to estimate hydraulic conductivity. The saturated thickness is impacted by the pumping because the pumping causes a decline in the regional water table. If it is assumed the saturated thickness is the length of the initial saturated screened interval (~43 ft before the pumping started) minus a half the observed drawdown (~10 ft), the estimated average hydraulic conductivity is about 49 m/d or 161 ft/d. However, this estimate is uncertain. Still, the value of hydraulic conductivity is consistent with the estimate obtained for R-28 (~120 ft/d).

The CrEX-1 transmissivity and hydraulic conductivity estimate suggests the extraction well is within a highly permeable zone of the regional aquifer. This can be very beneficial in terms of the CrEX-1 primary objective of hydraulic capture. Appendix D of the CrEX-1 Completion Report presents the complete results and analysis of the CrEX-1 aquifer test.

After the completion of the 24-h-pumping test, CrEX-1 was continuously pumped from October 5 to November 26, 2014. The 52-d pumping was conducted at an average pumping rate of about 81 gpm. On December 1, the pumping resumed for another 11 d at a similar rate. During the last 2 d of pumping, higher pumping rates were attempted, but it appeared that at rates greater than 100 gpm too much drawdown occurred in the well to sustain rates greater than 100 gpm.

The extended pumping at CrEX-1 provided additional data for analyses of aquifer properties. More importantly, the extended pumping allowed for detection of pressure declines at the nearby observation wells.

A-4.0 ANALYSIS OF CrEX-1 PUMPING TEST DATA

The water-level data for the CrEX-1 pumping test were analyzed using the method described in (Vesselinov and Harp 2011, 227709) to estimate the drawdowns that can be attributed to each nearby monitoring well. The analyses account for the pumping effects caused not only by CrEX-1 but also the municipal water supply pumping at PM-4, PM-2, O-4, etc. The analyses utilize two open-source codes developed at the Laboratory: WELLS (http://wells.lanl.gov) and MADS (http://mads.lanl.gov). WELLS is applied to simulate the drawdowns caused by the pumping at CrEX-1 and the water supply wells. MADS is applied to (1) deconstruct pumping drawdowns caused by different pumping wells and (2) estimate aquifer properties by matching the simulated and observed hydraulic heads at the observation wells.

Figures A-4.0-1 through A-4.0-19 present the results of this analysis. Each figure shows the model-based deconstruction of the water-level transients observed in each monitoring well during the 2014 CrEX-1 pumping period. In each figure, the upper plot shows the observed and simulated water levels at the monitoring well, and the lower plot shows the attribution of the drawdown to each of the wells pumped during the observation period: O-4, PM-2, PM-3, PM-4, PM-5, CrEX-1, R-42, and R-28. The analyses require long data records. The longer the record, the more accurate are the deconstructed pressure estimates. Table A-4.0-1 lists the estimated CrEX-1 drawdowns at the end of the CrEX-1 pumping tests.

Uncertainties associated with estimates of aquifer properties based on the CrEX-1 pumping data are because of the small magnitude of the drawdowns measured in some of the observation wells. The presented estimates in Table A-4.0-1 are preliminary. Additional data collected during upcoming 2015 CrEX-1 pumping test will help to substantially reduce the uncertainties and better characterize aquifer properties.

Based on the results shown in Figures A-4.0-1 through A-4.0-19, the following important observations can be made about the aquifer behavior during the 2014 CrEX-1 pumping test.

The CrEX-1 induced drawdown is uncertain at CrPZ-1 (CrCH-1 on Figure A-4.0-1). The collected pressure record was very short. However, it can be concluded that changes in the pumping rates in CrEX-1 in December 2014 may have caused pressure transients at CrPZ-1; although this conclusion is expected, more data are needed to better understand the CrPZ-1 hydraulic response to CrEX-1 pumping.

R-1 transients are well reproduced by the model but the model-estimated CrEX-1 drawdown is questionable and small, if present (Figure A-4.0-2). R-11 and R-13 transients are also well reproduced by the model (Figures A-4.0-3 and A-4.0-4); the CrEX-1 drawdown in these wells is small but potentially well defined by the existing data and applied model.

There are some potential problems with the late 2014 water-level data collected at R-15 (Figure A-4.0-5); the steady flat pressure decline observed in late 2014 contradicts the previous model analyses. Therefore, the data are not sufficient to define the CrEX-1 drawdown in this monitoring well.

R-33 screen 1 and R-35b transients are well reproduced by the model, but the CrEX-1 drawdown contribution is questionable and small, if present (Figures A-4.0-6 and A-4.0-7). The pressure data collected in R-33 screen 2 is difficult to analyze because of the strong pressure transients caused by the municipal water-supply pumping, and thus the data and modeling results are not included here.

Data gaps and uncertainties are associated with the R-42 pressure record that make the analyses difficult and the CrEX-1 drawdown estimate is uncertain (Figure A-4.0-8).

R-43 screen 1 and screen 2 transients are well reproduced by the model, but the model-predicted CrEX-1 drawdown is uncertain and small, if present (Figures A-4.0-9 and A-4.0-10).

Figures A-4.0-11 through A-4.0-18 show the drawdowns in a series of two-screen wells near CrEX-1: R-44, R-45, R-50, and R-61. The results for these wells show that pressure transients are very well reproduced by the model.

R-50 screens show the largest drawdowns observed by any of the monitoring wells (Figures A-4.0-15 and A-4.0-16). There are important discrepancies between the observed and model simulated pressure transients during the CrEX-1 pumping test related to R-50. The model reproduces relatively well the pressure transient including the limited recovery record after the pumping termination (Figures A-4.0-15 and A-4.0-16). However, the model overpredicts the pressure decline at the beginning of the CrEX-1 pumping test. It is expected that this be caused by phreatic effects. The applied model does not account for vadose zone and water table hydraulic impacts during the CrEX-1 pumping test and this is the possible reason for the discrepancy. This observation is important because it provides insights about the aquifer properties in the area between CrEX-1 and R-50. Additional pressure data collected during 2015 CrEX-1 pumping conducted for the interim measure will help to better understand site hydraulic conditions.

Figure A-4.0-19 shows the pressure transients in R-62. Data gaps and uncertainties are associated with R-62 pressure record that make the analyses difficult and the estimates unclear.

It is important to note that substantial data gaps and uncertainties are also associated with R-28 pressure records in 2014 (the data are not presented here), making a complete analysis related to the CrEX-1 pumping test difficult. More data are needed to understand the R-28 hydraulic response to CrEX-1 pumping.

As discussed earlier, the aquifer is expected to be heterogeneous. The estimated transmissivity and storativity values in Table A-4.0-1 seem to confirm this expectation. The estimated values in the table represent effective aquifer properties between the pumping (CrEX-1) and observation wells. The analyses are based on an analytical model (Theis) that assumes uniformity in aquifer properties and confined conditions. These assumptions are not expected to be valid so the estimated transmissivity and storativity values should be analyzed with care. Nevertheless, the relatively large variability in the estimated transmissivity and storativity values suggest pronounced aquifer heterogeneity.

A-5.0 ANALYTICAL ANALYSIS OF CrEX-1 CAPTURE ZONE

Table A-4.0-1 shows the pumping-related drawdowns at the end of the 2014 CrEX-1 pumping period. Here, the zone of influence (the ZOI or the cone of depression) is identified as the area within which measurable pumping drawdown greater than 0.01 m can be detected. Theoretically, very small (immeasurable) drawdowns will be manifested throughout the regional aquifer. However, practically speaking, the ZOI is defined as the zone where drawdown greater than 0.01 m can be detected. The CrEX-1 ZOI appears to be extensive (Table A-4.0-1). The only nearby well that was not apparently influenced by CrEX-1 pumping is R-36.

The ZOI during aquifer pumping is different than the CZ, which represents the portion of the aquifer that is affected by the pumping well in such a way that all the groundwater within the CZ will be pumped out by the well. In the case of a uniform isotropic aquifer, the shape of ZOI and CZ will be similar: it will be a circle centered at the pumping well. The radius of the circle will depend on the pumping time. Typically, the ZOI is larger than the CZ.

However, in the case of ambient flow, the shape of the CZ will have an elongated form with a predominantly upstream spatial extent. A schematic representation of the CZ shape is presented in Figure A-5.0-1. The CZ estimate typically assumes only an advective steady-state groundwater flow. However, because of groundwater dispersion, some of the groundwater within the CZ will escape capture while some of the groundwater outside the CZ will be captured. Because of transients in the groundwater pressures and flow velocities from induced pumping at CrEX-1, the CZ will grow around the pumping well until a quasi-steady-state flow regime is established around the pumping well.

Under the quasi-steady-state, the pressures still decline from pumping; however, the hydraulic gradients equilibrate to the final steady-state values. The zone of quasi-steady-state flow regime (ZQSS) grows in time around the pumping well, and the rate of propagation depends on the aquifer properties and the pumping rate. Both the ZOI and the ZQSS are expected to have a similar shape (circular in the case of a uniform aquifer). The CZ shape depends on the ambient flow properties (Figure A-5.0-1) that is, the magnitude of the ambient groundwater flow. The CZ extent upgradient grows in time and depends on both the pumping duration and rate, and on the ambient groundwater flow properties. The CZ extent downgradient reaches an inflection point after a given period of pumping and cannot be increased further.

In general, the CZs of pumping wells have a three-dimensional shape characterized by three-dimensional structure and properties of the regional groundwater flow during the aquifer test. As a result, the CZ depends on various hydrogeologic factors:

- pumping rate and duration;
- shape of the regional water table;
- aquifer thickness;
- spatial and temporal distribution in aquifer flow velocities controlled predominantly by heterogeneity and anisotropy in aquifer properties (permeability, storativity, etc.);
- spatial and temporal variability in aquifer recharge controlled predominantly by heterogeneity and anisotropy in vadose zone properties and spatial and temporal distribution of infiltration along the nearby canyons; and
- influence of water-supply pumping at nearby municipal water-supply wells (PM-3, PM-5, PM-4 and PM-2); the water-supply pumping causes small changes in the water levels measured at monitoring wells. As a result, it is expected that the water-supply pumping does not significantly affect the shape of the CrEX-1 CZ.

It is important to emphasize that the magnitude of aquifer recharge can be an important factor affecting the size of the estimated CrEX-1 CZ. In general, the magnitude of aquifer recharge on the Pajarito Plateau is relatively small (less than 1 mm/yr), and recharge at this scale is not expected to significantly influence the shape of the CZ of pumping wells. In this case, for modeling purposes, the regional water table can be approximated as a no-flow boundary. However, higher recharge rates in the plume area resulting from localized recharge along Sandia and Mortandad Canyons can significantly influence the shape of the CZ.

A-5.1 CrEX-1 Capture Zone Estimate Based on the Pumping Rate Only

The CZ at CrEX-1 can be estimated based on the volume of water pumped. This approach allows for better approximation of the CZ size at early times when the pumping period is relatively short (for example, less than 100 to 300 days).

In this case, the CZ is assumed to have a cylindrical shape with a constant vertical height *H* (depending on the well screen length) and time-varying horizontal radius *R*. To account for the three-dimensional component of groundwater flow near the well screen, the vertical height *H* is assumed to be approximately 1.5 times the screen length; for example, *H* is ~15 m (50 ft) for CrEX-1. In this case, the three-dimensional aspect of the groundwater flow increases the CZ thickness only below the screen, not above the screen because at the top the CZ is bounded by the regional water table. The cylinder radius can be computed using the following formula:

$$R = \sqrt{\frac{Q_P t}{\pi \phi_S H}}$$

where Q_p is the pumping rate, *t* is pumping duration, ϕ_S is the water storage porosity. If the total water-filled porosity is assumed to be 0.3, the CZ after 52 d of pumping has a radius of 32 m (~110 ft) around the well. However, this CZ estimate does not account for ambient groundwater flow in the aquifer.

A-5.2 CrEX-1 Capture Zone Estimate Based on Ambient Aquifer Flow

The CZ can also be estimated based on the width of groundwater flow within which the ambient groundwater flux is equal to the pumping rate (Figure A-5.0-1). In this case, the CZ grows upgradient until reaching a width within which the ambient groundwater flow rate is equal to the pumping rate (Figure A-5.0-1). This approach allows for a better approximation of the CZ size at late times when the pumping period is relatively long, allowing establishment of a quasi-steady state flow regime near the pumping well. This approach is best applied for long-duration pumping periods, greater than 100 to 300 days. This is a function of the aquifer properties. In this case, the width of the CZ perpendicular to the groundwater flow direction becomes a constant in time once the flow reaches a quasi-steady state.

Assuming uniform confined groundwater flow conditions, the flow rate *Q* through a vertical section in the regional aquifer with a horizontal width *W* can be computed as:

$$Q = ITW$$

The width *W* can be computed as:

$$W = \frac{Q_P}{IT}$$

The ambient groundwater flow in the aquifer near CrEX-1 has hydraulic gradient of about 0.001. For pumping rate of 81 gpm and transmissivity of 40,000 gpd/ft, the width of CZ upgradient from CrEX-1 is about 900 m (~3000 ft) perpendicular to the groundwater flow direction. The CZ width adjacent to CrEX-1, W_w (Figure A-5.0-1) is exactly half of the upgradient width *W*, or about 450 m (~1500 ft). These are initial model estimates because there are uncertainties in the ambient hydraulic gradient and the large-scale aquifer transmissivity that define the ambient groundwater flux. For example, if the hydraulic gradient is an order of magnitude higher (0.01, i.e., ambient groundwater flux is an order of magnitude higher), the width of CZ upgradient from CrEX-1 will be approximately 90 m (~300 ft). The data collected during fieldwork in 2015 (pumping and tracer tests) will provide additional information to constrain this uncertainty. It is also important to emphasize that these estimates are based on assumptions for uniform and homogenous groundwater flow; aquifer heterogeneity will further impact the shape and site of the CZs.

The maximum length of capture in the downgradient direction, L_0, from the pumping well (Figure A-5.0-1) can be expressed as follows:

$$L_0 = \frac{Q_p}{2\pi TI}$$

For a pumping rate of 81 gpm, the length of CrEX-1 CZ in the downgradient direction, L_0, is about 143 m (~580 ft). If the hydraulic gradient is an order of magnitude higher (0.01), the width of CZ upgradient from CrEX-1 is only about 14 m (~45 ft).

Once the equilibrium between the pumping and ambient flow rates has been established, the pumped well will capture the groundwater flowing toward the well in the CZ. The length *L* of the CZ upgradient of CrEX-1 (Figure A-5.0-1) depends on the groundwater flow pore velocity and the pumping duration.

It is important to emphasize that the dimension of the CZ computed above is for long-term pumping periods. For example, if the CrEX-1 pumping was turned on for an extended period of more than 300 d, the presented CZ estimates will be valid estimates (assuming that the aquifer is uniform). However, the CrEX-1 aquifer test data also demonstrate that the aquifer is also highly heterogeneous. As a result, the shape of the steady-state CZ will likely have a much more complicated shape and will likely have dimensions less than those estimated above.

The CrEX-1 CZ during the 2014 pumping period (because of the relatively short duration of the tests) is expected to be more consistent with the estimates based on the pumped volume. Therefore, the CrEX-1 CZ during the 2014 pumping period is estimated to have radius of about 32 m (110 ft) around the pumping well.

A-6.0 NUMERICAL MODEL ANALYSIS OF CrEX-1 PUMPING

A numerical model of groundwater flow and contaminant transport in the regional aquifer beneath the Sandia and Mortandad Canyons area is developed to inform and enhance the understanding of the fate and transport of chromium in the environment. This section describes the current state of the development of the numerical model and discusses the current modeling results. This is a work in progress and a continuation of the model analyses presented in the 2008 "Fate and Transport Investigations Update for Chromium Contamination from Sandia Canyon" (LANL 2008, 102996) and the 2012 "Phase II Investigation Report for Sandia Canyon" (LANL 2012, 228624).

Flow numerical simulations are applied to predict the groundwater flow in the regional aquifer in the chromium plume area. Groundwater flow and contaminant transport in the unsaturated zone are not part of the current modeling effort.

A three-dimensional unsaturated zone model is contained in Appendix J of the 2008 "Fate and Transport Investigations Update for Chromium Contamination from Sandia Canyon" (LANL 2008, 102996). The vadose-zone model analyses demonstrated the potential three-dimensional channeling and lateral diversion (along hydrostratigraphic contacts) of water infiltrating beneath Sandia Canyon before it reaches the regional aquifer. Further developments of the three-dimensional unsaturated zone model are ongoing as well.

The current goal is to generate a model calibrated against existing water-level observations during the 2014 CrEX-1 pumping period. The model will also be calibrated to reproduce the pumping effects caused by municipal water supply–well pumping near the plume area. Additionally, the model will be calibrated to the cross-well pumping effects caused by pumping at R-42 and R-28 during short- and longer-term pumping tests previously conducted in these wells.

However, the model currently does not represent (1) the ambient groundwater flow at the site, (2) the long-term water-level changes in the regional aquifer, and (3) the long-term chromium concentration transients observed in the site monitoring wells. In the future, these components will be added to the calibration process as well. The model is also representing the aquifer as confined. More complex model analyses accounting for the impacts of the phreatic and the vadose zones on the regional aquifer flow will be developed in the future as well. The model also currently simulates the flow medium as a single continuum and does not represent potential dual porosity within the aquifer materials. Updated modeling analyses will incorporate dual porosity effects for the regional aquifer, which may also exhibit substantial spatial variability especially as it affects storage of chromium.

The model is calibrated against existing water-level drawdowns observed at regional wells R-1, R-33 (2 screens), R-15, R-62, R-43 (2 screens), R-42, R-28, R-61 (2 screens), R-50 (2 screens), R-45 (2 screens), R-44 (2 screens), R-11, R-13, R-35b, R-36, and R-34; 16 wells and 22 screens in total. The model simulates the pumping effects caused by CrEX-1, R-42, R-28, PM-1, PM-2, PM-3, PM-4, PM-5, and O-4.

The model is calibrated using an automated calibration process employing the Levenberg-Marquardt optimization algorithm as implemented in the code MADS (http://mads.lanl.gov). The objective function subject to minimization is defined as

$$\Phi = [\mathbf{c} - f(\mathbf{b})]^T \mathbf{W} [\mathbf{c} - f(\mathbf{b})]$$

where **c** is a vector [N×1] of optimization targets, **b** is a vector [M×1] of model parameters, **W** is a diagonal weight matrix [N×M], and ***f*** is the model. While Φ is minimized, the algorithm searches for the maximum-likelihood parameter set **b** that provides the best fit between simulated $f(\mathbf{b})$ and measured **c** quantities. The vector of optimization targets includes estimated drawdowns in the monitoring wells. **W** represents the relative weight of each optimization target defined subjectively based on the magnitude of the calibration data. The vector **b** includes various model parameters considered in the inverse analysis.

The model development included a series of inverse analyses with different complexity. The final model has on the order of 84 unknown model parameters (outlined in the next section) and about 182,070 calibration targets.

The model domain and the computational grid are shown in Figure A-6.0-1. The figure represents the three-dimensional model domain, computational grid, and locations of the monitoring well screens included in the model. The computational grid is structured with local grid refinements near the existing wells. Vertically, the grid has higher resolution close to the top of the model and grid spacing increases with depth. The lateral spacing is approximately 50 × 50 m (~160 × 160 ft). The vertical spacing varies from about 1 m to 15 m. The grid includes about 540,000 nodes and about 3,053,000 elements. The colors in Figure A-6.0-1 represent the different geologic units. The top of the model is constrained by the regional water table. The grid is designed to provide sufficient computational accuracy and efficiency for the performed model analyses. The model domain extends approximately 20 km west-east, approximately 16.5 km north-south, and approximately 1075 m vertically. All the model boundaries are defined as no-flow boundaries. Initial boundary condition is a constant head (zero drawdown) throughout the model domain. The regional aquifer is simulated as confined while, in reality, the aquifer is phreatic (unconfined). Model simulations representing the regional water table as a material boundary are feasible but much more computationally intensive. Given the small magnitude of the water-level fluctuations, the current modeling approach is justified.

The computer code LaGriT (http://lagrit.lanl.gov) was used to create the computational grids. The flow and transport simulations were performed with the Finite Element Heat and Mass Transfer code ([FEHM] http://fehm.lanl.gov) (Zyvoloski et al. 1996, 054421; Zyvoloski et al. 1997, 070147). FEHM was developed by researchers at the Laboratory and is capable of simulating three-dimensional, time-dependent, multiphase, non-isothermal flow, and multicomponent reactive groundwater transport through porous and fractured media. FEHM has been used in a wide variety of applications. The software is mature, has users throughout the world, and has been certified through the Yucca Mountain Project Software Quality Assurance Program. FEHM is available to the public and operates under various operating systems (Windows, MAC OS X, Linux, etc.).

The simulations are performed assuming unknown aquifer properties. The grid does not include distinct stratigraphic boundaries although they are known to be present within the model domain. Previous analyses of water-level responses to water-supply pumping and during the CrEX-1, R-28, and R-42 pump tests indicate aquifer materials are heterogeneous potentially at scales less than the size of the individual units and no distinct contrasts exist between different units. Therefore, aquifer permeability is simulated using geostatistical modeling and the pilot-points method. The pilot points are fixed locations where aquifer permeability and storativity are adjusted during the calibration process. The permeability and storativity at the pilot points are applied to compute aquifer permeability and storativity within the model domain using kriging. The values at the pilot points are adjusted during model calibration to represent heterogeneous fields that produce groundwater flow consistent with the observed calibration data. The analyses presented below employed 28 pilot points located within and around the area containing the chromium plume. The applied set of pilot points cannot be expected to characterize small-scale aquifer heterogeneity; it is expected only to define potential large-scale structures that control groundwater flow and contaminant transport. No prior information from pumping tests at the monitoring wells is applied to define or constrain the aquifer permeability at the pilot points. The three-dimensional kriging is performed using the code GSTAT (http://www.gstat.org) to compute permeability values for each node in the model domain representing aquifer heterogeneity.

The modeling results representing a comparison between the calibration targets and obtained model drawdowns predictions are shown in Figures A-6.0-2 through A-6.0-17. In general, the model predicts with good fidelity the observed drawdowns. Some of the drawdowns during CrEX-1 pumping are matched very well, especially at the wells located relatively close to CrEX-1. For example, the calibration targets for R-11, R-13, R-44 screen 1, R-45 screen 1, R-50 screen 1, R-50 screen 2, drawdowns are well represented by the model. The matches between observations and model predictions for the other monitoring well screens need more work.

The inverse analysis specifically targeted the characterization of the mid- and late-time drawdowns in R-50 screens 1 and 2 (Figures A-6.0-15 and A-6.0-16) and these portions of the drawdown curves are well predicted by the numerical model. As discussed in section 4 above, the early-time drawdowns in R-50 (Figures A-4.0-15 and A-4.0-16) are not well represented because of a potential impact of conditions that are not embodied in the current numerical model; the 2015 CrEX-1 pumping record will help to better resolve this conceptual uncertainty. Since the hydraulic communication between R-50 and CrEX-1 is important for predictions related to the impact of CrEX-1 pumping on the R-50 chromium concentrations, the capability of the current model to represent a large portion of the observed drawdown curves in R-50 is of great importance.

It is essential to note that the results modeled are based on relatively limited existing data and will be significantly enhanced during the upcoming pumping and monitoring period.

The estimated hydraulic conductivity (lateral and vertical) is shown in Figure A-6.0-18. The inverse model analysis accounts for R-28 and CrEX-1 pumping records. The inverse model analysis also takes into account the pressure changes observed during municipal water-supply pumping in the nearby groundwater production wells. The obtained estimates of the aquifer properties represent a three-dimensional tomographic image of the aquifer hydraulic conductivity. The figure demonstrates the pronounced aquifer heterogeneity, which is an estimate, based only on the pumping drawdowns observed in the monitoring wells. It is expected the solution is nonunique and that numerical models with alternative conceptualization and model parameters can be obtained that are also consistent with the available data. Therefore, the obtained modeling results should not be considered to be the only possible solution of the analyzed problem. It is also important to note that these results are preliminary and will benefit from additional data collected for the interim measure. Additional modeling work is being performed to address these uncertainties and their impact on the selection of potential remediation scenarios.

A-7.0 NUMERICAL MODEL ANALYSIS OF CrEX-1 CAPTURE ZONE

The estimated hydraulic conductivity field discussed in section A-6.0 (Figure A-6.0-18) is applied to estimate the CrEX-1 CZ. To do so, the hydraulic conductivity field is applied in the 2012 numerical model. The 2012 model is used because it has been already calibrated to the hydraulic heads in the aquifer in the plume area (LANL 2012, 228624). The current model presented in section A-5.0 has not yet been calibrated to the hydraulic heads. The current model has been calibrated only against the drawdowns caused by site pumping tests and municipal water-supply pumping. The mapping of the new estimates of the hydraulic conductivity field on the 2012 model definitely impacts the accuracy in the model predicted hydraulic gradients. This is done only to get preliminary estimate of the potential shape of the CrEX-1 CZ and the effect of aquifer heterogeneity on model predictions. This is a preliminary analysis. An updated model currently being calibrated against hydraulic heads observed to date in the monitoring wells in the plume area combined with additional model updates based on future data will give much more representative results.

Preliminary model predictions of the CrEX-1 CZ after 1, 3, and 5 yr of pumping are presented in Figure A-7.0-1. The model predictions represent the groundwater flow paths assuming only advective flow. However, dispersion processes occurring in the groundwater flow within porous media will impact the CZ estimates. The predictions are based on the heterogeneities presented in Figure A-6.0-18.

The CrEX-1 modeled CZs are shown in Figure A-7.0-1. The model predicts that the CZ extends to the west-northwest of the well. This result suggests that long-term CrEX-1 pumping may have beneficial impact on the plume concentrations. However, because of aquifer heterogeneity, including a zone of relatively low permeability in the R-42 area (Figure A-6.0-18), the long-term CrEX-1 pumping would not be expected to significantly affect chromium concentrations in the centroid of the chromium plume.

Preliminary model predictions in Figure A-7.0-1 represent the groundwater flow paths, assuming only advective flow. However, dispersion processes are expected to occur in groundwater flow within porous media, and these processes will impact the shape of the CZs. As a result of the dispersion, some of the contaminant mass outside the model predicted CZ is expected to be captured as well. However, the dispersion may also cause some of contaminant mass within the modeled CZ to escape capture by CrEX-1. The CrEX-1 CZ will be also impacted by transients in the regional groundwater flow. Additional pumping and injection of groundwater near CrEX-1 will impact the shape of the CrEX-1 CZ as well.

These modeling results are preliminary and will be updated as more data are available from the pumping and monitoring of pressure responses. The preliminary results demonstrate the potential complexity in the aquifer properties and the associated difficulties to estimate the CrEX-1 CZs. The ongoing modeling analyses and the upcoming additional data collection activities in 2015 are expected to reduce these uncertainties.

A-8.0 NUMERICAL MODEL ANALYSIS OF PLUME RESPONSE TO THE INTERIM MEASURES

In this section, the 2012 model is applied to estimate the impact of the proposed interim measures activities on the chromium concentrations and plume configuration in the regional aquifer. The 2012 model is the preferred model for this analysis because it has been successfully calibrated to (1) the hydraulic heads and (2) the chromium concentrations in the aquifer in the plume area. However, the 2012 model is not calibrated to represent the drawdowns observed during the recent R-28 and CrEX-1 pumping periods. The 2012 model is also not calibrated to represent the 2014 tracer test data. Future modeling analyses will use the model update discussed in section 5 that will include all these calibration data sets.

A model prediction of the chromium concentrations in 2016 and 2021 without active pumping is shown in Figure A-8.0-1. The model predictions are based on the 2012 model (LANL 2012, 228624). These results are presented for a comparison with the modeling results presented below for the case of active groundwater pumping and injection.

Model predictions of the impact of various interim measures scenarios on the chromium concentrations are presented in Figure A-8.0-2 and A-8.0-3. The plots are showing model predictions in 2016, 2017, 2019, and 2021 (after 0, 1, 3 and 5 yr of pumping/injection, respectively).

In the first case (Figure A-8.0-2), CrEX-1 is pumping for 5 yr at 80 gpm (2016–2021), CrIN-4 and CrIN-5 are injecting at 40 gpm each for 5 yr (2016–2021). CrIN-4 and CrIN-5 are located east and west of R-50, respectively. The model predicts that pumping of CrEX-1 as well as the injection at CrIN-4 and CrIN-5 provide a very beneficial impact on the contaminant plume, substantially decreasing the contaminant concentrations at the downgradient plume edge in the area around R-50.

In the second case (Figure A-8.0-3), CrEX-1 is pumping for 5 yr at 80 gpm (2016–2021), CrIN-1 and CrIN-2 are injecting at 40 gpm each for 5 yr (2016–2021). CrIN-1 and CrIN-2 are located in the area near R-45. Note that in this case, the model predicts that pumping at CrEX-1 and injection near R-45 does not have as beneficial an impact on the contaminant plume near the Laboratory boundary as in the previous case with groundwater injection at CrIN-4 and CrIN-5. However, the model predicts that injection of groundwater in CrIN-1 and CrIN-2 has a beneficial impact on the contaminant concentrations in the R-45 area.

These model scenarios are also illustrated by the concentration curves for R-45 screen 1 and R-50 screen 1 presented in Figure A-8.0-4. The figure presents model predictions for the chromium concentration in these two well screens under different scenarios. The scenarios are (1) no action; (2) CrEX-1 pumping only (at 80 gpm for 5 yr); (3) CrEX-1 pumping and CrIN-4/CrIN-5 injecting (pumping regime as defined above); and (4) CrEX-1 pumping and CrIN-1/CrIN-2 injecting (pumping regime as defined above). R-45 concentrations are substantially impacted only by the CrIN-1/CrIN-2 injection (scenario 4 above). R-50 concentrations are impacted in all pumping/injection scenarios but the most favorable impact occurs when CrIN-4/CrIN-5 are injecting (scenario 4 above).

9.0 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.

LANL (Los Alamos National Laboratory), July 2008. "Fate and Transport Investigations Update for Chromium Contamination from Sandia Canyon," Los Alamos National Laboratory document LA-UR-08-4702, Los Alamos, New Mexico. (LANL 2008, 102996)

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LANL (Los Alamos National Laboratory), March 2014. "Summary Report for the 2013 Chromium Groundwater Aquifer Tests at R-42, R-28, and SCI-2," Los Alamos National Laboratory document LA-UR-14-21642, Los Alamos, New Mexico. (LANL 2014, 255110)

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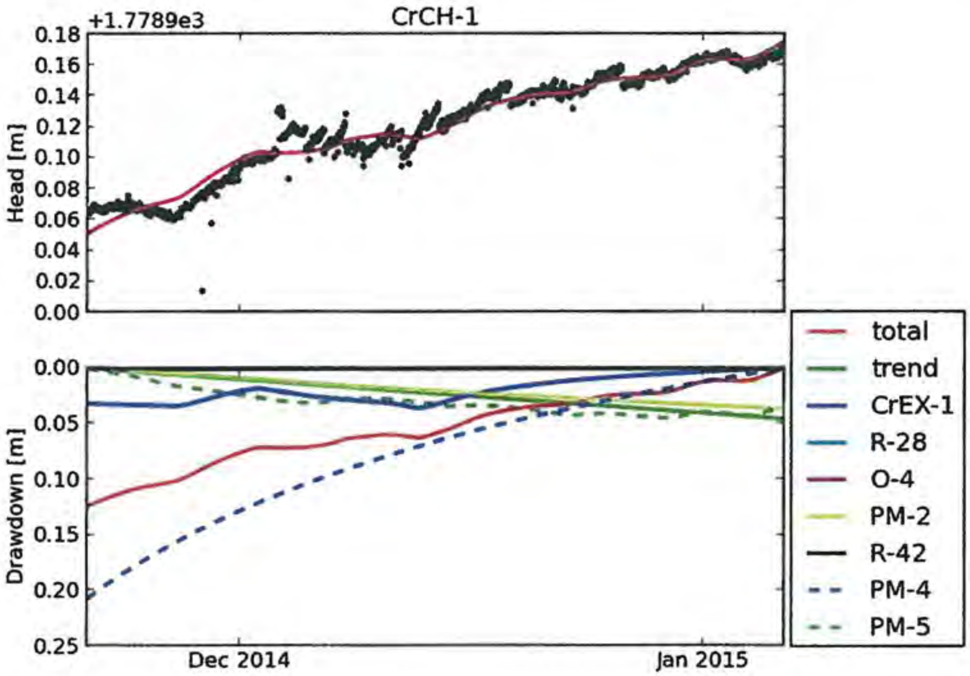


Figure A-4.0-1 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for CrCH-1

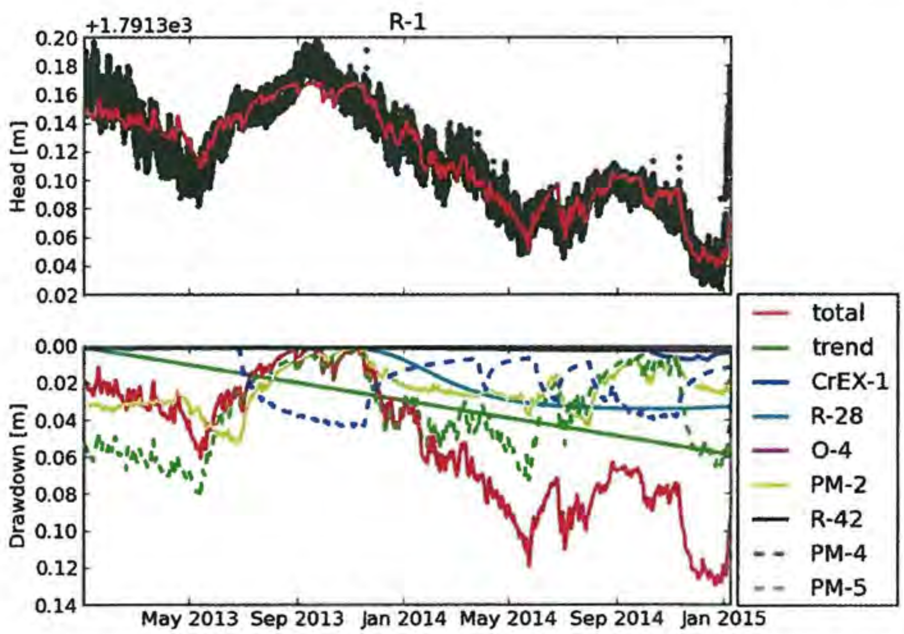


Figure A-4.0-2 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-1

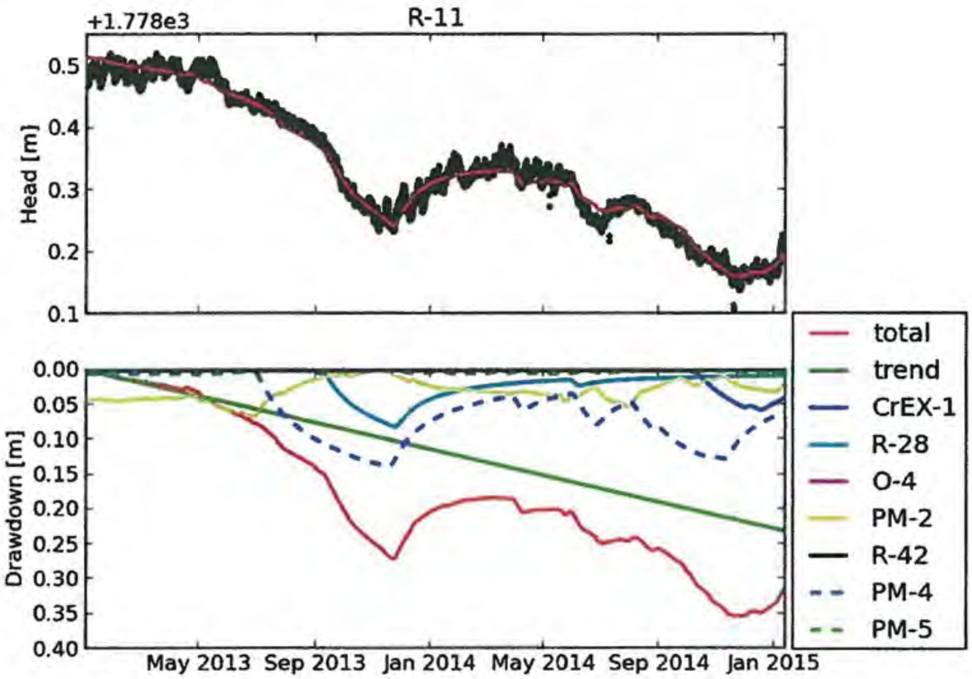


Figure A-4.0-3 **Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-11**

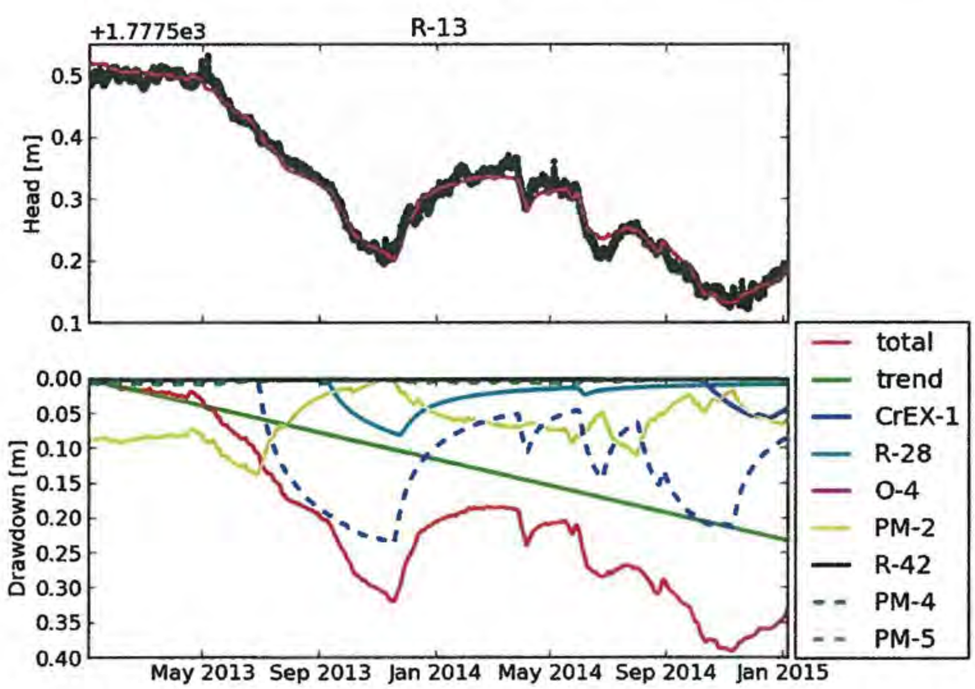


Figure A-4.0-4 **Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-13**

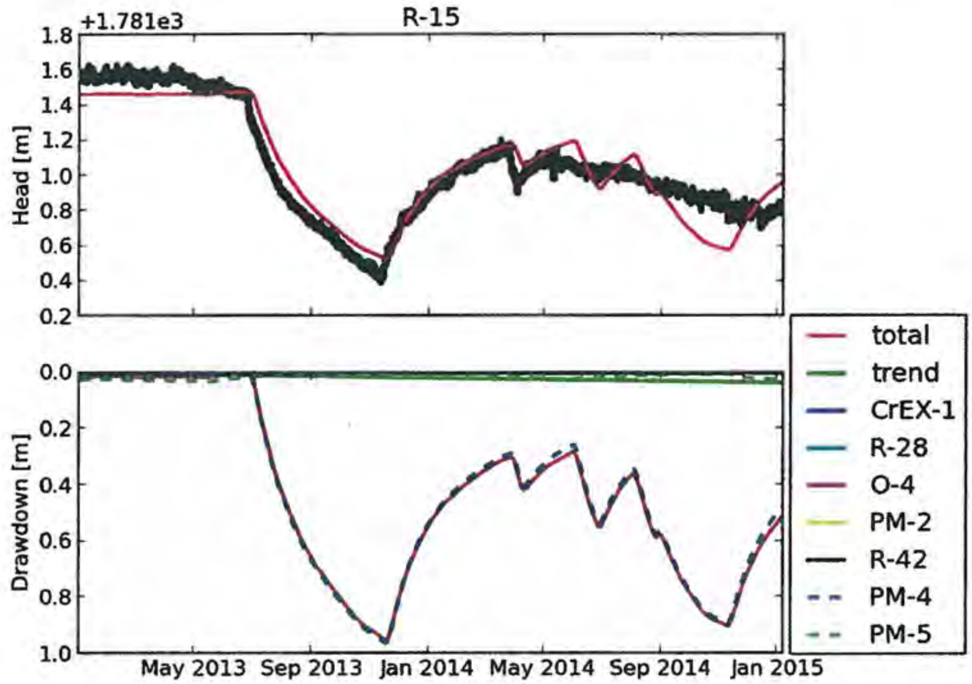


Figure A-4.0-5 **Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-15**

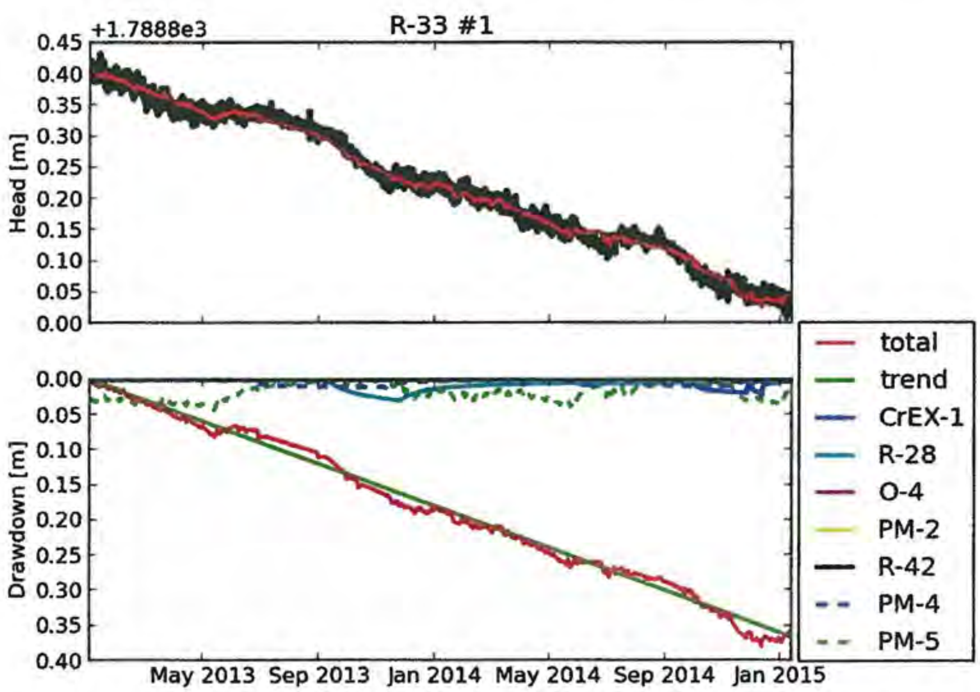


Figure A-4.0-6 **Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-33 screen 1**

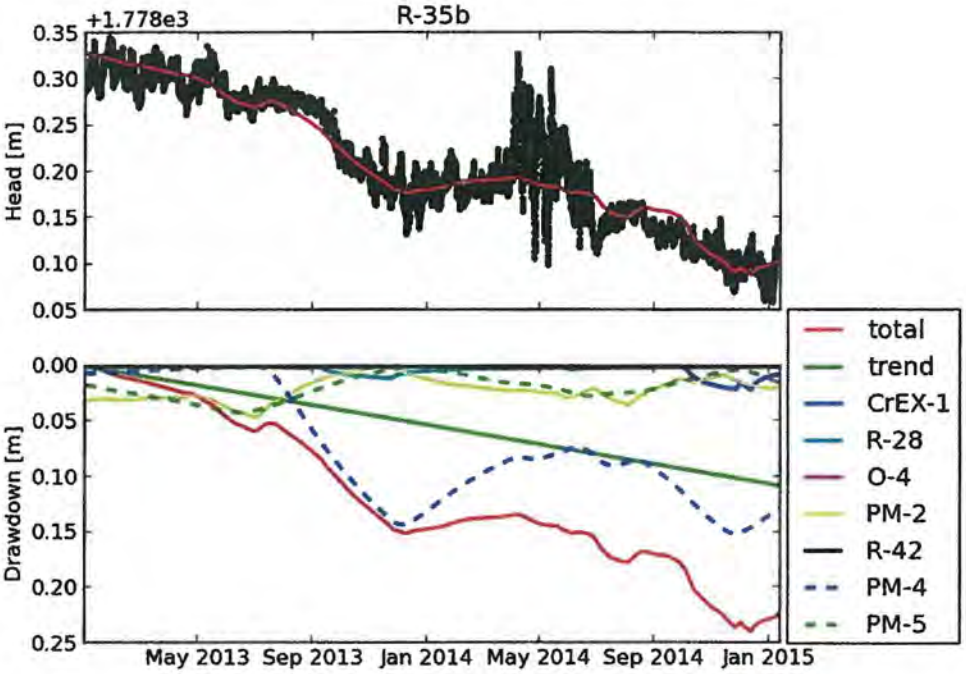


Figure A-4.0-7 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-35b

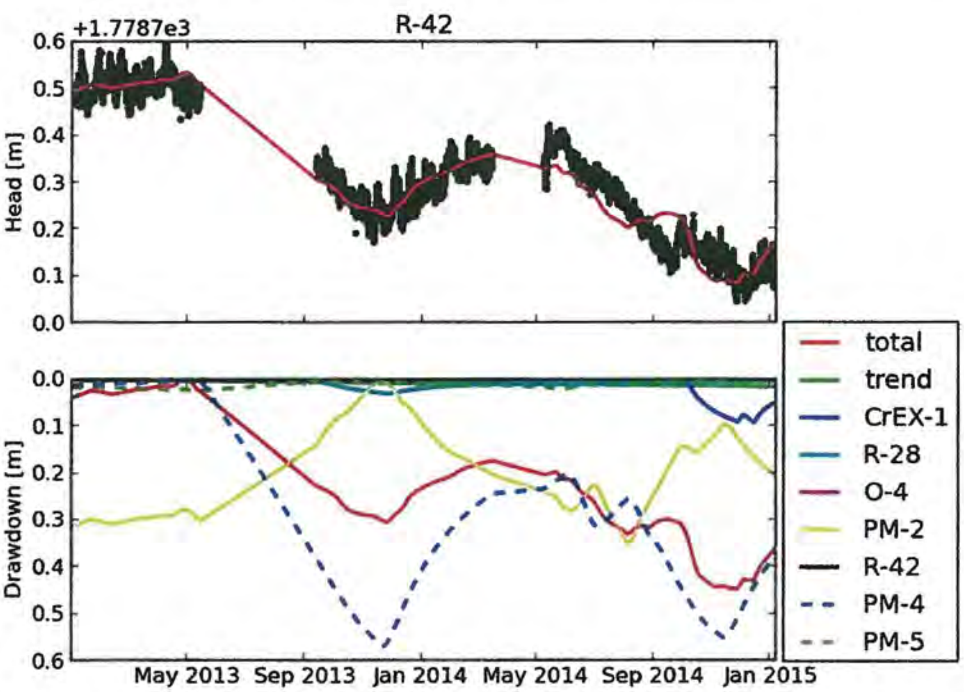


Figure A-4.0-8 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-42

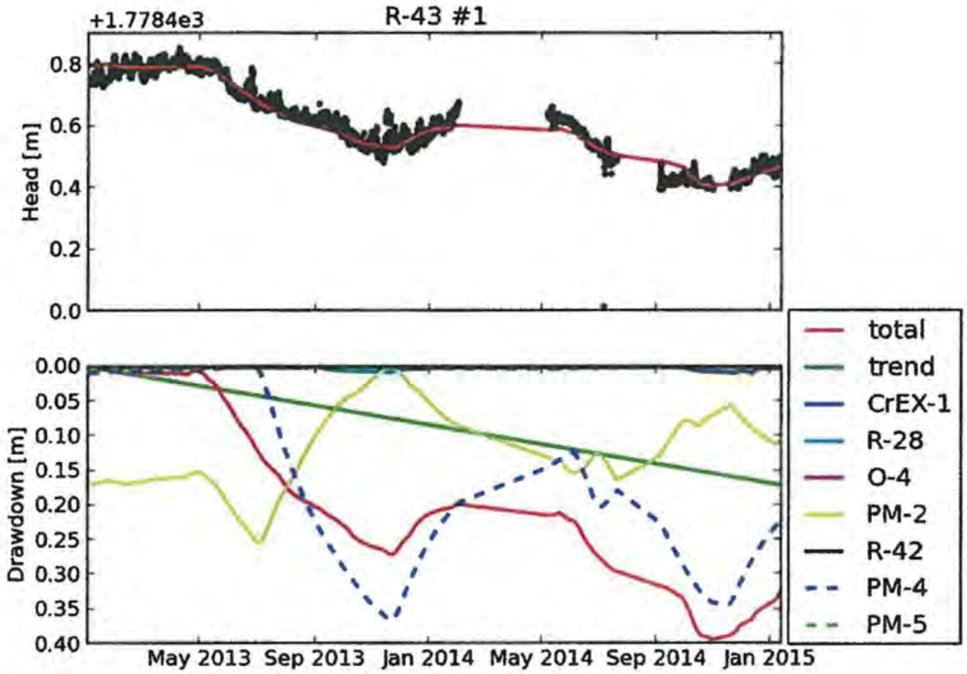


Figure A-4.0-9 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-43 screen 1

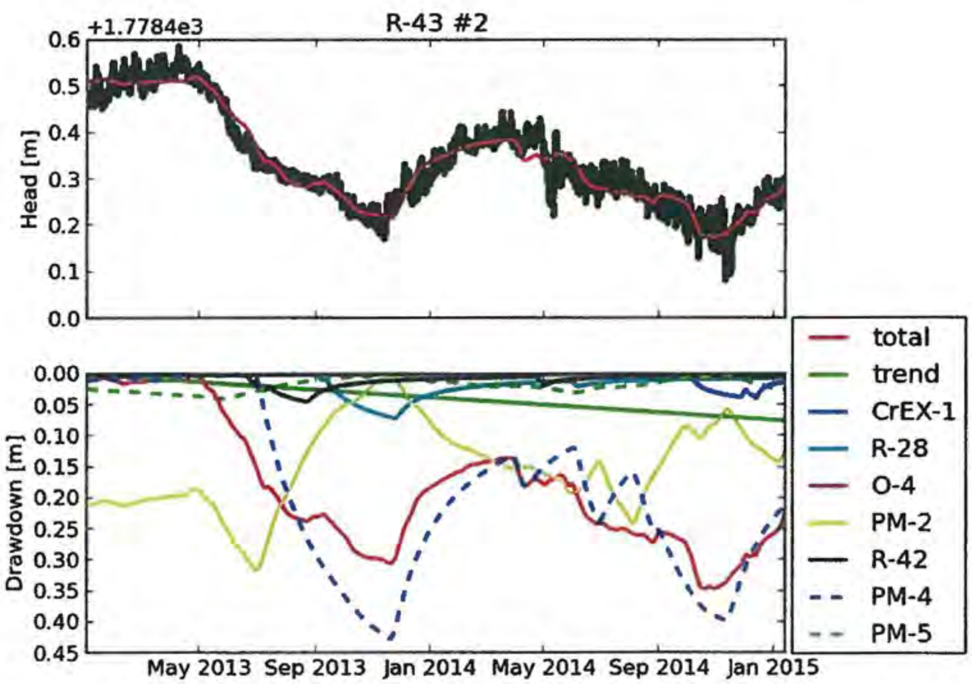


Figure A-4.0-10 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-43 screen 2

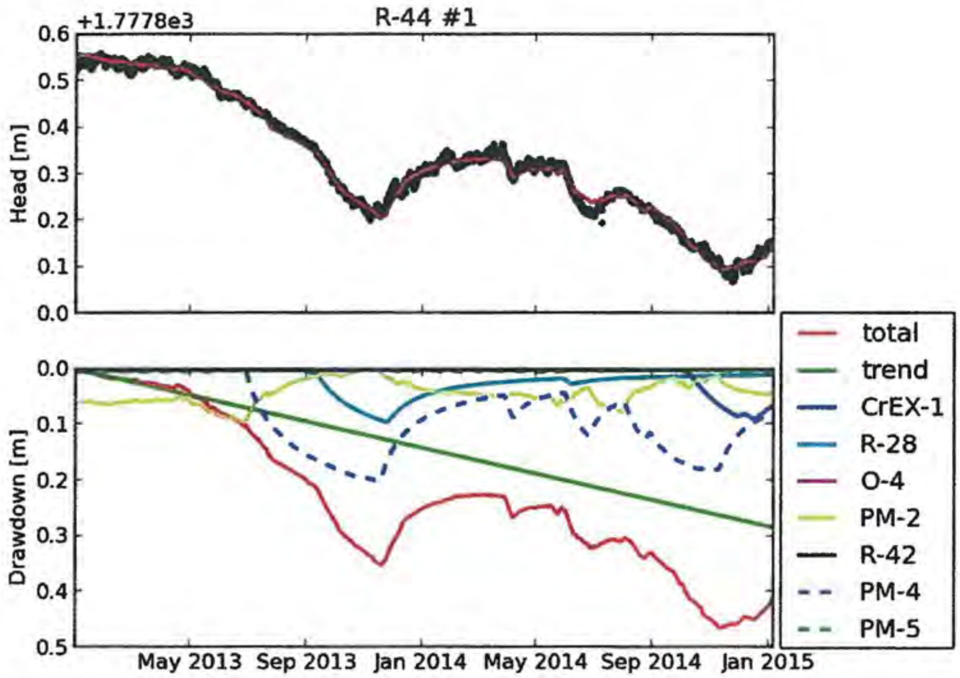


Figure A-4.0-11 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-44 screen 1

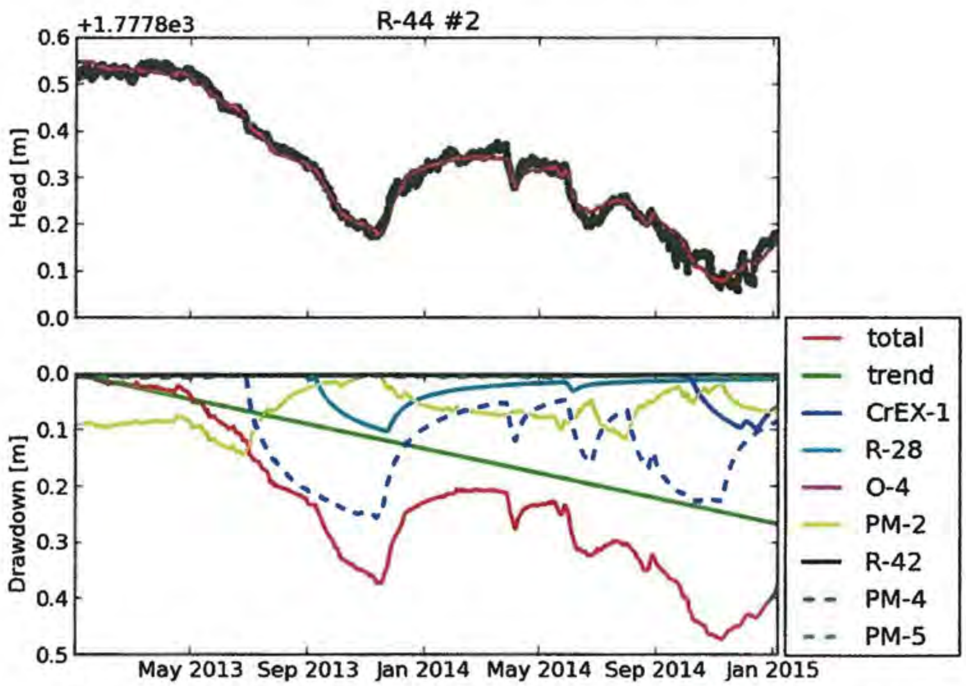


Figure A-4.0-12 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-44 screen 2

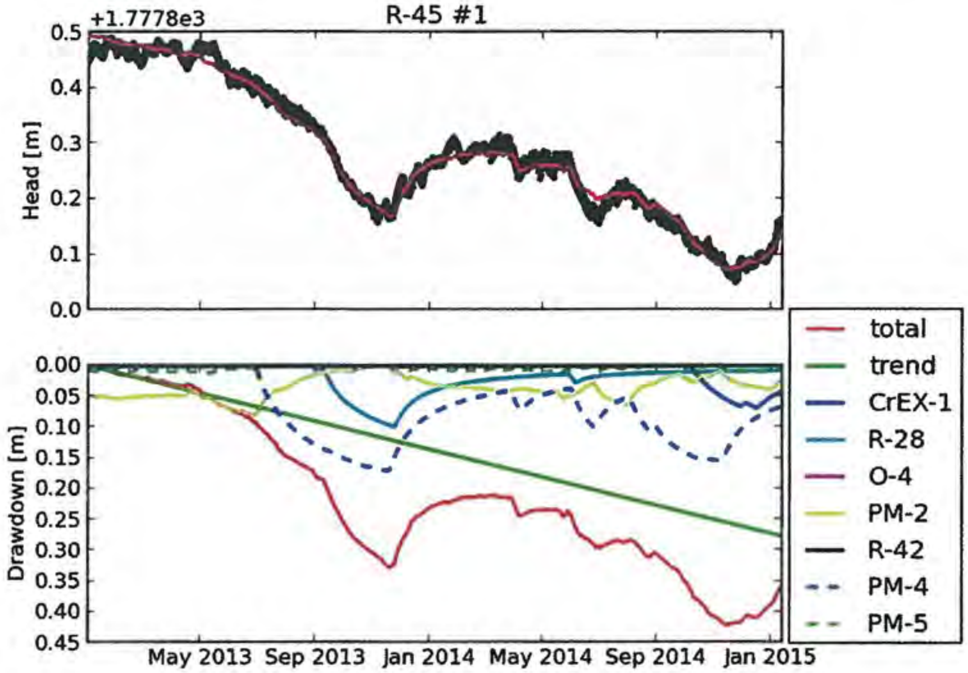


Figure A-4.0-13 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-45 screen 1

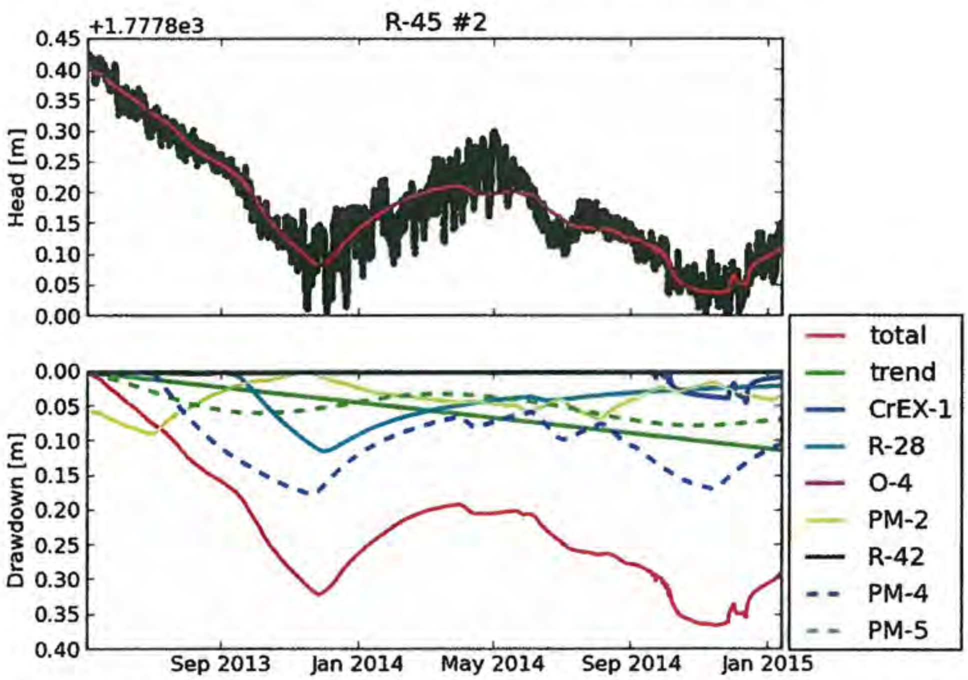


Figure A-4.0-14 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-45 screen 2

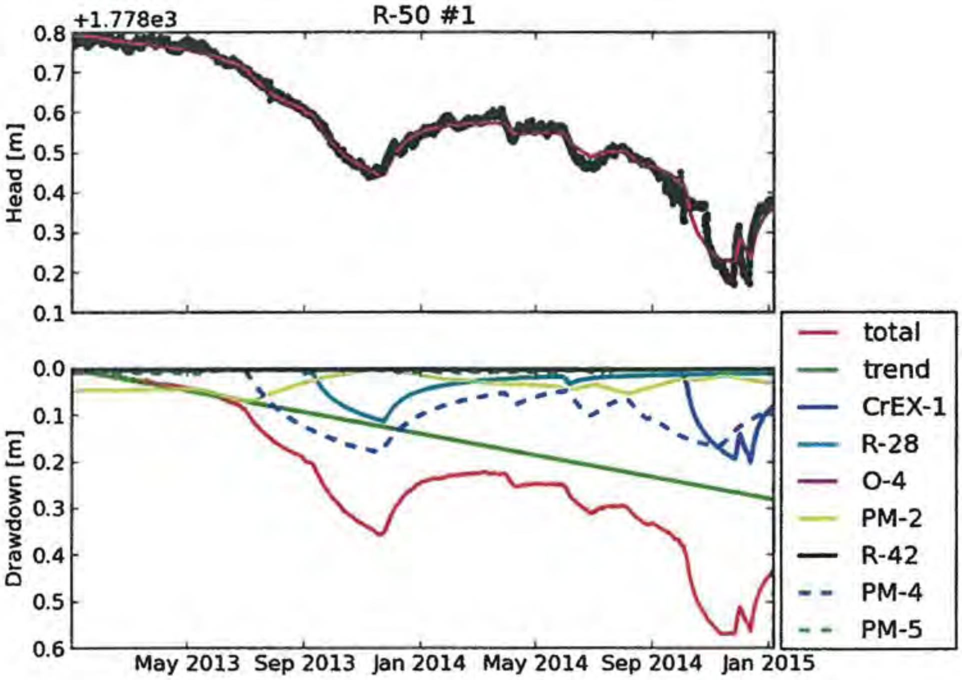


Figure A-4.0-15 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-50 screen 1

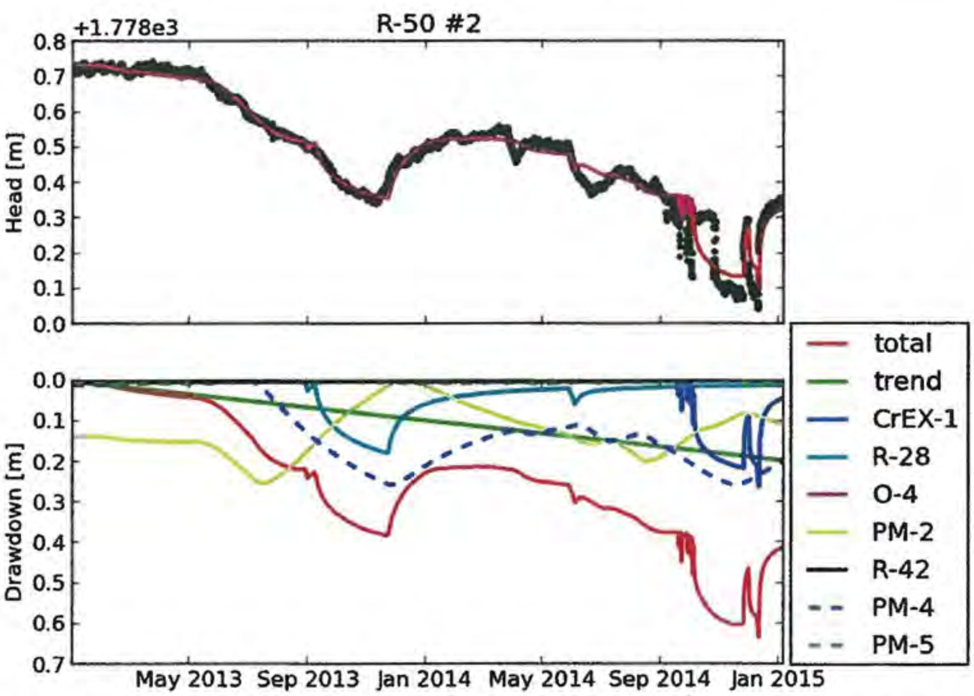


Figure A-4.0-16 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-50 screen 2

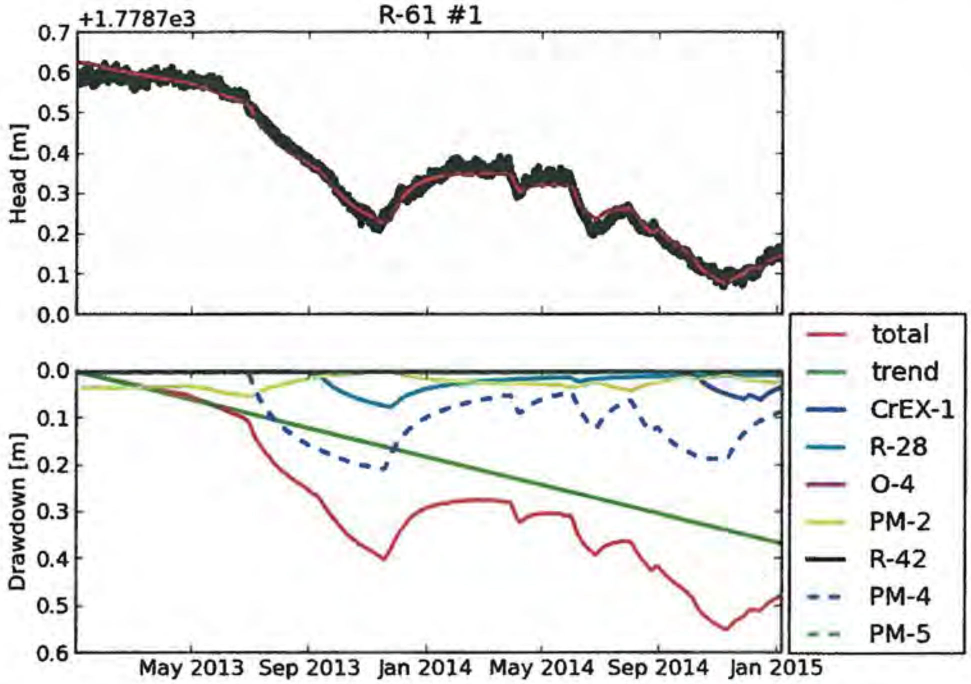


Figure A-4.0-17 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-61 screen 1

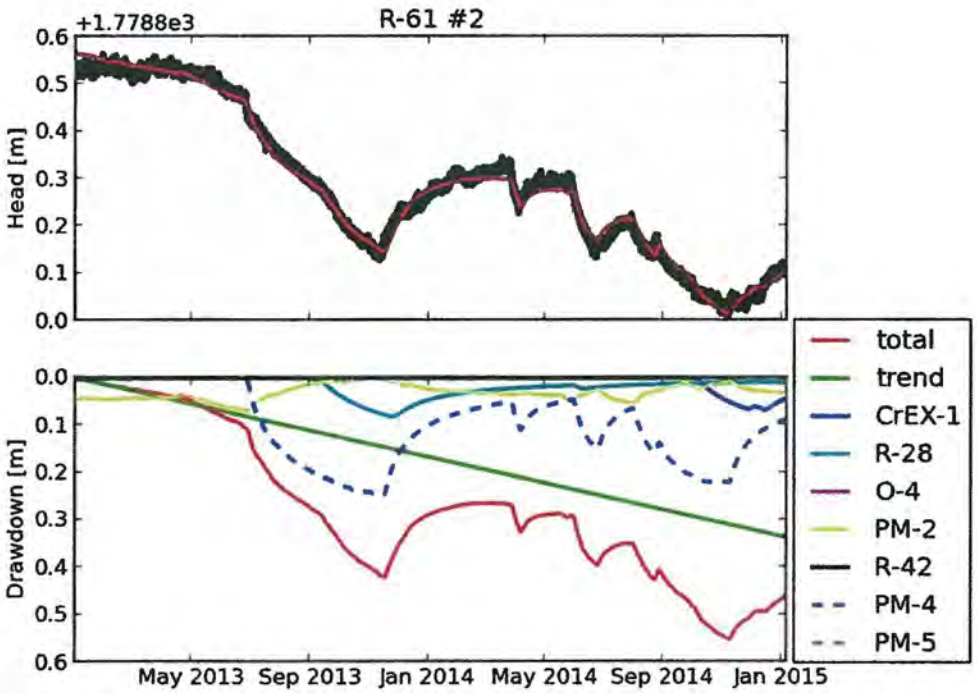


Figure A-4.0-18 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-61 screen 2

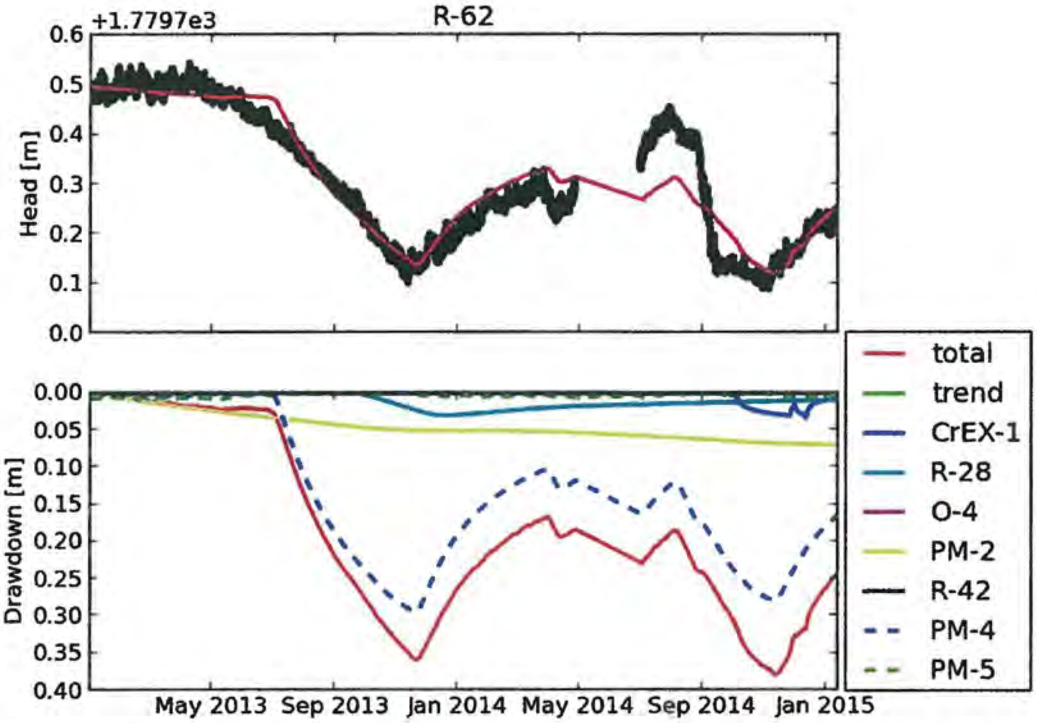


Figure A-4.0-19 Observed (black dots in the upper figure) and simulated (red line in the upper figure) heads are depicted in the upper figure, and the simulated drawdowns are depicted in the lower figure for R-62

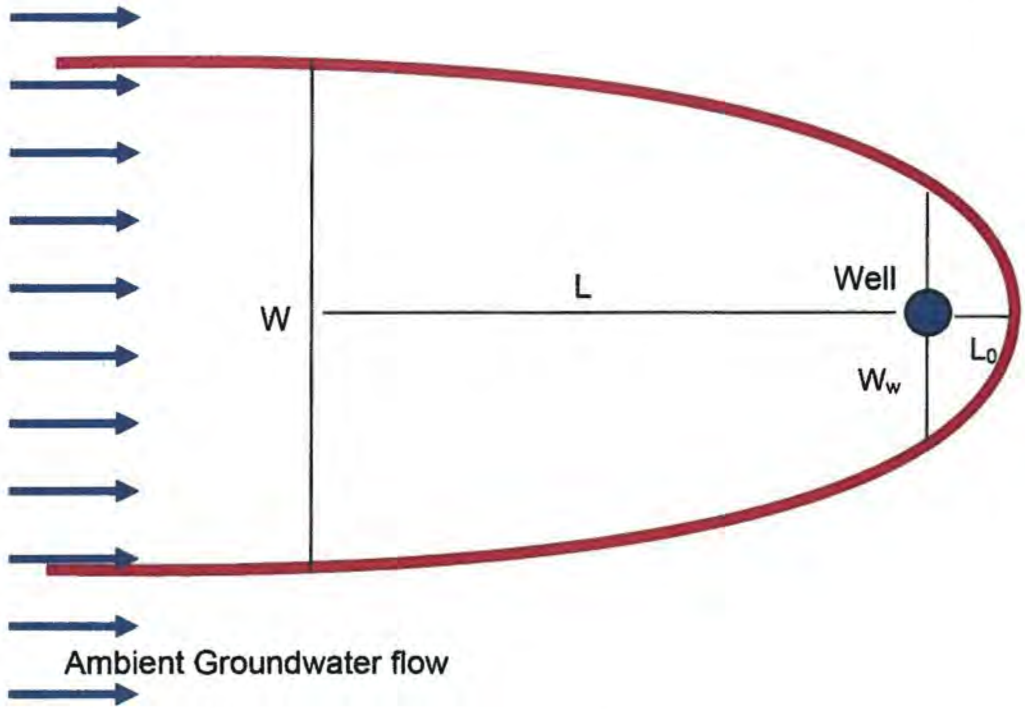


Figure A-5.0-1 Schematic representation of CZ of CrEX-1 assuming only advective steady-state groundwater flow through the regional aquifer

Notes: The computational grid is structured with local grid refinements near the existing wells. Vertically, the grid has higher resolution close to the top of the model and grid spacing increases with depth. The lateral spacing is ~50 × 50 m (~160 × 160 ft). The vertical spacing varies from about 1 m to 15 m. The grid includes about 540,000 nodes and about 3,053,000 elements. The coloring represents the different geologic units. The top of the model is constrained by the regional water table.

Figure A-6.0-1 The model domain and the computational grid

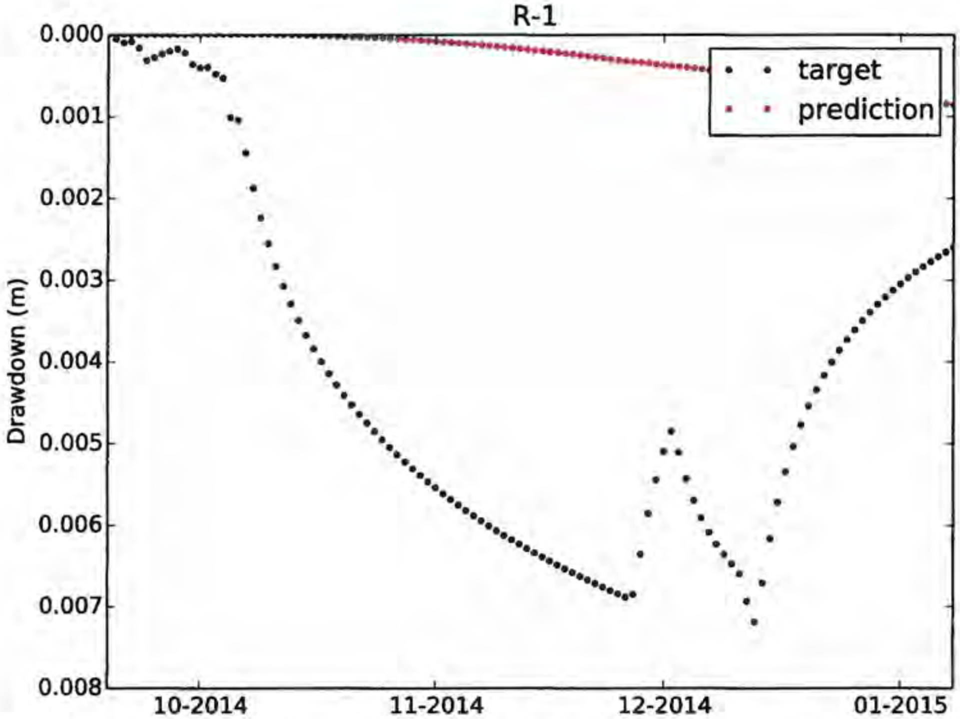


Figure A-6.0-2 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-1 to pumping at CrEX-1

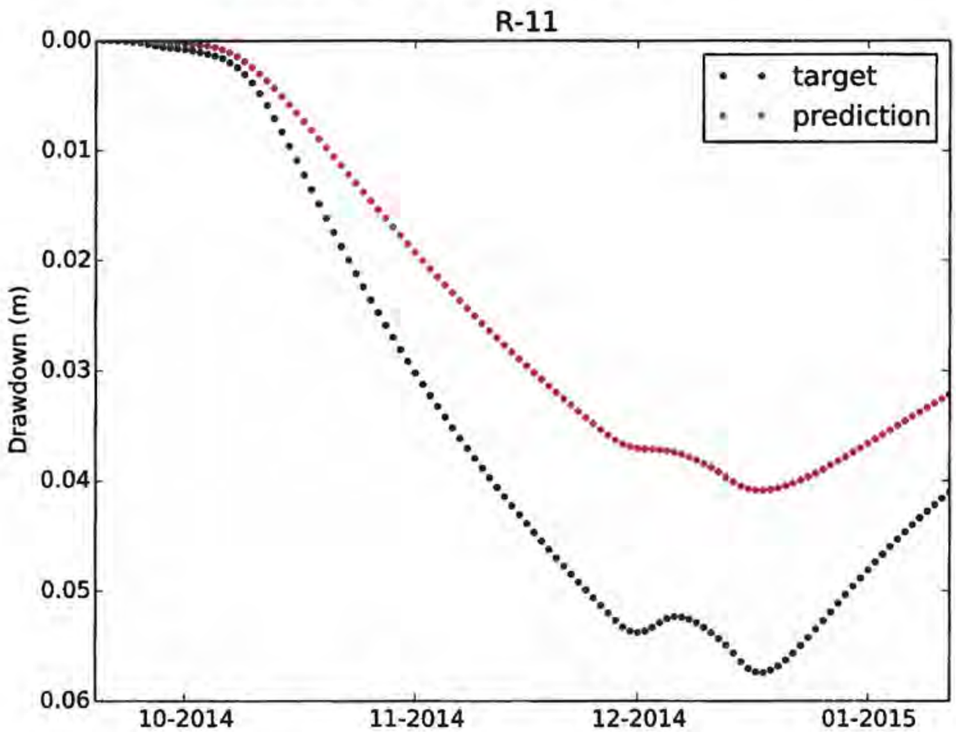


Figure A-6.0-3 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-11 to pumping at CrEX-1

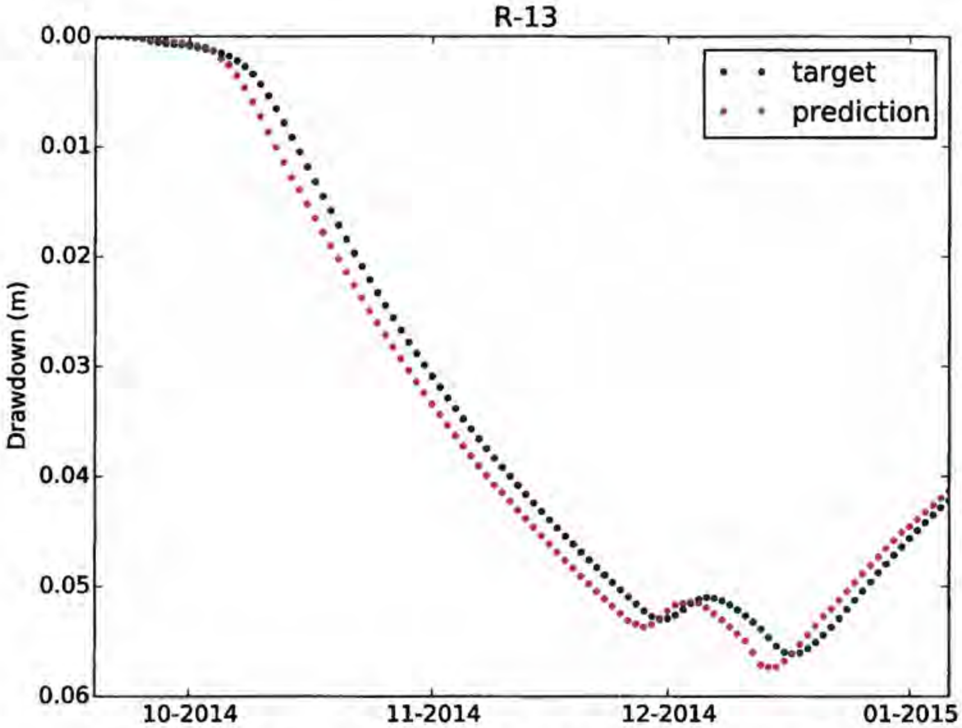


Figure A-6.0-4 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-13 to pumping at CrEX-1

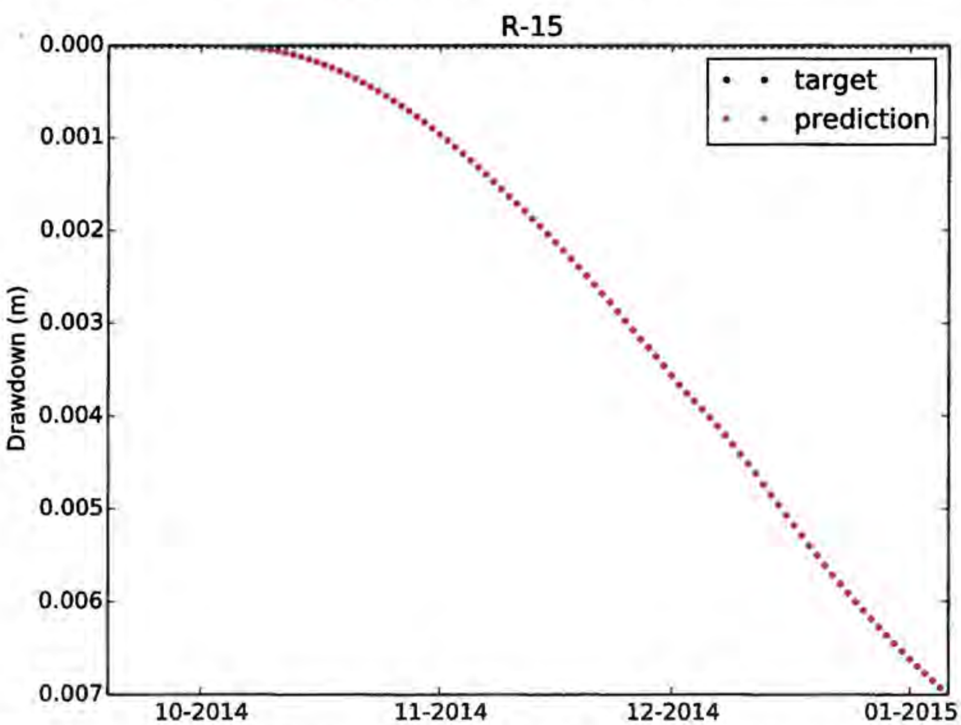


Figure A-6.0-5 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-15 to pumping at CrEX-1

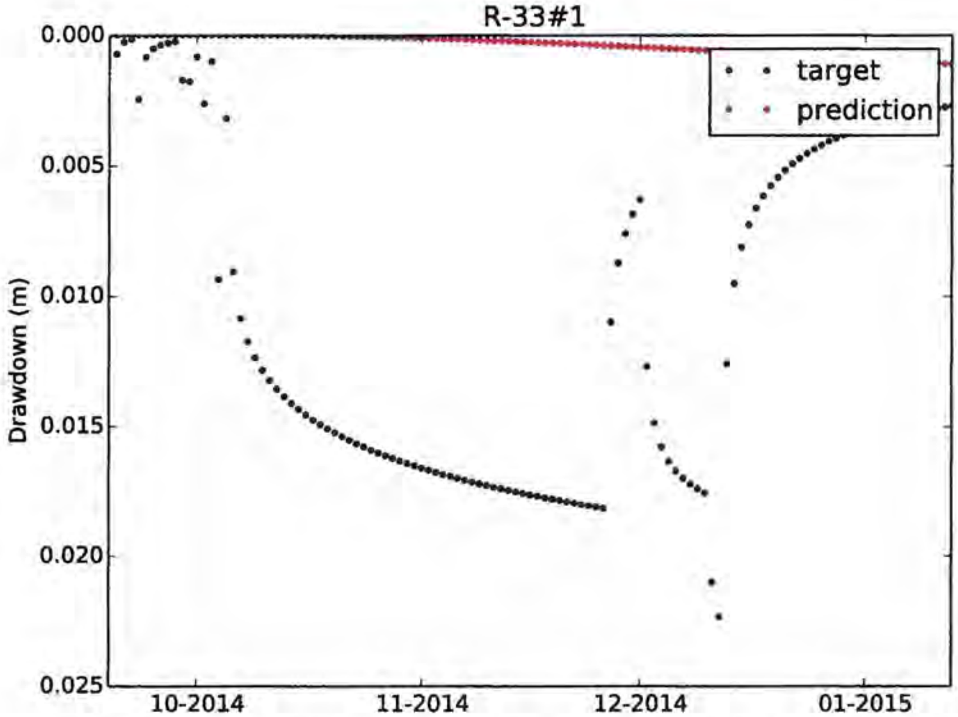


Figure A-6.0-6 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-33 #1 to pumping at CrEX-1

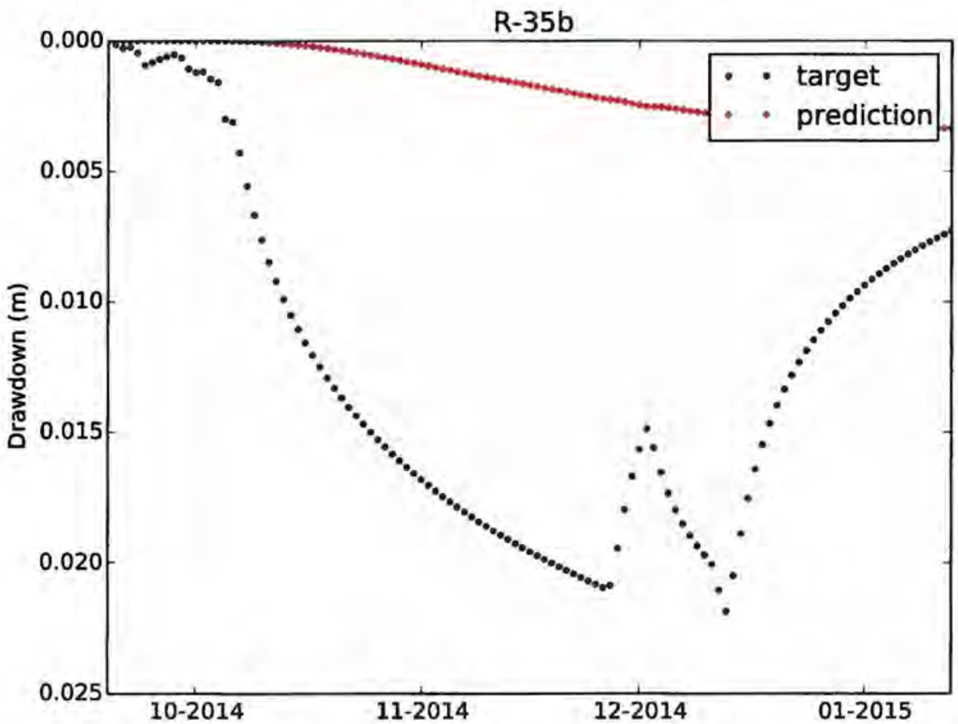


Figure A-6.0-7 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-35b to pumping at CrEX-1

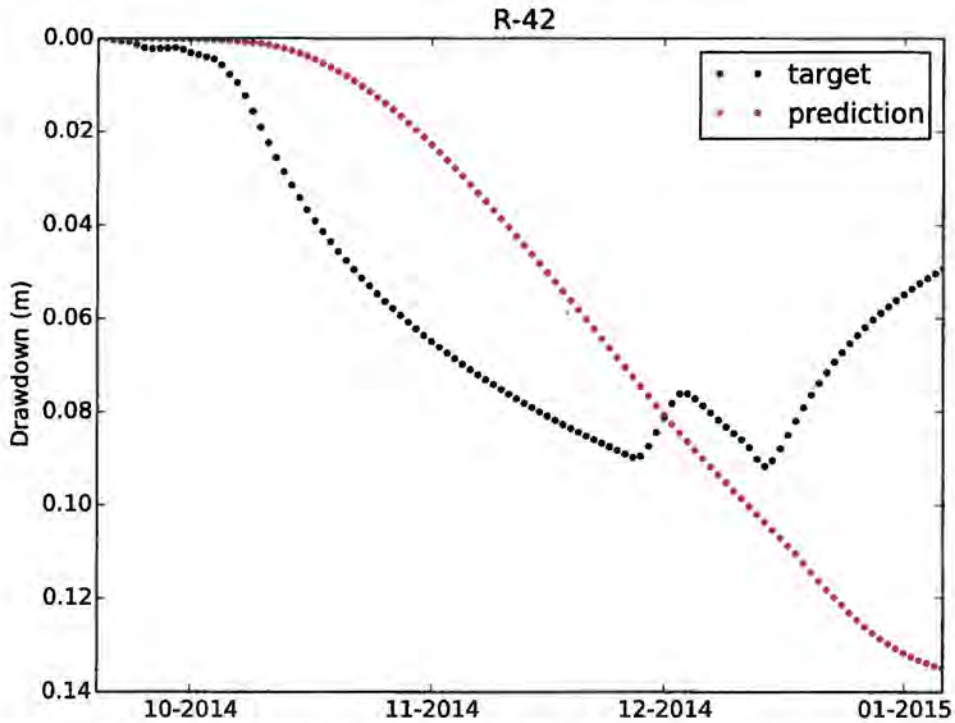


Figure A-6.0-8 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-42 to pumping at CrEX-1

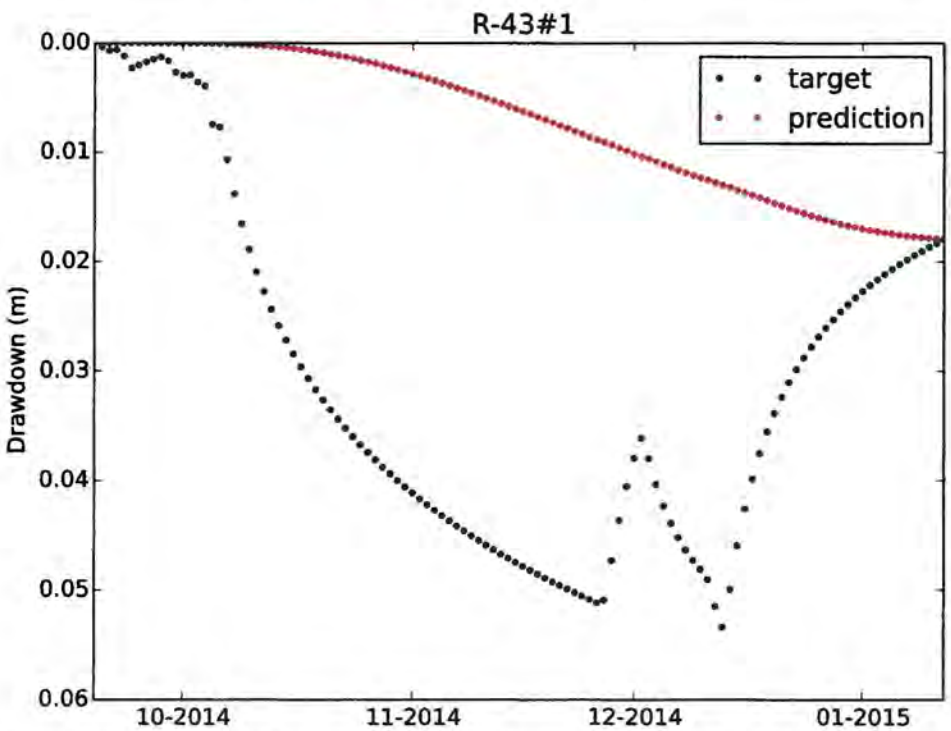


Figure A-6.0-9 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-43 screen 1 to pumping at CrEX-1

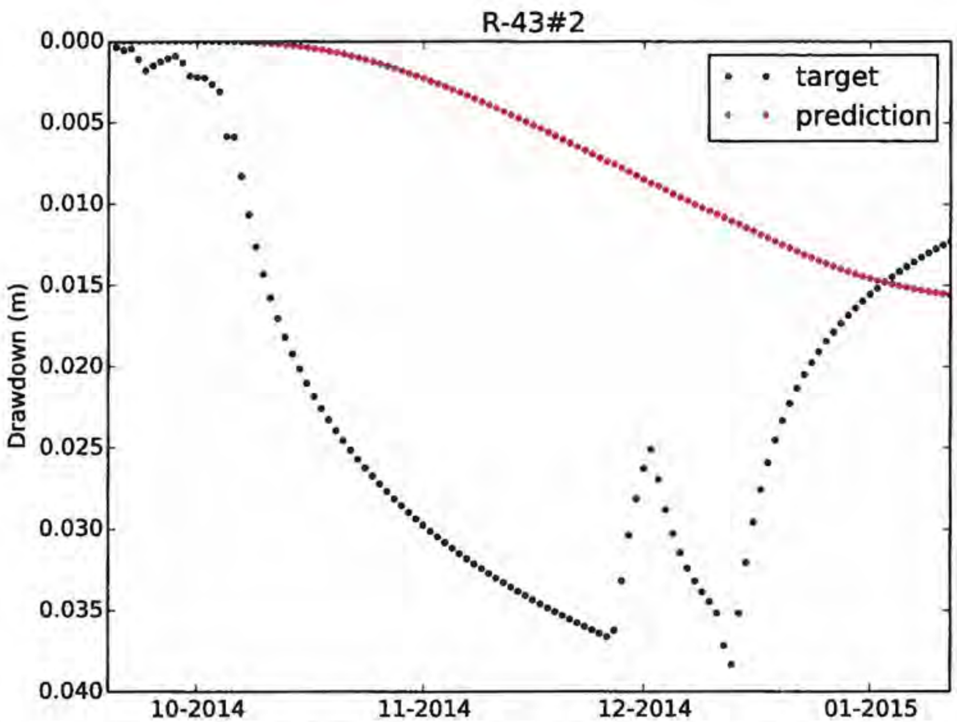


Figure A-6.0-10 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-43 screen 2 to pumping at CrEX-1

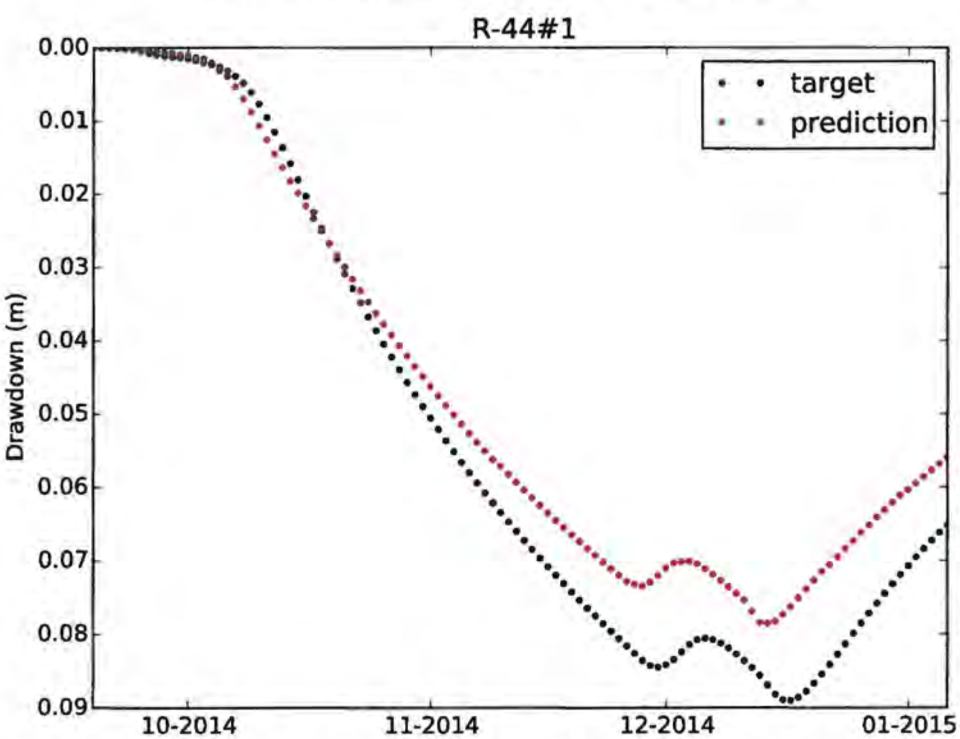


Figure A-6.0-11 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-44 screen 1 to pumping at CrEX-1

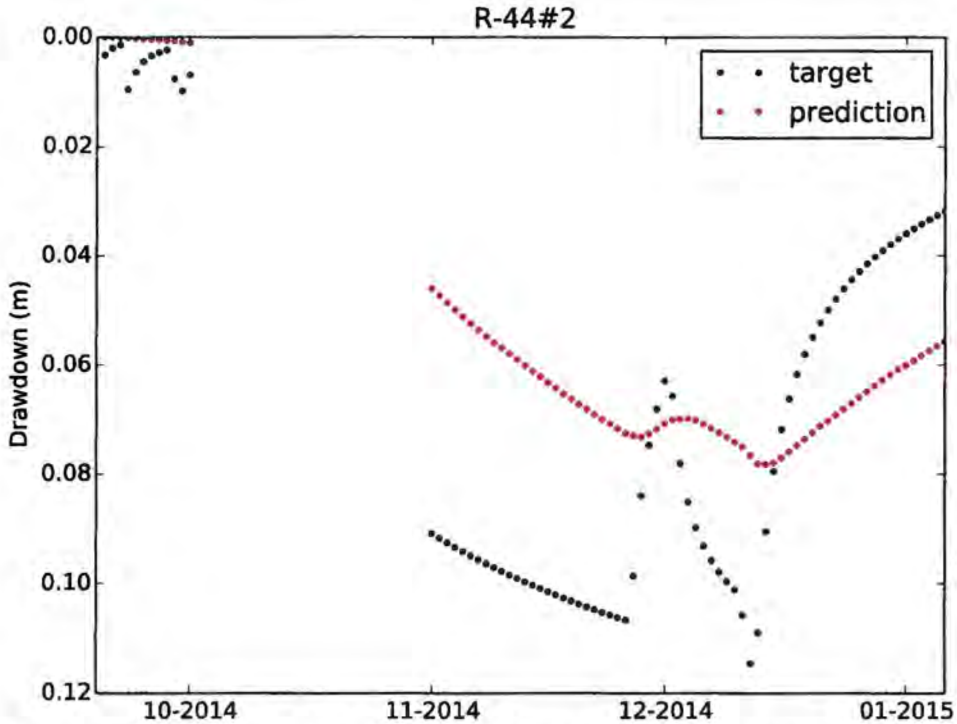


Figure A-6.0-12 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-44 screen 2 to pumping at CrEX-1

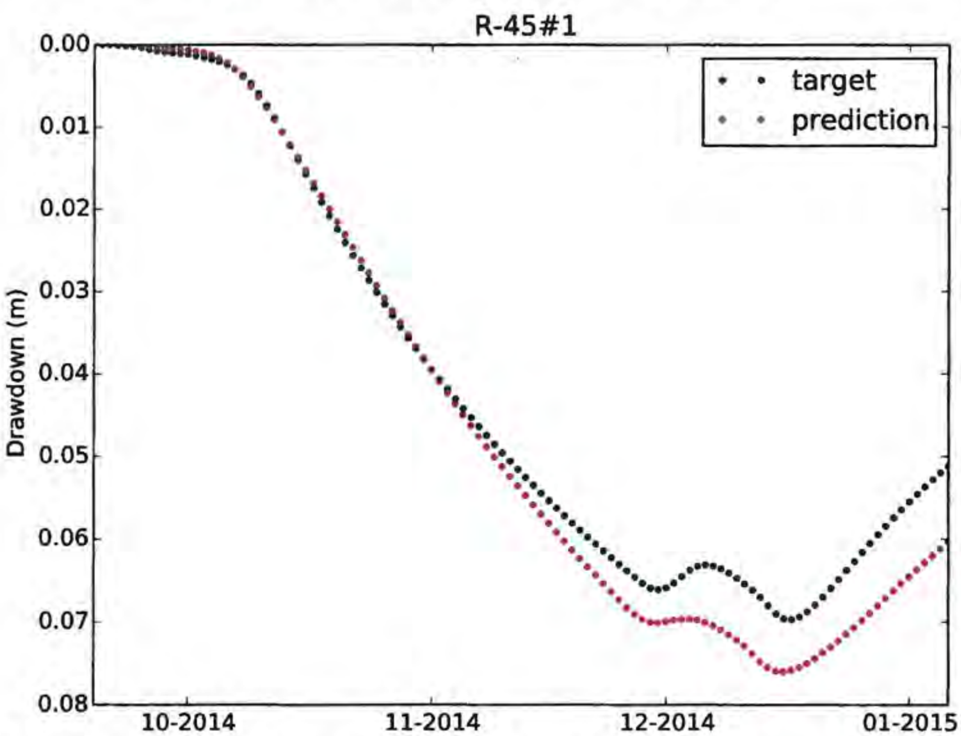


Figure A-6.0-13 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-45 screen 1 to pumping at CrEX-1

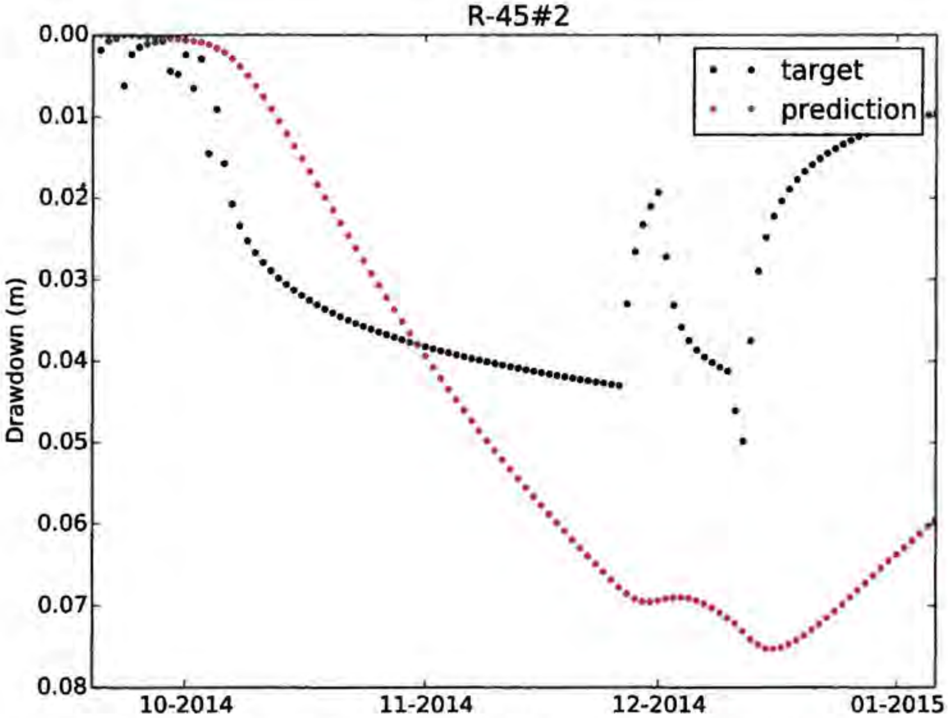


Figure A-6.0-14 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-45 screen 2 to pumping at CrEX-1

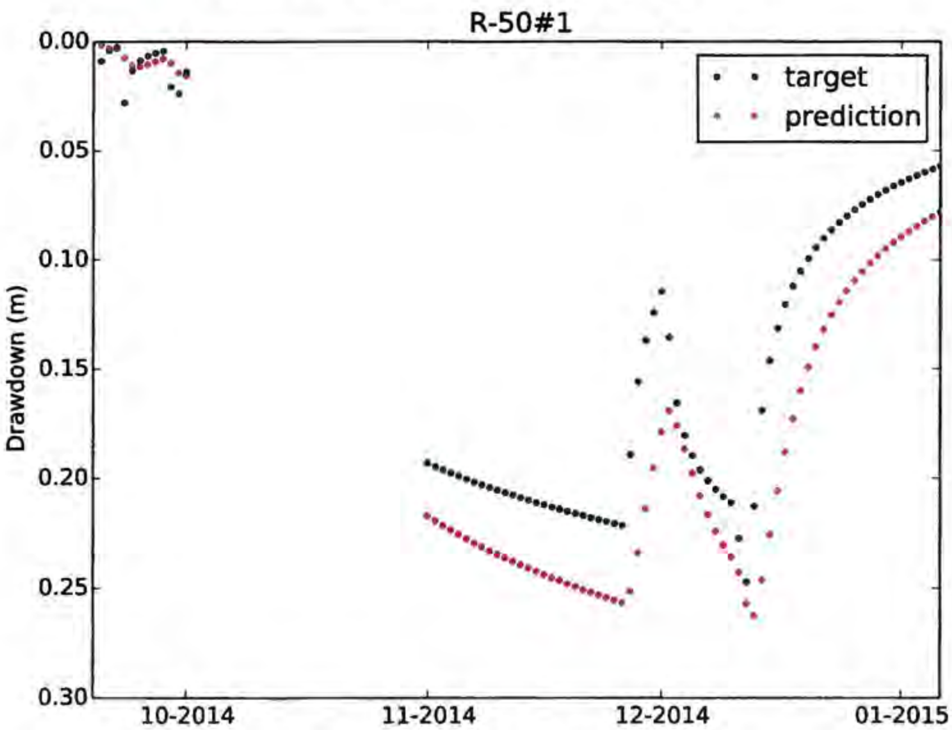


Figure A-6.0-15 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-50 screen 1 to pumping at CrEX-1

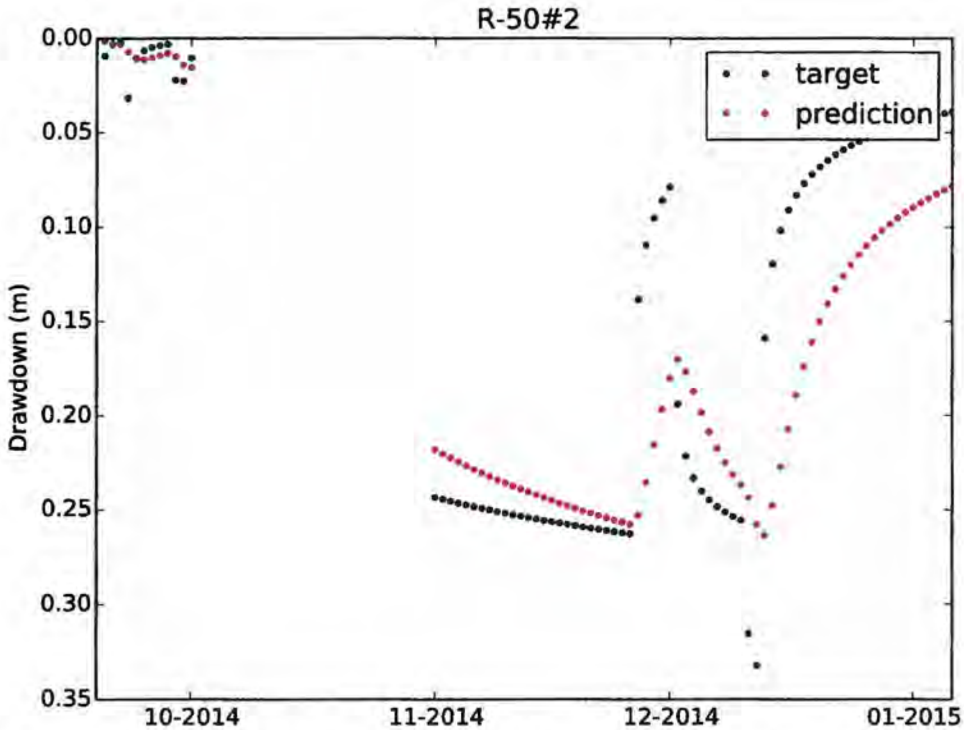


Figure A-6.0-16 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-50 screen 2 to pumping at CrEX-1

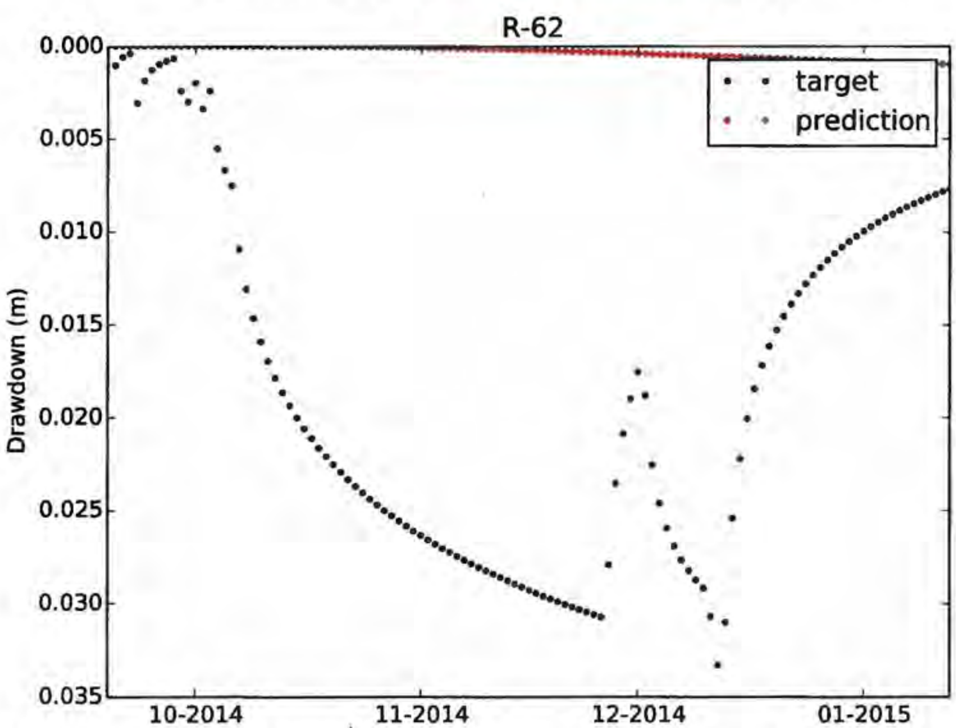
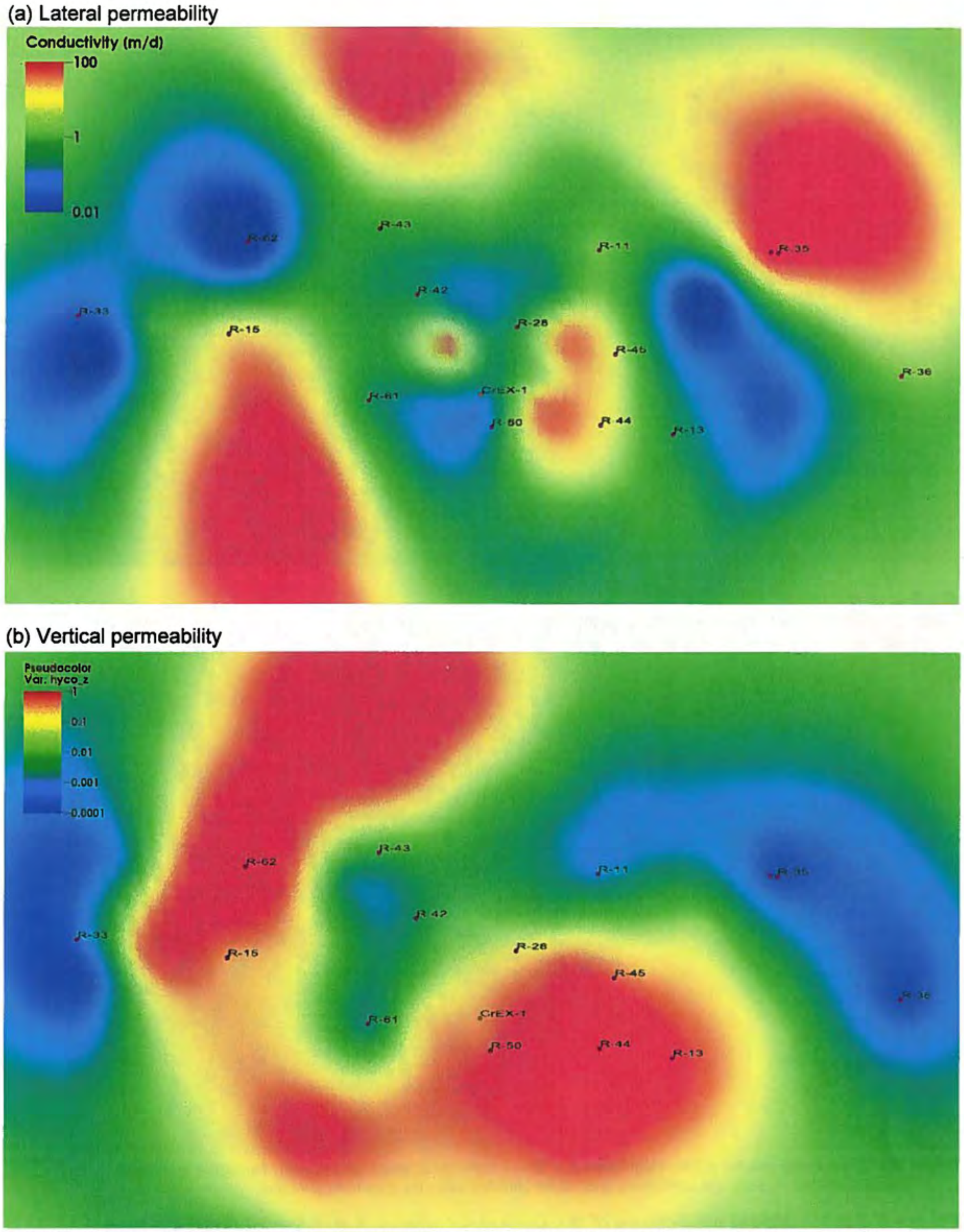


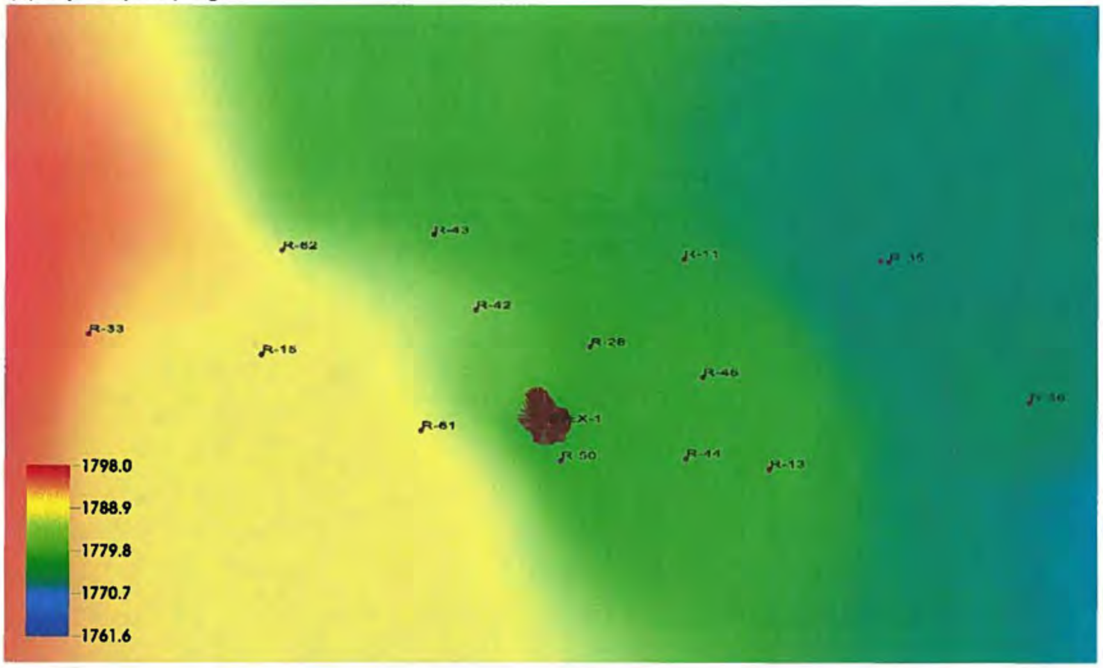
Figure A-6.0-17 Model calibration targets (black dots) and predictions (red dots) for the drawdown at R-62 to pumping at CrEX-1



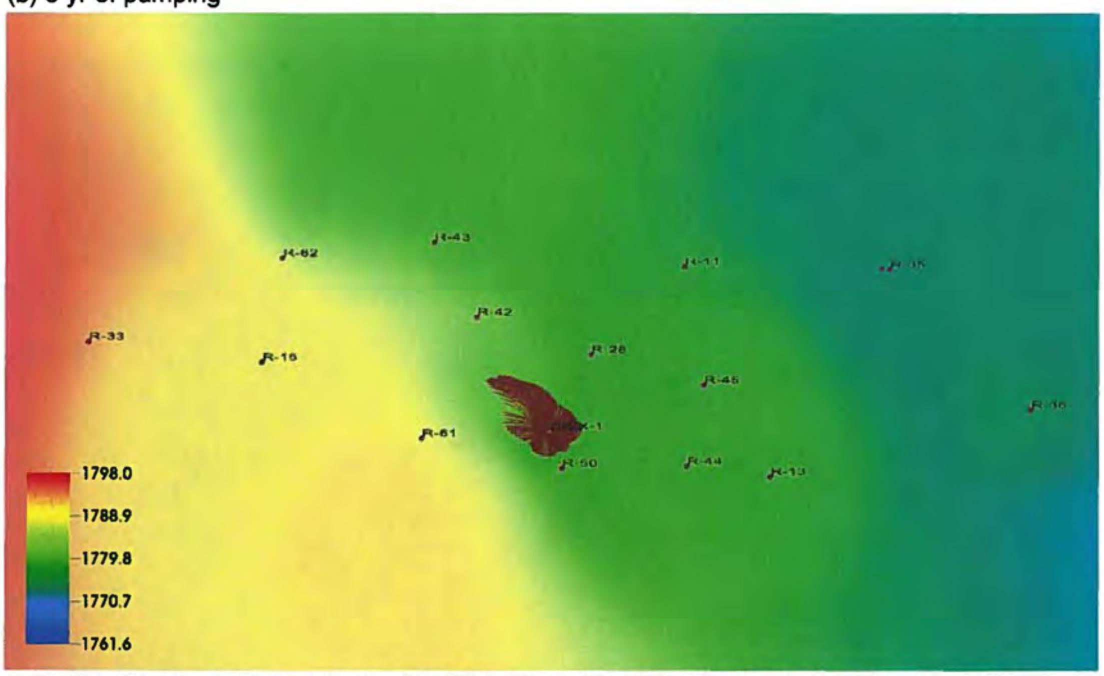
Notes: The inverse model analysis also takes into account the pressure changes observed from municipal water-supply pumping in the nearby groundwater production wells.

Figure A-6.0-18 Model estimated hydraulic conductivity (lateral and vertical) based on R-28 and CrEX-1 pumping tests

(a) 1 yr of pumping



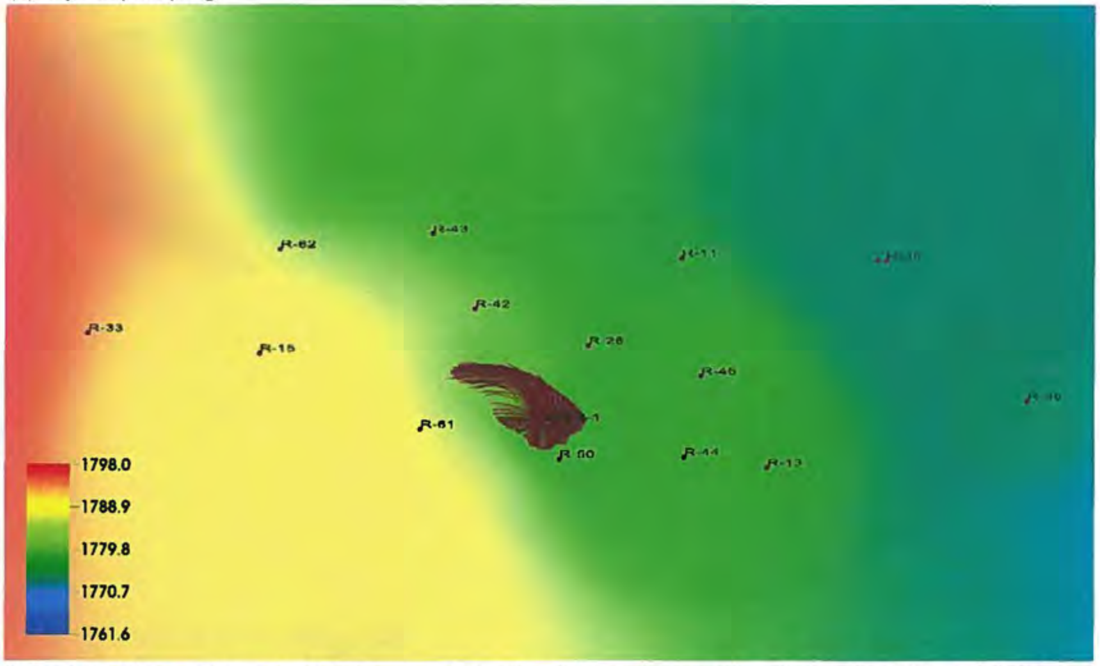
(b) 3 yr of pumping



Notes: The CZ accounts only for advective groundwater flow; it does not account for diffusion, dispersion and dual-porosity effects. Results are preliminary and will be updated with new data from pumping.

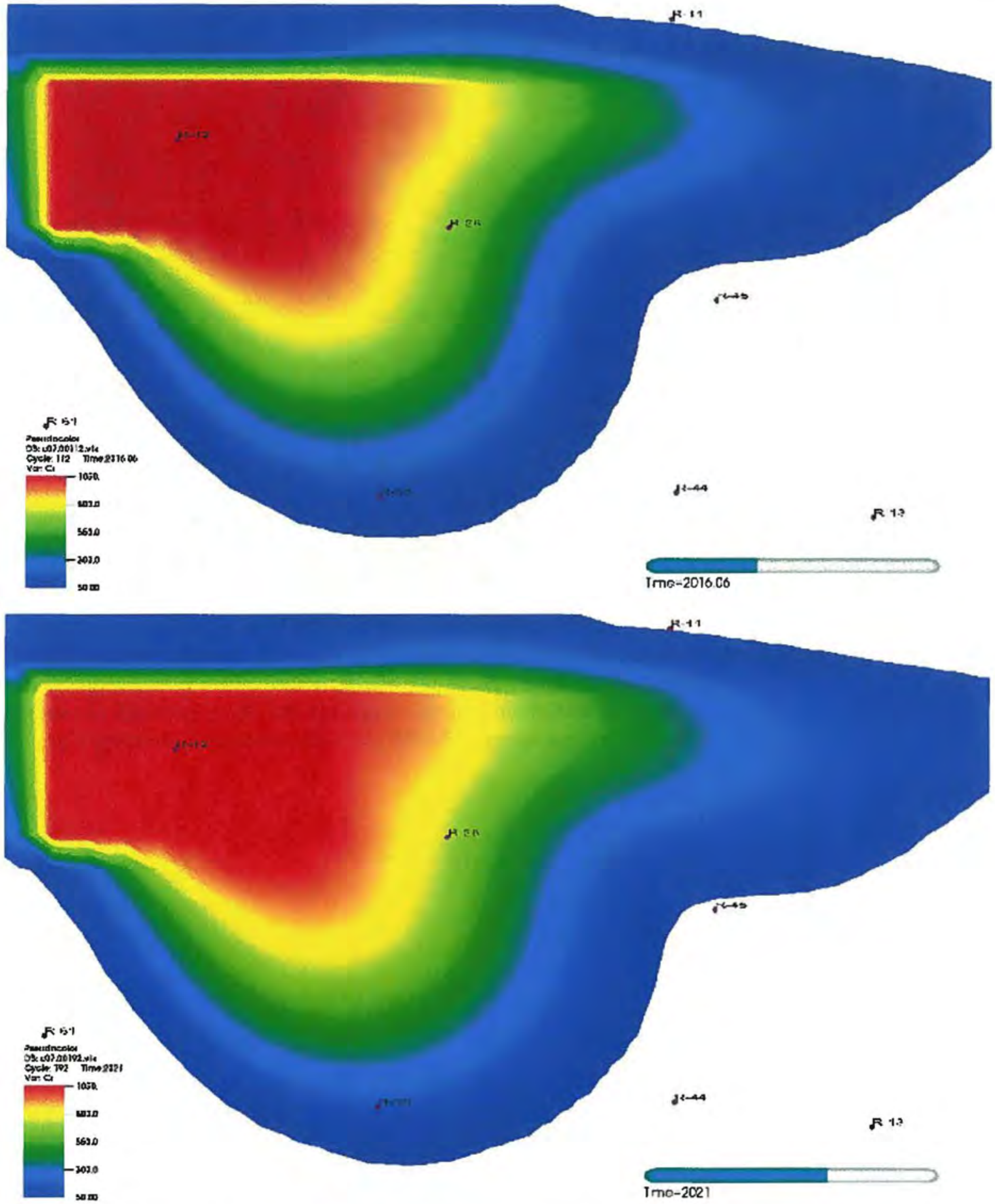
Figure A-7.0-1 Model predictions of the CrEX-1 CZ after 1, 3 and 5 yr of pumping model predictions using 2014 model update of the 2012 model (Phase II Sandia Investigation Report [LANL 2012, 228624]) accounting for aquifer heterogeneity based on R-28 and CrEX-1 pumping tests

(c) 5 yr of pumping



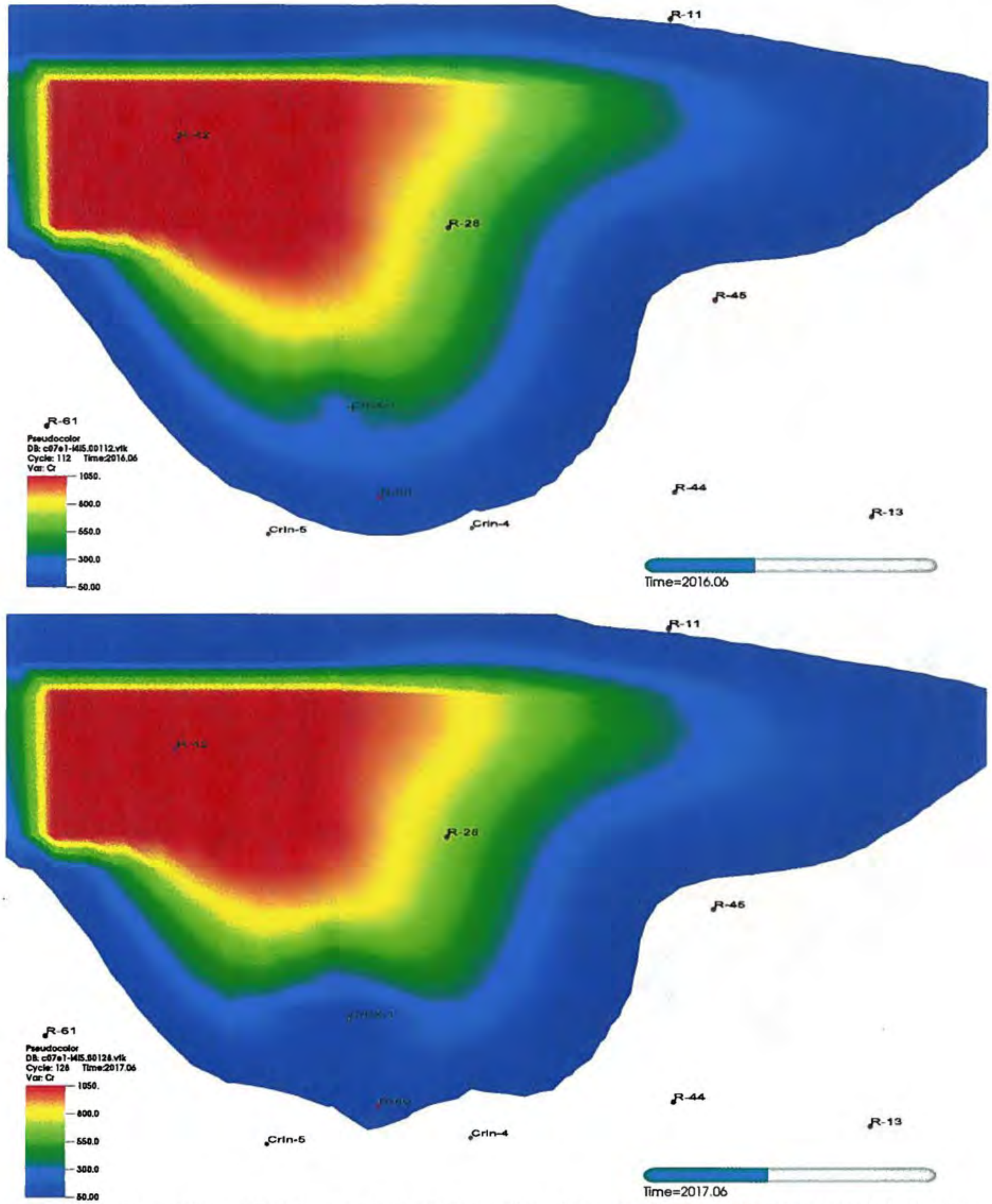
Notes: The CZ accounts for only advective groundwater flow; it does not account for diffusion, dispersion, and dual-porosity effects. Results are preliminary and will be updated with new data from pumping.

Figure A-7.0-1 (continued) Model predictions of the CrEX-1 CZ after 1, 3, and 5 yr of pumping model predictions using 2014 model update of the 2012 model (Phase II Sandia Investigation Report [LANL 2012, 228624]) accounting for aquifer heterogeneity based on R-28 and CrEX-1 pumping tests



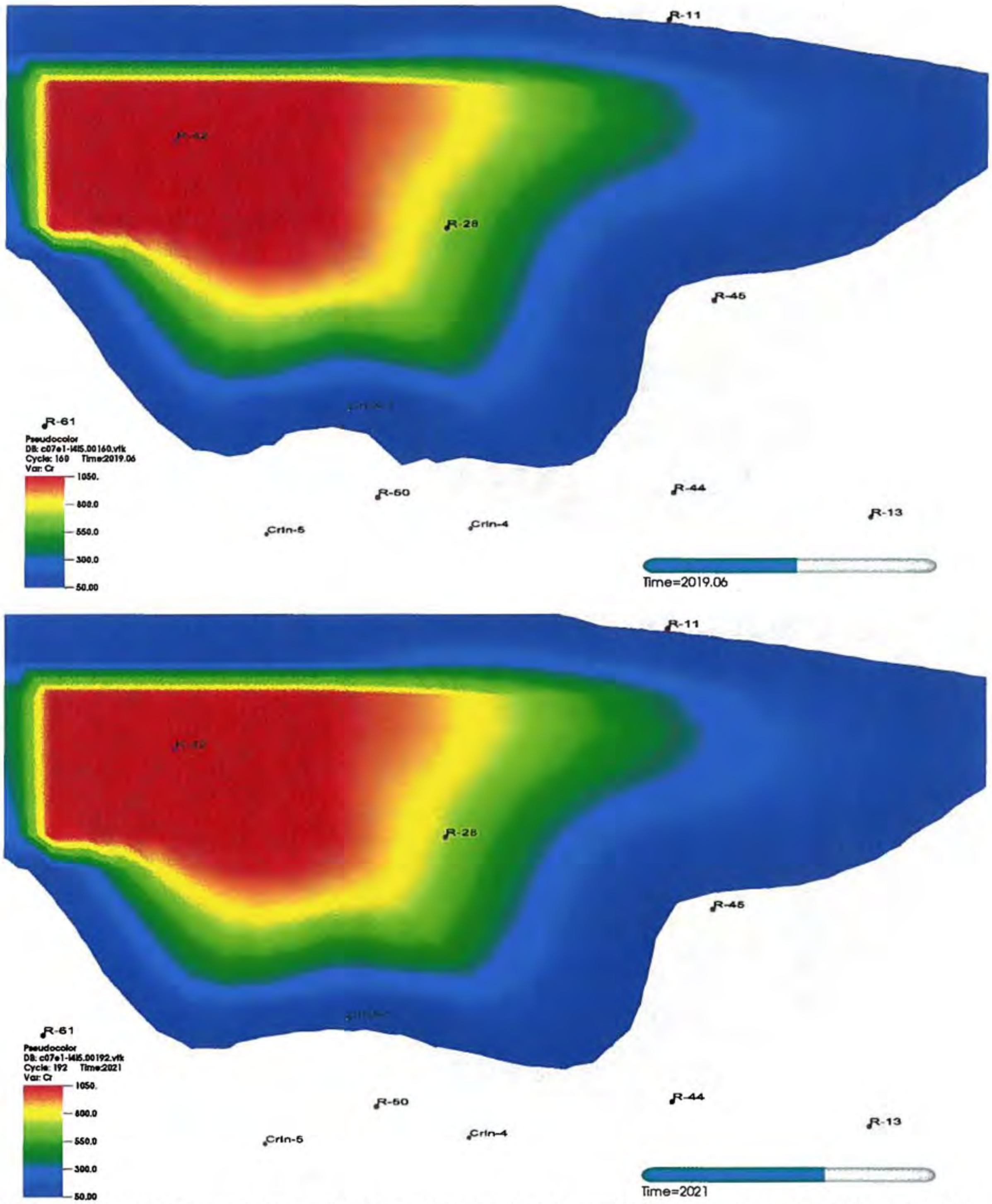
Notes: The model predictions are based on the 2012 model (Phase II Sandia Investigation Report [LANL 2012, 228624]). The results are preliminary and still a work in progress.

Figure A-8.0-1 Model predictions of the chromium concentrations at 2016 and 2021 without active pumping and injection



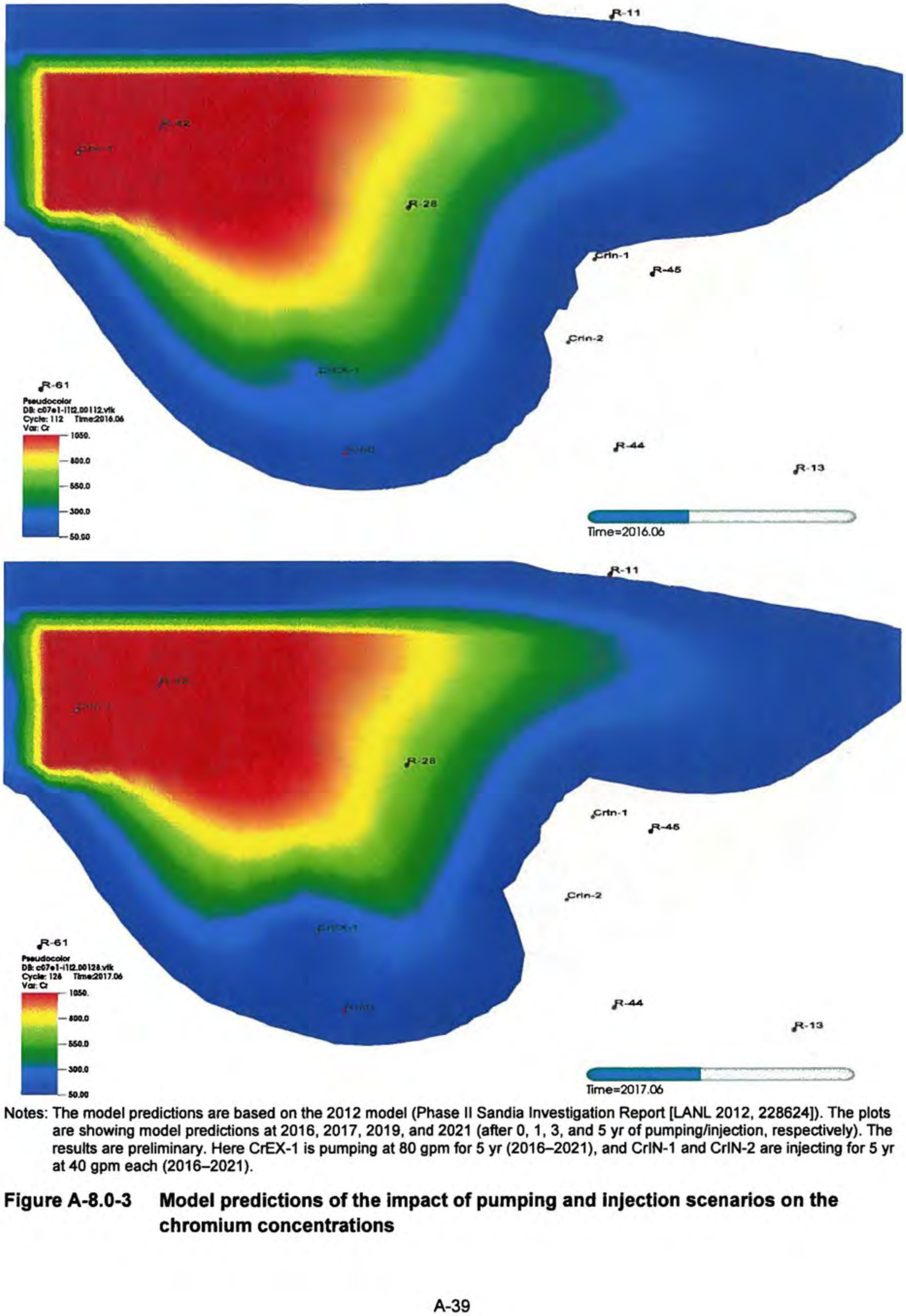
Notes: The model predictions are based on the 2012 model (Phase II Sandia Investigation Report [LANL 2012, 228624]). The plots show model predictions for 2016, 2017, 2019, and 2021 (after 0, 1, 3, and 5 yr of pumping/injection, respectively). The results are preliminary. Here CrEX-1 is pumping at 80 gpm for 5 yr (2016–2021), and CrIN-4 and CrIN-5 are injecting for 5 yr at 40 gpm each (2016–2021).

Figure A-8.0-2 Model predictions of the impact of pumping and injection scenarios on the chromium concentrations



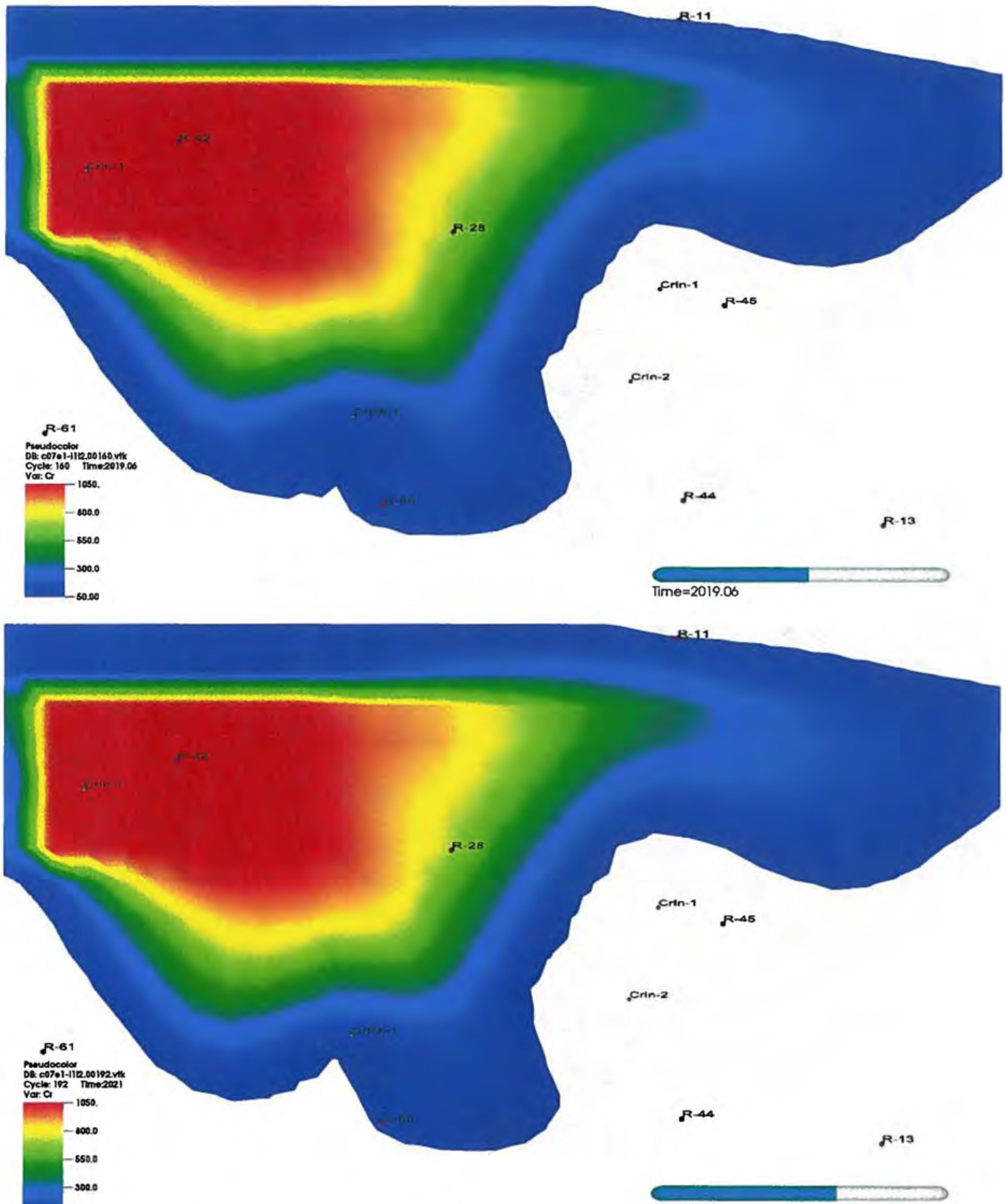
Notes: The model predictions are based on the 2012 model (Phase II Sandia Investigation Report [LANL 2012, 228624]). The plots are showing model predictions for 2016, 2017, 2019, and 2021 (after 0, 1, 3, and 5 yr of pumping/injection, respectively). The results are preliminary. Here CrEX-1 is pumping at 80 gpm for 5 yr (2016–2021), and CrIN-4 and CrIN-5 are injecting for 5 yr at 40 gpm each (2016–2021).

Figure A-8.0-2 (continued) Model predictions of the impact of pumping and injection scenarios on the chromium concentrations



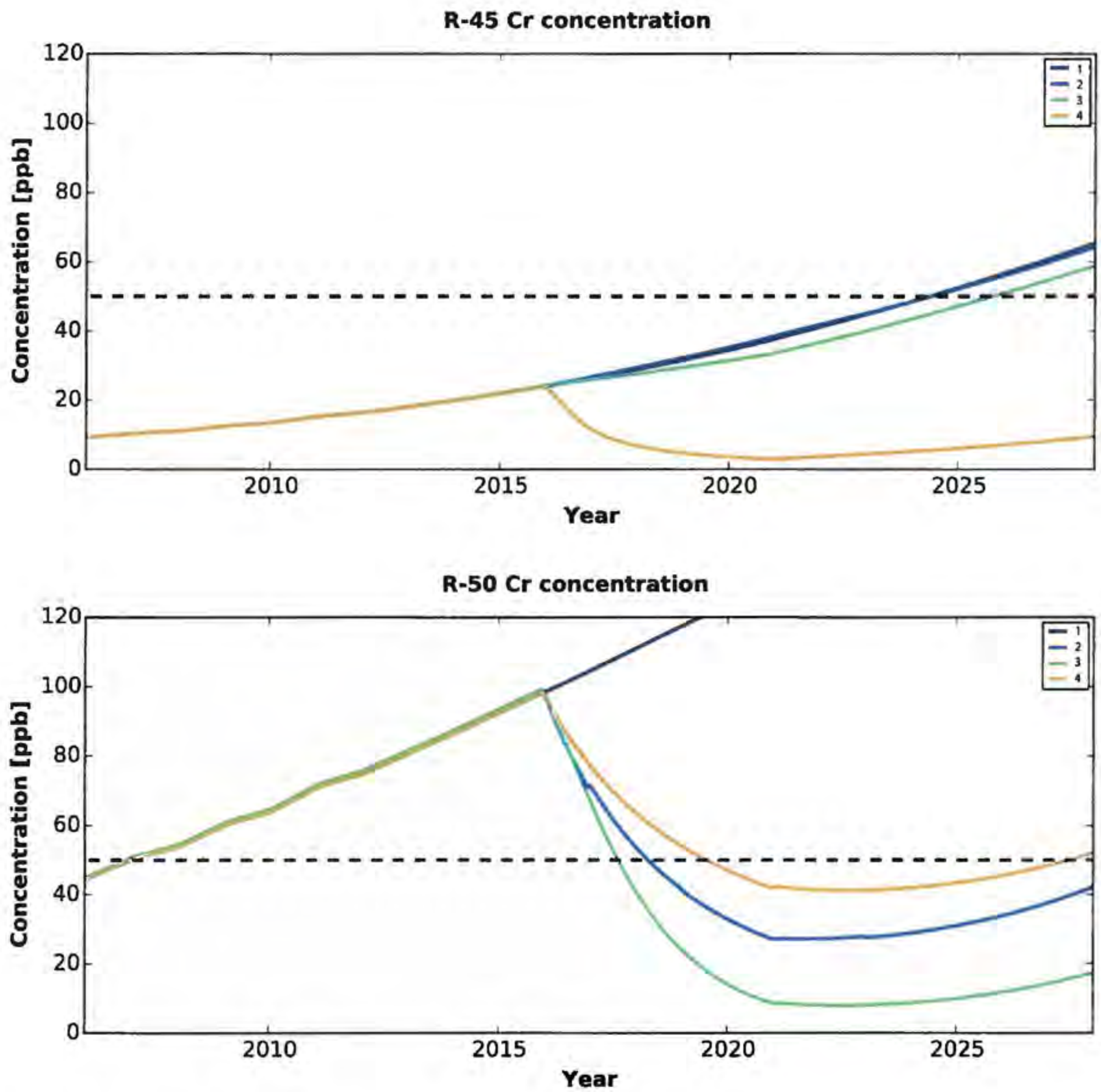
Notes: The model predictions are based on the 2012 model (Phase II Sandia Investigation Report [LANL 2012, 228624]). The plots are showing model predictions at 2016, 2017, 2019, and 2021 (after 0, 1, 3, and 5 yr of pumping/injection, respectively). The results are preliminary. Here CrEX-1 is pumping at 80 gpm for 5 yr (2016–2021), and CrIN-1 and CrIN-2 are injecting for 5 yr at 40 gpm each (2016–2021).

Figure A-8.0-3 Model predictions of the impact of pumping and injection scenarios on the chromium concentrations



Notes: The model predictions are based on the 2012 model (Phase II Sandia Investigation Report [LANL 2012, 228624]). The plots are showing model predictions at 2016, 2017, 2019, and 2021 (after 0, 1, 3, and 5 yr of pumping/injection, respectively). The results are preliminary. Here CrEX-1 is pumping at 80 gpm for 5 yr (2016–2021), and CrIN-1 and CrIN-2 are injecting for 5 yr at 40 gpm each (2016–2021).

Figure A-8.0-3 (continued) Model predictions of the impact of pumping and injection scenarios on the chromium concentrations



Notes: The dashed line represents 50 ppb chromium concentration. R-45 concentrations are substantially impacted only by the CrIN-3/CrIN-4 injection (see section A-8.0, scenario 4). R-50 concentrations are impacted in all pumping/injection scenarios but the highest impact is when CrIN-1 and CrIN-2 are injecting (scenario 4).

Figure A-8.0-4 Model predicted chromium concentration curves for R-45 screen 1 and R-50 screen 1 under different scenarios: (1) no action; (2) CrEX-1 pumping only; (3) CrEX-1 pumping and CrIN-4/CrIN-5 injecting; and (4) CrEX-1 pumping and CrIN-1/CrIN-2 injecting

Table A-4.0-1
Summary of the Estimated Effective Aquifer Properties between the Pumping (CrEX-1) and Observation Wells during 2014 CrEX-1 Pumping Test

Screen	Transmissivity (m^2/day)	Storativity (–)	Max drawdown (m)	Comment
CrCH-1	1700	0.06	0.06	Very limited pressure record
R-1	na*	na	>0.01	Difficult to analyze; small drawdown (?)
R-11	750	0.07	0.057	None
R-13	820	0.06	0.056	None
R-15	na	na	na	Potential transducer problems
R-28	na	na	na	Data gaps; difficult to analyze
R-33 #1	na	na	0.023	Difficult to analyze; small drawdown (?)
R-33 #2	na	na	na	Difficult to analyze small drawdown (?)
R-35a	na	na	na	Difficult to analyze; small drawdown (?)
R-35b	na	na	0.022	Difficult to analyze small drawdown (?)
R-36	na	na	na	Difficult to analyze; no drawdown (?)
R-42	820	0.06	0.092	Data gaps; difficult to analyze
R-43 #1	na	na	>0.01	Difficult to analyze; small drawdown (?)
R-43 #2	3100	0.03	0.039	None
R-44 #1	540	0.1	0.089	None
R-44 #2	680	0.06	0.097	None
R-45 #1	780	0.09	0.069	None
R-45 #2	5200	0.007	0.045	None
R-50 #1	540	0.2	0.2	None
R-50 #2	1000	0.01	0.26	None
R-61 #1	1200	0.1	0.06	None
R-61 #2	850	0.1	0.069	None
R-62	4900	0.007	0.034	Data gaps; difficult to analyze

*na = Not available.

LA-UR-15-24861
July 2015
EP2015-0127

Work Plan for Chromium Plume Center Characterization

Los Alamos
NATIONAL LABORATORY
EST 1943

Prepared by the Environmental Programs Directorate

EP2015-0127

Work Plan for Chromium Plume Center Characterization

July 2015

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CONTENTS

Figures

1.0 INTRODUCTION

This work plan for chromium plume center characterization describes proposed activities to be conducted by Los Alamos National Laboratory (LANL or the Laboratory) to further investigate the aquifer in the area of highest known concentrations (center) of the chromium plume and to further characterize the nature and extent of chromium (and related) contamination (Figure 1.0-1). Results from the plume center characterization work will be included in a corrective measures evaluation report.

The work presented in this plan follows from the "Interim Measures Work Plan for the Evaluation of Chromium Mass Removal," submitted to the New Mexico Environment Department (NMED) in April 2013 (LANL 2013, 241096). That work plan was prepared in response to requirements in a letter from NMED dated January 25, 2013 (NMED 2013, 521862), which directed the Laboratory to prepare an interim measures work plan to assess the potential for active long-term removal of chromium from the regional aquifer via pumping with a pilot extraction test well. The "Interim Measures Work Plan for Chromium Plume Control" (LANL 2015, 600458) that proposed hydraulic control to address plume migration was submitted to NMED in May 2015. This work plan supplements that document and the NMED's requirements by proposing an investigation of the potential for active long-term removal of chromium from the regional aquifer. Some of the investigations proposed in this work plan follow from the scope and objectives proposed in the "Drilling Work Plan for Chromium Project Coreholes" (LANL 2014, 259151).

Investigations and conceptual models related to chromium contamination are summarized in a number of reports, including the "Investigation Report for Sandia Canyon" (LANL 2009, 107453) and the "Phase II Investigation Report for Sandia Canyon" (LANL 2012, 228624).

Additional information presented in the "Summary Report for the 2013 Chromium Groundwater Aquifer Tests at R-42, R-28, and SCI-2" (LANL 2014, 255110) inform the technical recommendations in this report. Figure 1.0-1 shows the current extent of the plume defined by the 50 ppb New Mexico groundwater standard.

2.0 OBJECTIVES

The scope of this work plan addresses four objectives.

The first objective is to investigate the feasibility of chromium source removal from the center of the plume (as defined as the portion of the plume with the highest chromium concentrations). It is apparent from previous aquifer tests in groundwater monitoring wells R-28 and R-42 that chromium mass can be readily removed from the centroid even at relatively low pumping rates (R-42 was pumped at 8 gallons per minute [gpm]; R-28 was pumped at approximately 28 gpm) (Figure 2.0-1). However, chromium concentrations decreased substantially and rapidly during the several-week pumping period at both wells (Figure 2.0-2). This investigation proposes (1) to further evaluate the potential for optimizing chromium mass removal, (2) to determine the geochemical transients during pumping and recovery, (3) to investigate the potential for decline in chromium concentrations during pumping and rebound after pumping stops, and (4) to assess what optimal well configuration, well design, and operational mode are required for mass removal within the aquifer as one or more components of a final remedy for the plume.

A second objective is to further characterize key attributes of the aquifer, including heterogeneity and dual porosity principally for the purpose of evaluating potential in situ remedial strategies for the plume. This objective will be addressed with (1) aquifer dilution-tracer tests, and (2) field-scale cross-hole tracer tests, and (3) field-scale deployment of a pilot field test to evaluate potential in situ remediation approaches.

The data from these studies will be used to refine the groundwater models of aquifer flow and contaminant transport properties (heterogeneity, dual porosity, etc.) and associated uncertainties related to possible remediation approaches.

A third objective is to study the hydrologic and geochemical conditions that may occur within and adjacent to proposed injection wells as discussed in the "Interim Measures Work Plan for Chromium Plume Control" (LANL 2015, 600458). This objective will be addressed with field studies to evaluate the hydrogeologic and geochemical conditions that may evolve within and around injection points and that may adversely impact injection efficiency. These data will help optimize approaches to routine or required maintenance of injection wells.

A fourth objective is to characterize the infiltration beneath the shallow alluvial groundwater in Sandia Canyon. Based on the current conceptual model most of the historical and present-day infiltration occurs within that zone (LANL 2012, 228624). This objective will be addressed by installing and monitoring a series of piezometers within the primary infiltration area in Sandia Canyon.

3.0 INVESTIGATION APPROACH

3.1 Investigation of Source Removal

A location for an extraction well, CrEX-3, is proposed to investigate the potential for optimizing removal of chromium from the plume center (Figure 1.0-1). The location, south of R-28, is within a zone of expected high hydraulic conductivity that appears to be relatively continuous from R-11 southward towards CrEX-1 and possibly the deeper zone monitored by R-50, screen 2. The initial design for CrEX-3 consists of an 8-in. casing diameter with a 40-slot screen placed within 35–40 ft of the water table. Data from sampling conducted during sonic drilling in CrCH-2 and from piezometers CrPZ-2a and CrPZ-2b installed within the CrCH-2 corehole (LANL 2015, 600457) indicate contamination in the R-28 area is primarily within an interval zone approximately 30 ft below the aquifer water table (Figure 3.1-1). Thus, the extraction well is proposed to be screened in that same zone near the water table to optimize removal of the contaminant source. The decreases in chromium concentrations and subsequent rebound observed in R-28 during the 87-d pumping test may indicate that under ambient flow or routine sampling conditions (e.g., pumping of only approximately 3 casing volumes), R-28 predominantly receives groundwater flow from the upper portion of its screen and filter pack where the contaminant concentration is highest (Figure 3.1-1). But during extended pumping, the proportion of water entering the well from the less contaminated deeper zone increases, resulting in progressively decreasing concentrations in R-28 (Figure 2.0-2b). Therefore, the CrEX-3 screen is proposed to target that upper zone.

Hydraulic testing conducted for 87 d at R-28 propagated a zone of influence that extended upgradient into the highest known areas of contamination near R-42 but did not result in a significant pressure response at R-42 (Figure 3.1-2) (LANL 2014, 255110). This might be because of (1) a hydraulic boundary (e.g., stratification or channeling) that may exist between the wells or (2) active infiltration recharge near R-42 that may dampen the drawdown impacts (LANL 2014, 255110). Figure 3.1-3 is a cross-section line between R-62 and R-45 that shows the water table and plume span the contact between the overlying Puye Formation (Tpf) and underlying Miocene Pumiceous unit (Tjfp). This contact may be a factor in the potential boundary effects apparent between the R-28 area and R-42.

Continuous pumping at CrEX-3 for extended periods of time will provide key information about the heterogeneity of the aquifer in the plume center and the nature and orientation of a well-established capture zone. All monitoring wells in the chromium monitoring group and newly installed piezometers will have continuous pressure monitoring to evaluate the capture zone established by pumping at CrEX-3.

Additionally, samples will be collected periodically to analyze key plume constituents including chromium, nitrate, sulfate, and tritium to evaluate potential transients in the data. Pumping will likely begin at maximum rates achievable at CrEX-3 and will be reduced incrementally if chromium concentrations begin to decline significantly. The overall goal is to find the operational approach that achieves the greatest mass per gallon removed. Testing that was conducted at R-28 and R-42 showed that because of the higher hydraulic conductivities present in the R-28 area, greater overall mass removal was possible in the R-28 area even though concentrations are approximately half of what they are at R-42. In addition, if the capture zone can be established in the areas of the plume with the highest concentrations, the CrEX-3 location may be very efficient for capturing groundwater from the center portion of the plume with the highest known concentrations.

3.2 Aquifer Characterization and Evaluation of Potential Remediation Approaches

Aquifer (dilution) tracer tests and a field cross-hole tracer study are proposed to provide data to guide potential future field investigations that would support the development of remedial alternatives. Dilution tracer (aquifer) tests will be conducted at newly installed piezometers CrPZ-2a, CrPZ-2b, CrPZ-3, and at R-50 before pumping starts at CrEX-1. An additional dilution tracer test will then be conducted at R-50 late in the pumping period at CrEX-1 to evaluate the influence of CrEX-1 pumping on flow rates in the R-50 area. These data will be compared with flow-rate estimates derived from long-term pumping data from CrEX-1.

For the cross-hole test, piezometers CrPZ-3, CrPZ-2a, and CrPZ-2b will be used to deploy paired conservative tracers with different diffusion coefficients to enhance the potential for seeing different breakthrough behaviors that will be indicative of dual porosity in the aquifer. This information, in conjunction with transient contaminant data from pumping at CrEX-1 and CrEX-3, will be helpful for characterizing the spatial distribution of chromium (and related contaminants) in the aquifer.

The tracers will be monitored at R-42 for tracers used at CrPZ-3 and at R-28, CrEX-3, and CrEX-1 for tracers introduced at the CrPZ-2a and CrPZ-2b. The initial tracer mass that will be introduced will be determined to enhance the probability of detection in nearby downgradient wells. Active pumping at CrEX-3, and possibly CrEX-1, is expected to reduce the travel times between the introduction points and the monitored wells. Specific details of the dilution and cross-hole tracer tests are included in a notice of intent (NOI) to the NMED Groundwater Quality Bureau (GWQB).

After the hydrologic information from the cross-hole tracer tests is available, the Laboratory proposes to conduct an in situ field pilot treatability test. In situ approaches generally involve the use of amendments directly within the aquifer either to favorably alter the geochemistry of the contaminants or to enhance naturally occurring biological processes that favorably alter groundwater contaminants. The specific approach will be proposed at a later date after the cross-hole and bench-scale treatability data are available.

3.3 Injection-Well Study

A study will be conducted to investigate potential hydrologic and/or geochemical conditions that may develop in and surrounding an injection well used for dispositioning treated groundwater pumped from CrEX-3 and from CrEX-1 under the "Interim Measures Work Plan for Chromium Plume Control" (LANL 2015, 600458).

The approach will involve using column experiments at either CrEX-1 or CrEX-3. Treated water will be continuously injected into columns packed with aquifer sediments obtained from the sonic corehole drilling campaign or from other representative regional aquifer materials (Figure 3.3-1). Permeability and geochemistry will be measured from column effluent to gather data that may be useful for trouble-shooting and maintenance of operational injection wells. Two duplicate sequential column flow systems will be set up in the field near a treated water source to use as the feed to the columns. The first column in each duplicate sequence will be 2-in. in diameter and 1-ft long and will be packed with typical well filter-pack material. A second column in each sequence will be 5-in. in diameter and 5-ft long and will be packed with representative aquifer materials. Opaque columns and flow tubing will be used to avoid algae growth within the columns. For the 2-in.-diameter column, this flow will result in an entrance velocity of about 3 cm/min across the full cross-section of the column. This entrance velocity is equivalent to what would be observed across a 60-ft-long screen in a 10-in.-diameter casing flowing at 115 gpm (with uniform flow across the entire screen). The actual linear velocity within the column will be about 6 cm/min if the porosity is 50% and 12 cm/min if the porosity is 25%. Velocities are directly proportional to gallons per minute and inversely proportional to both screen length and diameter. For the 5-in.-diameter column, the linear entrance flow velocity will be about 0.5 cm/min, which translates to a 1 cm/min linear velocity in a 50% porosity column and 2 cm/min in a 25% porosity column. The two columns will approximate the linear flow rates expected in the filter pack (first column) and in the formation near the well bore (second column) of an injection well, although true radial flow will not be approximated. The mean water residence times in the two columns, assuming a 30% porosity, is as follows: in the 2-in.–inside diameter (I.D.) column approximately 3 min, and in the 5-in.-I.D. column approximately 100 min. The goal will be to keep the flow rates as continuous and constant as possible for a long period of time and monitor (1) pressure increases across the columns and (2) geochemical and biogeochemical changes in the water exiting each of the columns as a function of time. The system will be monitored for potential problems, such as a significant permeability decrease or plugging, and will attempt to determine the cause and remedies for these problems (either physical, geochemical, or both).

3.4 Characterization of Infiltration beneath Lower Sandia Canyon

A series of new alluvial piezometers are proposed for installation in a section of lower Sandia Canyon where it is believed that the majority of historical and present-day infiltration occurs. Some information on infiltration (i.e., seepage velocities) is available from piezometer studies presented in the "Sandia Canyon Investigation Report" (LANL 2009, 107453). The overall objective of the piezometer configuration will be to evaluate the integrated area of infiltration over the portion of the canyon highlighted in Figure 3.4-1. The specific design of the new piezometer array will be proposed in a separate work plan, but the general approach will be to obtain pressure data at varying depths throughout the saturated portion of the alluvium shown in Figure 3.4-1. Pressure data will be used to refine the current hydrologic model for infiltration of effluent and other surface water sources in Sandia Canyon. The data will also be used to establish a baseline to compare with potential future changes that may occur either because of operational changes in effluent volumes or future remediation strategies that may include discharge of treated groundwater to Sandia Canyon above the infiltration zone monitored by the piezometers. The estimated maximum depth for the piezometers will be approximately 40 ft, so drilling will probably be accomplished with auger drilling or by drive-points.

3.5 Treatment System Description

Groundwater extracted from the plume-center pumping well will be treated near the well and injected in the same injection wells used for the "Interim Measures Work Plan for Chromium Plume Control" (LANL 2015, 600458). The overall pumping, treatment, and injection system will consist of CrEX-1, CrEX-3, a treatment system, and ultimately of six injection wells (Figure 1.0-1). This system and the operational mode are subject to approval by NMED-GWQB. Once fully operational, the system will run continuously with pumped groundwater treated at the surface and delivered to injection wells via piping. The treatment unit is likely to be sited at each extraction location to minimize the distance contaminated groundwater is conveyed via piping. Two ion-exchange vessels will operate in series to treat groundwater extracted from CrEX-3 (and CrEX-1, which may be operating at the same time and will have its own treatment system). The first vessel removes up to 99% of the chromium (and nitrate), and the second vessel is used for redundancy and polishing. Water quality in the treatment stream will be monitored in accordance with an NMED-approved discharge permit to ensure water land-applied or dispositioned via reinjection will meet the criteria set forth in the permit(s).

When the injection wells are operational, computerized systems will be in place to monitor injection rates into the wells to ensure that systems are operating as designed. The flow rate of injected water will be monitored, and pressure at each injection well will be maintained at a design level. Water levels in all injection wells will be monitored by a control system with system shutdown mechanisms in place. Each injection well will also be equipped with a submersible pump to allow each well to be periodically back-flushed for maintenance. The approved discharge permit will also include contingencies for failures in any part of the treatment and discharge system. In the absence of an injection-well permit, treated water will be land-applied in accordance with a separate discharge permit and the system will operate at a lesser removal volume because of limitations in land application.

4.0 SCHEDULE

Implementation of this work scope, namely the installation of CrEX-3, depends on finalizing the National Environmental Policy Act (NEPA) Environmental Assessment (EA). The NEPA EA is currently expected to be completed in the fall of 2015. Following the installation of CrEX-3, near-term pumping will still depend on the Laboratory's receiving a discharge permit or temporary permission from NMED for land application of treated water and a Change in Point of Diversion permit for well pumping from the New Mexico Office of the State Engineer (NMOSE). NMED received comments on the Laboratory's permit application for the land-application discharge permit (DP-1793) during the second public notice period. A final draft of the permit was issued by NMED on May 28, 2015, but a second request for public hearing was submitted to the NMED on June 15, 2015 by Citizens for Clean Water (CCW 2015, 600514). A permit application to use the injection wells was submitted to the NMED-GWQB on April 9, 2015. An additional permit is required from NMOSE to allow pumping from CrEX-3 and CrEX-1. The Laboratory's goal is to have injection wells in place and permitted in 2016 to enable pumping and injection of water from CrEX-3 and CrEX-1 (LANL 2015, 600458).

Activities related to characterization of the sonic core material are underway. The field tracer studies and the injection well study also depend on the Laboratory's receiving permits with the NMED-GWQB, but it is expected that the field activities will be closely integrated with pumping schedules to optimize data collection.

5.0 MANAGEMENT OF INVESTIGATION-DERIVED WASTE

Investigation-derived waste will be managed in accordance with EP-DIR-SOP-10021, Characterization and Management of Environmental Programs Waste. This standard operating procedure incorporates the requirements of applicable U.S. Environmental Protection Agency and NMED regulations, U.S. Department of Energy orders, and Laboratory requirements. The primary waste streams include development water, drill cuttings, drilling fluid, decontamination fluids, and contact waste.

6.0 REFERENCES

The following list includes all documents cited in this plan. Parenthetical information following each reference provides the author(s), publication date, and ER ID 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.

CCW (Communities for Clean Water), June 15, 2015. "CCW Comments about May 28, 2015 draft DP-1793 for Los Alamos National Laboratory Groundwater Projects," Communities for Clean Water letter to S. Huddleson (NMED-GWQB) from J. Arends, K. Sanchez, B. Tsosie-Peña, M. Naranjo, R. Conn, J. Brown, and M. Perrotte, Santa Fe, New Mexico. (CCW 2015, 600514)

LANL (Los Alamos National Laboratory), October 2009. "Investigation Report for Sandia Canyon," Los Alamos National Laboratory document LA-UR-09-6450, Los Alamos, New Mexico. (LANL 2009, 107453)

LANL (Los Alamos National Laboratory), September 2012. "Phase II Investigation Report for Sandia Canyon," Los Alamos National Laboratory document LA-UR-12-24593, Los Alamos, New Mexico. (LANL 2012, 228624)

LANL (Los Alamos National Laboratory), April 2013. "Interim Measures Work Plan for the Evaluation of Chromium Mass Removal," Los Alamos National Laboratory document LA-UR-13-22534, Los Alamos, New Mexico. (LANL 2013, 241096)

LANL (Los Alamos National Laboratory), March 2014. "Summary Report for the 2013 Chromium Groundwater Aquifer Tests at R-42, R-28, and SCI-2," Los Alamos National Laboratory document LA-UR-14-21642, Los Alamos, New Mexico. (LANL 2014, 255110)

LANL (Los Alamos National Laboratory), July 2014. "Drilling Work Plan for Chromium Project Coreholes," Los Alamos National Laboratory document LA-UR-14-24829, Los Alamos, New Mexico. (LANL 2014, 259151)

LANL (Los Alamos National Laboratory), May 2015. "Interim Measures Work Plan for Chromium Plume Control," Los Alamos National Laboratory document LA-UR-15-23126, Los Alamos, New Mexico. (LANL 2015, 600458)

LANL (Los Alamos National Laboratory), May 2015. "Completion Report for Chromium Project Coreholes 1 through 5," Los Alamos National Laboratory document LA-UR-15-23197, Los Alamos, New Mexico. (LANL 2015, 600457)

NMED (New Mexico Environment Department), January 25, 2013. "Response, Proposal to Submit Interim Measures Work Plan for Chromium Contamination in Groundwater," 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 2013, 521862)

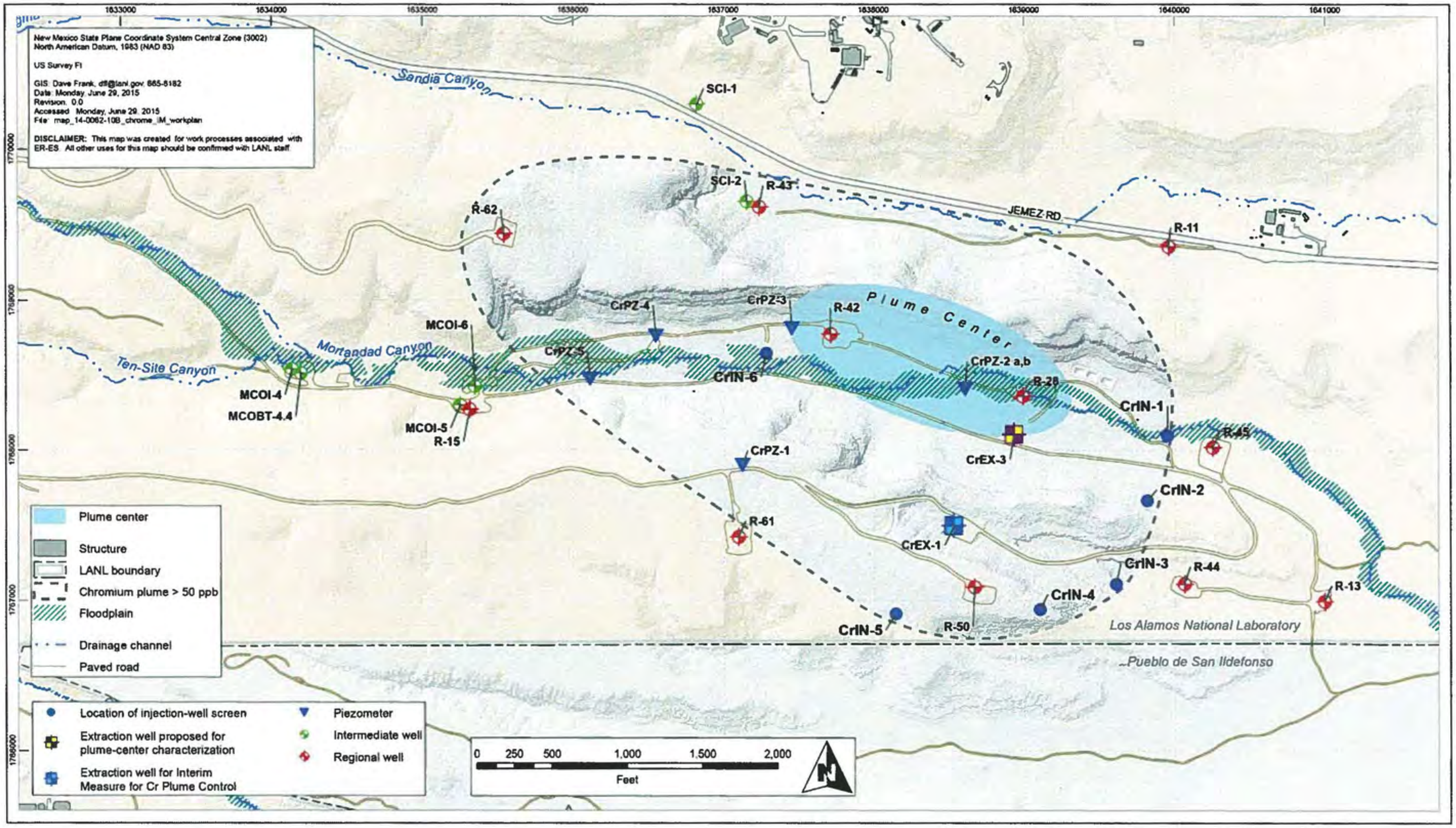
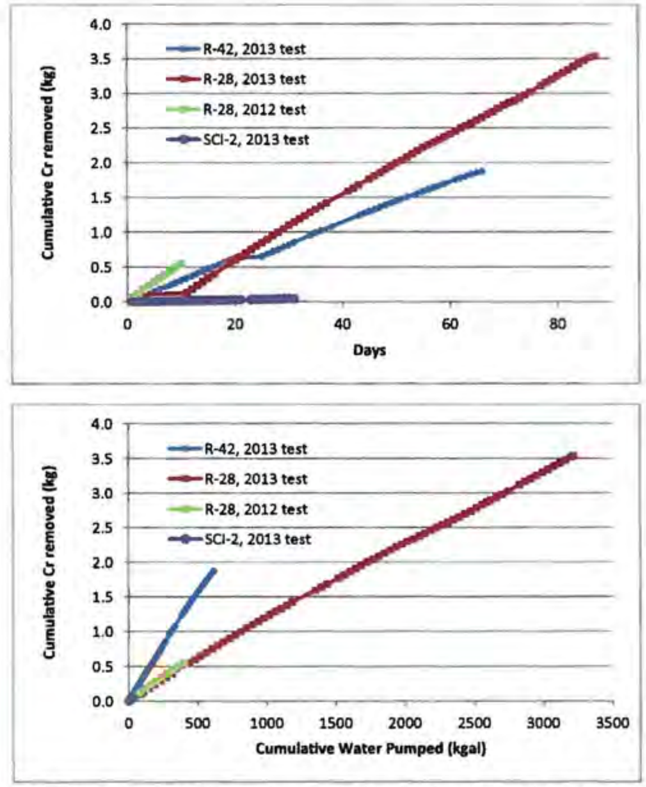


Figure 1.0-1 Current extent of the chromium plume and proposed location of the extraction well for plume center characterization



Notes: The top graph shows chromium mass removal as a function of days of pumping. The bottom graph shows chromium mass removal as a function of gallons pumped.

Figure 2.0-1 Cumulative chromium removal during 2014 pumping at R-28, R-42, and SCI-2

Chronology of pumping and rebound				
Well	Pumping	Pump failure	Rebound	Average Discharge Rate
R-42	6/18 - 7/6/13, 7/12 - 8/21/13	7/7 - 7/11/13	8/22 - 12/5/13	7 gpm*

*gpm = gallons per minute

pumping
recovery

a. R-42 time series plot for chromium and water level during pumping and rebound sampling.

Chronology of pumping and rebound				
Well	Pumping	Pump failure	Rebound	Average Discharge Rate
R-28	• 8/28 - 8/30/13 (pump set in shroud in sump below screen) • 9/7-11/6 (pump removed from shroud and reset above screen) • 11/7-11/22/13	• 8/30 - 9/7/13 • 11/6 (1730 hrs) - 11/7/13 (0700 hrs) generator tripped	11/22/13 - 3/4/14	28.9 gpm*

*gpm = gallons per minute

pumping
recovery

b. R-28 time series plot for chromium and water level during pumping and rebound sampling.

Note: The first graph shows R-42; the second graph shows R-28.

Figure 2.0-2 Graphs showing transient concentrations of chromium during extended pumping periods and during recovery (nonpumping) period

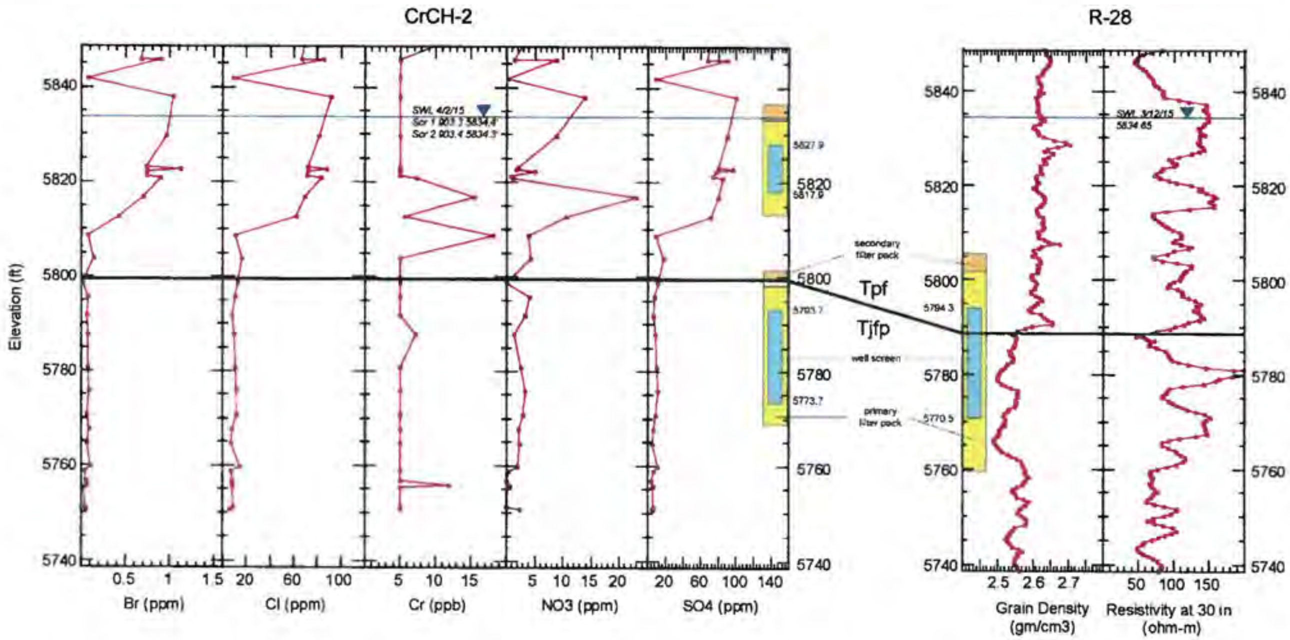
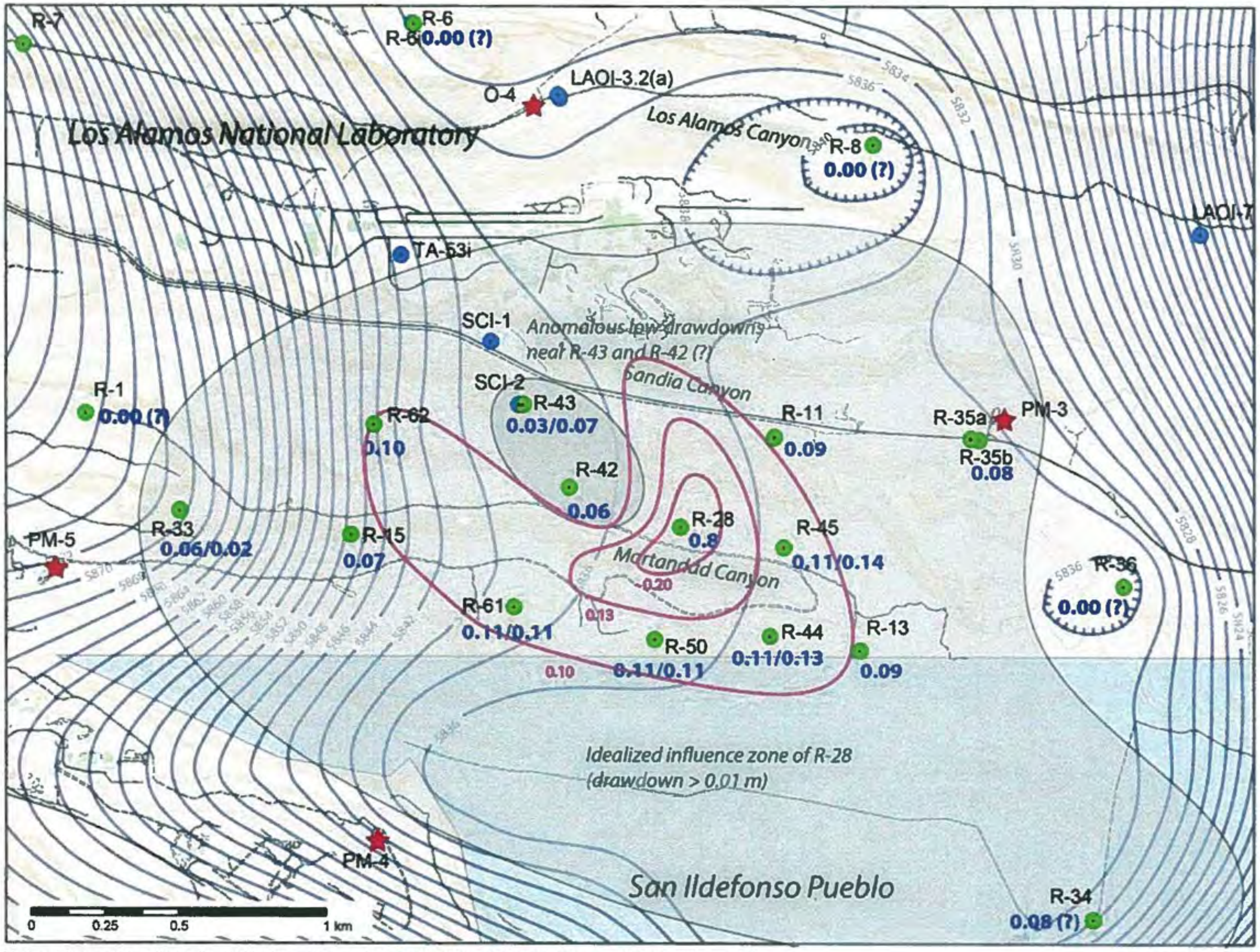


Figure 3.1-1 Concentration profile for representative constituents in CrCH-2 and relation to nearby R-28



Note: The contour lines (in pink) show the spatial distribution of the R-28 cone of depression (ZOI).

Figure 3.1-2 Spatial distribution of the pumping drawdowns in meters at the end of the R-28 aquifer test (shown in blue text)

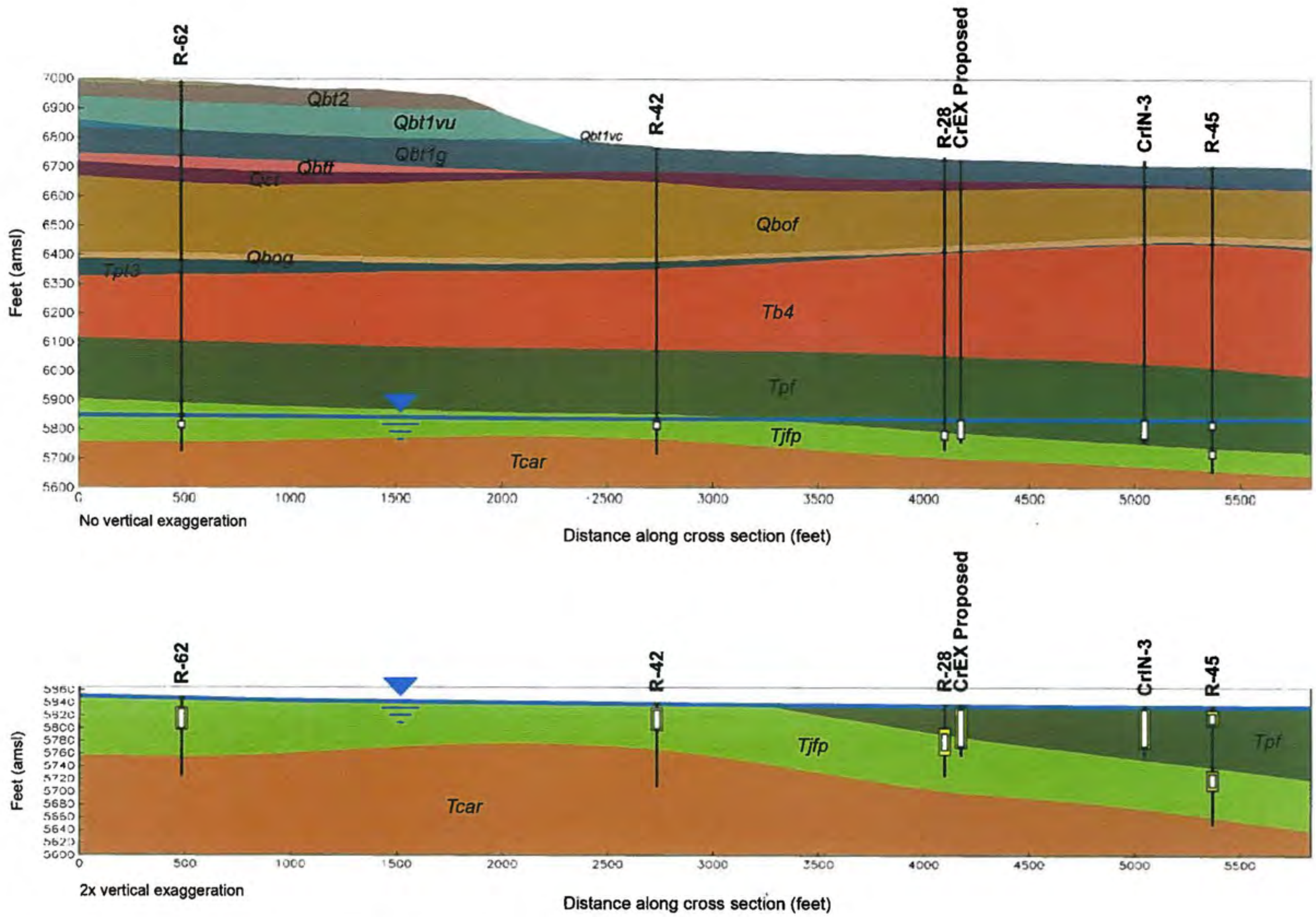


Figure 3.1-3 Cross-section line between R-62 and R-45

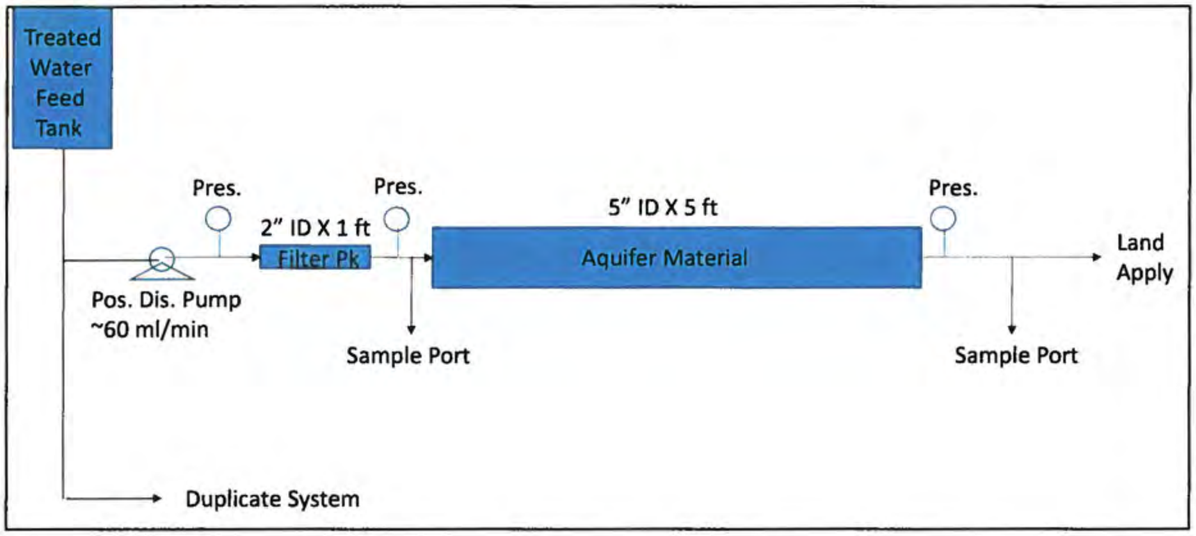


Figure 3.3-1 Conceptual design for injection well column study

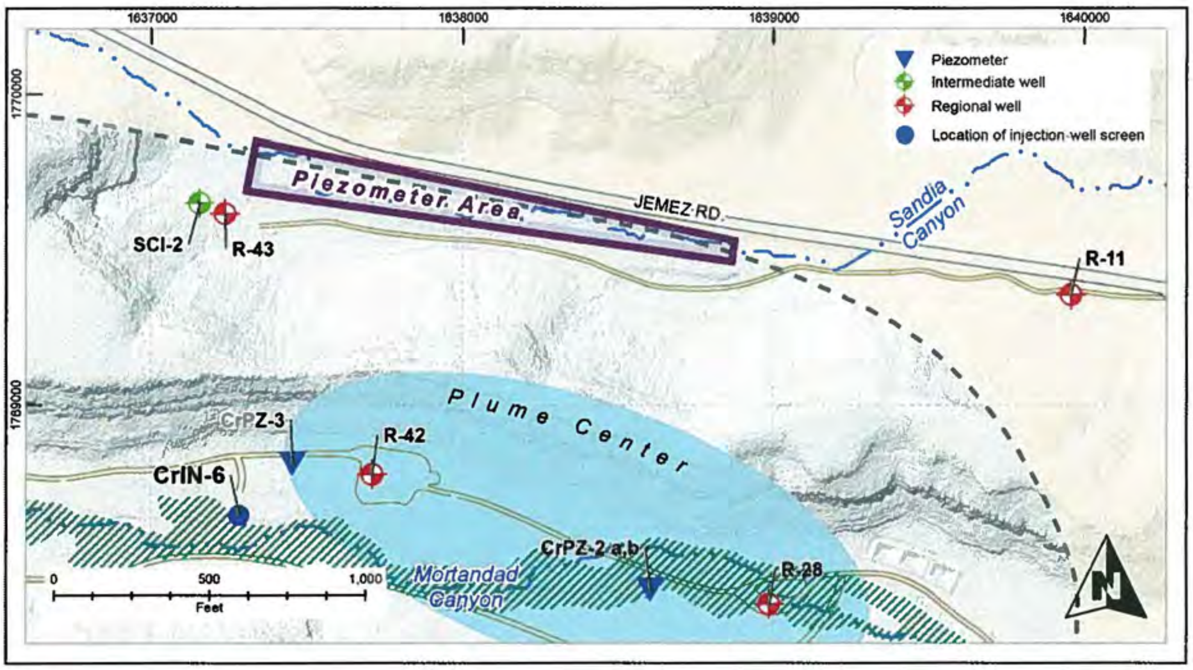


Figure 3.4-1 General location for shallow alluvial piezometer nests in lower Sandia Canyon

ENCLOSURE 3

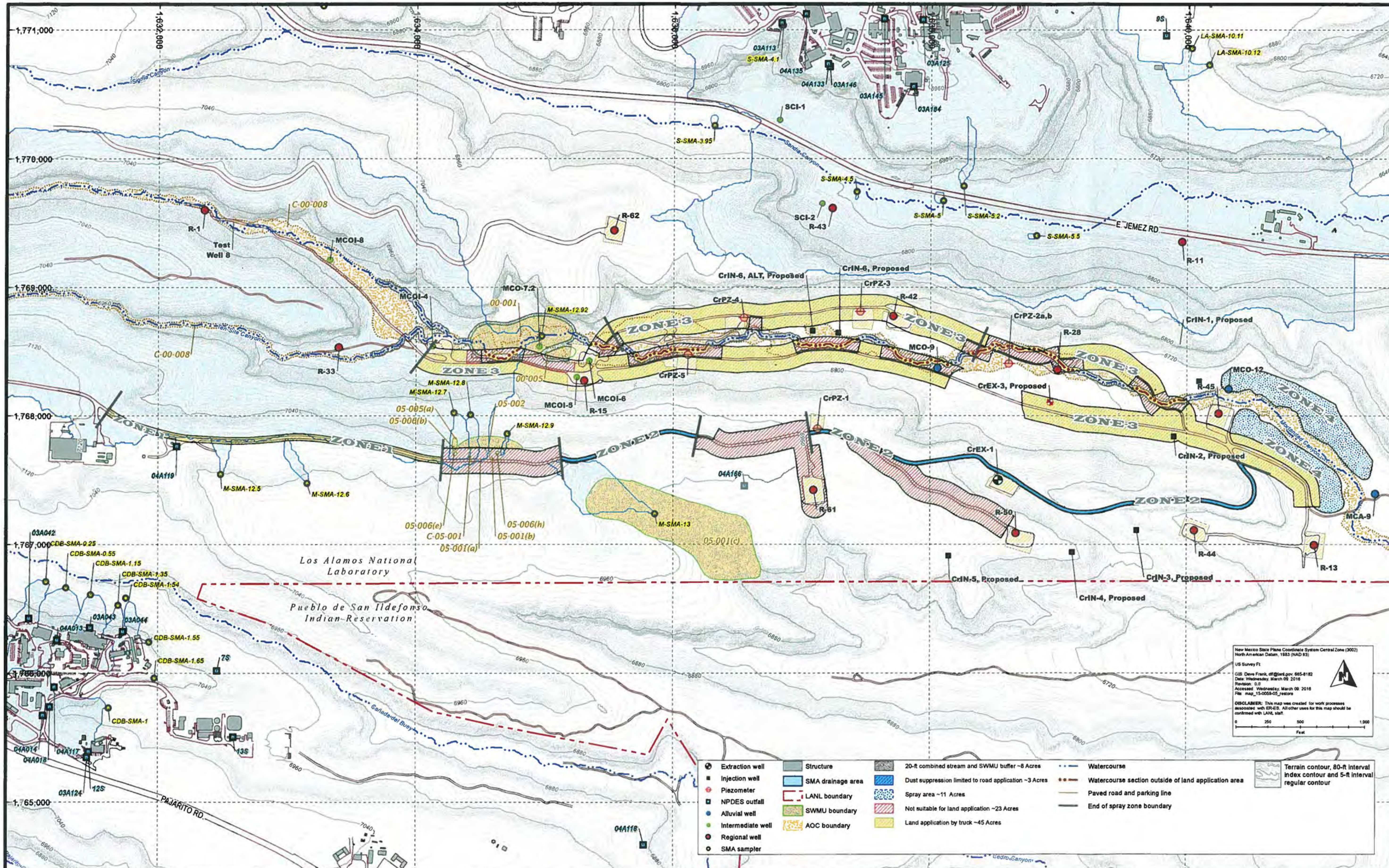
Topographic Map of the Project Site

EPC-DO-16-063

LA-UR-16-21509

U1501760

Date: MAR 2 2 2016


ZONE 1
ZONE 2
ZONE 3
ZONE 4
E JEMEZ RD
PAJARITO RD.
Los Alamos National Laboratory
Pueblo de San Ildefonso Indian Reservation
Sandia Canyon
Sigma Canyon
Cañada del Buey
Cedro Canyon
R-1
Test Well 8
C-00-008
MCOI-8
MCOI-4
MCO-7.2
M-SMA-12.92
00-001
00-005
R-33
R-62
R-15
MCOI-5
MCOI-6
M-SMA-12.8
M-SMA-12.7
05-005(a)
05-006(b)
05-002
M-SMA-12.9
M-SMA-12.5
M-SMA-12.6
04A119
05-006(e)
C-05-001
05-001(a)
05-006(h)
05-001(b)
M-SMA-13
05-001(c)
04A166
CrPZ-1
CrPZ-4
CrPZ-3
CrPZ-5
CrIN-6, ALT, Proposed
CrIN-6, Proposed
R-42
CrPZ-2a,b
R-28
MCO-9
CrEX-3, Proposed
CrEX-1
R-61
R-50
CrIN-1, Proposed
R-45
MCO-12
CrIN-2, Proposed
MCA-9
R-44
R-13
CrIN-5, Proposed
CrIN-3, Proposed
CrIN-4, Proposed
R-11
SCI-1
SCI-2
R-43
S-SMA-3.95
S-SMA-4.1
S-SMA-4.5
S-SMA-5
S-SMA-5.2
S-SMA-5.5
03A113
04A135
04A133
03A146
03A145
03A125
03A184
9S
LA-SMA-10.11
LA-SMA-10.12
03A042
CDB-SMA-0.25
CDB-SMA-0.55
CDB-SMA-1.15
CDB-SMA-1.35
CDB-SMA-1.54
03A043
03A044
04A013
CDB-SMA-1.55
CDB-SMA-1.65
7S
CDB-SMA-1
04A014
04A117
04A018
13S
03A124
12S
04A118
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1,634,000
1,636,000
1,640,000
New Mexico State Plane Coordinate System Central Zone (3002)
North American Datum, 1983 (NAD 83)
US Survey Ft
GIS: Dave Frank, dff@lanl.gov, 665-8182
Date: Wednesday, March 09, 2016
Revision: 0.0
Accessed: Wednesday, March 09, 2016
File: map_15-0059-05_restore
DISCLAIMER: This map was created for work processes associated with ER-ES. All other uses for this map should be confirmed with LANL staff.
0 250 500 1,000
Feet
N
Extraction well
Injection well
Piezometer
NPDES outfall
Alluvial well
Intermediate well
Regional well
SMA sampler
Structure
SMA drainage area
LANL boundary
SWMU boundary
AOC boundary
20-ft combined stream and SWMU buffer ~8 Acres
Dust suppression limited to road application ~3 Acres
Spray area ~11 Acres
Not suitable for land application ~23 Acres
Land application by truck ~45 Acres
Watercourse
Watercourse section outside of land application area
Paved road and parking line
End of spray zone boundary
Terrain contour, 80-ft interval index contour and 5-ft interval regular contour

ENCLOSURE 4

Table 3.4-1 (Chromium Investigation Monitoring Group) from the Monitoring Year 2016 Interim Facility-Wide Groundwater Monitoring Plan

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LA-UR-16-21509

U1501760

Date: MAR 2 2 2016

Table 3.4-1
Interim Monitoring Plan for Chromium Investigation Group

Location	Watershed	Monitoring Group	Surface Water Body or Source Aquifer	Metals	VOCs	SVOCs	Low-MDL VOCs and SVOCs	PCBs	HEXP	Dioxins/Furans	Radionuclides	Tritium	Low-Level Tritium	General Inorganics	Chromium Isotopes	$^{15}N/^{18}O$ Isotopes in Nitrate	Rationale for Selection of Location
MCOI-5	Mortandad	Chromium Investigation	Intermediate	Q	S	S	A	—[a]	—	—	A	A	—	Q	A	A	Monitors for potential contaminants from upper Mortandad and Ten Site Canyons or possibly Sandia Canyon.
MCOI-6	Mortandad	Chromium Investigation	Intermediate	Q	S	S	A	—	—	—	A	A	—	Q	Q	A	Monitors for potential contaminants from upper Mortandad and Ten Site Canyons or possibly Sandia Canyon.
SCI-1	Sandia	Chromium Investigation	Intermediate	S	B (2016)[b]	B (2016)	A	B (2016)	—	—	A	A	—	S	Q	Q	Monitors the first perched-intermediate groundwater encountered along the key infiltration pathway in Sandia Canyon.
SCI-2	Sandia	Chromium Investigation	Intermediate	Q	B (2016)	B (2016)	A	B (2016)	—	—	A	A	—	Q	Q	Q	Monitors key infiltration pathway in Sandia Canyon.
R-1	Mortandad	Chromium Investigation	Regional	S	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	S	A	A	Monitors for potential contaminants from upper Mortandad Canyon or possibly Sandia Canyon. Background location in GBIR R3.
R-11	Sandia	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	S	A	Monitors for potential contaminants from Sandia Canyon and possibly Los Alamos Canyon.
R-13	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	A	A	Monitors for nature and extent of contaminants originating in Mortandad and Sandia Canyons. Key lower boundary well. Background location in GBIR R3.
R-15	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	A	A	Monitors for potential contaminants from upper Ten Site or Mortandad Canyons.
R-28	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	A	—	Q	A	A	Monitors for potential contaminants from upper Sandia, Mortandad, or Ten Site Canyons or possibly sources in canyons to the north.
R-33 S1	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	A	A	Monitors for potential contaminants from upper Ten Site or Mortandad Canyons. Background location in GBIR R4.
R-33 S2	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	—	Q	A	A	Monitors for potential contaminants from upper Ten Site or Mortandad Canyons. Background location in GBIR R4.
R-35a	Sandia	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	A	A	Sentinel monitoring location for chromium contamination in regional groundwater. Located within the same stratigraphic zone as the upper louvered section of water-supply well PM-3.
R-35b	Sandia	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	A	A	Sentinel monitoring location for chromium contamination in the regional groundwater. Located near the water table above the louvered section of water-supply well PM-3.
R-36	Sandia	Chromium Investigation	Regional	Q	A	A	A	—	—	—	B (2016)	—	A	Q	A	A	Monitors for potential contaminants from the Sandia Canyon source and other potential sources from canyons to the north. Also serves as a sentinel well for water-supply well PM-1.
R-42	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	A	—	Q	A	A	Key characterization and monitoring point located upgradient of R-28.
R-43 S1	Sandia	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	Q	A	Monitors downgradient extent of contamination originating in Sandia Canyon and possibly canyons to the north.
R-43 S2	Sandia	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	Q	A	Monitors downgradient extent of contamination originating in Sandia Canyon and possibly canyons to the north.
R-44 S1	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	S	S	Monitors near the water table for nature and extent of contaminants from sources in Sandia Canyon and possibly sources in canyons to the north.

Table 3.4-1 (continued)

Location	Watershed	Monitoring Group	Surface Water Body or Source Aquifer	Metals	VOCs	SVOCs	Low-MDL VOCs and SVOCs	PCBs	HEXP	Dioxins/Furans	Radionuclides	Tritium	Low-Level Tritium	General Inorganics	Chromium Isotopes	$^{15}N/^{18}O$ Isotopes in Nitrate	Rationale for Selection of Location
R-44 S2	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	S	S	Monitors for nature and extent of contaminants from sources in Sandia Canyon and possibly sources in canyons to the north.
R-45 S1	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	Q	S	Monitors near the water table for nature and extent of contaminants from sources in Sandia Canyon and possibly sources in canyons to the north.
R-45 S2	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	Q	S	Monitors for nature and extent of contaminants from sources in Sandia Canyon and possibly sources in canyons to the north.
R-50 S1	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	S	Q	Q	A	Monitoring well located on the mesa south of Mortandad Canyon to define the southern extent of chromium contamination in the regional aquifer.
R-50 S2	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	S	Q	Q	A	Monitoring well located on the mesa south of Mortandad Canyon to define the southern extent of chromium contamination in the regional aquifer.
R-62	Mortandad	Chromium Investigation	Regional	Q	B (2016)	B (2016)	A	—	—	—	B (2016)	—	A	Q	S	S	Located on a ridge between Sandia and Mortandad Canyon at the east end of Sigma Mesa.

Notes: Sampling suites and frequencies: Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); B = biennial (1 time/2 yr); T = triennial (1 time/3 yr); V = quinquennial (1 time/5 yr).

[a] — = This analytical suite is not scheduled to be collected for this type of water at locations assigned to this monitoring group.

[b] 2016 = Samples scheduled to be collected during implementation of MY2016 Interim Plan.

Table 4.4-1
Interim Monitoring Plan for MDA C Group

Location	Watershed	Monitoring Group	Surface Water Body or Source Aquifer	Metals	VOCs	SVOCs	Low-MDL VOCs and SVOCs	PCBs	HEXP	Dioxins/Furans	Radionuclides	Tritium	Low-Level Tritium	General Inorganics	Chromium Isotopes	15N/18O Isotopes in Nitrate	Rationale for Selection of Location
R-14 S1	Mortandad	MDA C	Regional	A	S	S	A	—[a]	V (2020)[b]	—	A	—	S	A	—	—	Monitors for potential contaminants from Ten Site Canyon or upper Mortandad Canyon, including MDA C. Background location in GBIR R4.
R-46	Mortandad	MDA C	Regional	S	S	S	A	—	V (2020)	—	A	—	S	S	—	—	Monitors groundwater quality downgradient of MDA C.
R-60	Mortandad	MDA C	Regional	S	S	S	A	—	V (2020)	—	A	—	S	S	—	—	Located east of MDA C. Monitors for potential contaminant releases from MDA C.

Notes: Sampling suites and frequencies: Q = quarterly (4 times/yr); S = semiannual (2 times/yr); A = annual (1 time/yr); B = biennial (1 time/2 yr); T = triennial (1 time/3 yr); V = quinquennial (1 time/5 yr).

[a] — = This analytical suite is not scheduled to be collected for this type of water at locations assigned to this monitoring group.

[b] 2020 = Samples scheduled to be collected during implementation of MY2016 Interim Plan.

ENCLOSURE 5

As-Built Specifications for Wells and Piezometers

EPC-DO-16-063

LA-UR-16-21509

U1501760

Date: MAR 2 2 2016

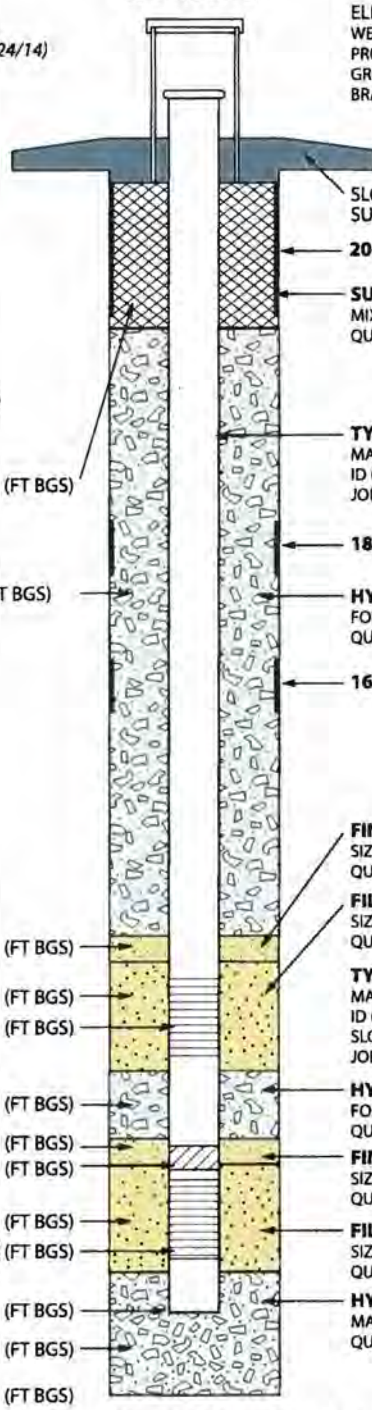
TOTAL LENGTH
OF CASING AND SCREEN (FT) 1115.6

DEPTH TO WATER
FOLLOWING INSTALLATION (FT BGS) 997.2 *(09/24/14)*

DIAMETER OF BOREHOLE
24.00 (IN) FROM 0 TO 55 (FT BGS)
19.00 (IN) FROM 55 TO 475 (FT BGS)
17.00 (IN) FROM 475 TO 816 (FT BGS)
14.75 (IN) FROM 816 TO 1211 (FT BGS)

SURFACE COMPLETION *(proposed)*
PROTECTIVE CASING
TYPE STEEL SIZE (IN) 16
PROTECTIVE POSTS INSTALLED YES
SURFACE SEAL AND PAD
CHECK FOR SETTLEMENT YES
PAD MATERIAL CONCRETE
REINFORCED WIRE MESH
PAD DIMENSIONS (FT) 10 (L) 10 (W) 0.5 (H)

ELEVATIONS (FT AMSL)
WELL CASING TBD
PROTECTIVE CASING TBD
GROUND SURFACE TBD
BRASS CAP (MARKER) TBD



20-IN CSG 0 TO 55 (FT BGS)

SURFACE SEAL
MIX (WT%) PORTLAND CEMENT 92 BENTONITE 8
QUANTITY USED 90.0 FT^3 CALC 90.0 FT^3

TYPE OF CASING
MATERIAL PASSIVATED A304 STAINLESS STEEL
ID (IN) 8.00 OD (IN) 8.625 (8⅝)
JOINT TYPE WELDED

18-IN CSG/SHOE 470.0 TO 475.0 (FT BGS)

HYDRATED BENTONITE SEAL
FORM ⅜-IN BENTONITE CHIP
QUANTITY USED 1253.2 FT^3 CALC 1100.7 FT^3

16-IN CSG/SHOE 811.0 TO 816.0 (FT BGS)

FINE SAND COLLAR
SIZE/TYPE 20/40 SILICA
QUANTITY USED 14.0 FT^3 CALC 4.7 FT^3

FILTER PACK SAND
SIZE/TYPE 10/20 SILICA
QUANTITY USED 46.5 FT^3 CALC 49.4 FT^3

TYPE OF SCREEN(S)
MATERIAL A304 STAINLESS STEEL
ID (IN) 8.00 OD (IN) 5.88 (5⅞)
SLOT SIZE (IN) 0.040
JOINT TYPE WELDED

HYDRATED BENTONITE SEAL
FORM ⅜-IN BENTONITE CHIP
QUANTITY USED 8.8 FT^3 CALC 11.7 FT^3

FINE SAND COLLAR
SIZE/TYPE 20/40 SILICA
QUANTITY USED 4.5 FT^3 CALC 2.3 FT^3

FILTER PACK SAND
SIZE/TYPE 10/20 SILICA
QUANTITY USED 23.0 FT^3 CALC 23.6 FT^3

HYDRATED BENTONITE BACKFILL
MATERIAL ⅜-IN BENTONITE CHIP
QUANTITY USED 83.0 FT^3 CALC 129.5 FT^3

SURFACE SEAL	4.0 TO 59.8	(FT BGS)
BENTONITE SEAL	59.8 TO 979.3	(FT BGS)
FINE SAND COLLAR	979.3 TO 985.3	(FT BGS)
FILTER PACK	985.3 TO 1048.0	(FT BGS)
SCREENED INTERVAL	990.0 TO 1040.0	(FT BGS)
BENTONITE SEAL	1048.0 TO 1063.0	(FT BGS)
FINE SAND COLLAR	1063.0 TO 1066.0	(FT BGS)
TAM PACKER	1062.0 TO 1068.0	(FT BGS)
FILTER PACK	1066.0 TO 1096.2	(FT BGS)
SCREENED INTERVAL	1070.0 TO 1090.0	(FT BGS)
BOTTOM OF CASING	1112.6	(FT BGS)
BACKFILL	1096.2 TO 1211.0	(FT BGS)
BOTTOM OF BORING	1211.0	(FT BGS)

STAINLESS-STEEL CENTRALIZERS
USED YES BETWEEN
LOWER AND UPPER SCREENS AND
EVERY 40 FT FROM 10 FT ABOVE
UPPER SCREEN TO 197 FT BGS

WELL COMPLETION BEGAN
DATE 08/12/14 TIME 1235h
WELL COMPLETION FINISHED
DATE 08/17/14 TIME 1100h

Los Alamos NATIONAL LABORATORY EST. 1943

Drafted By: PTM
Date: November 3, 2014
File Name: CrEX-1_AsBuiltDiagram_FactSheet

Well CrEX-1 As-Built Well Construction Diagram
Technical Area 05 (TA-05)
Los Alamos National Laboratory
Los Alamos, New Mexico

Fact Sheet
NOT TO SCALE

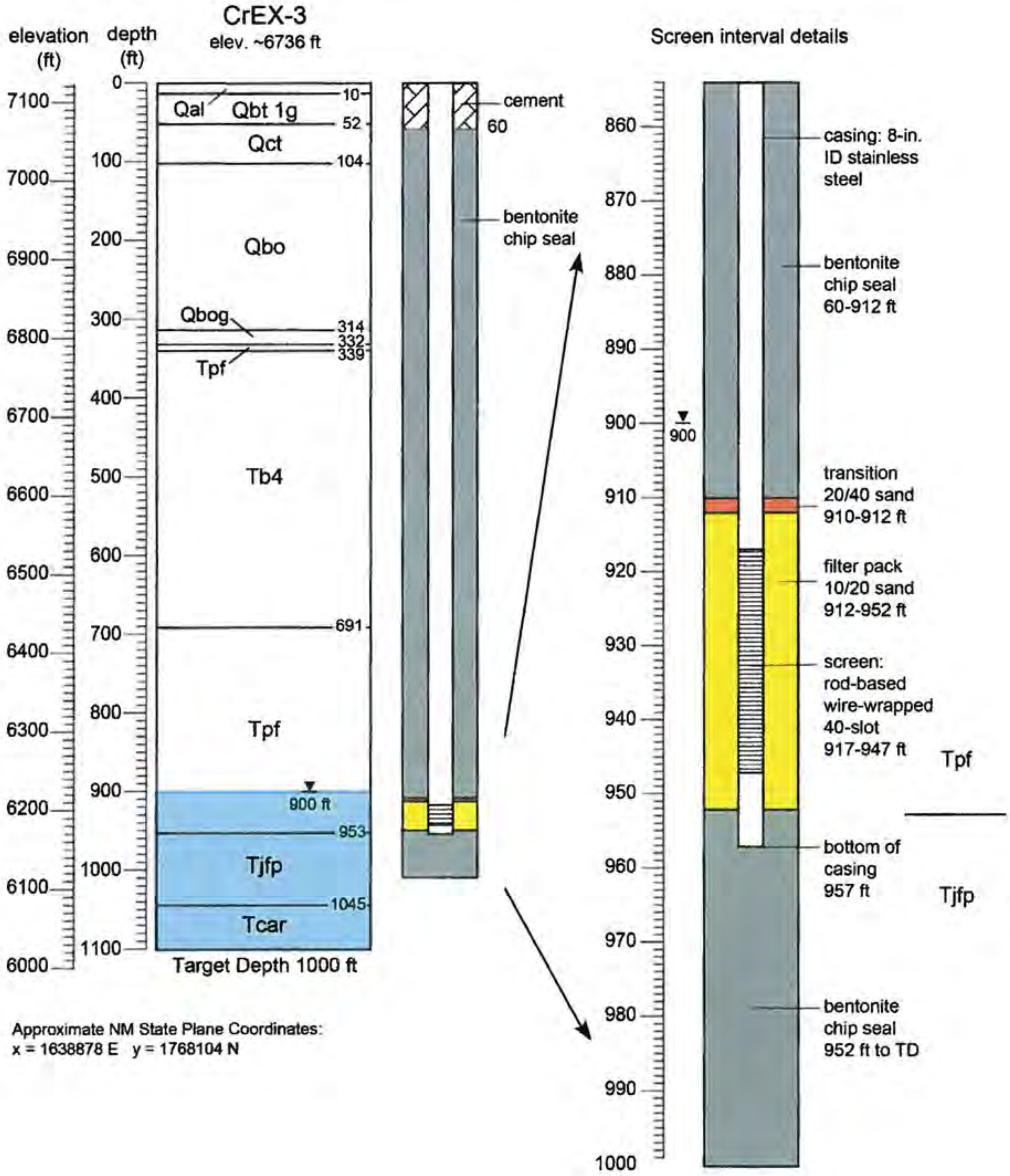
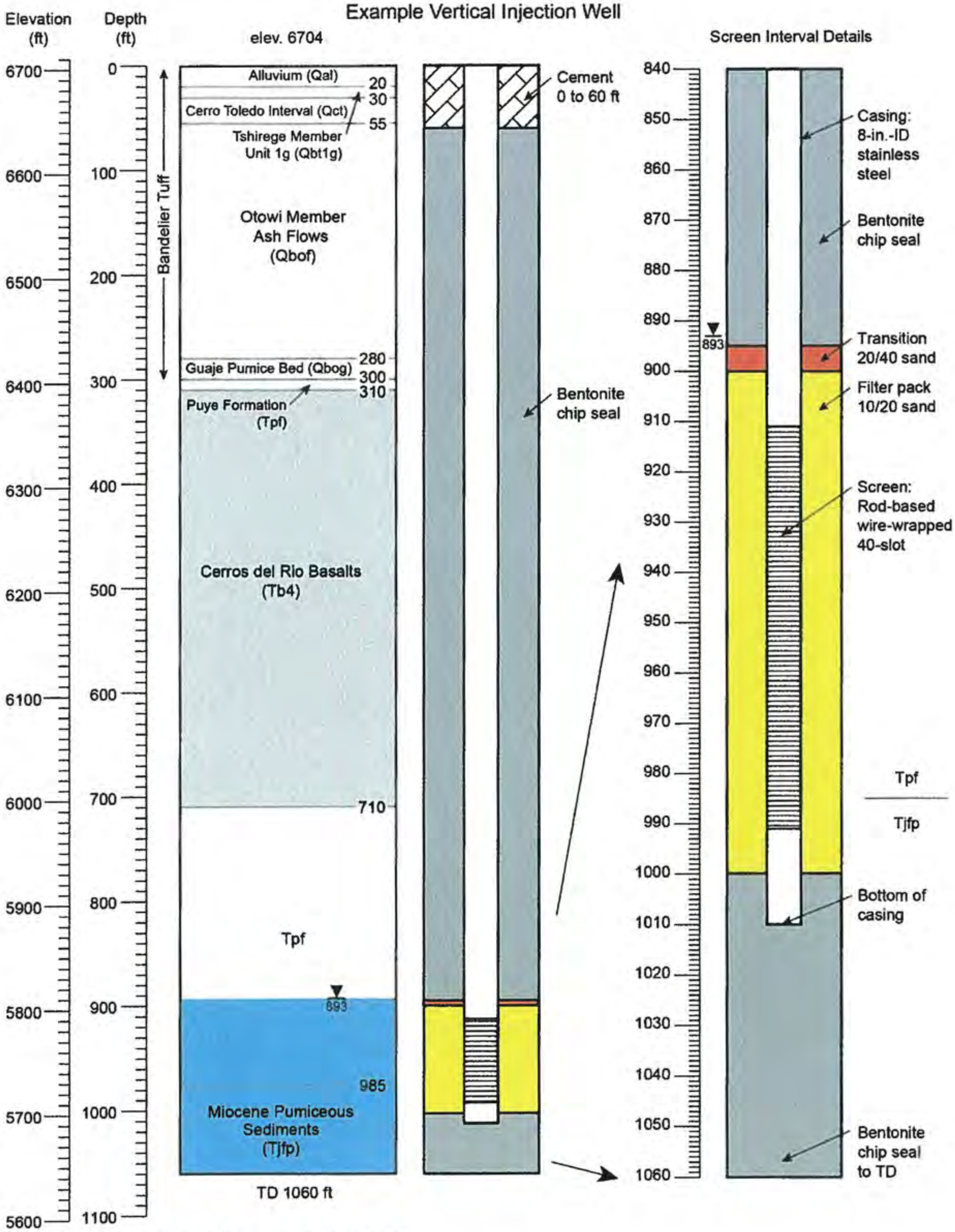
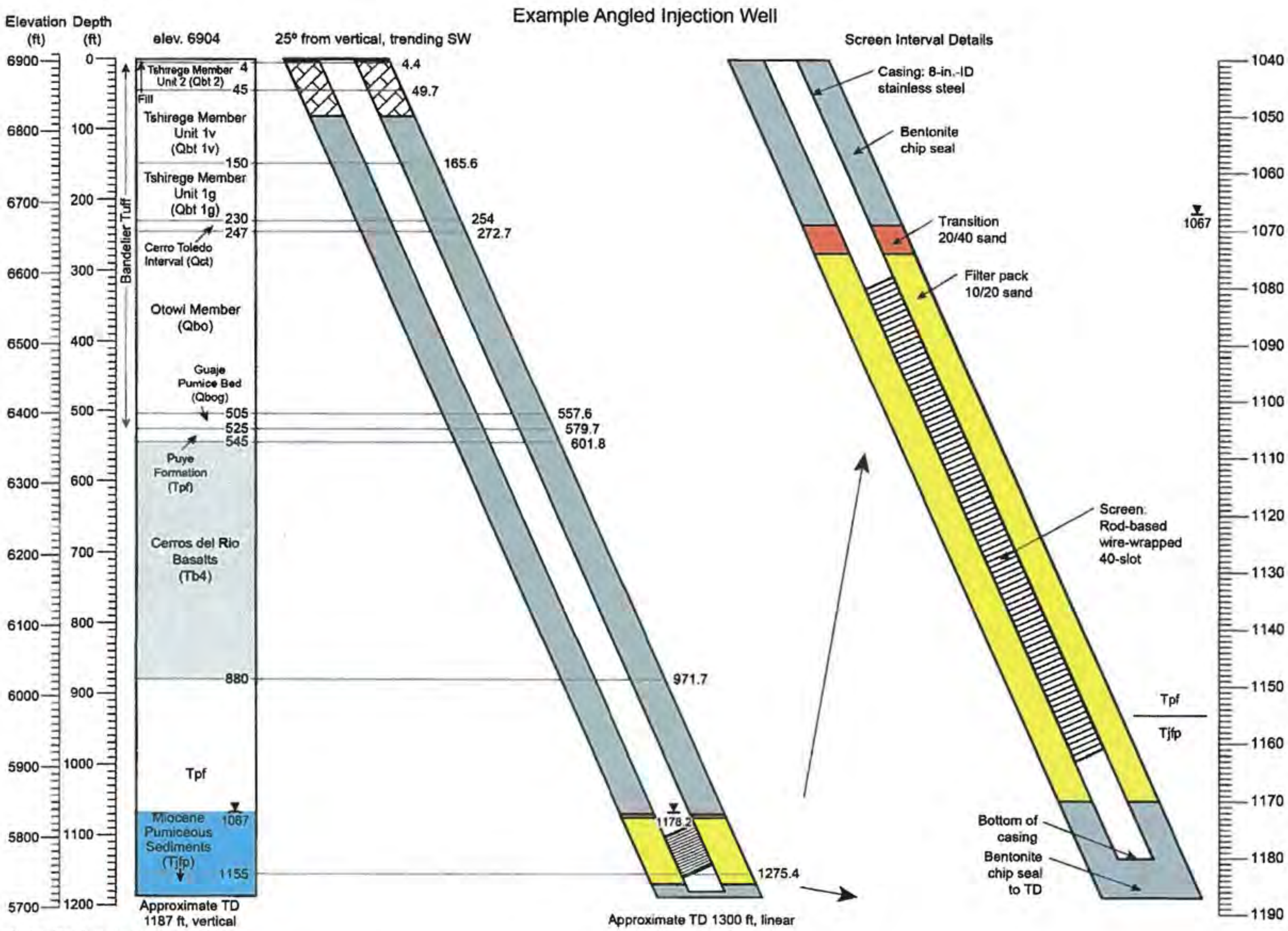


Figure 2 Predicted geology and conceptual well design for well CrEX-3



Note: Geology was estimated from wells R-44 and R-45.

Figure 2 Conceptual well design for vertical injection well



Note: Geology is from well R-50.

Figure 3 **Conceptual well design for angled injection well**

TOTAL LENGTH
OF CASING AND SCREEN (FT) 1141.6

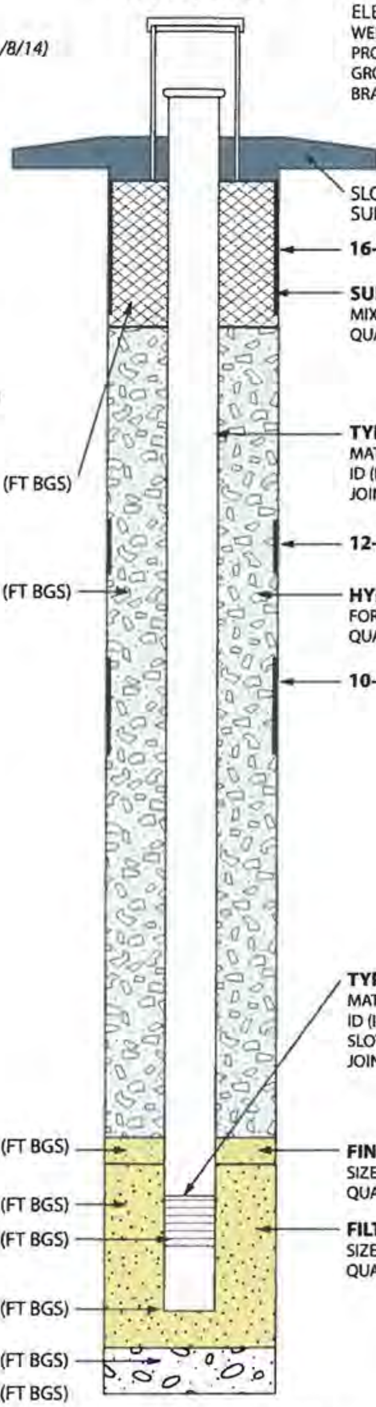
DEPTH TO WATER
FOLLOWING INSTALLATION (FT BGS) 1118.0 *(11/8/14)*

DIAMETER OF BOREHOLE
20.00 (IN) FROM 0.0 TO 60.0 (FT BGS)
12.00 (IN) FROM 60.0 TO 585.0 (FT BGS)
10.00 (IN) FROM 585.0 TO 905.0 (FT BGS)
6.00 (IN) FROM 905.5 TO 1158.0 (FT BGS)

SURFACE COMPLETION *(proposed)*
PROTECTIVE CASING
TYPE STEEL SIZE (IN) 16
PROTECTIVE POSTS INSTALLED YES
SURFACE SEAL AND PAD
CHECK FOR SETTLEMENT YES
PAD MATERIAL CONCRETE
REINFORCED WIRE MESH
PAD DIMENSIONS (FT) 10 (L) 10 (W) 0.5 (H)

LOCKING COVER

ELEVATIONS (FT AMSL)
WELL CASING TBD
PROTECTIVE CASING TBD
GROUND SURFACE TBD
BRASS CAP (MARKER) TBD



SLOPED CONCRETE PAD/
SURFACE SEAL

16-IN CSG 0 TO 60 (FT BGS)

SURFACE SEAL
MIX (WT%) PORTLAND CEMENT 92 BENTONITE 8
QUANTITY USED 79.0 FT³ CALC 77.8 FT³

TYPE OF CASING
MATERIAL PASSIVATED A304 STAINLESS STEEL
ID (IN) 2.00
JOINT TYPE THREADED

SURFACE SEAL 4.0 TO 61.0 (FT BGS)

12-IN CSG/SHOE 580.0 TO 585.0 (FT BGS)

BENTONITE SEAL 61.0 TO 1115.5 (FT BGS)

HYDRATED BENTONITE SEAL
FORM ⅜-IN BENTONITE CHIP
QUANTITY USED 743.4 FT³ CALC 596.9 FT³

10-IN CSG/SHOE 866.0 TO 886.0 (FT BGS)

TYPE OF SCREEN(S)
MATERIAL A304 STAINLESS STEEL
ID (IN) 2.00
SLOT SIZE (IN) 0.040
JOINT TYPE THREADED

FINE SAND COLLAR 1115.5 TO 1117.5 (FT BGS)

FILTER PACK 1117.5 TO 1145.0 (FT BGS)

SCREENED INTERVAL 1122.9 TO 1132.9 (FT BGS)

BOTTOM OF CASING 1138.0 (FT BGS)

SLOUGH 1145.0 TO 1158.0 (FT BGS)

BOTTOM OF BORING 1158.0 (FT BGS)

FINE SAND COLLAR
SIZE/TYPE 20/40 SILICA
QUANTITY USED 1.3 FT³ CALC 0.3 FT³

FILTER PACK SAND
SIZE/TYPE 10/20 SILICA
QUANTITY USED 10.0 FT³ CALC 4.8 FT³

STAINLESS-STEEL CENTRALIZERS
USED YES
ABOVE AND BELOW SCREEN AND
EVERY 40 FT FROM SCREEN TO 102 FT BGS

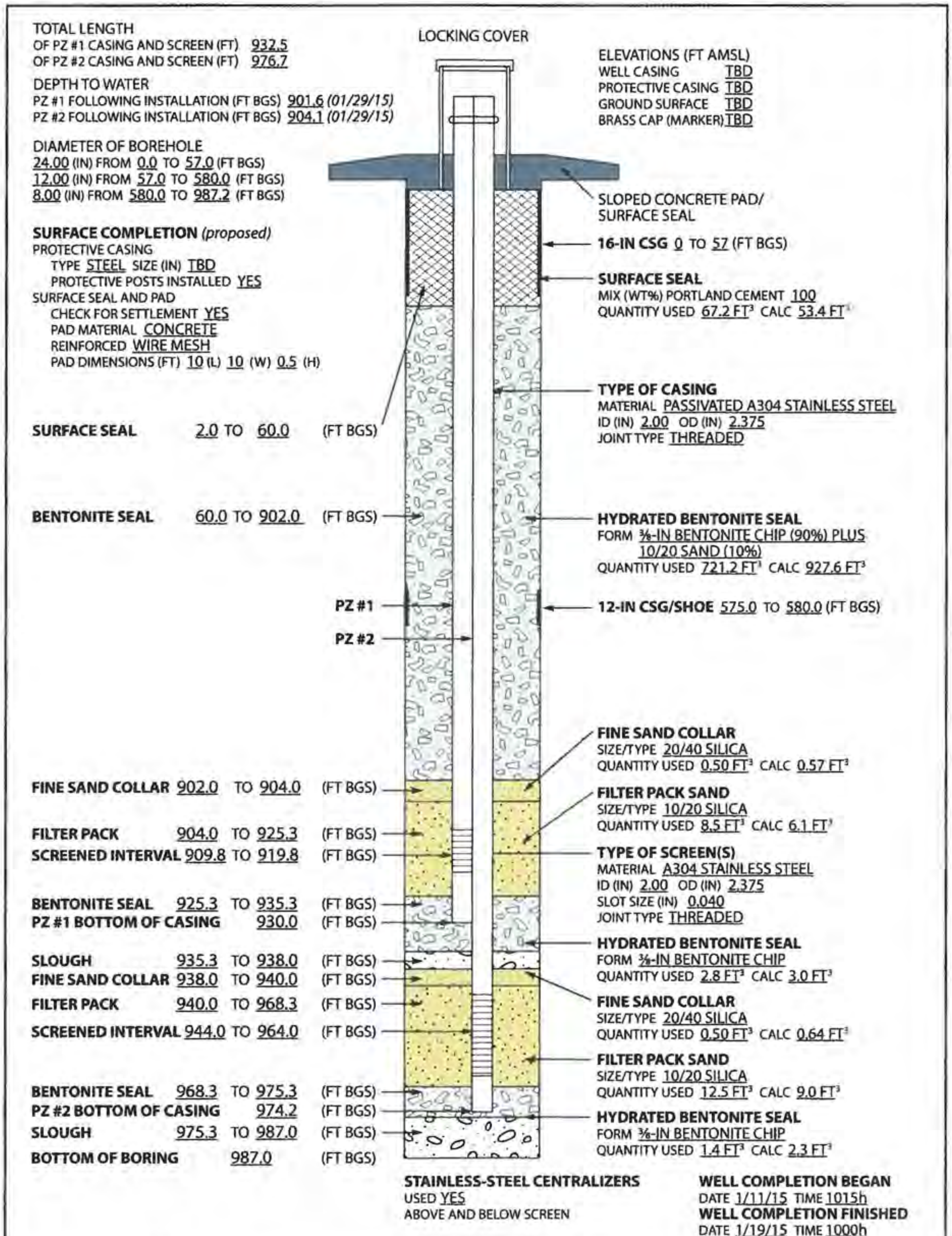
WELL COMPLETION BEGAN
DATE 10/25/14 TIME 1515h
WELL COMPLETION FINISHED
DATE 11/08/14 TIME 1900h

Los Alamos NATIONAL LABORATORY EST 1943

Drafted By: PTM
Date: December 2, 2014
File Name: CrCH-1_AsBuiltDiagram_FactSheet

Well CrCH-1 As-Built Well Construction Diagram
Technical Area 05 (TA-05)
Los Alamos National Laboratory
Los Alamos, New Mexico

Fact Sheet
NOT TO SCALE

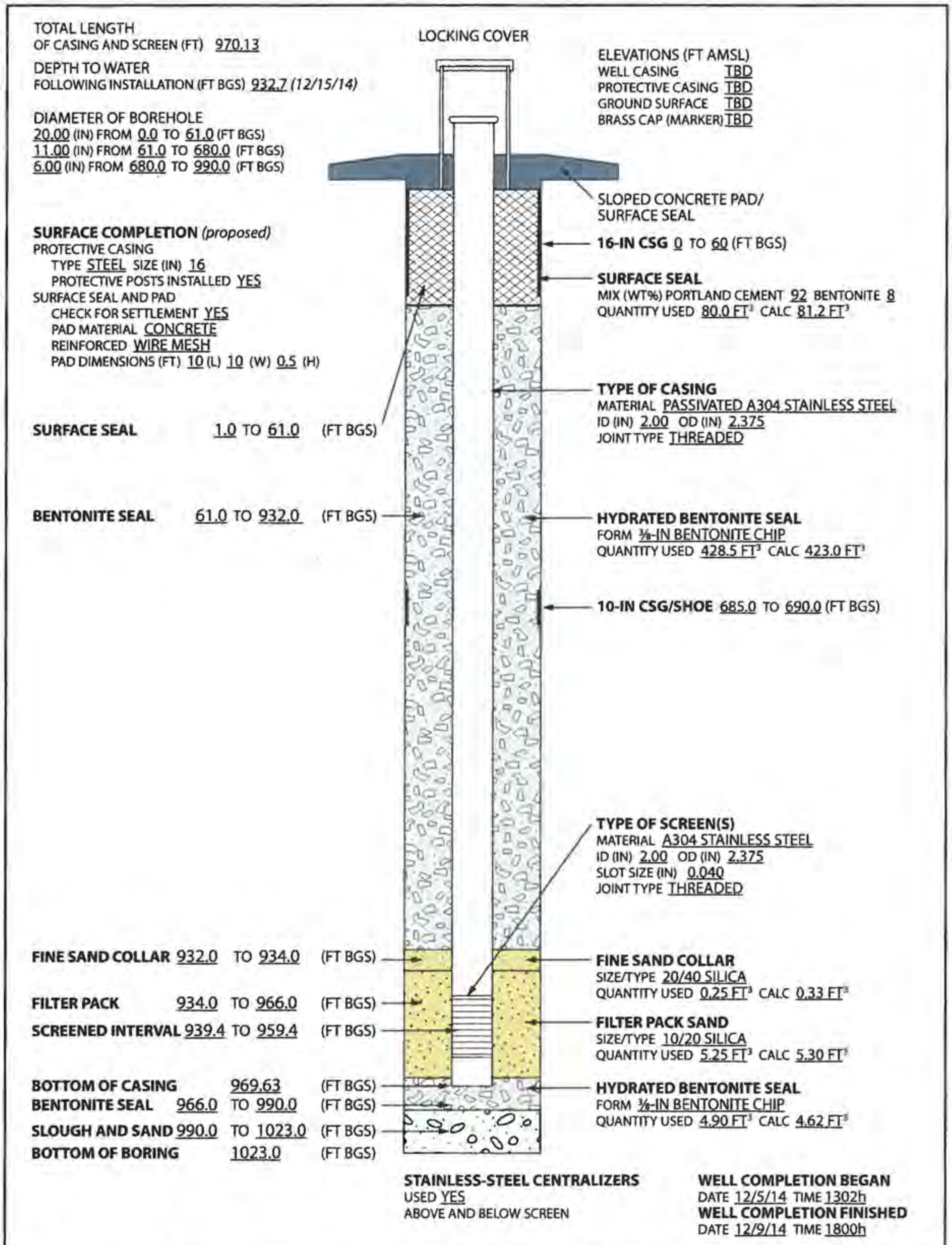


Los Alamos NATIONAL LABORATORY EST. 1943

Drafted By: PTM
Date: February 4, 2015
File Name: CrCH-2_AsBuiltDiagram_FactSheet

Well CrCH-2 As-Built Well Construction Diagram
Technical Area 05 (TA-05)
Los Alamos National Laboratory
Los Alamos, New Mexico

Fact Sheet
NOT TO SCALE

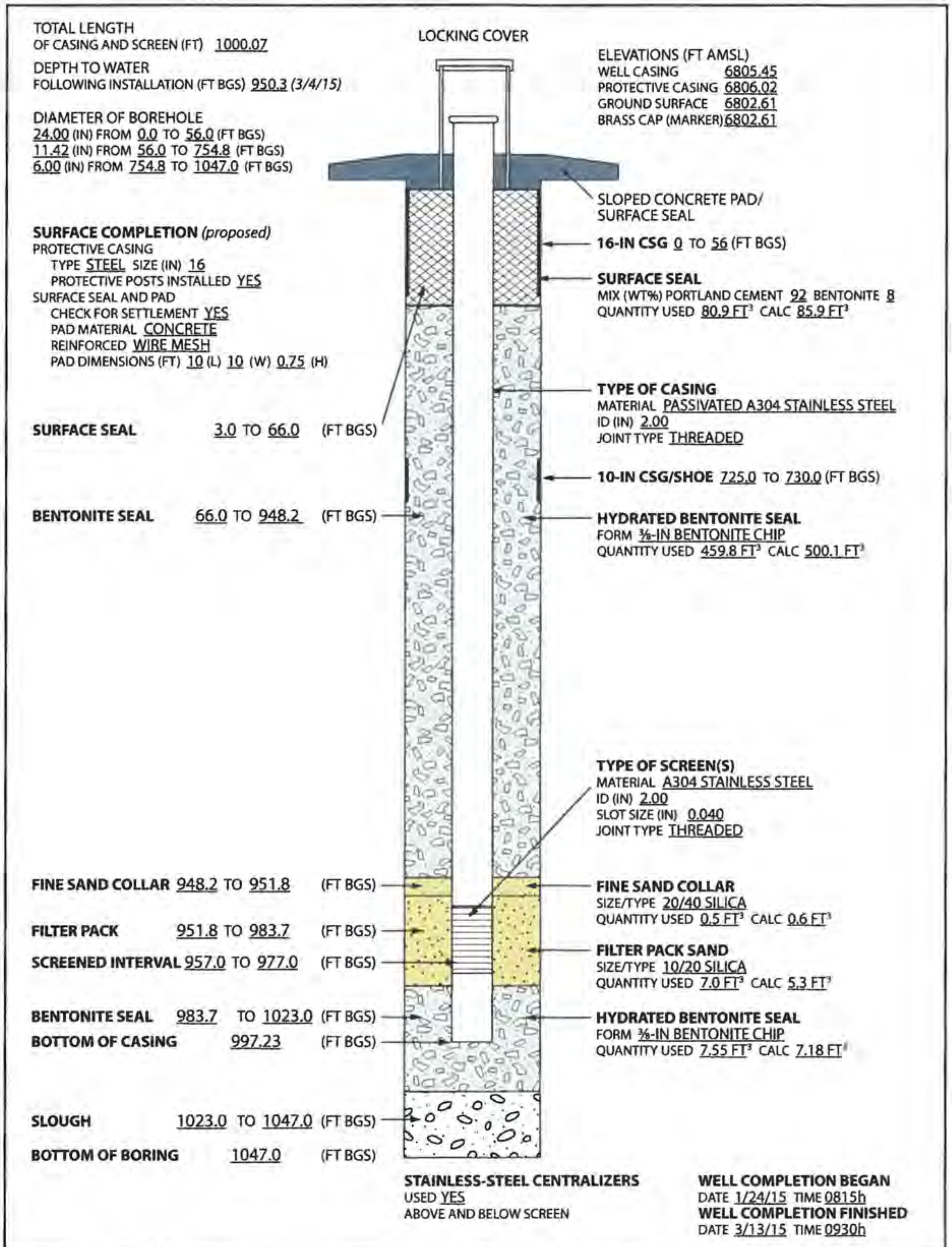


Los Alamos National Laboratory EST 1943

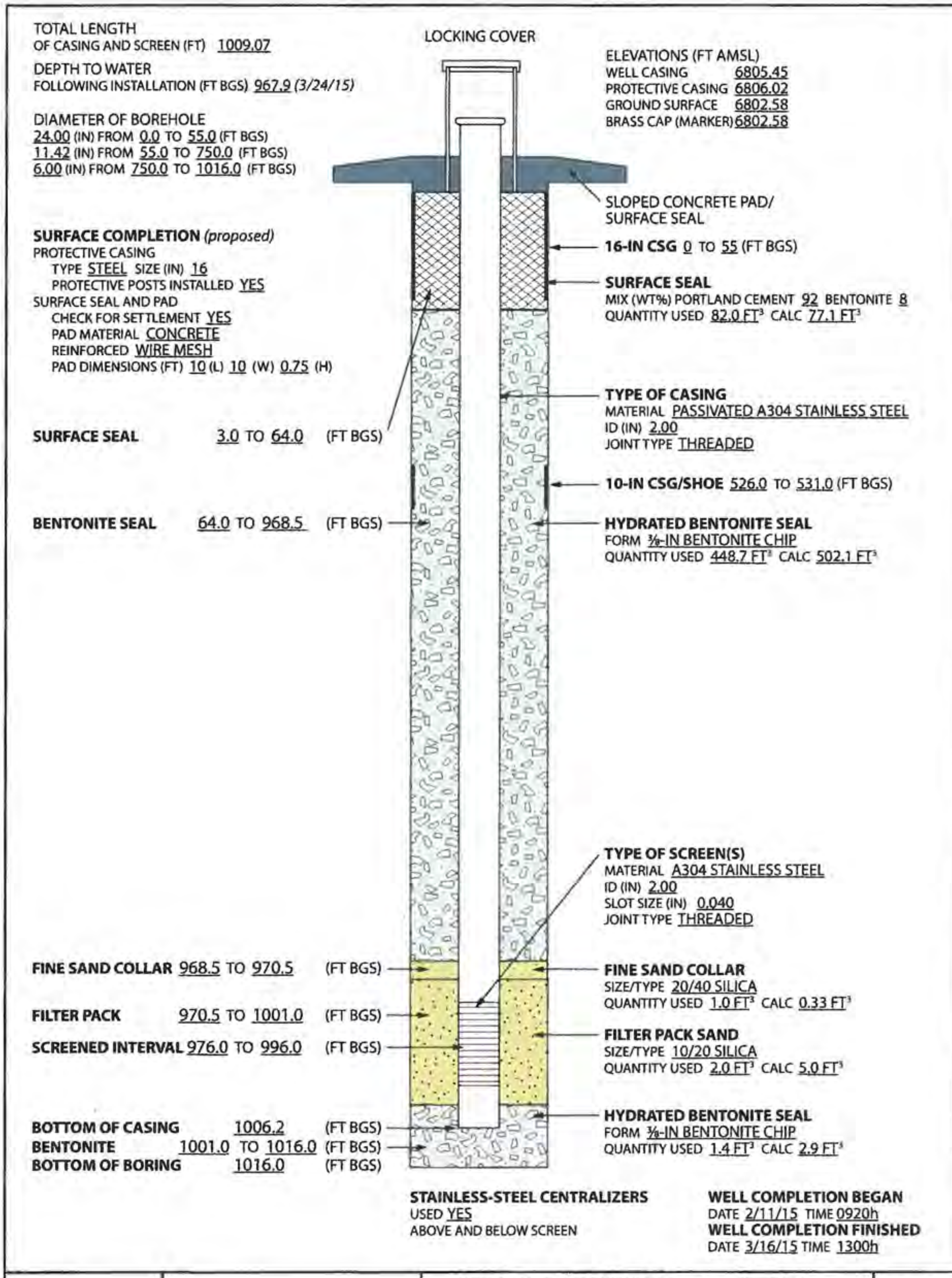
Drafted By: PTM
Date: December 18, 2014
File Name: CrCH-3_AsBuiltDiagram_FactSheet

Well CrCH-3 As-Built Well Construction Diagram
Technical Area 05 (TA-05)
Los Alamos National Laboratory
Los Alamos, New Mexico

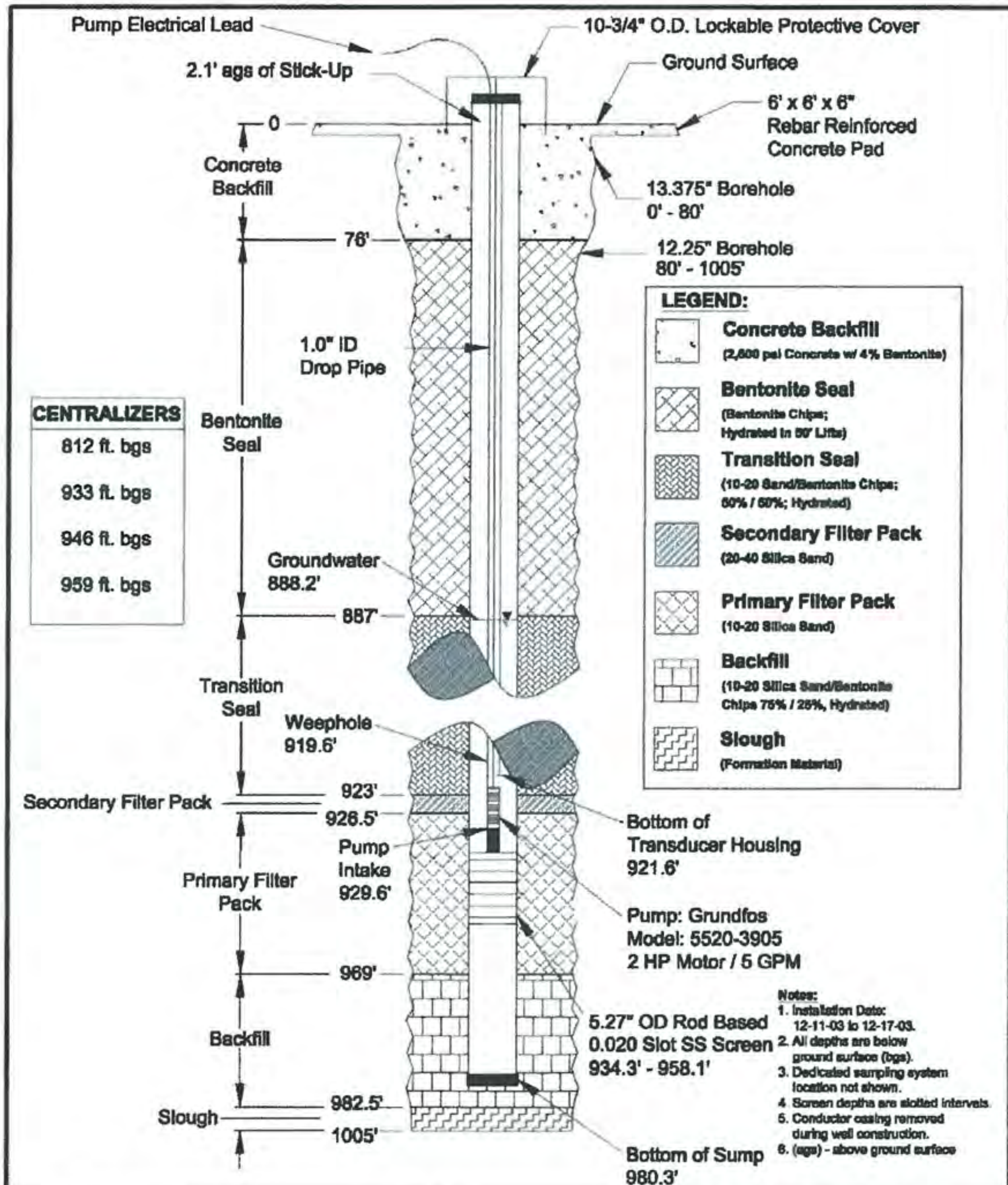
Fact Sheet
NOT TO SCALE



Los Alamos NATIONAL LABORATORY EST. 1943	Drafted By: PTM Date: April 16, 2015	**Well CrCH-4 As-Built Well Construction Diagram** Technical Area 05 (TA-05) Los Alamos National Laboratory Los Alamos, New Mexico	**Fact Sheet** NOT TO SCALE



Los Alamos National Laboratory EST 1943	Drafted By: PTM Date: April 16, 2015	**Well CrCH-5 As-Built Well Construction Diagram** Technical Area 05 (TA-05) Los Alamos National Laboratory Los Alamos, New Mexico	**Fact Sheet** NOT TO SCALE



KLEINFELDER		Schematic Diagram of Well R-28 Los Alamos National Laboratory Los Alamos, New Mexico	FIGURE 7.2-1
Drawn By: C. London	Date: August 2004		
Project No.: 37151	Filename: Figure 7.2-1 Rev1		
Scale: Not-To-Scale	Revision: 1		
Reviewed By: B. Bockisch	Approved By: M. Everett		

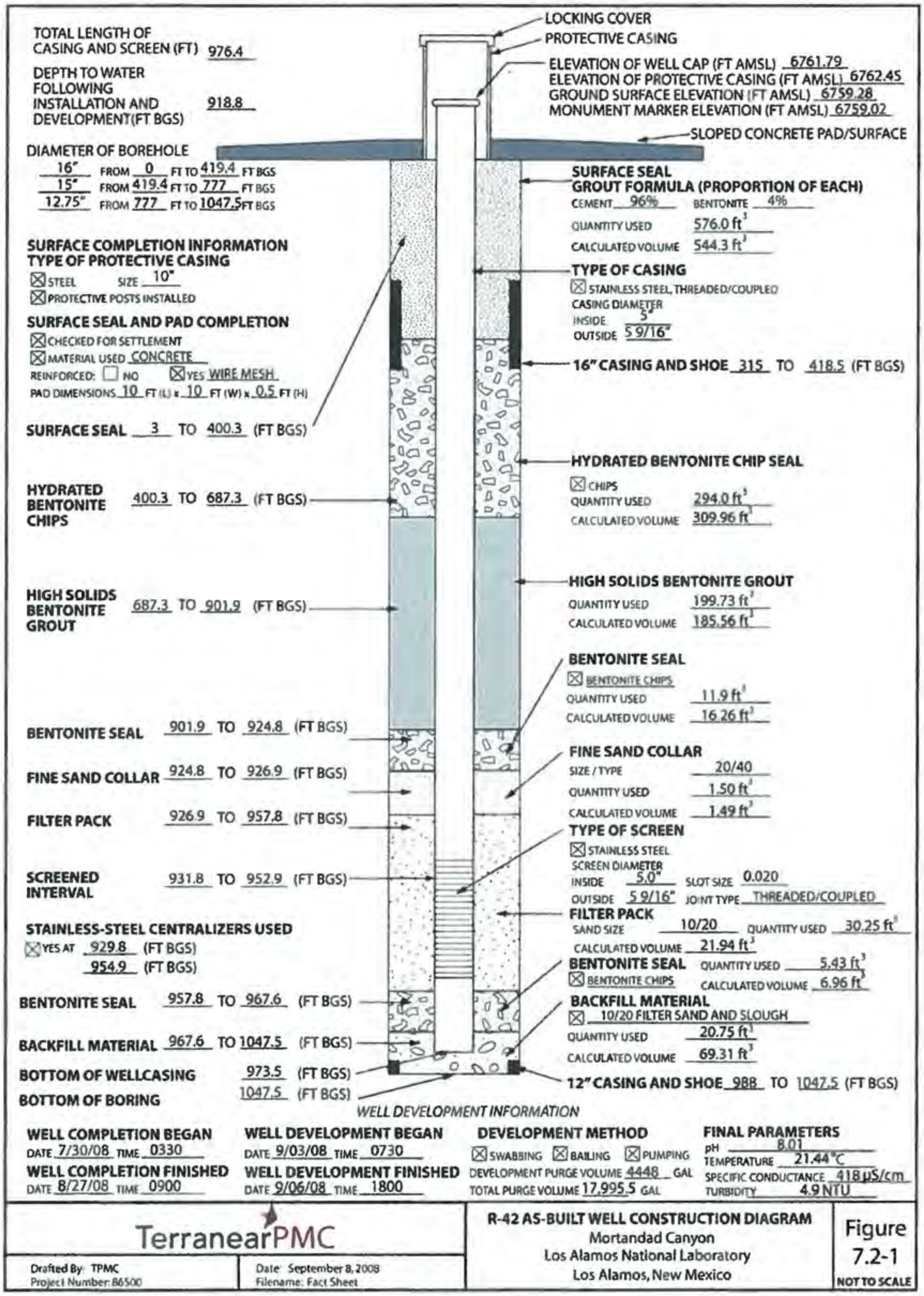


Figure 7.2-1 R-42 as-built well construction diagram

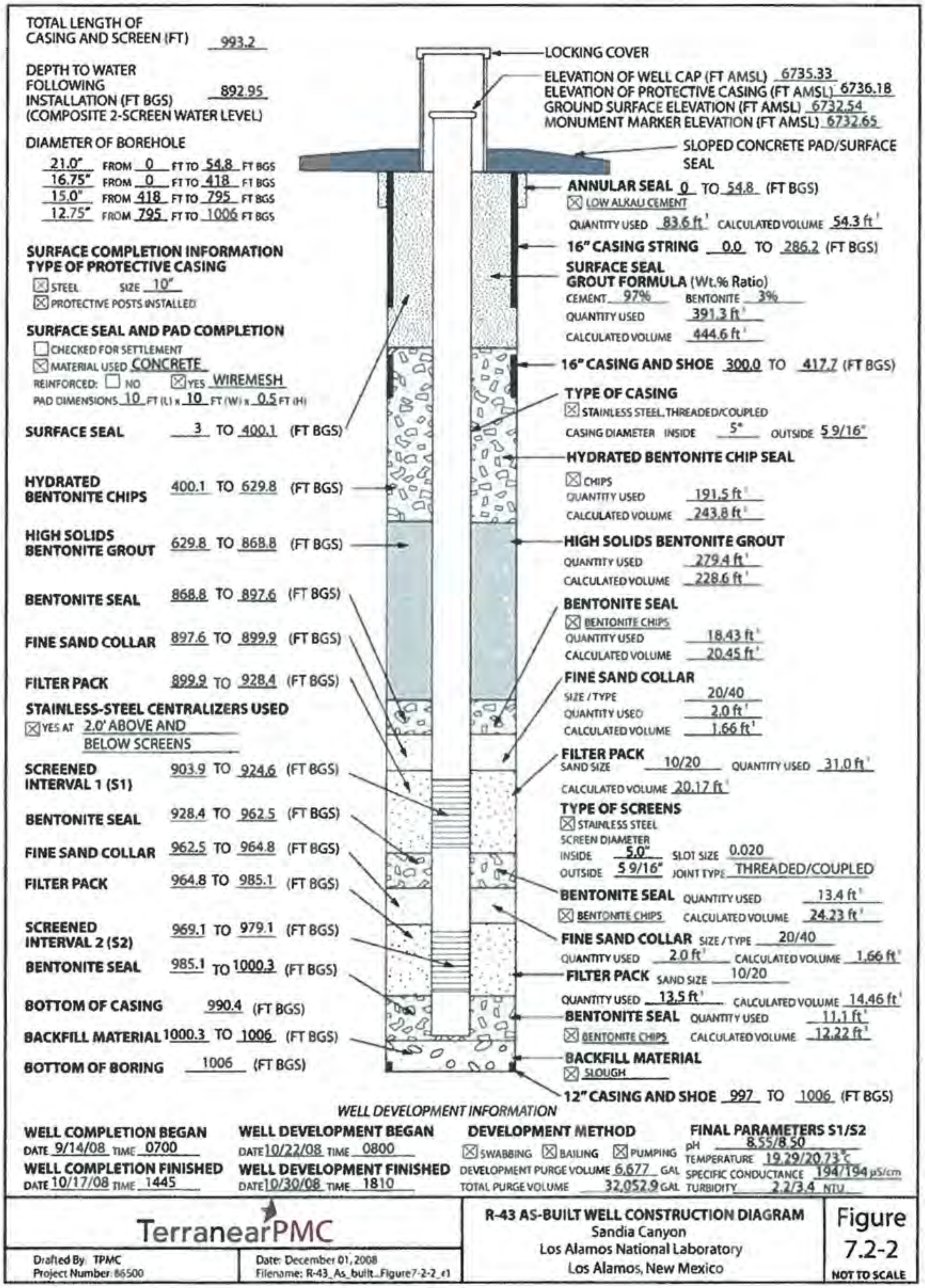


Figure 7.2-2 R-43 As-built construction diagram

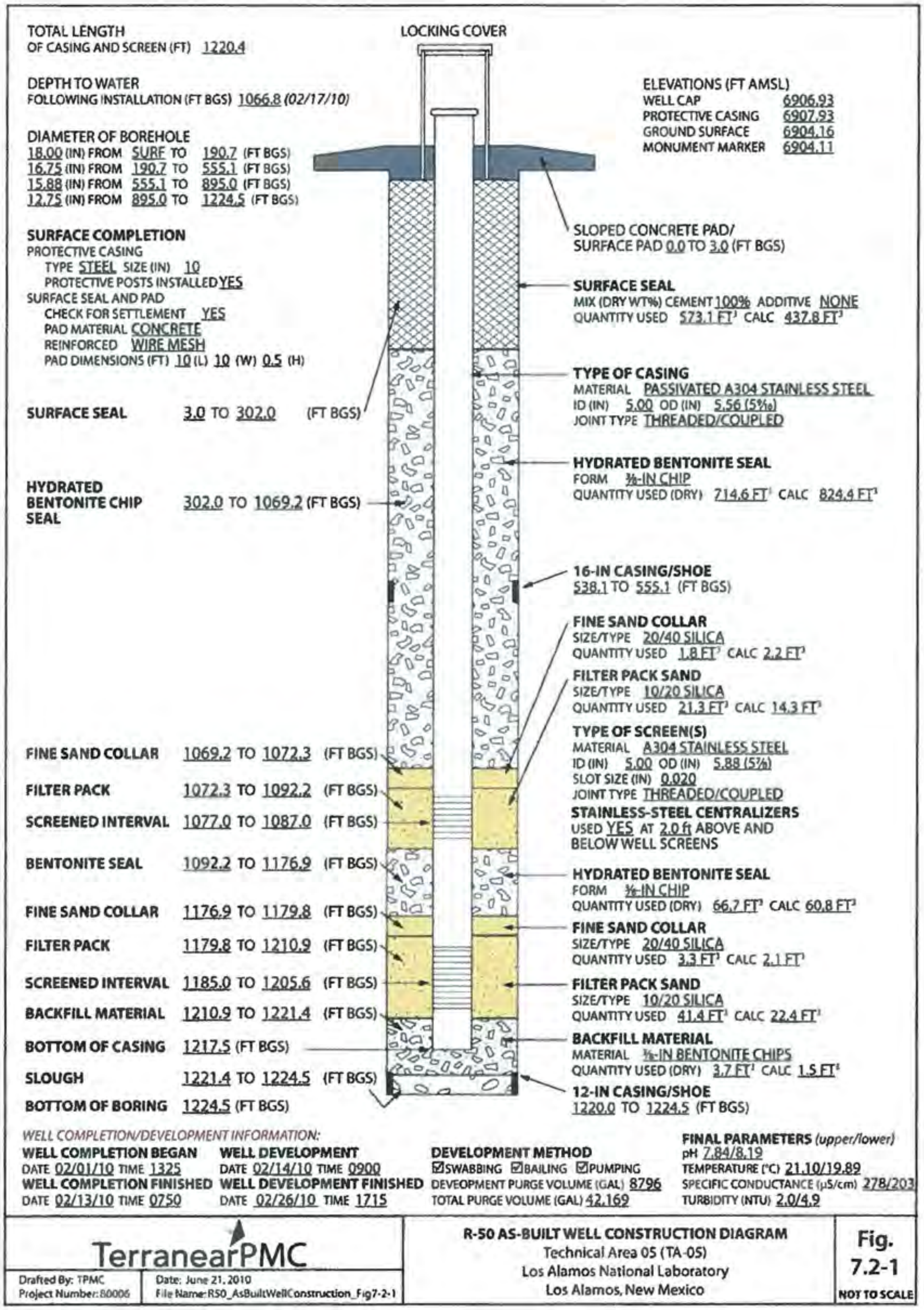


Figure 7.2-1 Regional monitoring well R-50 as-built well construction diagram

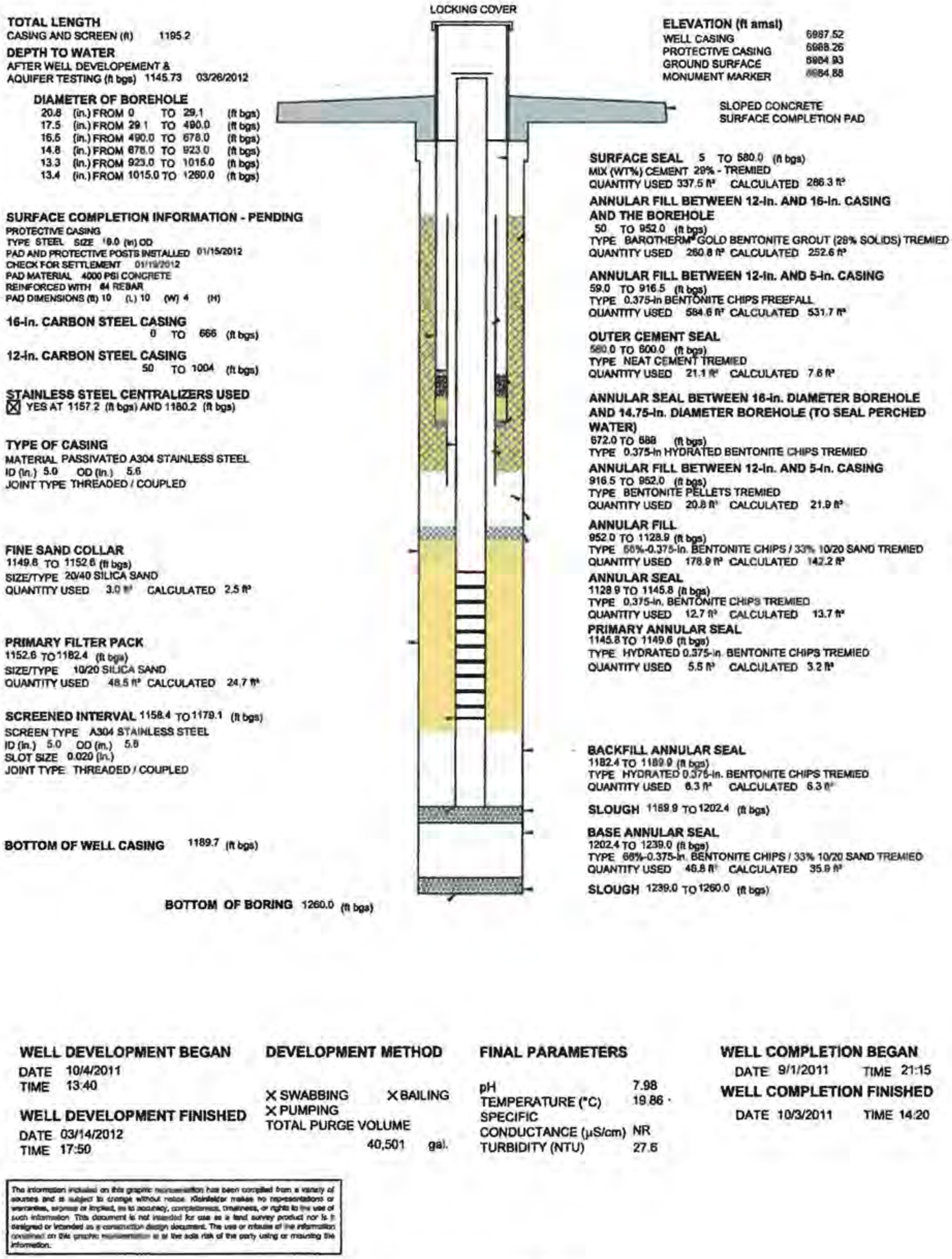


Figure 7.2-1 As-built construction diagram for well R-62

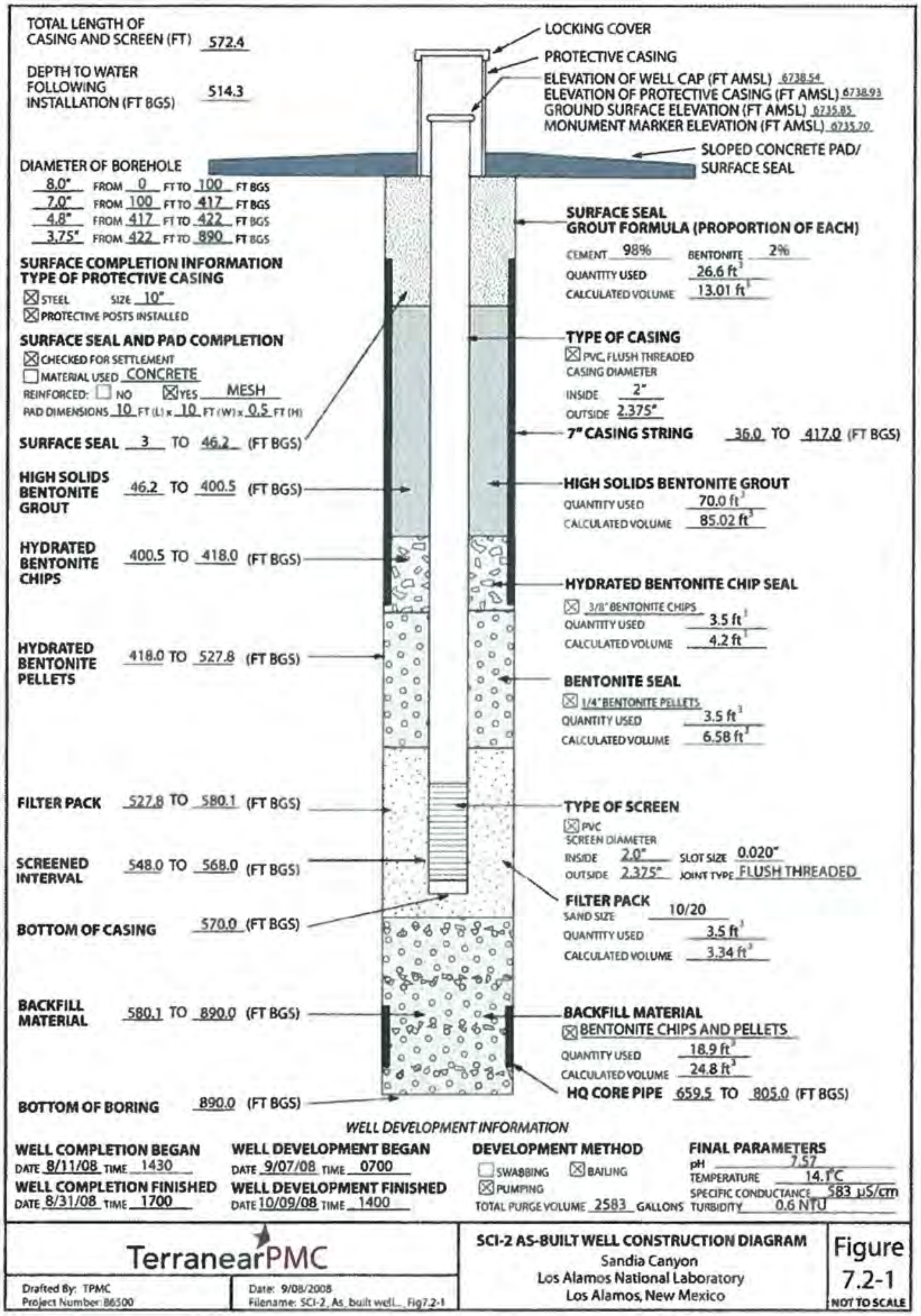


Figure 7.2-1 SCI-2 As-built construction diagram

ENCLOSURE 6

Water-Quality Data from CrEX-1, R-42, R-45, and R-50

EPC-DO-16-063

LA-UR-16-21509

U1501760

Date: MAR 2 2 2016

Location	Field preparation code (F/UF)	Analyte	Units	Number of Analyses	Number of Detects	Min	Avg	Max
CrEX-1	UF	Acidity or Alkalinity of a solution	SU	4	4	7.60	8.11	8.64
CrEX-1	UF	Alkalinity-CO3	mg/L	4	0	—	—	—
CrEX-1	UF	Alkalinity-CO3+HCO3	mg/L	4	4	85.03	99.07	119.07
CrEX-1	F	Aluminum	ug/L	4	1	27.25	27.25	27.25
CrEX-1	F	Antimony	ug/L	4	0	—	—	—
CrEX-1	F	Arsenic	ug/L	4	4	0.44	0.64	0.77
CrEX-1	F	Barium	ug/L	4	4	36.49	37.32	38.67
CrEX-1	F	Beryllium	ug/L	4	0	—	—	—
CrEX-1	F	Boron	ug/L	4	2	2.00	8.98	15.96
CrEX-1	UF	Bromide	mg/L	4	4	0.10	0.12	0.15
CrEX-1	F	Cadmium	ug/L	4	0	—	—	—
CrEX-1	F	Calcium	mg/L	4	4	21.71	22.23	22.67
CrEX-1	F	Cesium	ug/L	4	0	—	—	—
CrEX-1	UF	Chloride	mg/L	22	22	11.40	14.89	17.90
CrEX-1	F	Chromium	ug/L	22	11	2.10	57.76	163.14
CrEX-1	F	Cobalt	ug/L	4	0	—	—	—
CrEX-1	F	Copper	ug/L	4	1	1.78	1.78	1.78
CrEX-1	UF	Fluoride	mg/L	4	4	0.37	0.77	1.03
CrEX-1	F	Iron	ug/L	4	1	21.84	21.84	21.84
CrEX-1	F	Lead	ug/L	4	0	—	—	—
CrEX-1	F	Lithium	ug/L	4	4	26.14	26.89	27.88
CrEX-1	F	Magnesium	mg/L	4	4	7.56	7.79	8.08
CrEX-1	F	Manganese	ug/L	4	2	1.18	2.02	2.87
CrEX-1	F	Mercury	ug/L	4	0	—	—	—
CrEX-1	F	Molybdenum	ug/L	4	2	1.03	1.10	1.16
CrEX-1	F	Nickel	ug/L	4	4	4.02	4.32	4.52
CrEX-1	UF	Nitrate	mg/L	4	4	10.38	11.41	11.99
CrEX-1	UF	Nitrate as Nitrogen	mg/L	18	0	—	—	—
CrEX-1	UF	Nitrite	mg/L	4	1	0.02	0.02	0.02
CrEX-1	UF	Oxalate	mg/L	4	0	—	—	—
CrEX-1	UF	Perchlorate	ug/L	8	8	0.22	0.70	0.93
CrEX-1	UF	Phosphorus, Orthophosphate (Expressed as PO4)	mg/L	4	2	0.07	0.10	0.14
CrEX-1	F	Potassium	mg/L	4	4	1.52	1.63	1.72
CrEX-1	F	Selenium	ug/L	4	3	1.59	1.67	1.76
CrEX-1	F	Silicon Dioxide	mg/L	4	4	71.07	74.63	77.13
CrEX-1	F	Silver	ug/L	4	0	—	—	—
CrEX-1	F	Sodium	mg/L	4	4	12.06	12.37	12.64
CrEX-1	F	Strontium	ug/L	4	4	91.83	94.32	97.09
CrEX-1	UF	Sulfate	mg/L	4	4	20.87	21.53	22.36
CrEX-1	F	Thallium	ug/L	4	0	—	—	—
CrEX-1	F	Tin	ug/L	4	0	—	—	—
CrEX-1	F	Titanium	ug/L	4	0	—	—	—
CrEX-1	UF	Total Dissolved Solids	mg/L	18	18	111.00	160.17	207.00
CrEX-1	F	Uranium	ug/L	4	4	0.53	0.75	0.91
CrEX-1	F	Vanadium	ug/L	4	4	4.72	5.69	6.18
CrEX-1	F	Zinc	ug/L	4	4	75.02	392.39	1231.40
CrEX-1	UF	Tritium	pCi/L	3	3	47.42	48.23	49.44

Location	Field preparation code (F/UF)	Analyte	Units	Number of Analyses	Number of Detects	Min	Avg	Max
R-42	F	Acidity or Alkalinity of a solution	SU	4	4	7.49	7.70	7.83
R-42	F	Alkalinity-CO3	mg/L	4	0	—	—	—
R-42	F	Alkalinity-CO3+HCO3	mg/L	4	4	65.50	66.88	69.00
R-42	F	Aluminum	ug/L	4	0	—	—	—
R-42	F	Ammonia as Nitrogen	mg/L	4	2	0.05	0.09	0.13
R-42	F	Antimony	ug/L	4	0	—	—	—
R-42	F	Arsenic	ug/L	4	2	2.21	2.25	2.28
R-42	F	Barium	ug/L	4	4	94.10	97.60	102.00
R-42	F	Beryllium	ug/L	4	0	—	—	—
R-42	F	Boron	ug/L	4	3	19.70	20.17	20.60
R-42	F	Bromide	mg/L	4	4	0.25	0.26	0.28
R-42	F	Cadmium	ug/L	4	0	—	—	—
R-42	F	Calcium	mg/L	4	4	50.10	54.10	56.90
R-42	F	Chloride	mg/L	4	4	44.70	45.75	47.40
R-42	F	Chromium	ug/L	4	4	821.00	856.00	915.00
R-42	F	Cobalt	ug/L	4	0	—	—	—
R-42	F	Copper	ug/L	4	1	11.50	11.50	11.50
R-42	UF	Cyanide (Total)	mg/L	4	4	0.01	0.01	0.01
R-42	F	Fluoride	mg/L	4	4	0.22	0.23	0.24
R-42	F	Hardness	mg/L	4	4	184.00	197.75	208.00
R-42	F	Iron	ug/L	4	0	—	—	—
R-42	F	Lead	ug/L	4	0	—	—	—
R-42	F	Magnesium	mg/L	4	4	14.30	15.28	16.10
R-42	F	Manganese	ug/L	4	0	—	—	—
R-42	F	Mercury	ug/L	4	0	—	—	—
R-42	UF	Mercury	ug/L	4	0	—	—	—
R-42	F	Molybdenum	ug/L	4	4	0.48	0.55	0.63
R-42	F	Nickel	ug/L	4	4	26.00	29.48	34.00
R-42	F	Nitrate-Nitrite as Nitrogen	mg/L	4	4	4.75	5.40	5.95
R-42	F	Perchlorate	ug/L	4	4	1.09	1.20	1.28
R-42	F	Potassium	mg/L	4	4	2.20	2.32	2.52
R-42	F	Selenium	ug/L	4	0	—	—	—
R-42	F	Silicon Dioxide	mg/L	4	4	69.10	73.20	75.90
R-42	F	Silver	ug/L	4	0	—	—	—
R-42	F	Sodium	mg/L	4	4	16.80	17.50	18.30
R-42	F	Specific Conductance	uS/cm	4	4	181.00	419.50	530.00
R-42	F	Strontium	ug/L	4	4	196.00	209.25	220.00
R-42	F	Sulfate	mg/L	4	4	77.10	78.50	80.90
R-42	F	Thallium	ug/L	4	0	—	—	—
R-42	F	Tin	ug/L	4	2	4.00	4.33	4.65
R-42	F	Total Dissolved Solids	mg/L	4	4	363.00	380.50	394.00
R-42	UF	Total Kjeldahl Nitrogen	mg/L	4	2	0.07	0.07	0.07
R-42	UF	Total Organic Carbon	mg/L	4	4	0.82	0.91	1.07
R-42	F	Total Phosphate as Phosphorus	mg/L	4	2	0.02	0.04	0.07
R-42	F	Uranium	ug/L	4	4	0.92	0.98	1.03
R-42	F	Vanadium	ug/L	4	4	4.50	4.96	5.46
R-42	F	Zinc	ug/L	4	4	5.88	9.12	14.30
R-42	UF	Acenaphthene	ug/L	2	0	—	—	—
R-42	UF	Acenaphthylene	ug/L	2	0	—	—	—
R-42	UF	Acetone	ug/L	1	0	—	—	—
R-42	UF	Acetonitrile	ug/L	1	0	—	—	—
R-42	UF	Acrolein	ug/L	2	0	—	—	—
R-42	UF	Acrylonitrile	ug/L	2	0	—	—	—
R-42	UF	Aniline	ug/L	1	0	—	—	—
R-42	UF	Anthracene	ug/L	2	0	—	—	—
R-42	UF	Atrazine	ng/L	1	0	—	—	—
R-42	UF	Azobenzene	ug/L	1	0	—	—	—

Location	Field preparation code (F/UF)	Analyte	Units	Number of Analyses	Number of Detects	Min	Avg	Max
R-42	UF	Benzene	ug/L	1	0	—	—	—
R-42	UF	Benzidine	ug/L	2	0	—	—	—
R-42	UF	Benzo(a)anthracene	ug/L	2	0	—	—	—
R-42	UF	Benzo(a)pyrene	ug/L	2	0	—	—	—
R-42	UF	Benzo(b)fluoranthene	ug/L	2	0	—	—	—
R-42	UF	Benzo(g,h,i)perylene	ug/L	2	0	—	—	—
R-42	UF	Benzo(k)fluoranthene	ug/L	2	0	—	—	—
R-42	UF	Benzoic Acid	ug/L	1	0	—	—	—
R-42	UF	Benzyl Alcohol	ug/L	1	0	—	—	—
R-42	UF	Bis(2-chloroethoxy)methane	ug/L	1	0	—	—	—
R-42	UF	Bis(2-chloroethyl)ether	ug/L	2	0	—	—	—
R-42	UF	Bis(2-ethylhexyl)phthalate	ug/L	1	0	—	—	—
R-42	UF	Bromobenzene	ug/L	1	0	—	—	—
R-42	UF	Bromochloromethane	ug/L	1	0	—	—	—
R-42	UF	Bromodichloromethane	ug/L	1	0	—	—	—
R-42	UF	Bromoform	ug/L	1	0	—	—	—
R-42	UF	Bromomethane	ug/L	1	0	—	—	—
R-42	UF	Bromophenyl-phenylether[4-]	ug/L	1	0	—	—	—
R-42	UF	Butanol[1-]	ug/L	1	0	—	—	—
R-42	UF	Butanone[2-]	ug/L	1	0	—	—	—
R-42	UF	Butylbenzene[n-]	ug/L	1	0	—	—	—
R-42	UF	Butylbenzene[sec-]	ug/L	1	0	—	—	—
R-42	UF	Butylbenzene[tert-]	ug/L	1	0	—	—	—
R-42	UF	Butylbenzylphthalate	ug/L	1	0	—	—	—
R-42	UF	Carbon Disulfide	ug/L	1	0	—	—	—
R-42	UF	Carbon Tetrachloride	ug/L	1	0	—	—	—
R-42	UF	Chloro-1,3-butadiene[2-]	ug/L	2	0	—	—	—
R-42	UF	Chloro-1-propene[3-]	ug/L	1	0	—	—	—
R-42	UF	Chloro-3-methylphenol[4-]	ug/L	1	0	—	—	—
R-42	UF	Chloroaniline[4-]	ug/L	1	0	—	—	—
R-42	UF	Chlorobenzene	ug/L	1	0	—	—	—
R-42	UF	Chlorodibromomethane	ug/L	1	0	—	—	—
R-42	UF	Chloroethane	ug/L	1	0	—	—	—
R-42	UF	Chloroform	ug/L	1	0	—	—	—
R-42	UF	Chloromethane	ug/L	1	0	—	—	—
R-42	UF	Chloronaphthalene[2-]	ug/L	2	0	—	—	—
R-42	UF	Chlorophenol[2-]	ug/L	1	0	—	—	—
R-42	UF	Chlorophenyl-phenyl[4-] Ether	ug/L	1	0	—	—	—
R-42	UF	Chlorotoluene[2-]	ug/L	1	0	—	—	—
R-42	UF	Chlorotoluene[4-]	ug/L	1	0	—	—	—
R-42	UF	Chrysene	ug/L	2	0	—	—	—
R-42	UF	Dibenz(a,h)anthracene	ug/L	2	0	—	—	—
R-42	UF	Dibenzofuran	ug/L	1	0	—	—	—
R-42	UF	Dibromo-3-Chloropropane[1,2-]	ug/L	1	0	—	—	—
R-42	UF	Dibromoethane[1,2-]	ug/L	1	0	—	—	—
R-42	UF	Dibromomethane	ug/L	1	0	—	—	—
R-42	UF	Dichlorobenzene[1,2-]	ug/L	2	0	—	—	—
R-42	UF	Dichlorobenzene[1,3-]	ug/L	2	0	—	—	—
R-42	UF	Dichlorobenzene[1,4-]	ug/L	2	0	—	—	—
R-42	UF	Dichlorobenzidine[3,3'-]	ug/L	2	0	—	—	—
R-42	UF	Dichlorodifluoromethane	ug/L	1	0	—	—	—
R-42	UF	Dichloroethane[1,1-]	ug/L	1	0	—	—	—
R-42	UF	Dichloroethane[1,2-]	ug/L	1	0	—	—	—
R-42	UF	Dichloroethene[1,1-]	ug/L	1	0	—	—	—
R-42	UF	Dichloroethene[cis-1,2-]	ug/L	1	0	—	—	—
R-42	UF	Dichloroethene[trans-1,2-]	ug/L	1	0	—	—	—
R-42	UF	Dichlorophenol[2,4-]	ug/L	1	0	—	—	—

Location	Field preparation code (F/UF)	Analyte	Units	Number of Analyses	Number of Detects	Min	Avg	Max
R-42	UF	Dichloropropane[1,2-]	ug/L	1	0	—	—	—
R-42	UF	Dichloropropane[1,3-]	ug/L	1	0	—	—	—
R-42	UF	Dichloropropane[2,2-]	ug/L	1	0	—	—	—
R-42	UF	Dichloropropene[1,1-]	ug/L	1	0	—	—	—
R-42	UF	Dichloropropene[cis-1,3-]	ug/L	1	0	—	—	—
R-42	UF	Dichloropropene[trans-1,3-]	ug/L	1	0	—	—	—
R-42	UF	Diethyl Ether	ug/L	1	0	—	—	—
R-42	UF	Diethylphthalate	ug/L	1	0	—	—	—
R-42	UF	Dimethyl Phthalate	ug/L	1	0	—	—	—
R-42	UF	Dimethylphenol[2,4-]	ug/L	1	0	—	—	—
R-42	UF	Di-n-butylphthalate	ug/L	1	0	—	—	—
R-42	UF	Dinitro-2-methylphenol[4,6-]	ug/L	1	0	—	—	—
R-42	UF	Dinitrophenol[2,4-]	ug/L	1	0	—	—	—
R-42	UF	Dinitrotoluene[2,4-]	ug/L	1	0	—	—	—
R-42	UF	Dinitrotoluene[2,6-]	ug/L	1	0	—	—	—
R-42	UF	Di-n-octylphthalate	ug/L	1	0	—	—	—
R-42	UF	Dinoseb	ug/L	1	0	—	—	—
R-42	UF	Dioxane[1,4-]	ug/L	1	0	—	—	—
R-42	UF	Diphenylamine	ug/L	1	0	—	—	—
R-42	UF	Ethyl Methacrylate	ug/L	1	0	—	—	—
R-42	UF	Ethylbenzene	ug/L	1	0	—	—	—
R-42	UF	Fluoranthene	ug/L	2	0	—	—	—
R-42	UF	Fluorene	ug/L	2	0	—	—	—
R-42	UF	Hexachlorobenzene	ug/L	2	0	—	—	—
R-42	UF	Hexachlorobutadiene	ug/L	2	0	—	—	—
R-42	UF	Hexachlorocyclopentadiene	ug/L	1	0	—	—	—
R-42	UF	Hexachloroethane	ug/L	1	0	—	—	—
R-42	UF	Hexanone[2-]	ug/L	1	0	—	—	—
R-42	UF	Indeno(1,2,3-cd)pyrene	ug/L	2	0	—	—	—
R-42	UF	Iodomethane	ug/L	1	0	—	—	—
R-42	UF	Isobutyl alcohol	ug/L	1	0	—	—	—
R-42	UF	Isophorone	ug/L	1	0	—	—	—
R-42	UF	Isopropylbenzene	ug/L	1	0	—	—	—
R-42	UF	Isopropyltoluene[4-]	ug/L	1	0	—	—	—
R-42	UF	Methacrylonitrile	ug/L	1	0	—	—	—
R-42	UF	Methyl Methacrylate	ug/L	1	0	—	—	—
R-42	UF	Methyl tert-Butyl Ether	ug/L	1	0	—	—	—
R-42	UF	Methyl-2-pentanone[4-]	ug/L	1	0	—	—	—
R-42	UF	Methylene Chloride	ug/L	1	0	—	—	—
R-42	UF	Methylnaphthalene[1-]	ug/L	2	0	—	—	—
R-42	UF	Methylnaphthalene[2-]	ug/L	2	0	—	—	—
R-42	UF	Methylphenol[2-]	ug/L	1	0	—	—	—
R-42	UF	Methylphenol[4-]	ug/L	1	0	—	—	—
R-42	UF	Naphthalene	ug/L	3	0	—	—	—
R-42	UF	Nitroaniline[2-]	ug/L	1	0	—	—	—
R-42	UF	Nitroaniline[3-]	ug/L	1	0	—	—	—
R-42	UF	Nitroaniline[4-]	ug/L	1	0	—	—	—
R-42	UF	Nitrobenzene	ug/L	1	0	—	—	—
R-42	UF	Nitrophenol[2-]	ug/L	1	0	—	—	—
R-42	UF	Nitrophenol[4-]	ug/L	1	0	—	—	—
R-42	UF	Nitrosodiethylamine[N-]	ug/L	2	0	—	—	—
R-42	UF	Nitrosodimethylamine[N-]	ug/L	2	0	—	—	—
R-42	UF	Nitroso-di-n-butylamine[N-]	ug/L	2	0	—	—	—
R-42	UF	Nitroso-di-n-propylamine[N-]	ug/L	2	0	—	—	—
R-42	UF	Nitrosopyrrolidine[N-]	ug/L	2	0	—	—	—
R-42	UF	Oxybis(1-chloropropane)[2,2'-]	ug/L	1	0	—	—	—
R-42	UF	Pentachlorobenzene	ug/L	1	0	—	—	—

Location	Field preparation code (F/UF)	Analyte	Units	Number of Analyses	Number of Detects	Min	Avg	Max
R-42	UF	Pentachlorophenol	ug/L	2	0	—	—	—
R-42	UF	Phenanthrene	ug/L	2	0	—	—	—
R-42	UF	Phenol	ug/L	1	0	—	—	—
R-42	UF	Propionitrile	ug/L	1	0	—	—	—
R-42	UF	Propylbenzene[1-]	ug/L	1	0	—	—	—
R-42	UF	Pyrene	ug/L	2	0	—	—	—
R-42	UF	Pyridine	ug/L	1	0	—	—	—
R-42	UF	Styrene	ug/L	1	0	—	—	—
R-42	UF	Tetrachlorobenzene[1,2,4,5]	ug/L	1	0	—	—	—
R-42	UF	Tetrachloroethane[1,1,1,2-]	ug/L	1	0	—	—	—
R-42	UF	Tetrachloroethane[1,1,2,2-]	ug/L	1	0	—	—	—
R-42	UF	Tetrachloroethene	ug/L	1	0	—	—	—
R-42	UF	Tetrachlorophenol[2,3,4,6-]	ug/L	1	0	—	—	—
R-42	UF	Toluene	ug/L	1	0	—	—	—
R-42	UF	Trichloro-1,2,2-trifluoroethane[1,1,2-]	ug/L	1	0	—	—	—
R-42	UF	Trichlorobenzene[1,2,3-]	ug/L	1	0	—	—	—
R-42	UF	Trichlorobenzene[1,2,4-]	ug/L	2	0	—	—	—
R-42	UF	Trichloroethane[1,1,1-]	ug/L	1	0	—	—	—
R-42	UF	Trichloroethane[1,1,2-]	ug/L	1	0	—	—	—
R-42	UF	Trichloroethene	ug/L	1	0	—	—	—
R-42	UF	Trichlorofluoromethane	ug/L	1	0	—	—	—
R-42	UF	Trichlorophenol[2,4,5-]	ug/L	1	0	—	—	—
R-42	UF	Trichlorophenol[2,4,6-]	ug/L	1	0	—	—	—
R-42	UF	Trichloropropane[1,2,3-]	ug/L	2	0	—	—	—
R-42	UF	Trimethylbenzene[1,2,4-]	ug/L	1	0	—	—	—
R-42	UF	Trimethylbenzene[1,3,5-]	ug/L	1	0	—	—	—
R-42	UF	Vinyl acetate	ug/L	1	0	—	—	—
R-42	UF	Vinyl Chloride	ug/L	1	0	—	—	—
R-42	UF	Xylene tot calc.	ug/L	1	0	—	—	—
R-42	UF	Xylene[1,2-]	ug/L	1	0	—	—	—
R-42	UF	Xylene[1,3-]+Xylene[1,4-]	ug/L	1	0	—	—	—
R-42	UF	Americium-241	pCi/L	1	0	—	—	—
R-42	UF	Cesium-137	pCi/L	1	0	—	—	—
R-42	UF	Cobalt-60	pCi/L	1	0	—	—	—
R-42	UF	Gross alpha	pCi/L	1	0	—	—	—
R-42	UF	Gross beta	pCi/L	1	1	5.38	5.38	5.38
R-42	UF	Neptunium-237	pCi/L	1	0	—	—	—
R-42	UF	Plutonium-238	pCi/L	1	0	—	—	—
R-42	UF	Plutonium-239/240	pCi/L	1	0	—	—	—
R-42	UF	Potassium-40	pCi/L	1	0	—	—	—
R-42	UF	Sodium-22	pCi/L	1	0	—	—	—
R-42	UF	Strontium-90	pCi/L	1	0	—	—	—
R-42	UF	Tritium	pCi/L	1	1	201.00	201.00	201.00
R-42	UF	Uranium-234	pCi/L	1	1	0.81	0.81	0.81
R-42	UF	Uranium-235/236	pCi/L	1	0	—	—	—
R-42	UF	Uranium-238	pCi/L	1	1	0.34	0.34	0.34

— no value entered because there were no detections for the constituent or no applicable standard

highlighted field is for constituents that exceed a standard

Location	Field preparation code (F/UF)	Analyte	Units	Number of Analyses	Number of Detects	Min	Avg	Max
R-45 S1	F	Acidity or Alkalinity of a solution	SU	4	4	7.84	7.885	7.95
R-45 S1	*F*	*Alkalinity-CO3*	*mg/L*	*4*	*0*	—	—	—
R-45 S1	F	Alkalinity-CO3+HCO3	mg/L	4	4	63.7	69.7	85
R-45 S1	*F*	*Aluminum*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	*F*	*Antimony*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	F	Arsenic	ug/L	4	2	1.74	1.82	1.9
R-45 S1	F	Barium	ug/L	4	4	28.3	29.225	30.4
R-45 S1	*F*	*Beryllium*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	F	Boron	ug/L	4	4	16.7	17.35	18.4
R-45 S1	F	Bromide	mg/L	4	1	0.0715	0.0715	0.0715
R-45 S1	*F*	*Cadmium*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	F	Calcium	mg/L	4	4	16.5	17.975	19.1
R-45 S1	F	Chloride	mg/L	4	4	4.69	4.79	4.91
R-45 S1	F	Chromium	ug/L	4	4	27.3	33.95	37.8
R-45 S1	*F*	*Cobalt*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	*F*	*Copper*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	*UF*	*Cyanide (Total)*	*mg/L*	*4*	*0*	—	—	—
R-45 S1	F	Fluoride	mg/L	4	4	0.266	0.288	0.308
R-45 S1	*F*	*Iron*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	*F*	*Lead*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	F	Magnesium	mg/L	4	4	4.76	5.115	5.4
R-45 S1	*F*	*Manganese*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	*UF*	*Mercury*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	F	Molybdenum	ug/L	4	4	0.663	0.73325	0.789
R-45 S1	F	Nickel	ug/L	4	1	0.535	0.535	0.535
R-45 S1	F	Nitrate-Nitrite as Nitrogen	mg/L	4	4	2.75	3.0025	3.47
R-45 S1	F	Perchlorate	ug/L	4	4	0.577	0.59775	0.633
R-45 S1	F	Potassium	mg/L	4	4	1.26	1.3125	1.39
R-45 S1	*F*	*Selenium*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	F	Silicon Dioxide	mg/L	4	4	69.1	71.1	75.5
R-45 S1	*F*	*Silver*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	F	Sodium	mg/L	4	4	10.4	10.825	11.3
R-45 S1	F	Strontium	ug/L	4	4	74.9	77.275	79.3
R-45 S1	F	Sulfate	mg/L	4	4	7.3	7.4475	7.61
R-45 S1	*F*	*Thallium*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	*F*	*Tin*	*ug/L*	*4*	*0*	—	—	—
R-45 S1	F	Total Dissolved Solids	mg/L	4	4	106	139.75	183
R-45 S1	F	Total Phosphate as Phosphorus	mg/L	4	1	0.0286	0.0286	0.0286
R-45 S1	F	Uranium	ug/L	4	4	0.661	0.72775	0.759
R-45 S1	F	Vanadium	ug/L	4	4	4.99	5.08	5.2
R-45 S1	F	Zinc	ug/L	4	1	3.54	3.54	3.54
R-45 S1	UF	Tritium	pCi/L	1	1	5.291	5.291	5.291
R-45 S1	UF	Uranium-234	pCi/L	1	1	0.484	0.484	0.484
R-45 S1	*UF*	*Uranium-235/236*	*pCi/L*	*1*	*0*	—	—	—
R-45 S1	UF	Uranium-238	pCi/L	1	1	0.248	0.248	0.248

Location	Field preparation code (F/UF)	Analyte	Units	Number of Analyses	Number of Detects	Min	Avg	Max
R-45 S2	F	Acidity or Alkalinity of a solution	SU	4	4	8.09	8.165	8.28
R-45 S2	*F*	*Alkalinity-CO3*	*mg/L*	*4*	*0*	—	—	—
R-45 S2	F	Alkalinity-CO3+HCO3	mg/L	4	4	70.7	72.575	73.3
R-45 S2	*F*	*Aluminum*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	*F*	*Antimony*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	F	Arsenic	ug/L	4	1	2.23	2.23	2.23
R-45 S2	F	Barium	ug/L	4	4	29	29.875	30.7
R-45 S2	*F*	*Beryllium*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	F	Boron	ug/L	4	4	19.1	24.3	35.7
R-45 S2	*F*	*Bromide*	*mg/L*	*4*	*0*	—	—	—
R-45 S2	*F*	*Cadmium*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	F	Calcium	mg/L	4	4	15.7	16.95	17.5
R-45 S2	F	Chloride	mg/L	4	4	3.72	3.8025	3.92
R-45 S2	F	Chromium	ug/L	4	4	16.2	17.475	18.4
R-45 S2	*F*	*Cobalt*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	*F*	*Copper*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	*UF*	*Cyanide (Total)*	*mg/L*	*4*	*0*	—	—	—
R-45 S2	F	Fluoride	mg/L	4	4	0.34	0.354	0.376
R-45 S2	*F*	*Iron*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	*F*	*Lead*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	F	Magnesium	mg/L	4	4	4.74	5.08	5.22
R-45 S2	*F*	*Manganese*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	*UF*	*Mercury*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	F	Molybdenum	ug/L	4	4	0.866	0.9135	0.971
R-45 S2	F	Nickel	ug/L	4	4	0.512	0.6995	0.858
R-45 S2	F	Nitrate-Nitrite as Nitrogen	mg/L	4	4	0.672	0.77625	0.86
R-45 S2	F	Perchlorate	ug/L	4	4	0.392	0.40225	0.42
R-45 S2	F	Potassium	mg/L	4	4	1.36	1.4	1.45
R-45 S2	*F*	*Selenium*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	F	Silicon Dioxide	mg/L	4	4	73	75.175	78.4
R-45 S2	*F*	*Silver*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	F	Sodium	mg/L	4	4	10.8	11.25	12
R-45 S2	F	Strontium	ug/L	4	4	69.3	71.575	75.8
R-45 S2	F	Sulfate	mg/L	4	4	4.3	4.41	4.59
R-45 S2	*F*	*Thallium*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	*F*	*Tin*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	F	Total Dissolved Solids	mg/L	4	4	123	137.25	159
R-45 S2	F	Total Phosphate as Phosphorus	mg/L	4	2	0.0196	0.0253	0.031
R-45 S2	F	Uranium	ug/L	4	4	0.682	0.699	0.732
R-45 S2	F	Vanadium	ug/L	4	4	6.84	6.8975	6.96
R-45 S2	*F*	*Zinc*	*ug/L*	*4*	*0*	—	—	—
R-45 S2	UF	Gross beta	pCi/L	1	1	3.33	3.33	3.33
R-45 S2	UF	Tritium	pCi/L	1	1	3.922	3.922	3.922
R-45 S2	UF	Uranium-234	pCi/L	1	1	0.519	0.519	0.519
R-45 S2	*UF*	*Uranium-235/236*	*pCi/L*	*1*	*0*	—	—	—
R-45 S2	UF	Uranium-238	pCi/L	1	1	0.231	0.231	0.231

Location	Field preparation code (F/UF)	Analyte	Units	Number of Analyses	Number of Detects	Min	Avg	Max
R-50 S1	F	Acidity or Alkalinity of a solution	SU	5	5	7.56	7.788	7.99
R-50 S1	*F*	*Alkalinity-CO3*	*mg/L*	*5*	*0*	—	—	—
R-50 S1	F	Alkalinity-CO3+HCO3	mg/L	5	5	57.6	98.16	158
R-50 S1	*F*	*Aluminum*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	*F*	*Antimony*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	F	Arsenic	ug/L	5	3	1.94	2.02	2.09
R-50 S1	F	Barium	ug/L	5	5	17.1	17.8	18.6
R-50 S1	*F*	*Beryllium*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	F	Boron	ug/L	5	4	15.4	16.025	16.7
R-50 S1	F	Bromide	mg/L	5	2	0.0847	0.0909	0.0971
R-50 S1	*F*	*Cadmium*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	F	Calcium	mg/L	5	5	15.7	16.06	16.5
R-50 S1	F	Chloride	mg/L	5	5	7.26	8.096	9.12
R-50 S1	F	Chromium	ug/L	5	5	93.9	104.72	117
R-50 S1	*F*	*Cobalt*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	F	Copper	ug/L	5	1	3.55	3.55	3.55
R-50 S1	*UF*	*Cyanide (Total)*	*mg/L*	*5*	*0*	—	—	—
R-50 S1	F	Fluoride	mg/L	5	5	0.255	0.2844	0.31
R-50 S1	*F*	*Iron*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	*F*	*Lead*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	F	Magnesium	mg/L	5	5	4.55	4.772	4.99
R-50 S1	F	Manganese	ug/L	5	2	2.09	2.2	2.31
R-50 S1	*UF*	*Mercury*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	F	Molybdenum	ug/L	5	5	0.856	0.8798	0.897
R-50 S1	F	Nickel	ug/L	5	5	6.99	7.65	8.34
R-50 S1	F	Nitrate-Nitrite as Nitrogen	mg/L	5	5	0.398	1.6056	2
R-50 S1	F	Perchlorate	ug/L	5	5	0.557	0.5814	0.588
R-50 S1	F	Potassium	mg/L	5	5	1.34	1.476	1.52
R-50 S1	*F*	*Selenium*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	F	Silicon Dioxide	mg/L	5	5	68.8	70.02	71.8
R-50 S1	*F*	*Silver*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	F	Sodium	mg/L	5	5	13.3	13.6	14
R-50 S1	F	Strontium	ug/L	5	5	58.7	63.14	66.6
R-50 S1	F	Sulfate	mg/L	5	5	10.3	11.56	13.2
R-50 S1	*F*	*Thallium*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	*F*	*Tin*	*ug/L*	*5*	*0*	—	—	—
R-50 S1	F	Total Dissolved Solids	mg/L	5	5	131	158.2	187
R-50 S1	F	Total Phosphate as Phosphorus	mg/L	5	2	0.0332	0.0335	0.0338
R-50 S1	F	Uranium	ug/L	5	5	0.47	0.5026	0.549
R-50 S1	F	Vanadium	ug/L	5	5	4.75	4.924	5.05
R-50 S1	F	Zinc	ug/L	5	5	4.16	9.574	12.3
R-50 S1	UF	Gross alpha	pCi/L	2	1	6.92	6.92	6.92
R-50 S1	UF	Gross beta	pCi/L	2	1	4.65	4.65	4.65
R-50 S1	UF	Tritium	pCi/L	3	3	15.974	19.5903333	25.581
R-50 S1	UF	Uranium-234	pCi/L	2	2	0.383	0.3935	0.404
R-50 S1	*UF*	*Uranium-235/236*	*pCi/L*	*2*	*0*	—	—	—
R-50 S1	UF	Uranium-238	pCi/L	2	2	0.173	0.1815	0.19

Location	Field preparation code (F/UF)	Analyte	Units	Number of Analyses	Number of Detects	Min	Avg	Max
R-50 S2	F	Acidity or Alkalinity of a solution	SU	4	4	7.69	7.9375	8.06
R-50 S2	*F*	*Alkalinity-CO3*	*mg/L*	*4*	*0*	—	—	—
R-50 S2	F	Alkalinity-CO3+HCO3	mg/L	4	4	60.2	85.225	160
R-50 S2	*F*	*Aluminum*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	*F*	*Antimony*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	F	Arsenic	ug/L	4	1	2.12	2.12	2.12
R-50 S2	F	Barium	ug/L	4	4	23.3	24.2	25
R-50 S2	*F*	*Beryllium*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	F	Boron	ug/L	4	4	15.1	15.725	16.6
R-50 S2	*F*	*Bromide*	*mg/L*	*4*	*0*	—	—	—
R-50 S2	*F*	*Cadmium*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	F	Calcium	mg/L	4	4	11.2	11.5	11.7
R-50 S2	F	Chloride	mg/L	4	4	2	2.05	2.08
R-50 S2	F	Chromium	ug/L	4	4	3.68	3.82	4
R-50 S2	*F*	*Cobalt*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	*F*	*Copper*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	*UF*	*Cyanide (Total)*	*mg/L*	*4*	*0*	—	—	—
R-50 S2	F	Fluoride	mg/L	4	4	0.332	0.3565	0.377
R-50 S2	*F*	*Iron*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	*F*	*Lead*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	F	Magnesium	mg/L	4	4	3.98	4.07	4.18
R-50 S2	*F*	*Manganese*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	UF	Mercury	ug/L	4	1	1.91	1.91	1.91
R-50 S2	F	Molybdenum	ug/L	4	4	0.99	1.035	1.11
R-50 S2	F	Nickel	ug/L	4	4	0.924	1.056	1.15
R-50 S2	F	Nitrate-Nitrite as Nitrogen	mg/L	4	4	0.482	0.72875	1.43
R-50 S2	F	Perchlorate	ug/L	4	4	0.307	0.317	0.339
R-50 S2	F	Potassium	mg/L	4	4	1.29	1.3525	1.4
R-50 S2	*F*	*Selenium*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	F	Silicon Dioxide	mg/L	4	4	75	77.45	79.4
R-50 S2	*F*	*Silver*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	F	Sodium	mg/L	4	4	10.3	10.725	11.1
R-50 S2	F	Strontium	ug/L	4	4	47.6	49.4	51.4
R-50 S2	F	Sulfate	mg/L	4	4	2.25	2.405	2.49
R-50 S2	*F*	*Thallium*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	*F*	*Tin*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	F	Total Dissolved Solids	mg/L	4	4	109	138	173
R-50 S2	F	Total Phosphate as Phosphorus	mg/L	4	1	0.0324	0.0324	0.0324
R-50 S2	F	Uranium	ug/L	4	4	0.471	0.51175	0.554
R-50 S2	F	Vanadium	ug/L	4	4	6.24	7.02	7.48
R-50 S2	*F*	*Zinc*	*ug/L*	*4*	*0*	—	—	—
R-50 S2	UF	Gross alpha	pCi/L	1	1	4.28	4.28	4.28
R-50 S2	UF	Gross beta	pCi/L	1	1	3.11	3.11	3.11
R-50 S2	UF	Tritium	pCi/L	2	1	4.393	4.393	4.393
R-50 S2	UF	Uranium-234	pCi/L	1	1	0.407	0.407	0.407
R-50 S2	*UF*	*Uranium-235/236*	*pCi/L*	*1*	*0*	—	—	—
R-50 S2	UF	Uranium-238	pCi/L	1	1	0.191	0.191	0.191

ENCLOSURE 7

Schematic of the IX Treatment System and Technical Specifications of the IX Vessels and Resin

EPC-DO-16-063

LA-UR-16-21509

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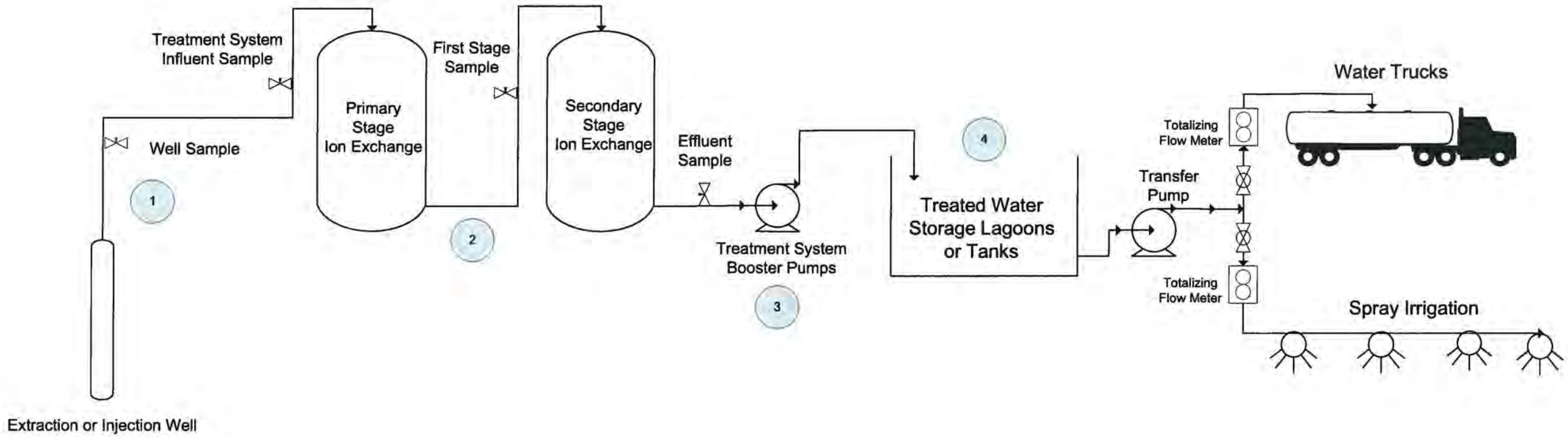
Date: MAR 2 2 2016

LANL Chromium Ion Exchange Treatment Systems



Point 1 Chromium Extraction	Point 2 Ion Exchange Treatment Trains	Point 3 Treatment System Booster Pumps	Point 4 Treated Water Storage Lagoons	Comments
Up to 200 GPM	1-3 trains (primary and secondary IX vessel) at each treatment system	2 pumps (incl spare)	6 single-lined lagoons	One dedicated treatment system stages near well R-28 and a second portable treatment system for use at well sites

USFilter

ION EXCHANGE

USF A-284 ANION RESIN

Description:

USF A-284 is a strong base Type I gel anion resin consisting of a styrene divinylbenzene matrix. The general appearance is a hard spherical bead which is amber in color. This resin has the ability to remove anions and weak acids from aqueous solutions, such as carbonic and silicic acids. This resin is particularly well-suited for low silica effluent requirements.

Chemical Properties

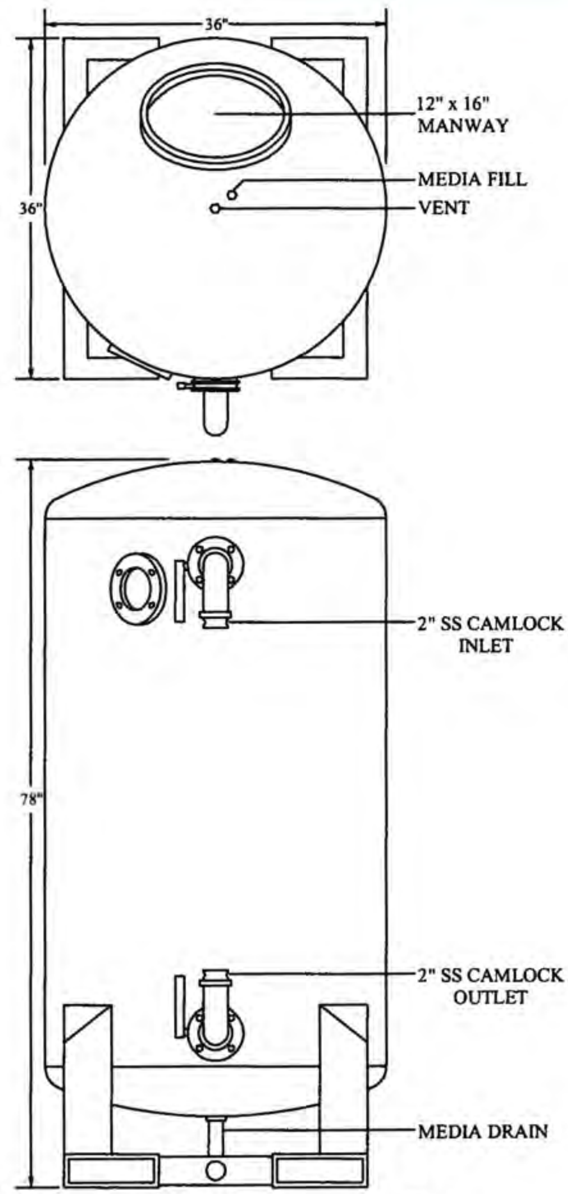
Ionic Form (as shipped)	Chloride
Moisture Content	43 - 48% (Cl form)
Exchange Capacity	1.4 meq / ml minimum (Cl form)
Kinetics	> 15 megohm (USFilter Kinetics Test)

Physical Properties

Particle Screen Sizing	
+16 Mesh	5% maximum
-50 Mesh	1% maximum
Effective Size	0.45 - 0.60 mm
Whole Beads (%)	90 minimum
Shipping Weight	44 lbs. / cu. ft.

Operating Conditions

Operating pH Range	0 to 14
Service Flow Rate	2 - 4 gpm / cu. ft.
Regenerant Flow Rate	0.25 - 0.5 gpm / cu. ft.
Rinse Flow Rate	0.25 - 0.5 gpm / cu ft. initially, then 1.5 gpm / cu. ft.
Rinse Volume	60 - 75 gallons / cu. ft.
Maximum Operating Temperature	140°F



SERVICE FLOW RATE:	25-75gpm
MAX. OPERATING PRESSURE:	100psig
MAX. OPERATING TEMPERATURE:	110°F
WEIGHT (EMPTY):	1,815lbs
WEIGHT (FULL):	3,500lbs

SIEMENS Water Technologies
Roseville, MN
651-638-1300 Fax 651-633-5074

DESIGNER DATE | CHECKER DATE | ENGINEER DATE | MANAGER DATE | FILE: | SCALE:

TITLE | CLIENT | PROJECT | CODE | DRAWING | SHEET OF | REV

STD: BORDER-0106-8X11A

INTL REF:

BAR = 1" AT PLOT SCALE

ENCLOSURE 8

2016 Chromium Groundwater Project
Land Application Layout

EPC-DO-16-063

LA-UR-16-21509

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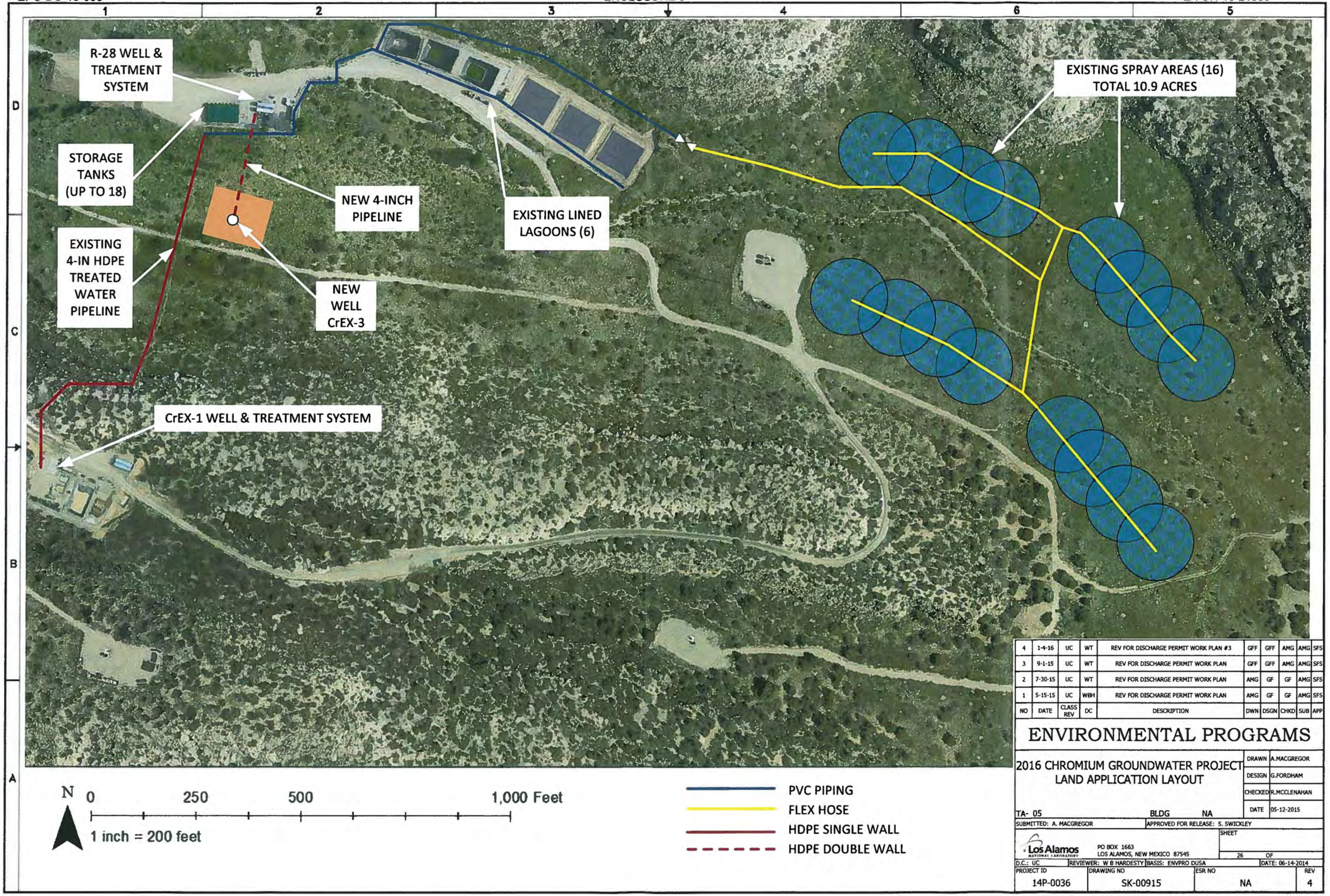
Date: MAR 2 2 2016



NO	DATE	CLASS REV	DC	DESCRIPTION	DWN	DSGN	CHKD	SUB	APP
4	1-4-16	UC	WT	REV FOR DISCHARGE PERMIT WORK PLAN #3	GFF	GFF	AMG	AMG	SFS
3	9-1-15	UC	WT	REV FOR DISCHARGE PERMIT WORK PLAN	GFF	GFF	AMG	AMG	SFS
2	7-30-15	UC	WT	REV FOR DISCHARGE PERMIT WORK PLAN	AMG	GF	GF	AMG	SFS
1	5-15-15	UC	WBH	REV FOR DISCHARGE PERMIT WORK PLAN	AMG	GF	GF	AMG	SFS

ENVIRONMENTAL PROGRAMS

2016 CHROMIUM GROUNDWATER PROJECT LAND APPLICATION LAYOUT

DRAWN	A.MACGREGOR
DESIGN	G.FORDHAM
CHECKED	R.MCCLENAHAN
DATE	05-12-2015

TA- 05 BLDG NA

SUBMITTED: A. MACGREGOR APPROVED FOR RELEASE: S. SWICKLEY

Los Alamos NATIONAL LABORATORY PO BOX 1663 LOS ALAMOS, NEW MEXICO 87545

SHEET 26 OF

D.C.: UC REVIEWER: W B HARDESTY BASIS: ENVPRO DUSA DATE: 06-14-2014

PROJECT ID	DRAWING NO	ESR NO	REV
14P-0036	SK-00915	NA	4

ENCLOSURE 9

Sample Land-Application Zone Signage

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Date: MAR 2 2 2016

SPRAY

NO SPRAY

ZONE 1