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Completion Report for Regional Aquifer Well R-49

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EXECUTIVE SUMMARY

This well completion report describes the drilling, installation, development, and aquifer testing of regional aquifer well R-49, located in Pajarito Canyon, Technical Area 36 (TA-36), at Los Alamos National Laboratory (the Laboratory) in Los Alamos County, New Mexico. This report was written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005, Compliance Order on Consent. The well was installed at the direction of the New Mexico Environment Department (NMED). During planning and the initial phases of drilling, this borehole location was known as PCI-1, which was an intermediate-depth drilling project. The objective of the intermediate-depth well was to characterize the presence and nature of a potential perched groundwater zone, and if groundwater was present, to provide detection monitoring of potential impacts to perched intermediate-depth groundwater from sources at adjacent Material Disposal Area (MDA) G at TA-54. Because the targeted perched water was absent, the decision was made to drill deeper to the regional aquifer, rather than abandon the borehole, and the borehole's name was changed to R-49 to be consistent with naming conventions used for other recent monitoring wells at the Laboratory.

The R-49 borehole was drilled using dual-rotary air-drilling equipment to a total depth (TD) of 977.5 ft below ground surface (bgs). Drilling fluid additives included potable water and foam. Foam-assisted air drilling was used only in the vadose zone and ceased at 577 ft bgs; only small amounts of potable water were added to the air while drilling the roughly 275 ft to and within the regional aquifer. Additive-free drilling provided minimal impacts to the groundwater and formation. The R-49 borehole was successfully drilled to TD using both casing-advance and open-hole drilling methods. A retractable 16-in. casing was advanced through the Bandelier Tuff, Guaje Pumice Bed, and basaltic volcaniclastic sediments to a depth of 198.5 ft bgs. Then a 15-in. open borehole was advanced with fluid-assisted air-rotary methods and a downhole hammer bit through the basaltic volcanic rocks and slightly into altered scoria to a depth of 361.0 ft bgs. Twelve-inch casing was then advanced using an 11 0.625-in. tricone bit to a depth of 576.9 ft bgs in intercalated lavas, breccias, and sediments. Again, drilling open hole, with an 11 0.625-in. bit, the borehole was advanced to 899.5 ft bgs into fluvial clastic sediments. Finally, 10-in. casing was advanced to 977.5 ft bgs in similar sediments.

Well R-49 was completed as a dual-screen well, allowing evaluation of water quality and water levels at two discrete depth intervals within the regional aquifer. The upper 10-ft-long screened interval has the top of the screen set at 845.0 ft bgs within the intercalated dacitic lavas, breccias, and sediments, while the lower 20-ft long screened interval has the top of the screen set at 905.6 ft bgs within fluvial sediments. The composite depth to water after well installation and well development was 832.4 ft bgs. The well screens are separated by a packer as part of the permanent sampling system to ensure isolation of each screen interval.

The well was completed in accordance with an NMED-approved well design and was thoroughly developed and met target water-quality parameters. Hydrogeologic testing indicates that monitoring well R-49 is highly productive and will perform effectively to meet the planned objectives. Water-level transducers have been placed in the upper and lower well screen intervals, and groundwater sampling at R-49 will be performed as part of the facility-wide groundwater-monitoring program.

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Acronyms and Abbreviations

µS/cm	microsiemens per centimeter
AIT	Array Induction Tool
AK	acceptable knowledge
amsl	above mean sea level
APS	Accelerator Porosity Sonde
ASTM	American Society for Testing and Materials
BETCO	barometric and Earth tide correction
bgs	below ground surface
CMR	Combinable Magnetic Resonance
CNT	Compensated Neutron Tool
cu	capture unit
DO	dissolved oxygen
ECS	Elemental Capture Spectroscopy
EES-14	Environmental and Earth Sciences Group
Eh	oxidation-reduction potential
FMI	Formation Micro-Imager
gAPI	American Petroleum Institute gamma ray
GR	gamma ray
HNGS	Hostile Natural Gamma Spectroscopy
ICPMS	inductively coupled (argon) mass spectrometry
ICPOES	inductively coupled (argon) plasma optical emission spectroscopy
I.D.	inside diameter
IDL	instrument detection limit
LANL	Los Alamos National Laboratory
lbf	pound force
MCFL	Micro-Cylindrically Focused Log
mg/C	milligram carbon
ms	millisecond
mV	millivolt
n/a	not applicable
NMED	New Mexico Environment Department
n/r	not recorded
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxidation-reduction potential
PVC	polyvinyl chloride
Qal	Quaternary alluvium

Qbo	Quaternary Otowi Member of the Bandelier Tuff
Qbog	Quaternary Guaje Pumice Bed of Otowi Member of the Bandelier Tuff
QC	quality control
RPF	Records Processing Facility
SOP	standard operating procedure
SWL	static water level
TA	technical area
Tb 4	Tertiary Cerros del Rio basalt
TD	total depth
TDL	Triple Detector Litho-Density
TDS	total dissolved solids
TOC	total organic carbon
Tpf	Tertiary Puye formation
Tjfp	Tertiary (Miocene) pumiceous sediments
Tsfu	Tertiary Santa Fe Group undifferentiated
XRF	x-ray fluorescence

1.0 INTRODUCTION

This completion report summarizes the site preparation, drilling, well construction, well development, aquifer testing, and dedicated sampling system installation for well R-49. The report is written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005, Compliance Order on Consent. During planning and initial drilling, this borehole was known as PCI-1, an intermediate-depth drilling project; however, after the decision was made to advance the borehole to the regional aquifer, the name was changed to R-49 to be consistent with naming conventions used for other recent monitoring wells at the Los Alamos National Laboratory (LANL or the Laboratory). Well R-49 was drilled from March 30 to April 30, 2009, and the well was completed from May 3 to June 1, 2009, at the Laboratory for the LANL Water Stewardship Program.

The R-49 project site is located in Pajarito Canyon in Technical Area 36 (TA-36), Los Alamos County, New Mexico (Figure 1.0-1). The initial purpose of the R-49 monitoring well was to characterize the presence and nature of a potential perched intermediate-depth groundwater zone and if groundwater was present, to provide detection monitoring of potential impacts to perched intermediate-depth groundwater from sources at adjacent Material Disposal Area (MDA) G at TA-54. However, because no significant perched water was detected, the R-49 borehole was deepened to the regional aquifer rather than being abandoned and will now allow monitoring potential impacts to regional groundwater from sources at MDA-G.

The primary objective of the drilling activities at R-49, after the decision to deepen the borehole, was to drill and install a dual-screen regional aquifer monitoring well in the uppermost part of the regional groundwater system. Water-level transducers have been placed in upper and lower well screen intervals to evaluate hydraulic relationships between this well and other nearby monitoring wells. Secondary objectives were to collect drill-cutting samples and conduct borehole geophysical logging.

The R-49 borehole was drilled to a total depth (TD) of 977.5 ft below ground surface (bgs). During drilling, cuttings samples were collected at 5-ft intervals in the borehole from ground surface to TD. A monitoring well was installed with two screens. The upper 10-ft-long screened interval is between 845.0 and 855.0 ft bgs, and the lower 20-ft-long screened interval is between 905.6 and 926.4 ft bgs. The composite depth to water after well installation and well development was 832.4 ft bgs, recorded on June 9, 2009. An inflatable packer isolated the two well screens as part of the well's permanent sampling system and allowed discrete sampling and water-level monitoring of both intervals. Postinstallation activities included well development, aquifer testing, surface completion, sampling system installation, and a geodetic survey. Future activities include site restoration and waste management.

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the Laboratory's Records Processing Facility (RPF). This report contains brief descriptions of activities and supporting figures, tables, and appendixes completed to date associated with the R-49 project. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to the New Mexico Environment Department (NMED) in accordance with U.S. Department of Energy policy.

2.0 PRELIMINARY ACTIVITIES

Preliminary activities included preparing administrative planning documents and predrill preparations at the drill site. All preparatory activities were completed in accordance with Laboratory policies and procedures and regulatory requirements.

2.1 Administrative Preparation

The following documents helped guide the implementation of the scope of work for well R-49: "Drilling Plan for Regional Aquifer Well R-46" (TerranearPMC 2008, 105083); "Integrated Work Document for Regional and Intermediate Aquifer Well Drilling (Mobilization, Site preparation, and Setup Stages)" (LANL 2007, 100972); "Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan" (LANL 2006, 092600); and "Waste Characterization Strategy Form for the R -38, R-41, R-44, R-45, and R-46 Regional Groundwater Well Installation and Corehole Drilling" (LANL 2008, 103916).

2.2 Site Preparation

The R-49 (at the time, PCI-1) drill pad had been prepared by Laboratory personnel several months before mobilization. The drill rig, air compressors, trailers, and support vehicles were mobilized to the drill site on March 29 and 30, 2009. Concurrently, staging of alternative drilling tools and construction materials occurred at the Pajarito Road lay-down yard.

All potable water was obtained from a Pajarito Road fire hydrant at TA-18. Safety barriers and signs were installed around the borehole cuttings containment pit and along the perimeter of the work area.

3.0 DRILLING ACTIVITIES

This section describes the drilling strategy and approach and provides a chronological summary of field activities conducted at monitoring well R-49.

3.1 Drilling Approach

The drilling methodology and selection of equipment and drill-casing sizes for R-49 were designed to retain the ability to case off perched groundwater (those shallower than the initial perched water target) and ensure reaching TD with a sufficiently sized casing to allow well installation with the required 2-in. minimum annular filter pack thickness for a 5.56-in.-outside diameter (O.D.) well. It was anticipated that if shallow perched groundwater was encountered, the zone would be isolated and sealed off with either casing or by cementing to avoid commingling groundwater zones. In the initial (intermediate-depth) well plan, the borehole was to be abandoned if the target depth perched water zone was absent. Instead, the decision was made to deepen the borehole to the regional aquifer when the target intermediate zone was not encountered.

Dual-rotary drilling methods using a Foremost DR-24HD drill rig were employed to drill the R-49 borehole. Dual-rotary drilling has the advantage of simultaneously advancing and casing the borehole. The Foremost DR-24HD drill rig was equipped with conventional drilling rods, tricone bits, downhole hammer bits, a deck-mounted 900 ft^3/min air compressor, and general drilling equipment. Auxiliary equipment included two Sullair 1150 ft^3/min trailer-mounted air compressors. Three sizes of A53 grade B flush-welded mild carbon-steel casing (16-in., 12-in., and 10-in.) were used for the R-49 project. The dual-rotary technique used filtered air and fluid-assisted air to evacuate cuttings from the borehole. Cuttings samples were collected at 5-ft intervals in the borehole from ground surface to TD to characterize the hydrostratigraphy of rock units encountered in the borehole.

Drilling fluids, other than air, used in the vadose zone included municipal water and a mixture of municipal water with Baroid AQF-2 foaming agent. The fluids were used to cool the bit and help lift cuttings from the borehole. Use of foaming agent was terminated at 450 ft but was employed briefly at 577.0 ft bgs, approximately 275 ft above the regional aquifer, to establish circulation. No additives other than municipal water were used for drilling within the regional aquifer. Total amounts of drilling fluids introduced into the borehole and those recovered during well development and aquifer testing are recorded and presented in Table 3.1-1.

3.2 Chronology of Drilling Activities

Mobilization of drilling equipment and supplies to the R-49 drill site occurred on March 29 and 30, 2009. The borehole was initiated (1700 h) near shift-end on March 30 using dual-rotary methods employing 16-in. drill casing and a 15-in. tricone bit. Drilling and advancing 16-in. casing proceeded rapidly through canyon-bottom alluvium, unit 1g of the Tshirege Member (of the Bandelier Tuff), and Otowi Member ash flows to a depth of 177.0 ft bgs where possible perched groundwater was detected in the Guaje Pumice Bed. A water sample was collected (air-lifted) from a water flow initially estimated at 15 gpm, which quickly decreased to 7 gpm in 10 min. Drilling ceased for the day, and the borehole was left open overnight. Upon return to the site on April 1, the water level in the borehole appeared stabilized at 154.1 ft bgs. Drilling resumed and progressed to 193 ft bgs, when a 2- to 3-ft lift of the 16-in. drill casing resulted in an estimated 40 gpm water flow. After drilling ahead to 198.2 ft bgs, the flow dropped to <0.5 gpm. To evaluate this zone, which occurred within basaltic clastics at the top of an interval of basaltic volcanics, the decision was made to retract one joint of casing (20 ft), remove the drill tools, and monitor water levels. With the bottom of the 16-in. casing lifted to 179.4 ft bgs, a water level was measured at 195.2 ft bgs. Later that day, one more casing joint was removed from the casing string (159.6 ft bgs, casing TD) in preparation for logging the borehole. That evening (April 1), Laboratory personnel ran both video and natural gamma ray surveys. The video log showed no evidence of water entering the borehole. An induction log was run the morning of April 2, before 10.5 ft of bentonite was added and hydrated at TD to seal off the perched water zone. The two joints of casing were welded to the casing string and the 16-in. casing advanced and landed at 198.5 ft bgs.

On April 2 (1500 h), open-hole drilling commenced using a 15-in. hammer bit. The next day, after difficult drilling through mixed, largely basaltic lithology to 352 ft bgs, the decision was made to switch bits. The hammer bit was replaced with a 14.75-in. tricone bit, and drilling progressed, but with minor cuttings return, to 361 ft bgs by late in the day on April 4 (1805 h). Because of continuing drilling difficulties, it was decided to cut off the 16-in. casing shoe and drill ahead using dual-rotary methods with smaller tools. The 16-in. casing was cut at 190.0 ft bgs, and a 12-in. casing string started into the borehole the next day. With 119 ft of 12-in. casing hanging in the borehole, Laboratory personnel logged the open-hole section with video, natural gamma ray, and induction surveys on April 6.

Drilling recommenced on April 7 with the 12-in. drill casing and a 12-in. underreaming hammer bit. By the end of the work day on April 10, the borehole TD was at 576.9 ft bgs. Drilling was fairly steady but was accompanied by multiple short intervals of lost circulation. No indications were detected of perched water within the intermediate-composition volcanic section lying below the basaltic volcanic interval. Reconnaissance for water-bearing zones was routinely conducted at each (20 ft) 12-in. casing connection. The next day, the drilling tools were tripped out of the hole, and plans were made to again drill open hole with a hammer bit. Problems obtaining the correct bit to fit inside the 12-in. casing delayed drilling until late in the day on April 16.

After drilling to 663 ft bgs by midafternoon on April 17, the tools were removed from the borehole to allow the Laboratory video camera to investigate a water flow of 20–25 gpm (driller's estimate) observed while penetrating the 620–640-ft bgs interval. The video showed possible water entering the borehole from 610 to 620 ft bgs and standing water at 659.8 ft bgs. It also revealed the borehole wall caked with silty clay. No further drilling occurred that day. A repeat video run the next morning on April 18 indicated that the water observed the day before was likely drilling water and not the targeted perched water zone because no water was present in the bottom of the hole. As a result of the absence of the target perched water interval, the decision was made to advance the borehole to the regional aquifer rather than plug and abandon the borehole.

Open-hole drilling began again immediately and reached 910 ft bgs by the end of the day. Of note, a formational change to rounded, mixed lithology clastics and (likely) regional water was observed at approximately 901 ft bgs. The next day, April 19, after removing the drill tools, a water level was measured at 810.3 ft bgs, and the 12-in. casing was cut at 570.0 ft bgs in preparation for running 10-in. drill casing. Later that day, a Laboratory video survey verified a successful casing cut and showed standing water at 809.9 ft bgs. On April 20, natural gamma ray and induction logs were recorded by Laboratory personnel, followed the next day by additional geophysical logging by Schlumberger Wireline and Testing Services. The latter open-hole suite consisted of Hostile Natural Gamma Spectroscopy (HNGS), Accelerator Porosity Sonde (APS), Formation Micro-Imager (FMI), Combinable Magnetic Resonance (CMR), and Array Induction Tool (AIT) surveys that were run during the evening and morning of April 20–21.

Ten-inch drill casing was started in the borehole midday on April 24, 2009. As casing continued in the borehole, plans were made to evaluate the regional water zone observed at the then current TD by isolating the interval and conducting an informal pump test. On April 26, the 10-in. casing was stopped at 839.6 ft bgs, roughly 70 ft above TD. The next day, after running in a combined packer and pump (pump below packer) assembly and setting the packer at 862 ft bgs, 300 gal. of water was pumped from the borehole. The fluid level in the borehole (i.e., above the packer) was drawn down 26.5 ft (814.7 to 841.2 ft bgs) by 46 min of pumping. On April 28, 90 min of pumping (800 gal.), at rates decreasing from 10 to 7.4 gpm, drew the water level down 39.8 ft (818.2 to 858.0 ft bgs). After the conclusion of pumping, the water level rose to 824.3 ft bgs in 270 min when the packer was deflated. After 130 min, the water level had fallen just slightly and stabilized at 825.7 ft bgs. The pump assembly was removed from the borehole the next day, and several joints of 10-in. casing were added to the existing hanging casing string in preparation for further drilling.

Just before day's end on April 29, dual-rotary drilling using the 10-in. casing and a 9.88-in. tricone bit pushed TD to 918 ft bgs. On April 30, water production from the rig's discharge line, at an estimated 30–35 gpm, was observed while drilling at 953 ft bgs in granite- and quartzite-rich pebbles and cobbles. Formation heaving became an issue at 977.5 ft bgs, and this depth was declared the final borehole TD at 1530 h on April 30. The drilling tools were then removed from the borehole.

Laboratory personnel ran a natural gamma ray log the next morning (May 1), and the water level in the borehole was monitored the remainder of the day; it reached 851.2 ft bgs by 1600 h.

During drilling operations, field crews typically worked a single 12-h shift each day, 7 d/wk. Daily activities proceeded normally without incident except for the short delay in obtaining the correctly sized (O.D.) 12-in. hammer bit and again when determining the course of action to be taken before running in the 10-in. casing to deepen the borehole to the regional aquifer.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater-sampling activities at well R-49. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-49 borehole at 5-ft intervals from ground surface to the TD of 977.5 ft bgs. At each interval, approximately 500 mL of bulk cuttings was collected by the site geologist from the cyclone's discharge, placed in resealable plastic bags, labeled, and archived in core boxes. Sieved fractions (>#10 and >#35 mesh) were also collected (from ground surface to TD) and placed in chip trays along with unsieved (whole rock) cuttings. Recovery of the cuttings samples was excellent (100%) of the borehole.

The core boxes and chip trays were delivered to the Laboratory's archive at the conclusion of drilling activities. Radiation control technicians screened all cuttings before removal from the site. All screening measurements were within the range of background values.

The borehole lithologic log for R-49 is summarized in section 5.1 and detailed in Appendix A.

4.2 Water Sampling

A groundwater-screening sample was first taken at 177 ft bgs from a suspected perched water zone observed while drilling in the Guaje Pumice Bed. Groundwater-screening samples were collected periodically between 554 ft bgs and the top of the regional aquifer to determine if the targeted perched groundwater was present. Typically, upon reaching the bottom of a 20-ft run of casing, the driller would stop water circulation (if injecting water) and circulate air to clean out the borehole. As the discharge cleared, a water sample was collected directly from the discharge hose. Not all depth intervals yielded water at the end of each casing run. Alternatively, some water samples were collected upon start-up of the next casing run after the borehole equilibrated. Table 4.2-1 presents a summary of screening samples collected at well R-49. Analytical results for groundwater-screening samples are presented in Appendix B.

Three paired groundwater-screening samples (six samples total) from depths of 177, 623, and 908 ft bgs were collected during drilling operations by air-lifting water samples through the drill string. These drilling samples were analyzed for anions and metals (one sample from each pair), and tritium (the other sample from each pair).

Six regional groundwater-screening samples were collected during well development: three from the upper screen interval (845.0–855.0 ft bgs) and three from the lower screen interval (905.6–926.4 ft bgs). Development screening samples were analyzed for anions, metals, and total organic carbon (TOC).

Thirteen regional groundwater-screening samples were collected at regular intervals (approximately one sample per 4 h) during aquifer testing. Seven screening samples were collected from the upper screen interval (845.0–855.0 ft bgs), and six screening samples were collected from the lower screen interval (905.6–926.4 ft bgs). The groundwater samples were collected from a surface sampling tee on the riser pipe connected to the discharge port of the submersible pump. Aquifer-testing screening samples were analyzed for dissolved anions, metals, and TOC.

Groundwater-characterization samples were collected from the completed well at the end of the aquifer test from each screen. The samples were analyzed for the full suite of constituents, including radioactive elements; anions/cations; general inorganic chemicals; volatile and semivolatile organic compounds; and stable isotopes of hydrogen, nitrogen, and oxygen. These groundwater analytical results will be reported in the annual update to the "Interim Facility-Wide Groundwater Monitoring Plan."

5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered at R-49 is presented below. The Laboratory's geology task leader and site geologists examined cuttings and geophysical logs to determine geologic contacts and hydrogeologic conditions. Drilling observations, video logging, water-level measurements, and geophysical logs were used to characterize groundwater occurrences encountered at R-49.

5.1 Stratigraphy

The stratigraphy for the R-49 borehole is presented below in order of youngest to oldest geologic units. Lithologic descriptions are based on cuttings samples collected from the rig's cyclone outlet. Cuttings and borehole geophysical logs were used to identify geologic contacts. Figure 5.1-1 illustrates the stratigraphy at R-49. A detailed lithologic log based on analysis of drill cuttings is presented in Appendix A.

5.1.1 Alluvium (0–45 ft bgs)

Alluvial sediments were encountered from ground surface to 45 ft bgs. The upper few feet of this interval represent base coarse gravel used in drill pad construction. Alluvium below 10 ft bgs consists of tuffaceous sediments made up of unconsolidated silty fine to coarse sand with pebble gravel containing detrital materials derived from local tuff and other volcanic rocks. No evidence of alluvial groundwater was observed.

5.1.2 Unit 1g of the Tshirege Member of the Bandelier Tuff, Qbt 1g (45–104 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff was encountered from 45 to 104 ft bgs as interpreted from cuttings and natural gamma ray geophysical log data. This unit is estimated to be 59 ft thick. Unit 1g is recognized by the appearance of vitric pumices as a primary tuff component. The section in R-49 represents ash-flow tuff that is generally poorly welded, strongly pumiceous, crystal- and lithic-bearing with a matrix of weathered to vitric ash. Unit 1g cuttings commonly exhibit pale orange to white glassy, quartz- and sanidine-phyric pumice lapilli, small (less than 5 mm in diameter) subangular volcanic lithic fragments (predominantly dacitic), free quartz and sanidine crystals, and locally abundant orange-tan vitric ash. Indurated fragments of unit 1g tuff are generally not preserved in drill cuttings.

5.1.3 Cerro Toledo Interval, Qct (not present locally)

The Cerro Toledo interval, a section of tuff and tuffaceous sediments that regionally separates the Tshirege and Otowi Members of the Bandelier Tuff, was not observed in the R-49 borehole.

5.1.4 Otowi Member of the Bandelier Tuff, Qbo (104–166 ft bgs)

The Otowi Member of the Bandelier Tuff, encountered in R-49 from 104 to 166 ft bgs, is 62 ft thick as interpreted from cuttings and natural gamma ray geophysical log data. The Otowi Member is a poorly welded, pumiceous, locally lithic-rich, crystal-bearing ash-flow tuff. The Otowi Member locally contains abundant white to pale orange, glassy pumice lapilli (fibrous-textured and quartz- and sanidine-phyric), volcanic lithic fragments (i.e., xenoliths) and moderately abundant quartz and sanidine crystals enclosed in a matrix of vitric ash. Locally abundant subangular lithic fragments (up to 15 mm in diameter) are predominantly of intermediate volcanic compositions that include gray to pinkish gray hornblende- and/or biotite-phyric dacites and andesite. Preserved fragments of Otowi Member tuff are generally not preserved in drill cuttings.

5.1.5 Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (166–185 ft bgs)

The Guaje Pumice Bed occurs in R-49 from 166 to 185 ft bgs on the basis of cuttings and natural gamma ray log interpretation and is locally estimated to be 19 ft thick. This tuff unit is commonly characterized by a predominance of white vitric pumice lapilli. Cuttings suggest that the Guaje Pumice Bed is pumiceous, lithic-rich and crystal-bearing. Abundant subangular to rounded dacitic lithics, quartz and sanidine phenocrysts, and fine ash are present.

5.1.6 Cerros del Rio Basaltic Volcanics, Tb4 (185–310 ft bgs)

A 125-ft-thick section composed of basaltic lavas, breccias, and maar deposits was intersected in R-49 from 185 to 310 ft bgs. The upper 15 ft of this section is made up of clastic basaltic debris, including reddish, very fine-grained sandstone composed of massive and glassy olivine-basalt of possible hydromagnetic origin. A section interpreted to be made up of thin basaltic lavas and interflow breccias was encountered from 200 to 265.5 ft, based on cuttings and natural gamma ray log data. At least two olivine-basaltic flows, each approximately 10 ft thick, were recognized in drill cuttings. Interflow tuff/breccias separating the lavas are characterized by subrounded detrital clasts of vesicular olivine-basalt, vitrophyric basaltic lapilli (i.e., cinders), and minor pumice. An interval of mafic tuff and reworked sediments, from 265.5 to 310 ft bgs, is interpreted to represent basaltic maar deposits. Drill cuttings in this section contain abundant scoriaceous glassy basaltic lapilli with rinds of yellowish palagonitic clay, rounded detrital basaltic granules and pebbles, and fragments of very fine-grained basalt-bearing sandstone.

5.1.7 Cerros del Rio Intermediate-Composition Volcanics, Tb4 (310–897 bgs)

A complex volcanic section made up of intermediate-composition lavas, cinder deposits, sediments, and breccias was intersected in R-49 from 310 to 897 ft bgs. The complete volcanic sequence is estimated to be 587 ft thick. The upper part of the section, from 310 to 559 ft bgs, represents a thick pile of pyroclastic tuff predominantly of rounded, scoriaceous lapilli exhibiting strong to intense brick-red hematite alteration. X-ray fluorescence (XRF) analyses of hand-picked cuttings samples from depths of 335–340 and 545–550 ft indicate these scoria deposits are trachyandesite and basaltic trachyandesite in composition. For simplicity, these scoria deposits are referred to as trachyandesites in Figure 5.1-1. XRF data for a sample collected from a depth of 600 to 605 ft indicate the scoria deposits overlie a trachyandesite lava, tentatively located between a depth of 559 and 611.5 ft. The lower part of the intermediate-composition volcanic complex, intersected from 611.5 to 897 ft bgs, is made up of intercalated dacitic lavas, breccias, and sediments. XRF data for samples collected from depths of 640–645 ft, 715-720 ft, and 880–885 ft confirm that these volcanic rocks are of dacitic composition. Cuttings indicate that these dacitic lavas are homogeneous, massive, and characteristically phenocryst-poor. Lava fragments exhibit phenocrysts (up to 1% by volume) of black opaque clinopyroxene and amber-colored orthophyroxene, commonly in cumulophyric clusters, set in a medium gray aphanitic groundmass. Interflow dacitic breccias are indicated in drill cuttings by the presence of weakly porphyritic dacite with altered aphanitic to glassy groundmass. Thin layers of reworked sediments contain subrounded detrital dacite, basalt, and pumice.

5.1.8 Totavi-Like Gravels, Riverine Sediments (897–977.5 bgs)

An 83-ft-thick section of fluvial sands and gravels, representing axial river deposits associated with the ancestral Rio Grande, was encountered from 897 to the R-49 borehole TD at 977.5 ft bgs. These sediments are characterized by well-rounded pebble clasts composed of diverse volcanic lithologies (e.g., dacite, andesite, rhyolite, basalt, and minor pumice) and equally abundant Precambrian quartzo-feldspathic rocks (e.g., quartzite, granite, and microcline). A 10-ft-thick interlayer of pumice-rich siltstone was identified from 940 to 950 ft bgs. Although these deposits have lithological characteristics in common with the Pliocene Totavi Lentil, their age is uncertain and they may represent the Miocene Chamita Formation.

5.2 Groundwater

Potential perched groundwater was first encountered and sampled while drilling at 177 ft bgs on March 31, 2009. Slight indications of groundwater occurrence persisted to approximately 200 ft bgs. A water level was measured at 195.2 ft bgs (when the borehole was 198.2 ft deep) before drilling ahead. The perched water identified between 177 and 195.2 ft bgs was considered to be legitimate groundwater; however, it was of limited extent, and the drilling process exhausted whatever quantity was present. Subsequent video logs collected with the casing retracted to 159.6 ft bgs showed no water entering the borehole from any of the intervals suspected of producing water during drilling.

An indicated water occurrence over the 620–640 ft bgs interval, detected on April 17, was deemed not to be perched water but was likely drilling fluid. The observed water most likely represents drainage from multiple intervals of lost circulation that occurred while drilling this zone. Borehole video observations indicated that water entering the borehole not only stopped, but previous accumulation in the bottom disappeared entirely after resting the borehole overnight (approximately 13 h). The lack of perched groundwater in the target zone resulted in the decision to drill deeper to the regional aquifer rather than abandon the borehole.

Groundwater was first recognized in the regional aquifer at approximately 901 ft bgs in Totavi-like fluvial clastics on April 18, 2009. After this zone was sampled and evaluated, the borehole was drilled deeper using 10-in. casing, and another more productive groundwater zone was encountered at 953 ft bgs before reaching final TD (977.5 ft bgs). A prewell-construction depth to water measurement of 851.2 ft bgs was taken on May 1, 2009.

Groundwater-screening samples collected during drilling, well development, and aquifer testing are discussed in section 4.2. Groundwater chemistry and field water-quality parameters are discussed in Appendix B. Aquifer testing data and analysis are discussed in Appendix C.

6.0 BOREHOLE LOGGING

Multiple video and geophysical logs were collected during the R-49 drilling project by Laboratory personnel, and a suite of open-hole geophysical logs was recorded by Schlumberger Wireline Services. Jet West Geophysical also recorded two video surveys during well construction. A summary of all video and geophysical logging runs is presented in Table 6.0-1.

6.1 Video Logging

Video logs were run in the uncased borehole by Laboratory personnel to check for the presence of potential perched or regional aquifer groundwater on April 4, 6, 17, 18, and 19, 2009, while drilling the

R-49 borehole. The video runs of April 6 and 19 verified successful cuts of the 16- and 12-in. casing strings. The target perched water zone investigated during the April 17–18 survey was deemed to be drilling fluid.

Laboratory personnel also ran a video inside the 5-in. well casing on May 11, 2009, which showed some bentonite visible on the upper well screen slots. The latter occurred because of bentonite plugging of the 10-in. casing during construction of the well's middle bentonite seal. Jet West Geophysical made two subsequent video runs outside of the well casing in the 10 × 5-in. annulus on May 12 and 13. These videos also showed some bentonite on the upper screen, mostly over the upper 5 ft.

The April 2009 video logs from the borehole are presented on a DVD as part of Appendix D included with this document. Table 6.0-1 provides details of individual video logging runs.

6.2 Geophysical Logging

Laboratory personnel ran natural gamma ray and induction logs on April 1–2, 6, 20, and a gamma ray log only on May 1. A suite of open hole Schlumberger geophysical logs was run on April 20–21, 2009. At the time of the Schlumberger logging, the terminations of the two casing strings in the borehole were located at the following depths: 16-in. casing at 198.5 ft bgs and the 12-in. casing at 576.9 ft bgs. The geophysical suite included HNGS tool , APS, FMI, CMR, and AIT. Files from the Laboratory logging operations and interpretation and details of the Schlumberger logging are presented on CD as part of Appendix E.

Details of the logging operations are presented in Table 6.0-1. The results of the geophysical logging are presented on plots in Appendix E.

7.0 WELL INSTALLATION

R-49 well casing and annular fill were installed between May 3 and June 1, 2009.

7.1 Well Design

The R-49 well was designed with dual screens to monitor groundwater quality near the top of the regional aquifer within intercalated dacitic lavas, breccias, and sediments and deeper in the regional aquifer within fluvial sediments. NMED approved the well design before installation.

7.2 Well Construction

The R-49 monitoring well was constructed of 5.0-in.-inside diameter (I.D.)/5.56-in.-O.D., type A304 stainless-steel threaded casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. The two screened intervals utilize 10-ft lengths of 5.0-in.-I.D. rod-based 0.020-in. wire-wrapped well screen. Compatible external stainless-steel couplers (also type A304 stainless steel fabricated to ASTM A312 standards) were used to join all individual casing and screen sections. The coupled unions between threaded sections were approximately 0.7 ft long. All casing and screen were steam- and pressure-washed on-site before installation. A nominal 2-in.-I.D. steel threaded/coupled tremie pipe string, decontaminated before use, was utilized for delivery of backfill and annular fill materials downhole during well construction.

The placement of annular and backfill materials typically had two components: installing materials and retracting the drill casing accompanied by raising the tremie pipe. As each section of drill casing was cut off the string, it was picked up and laid down. During this part of the process, well casing was hung on a wireline while the drill casing was supported by a ring and slips. Short lengths of 12-in. (6.9-ft casing/shoe) and 16-in. (8.5-ft casing/shoe) drill casing remain in the borehole. Both the 12-in. and 16 in. casing stubs were entombed in bentonite during well construction. All the 10-in. drill casing (and shoe) were removed from the borehole.

Two screened intervals were chosen for the R-49 well design. The upper nominal 10-ft long screened interval had the top of the screen set at 845.0 ft bgs, and the lower nominal 20-ft long screened interval had the top of the screen set at 905.6 ft bgs. A 22.9-ft stainless-steel sump was placed below the bottom of the lower screen. Stainless-steel centralizers (four sets of four) were welded to the well casing approximately 2.0 ft above and below each screen. The Foremost dual-rotary drilling rig remained on-site after drilling the borehole and was used for initial well construction activities; it was later replaced with a Pulstar work-over rig. Figure 7.2-1 presents an as-built schematic showing construction details for the completed well.

Mobilization of initial well construction materials to the R-49 site occurred on May 2, 2009. Before running well casing, approximately 20 ft of backfill (20/40 silica sand) was added to the borehole. On May 3, at 1230 h, 5-in. well casing was started into the wellbore with all casing, screens, and couplers decontaminated before installation. After hanging the well casing at 949.3 ft bgs, more backfill (20/40 and 10/20 sand with a small amount of bentonite chips) was added that brought the top of the backfill to 946.0 ft bgs. A total of 32.0 ft^3 of backfill was installed and consisted of 27.0 ft^3 of 20/40 silica sand, 3.0 ft^3 of 10/20 silica sand, and 2.0 ft^3 of bentonite chips.

After the backfill, a lower seal composed of 0.375-in. chips and minor amount 0.25-in. bentonite pellets (total 7.4 ft^3) was placed from 931.0 to 946.0 ft bgs. Then the lower filter pack was installed from 900.6 to 931.0 ft bgs using 10/20 silica sand and surged to promote compaction (total 10/20 sand: 36.0 ft^3). At the conclusion of surging, it was found that the swab tool/wireline connection had parted and the tool remained downhole. Because the tool was in the well casing (in the sump) and relatively easy to retrieve, the decision was made to proceed with well construction and recover the tool later. A 20/40 silica sand transition was then added on top of the lower sand pack from 897.9 to 900.6 ft bgs (4.0 ft^3).

On May 8, while installing the middle bentonite seal (0.375-in. chip) between the upper and lower screens, the 10-in. casing became plugged with bentonite. To remedy the situation, an inflatable packer was set between the screens in the well casing, and water (head) was added to the 10-in. casing to dislodge the bentonite plug. This proved unsuccessful. As a result, on May 11, all remaining 10-in. casing was pulled from the borehole. On the surface, the bottom two joints of the 10-in. casing were found to contain a 17-ft long annular ring of hydrated bentonite. A video survey using Laboratory equipment run later that day inside the well casing over the upper screen showed traces of bentonite on the screen; the water in the casing was too murky to allow inspection of the lower screen. Over May 11–12, the Foremost dual-rotary drilling rig was swapped out for the Pulstar work-over rig. Jet West Geophysical arrived on-site on May 12 and ran a video survey in the borehole annulus (outside the well casing) over the upper 6 ft of the upper screen—because of the tool's size, the camera would not go deeper. The resulting video also showed some bentonite on the upper screen. The next day, a repeat video (Jet West Geophysical) reached the bottom of the upper screen and showed less bentonite. For the repeat video, the tremie pipe had been lowered to the middle of the upper screen, and 300 gal. of potable water was added to aid visibility. Unfortunately, the visibility did not improve.

While devising a plan to remove the bentonite observed on the upper screen, the previously lost swab tool was successfully fished from the well casing on the morning of May 15.

To deal with the bentonite on the upper screen, a 10-hp pump with a packer 21 ft below the pump was run into the well casing on drop pipe. The configuration of pump and packer allowed surging of the upper screen by setting the packer between the screens, drawing (pumping) water through the upper slots to surface in the drop pipe, turning off the pump, and slowly allowing the water column in the drop pipe to flush back through the upper screen slots. The downhole pump/packer assembly was moved at 2-ft intervals across the upper screen from 845.0 to 855.0 ft bgs, and four surge cycles were conducted per interval. During each surge cycle, the pumped water was visually inspected (at surface) and it remained clear throughout. The surging operation was conducted on May 16 over a continuous period of 12 h.

On May 17, well construction resumed on the middle bentonite seal. Slowly, the seal was installed from 859.7 to 897.9 ft bgs using a total of 23.0 ft^3 bentonite, almost all of which was 0.375-in. chip with a very minor amount of 0.25-in. pellets. Addition of bentonite was followed by several surge cycles with the pump and packer assembly that was used previously to keep the upper screen free of bentonite.

After successfully completing the middle seal, the upper screen filter pack was installed from 840.0 to 859.7 ft bgs using 13.2 ft^3 of 10/20 silica sand. It was then surged using a swab tool to ensure sand compaction. A fine 20/40 silica sand transition was then placed on top of the upper filter pack from 837.2 to 840.0 ft bgs (1.2 ft^3).

Installation of the well's long upper bentonite seal started on May 19 and required a total of 375.9 ft^3 of 0.375-in. chips. This seal was installed from 306.6 to 837.2 ft bgs.

The surface seal, neat Portland cement with <1 wt% Baroid IDP-381, was placed above the upper bentonite seal from 2.9 to 306.6 ft bgs using a total volume of 661.5 ft^3 of cement slurry. The large overage of cement (167% of calculated volume) appeared because of substantial loss in basaltic clastics encountered while drilling from 185 to 200 ft bgs. To remedy the cement loss, a formation "plug" of 40.2 ft^3 of bentonite chips was placed within the surface seal interval from 184.2 to 213.9 ft bgs. Cement addition resumed at the calculated fill volume above the bentonite plug to the surface (2.9 ft bgs). Table 7.2-1 itemizes volumes of all materials used during well construction.

Operationally, well construction proceeded smoothly for the most part, 12 h/d, 7 d/wk, from May 3 (well casing installation) to June 1, 2009—the NMED well construction completion (1415 h). Delays occurred as a result of the bentonite removal from the upper screen and the recovery of the lost swab tool. From May 21 to May 26, field operations ceased over the long Memorial Day weekend.

8.0 POSTINSTALLATION ACTIVITIES

After well installation, the well was developed and aquifer pumping tests were conducted. Total groundwater removed during development and aquifer testing was 65,509 gal. A dedicated dual-zone submersible pump system, including an isolation packer and two transducers, has been installed in the well. The wellhead and surface pad are complete, and a geodetic survey of the wellhead was performed. Site restoration activities will be completed, following final disposition of contained drill cuttings, and groundwater is determined in accordance with the NMED-approved waste decision trees and regulatory requirements.

8.1 Well Development

Well development was conducted between June 3 and 13, 2009. Initially, both screen intervals were bailed and swabbed to remove formation fines in the filter pack and well sump. Bailing and swabbing continued until water clarity visibly improved. Final development was then performed with a submersible pump. The swabbing tool was a 4.5-in.-O.D. 1-in.-thick nylon disc attached to a weighted steel rod. The swabbing tool was lowered by wireline and drawn repeatedly in both directions across the screen intervals. Each interval of swabbing was followed by an interval of bailing to remove fines. After bailing and swabbing, a 5-hp, 4-in.-Grundfos submersible pump was installed in the well for the final stage of well development for the upper screen; a 10-hp pump was used for lower screen development.

During the pumping stage of well development, turbidity, temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and specific conductance parameters were measured. In addition, water samples for TOC analysis were collected. The required values for TOC and turbidity to determine adequate well development are less than 2.0 ppm and less than 5 nephelometric turbidity units (NTUs), respectively. The TOC measurements at the end of R-49 well development were less than 0.8 ppm, and the final turbidity values after aquifer testing were 4.2 NTUs for the upper screen and 2.9 NTUs for the lower screened interval.

Approximately 25,075 gal. of groundwater was purged during well development activities. A discussion of water removed during well development, field water-quality parameters, and analytical results for samples collected during development is summarized below in section 8.1.1 and detailed in Table B.1.2-1 of Appendix B.

8.1.1 Well Development Field Parameters

Field parameters, including pH, temperature, DO, ORP, specific conductance, and turbidity, were measured at regular time intervals during well development. Results and further discussion are provided in Appendix B. Field parameters were measured by collecting aliquots of groundwater from the discharge pipe without the use of a flow-through cell, allowing the samples to be exposed to the atmosphere. This condition probably resulted in a slight variation of field parameters during well development and during the pumping test, most notably, temperature, pH, and DO.

During development of the upper screen, 13 measurements of pH and temperature varied from 7.92 to 8.16 and from 21.97°C to 25.51°C, respectively. Concentrations of DO varied from 2.07 to 5.72 mg/L. ORP values varied from -7.4 to 63.0 millivolts (mV). Specific conductance varied from 132 to 151 microsiemens per centimeter (μS/cm), and turbidity values generally increased from 18.7 to 544 NTUs during well development of the R-49 upper screen.

During development of the lower screen, nine measurements of pH and temperature varied from 8.03 to 8.18 and from 22.12°C to 22.66°C, respectively. Concentrations of DO generally increased from 4.19 to 5.10 mg/L. ORP values varied from -26.4 to -4.1 mV. Specific conductance decreased from 129 to 122 μS/cm, and turbidity values generally decreased from 8.2 to 2.9 NTUs during well development of the R-49 upper screen.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-49 between June 14 and 23, 2009. Several short-duration tests with short-duration recovery periods were performed on the first day of testing for each of the two screen intervals. A 24-h test followed by a 24-h recovery period completed the testing of each screen interval. A 10-hp Grundfos pump was used for the aquifer test on the prolific lower screen interval, the pump was swapped for a 5-hp model for the upper screen testing. Approximately 40,434 gal. of groundwater was purged during aquifer testing activities. The results of the R-49 aquifer tests are presented in Appendix C.

8.2.1 Aquifer Testing Field Parameters

Field parameters, including pH, temperature, DO, ORP, specific conductance, and turbidity, were measured at regular time intervals during aquifer testing in the same manner as during well development. Parameters were measured by collecting aliquots of groundwater from the discharge pipe without the use of a flow-through cell, allowing the samples to be exposed to the atmosphere. This condition probably resulted in a slight variation of field parameters during well development and during the pumping test, most notably, temperature, pH, and DO. Results are provided in Appendix B.

8.3 Dedicated Sampling System Installation

The dedicated sampling system for R-49 has been installed. The system is a Baski Inc.-manufactured system that utilizes a single 2-hp, 4-in.-O.D. environmentally retrofitted Grundfos submersible pump capable of purging each screen interval discretely via pneumatically actuated access port valves. The system includes a viton-wrapped isolation packer between the screen intervals. Pump riser pipe consists of threaded and coupled nonannealed 1-in.-diameter stainless steel. Two 1-in.-diameter schedule 80 polyvinyl chloride (PVC) tubes are installed along with and banded to the pump riser for dedicated transducers. The upper PVC transducer tube is equipped with a 6-in. section of 0.010-in. slot screen with a threaded end cap at the bottom of the tube. The lower PVC transducer tube is equipped with a flexible nylon tube that extends from a threaded end cap at the bottom of the PVC tube to the isolation packer and measures water levels in the lower screen interval. Two In-Situ Level Troll 500 transducers have been installed in the PVC tubes to monitor water levels in each screen interval. Postinstallation construction and sampling system component installation details for R-49 are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 6 in. thick, was installed at the R-49 well head in July 2009. The pad will provide long-term structural integrity for the well. A brass survey monument imprinted with well identification information was placed in the northwest corner of the pad. A 10-in.-I.D. steel protective casing with a locking lid was installed around the stainless-steel well riser. A weep hole was installed to prevent water buildup inside the protective casing. The concrete pad is slightly elevated above the ground surface to promote runoff. A total of four bollards, painted yellow for visibility, are set at the outside corners of the pad to protect the well from traffic. All of the four bollards are designed for easy removal to allow access to the well. Details of the wellhead completion are presented in Figure 8.3-1a.

8.5 Geodetic Survey

A New Mexico licensed professional land surveyor conducted a geodetic survey on August 24, 2009, (Table 8.5-1). The survey data collected conforms to Laboratory Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA-D802, “Geospatial Positioning Accuracy Standard for A/E/C and Facility Management.” All coordinates are expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83); elevation is expressed in feet above mean sea level using the National Geodetic Vertical Datum of 1929. Survey points include ground-surface elevation near the concrete pad, the top of the brass pin in the concrete pad, the top of the well casing, and the top of the protective casing. Survey results are summarized in Figure 8.3-1b.

8.6 Waste Management and Site Restoration

Waste generated from the R-49 project includes decontamination water, drilling fluids, purged groundwater, drill cuttings, and contact waste. A summary of the waste characterization samples collected from the R-49 well is presented in Table 8.6-1.

All waste streams produced during drilling and development activities were sampled in accordance with “Waste Characterization Strategy Form for the R-38, R-41, R-44, R-45, and R-46 Regional Groundwater Well Installation and Corehole Drilling” (LANL 2008, 103916).

Fluids produced during drilling and well development are expected to be land-applied after a review of associated analytical results per the waste characterization strategy form and the EP-Directorate Standard Operating Procedure (SOP) 010.0, Land Application of Groundwater. If it is determined that drilling fluids are nonhazardous but cannot meet the criterion for land application, the drilling fluids will be evaluated for treatment and disposal at one of the Laboratory’s six wastewater treatment facilities. If analytical data indicate that the drilling fluids are hazardous/nonradioactive or mixed low-level waste, the drilling fluids will be disposed of at an authorized facility.

Cuttings produced during drilling are anticipated to be land-applied after a review of associated analytical results per the waste characterization strategy form and ENV-RCRA SOP-011.0, Land Application of Drill Cuttings. If the drill cuttings do not meet the criterion for land application, they will be removed from the pit and disposed of at an authorized facility. Characterization of contact waste will be based upon acceptable knowledge (AK), pending analyses of the waste samples collected from the drill cuttings, and purge water. Decontamination fluid used for cleaning the drill rig and equipment is containerized. The fluid waste was sampled and will be disposed of at an authorized facility.

Site restoration activities will include removing drilling fluids and cuttings from the pit and managing the fluids and cuttings in accordance with SOP-010.06, removing the polyethylene liner, removing the containment area berms, and backfilling and regrading the containment area, as appropriate.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

R-49 was originally named PCI-1 in the “Drilling Work Plan for Regional and Intermediate Wells at Technical Area 54” (LANL 2007, 099662). PCI-1 was designed to determine if perched intermediate groundwater occurs beneath Pajarito Canyon near MDA G, and if present, to provide detection monitoring for contaminants. The target depth of 654 ft for PCI-1 was designed to intersect a perched groundwater identified to the east at well R-23i. The objectives of PCI-1 were satisfied when the borehole reached 654-ft depth, and no zones of perched groundwater of sufficient size for a well were encountered. The work plan states that PCI-1 would be plugged and abandoned if the borehole did not encounter perched groundwater. Because of uncertainties about local hydraulic gradients near MDA G, based on recently installed wells R-39 and R-41, the Laboratory, in consultation with NMED, decided to complete PCI-1 as a regional monitoring well to augment the MDA G monitoring network. Because of the conversion to a regional well, PCI-1 was renamed R-49 to be consistent with the Laboratory’s naming convention for regional monitoring wells.

10.0 ACKNOWLEDGMENTS

Boart Longyear drilled the R-49 borehole and installed the well.

Jet West Geophysical ran all downhole video equipment.

Schlumberger Wireline Services performed the final geophysical logging of the borehole.

Patrick Longmire wrote Appendix B, Groundwater Analytical Results.

David Schafer designed, conducted, and prepared Appendix C, Aquifer Testing Report.

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

11.0 REFERENCES AND MAP SOURCES

11.1 References

The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's RPF and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

LANL (Los Alamos National Laboratory), March 2006. "Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan," Los Alamos National Laboratory document LA-UR-06-1840, Los Alamos, New Mexico. (LANL 2006, 092600)

LANL (Los Alamos National Laboratory), October 4, 2007. "Integrated Work Document for Regional and Intermediate Aquifer Well Drilling (Mobilization, Site Preparation and Setup Stages)," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2007, 100972)

LANL (Los Alamos National Laboratory), November 2007. "Drilling Work Plan for Regional and Intermediate Wells at Technical Area 54," Los Alamos National Laboratory document LA-UR-07-7578, Los Alamos, New Mexico. (LANL 2007, 099662)

LANL (Los Alamos National Laboratory), October 2008. "Waste Characterization Strategy Form for the R 38, R-41, R-44, R-45, and R-46 Regional Groundwater Well Installation and Corehole Drilling," Los Alamos, New Mexico. (LANL 2008, 103916)

TerranearPMC, December 2008. "Drilling Plan for Regional Aquifer Well R-46," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2008, 105083)

11.2 Map Data Sources

Point Feature Locations of the Environmental Restoration Project Database; Los Alamos National Laboratory, Waste and Environmental Services Division, EP2008-0109; February 28, 2008.

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

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

Paved Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; January 6, 2004; as published January 4, 2008.

Dirt Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; January 6, 2004; as published January 4, 2008.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; January 6, 2004; as published January 4, 2008.

Technical Area Boundaries; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Division; September 19, 2007.

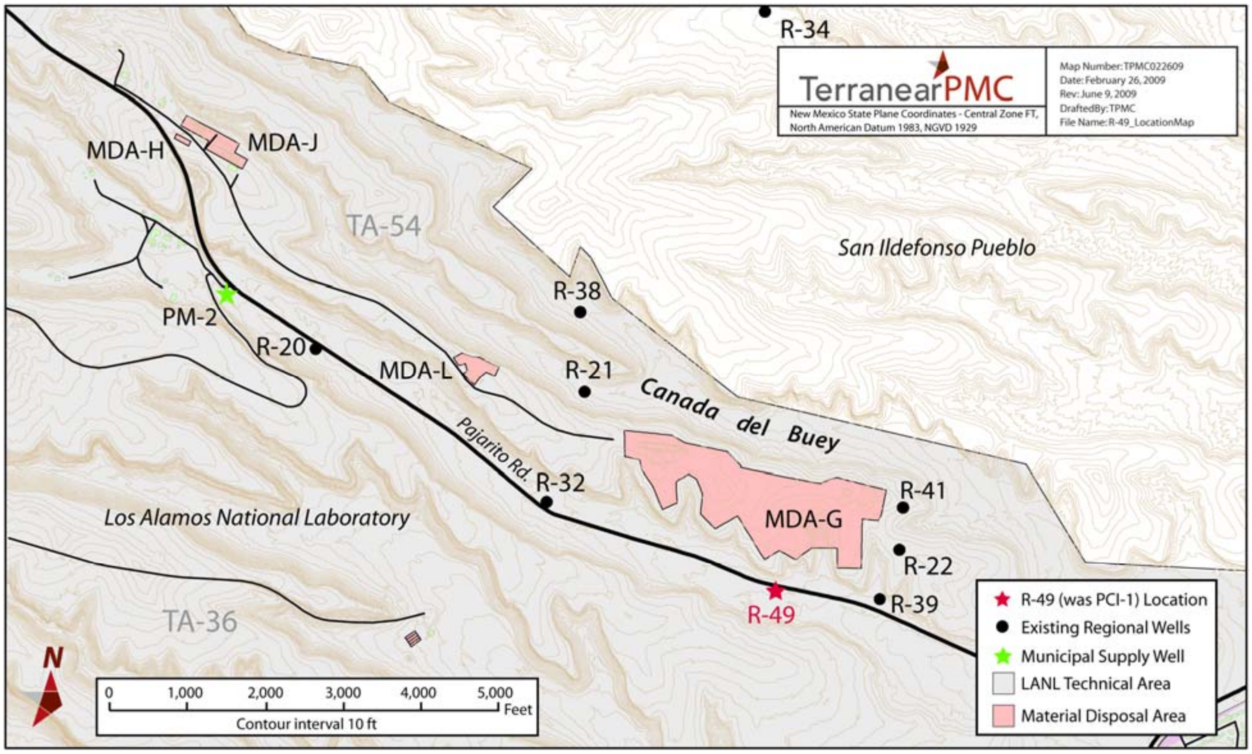

Figure 1.0-1 Regional aquifer well R-49 with respect to surrounding regional wells

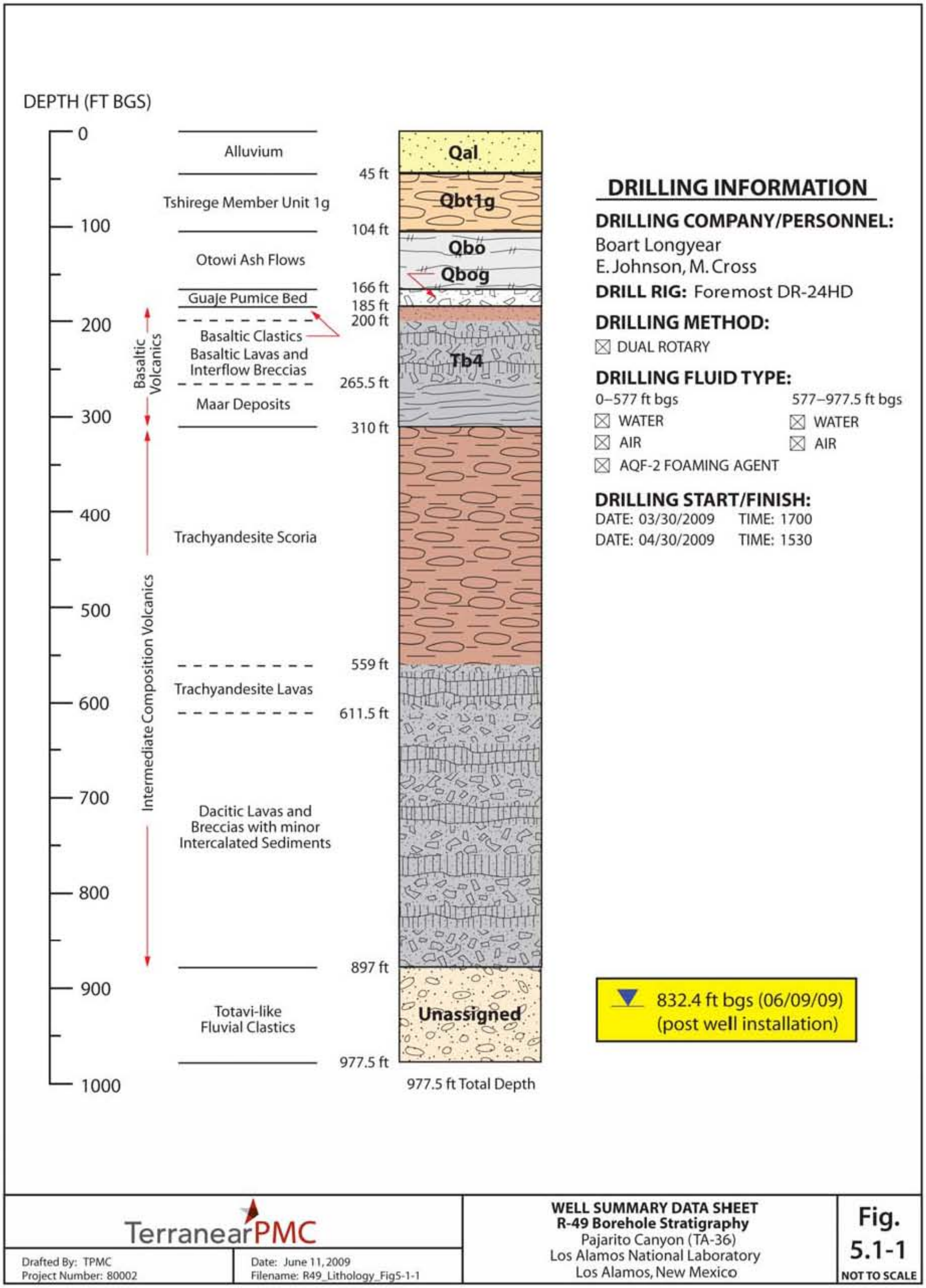

Figure 5.1-1 R-49 borehole stratigraphy

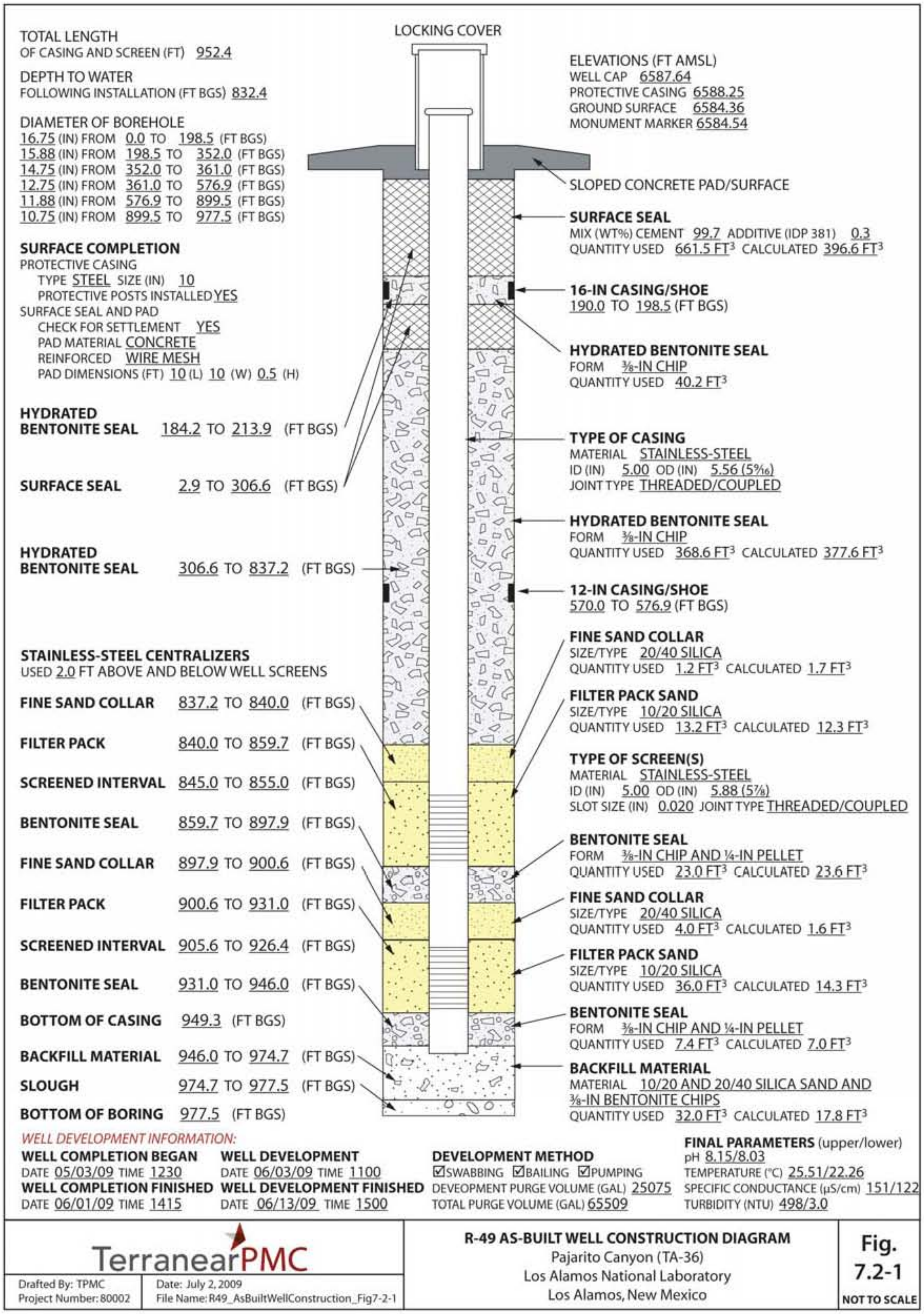

Figure 7.2-1 R-49 as-built well construction diagram

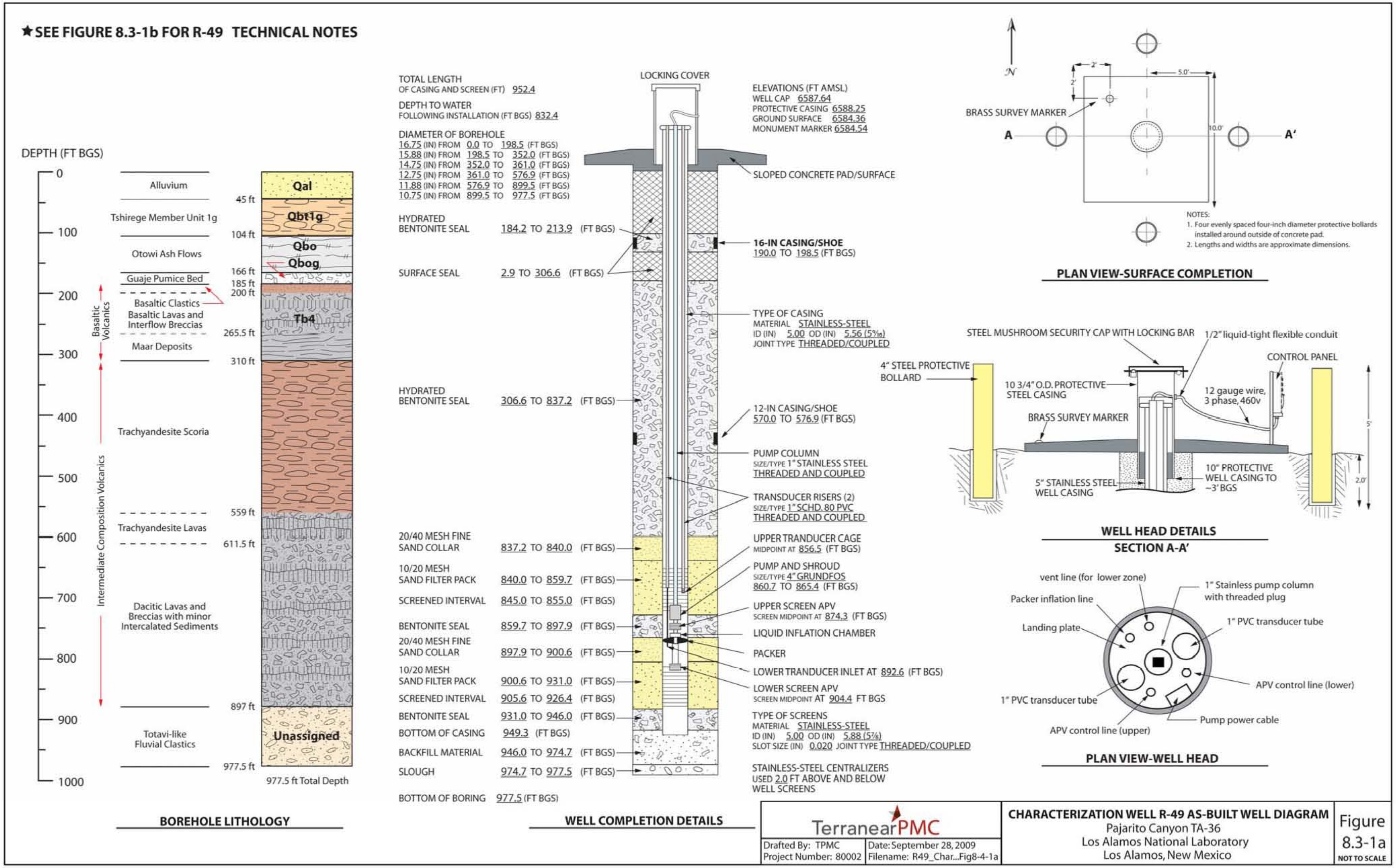

Figure 8.3-1a As-built schematic for regional well R-49

R-49 TECHNICAL NOTES: *

SURVEY INFORMATION[2]

Brass Marker

Northing:	1756401.85 ft
Easting:	1643900.90 ft
Elevation:	6584.54 ft AMSL

Well Casing (top of stainless steel)

Northing:	1756396.44 ft
Easting:	1643903.62 ft
Elevation:	6587.64 ft AMSL

BOREHOLE GEOPHYSICAL LOGS

LANL: natural gamma ray, induction (× 3)
Schlumberger: HNGS, APS, FMI, CMR, AIT

DRILLING INFORMATION

Drilling Company
Boart Longyear

Drill Rig
Foremost DR-24HD

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

Drilling Fluids
Air, potable water, AQF-2 Foam

MILESTONE DATES

Drilling

Start:	03/30/2009
Finished:	04/30/2009

Well Completion

Start:	05/03/2009
Finished:	06/01/2009

Well Development

Start:	06/03/2009
Finished:	06/13/2009

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Total Volume Purged: 25075 gallons (both screens)

Parameter Measurments (Final, upper screen/lower screen)

pH:	8.15/8.03
Temperature:	25.51/22.26°C
Specific Conductance:	151/122 μS/cm
Turbidity:	498/3.0 NTU

AQUIFER TESTING

Constant Rate Pumping Tests

Upper Screen

Water Produced:	2413 gallons
Average Flow Rate:	1.5 gpm
Performed on:	06/14–18/2009

Lower Screen

Water Produced:	38021 gallons
Average Flow Rate:	23.3 gpm
Performed on:	06/19–23/2009

DEDICATED SAMPLING SYSTEM

Pump
Type: Grunfos
Model: 5520-39DS
5 U.S. gpm, APVs (Access Port Valves) midpoints at 874.3 (Upper) and 904.4 (Lower) ft bgs

Motor
Type: Franklin Electric
Model: 2343258600
2hp, 3-phase

Pump Column
1-in. threaded/coupled sched. 40
stainless-steel tubing

Transducer Tubes
1-in. flush threaded schd. 80 PVC tubing
Upper: 0.01-in. slot screen at 856.2–856.8 ft bgs
Lower: flexible tube from transducer set at 892.6 ft bgs

Transducers
Make: In-Situ, Inc.
Model: Level TROLL 500
30 psig range (vented)
S/N: 149360, 149409

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

TerranearPMC
Drafted By: TPMC
Project Number: 80002
Date: September 28, 2009
Filename: R49_TechnicalNotes_Fig8-3-1b

R-49 TECHNICAL NOTES
Pajarito Canyon (TA-36)
Los Alamos National Laboratory
Los Alamos, New Mexico

Figure 8.3-1b
NOT TO SCALE

Figure 8.3-1b As-built technical notes for R-49

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

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
Drilling				
03/30/09	200	200	2	2
03/31/09	1000	1200	4	6
04/01/09	100	1300	1	7
04/02/09	1500	2800	10	17
04/03/09	5000	7800	15	32
04/04/09	300	8100	0	32
04/07/09	300	8400	0	32
04/08/09	3000	11,400	3	35
04/09/09	3500	14,900	tr[a]	35
04/10/09	5000	19,900	tr	35
04/14/09	300	20,200	0	35
04/16/09	100	20,300	0	35
04/17/09	300	20,600	0	35
04/18/09	1000	21,600	0	35
04/19/09	100	21,700	0	35
04/27/09	–300[b]	21,400	0	35
04/28/09	–802[b]	20,598	0	35
04/29/09	50	20,648	0	35
04/30/09	200	20,848	0	35
Well Construction				
05/05/09	1500	22,348	n/a[c]	35
05/06/09	1000	23,348	n/a	35
05/07/09	2500	25,848	n/a	35
05/08/09	5000	30,848	n/a	35
05/09/09	250	31,098	n/a	35
05/13/09	300	31,398	n/a	35
05/15/09	–211[b]	31,187	n/a	35
05/16/09	–851[b]	30,336	n/a	35
05/17/09	200	30,536	n/a	35
05/18/09	2500	33,036	n/a	35
05/19/09	1200	34,236	n/a	35
05/20/09	2500	36,736	n/a	35
05/27/09	700	37,436	n/a	35
05/28/09	500	37,936	n/a	35

Table 3.1-1 (continued)

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
Well Construction				
05/30/09	1000	38,936	n/a	35
05/31/09	800	39,736	n/a	35
06/01/09	1300	41,036	n/a	35
Total Volume (gal.)				
R-49	41,036			

Note: Foam use terminated before completing drilling activities; none used during well construction.

[a] tr = Trace (<16 oz).

[b] = Water removed by pumping.

[c] n/a = Not applicable.

Table 4.2-1
Summary of Groundwater-Screening Samples Collected during Drilling, Well Development, and Aquifer Testing of Well R-49

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Drilling					
R-49	CAPA-09-7021	03/31/09	177	Groundwater, air-lifted	Anions, metals
R-49	CAPA-09-7061	03/31/09	177	Groundwater, air-lifted	Tritium
R-49	CAPA-09-7022	04/17/09	623	Groundwater, air-lifted	Anions, metals
R-49	CAPA-09-7062	04/17/09	623	Groundwater, air-lifted	Tritium
R-49	CAPA-09-7023	04/18/09	908	Groundwater, air-lifted	Anions, metals
R-49	CAPA-09-7063	04/18/09	908	Groundwater, air-lifted	Tritium
Development					
R-49	CAPA-09-7042	06/10/09	905.6–926.4	Groundwater, pumped, lower screen	Anions, metals, TOC
R-49	CAPA-09-7043	06/10/09	905.6–926.4	Groundwater, pumped, lower screen	Anions, metals, TOC
R-49	CAPA-09-7044	06/10/09	905.6–926.4	Groundwater, pumped, lower screen	Anions, metals, TOC
R-49	CAPA-09-7045	06/12/09	845.0–855.0	Groundwater, pumped, upper screen	Anions, metals, TOC
R-49	CAPA-09-7046	06/13/09	845.0–855.0	Groundwater, pumped, upper screen	Anions, metals, TOC
R-49	CAPA-09-7047	06/13/09	845.0–855.0	Groundwater, pumped, upper screen	Anions, metals, TOC

Table 4.2-1 (continued)

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Pump Testing					
R-49	CAPA-09-7048	06/17/09	905.6–926.4	Groundwater, pumped, lower screen	Anions, metals, TOC
R-49	CAPA-09-7049	06/17/09	905.6–926.4	Groundwater, pumped, lower screen	Anions, metals, TOC
R-49	CAPA-09-7050	06/17/09	905.6–926.4	Groundwater, pumped, lower screen	Anions, metals, TOC
R-49	CAPA-09-7051	06/17/09	905.6–926.4	Groundwater, pumped, lower screen	Anions, metals, TOC
R-49	CAPA-09-7052	06/18/09	905.6–926.4	Groundwater, pumped, lower screen	Anions, metals, TOC
R-49	CAPA-09-7053	06/18/09	905.6–926.4	Groundwater, pumped, lower screen	Anions, metals, TOC
R-49	CAPA-09-7054	06/22/09	845.0–855.0	Groundwater, pumped, upper screen	Anions, metals, TOC
R-49	CAPA-09-7055	06/22/09	845.0–855.0	Groundwater, pumped, upper screen	Anions, metals, TOC
R-49	CAPA-09-7056	06/22/09	845.0–855.0	Groundwater, pumped, upper screen	Anions, metals, TOC
R-49	CAPA-09-7057	06/22/09	845.0–855.0	Groundwater, pumped, upper screen	Anions, metals, TOC
R-49	CAPA-09-7058	06/22/09	845.0–855.0	Groundwater, pumped, upper screen	Anions, metals, TOC
R-49	CAPA-09-7059	06/23/09	845.0–855.0	Groundwater, pumped, upper screen	Anions, metals, TOC
R-49	CAPA-09-7060	06/23/09	845.0–855.0	Groundwater, pumped, upper screen	Anions, metals, TOC

Table 6.0-1
R-49 Video and Geophysical Logging Runs

Date	Depth (ft bgs)	Description
04/01/09	198.3	Ran LANL video and natural gamma ray tools with 16-in. drill casing pulled back to approximately 160 ft bgs.
04/02/09	198.3	Finish logging suite started yesterday. Ran LANL induction tool.
04/06/09	342.0	Ran LANL video, natural gamma ray, and induction logs over open-hole section of borehole. Video shows a clean cut in the 16-in. casing and a standing water level at 334 ft bgs. Appears to be approximately 20 ft of fill in the borehole.
04/17/09	663.5	Ran LANL video log over newly drilled open-hole section. Video shows possible water entering the borehole from 610 to 620 ft bgs and standing water at 659.8 ft bgs.
04/18/09	663.5	Rerun the LANL video camera over open-hole section. In this run, the video shows no significant water entering the borehole.
04/19/09	903.9	Ran LANL video tool, which verified 12-in. casing cut and standing water in the borehole at 809 ft bgs.
04/20/09	901.7	Finished logging suite started yesterday. Ran LANL natural gamma ray and induction tools.
04/20–21/09	901.7	Schlumberger ran an open-hole suite consisting of HNGS, APS, FMI, CMR, and AIT surveys.
05/01/09	977.5	Ran LANL natural gamma ray log over the bottom portion of the borehole.
05/11/09	~925	Ran LANL video camera inside 5.5-in. well casing to view possible bentonite plugging of upper screen during well construction. Some bentonite observed at top and bottom of upper screen. Lower screen slots not visible because of water turbidity .

Table 6.0-1 (continued)

Date	Depth (ft bgs)	Description
05/12/09	~851	Run Jet West Geophysical video camera in 12 × 5.5-in. annular void to investigate possible bentonite location and plugging of the upper well screen. Partially unsuccessful because of camera refusing to go below 851 ft bgs—6 ft below the upper screen top. Some bentonite observed on portion of screen viewed and in annulus. Note: Jet West measured depths off slightly (possible wireline wrap of well casing), actual screen depths referenced.
05/13/06	~855	Jet West Geophysical rerun of video camera in 12 × 5.5-in. annular void, managed to get to bottom of upper screen by lowering tremie to midscreen. Less bentonite observed than on 05/12 run (day before).

Table 7.2-1
R-49 Annular Fill Materials

Material	Volume (ft^3)
Surface seal: cement slurry	661.5
Surface formation plug: bentonite chips	40.2
Upper seal: bentonite chips	375.9
Upper (upper) fine sand collar: 20/40 silica sand	1.2
Upper filter pack: 10/20 silica sand	13.2
Middle seal: bentonite chips and pellets	23.0
Upper (lower) fine sand collar: 20/40 silica sand	4.0
Lower filter pack: 10/20 silica sand	36.0
Lower seal: bentonite chips and pellets	7.4
Backfill: 10/20 and 20/40 silica and minor amount of bentonite chips	32.0

Table 8.5-1
R-49 Survey Coordinates

Identification	North	East	Elevation
R-49 brass pin embedded in pad	1756401.85	1643900.90	6584.54
R-49 ground surface near pad	1756396.34	1643898.35	6584.36
R-49 top of 10-in. protective casing	1756396.52	1643903.34	6588.25
R-49 top of stainless-steel well casing	1756396.44	1643903.62	6587.64

Notes: All coordinates are expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83). Elevation is expressed in feet above mean sea level using the National Geodetic Vertical Datum of 1929.

Table 8.6-1
Summary of Waste Samples Collected during Drilling and Development of R-49

Location ID	Sample ID	Date Collected	Description	Sample Type
R-49	n/a*	n/a	Contact waste, use AK from drill cuttings	Solid
R-49	RC54-09-5719	6/08/09	Drilling fluid	Liquid
R-49	RC54-09-5720	6/08/09	Drilling fluid	Liquid
R-49	RC54-09-5721	6/08/09	Drilling fluid	Liquid
R-49	RC54-09-5722	6/08/09	Drilling fluid	Liquid
R-49	RC54-09-5741	6/4/09	Drill cuttings	Solid
R-49	RC54-09-5742	6/4/09	Drill cuttings	Solid
R-49	CAPA-09-8102	6/29/09	Petroleum-contaminated soil	Solid
R-49	CAPA-09-8103	6/29/09	Petroleum-contaminated soil	Solid
R-49	CAPA-09-8104	6/29/09	Petroleum-contaminated soil	Solid
R-49	RC54-09-5731	6/22/09	Development water	Liquid
R-49	RC54-09-5732	6/22/09	Development water	Liquid
R-49	RC54-09-5733	6/22/09	Development water	Liquid
R-49	RC54-09-5734	6/22/09	Development water	Liquid
R-49	RC54-09-5779	6/29/09	Decon fluid	Liquid
R-49	RC54-09-5780	6/29/09	Decon fluid	Liquid
R-49	RC54-09-5781	6/29/09	Decon fluid	Liquid
R-49	RC54-09-5782	6/29/09	Decon fluid	Liquid

* n/a = Not applicable.

Appendix A

Well R-49 Lithologic Log

Los Alamos National Laboratory
Regional Hydrogeologic Characterization Project
Borehole Lithologic Log

COREHOLD IDENTIFICATION (ID): R-46	**Technical Area (TA):** 63	**PAGE**: 1 of 25
DRILLING COMPANY: Boart Longyear Company	**START DATE/TIME**: 12/13/08: 1215	**END DATE/TIME**: 02/05/09: 1235
Drilling Method: Dual Rotary	**MACHINE**: Foremost DR24 HD	**Sampling Method**: Grab
Ground Elevation:		**TOTAL DEPTH**: 1415 ft below ground surface (bgs)
DRILLERS: C. Johnson, J. Staloch	**SITE GEOLOGISTS**: C. Pigman, J.R. Lawrence	

Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
0–10	**ALLUVIUM:** Construction fill—pale reddish brown (10R 5/4), unconsolidated silty pebble gravel with fine to coarse sand, detritus of mixed volcanic clasts (dacite, black-orange vitrophyre) and exotic quartzite and granite (indicating drill pad base-coarse gravel). 0–10 ft WR: organic-rich silty sand. +10F: subangular granules composed of quartz and sanidine crystals, fragments of indurated tuff and predominantly dacitic lithics; abundant organic matter (root segments, wood fragments, bark).	Qal	Note: Drill cuttings for microscopic and descriptive analysis were collected at 5-ft intervals from 0 ft to borehole TD at 977.5 ft bgs. Alluvial sediments, encountered from 0 to 45 ft, are approximately 45 ft thick.
10–30	Tuffaceous sediments—light brown (5YR 6/4) to grayish orange (10YR 7/), unconsolidated, silty pebble gravel with fine to coarse sand. 10–30 ft +10F/35F: detrital clasts subangular to subrounded predominantly of gray porphyritic dacite, trace white rhyolite, abundant sand grains of quartz and sanidine crystals and dacite.	Qal	
30–45	Tuffaceous sediments—light brown (5YR 6/4), unconsolidated, silty fine to coarse sand with pebble gravel. 30–45 ft +10F: detritus subangular to subrounded pebbles and granules predominantly silt-coated dacitic lithics, abundant sand-size quartz and sanidine crystals and dacitic grains.	Qal	The Qal–Qbt 1g contact is estimated to be at 45 ft bgs based on cuttings and natural gamma ray log data.
45–60	**UNIT 1g OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Tuff—light brown (5YR 6/4), poorly welded, lithic-bearing, crystal-rich. 45–60 ft +10F: subangular to subrounded dacitic lithics. +35F: abundant quartz and sanidine crystals and dacitic grains.	Qbt 1g	Unit 1g of the Tshirege Member of the Bandelier Tuff (Qbt 1g), encountered from 45 to 104 ft bgs, is estimated to be 59 ft thick.

Borehole Lithologic Log (continued)

Borehole ID: R-49	**TA:** 36		**PAGE:** 2 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
60–70	Tuff—grayish orange pink (5YR 7/2), poorly welded, pumiceous, crystal- and lithic-bearing. 60–70 WR: abundant pinkish volcanic ash. +10F: 75%–85% pale orange, glassy, pumice fragments with moderately abundant spots of secondary manganese oxide. 15–25% subangular light pink to light gray dacitic lithics (up to 5 mm in diameter). +35F: 10%–15% fragments of glassy pumice; 75%–85% quartz and sanidine crystals; 10%–15% dacitic grains.	Qbt 1g	
70–85	Tuff— very pale orange (10YR 8/2), poorly welded, strongly pumiceous, lithic- and crystal-bearing. No indurated tuff fragments preserved. 70–80 ft WR: abundant pinkish orange volcanic ash. +10F: small volume of sample preserved; 85–95% subrounded to rounded pumice lapilli, glassy, quartz- and sanidine-phyric exhibiting small clots of secondary manganese oxides; 5%–15% small (up to 4 mm in diameter) dacitic lithics; proportion of lithics to pumice increasing downward in the interval. +35F: 80%–85% quartz and sanidine crystals; 10%–15% glassy pumice fragments; 3%–5% dacite. 80–85 ft+10F: small sample volume preserved; 90%–95% subangular dacitic lithics (up to 5 mm in diameter); 5%–10% glassy pumice lapilli; trace quartz and sanidine crystals.	Qbt 1g	
85–100	Tuff— moderate orange pink (5YR 8/4), poorly welded, strongly pumiceous, crystal-bearing lithic-poor. No indurated tuff fragments present. 85–95 ft WR: abundant orange-pink silty to vitric ash. +10F: 99%–100% subrounded pumice lapilli (up to 7 mm in diameter), glassy, quartz- and sanidine-phyric; moderate spots of secondary manganese oxide; up to 1% dacitic lithic fragments. +35F: 70%–80% quartz and sanidine crystals; 20%–30% fragments of glassy pumice fragments (proportion of pumices increasing downward in the interval); 2%–5% dacitic lithic grains. 95–100 ft +35F: 20%–30% quartz and sanidine crystals; 65%–75% fragments of glassy pumice fragments (proportion of pumices increasing downward in the interval); 2%–5% dacitic lithic grains.	Qbt 1g	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49		**TA:** 36		**PAGE:** 3 of 18
Depth (ft bgs)	Lithology		Lithologic Symbol	Notes
100–104	Tuff— moderate orange pink (5YR 8/4), poorly welded, strongly pumiceous, crystal-bearing lithic-bearing. No indurated tuff fragments present. 100–104 WR: abundant orange-pink silty to vitric ash. +10F: 90% subangular to rounded pumice lapilli (up to 7 mm in diameter), glassy, quartz- and sanidine-phyric; 10% subangular to subrounded volcanic (dacitic, rhyodacite) lithics (up to 10 mm in diameter). +35F: 70%–80% quartz and sanidine crystals; 20%–30% fragments of glassy pumice fragments (proportion of pumice increasing downward in the interval); 2%–5% dacitic lithic grains.		Qbt 1g	The estimated Qbt 1g–Qbo contact at 104 ft bgs is based on cuttings and natural gamma ray log interpretation. Note: the Cerro Toledo Interval (Qct) appears not to be present at this location.
104–115	**OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff—moderate orange pink (5YR 8/4), poorly welded, pumiceous, lithic- and crystal-bearing. No indurated tuff fragments present. 104–110 ft WR: abundant pinkish tan silty volcanic ash. +10F: no sample preserved of this size fraction. +35F: 15%–20% vitric pumice fragments; 75%–80% quartz and sanidine crystals; 5%–7% volcanic lithics. 110–115 ft +10F: very small volume of sample preserved; 15%–20% small (up to 5 mm in diameter) volcanic lithics (dacite, black and orange vitrophyre, rhyodacite); 80%–85% vitric pumices.		Qbo	The Otowi Member of the Bandelier Tuff (Qbo), intersected from 104 to 166 ft bgs, is estimated to be 62 ft thick.
115–130	Tuff—moderate orange pink (5YR 8/4), poorly welded, lithic-poor, strongly pumiceous, crystal-bearing. No indurated tuff fragments present. 115–130 ft WR: abundant pale pinkish tan vitric volcanic ash preserved. +10F: 95%–99% pale orange vitric pumice lapilli (up to 11 mm in diameter), subrounded, quartz- and sanidine-phyric; 1%–5% volcanic (predominantly dacite) lithics (up to 5 mm in diameter). +35F: variable proportions of vitric pumice fragments, quartz and sanidine crystals and volcanic lithic grains.		Qbo	
130–135	Tuff—moderate orange pink (5YR 8/4), poorly welded, lithic-rich, pumiceous, crystal-bearing. No indurated tuff fragments present. 130–135 ft WR: abundant silty volcanic ash. +10F: 95–99% pale orange vitric pumice lapilli (up to 12 mm in diameter), subrounded, quartz- and sanidine-phyric; 20%–25% subrounded hornblende-dacitic lithic fragments (up to 7 mm in diameter).		Qbo	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 4 of 18
Depth (ft bgs)	**Lithology**	**Lithologic Symbol**	**Notes**
135–140	Tuff—moderate orange-pink (5YR 8/4), poorly welded, lithic-poor, strongly pumiceous, crystal-bearing. No indurated tuff fragments present. 135–140 ft +10F: 100% pale orange vitric pumice lapilli (up to 10 mm in diameter), subrounded, quartz- and sanidine-phyric.	Qbo	
140–160	Tuff—moderate orange pink (5YR 8/4), poorly welded, lithic-rich, pumiceous, crystal-bearing. No indurated tuff fragments present. 140–155 ft WR: abundant silty volcanic ash preserved. +10F: 40%–50% very pale orange vitric pumice lapilli (up to 12 mm in diameter), subrounded, quartz- and sanidine-phyric (proportion of pumice fragments increasing downward in the interval); 50%–60% volcanic (predominantly gray hornblende-dacites) lithics (up to 15 mm in diameter). +35F: variable proportions of vitric pumice fragments, quartz and sanidine crystals and volcanic lithic grains. 155–160 ft +10F: 60%–70% vitric pumice lapilli, quartz- and sanidine-phyric; 30%–40% angular to subangular volcanic lithics (dacites, andesite).	Qbo	
160–166	Tuff—moderate orange pink (5YR 8/4), poorly welded, strongly pumiceous, crystal- and lithic-poor. No indurated tuff fragments present. 160–166 ft WR: abundant pale orange volcanic ash. +10F: 100% very pale orange vitric pumice lapilli (up to 8 mm in diameter). +35F: 98%–99% vitric pumice fragments; 1%–2% quartz and sanidine crystals; trace volcanic lithic grains.	Qbo	The estimated Qbo–Qbog contact at 166 ft bgs is based on cuttings and natural gamma ray log interpretation.
166–175	**GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF:** Tuff—moderate orange pink (5YR 8/4), nonwelded, lithic-rich, pumiceous, lithic- and crystal-bearing. 166–175 ft WR: abundant pale orange vitric volcanic ash preserved. +10F: 80%–95% very pale orange vitric pumice lapilli (up to 19 mm in diameter), subangular to subrounded, quartz- and sanidine-phyric (proportion of pumice fragments increasing downward in the interval); 5%–20% angular dacitic lithic fragments (up to 7 mm in diameter). +35F: 70%–80% vitric pumice fragments; 10%–20% quartz and sanidine crystals; 10%–15% dacitic lithic grains.	Qbog	The Guaje Pumice Bed (Qbog), intersected from 166 to 185 ft bgs, is estimated to be 19 ft thick.

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 5 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
175–185	Tuff—moderate orange pink (5YR 8/4), nonwelded, lithic-rich, pumiceous, lithic- and crystal-bearing. 175–185 ft WR: abundant pale orange vitric volcanic ash preserved. +10F: 99%–100% very pale orange vitric, quartz- and sanidine-phyric pumice lapilli and lesser white hornblende-phyric pumice fragments (up to 8 mm in diameter); trace dacitic lithics. +35F: variable proportions of vitric pumice fragments, quartz and sanidine crystals and dacitic lithic grains.	Qbog	The contact between the Guaje Pumice Bed (Qbog) and underlying Cerros del Rio basalt (Tb4) section, estimated at 185 ft bgs, is based on cuttings and natural gamma ray log interpretation.
185–190	**CERROS DEL RIO BASALT:** Tuff—moderate orange pink (5YR 8/4), nonwelded, lithic-rich, strongly pumiceous, lithic-poor, crystal-bearing. Probably represents residual Bandelier Tuff not cleaned from the borehole. 185–190 ft WR: abundant volcanic ash. +10F: 100% very pale orange vitric, phenocryst-poor pumice lapilli (up to 10 mm in diameter). +35F: 20%–25% vitric pumice fragments; 50%–60% quartz and sanidine crystals; 20%–30% dacitic lithic grains.	Tb4	The Cerros del Rio basaltic (Tb4) section, including lavas, intercalated flow breccias and maar deposits, was intersected from 185 to 310 ft bgs (natural gamma ray log), and is estimated to be 125 ft thick.
190–200	Basaltic sediments—moderate orange pink (5YR 8/4) pebble gravel with fine to coarse sand, mixed tuffaceous and basaltic detritus. 190–195 ft WR: abundant to moderately abundant silty volcanic ash present. +10F: 85%–90% broken chips and subrounded pebble clasts (up to 15 mm in diameter) composed of medium gray vesicular, olivine-phyric basalt, clasts silt-coated; 5%–10% reddish brown fragments of very fine-grained sandstone containing grains of black vitrophyre. +35F: 70%–80% white pumice fragments and quartz and sanidine crystals (probably residual Bandelier Tuff not cleaned from borehole); 20%–30% angular to subangular basalt grains, glassy basalt and minor dacite. 195–200 ft +35F: 80%–85% basalt and vitrophyric basalt; 15%–20% pumice and quartz and sanidine crystals.	Tb4	
200–210	Basalt lava—medium gray (N5) chips of weakly porphyritic basalt, aphanitic groundmass, olivine-phyric basalt. 200–210 ft WR/+10F: 100% angular chips of massive to partly vesicular basalt, phenocrysts (2%–4% by volume) of anhedral olivine (up to 3 mm in diameter, minor alteration to iddingsite) and euhedral plagioclase (up to 2 mm in diameter); tan clay coating/lining vesicles; vesicularity of basalt diminishing downward in the interval.	Tb4	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49		TA: 36	PAGE: 6 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
210–230	Basaltic tuff/interflow breccia—medium gray (N5) mixed chips olivine-phyric basalt and lesser strongly vesicular basalt lapilli, abundant clay. 210–230 ft +10F: predominantly angular chips and fragments of strongly vesicular olivine- and plagioclase-phyric basalt, vesicles lined with hematite or infilled with pale tan and/or white clay; less abundant subrounded scoriaceous basalt lapilli (cinders). +35F: contains minor grains of quartz crystal, quartzite and fragments of very fine-grained silty sandstone.	Tb4	
230–240	Basaltic lava—medium gray (N5) angular chips of massive, weakly porphyritic basalt, olivine-phyric basalt with aphanitic groundmass. 230–240 ft WR/+10F: predominantly angular chips of massive basalt, phenocrysts (1%–3% by volume) of small (up to 1 mm in diameter) green anhedral olivine and euhedral plagioclase set in an aphanitic groundmass that is weakly altered.	Tb4	
240–265.5	Basaltic tuff/interflow breccia—medium gray (N5) mixed broken chips of olivine-phyric basalt and subrounded vesicular basalt lapilli. 240–265.5 ft WR/+10F: varying proportions of broken olivine basalt chips and subrounded vesicular basalt lapilli (up to 20 mm in diameter) that suggest tuff cinders and/or reworked basaltic detritus, basalt vesicles commonly lined with secondary iron oxides or infilled with light clay; trace white glassy pumice fragments. +35F: contains minor fragments of basalt vitrophyre.	Tb4	
265.5–275	Basaltic hydromagmatic tuff/sediments—medium gray (N5) mixed chips olivine-phyric basalt, clastic detrital basalt and glassy basalt scoria. 265.5–275 ft +10F: varying proportions of angular/broken chips of olivine-plagioclase basalt, subrounded (reworked?) detrital basalt granules (up to 5 mm in diameter) frequently with limonite rinds, lesser scoriaceous basaltic glass with yellowish and white palagonitic clay, and fragments of pale tan clay.	Tb4	

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 7 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
275–295	Basaltic hyrdomagmatic tuff/sediments—medium gray (N5) mixed abundant subrounded basaltic detritus, including granules/small pebbles of glassy basalt scoria. 275–295 ft WR/+10F: predominantly subangular to subrounded detrital grains and small pebbles (up to 22 mm in diameter) olivine-basalt; minor fragments of very fine-grained basalt-bearing sandstone and minor scoriaceous basalt vitrophyre. +35F: predominantly grains of glassy basalt scoria with yellowish clay rinds, olivine crystals, quartz crystal, detrital grains of quartzite and fragments of very fine-grained basalt-bearing sandstone; abundant pale yellow clay rinds on grains.	Tb4	
295–310	Basaltic hyrdomagmatic tuff/sediments—medium gray (N5) predominantly subrounded lapilli of vesicular basalt with abundant grains of glassy basalt scoria and minor exotic fine quartzo-feldspathic detritus (possible reworked lapilli tuff). 295–310 WR/+10F: 99%–100% subangular to subrounded (i.e., reworked) olivine-basaltic granules (up to 10 mm in diameter) with locally strong secondary iron oxides; minor scoriaceous basalt vitrophyre. +35F: predominantly subangular to subrounded grains of glassy basalt scoria with rinds of pale tan silty very fine-grained sandstone; less abundant altered olivine-basalt, olivine crystals, quartzite, quartz crystal and granite.	Tb4	The contact between the Cerros del Rio basaltic section (Tb4) and underlying intermediate-composition volcanic section is estimated at 310 ft bgs, based on cuttings and natural gamma log interpretation.
310–325	**INTERMEDIATE-COMPOSITION VOLCANICS:** Trachyandesite tuff/scoria—varicolored, medium gray (N5) and moderate reddish brown (10YR 4/6), mixed components of olivine-basalt lapilli and less abundant red aphyric(?) scoriaceous lapilli. 310–315 ft WR/+10F: similar to 295–310 ft. 315–325 ft WR/+10F: 60%–70% broken chips and subangular to subrounded clasts (up to 13 mm in diameter) of and minor glassy basalt scoria; 30%–40% brick-red aphyric scoriaceous lapilli (up to 15 mm in diameter); minor fragments of very fine-grained volcaniclastic sandstone. +35F: sand-sized grains made up of varying proportions of gray subrounded detrital basalt, glassy basalt and red scoria.	Tb4	The intermediate-composition volcanic section of lavas, cinder deposits and breccias was intersected from 310 ft to 897 ft bgs, and is estimated to be 587 ft thick. X-ray fluorescence (XRF) analyses of cutting samples indicate that from 310 to 611.5 ft these intermediate-composition scoria deposits and lavas are trachyandesite and basaltic trachyandesite in composition. For simplicity they are referred to as trachyandesite in this log. XRF analyses indicate the lavas, breccias, and sediments from 611.5 to 897 ft are dacitic in composition.

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 8 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
325–345	Trachyandesite tuff/scoria—varicolored, medium gray (N5) and moderate reddish brown (10YR 4/6), mixed red scoriaceous cinders and fragments of gray phenocryst-poor aphanitic lava. 325–345 WR/+10F: 50%–60% brick-red scoriaceous, phenocryst-poor lapilli (up to 23 mm in diameter) exhibiting trace phenocrysts of black clinopyroxene and plagioclase; 40%–50% gray vesicular lapilli, subangular to subrounded, with sparse phenocrysts (up to 1% by volume) of small (up to 1 mm in diameter) and possible very small olivine and/or orthopyroxene(?) in an aphanitic groundmass. Plagioclase (both andesite and basalt likely present). +35F: mixed grains of red scoria, massive and glassy scoria, lava, olivine crystals, trace detrital quartzo-feldspathic detritus (basaltic materials diminishing in proportion to intermediate-composition volcanics downward in the interval).	Tb4	
345–370	Trachyandesite tuff/scoria—varicolored, medium gray (N5) and moderate reddish brown (10YR 4/6), mixed red ferruginous scoria lapilli and fragments of gray aphanitic vesicular lava. 345–370 ft WR/+10F: 70–80% brick-red scoriaceous (rounded, up to 20 mm in diameter) lapilli; 20%–30% fragments and pyroclastic lapilli of gray phenocryst-poor vesicular to massive lava. +35F: 40%–50% grains of scoria; 40%–50% grains of gray lava; minor olivine basaltic vitrophyre; trace white pumice.	Tb4	345–370
370–390	Trachyandesite tuff/scoria—moderate reddish orange (10YR 6/6), predominantly fine to coarse cinders composed of red ferruginous scoria, phenocryst-poor, plagioclase-phyric. 370–390 ft WR/+10F: 90–99% brick-red scoriaceous (subrounded, up to 22 mm in diameter) lapilli composed of plagioclase-phyric (phenocrysts up to 1 mm in diameter) material; 1%–10% fragments of gray, vesicular, aphanitic lava. +35F: 60%–70% grains of scoria; 30%–40% grains of gray lava. Note: small black spindle-shaped ejecta at 380–385 ft.	Tb4	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 9 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
390–410	Trachyandesite tuff/scoria—moderate reddish orange (10YR 6/6), monolithologic interval consisting of fine to coarse red ferruginous scoria/cinders. 390–410 ft WR/+10F: 100% brick-red subangular to subrounded hematitic scoriaceous lapilli (up to 22 mm in diameter) with trace abundances of small (up to 1 mm in diameter) plagioclase phenocrysts and aphanitic groundmass, intense hematite alteration throughout. +35F: 100% grains of ferruginous scoria.	Tb4	
410–430	Trachyandesite tuff/scoria—moderate reddish orange (10YR 6/6), monolithologic interval consisting of fine to coarse red ferruginous scoria/cinders, intense hematite alteration. 410–430 ft WR/+10F: 100% brick-red subangular to subrounded hematitic scoriaceous lapilli (up to 25 mm in diameter) with trace abundances of small (up to 1 mm in diameter) plagioclase phenocrysts and aphanitic groundmass, intense hematite alteration throughout. +35F: 100% grains of ferruginous scoria.	Tb4	
430–450	Trachyandesite tuff/scoria—moderate reddish brown (10YR 4/6), monolithologic interval consisting of fine to coarse red ferruginous scoria/cinders exhibiting intense hematite alteration. 430–450 ft WR/+10F: 100% brick-red subangular to subrounded hematitic scoriaceous lapilli (up to 28 mm in diameter), phenocryst-poor with trace abundance of small (up to 1 mm in diameter) plagioclase phenocrysts and aphanitic groundmass. +35F: 100% grains of ferruginous scoria.	Tb4	
450–470	Trachyandesite tuff/scoria—pale red (10R 6/2) to moderate reddish brown (10YR 4/6), predominantly red scoriaceous lapilli and less abundant fragments of massive to vesicular phenocryst-poor lava. 450–470 ft WR/+10F/+35F: 70%–80% reddish subangular to subrounded hematitic scoriaceous lapilli (up to17 mm in diameter); 20%–30% fragments of massive to weakly vesicular aphanitic lava (both components composed of very weakly porphyritic, plagioclase-phyric trachyandesite exhibiting strong hematite alteration). +35F: compositionally similar to WR/+10F.	Tb4	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 10 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
470–485	Trachyandesite tuff/scoria—pale red (10R 6/2) to moderate reddish orange (10R 6/6), predominantly red scoriaceous lapilli and less abundant fragments of massive aphanitic, phenocryst-poor lava. 470–485 ft WR/+10F: 80%–90% subangular to subrounded hematitic scoriaceous lapilli (up to 20 mm in diameter); 10%–20% fragments of massive to weakly vesicular aphanitic lava (both components composed of ferruginous very weakly porphyritic to aphanitic lava exhibiting strong hematite alteration). +35F: compositionally similar to WR/+10F.	Tb4	
485–505	Trachyandesite tuff/scoria—pale red (10R 6/2) to moderate reddish orange (10R 6/6), mixed fragments of aphanitic lava and scoriaceous lapilli, both composed of hematite-altered phenocryst-poor lava. 485–505 WR/+10F: 50%–70% angular to subangular fragments of pale violet, massive to weakly vesicular, phenocryst-poor lava, sparse phenocrysts (less than 1% by volume) of small (up to 2 mm in diameter) plagioclase plus black clinopyroxene and amber orthopyroxene that commonly occur as intergrown clots, aphanitic groundmass; 30%–50% subangular to subrounded scoriaceous lapilli (up to 12 mm in diameter).	Tb4	Note: Possible thin lava flow(s) intercalated with scoria deposits.
505–515	Trachyandesite tuff/scoria deposits—pale red (10R 6/2) to moderate reddish orange (10R 6/6), mixed fragments of aphanitic lava and scoriaceous lapilli, both composed of hematite-altered phenocryst-poor lava. 505–515 ft WR/+10F: 50%–70% fragments of pink phenocryst-poor lava, small (up to 2 mm in diameter) phenocrysts (up to 1% by volume) of subhedral plagioclase and rare black clinopyroxene, aphanitic groundmass. +10F: 30%–50% subangular fragments reddish scoriaceous lapilli (up to 12 mm in diameter) similarly composed of phenocryst-poor plagioclase-phyric, hematite-altered material.	Tb4	Note: Possible thin lava flow(s) intercalated with scoria deposits.
515–535	Trachyandesite tuff/scoria deposits—pale red (10R 6/2) monolithologic interval made up of reddish phenocryst-poor lapilli/cinders. 515–535 ft WR/+10F/35F: 100% subangular to subrounded pale reddish violet scoriaceous lapilli (up to 23 mm in diameter) that contains sparse phenocrysts (less than 1% by volume) of small (up to 2 mm in diameter) anhedral plagioclase, aphanitic groundmass.	Tb4	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 11 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
535–550	Trachyandesite tuff/scoria deposits—pale red (10R 6/2) monolithologic interval made up of reddish phenocryst-poor lapilli/cinders. 535–550 ft WR/+10F/35F: 100% subangular to subrounded pale reddish violet scoriaceous lapilli (up to 25 mm in diameter) that contains sparse phenocrysts (less than 1% by volume) of small (up to 4 mm in diameter) anhedral plagioclase, aphanitic groundmass.	Tb4	
550–559	Trachyandesite tuff/scoria deposits—pale red (10R 6/2) monolithologic interval made up of ferruginous, phenocryst-poor, scoriaceous lapilli/cinders. 550–559 ft WR/+10F/35: 100% subangular to subrounded, hematite-stained scoriaceous lapilli (up to 22 mm in diameter), sparse phenocrysts (up to 1% by volume) of subhedral plagioclase (up to 2 mm in diameter) and small (up to 1 mm in diameter) black clinopyroxene, aphanitic groundmass.	Tb4	
559–570	Trachyandesite lava— pale red (5YR 6/2) mixed massive (i.e., nonvesicular) and scoriaceous dacitic lava and cinders. 559–570 WR/+10F: 30%–40% subangular to subrounded, hematite-stained scoriaceous dacite cinders; 60%–70% grayish red dacitic lava fragments, small (up to 1 mm in diameter) phenocrysts (up to 1% by volume) of subhedral plagioclase and black clinopyroxene, aphanitic groundmass.	Tb4	
570–575	Trachyandesite lava—pale red (5YR 6/2) and medium light gray (N6) mixed chips of reddish (partly scoriaceous) and gray massive lava, phenocryst-poor. 570–575 ft +10F: 20–25% pale red lava chips; 75%–80% fragments and subrounded to well rounded clasts (up to 18 mm in diameter) composed of massive gray lava and trace olivine-plagioclase-phyric basalt.	Tb4	Note: Likely presence of thin layer(s) of basalt-bearing intermediate-composition sediments as indicated by distinctively rounded detrital clasts
575–590	Trachyandesite lava—medium light gray (N6) monolithologic interval, phenocryst-poor lava with altered aphanitic groundmass. 575–590 ft WR/+10F/+35F: 100% angular chips of very weakly porphyritic lava, phenocrysts (less than 1% by volume) small (up to 1 mm in diameter) plagioclase, black clinopyroxene and orthopyroxene , aphanitic groundmass that is weakly altered.	Tb4	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 12 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
590–611.5	Trachyandesite lava—medium light gray (N6) monolithologic interval, phenocryst-poor massive dacite with altered aphanitic groundmass. 590–611.5 ft WR: exhibits moderate to locally abundant very light gray silt suggesting hydrothermal alteration of lava groundmass. +10F/+35F: 100% angular chips of very weakly porphyritic lava, phenocrysts (less than 1% by volume) small (up to 1 mm in diameter) plagioclase, black clinopyroxene; aphanitic groundmass that is weakly altered.	Tb4	
611.5–616	Dacitic breccia—medium light gray (N6) monolithologic interval, phenocryst-poor massive dacite with altered aphanitic groundmass. 611.5–616 ft WR: abundant very light gray silt suggesting hydrothermal alteration of dacitic lava groundmass. +10F/+35F: 100% angular chips of phenocryst-poor dacite, small phenocrysts (less than 1% by volume) of plagioclase, black clinopyroxene; aphanitic groundmass is weakly altered.	Tb4	
616–620	Dacitic volcanic sediments—varicolored medium light gray (N6) to white (N9), tuffaceous-volcaniclastic silty pebble gravel with fine to coarse sand, detrital clasts of dacite, pumice and basalt. 616–620 ft +10F: subangular to subrounded detrital granules and small pebbles (up to 16 mm in diameter) composed of aphanitic and hornblende-phyric dacites, white weathered pumices, trace dacitic vitrophyre. +35F: 30%–40% white pumice grains; 60%–70% massive and glassy dacites.	Tb4	616–620
620–635	Dacitic sediments—medium light gray (N6) to pale yellowish gray (5YR 8/1), silty pebble gravel with fine to coarse sand, partly well rounded detritus, predominantly dacitic. 620–625 ft WR: abundant silty matrix. +10F: 90%–95% partly well rounded pebbles (up to 15 mm in diameter) of gray aphanitic and strongly weathered biotite-phyric dacites, minor subangular glassy dacite; 5%–10% white pumice fragments. 625–635 ft WR: abundant silty matrix. +10F: subangular to subrounded detrital granules/pebbles of gray massive and glassy dacite; minor pumice; also minor fragments of strongly weathered tan-colored dacite.	Tb4	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 13 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
635–650	Dacitic breccia—pale yellowish gray (5Y 8/1), chips of weakly porphyritic clinopyroxene-phyric dacite with weakly altered aphanitic groundmass. 635–650 ft WR: abundant silt indicating altered dacitic groundmass. +10F: 100% angular to subangular chips of dacitic lava, phenocrysts (up to 1% by volume) of black anhedral clinopyroxene (up to 1 mm in diameter), subhedral plagioclase (up to 2 mm in diameter) and trace orthopyroxene (phenocrysts commonly intergrown); groundmass crypto-crystalline to vitrophyric, having a pitted, corroded appearance that indicates hydrothermal alteration.	Tb4	
650–670	Dacitic breccia—pale yellowish gray (5Y 8/1) to medium dark gray (N4) chips of weakly porphyritic, clinopyroxene-phyric dacite with weakly altered glassy groundmass. 650–670 ft WR: silt-rich samples indicating altered dacitic groundmass. +10F: 100% angular to subangular chips of phenocryst-poor, glassy dacite, phenocrysts (1%–2% by volume) black anhedral to subhedral clinopyroxene and subhedral plagioclase (phenocrysts typically intergrown), trace rounded (resorbed) xenocrystic quartz (up to 2 mm in diameter), groundmass glassy to crypto-crystalline, pitted with abundant pore spaces; up to 1% fragments of very pale tan clay.	Tb4	
670–690	Dacitic lava—pale yellowish gray (5Y 8/1) to medium dark gray (N4), monolithologic interval, phenocryst-poor clinopyroxene-phyric dacite with altered glassy groundmass. 670–690 ft WR: +10F: 100% angular chips of phenocryst-poor, glassy dacite, phenocrysts (1%–2% by volume) anhedral plagioclase (up to 2 mm in diameter) and small (up to 1 mm in diameter) black clinopyroxene (clinopyroxene commonly as overgrowth rims on plagioclase), groundmass pitted with corroded appearance; trace fragments of very pale tan clay.	Tb4	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 14 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
690–710	Dacitic lava—pale yellowish gray (5Y 8/1) to medium dark gray (N4), monolithologic interval, phenocryst-poor clinopyroxene-phyric dacite with altered glassy groundmass. 690–710 ft WR: abundant silt particles indicating strong hydrothermal alteration. +10F: 100% angular chips of phenocryst-poor, glassy dacite, phenocrysts (up to 1% by volume) anhedral plagioclase (up to 2 mm in diameter) and euhedral to subhedral clinopyroxene (up to 1 mm in diameter), trace resorbed quartz xenocryst; groundmass glassy to cryptocrystalline, moderately to strongly altered.	Tb4	690–710
710–730	Dacitic lava—very light gray (N8) monolithologic interval, weakly porphyritic clinopyroxene-phyric dacite with altered glassy groundmass. 710–730 ft WR: abundant silt. +10F: 100% angular chips of glassy dacite, phenocrysts (up to 1% by volume) anhedral plagioclase and euhedral to subhedral clinopyroxene; groundmass glassy to cryptocrystalline, exhibits strong hydrothermal alteration.	Tb4	
730–750	Dacitic lava—very light gray (N8) monolithologic interval, weakly porphyritic clinopyroxene-phyric dacite, glassy groundmass commonly obscured by hydrothermal alteration. 730–750 ft WR: abundant silt-sized particles indicating alteration. +10F: 100% angular chips of glassy dacite, phenocrysts (1%–2% by volume) anhedral plagioclase, euhedral to subhedral clinopyroxene (up to 1 mm in diameter) and trace amber elongate orthopyroxene; groundmass glassy to cryptocrystalline, exhibits strong hydrothermal alteration.	Tb4	
750–790	Dacitic lava—very light gray (N8) monolithologic interval, weakly porphyritic clinopyroxene-phyric dacite, continued strong alteration obscuring glassy groundmass. 750–790 ft WR: abundant silt-sized particles indicating alteration. +10F: 100% angular chips of glassy dacite, phenocrysts (1%–2% by volume) anhedral plagioclase, euhedral to subhedral clinopyroxene (up to 1 mm in diameter) and grayish amber orthopyroxene (phenocrysts in cumulophyric clusters and/or intergrowths); groundmass glassy to cryptocrystalline, exhibits strong to intense hydrothermal alteration.	Tb4	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	TA: 36		PAGE: 15 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
790–830	Dacitic lava—very light gray (N8) monolithologic interval, phenocryst-poor, pyroxene-phyric, strongly altered aphanitic groundmass. 790–830 ft WR: silt-rich samples. +10F: 100% angular dacitic chips, phenocrysts (less than 1% by volume) small (up to 1 mm in diameter), euhedral clinopyroxene intergrown with grayish amber tabular orthopyroxene, resorbed plagioclase (up to I mm in diameter) and groundmass that exhibits strong to intense hydrothermal alteration.	Tb4	
830–844	Dacitic lava—very light gray (N8) monolithologic interval, phenocryst-poor, pyroxene-phyric, strongly altered aphanitic groundmass. 830–844 ft WR: silt-rich samples. +10F: 100% angular dacitic chips, phenocrysts (less than 1% by volume) small intergrown clots of clinopyroxene and orthopyroxene, resorbed plagioclase, strong to intense altered groundmass.	Tb4	
844–860	Dacitic breccia—very light gray (N8), phenocryst-poor, pyroxene-phyric, strongly altered aphanitic and glassy groundmass. 844–860 ft WR: samples rich in very light gray silt and clay indicating strong alteration. +10F: 90%–95% angular chips of mottled gray and pale orange tan dacite that is partly aphanitic, partly vitrophyric, phenocrysts (up to 1% by volume) black clinopyroxene (up to 1 mm in diameter) and resorbed plagioclase (up to 2 mm in diameter), strongly to intensely altered groundmass; 5%–10% fragments very pale tan clay.	Tb4	
860–880	Dacitic breccia—very light gray (N8) to medium gray (N5), phenocryst-poor, pyroxene-phyric, strongly altered aphanitic and glassy groundmass. 860–875 ft WR: moderate to abundant clay/silt indicating strong hydrothermal alteration in this interval. +10F: 100% angular chips of medium gray to pale pinkish gray aphanitic to partly vitrophyric dacite, phenocrysts (up to 1% by volume) black clinopyroxene (up to 1 mm in diameter) and resorbed plagioclase, strongly to intensely altered groundmass exhibiting clay-filled pits. 875–880 ft WR: sample is exceptionally clay-rich. +10F: similar to 860–875 ft.	Tb4	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 16 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
880–897	Dacitic breccia—light brownish gray (5YR 6/1) to medium gray (N5), phenocryst-poor, pyroxene-phyric, strongly altered aphanitic and glassy groundmass. 880–897 ft WR: moderate to abundant clay/silt. +10F: 93%–97% angular to subangular chips of aphanitic to partly glassy dacite, phenocrysts (up to 1% by volume) black clinopyroxene (less than 1 mm in diameter) and anhedral plagioclase (up to 2 mm in diameter), altered groundmass pitted with corroded appearance; 3%–7% fragments of white clay.	Tb4	The contact between the dacitic volcanic section and underlying axial river gravels is estimated at 897 ft bgs, based on drill cuttings analysis and natural gamma ray log interpretation.
897–905	**TOTAVI-LIKE GRAVELS:** Axial river sediments—medium gray (N5) mixed angular to subrounded fragments of glassy to aphanitic dacite and minor quartzo-feldspathic detrital clasts. 897–905 ft WR: abundant clay/silt. +10F: 99%–97% angular to subangular chips of aphanitic to partly glassy dacite; 1%–3% fragments of white siltstone; trace subangular to subrounded pebbles (up to 12 mm in diameter) Precambrian granite.	Riverine Gravels	An 83-ft-thick interval of axial river gravel sediments was intersected from 897 ft to the borehole TD at 977.5 ft bgs. The age of these axial river deposits is uncertain and may represent either Pliocene Totavi deposits or Miocene Chamita Formation.
905–910	Axial river sediments—pale pinkish gray (5YR 8/1) silty gravels with fine to coarse sand, composed of mixed dacitic chips and rounded volcanic and quartzo-feldspathic detritus. 905–910 ft WR: abundant silt matrix. +10F: 10%–15% aphanitic subangular dacitic chips; 40%–50% subrounded clasts of diverse volcanic lithologies (flow-banded rhyolite, phenocryst-rich dacites); 30%–40% subangular to well rounded pebbles (up to 22 mm in diameter) quartzo-feldspathic rocks. +35F: 70%–80% angular glassy phenocryst-poor dacitic chips; 15%–15% mixed quartzo-feldspathic and volcanic grains.	Riverine Gravels	
910–925	Axial river sediments—pale tan (5YR 7/2) to varicolored, pebble gravel with coarse to fine sand and silt, mixed volcanic and quartzo-feldspathic detritus. 910–925 ft WR: moderately silty interval. +10F: subangular to well rounded detrital granules and pebbles (up to 21 mm in diameter) composed of 40%–60% quartzo-feldspathic rocks (quartzite, granite, microcline); 40%–50% clasts of diverse volcanic lithologies (pink and gray porphyritic dacites, andesite, rhyolite). +35F: 60%–70% quartzo-feldspathic grains; 30%–40% grains of various volcanic lithologies.	Riverine Gravels	

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 17 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
925–940	Axial river sediments—moderate orange pink (5YR 8/4), silty fine to medium sandstone with pebble gravel, predominantly volcanic detritus. 925–930 ft WR: silt-rich matrix. +10F: 70%–80% subrounded fragments of silty fine-grained sandstone to sandy siltstone with volcanic and quartz grains; 10%–20% volcanic pebbles (up to 12 mm in diameter); 5%–10% quartzo-feldspathic pebbles. 930–940 ft +10F: 60–80% subrounded fragments of silty fine-grained sandstone to sandy; 20%–40% subangular to subrounded granules and pebbles (up to 15 mm in diameter) predominantly of light gray hornblende- and/or biotite-phyric dacites. +35F: 70%–80% siltstone fragments; 20%–25% volcanic grains; 2%–5% quartzo-feldspathic grains.	Riverine Gravels	Note: 925–940 ft abrupt disappearance of quartzo-feldspathic constituents in this interval.
940–950	Pumiceous fluvial sediments—light grayish tan (5YR 7/2), siltstone with fine to medium sand and fine gravel, detrital granules predominantly of pumice with minor dacite. 940–950 ft WR: silt-rich matrix (fines >50% by volume). +10F: 55%–65% subrounded to rounded fragments of weathered to glassy hornblende-bearing pumice; 30%–40% subrounded fragments of very fine-grained sandy siltstone; 10%–15% subrounded to rounded granules and pebbles (up to 10 mm in diameter) of gray porphyritic dacite. +35F: 75%–85% mixed pumice and siltstone fragments; 15%–25% volcanic grains; 1%–2% quartzo-feldspathic grains.	Pumiceous Sediments	Note: 940–950 ft pumiceous interval with minor quartzo-feldspathic constituents.

Borehole Lithologic Log (continued)

BOREHOLE ID: R-49	**TA:** 36		**PAGE:** 18 of 18
Depth (ft bgs)	Lithology	Lithologic Symbol	Notes
950–977.5	Axial river sediments—varicolored pale tan (5YR 7/2) to medium light gray (N6) fine to medium gravels with coarse to fine sand; coarser detritus conspicuously rounded of mixed quartzo-feldspathic and volcanic lithologies. 950–970 ft+10F: broken (up to 20 mm in diameter) and subrounded to well rounded detrital granules and pebbles made up of 40%–50% diverse varieties of volcanic rocks (andesite, rhyolite, basalt); 50%–60% Precambrian quartzo-feldspathic rocks (quartzite, granite); minor abundance of hornblende-bearing pumice. +35F: 70%–80% subangular to angular grains of quartz and feldspar; 20%–30% angular grains of various volcanic lithologies. 970–977.5 ft WR: abundant silt matrix. +10F: 30%–40% subrounded fragments of pale tan very fine-grained sandy silt; 20%–30% subrounded to well rounded quartzo-feldspathic detrital clasts; 20%–30% clasts of various volcanic lithologies. +35F: compositionally similar to 950–970 ft.	Riverine Gravels	Note: 950–977.5 ft abrupt reappearance of abundant quartzo-feldspathic and volcanic constituents and corresponding disappearance of pumice. R-49 borehole reached TD at 977.5 ft bgs.

ABBREVIATIONS

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

% = estimated per cent by volume of a given sample constituent

AMSL = above mean sea level

bgs = below ground surface

ft = feet.

GM = groundmass

Qal = Quaternary Alluvium.

Qbo = Otowi Member of Bandelier Tuff

Qbog = Guaje Pumice Bed

Qbt = Tshirege Member of the BandelierTuff

Qct = Cerro Toledo Interval

Tb4 = Cerros del Rio basalt

TD = total depth

Tpf = Puye Formation

Tb4 = dacitic lava

N/S = no assigned symbol for geologic unit

+10F = plus No. 10 sieve sample fraction

+35F = plus No. 35 sieve sample fraction

WR = whole rock (unsieved sample)

1mm = 0.039 in.

1 in. = 25.4 mm

Appendix B

Groundwater Analytical Results

B-1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-49

A total of 24 groundwater samples were collected during drilling (6 samples), development (5 samples), and aquifer testing (13 samples) at the regional aquifer well R-49. Four groundwater samples were collected from the vadose zone (two samples from 177 ft below ground surface [bgs] and two samples from 623 ft bgs) and two from the regional aquifer during drilling at a depth of 908 ft bgs. The vadose zone samples most likely consist of groundwater, based on dissolved concentrations of chloride and fluoride exceeding concentrations of these anions measured in municipal water. The groundwater sample collected from 177 ft bgs contained dissolved concentrations of total carbonate alkalinity less than that measured in municipal water. These two saturated zones did not yield significant quantities of groundwater during drilling. The vadose zone water samples were analyzed for tritium and inorganic solutes. During aquifer performance (pumping) testing, seven groundwater samples were collected from screen 1 (upper screen) between a depth interval ranging from 845.0 to 855.0 ft bgs, and six groundwater samples were collected from screen 2 (lower screen) between a depth interval of 905.6 and 926.4 ft bgs. Groundwater samples pumped from screen 1 were collected within intercalated dacitic lavas, breccias, and sediments, and groundwater samples pumped from screen 2 were collected within Totavi-like fluvial sediments. The filtered samples were analyzed for cations, anions, perchlorate, and metals. A total of 25,075 gal of groundwater was pumped from well R-49 during development before emplacing a packer to seal off screens 1 and 2. During the pumping tests conducted at well R-49, a total of 40,434 gal. of groundwater was pumped from screens 1 and 2.

B-1.1 Field Preparation and Analytical Techniques

Chemical analyses of groundwater-screening samples collected from well R-49 were performed at Los Alamos National Laboratory's (LANL's, or the Laboratory's) Earth and Environmental Sciences Group 14 (EES-14). Groundwater samples were filtered (0.45-µm membranes) before preservation and chemical analyses. Samples were acidified at the EES-14 wet chemistry laboratory with analytical grade nitric acid to a pH of 2.0 or less for metal and major cation analyses.

Groundwater samples were analyzed using techniques specified by the U.S. Environmental Protection Agency (EPA) methods for water analyses. Ion chromatography (EPA Method 300, Rev. 2.1) was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. The instrument detection limits (IDLs) for perchlorate typically are 0.002 and 0.005 ppm (EPA Method 314.0, Rev. 1). Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) (EPA Method 200.7, Rev. 4.4) was used for analyses of dissolved aluminum, barium, boron, calcium, total chromium, iron, lithium, magnesium, manganese, potassium, silica, sodium, strontium, titanium, and zinc. Dissolved aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, cesium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, rubidium, selenium, silver, thallium, thorium, tin, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS) (EPA Method 200.8, rev. 5.4). The precision limits (analytical error) for major ions and trace elements were generally less than ±7% using ICPOES and ICPMS. Total carbonate alkalinity (EPA Method 310.1) was measured using standard titration techniques. No groundwater samples were collected for total organic carbon (TOC) analyses at R-49 before well development. Analyses of TOC were performed on groundwater samples collected during well development and aquifer performance testing following EPA Method 415.1. Charge balance errors for total cations and anions were generally less than ±8% for complete analyses of the above inorganic chemicals. The negative cation-anion charge balance values indicate excess anions for the filtered samples.

Three borehole water samples collected during drilling of R-49 were analyzed for tritium using the direct counting and electrolytic enrichment methods performed by the University of Miami.

B-1.2 Field Parameters

B-1.2.1 Well Development

Water samples were drawn from the pump flow line into sealed containers, and field parameters were measured using a YSI multimeter. Results of field parameters, consisting of pH, temperature, percent saturation of dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductance, and turbidity measured during well development and aquifer performance testing conducted at R-49 are provided in Table B-1.2-1. Thirteen measurements of pH and temperature varied from 7.92 to 8.16 and from 21.97°C to 25.51°C, respectively, in groundwater pumped from well R-49 screen 1 during development. Concentrations of DO varied from 2.07 to 5.72 mg/L at R-49 screen 1 during well development, suggesting that groundwater is oxic. Noncorrected ORP values varied from –7.4 to 63.0 millivolts (mV) during well development of R-49 screen 1 (Table B-1.2-1). Temperature-dependent correction factors for calculating oxidation-potential reduction (Eh) values from field ORP measurements were based on an Ag/AgCl- and KCl-saturated filling solution contained in the ORP electrode. The correction factors are 203.9, 198.5, and 193.5 mV at 20ºC, 25ºC, and 30ºC, respectively. Corrected Eh values ranged from 196.5 to 261.5 mV during development of well R-49 screen 1. These corrected Eh values associated with well R-49 screen 1 are considered to be reliable and representative of the known relatively oxidizing conditions characteristic of the regional aquifer beneath the Pajarito Plateau, based on analytical results for redox-sensitive solutes, including detectable nitrate and sulfate and low concentrations of manganese provided in Table B-1.2-2. Measurable concentrations of these solutes are consistent with overall oxidizing conditions encountered at the well. These DO measurements taken during well development are generally consistent with the corrected Eh values. Specific conductance varied from 132 to 151 microsiemens per centimeter (μS/cm), and turbidity values generally increased from 18.7 to 544 nephelometric turbidity units (NTUs) during well development of R-49 screen 1 (Table B-1.2-1).

Nine measurements of pH and temperature varied from 8.03 to 8.18 and from 22.12°C to 22.66°C, respectively, in groundwater pumped from well R-49 screen 2 during development. Concentrations of DO generally increased from 4.19 to 5.10 mg/L at R-49 screen 2 during well development, suggesting that groundwater is oxic. Noncorrected ORP values varied from –26.4 to –4.1 mV during well development of R-49 screen 2 (Table B-1.2-1). Corrected Eh values ranged from 177.5 to 194.4 mV during development of well R-49 screen 2. Measurable concentrations of redox-sensitive solutes including nitrate and sulfate are consistent with overall oxidizing conditions encountered at the well. These DO measurements taken during well development are consistent with the corrected Eh values. Specific conductance decreased from 129 to 122 µS/cm, and turbidity values generally decreased from 8.2 to 2.9 NTUs during well development of R-49 screen 2 (Table B-1.2-1).

B-1.2.2 Aquifer Performance Testing

During aquifer performance testing, seven measurements of pH and temperature varied from 7.59 to 8.10 and from 18.39°C to 29.88°C, respectively, at well R-49 screen 1 (Table B-1.2-1). The higher temperatures exceeding 25°C are reflective of atmospheric land-surface conditions at the site during sampling. Concentrations of DO varied from 0.52 to 5.08 mg/L at R-49 screen 1 during aquifer testing, suggesting that groundwater is oxic. Noncorrected ORP values varied from 42.9 to 141 mV during aquifer testing of R-49 screen 1 (Table B-1.2-1). Corrected Eh values ranged from 241.4 to 334.5 mV during aquifer testing of well R-49 screen 1. These DO measurements taken during aquifer testing are generally consistent with the corrected Eh values. Specific conductance decreased from 185 to 207 µS/cm, and turbidity values generally decreased from 49.5 to 4.0 NTUs during this phase of testing of R-49 screen 1 (Table B-1.2-1).

Six measurements of pH and temperature varied from 8.10 to 8.27 and from 19.21°C to 24.09°C, respectively, during aquifer performance testing conducted at well R-49 screen 2 (Table B-1.2-1). Concentrations of DO varied from 6.37 to 7.04 mg/L at R-49 screen 2 during aquifer testing, suggesting that groundwater is oxic. Noncorrected ORP values varied from 21.9 to 84.5 mV during aquifer testing of R-49 screen 2 (Table B-1.2-1). Corrected Eh values ranged from 2225.8 to 283.0 mV during aquifer testing of well R-49 screen 2. Specific conductance decreased from 134 to 1118 μS/cm for the R-49 screen 2 samples measured during aquifer performance testing. Turbidity decreased from 2.3 to 0.9 NTUs in groundwater pumped from R-49 screen 2 during this phase of testing (Table B-1.2-1).

B-1.3.1 Tritium Analyses of Borehole R-49

Concentrations of tritium in two screening borehole samples, CAPA-09-7061 and CAPA-09-7062, were nondetect (IDL]equal to 6 pCi/L) and nondetect (IDL equal to 0.28 pCi/L), respectively. Sample CAPA-09-7061 was analyzed by direct counting, and sample CAPA-09-7062 was analyzed by electrolytic enrichment. The one detect of tritium (sample CAPA-09-7063 at 1.87 pCi/L) was analyzed by electrolytic enrichment.

B-1.3 Analytical Results for R-49 Groundwater-Screening Samples

Analytical results for groundwater-screening samples collected at well R-49 during drilling, well development, and aquifer performance testing are provided in Table B-1-2-2. All samples were analyzed in-house at the EES-14 laboratory.

B-1.3-1 Well Development

Seven groundwater samples were collected from R-49 screens 1 and 2 during well development, and selected analytical results for these samples are discussed in the following discussion. Calcium and sodium are the dominant cations in regional aquifer groundwater pumped from well R-49. During well development of R-49 screen 1, dissolved concentrations of calcium ranged from 10.82 to 12.14 ppm (10.82 to 12.14 mg/L) and from 19.15 to 27.56 ppm, respectively. Dissolved concentrations of chloride and fluoride ranged from 4.18 to 4.33 ppm and from 0.31 to 0.32 ppm, respectively, during development conducted at well R-49 screen 1 (Table B-1.2-2). Dissolved concentrations of nitrate(N) decreased from 0.87 to 0.70 ppm, and dissolved concentrations of sulfate ranged from 10.81 to 16.20 ppm during development at well R-49 screen 1. Dissolved concentrations of chloride, nitrate(N), and sulfate exceeded Laboratory median background for regional aquifer groundwater (LANL 2007, 095817). Median background concentrations for dissolved chloride, nitrate plus nitrite(N), and sulfate in the regional aquifer are 2.17 mg/L, 0.31 mg/L, and 2.83 mg/L, respectively (LANL 2007, 095817). Detectable concentrations of TOC slightly increased from 0.53 to 1.04 milligrams carbon per liter (mgC/L) in groundwater-screening samples collected during development conducted at well R-49 screen 1 (Table B-1.2-2). The median background concentration of TOC is 0.34 mgC/L for regional aquifer groundwater (LANL 2007, 095817).

During well development conducted at R-49 screen 1, dissolved concentrations of iron increased from 0.010 to 0.087 ppm (10 to 87 μg/L or 10 to 87 ppb) using ICPOES (Table B-1.2-2), which do not exceed the maximum background value of 147 μg/L for regional aquifer groundwater (LANL 2007, 095817). Dissolved concentrations of manganese decreased from 0.010 to 0.005 ppm (Table B-1.2-2) in groundwater samples pumped from R-49 screen 1, which exceed the median background value of 1.0 μg/L for regional aquifer groundwater (LANL 2007, 095817). A carbon-steel discharge pipe was used during well development at R-49, which contributed iron and manganese in the form of colloidal rust to the filtered groundwater samples. Dissolved concentrations of boron ranged from 0.020 to 0.026 ppm (Table B-1.2-2) at well R-49 screen 1, which is below the maximum background value of 51.6 μg/L for the regional aquifer (LANL 2007, 095817). Dissolved concentrations of nickel were less than analytical detection (0.001 ppm, ICPMS method) (Table B-1.2-2) in the three groundwater-screening samples collected during well development conducted at R-49 screen 1. Dissolved concentrations of zinc were 0.005 and 0.006 ppm in groundwater-screening samples collected at well R-49 screen 1 during development (Table B-1.1-2). The background median concentration of zinc in filtered samples was 1.45 μg/L for the regional aquifer (LANL 2007, 095817). Total dissolved concentrations of chromium were 0.001 and 0.002 ppm (1 and 2 μg/L) at well R-49 screen 1 (Table B-1.2-2). Background mean, median, and maximum concentrations of total dissolved chromium are 3.07 μg/L, 3.05 μg/L, and 7.20 μg/L, respectively, for the regional aquifer (LANL 2007, 095817). During development of well R-49 screen 2, dissolved concentrations of calcium ranged from 10.87 to 11.82 ppm, and dissolved concentrations of sodium decreased from 21.14 to 17.96 ppm. Dissolved concentrations of chloride and fluoride decreased from 4.04 to 3.72 ppm and from 0.33 to 0.31 ppm, respectively, during development conducted at well R-49 screen 2 (Table B-1.2-2). Dissolved concentrations of nitrate(N) and sulfate decreased from 0.75 to 0.71 ppm and from 13.10 to 9.27 ppm, respectively, during development at well R-49 screen 2. Dissolved concentrations of chloride, nitrate(N), and sulfate exceeded Laboratory median background for regional aquifer groundwater (LANL 2007, 095817). Median background concentrations for dissolved chloride, nitrate plus nitrite(N), and sulfate in the regional aquifer are 2.17 mg/L, 0.31 mg/L, and 2.83 mg/L, respectively (LANL 2007, 095817). Detectable concentrations of TOC decreased from 0.29 to 0.23 mgC/L in groundwater-screening samples collected during development conducted at well R-49 screen 2 (Table B-1.2-2). The median background concentration of TOC is 0.34 mgC/L for regional aquifer groundwater (LANL 2007, 095817). Analytical results for perchlorate are pending for groundwater samples collected from well R-49.

During well development conducted at R-49 screen 2, dissolved concentrations of iron ranged from 0.090 to 0.276 ppm using ICPOES (Table B-1.2-2), which exceeded the maximum background value of 147 μg/L for regional aquifer groundwater (LANL 2007, 095817). Dissolved concentrations of manganese generally decreased from 0.015 to 0.010 ppm (Table B-1.2-2) in groundwater samples pumped from R-49 screen 2, which exceeded the median background value of 1.0 μg/L for regional aquifer groundwater (LANL 2007, 095817). Dissolved concentrations of boron decreased from 0.031 to 0.019 ppm (Table B-1.2-2) at well R-49 screen 2, which is below the maximum background value of 51.6 μg/L for the regional aquifer (LANL 2007, 095817). Dissolved concentrations of nickel generally were less than analytical detection (0.001 ppm, ICPMS method) (Table B-1.2-2) in the four groundwater-screening samples collected during well development conducted at R-49 screen 2. Dissolved concentrations of zinc varied from 0.004 to 0.008 ppm in groundwater-screening samples collected at well R-49 screen 2 during development (Table B-1.2-2). The background median concentration of zinc in filtered samples is 1.45 μg/L for the regional aquifer (LANL 2007, 095817). Total dissolved concentrations of chromium were 0.002 and 0.003 ppm (2 and 3 μg/L) at well R-49 screen 2 (Table B-1.2-2). Background mean, median, and maximum concentrations of total dissolved chromium are 3.07 μg/L, 3.05 μg/L, and 7.20 μg/L, respectively, for the regional aquifer (LANL 2007, 095817).

B-1.3-2 Aquifer Performance Testing

During aquifer performance testing of R-49 screen 1, dissolved concentrations of calcium ranged from 12.59 to 12.83 ppm, and dissolved concentrations of sodium generally decreased from 17.54 to 13.63 ppm, which are slightly higher than those measured in groundwater-screening samples collected from R-49 screen 2. Dissolved concentrations of chloride and fluoride slightly varied from 4.29 to 4.61 ppm and from 0.32 to 0.38 ppm, respectively, during aquifer performance testing at well R-49 screen 1 (Table B-1.2-2). Dissolved concentrations of nitrate(N) varied from 0.44 to 0.63 ppm, which are less than dissolved concentrations of nitrate(N) measured in groundwater-screening samples collected from R-49 screen 2. Dissolved concentrations of sulfate varied from 9.06 to 14.88 ppm during aquifer performance testing at well R-49 screen 1, which are higher than those measured in groundwater-screening samples collected from R-49 screen 2. Dissolved concentrations of chloride, nitrate(N), and sulfate at well R-49 exceeded Laboratory median background within regional aquifer groundwater (LANL 2007, 095817). Concentrations of TOC fluctuated from 0.98 to 4.20 mgC/L during aquifer performance testing at well R-49 screen 1 (Table B-1.2-2). It is unlikely that the elevated TOC values result from residual drilling fluid because TOC concentrations generally were less than 1 mgC/L during development of well R-49.

During aquifer performance testing conducted at R-49 screen 1, dissolved concentrations of iron were less than analytical detection (0.010 ppm) using ICPOES (Table B-1.2-2). A stainless-steel discharge pipe was used during aquifer performance testing at R-49 screens 1 and 2, which is much less corrosive than carbon steel. Dissolved concentrations of manganese decreased from 0.015 to 0.007 ppm (Table B-1.2-2) at well R-49 screen 1 during this phase of testing. Dissolved concentrations of boron varied from 0.017 to 0.030 ppm (Table B-1.2-2) in groundwater-screening samples collected from well R-49 screen 1, which is below the maximum background value of 51.6 μg/L for the regional aquifer (LANL 2007, 095817). Dissolved concentrations of nickel were less than analytical detection (0.001 ppm, ICPMS method) (Table B-1.2-2) in seven groundwater-screening samples collected from R-49 screen 1 during aquifer performance testing. Dissolved concentrations of zinc generally increased from 0.007 and 0.012 ppm in groundwater-screening samples collected from R-49 screen 1 during this phase of testing (Table B-1.2-2). The background median concentration of zinc in filtered samples is 1.45 μg/L for the regional aquifer (LANL 2007, 095817). Total dissolved concentrations of chromium were 0.003 ppm (3 μg/L) in the seven groundwater-screening samples collected from R-49 screen 1 during aquifer performance testing (Table B-1.2-2). Background mean, median, and maximum concentrations of total dissolved chromium are 3.07 μg/L, 3.05 μg/L, and 7.20 μg/L, respectively, for the regional aquifer (LANL 2007, 095817).

Dissolved concentrations of calcium and sodium ranged from 9.92 to 10.84 ppm and from 11.94 to 14.04 ppm, respectively, during aquifer performance testing conducted at R-49 screen 2 (Table B-1.2-2). Dissolved concentrations of chloride and fluoride decreased from 3.95 to 3.50 ppm and from 0.39 to 0.35 ppm, respectively, during this phase of testing conducted at well R-49 screen 2 (Table B-1.2-2). Dissolved concentrations of nitrate(N) and sulfate decreased from 0.74 to 0.56 ppm and from 6.10 to 5.07 ppm, respectively, during aquifer performance testing performed at well R-49 screen 2. Dissolved concentrations of chloride, nitrate(N), and sulfate in groundwater-screening samples collected from R-49 screen 2 exceeded Laboratory median background within regional aquifer groundwater (LANL 2007, 095817). Median background concentrations for dissolved chloride, nitrate plus nitrite(N), and sulfate in the regional aquifer are 2.17 mg/L, 0.31 mg/L, and 2.83 mg/L, respectively (LANL 2007, 095817). Concentrations of TOC measured in groundwater-screening samples varied from 0.30 to 0.95 mgC/L during aquifer performance testing at well R-49 screen 2 (Table B-1.2-2).

During aquifer performance testing conducted at R-49 screen 2, dissolved concentrations of iron were less than analytical detection (0.010 ppm) using ICPOES (Table B-1.2-2). Dissolved concentrations of manganese increased slightly from 0.002 to 0.005 ppm (Table B-1.2-2) during aquifer performance testing conducted at well R-49 screen 2. Dissolved concentrations of boron decreased from 0.024 to 0.014 pm (Table B-1.2-2) at well R-49 screen 2, which is below the maximum background value of 51.6 μg/L for the regional aquifer (LANL 2007, 095817). Dissolved concentrations of boron are lower in groundwater samples collected from the lower screen compared with the upper screen at well R-49 (Table B-1.2-2). Detectable dissolved concentrations of nickel were 0.001 ppm in groundwater-screening samples collected from R-49 screen 2 during aquifer performance testing (Table B-1.2-2). Dissolved concentrations of zinc varied from 0.003 to 0.006 ppm in groundwater-screening samples collected from R-49 screen 2 during aquifer performance testing (Table B-1.2-2). Total dissolved concentrations of chromium varied slightly between 0.002 and 0.004 ppm (3 and 4 μg/L) at well R-49 screen 2

(Table B-1.2-2). Background mean, median, and maximum concentrations of total dissolved chromium are 3.07 μg/L, 3.05 μg/L, and 7.20 μg/L, respectively, for the regional aquifer (LANL 2007, 095817). Total dissolved concentrations of chromium are similar in groundwater samples collected from both screens at R-49.

In summary, groundwater at well R-49 is relatively oxidizing, based on corrected Eh values and measurable concentrations of DO, nitrate(N), and sulfate. Concentrations of total dissolved solids (TDS), including total carbonate alkalinity, sulfate, and chloride, are higher in groundwater samples pumped from well R-49 screen 1 compared with those values measured in the R-49 screen 2 samples. Dissolved concentrations of chloride, nitrate(N), and sulfate exceed median background concentrations of these three anions within the regional aquifer at well R-49. The presence of nitrate and chloride at well R-49 suggests that a small component of groundwater at the well is derived from the inactive sewage lagoons at TA-18 in Pajarito Canyon. Well R-49 is located downgradient from the TA-18 sewage lagoons. Elevated above-background concentrations of TOC at R-49 screen 1 suggest possible presence of a sewage plume most likely derived from the inactive sewage lagoons at TA-18.

B-2.0 REFERENCE

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

LANL (Los Alamos National Laboratory), May 2007. "Groundwater Background Investigation Report, Revision 3," Los Alamos National Laboratory document LA-UR-07-2853, Los Alamos, New Mexico. (LANL 2007, 095817)

Table B-1.2-1
Well Development Volumes, Aquifer Pump Test Volumes, and Associated Field Water-Quality Parameters for R-49

Date	pH	Temp (°C)	DO (mg/L)	ORP, Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development								
06/03/09	n/r*; bailing						117	117
06/04/09	n/r, bailing						774	891
06/05/09	n/r, bailing						260	1151
06/07/009	n/r, pumping with swabbing						1971	3122
06/08/09	n/r, pumping with swabbing						3902	7024
06/08/09 (upper screen)	7.97	22.81	5.64	4.2,202.7	137	29.2	13	7037
	8.02	23.81	3.94	3.4,201.9	144	18.7	22	7059
	8.00	22.74	4.03	34.1, 232.6	144	21.0	45	7104
	8.04	22.17	5.72	18.4, 222.3	143	26.3	12	7116
	7.92	22.35	4.43	-7.4, 196.5	136	36.8	37	7153
	8.00	21.97	3.17	0.9, 204.8	132	92.1	37	7190
	7.98	22.99	2.22	1.8, 200.3	141	247.0	37	7227
	8.02	24.13	2.07	14.4, 212.9	144	274.0	37	7264
	8.06	24.04	2.63	29.6, 228.1	142	195.0	37	7301
	8.07	24.98	2.79	35.4, 233.9	146	485.0	37	7338
	8.16	25.51	2.87	6.4, 204.9	148	445.0	37	7375
	8.12	25.42	2.95	63.0, 261.5	149	544.0	37	7412
	8.15	25.51	2.94	44.5, 243.0	151	498.0	43	7455
	n/r, pumping						7245	14,700
06/08/09 (lower screen)	8.18	22.66	4.19	-4.1, 194.4	129	8.2	345	15,045
	8.15	22.47	4.58	-18.0, 185.9	128	7.3	345	15,390
	8.09	22.24	4.60	-16.0, 187.9	126	5.0	345	15,735
	8.14	22.12	4.45	-16.2, 187.7	126	4.0	345	16,080
	8.09	22.34	4.80	-26.4, 177.5	125	3. 6	345	16,425
	8.11	22.46	4.84	-19.5, 184.4	125	3.2	345	16,770
	8.04	22.29	4.98	-22.1, 181.8	124	3.0	345	17,115
	8.08	22.28	5.06	-10.3, 193.6	123	2.9	345	17,460
	8.03	22.26	5.10	-23.1, 180.8	122	3.0	345	17,805
06/11/09	n/r, pumping						5520	23,325
06/12/09 (upper screen)	Turbidity (final) >1000 NTUs, pumping						700	24,025
06/13/09 (upper screen)	Turbidity (final) >1000 NTUs, pumping						1050	25,075

Table B-1.2-1 (continued)

Aquifer Pump Test Volumes								
06/14/9	n/r, pumping, test pump operation						220	220
06/15/09	n/r, pumping, mini-test lower screen						4266	4486
06/17/09 (lower screen)	8.23	21.13	6.37	21.9, 225.8	134	2.3	1400	5886
	8.13	23.67	6.91	60.0, 258.5	125	1.3	5590	11,476
	8.10	24.09	6.99	84.5, 283.0	122	1.3	8378	19,854
	8.07	22.83	7.04	46.9, 245.4	119	0.9	2786	22,640
06/18/09 (lower screen)	8.26	20.83	7.03	29.7, 233.6	118	0.9	5589	28,229
	8.27	19.21	6.96	58.4, 262.3	118	1.0	5949	34,178
	n/r						3843	38,021
06/19/09	n/r, pumping, test pump operation						62	38,083
06/20/09	n/r, pumping, step tests upper screen						191	38,274
06/22/09 (upper screen)	7.59	18.39	2.63	62.8, 266.7	198	49.5	88	38,362
	8.10	27.31	5.08	80.6, 279,1	207	11.0	356	38,718
	7.98	29.88	1.61	141.0, 334.5	200	4.73	356	39,074
	7.79	27.30	1.47	87.8, 286.3	191	5.0	416	39,490
	7.97	24.53	0.81	42.9, 241.4	186	4.0	326	39,816
06/23/09 (upper screen)	7.89	24.34	2.19	55.9, 254.4	185	4.0	266	40,082
	7.86	23.70	0.52	59.1, 257.6	189	4.2	266	40,348
	n/r						86	40,434

Note: Cumulative purge volumes calculated using average pump discharge rate of 23.3 gpm for the lower screen and 1.5 gpm for the upper screen during 24-h pump tests. Corrected Eh values are provided in this table. See text for correction factors converting ORP to Eh.

* n/r = Not recorded.

Table B-1.2-2
Analytical Results for Groundwater Screening Samples Collected from Well R-49, Pajarito Canyon

Sample ID	Date Collected	Date Received	ER/RRES-WQH	PHASE	Depth (ft)	Ag rslt (ppm)	stdev (Ag)	Al rslt (ppm)	stdev (Al)	As rslt (ppm)	stdev (As)	B rslt (ppm)	stdev (B)	Ba rslt (ppm)	stdev (Ba)	Be rslt (ppm)	stdev (Be)	Br(-) ppm
CAPA-09-7021	3/31/2009	4/2/2009	09-1361	Drilling	177	0.001	U	4.91	0.05	0.0020	0.0010	0.054	0.000	0.143	0.001	0.001	U	0.05
CAPA-09-7022	4/17/2009	4/20/2009	09-1516	Drilling	623	0.001	U	0.19	0.01	0.0008	0.0000	0.112	0.005	0.110	0.004	0.001	U	0.01
CAPA-09-7023	4/18/2009	4/20/2009	09-1516	Drilling	908	0.001	U	0.015	0.000	0.0008	0.0000	0.040	0.002	0.038	0.000	0.001	U	0.03
CAPA-09-7041	6/10/2009	6/15/2009	09-2297	Development	905.6–926.4	0.001	U	0.003	0.000	0.0005	0.0000	0.031	0.001	0.029	0.000	0.001	U	0.07
CAPA-09-7042	6/10/2009	6/15/2009	09-2297	Development	905.6–926.4	0.001	U	0.003	0.001	0.0007	0.0000	0.024	0.000	0.042	0.001	0.001	U	0.06
CAPA-09-7043	6/10/2009	6/15/2009	09-2297	Development	905.6–926.4	0.001	U	0.003	0.000	0.0006	0.0000	0.022	0.000	0.041	0.001	0.001	U	0.06
CAPA-09-7044	6/10/2009	6/15/2009	09-2297	Development	905.6–926.4	0.001	U	0.002	0.000	0.0006	0.0000	0.019	0.001	0.042	0.001	0.001	U	0.06
CAPA-09-7045	6/10/2009	6/15/2009	09-2297	Development	845.0–855.0	0.001	U	0.002	0.000	0.0008	0.0000	0.020	0.000	0.037	0.000	0.001	U	0.07
CAPA-09-7046	6/13/2009	6/15/2009	09-2323	Development	845.0–855.0	0.001	U	0.028	0.001	0.0009	0.0000	0.026	0.001	0.043	0.001	0.001	U	0.06
CAPA-09-7047	6/13/2009	6/15/2009	09-2323	Development	845.0–855.0	0.001	U	0.231	0.005	0.0010	0.0001	0.021	0.000	0.048	0.002	0.001	U	0.06
CAPA-09-7048	6/17/2009	6/18/2009	09-2391	Aquifer Testing	905.6–926.4	0.001	U	0.003	0.000	0.0010	0.0002	0.024	0.000	0.051	0.001	0.001	U	0.05
CAPA-09-7049	6/17/2009	6/18/2009	09-2391	Aquifer Testing	905.6–926.4	0.001	U	0.005	0.001	0.0006	0.0000	0.020	0.000	0.046	0.001	0.001	U	0.04
CAPA-09-7050	6/17/2009	6/18/2009	09-2391	Aquifer Testing	905.6–926.4	0.001	U	0.004	0.000	0.0006	0.0000	0.017	0.001	0.047	0.000	0.001	U	0.04
CAPA-09-7051	6/17/2009	6/18/2009	09-2391	Aquifer Testing	905.6–926.4	0.001	U	0.005	0.000	0.0006	0.0000	0.016	0.000	0.047	0.000	0.001	U	0.04
CAPA-09-7052	6/18/2009	6/18/2009	09-2391	Aquifer Testing	905.6–926.4	0.001	U	0.005	0.001	0.0006	0.0001	0.014	0.000	0.046	0.000	0.001	U	0.04
CAPA-09-7053	6/18/2009	6/18/2009	09-2391	Aquifer Testing	905.6–926.4	0.001	U	0.004	0.000	0.0006	0.0000	0.014	0.000	0.047	0.000	0.001	U	0.03
CAPA-09-7054	6/22/2009	6/23/2009	09-2448	Aquifer Testing	845.0–855.0	0.001	U	0.009	0.000	0.0011	0.0000	0.017	0.000	0.059	0.001	0.001	U	0.07
CAPA-09-7055	6/22/2009	6/23/2009	09-2448	Aquifer Testing	845.0–855.0	0.001	U	0.024	0.002	0.0012	0.0001	0.019	0.000	0.059	0.000	0.001	U	0.07
CAPA-09-7056	6/22/2009	6/23/2009	09-2448	Aquifer Testing	845.0–855.0	0.001	U	0.006	0.000	0.0010	0.0000	0.026	0.000	0.055	0.001	0.001	U	0.07
CAPA-09-7057	6/22/2009	6/23/2009	09-2448	Aquifer Testing	845.0–855.0	0.001	U	0.004	0.000	0.0009	0.0000	0.048	0.001	0.053	0.001	0.001	U	0.07
CAPA-09-7058	6/22/2009	6/23/2009	09-2448	Aquifer Testing	845.0–855.0	0.001	U	0.006	0.001	0.0009	0.0000	0.036	0.000	0.051	0.001	0.001	U	0.07
CAPA-09-7059	6/23/2009	6/23/2009	09-2448	Aquifer Testing	845.0–855.0	0.001	U	0.006	0.000	0.0008	0.0000	0.032	0.000	0.051	0.001	0.001	U	0.06
CAPA-09-7060	6/23/2009	6/23/2009	09-2448	Aquifer Testing	845.0–855.0	0.001	U	0.005	0.000	0.0008	0.0000	0.030	0.001	0.049	0.000	0.001	U	0.07

Table B-1.2-2 (continued)

Sample ID	Date Collected	Date Received	TOC rslt (ppm)	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	stdev (Cd)	Cl(-) ppm	ClO4(-) ppm	ClO4(-) (U)	Co rslt (ppm)	stdev (Co)	Alk-CO3 rslt (ppm)	ALK-CO3 (U)	Cr rslt (ppm)	stdev (Cr)	Cs rslt (ppm)	stdev (Cs)	Cu rslt (ppm)	stdev (Cu)
CAPA-09-7021	3/31/2009	4/2/2009	Not analyzed	9.93	0.03	0.001	U	9.32	Pending	Pending	0.001	U	0.8	U	0.004	0.000	0.001	U	0.005	0.000
CAPA-09-7022	4/17/2009	4/20/2009	Not analyzed	24.91	0.13	0.001	U	10.14	Pending	Pending	0.001	U	0.8	U	0.008	0.000	0.001	U	0.002	0.000
CAPA-09-7023	4/18/2009	4/20/2009	Not analyzed	17.54	0.09	0.001	U	7.04	Pending	Pending	0.001	U	0.8	U	0.007	0.000	0.001	U	0.002	0.000
CAPA-09-7041	6/10/2009	6/15/2009	0.29	11.82	0.10	0.001	U	4.04	Pending	Pending	0.001	U	0.8	U	0.002	0.000	0.001	U	0.001	0.000
CAPA-09-7042	6/10/2009	6/15/2009	0.25	11.08	0.08	0.001	U	3.82	Pending	Pending	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	0.000
CAPA-09-7043	6/10/2009	6/15/2009	0.26	11.01	0.01	0.001	U	3.79	Pending	Pending	0.001	U	0.8	U	0.002	0.000	0.001	U	0.001	U
CAPA-09-7044	6/10/2009	6/15/2009	0.23	10.87	0.05	0.001	U	3.72	Pending	Pending	0.001	U	0.8	U	0.002	0.000	0.001	U	0.001	U
CAPA-09-7045	6/10/2009	6/15/2009	0.53	11.86	0.07	0.001	U	4.33	Pending	Pending	0.001	U	0.8	U	0.001	0.000	0.001	U	0.001	0.000
CAPA-09-7046	6/13/2009	6/15/2009	0.87	12.14	0.06	0.001	U	4.18	Pending	Pending	0.001	U	0.8	U	0.001	0.000	0.001	U	0.001	0.000
CAPA-09-7047	6/13/2009	6/15/2009	1.04	10.82	0.06	0.001	U	4.30	Pending	Pending	0.001	U	0.8	U	0.002	0.000	0.001	U	0.002	0.000
CAPA-09-7048	6/17/2009	6/18/2009	0.34	10.84	0.05	0.001	U	3.95	Pending	Pending	0.001	U	0.8	U	0.002	0.000	0.001	U	0.001	U
CAPA-09-7049	6/17/2009	6/18/2009	0.30	9.92	0.09	0.001	U	3.58	Pending	Pending	0.001	U	6.89	0.69	0.003	0.000	0.001	U	0.001	U
CAPA-09-7050	6/17/2009	6/18/2009	0.31	9.95	0.09	0.001	U	3.54	Pending	Pending	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7051	6/17/2009	6/18/2009	0.95	10.06	0.04	0.001	U	3.54	Pending	Pending	0.001	U	0.8	U	0.004	0.000	0.001	U	0.001	U
CAPA-09-7052	6/18/2009	6/18/2009	0.51	10.10	0.05	0.001	U	3.51	Pending	Pending	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7053	6/18/2009	6/18/2009	0.49	10.04	0.09	0.001	U	3.50	Pending	Pending	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7054	6/22/2009	6/23/2009	0.98	12.61	0.09	0.001	U	4.59	Pending	Pending	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7055	6/22/2009	6/23/2009	1.59	12.71	0.10	0.001	U	4.61	Pending	Pending	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7056	6/22/2009	6/23/2009	3.24	12.59	0.13	0.001	U	4.45	Pending	Pending	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7057	6/22/2009	6/23/2009	4.20	12.61	0.06	0.001	U	4.41	Pending	Pending	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7058	6/22/2009	6/23/2009	3.00	12.62	0.12	0.001	U	4.29	Pending	Pending	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7059	6/23/2009	6/23/2009	2.18	12.83	0.06	0.001	U	4.31	Pending	Pending	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7060	6/23/2009	6/23/2009	2.11	12.80	0.08	0.001	U	4.31	Pending	Pending	0.001	U	0.8	U	0.003	0.000	0.001	U	0.001	U

Table B-1.2-2 (continued)

Sample ID	Date Collected	Date Received	F(-) ppm	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)	Hg rslt (ppm)	stdev (Hg)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	stdev (Li)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	stdev (Mo)	Na rslt (ppm)	stdev (Na)
CAPA-09-7021	3/31/2009	4/2/2009	1.21	3.380	1.790	54.0	0.00022	0.00002	11.42	1.29	0.014	0.001	2.08	0.01	0.160	0.008	0.032	0.000	19.81	0.19
CAPA-09-7022	4/17/2009	4/20/2009	0.82	0.730	0.020	141.0	0.00025	0.00000	3.63	0.12	0.042	0.002	6.44	0.20	0.023	0.001	0.064	0.001	21.87	0.57
CAPA-09-7023	4/18/2009	4/20/2009	0.68	0.060	0.000	119.0	0.00014	0.00001	4.06	0.05	0.048	0.001	4.9	0.05	0.020	0.001	0.041	0.000	20.34	0.16
CAPA-09-7041	6/10/2009	6/15/2009	0.33	0.090	0.000	93.0	0.00010	0.00002	1.42	0.01	0.021	0.000	3.02	0.01	0.015	0.000	0.002	0.000	21.14	0.10
CAPA-09-7042	6/10/2009	6/15/2009	0.31	0.244	0.001	86.0	0.00007	0.00001	1.29	0.00	0.026	0.001	2.86	0.01	0.013	0.001	0.002	0.000	19.09	0.15
CAPA-09-7043	6/10/2009	6/15/2009	0.31	0.271	0.001	86.0	0.00009	0.00002	1.33	0.00	0.021	0.001	2.98	0.02	0.010	0.000	0.002	0.000	19.31	0.03
CAPA-09-7044	6/10/2009	6/15/2009	0.31	0.276	0.001	85.0	0.00017	0.00002	1.27	0.00	0.017	0.000	2.86	0.02	0.011	0.000	0.002	0.000	17.96	0.08
CAPA-09-7045	6/10/2009	6/15/2009	0.31	0.010	U	89.0	0.00020	0.00002	1.41	0.01	0.018	0.000	2.84	0.01	0.010	0.000	0.002	0.000	19.15	0.06
CAPA-09-7046	6/13/2009	6/15/2009	0.31	0.024	0.000	97.0	0.00022	0.00003	1.62	0.01	0.023	0.002	3.32	0.01	0.006	0.000	0.002	0.000	27.56	0.14
CAPA-09-7047	6/13/2009	6/15/2009	0.32	0.087	0.002	96.0	0.00049	0.00001	1.19	0.01	0.018	0.002	2.35	0.02	0.005	0.000	0.005	0.000	25.77	0.16
CAPA-09-7048	6/17/2009	6/18/2009	0.39	0.010	U	84.0	0.00015	0.00002	1.17	0.01	0.019	0.001	2.61	0.01	0.002	0.000	0.001	0.000	14.04	0.12
CAPA-09-7049	6/17/2009	6/18/2009	0.37	0.010	U	80.0	0.00017	0.00001	1.16	0.00	0.029	0.001	2.54	0.01	0.004	0.000	0.001	0.000	13.37	0.03
CAPA-09-7050	6/17/2009	6/18/2009	0.36	0.010	U	79.0	0.00015	0.00000	1.18	0.00	0.029	0.002	2.64	0.01	0.005	0.000	0.001	0.000	13.15	0.06
CAPA-09-7051	6/17/2009	6/18/2009	0.36	0.010	U	78.0	0.00015	0.00002	1.18	0.01	0.030	0.001	2.67	0.02	0.005	0.000	0.001	U	12.53	0.01
CAPA-09-7052	6/18/2009	6/18/2009	0.36	0.010	U	78.0	0.00014	0.00002	1.17	0.01	0.028	0.002	2.67	0.01	0.005	0.000	0.001	U	11.94	0.10
CAPA-09-7053	6/18/2009	6/18/2009	0.35	0.010	U	78.0	0.00015	0.00003	1.24	0.01	0.029	0.001	2.80	0.02	0.005	0.000	0.001	U	12.05	0.14
CAPA-09-7054	6/22/2009	6/23/2009	0.38	0.010	U	95.0	0.00016	0.00001	1.34	0.01	0.029	0.000	3.12	0.02	0.015	0.001	0.002	0.000	17.51	0.11
CAPA-09-7055	6/22/2009	6/23/2009	0.35	0.010	U	89.0	0.00014	0.00003	1.39	0.00	0.032	0.002	3.26	0.02	0.011	0.001	0.002	0.000	17.54	0.10
CAPA-09-7056	6/22/2009	6/23/2009	0.32	0.010	U	87.0	0.00016	0.00002	1.36	0.01	0.031	0.001	3.26	0.03	0.010	0.000	0.002	0.000	15.39	0.20
CAPA-09-7057	6/22/2009	6/23/2009	0.34	0.010	U	87.0	0.00017	0.00002	1.44	0.02	0.031	0.001	3.30	0.01	0.009	0.000	0.002	0.000	14.75	0.14
CAPA-09-7058	6/22/2009	6/23/2009	0.34	0.010	U	86.4	0.00016	0.00001	1.42	0.01	0.033	0.002	3.34	0.01	0.008	0.001	0.002	0.000	14.15	0.08
CAPA-09-7059	6/23/2009	6/23/2009	0.38	0.010	U	86.5	0.00014	0.00001	1.38	0.01	0.033	0.000	3.34	0.01	0.008	0.000	0.002	0.000	13.63	0.13
CAPA-09-7060	6/23/2009	6/23/2009	0.35	0.010	U	86.7	0.00013	0.00002	1.40	0.01	0.031	0.002	3.39	0.02	0.007	0.000	0.001	0.000	13.74	0.06

Table B-1.2-2 (continued)

Sample ID	Date Collected	Date Received	Ni rslt (ppm)	stdev (Ni)	NO2 (ppm)	NO2-N rslt	NO2-N (U)	NO3 ppm	NO3-N rslt	C2O4 rslt (ppm)	C2O4 (U)	Pb rslt (ppm)	stdev (Pb)	pH	PO4(-3) rslt (ppm)	Rb rslt (ppm)	stdev (Rb)	Sb rslt (ppm)	stdev (Sb)	Se rslt (ppm)	stdev (Se)
CAPA-09-7021	3/31/2009	4/2/2009	0.002	0.000	0.01	0.003	U	0.01	0.002, U	0.01	U	0.0143	0.0004	7.35	0.11	0.056	0.001	0.001	U	0.002	0.001
CAPA-09-7022	4/17/2009	4/20/2009	0.002	0.000	0.01	0.003	U	0.01	0.002, U	0.08	U	0.0058	0.0002	7.95	0.01, U	0.006	0.000	0.001	U	0.001	U
CAPA-09-7023	4/18/2009	4/20/2009	0.001	0.000	0.01	0.003	U	0.01	0.002, U	0.04	U	0.0003	0.0000	7.22	0.01, U	0.004	0.000	0.001	U	0.001	U
CAPA-09-7041	6/10/2009	6/15/2009	0.001	0.000	0.01	0.003	U	3.34	0.75	0.01	U	0.0002	U	7.85	0.01, U	0.002	0.000	0.001	U	0.001	U
CAPA-09-7042	6/10/2009	6/15/2009	0.001	U	0.01	0.003	U	3.24	0.73	0.01	U	0.0002	U	7.76	0.05	0.002	0.000	0.001	U	0.001	U
CAPA-09-7043	6/10/2009	6/15/2009	0.001	U	0.01	0.003	U	3.21	0.72	0.01	U	0.0002	U	7.70	0.05	0.002	0.000	0.001	U	0.001	U
CAPA-09-7044	6/10/2009	6/15/2009	0.001	U	0.01	0.003	U	3.16	0.71	0.01	U	0.0002	U	7.70	0.05	0.002	0.000	0.001	U	0.001	U
CAPA-09-7045	6/10/2009	6/15/2009	0.001	U	0.01	0.003	U	3.84	0.87	0.01	U	0.0002	U	7.81	0.04	0.002	0.000	0.001	U	0.001	U
CAPA-09-7046	6/13/2009	6/15/2009	0.001	U	0.22	0.067	0.007	3.15	0.71	0.01	U	0.0002	U	7.87	0.01, U	0.001	0.000	0.001	U	0.001	U
CAPA-09-7047	6/13/2009	6/15/2009	0.001	U	0.26	0.079	0.008	3.11	0.70	0.01	U	0.0002	U	7.95	0.01, U	0.002	0.000	0.001	U	0.001	U
CAPA-09-7048	6/17/2009	6/18/2009	0.001	U	0.01	0.003	U	3.27	0.74	0.01	U	0.0002	U	7.76	0.05	0.003	0.000	0.001	U	0.001	U
CAPA-09-7049	6/17/2009	6/18/2009	0.001	U	0.01	0.003	U	2.66	0.60	0.01	U	0.0002	U	7.83	0.05	0.002	0.000	0.001	U	0.001	U
CAPA-09-7050	6/17/2009	6/18/2009	0.001	U	0.01	0.003	U	2.59	0.58	0.01	U	0.0002	U	7.80	0.07	0.002	0.000	0.001	U	0.001	U
CAPA-09-7051	6/17/2009	6/18/2009	0.001	U	0.01	0.003	U	2.52	0.57	0.01	U	0.0002	U	7.78	0.06	0.002	0.000	0.001	U	0.001	U
CAPA-09-7052	6/18/2009	6/18/2009	0.001	U	0.01	0.003	U	2.48	0.56	0.01	U	0.0002	U	7.76	0.06	0.003	0.000	0.001	U	0.001	U
CAPA-09-7053	6/18/2009	6/18/2009	0.001	U	0.01	0.003	U	2.47	0.56	0.01	U	0.0002	U	7.83	0.06	0.003	0.000	0.001	U	0.001	U
CAPA-09-7054	6/22/2009	6/23/2009	0.001	U	0.01	0.003	U	2.55	0.58	0.01	U	0.0002	U	7.47	0.01, U	0.002	0.000	0.001	U	0.001	U
CAPA-09-7055	6/22/2009	6/23/2009	0.001	U	0.01	0.003	U	2.77	0.63	0.01	U	0.0002	U	7.38	0.01, U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7056	6/22/2009	6/23/2009	0.001	U	0.01	0.003	U	2.72	0.61	0.04	0.00	0.0002	U	7.37	0.04	0.003	0.000	0.001	U	0.001	U
CAPA-09-7057	6/22/2009	6/23/2009	0.001	U	0.01	0.003	U	2.24	0.51	0.01	U	0.0002	U	7.33	0.01, U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7058	6/22/2009	6/23/2009	0.001	U	0.34	0.103	U	2.30	0.52	0.01	U	0.0002	U	7.22	0.01, U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7059	6/23/2009	6/23/2009	0.001	U	0.38	0.116	U	1.93	0.44	0.01	U	0.0002	U	6.48	0.01, U	0.003	0.000	0.001	U	0.001	U
CAPA-09-7060	6/23/2009	6/23/2009	0.001	U	0.01	0.003	U	2.00	0.45	0.01	U	0.0002	U	7.25	0.01, U	0.003	0.000	0.001	U	0.001	U

Table B-1.2-2 (continued)

Sample ID	Date Collected	Date Received	Si rslt (ppm)	stdev (Si)	SiO2 rslt (ppm)	stdev (SiO2)	Sn rslt (ppm)	stdev (Sn)	SO4(-2) rslt (ppm)	Sr rslt (ppm)	stdev (Sr)	Th rslt (ppm)	stdev (Th)	Ti rslt (ppm)	stdev (Ti)	Tl rslt (ppm)	stdev (Tl)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)
CAPA-09-7021	3/31/2009	4/2/2009	37.72	0.33	80.71	0.71	0.001	U	5.42	0.036	0.000	0.014	0.000	0.074	0.001	0.001	U	0.0020	0.0000	0.004	0.000
CAPA-09-7022	4/17/2009	4/20/2009	34.51	1.29	73.85	2.77	0.001	U	6.18	0.112	0.002	0.001	U	0.262	0.008	0.001	U	0.0064	0.0003	0.008	0.000
CAPA-09-7023	4/18/2009	4/20/2009	22.53	0.25	48.22	0.53	0.001	U	6.2	0.074	0.002	0.001	U	0.053	0.000	0.001	U	0.0026	0.0001	0.006	0.000
CAPA-09-7041	6/10/2009	6/15/2009	32.06	0.05	68.62	0.11	0.001	U	13.10	0.102	0.001	0.001	U	0.002	U	0.001	U	0.0009	0.0000	0.003	0.000
CAPA-09-7042	6/10/2009	6/15/2009	32.76	0.23	70.11	0.49	0.001	U	10.50	0.099	0.000	0.001	U	0.002	U	0.001	U	0.0011	0.0000	0.005	0.000
CAPA-09-7043	6/10/2009	6/15/2009	34.28	0.22	73.36	0.46	0.001	U	10.05	0.097	0.000	0.001	U	0.002	U	0.001	U	0.0011	0.0000	0.005	0.000
CAPA-09-7044	6/10/2009	6/15/2009	32.98	0.26	70.57	0.55	0.001	U	9.27	0.090	0.001	0.001	U	0.002	U	0.001	U	0.0009	0.0000	0.004	0.000
CAPA-09-7045	6/10/2009	6/15/2009	31.48	0.21	67.38	0.44	0.001	U	10.81	0.170	0.001	0.001	U	0.002	U	0.001	U	0.0006	0.0000	0.004	0.000
CAPA-09-7046	6/13/2009	6/15/2009	38.28	0.08	81.92	0.17	0.001	U	16.20	0.260	0.002	0.001	U	0.002	U	0.001	U	0.0009	0.0000	0.004	0.000
CAPA-09-7047	6/13/2009	6/15/2009	32.26	0.33	69.04	0.71	0.001	U	15.90	0.236	0.002	0.001	U	0.005	0.000	0.001	U	0.0008	0.0001	0.006	0.000
CAPA-09-7048	6/17/2009	6/18/2009	30.60	0.14	65.48	0.30	0.001	U	6.10	0.094	0.025	0.001	U	0.002	U	0.001	U	0.0006	0.0000	0.005	0.000
CAPA-09-7049	6/17/2009	6/18/2009	31.44	0.14	67.29	0.31	0.001	U	5.51	0.064	0.002	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.006	0.000
CAPA-09-7050	6/17/2009	6/18/2009	32.03	0.10	68.55	0.22	0.001	U	5.38	0.061	0.000	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.007	0.000
CAPA-09-7051	6/17/2009	6/18/2009	31.91	0.47	68.30	1.00	0.001	U	5.20	0.057	0.000	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.007	0.000
CAPA-09-7052	6/18/2009	6/18/2009	31.10	0.41	66.55	0.89	0.001	U	5.14	0.057	0.000	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.006	0.000
CAPA-09-7053	6/18/2009	6/18/2009	32.23	0.42	68.98	0.90	0.001	U	5.07	0.056	0.000	0.001	U	0.002	U	0.001	U	0.0005	0.0000	0.007	0.000
CAPA-09-7054	6/22/2009	6/23/2009	30.77	0.12	65.85	0.26	0.001	U	12.73	0.107	0.003	0.001	U	0.002	U	0.001	U	0.0007	0.0000	0.006	0.000
CAPA-09-7055	6/22/2009	6/23/2009	31.11	0.17	66.57	0.37	0.001	U	14.88	0.098	0.005	0.001	U	0.002	U	0.001	U	0.0009	0.0000	0.006	0.000
CAPA-09-7056	6/22/2009	6/23/2009	30.86	0.30	66.05	0.64	0.001	U	11.13	0.094	0.002	0.001	U	0.002	U	0.001	U	0.0008	0.0000	0.006	0.000
CAPA-09-7057	6/22/2009	6/23/2009	30.96	0.26	66.25	0.56	0.001	U	9.69	0.089	0.003	0.001	U	0.002	U	0.001	U	0.0007	0.0000	0.006	0.000
CAPA-09-7058	6/22/2009	6/23/2009	31.07	0.04	66.48	0.10	0.001	U	9.17	0.086	0.003	0.001	U	0.002	U	0.001	U	0.0006	0.0000	0.006	0.000
CAPA-09-7059	6/23/2009	6/23/2009	30.65	0.15	65.58	0.33	0.001	U	9.06	0.086	0.001	0.001	U	0.002	U	0.001	U	0.0006	0.0000	0.006	0.000
CAPA-09-7060	6/23/2009	6/23/2009	30.94	0.28	66.21	0.59	0.001	U	9.27	0.083	0.002	0.001	U	0.002	U	0.001	U	0.0006	0.0000	0.006	0.000

Table B-1.2-2 (continued)

Sample ID	Date Collected	Date Received	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
CAPA-09-7021	3/31/2009	4/2/2009	0.020	0.002	204	1.83	1.44	0.12
CAPA-09-7022	4/17/2009	4/20/2009	0.008	0.000	291	2.83	2.81	0.01
CAPA-09-7023	4/18/2009	4/20/2009	0.006	0.000	229	2.28	2.34	-0.01
CAPA-09-7041	6/10/2009	6/15/2009	0.005	0.000	221	1.80	2.01	-0.06
CAPA-09-7042	6/10/2009	6/15/2009	0.008	0.000	210	1.66	1.83	-0.05
CAPA-09-7043	6/10/2009	6/15/2009	0.005	0.000	213	1.67	1.82	-0.04
CAPA-09-7044	6/10/2009	6/15/2009	0.004	0.000	206	1.60	1.79	-0.06
CAPA-09-7045	6/10/2009	6/15/2009	0.006	0.000	212	1.70	1.91	-0.06
CAPA-09-7046	6/13/2009	6/15/2009	0.005	0.000	249	2.13	2.15	0.00
CAPA-09-7047	6/13/2009	6/15/2009	0.005	0.000	231	1.89	2.13	-0.06
CAPA-09-7048	6/17/2009	6/18/2009	0.006	0.001	193	1.40	1.72	-0.10
CAPA-09-7049	6/17/2009	6/18/2009	0.004	0.000	194	1.32	1.82	-0.16
CAPA-09-7050	6/17/2009	6/18/2009	0.003	0.000	187	1.32	1.60	-0.09
CAPA-09-7051	6/17/2009	6/18/2009	0.003	0.000	185	1.30	1.58	-0.09
CAPA-09-7052	6/18/2009	6/18/2009	0.004	0.000	183	1.28	1.57	-0.10
CAPA-09-7053	6/18/2009	6/18/2009	0.005	0.000	186	1.29	1.57	-0.10
CAPA-09-7054	6/22/2009	6/23/2009	0.009	0.000	217	1.69	2.04	-0.09
CAPA-09-7055	6/22/2009	6/23/2009	0.007	0.000	214	1.71	1.99	-0.08
CAPA-09-7056	6/22/2009	6/23/2009	0.010	0.001	205	1.61	1.87	-0.08
CAPA-09-7057	6/22/2009	6/23/2009	0.010	0.001	203	1.59	1.84	-0.07
CAPA-09-7058	6/22/2009	6/23/2009	0.010	0.001	202	1.56	1.82	-0.08
CAPA-09-7059	6/23/2009	6/23/2009	0.012	0.000	200	1.55	1.82	-0.08
CAPA-09-7060	6/23/2009	6/23/2009	0.011	0.000	201	1.56	1.82	-0.08

Appendix C

Aquifer Testing Report

C-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted at well R-49, a dual-screen well located in lower Pajarito Canyon. Testing of each screen consisted of brief trial pumping, background water-level data collection, and a 24-h constant-rate pumping test. Water-level monitoring included both screens in R-49 as well as R-39 located just over 1100 ft away. Hydraulic testing was performed to estimate the aquifer parameters at each screen, assess the leakance and cross-connection between the screened intervals, and evaluate possible cross-connection between R-49 and R-39.

Consistent with most of the R-well pumping tests conducted on the plateau, an inflatable packer system was used in R-49 to minimize the effects of casing storage on the test data. This approach was effective in obtaining good data from screen 2. For screen 1, however, the data indicated possible storage effects. It was possible that the screen and filter pack had become dewatered temporarily during the original well completion and development procedures. Had this occurred, air may have been trapped in the filter pack opposite the blank casing above the top of the screen. If this had occurred, expansion and contraction of the trapped air during drawdown and recovery would have caused a storagelike effect.

Conceptual Hydrogeology

Well R-49 was drilled through dacitic lavas and breccias (Cerros del Rio), which extend to 897 ft below ground surface (bgs) and into underlying Totavi-like sediments. Screen 1 is 10 ft long, set in the dacitic lavas between the depths of 845 and 855 ft bgs. Screen 2 is 20.8 ft long, set in the underlying Totavi-like coarse-grained sedimentary deposits from 905.6 to 926.4 ft bgs.

The nearest well to R-49 is R-39 located just over 1100 ft to the east. Like R-49 screen 2, R-39 is screened in unconsolidated sediments just beneath the basalts. To gauge possible response to the R-49 pumping tests, groundwater-level data were collected from R-39.

At the outset of testing on June 14, 2009, the composite water level measured in R-49 was 832.14 ft bgs. When the zones were isolated with an inflatable packer, the water level in screen 1 rose 22.64 ft, to a static water level (SWL) 809.50 ft bgs (5774.86 ft above mean sea level [amsl]). At the same time, the screen 2 water level dropped 0.83 ft, to a SWL 832.97 ft bgs (5751.39 ft amsl). The head difference of 23.47 ft between the screen zones showed a strong downward gradient and implied the existence of an intervening aquitard.

R-49 Testing

Well R-49 was tested from June 14 to June 24, 2009. Screen 2 was tested first between June 14 and June 19, while screen 1 testing followed from June 19 to June 24.

Screen 2 testing began on June 14 when brief pumping was performed to fill the drop pipe and obtain discharge-rate information. On June 15, two trial tests were performed. Trial 1 was conducted at a discharge rate of 23.6 gpm for 60 min from 7:00 to 8:00 a.m. and was followed by 60 min of recovery until 9:00 a.m. Trial 2 was conducted at 23.7 gpm for 120 min from 9:00 to 11:00 a.m. and was followed by 1920 min of recovery/background data collection until 7:00 a.m. on June 17.

At 7:00 a.m. on June 17, the 24-h screen 2 pumping test began at a rate of 23.4 gpm using a 10-hp electric submersible pump. A leak in the discharge piping required shutting down the test after 1 min of pumping. After the false start and premature shutdown, the test was restarted 4 min later at 7:05 a.m. Pumping continued until 7:00 a.m. on June 18. After shutdown, recovery measurements were recorded for 1440 min until 7:00 a.m. on June 19 when the pump was tripped out of the well.

Screen 1 testing began on the afternoon of June 19 when brief pumping was performed open hole (both screens open) to fill the drop pipe and set the discharge rate to a low level by adjusting the valve. This was done to minimize the chance of dewatering screen 1 while filling the drop pipe with no back pressure on the pump. After shutdown, packers above and below screen 1 were inflated to isolate the zone for testing. On June 20, two trial tests were performed. Trial 1 was performed for 60 min from 7:00 to 8:00 a.m. and was followed by 60 min of recovery until 9:00 a.m. The discharge rate using a 5-hp electric submersible pump was unsteady, starting at 1.73 gpm and averaging 1.64 gpm for the duration of the test. Trial 2 was conducted for 60 min from 9:00 to 10:00 a.m. and was followed by 1980 min of recovery/background data collection until 7:00 a.m. on June 22. Again, the discharge rate was unsteady, 1.63 gpm initially and averaging 1.55 gpm overall. The fluctuation in discharge rates may have been caused by variations in the output of the particular electric generator used for the tests.

At 7:00 a.m. on June 22, the 24-h screen 1 pumping test was began. The initial pumping rate was 1.70 gpm, declining slightly during the test and averaging 1.50 gpm. Pumping continued until 7:00 a.m. on June 23. After shutdown, recovery measurements were recorded for 1440 min until 7:00 a.m. on June 24 when the pump was tripped out of the well.

C-2.0 BACKGROUND DATA

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

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

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

Subsequent pumping tests, including R-49, have utilized nonvented transducers. These devices simply record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated “apparent” hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When monitored using a vented transducer, an increase in barometric pressure of 1 unit causes a decrease in recorded downhole pressure of 0.9 unit because the water level is forced downward 0.9 unit by the barometric pressure change. However, using a nonvented transducer, the total measured pressure increases by 0.1 unit (the combination of the barometric pressure increase and the water-level decrease). Thus, the resulting apparent hydrograph changes by a factor of 100 minus the barometric efficiency and in the same direction as the barometric pressure change, rather than in the opposite direction.

Barometric pressure data were obtained from Technical Area 54 (TA-54) tower site from the Waste and Environmental Services Division–Environmental Data and Analysis. The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead elevation is reportedly 6584.36 ft amsl. The composite SWL in R-49 was 832.14 ft below land surface, making the calculated water-table elevation

5752.22 ft amsl. Therefore, the measured barometric pressure data from TA-54 had to be adjusted to reflect the pressure at the elevation of the water table within R-49.

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

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R}\left(\frac{E_{R-49} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R-49}}{T_{WELL}}\right)\right]$$ **Equation C-1**

Where, P_{WT} = barometric pressure at the water table inside R-49

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

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

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

E_{R-49} = land-surface elevation at R-49 site, in feet (6584.36 ft)

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

E_{WT} = elevation of the water level in R-49, in feet (approximately 5752.22 ft)

T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 66.0 degrees Fahrenheit, or 292.1 degrees Kelvin)

T_{WELL} = air temperature inside R-49, in degrees Kelvin (assigned a value of 65.3 degrees Fahrenheit, or 291.7 degrees Kelvin)

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

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

C-3.0 IMPORTANCE OF EARLY DATA

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

Unfortunately, in many pumping tests, including R-49, casing-storage effects dominate the early-time data, potentially hindering the effort to determine the transmissivity of the screened interval. The duration of casing-storage effects can be estimated using the following equation (Schafer 1978, 098240):

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

Equation C-2

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

D = inside diameter of well casing, in inches

d = outside diameter (O.D.) of column pipe, in inches

Q = discharge rate, in gallons per minute

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

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

For wells screened across the water table, there can be an additional storage contribution from the filter pack around the screen. The following equation provides an estimate of the storage duration accounting for both casing and filter pack storage:

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

Equation C-3

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

D_B = diameter of borehole, in inches

D_C = O.D. of well casing, in inches

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

In some instances, it is possible to eliminate casing-storage effects by setting an inflatable packer above the tested screen interval before conducting the test. Therefore, this option has been implemented for the R-well testing program.

C-4.0 TIME-DRAWDOWN METHODS

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

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

Where,

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

and

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

and where, s = drawdown, in feet

Q = discharge rate, in gallons per minute

T = transmissivity, in gallons per day per foot

S = storage coefficient (dimensionless)

t = pumping time, in days

r = distance from center of pumpage, in feet

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

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

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

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

S = storage coefficient

Q = discharge rate, in gallons per minute

$W(u)$ = match-point value

s = match-point value, in feet

u = match-point value

t = match-point value, in minutes

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

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

Equation C-9

The Cooper–Jacob equation is a simplified approximation of the Theis equation and is valid whenever the *u* value is less than about 0.05. For small radius values (e.g., corresponding to borehole radii), *u* is less than 0.05 at very early pumping times and therefore is less than 0.05 for most or all measured drawdown values. Thus, for the pumped well, the Cooper–Jacob equation usually can be considered a valid approximation of the Theis equation.

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

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

Equation C-10

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

Q = discharge rate, in gallons per minute

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

C-5.0 RECOVERY METHODS

Recovery data were analyzed using the Theis recovery method (1934–1935, 098241). This is a semilog analysis method similar to the Cooper–Jacob procedure.

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

$$T = \frac{264Q}{\Delta s}$$ **Equation C-11**

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

Equation C-11 is valid as long as the u-value criterion cited above is met. For very early data from wells in low-diffusity formations (low transmissivity and/or high storage coefficient), it is possible for u to be greater than 0.05, making the Theis recovery analysis invalid. In such cases, it is necessary to plot feet of recovery versus recovery time on a log-log scale and apply Theis curve matching to solve for aquifer parameters. With this approach, the recovery data are processed in a manner similar to Theis curve matching of time-drawdown data described above.

C-6.0 SPECIFIC CAPACITY METHOD

The specific capacity of the pumped well can be used to obtain a lower-bound value of hydraulic conductivity. The hydraulic conductivity is computed using formulas that are based on the assumption that the pumped well is 100% efficient. The resulting hydraulic conductivity is the value required to sustain the observed specific capacity. If the actual well is less than 100% efficient, it follows that the actual hydraulic conductivity would have to be greater than calculated to compensate for well inefficiency. Thus, because the efficiency is unknown, the computed hydraulic conductivity value represents a lower bound. The actual conductivity is known to be greater than or equal to the computed value.

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

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

$$s_P = \frac{1-\frac{L}{b}}{\frac{L}{b}}\left[\ln\frac{b}{r_w} - 2.948 + 7.363\frac{L}{b} - 11.447\left(\frac{L}{b}\right)^2 + 4.675\left(\frac{L}{b}\right)^3\right]$$ **Equation C-12**

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

$$K = \frac{264Q}{sb}\left(\log\frac{0.3Tt}{r_w^2 S} + \frac{2s_P}{\ln 10}\right)$$ **Equation C-13**

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

To apply this procedure, a storage coefficient value must be assigned. Confined conditions were assumed for both screens in R-49. For screen 1, it was possible that overlying lava flows could have served as confining layers. The screen 2 zone was clearly confined based on the depth of the screen, overlying aquitard, and piezometric levels. Storage coefficient values for confined conditions can be expected to range from about 10^{-5} to 10^{-3} (Driscoll 1986, 104226). The calculation result is not particularly sensitive to the choice of storage coefficient value, so a rough estimate of the storage coefficient is generally adequate to support the calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, b. The thickness of the contiguous aquifer penetrated by screen 1 was not known. For the purposes of the specific capacity calculations, fully penetrating conditions were assumed because of the likelihood of overlying lava flows acting as aquitards, isolating screen 1 from other saturated portions of the aquifer. For screen 2, an arbitrary thickness of 100 ft was used in the calculations. For partially penetrating conditions, the lower-bound transmissivity calculation is not sensitive to the selection of aquifer thickness because sediments far above or below the well screen have little effect on yield.

Computing the lower-bound estimate of hydraulic conductivity can provide a useful frame of reference for evaluating the other pumping test calculations.

C-7.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-49 tests were plotted along with barometric pressure to determine the barometric effect on water levels.

Figure C-7.0-1 shows aquifer pressure data from R-49 screen 1 along with barometric pressure data from TA-54 that have been corrected to equivalent barometric pressure in feet of water at the water table. The R-49 screen 1 data are referred to in the figure as the “apparent hydrograph” because the measurements reflect the sum of water pressure and barometric pressure, having been recorded using a nonvented pressure transducer. The times of the pumping periods for the R-49 screen 1 and 2 pumping tests were included in the figure for reference.

It appeared in Figure C-7.0-1 that changes in barometric pressure had little effect on total aquifer pressure. However, much of the data signal reflected significant ongoing recovery, masking somewhat the barometric pressure effects. Close examination of the data on June 21 and 22 suggested a subtle, delayed barometric pressure effect on aquifer pressure.

To illustrate this, the barometric pressure data were corrected for barometric efficiency and lag time and replotted in Figure C-7.0-2. The barometric efficiency and lag time were adjusted to obtain a reasonable fit between the apparent hydrograph and corrected barometric pressure curve. The analysis shown in the figure suggested a barometric efficiency around 75% and about a 7-h lag time.

Of significance in Figure 7.0-1 was the effect on screen 1 water levels caused by pumping screen 2. According to the graph, the 24-h screen 2 pumping test caused roughly 0.06 ft of drawdown in screen 1.

Figure C-7.0-3 shows aquifer pressure data from R-49 screen 2 along with barometric pressure data from TA-54. The data were replotted in Figure C-7.0-4 as a rolling average to filter some of the noise out of the apparent hydrograph signal. The times of the pumping periods for the R-49 screen 1 and 2 pumping tests were included in both figures for reference Unlike the screen 1 water-level data, the responses shown in Figures C-7.0-3 and C-7.0-4 did not show a correlation with changes in barometric pressure, indicating a barometric efficiency near 100%. The minor water-level perturbations of a couple hundredths of a foot visible on the graphs were probably Earth tide responses.

Hydrograph data collected from R-39 were corrected for barometric pressure and Earth tide effects and plotted in Figure C-7.0-5. The BETCO (barometric and Earth tide correction) method was used to correct the data. This is a mathematically complex correction algorithm that uses regression deconvolution (Toll and Rasmussen 2007, 104799) to modify the data. The corrected hydrograph curve is shown along with the barometric pressure data in the figure. It appeared on the graph that R-39 showed a response to pumping R-49 screen 2. The magnitude of the apparent response was about 0.06 ft after 24 h of pumping. It was clear from the figure that the correction algorithm was not perfect because there appeared to be some lingering Earth tide or barometric pressure signal remaining in the corrected data.

C-8.0 WELL R-49 SCREEN 1 DATA ANALYSIS

This section presents the data obtained from the R-49 screen 1 pumping tests and the results of the analytical interpretations. Data are presented for drawdown and recovery for trials 1 and 2 and the 24-h constant-rate pumping test.

C-8.1 Well R-49 Screen 1 Trial 1

Figure C-8.1-1 shows a semilog plot of the drawdown data collected from trial 1. As indicated on the graph, the discharge rate was 1.73 gpm initially and declined over time, averaging 1.64 gpm. The curvature of the early portion of the data trace suggested two possibilities. The form of the data plot looked like that seen in storage-affected data, even though screen 1 was submerged under tens of feet of head. It was possible that the original completion and development activities had dewatered the screen and filter pack, trapping air in the upper portion of the filter pack above the well screen and causing a storagelike effect. Another possibility was that the u value was greater than 0.05, resulting in the early curved data trace. There was no way to determine from the data which was the case. Considering that the u-value criterion may not have been met, the data were replotted on a log-log scale so that Theis curve matching could be performed. The curve-matching method is more general than the semilog straight-line method and is valid for all u values.

Figure C-8.1-2 shows a log-log plot of the drawdown data from trial 1. Analysis of the early data showed a transmissivity of 50 gpd/ft. Both Figures C-8.1-1 and C-8.1-2 showed variations in drawdown associated with discharge-rate fluctuations. They also showed a flattening of the drawdown curve, presumably in response to either leakage from above and/or below the screened interval or a substantial lateral increase in permeability.

Figures C-8.1-3 and C-8.1-4 show semilog and log-log plots of the trial 1 recovery data. The log-log graph shows feet of recovery plotted against recovery time. Theis curve matching of the early data showed a transmissivity of 30 gpd/ft, substantially lower than the value determined from the drawdown data. The discrepancy between the drawdown and recovery results may have been an indication that the data were storage-affected. During drawdown, the hypothesized trapped air volume in the filter pack starts as a minimum and increases during the test. Conversely, during recovery, the trapped air volume, which expands during drawdown, starts out as a maximum and decreases as recovery proceeds. Thus, asymmetry in the response is expected if the data are storage-affected. Unfortunately, there was no way to confirm whether the data were storage-affected. If storage effects were present, the computed transmissivity values would be underestimated.

C-8.2 Well R-49 Screen 1 Trial 2

Figures C-8.2-1 and C-8.2-2 show semilog and log-log plots of the trial 2 drawdown data. As with trial 1, the data showed drawdown variation associated with discharge-rate fluctuations as well as stabilization after a short time because of leakage. The transmissivity value determined from Theis curve matching was 50 gpd/ft, consistent with the result from the trial 1 drawdown analysis.

The early data showed a drawdown of about 6 ft almost instantly within the first quarter second of pumping. This drawdown level was fairly steady for several seconds before gradually increasing. This effect was absent from the trial 1 data because very early data were not recorded during trial 1. There was no obvious explanation for this unusual response. It was possible that it might have been related to storage effects, for example, recharge from the filter pack stabilizing the water level briefly as the hypothesized trapped air in the filter pack began expanding and releasing water. However, there was no way to verify this. Nevertheless, this response was highly unusual.

Figures C-8.2-3 and C-8.2-4 show semilog and log-log plots of the trial 2 recovery data. As with trial 1, the data produced a transmissivity of only 30 gpd/ft, in conflict with the drawdown analysis. The recovery data also showed the “instant” water-level response followed by brief stabilization for several seconds. In the recovery data set, however, the magnitude of the rapid recovery was only about 1 ft, rather than 6 ft as occurred in the drawdown data. Normally, recovery data should mirror the drawdown response. There was no explanation for this unusual departure from the drawdown response, but it was possible that it was an asymmetric storage response associated with contraction of trapped air in the filter pack. There was no way to determine the cause of this unusual response.

C-8.3 Well R-49 Screen 1 24-H Constant-Rate Pumping Test

Figures C-8.3-1 and C-8.3-2 show semilog and log-log plots of the 24-h drawdown data. As observed in trial 2, several feet of drawdown were achieved in the first fraction of a second, followed by stabilization for several seconds. The drawdown data again showed the effects of varying discharge rate and leakage. The transmissivity value determined from the drawdown analysis was 50 gpd/ft, consistent with the trial test drawdown results.

Figures C-8.3-3 and C-8.3-4 show semilog and log-log plots of the recovery data. As with trials 1 and 2, the data produced a transmissivity of only 30 gpd/ft, in conflict with the drawdown analysis. The recovery data also showed the “instant” water-level response, followed by brief stabilization for several seconds. As was observed in trial 2, the early-recovery response was only about 1 ft, substantially less than the early-drawdown response.

C-8.4 Well R-49 Screen 1 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound transmissivity value for the permeable zone penetrated by R-49 screen 1. This was done to provide a frame of reference for evaluating the foregoing analyses.

In addition to specific capacity, other input values used in the calculations included a storage coefficient value of 0.001 and a borehole radius of 0.51 ft. To minimize the effect of leakage on the calculations, an early drawdown data point was used. Leakage effects appeared after just a few minutes of pumping. Therefore, data corresponding to a pumping time of 3 min were used to estimate the lower-bound transmissivity.

During the 24-h pumping test, R-49 was pumped at a rate of 1.7 gpm for the first 3 min with 18.6 ft of drawdown for an estimated specific capacity of 0.091 gpm/ft. Applying the Brons and Marting method (1961, 098235) to these inputs for fully penetrating conditions yielded a lower-bound transmissivity of 50 gpd/ft, in agreement with the time-drawdown values cited above. After pumping at 1.5 gpm for 24 h, the drawdown was about 20 ft for a specific capacity of 0.075 gpm/ft.

Generally, the transmissivity calculation is relatively insensitive to the choice of storage coefficient. However, for small transmissivity values and short pumping times, sensitivity to the magnitude of the storage coefficient can increase. Therefore, lower-bound transmissivities were computed for additional values of storage coefficient to gauge the sensitivity of the relationship. Figure C-8.4-1 shows the results of the calculations for a range of storage coefficient values between 10^{-4} and 10^{-2}. The computed lower-bound transmissivity values shown on the graph ranged from about 20 to 80 gpd/ft, increasing with decreasing storage coefficient.

Thus, calculations implied a lower-bound transmissivity of 50 gpd/ft or larger. The pumping test results, on the other hand, produced transmissivity values of 50 gpd/ft and smaller. This suggested the possibility that the pumping test analyses underestimated the transmissivity somewhat, perhaps because of minor storage effects associated with trapped air in the filter pack above screen 1.

C-9.0 WELL R-49 SCREEN 2 DATA ANALYSIS

This section presents the data obtained from the R-49 screen 2 pumping tests and the results of the analytical interpretations. Data are presented for drawdown and recovery for trials 1 and 2 and the 24-h constant-rate pumping test.

C-9.1 Well R-49 Screen 2 Trial 1

Figure C-9.1-1 shows a semilog plot of the drawdown data collected from trial 1 at a discharge rate of 23.6 gpm. Data from the first few minutes of pumping suggested a transmissivity of 18,100 gpd/ft. The aquifer thickness corresponding to this transmissivity was not known.

After 3 or 4 min, the drawdown curve became nearly flat. This effect implied adjacent sediments having enormous transmissivity. The effect could have been caused by a lateral increase in transmissivity near the well or by a highly transmissive aquifer beneath the zone in which the screen is placed. Regardless, the drawdown stabilization implied the existence of a highly transmissive zone.

Figure C-9.1-2 shows a semilog plot of the recovery data from trial 1. Analysis of the early data showed a transmissivity of 17,700 gpd/ft, consistent with the drawdown analysis. Again, the late data showed a nearly flat trace, indicating very high transmissivity in the vicinity of the well.

C-9.2 Well R-49 Screen 2 Trial 2

Figure C-9.2-1 shows a semilog plot of the drawdown data collected from trial 2 at a discharge rate of 23.7 gpm. The data collection scheme for trial 2 differed from that of trial 1 in that very early-response data were recorded. The transducer was programmed to record the initial data at 0.25-s intervals. This allowed obtaining a “snapshot” of the expansion of the cone of depression around the screen at very early time before significant vertical expansion. It was expected that the early data would allow estimating the transmissivity of the screened interval. This same data collection approach was used for drawdown and recovery data collection for trial 2 and both portions of the 24-h test—the false start and the restart.

When collecting the very early data, it was not possible to know the elapsed times for the first few data points with accuracy because the starting time of the pump could not be synchronized exactly to the transducer clock. The result of this was that the first data point could have fallen anywhere between zero and 0.25 s, averaging 0.875 s. Therefore, the data times were adjusted so that the first data point was assigned a pumping or recovery time of 0.875 s. In instances where the actual elapsed time was greater than 0.875 s, this approach would have overestimated the transmissivity determined from the very early data. Conversely, in cases where the elapsed time was less than 0.875 s, the early-time transmissivity would have been underestimated. On average, though, the statistical mean computed value would be expected to reasonably reflect actual aquifer characteristics.

Data in Figure C-9.2-1 from the first second or so of pumping suggested a transmissivity for the screened interval of 1400 gpd/ft.

After about 1 s, the drawdown curve flattened somewhat. These data were plotted on the expanded-scale graph shown in Figure C-9.2-2. The first several minutes of data supported a transmissivity calculation of 19,100 gpd/ft, consistent with the values obtained from the trial 1 analysis.

After 3 or 4 min, the slope of the drawdown curve diminished, becoming essentially flat near the end of the test—similar to what was observed in trial 1.

Figure C-9.2-3 shows a plot of the recovery data following trial 2. The very early data supported a transmissivity calculation for the screened interval of 2900 gpd/ft. This was different than the value computed from the drawdown data and was probably attributable to the variation associated with uncertainty in the exact starting times of pumping and recovery.

After about 1 s of recovery, the response curve flattened somewhat. These data were plotted on the expanded-scale graph shown in Figure C-9.2-4. The first several minutes of data supported a transmissivity calculation of 19,500 gpd/ft, consistent with previous values.

The trial 2 data suggested a relatively low transmissivity for the screened interval (1400 and 2900 gpd/ft), a larger transmissivity for the contiguous aquifer in which the screen is placed (19,100 and 19,500 gpd/ft), and an enormous transmissivity for sediments beneath or adjacent to the screened aquifer (flat late-data curve).

C-9.3 Well R-49 Screen 2 24-H Constant-Rate Pumping Test

Screen 2 was pumped for 1 min at 23.4 gpm followed by 4 min of recovery at the beginning of the attempted 24-h pumping test. Figures C-9.3-1 and C-9.3-2 show semilog plots of drawdown and recovery data for this false-start episode. The early portions of these data sets allowed computing the transmissivity of the screened interval, resulting in values of 5840 and 2500 gpd/ft, respectively. Again, there was variation in the results because of uncertainty in the exact pumping and recovery start times.

Figure C-9.3-3 shows a plot of the 24-h drawdown data recorded after the pumping test was restarted. The very early data (first 1 s of pumping) showed a screen interval transmissivity of 2150 gpd/ft, more or less consistent with previous values.

Figure C-9.3-4 shows an expanded-scale plot of the drawdown data allowing examination of the second slope on the graph that occurred during the first few minutes of pumping. The transmissivity determined from this slope was 19,800 gpd/ft, similar to previous values obtained for the transmissivity of the contiguous aquifer in which the screen is placed. After a few minutes of pumping, the drawdown curve became essentially flat, implying very large transmissivity near the pumped well.

Figure C-9.3-5 shows a plot of the recovery data following the 24-h pumping test. The first second of the response suggested a screen interval transmissivity of 6970 gpd/ft.

The subsequent few minutes of recovery data were plotted on the expanded scale shown in Figure C-9.3-6. The transmissivity determined from these data was 20,000 gpd/ft, consistent with previous calculations.

Figure C-9.3-7 shows an analysis of the late-recovery data from screen 2. Calculations suggested a transmissivity greater than 100,000 gpd/ft.

C-9.4 Well R-49 Screen 2 Transmissivity Summary

Table C-9.4-1 summarizes the transmissivity values determined from screen 2 for the screened interval itself (1-s transmissivity) and the contiguous responding aquifer in which the screen is placed (several-minute transmissivity).

The transmissivity values determined for the screened interval showed substantial variation because of uncertainty in the exact start and stop times for the pump as discussed previously. The average value of 3630 gpd/ft is probably reasonably representative of formation properties around the screen. Based on the screen length of 20.8 ft, the average hydraulic conductivity computes to 175 gpd/ft^2, or 23.3 ft/d.

The transmissivity values determined for the contiguous aquifer were consistent, spanning a narrow range. The average value was 19,000 gpd/ft. The aquifer thickness corresponding to this transmissivity value was not known. If the hydraulic conductivity value for the screened interval (175 gpd/ft^2) prevailed uniformly, a transmissivity of 19,000 gpd/ft would imply an aquifer thickness of 19,000 divided by 175 = 109 ft. The sediments may not be uniform, so that actual contiguous aquifer thickness could vary substantially from this value.

C-9.5 Well R-49 Screen 2 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound transmissivity value for the permeable zone penetrated by R-49 screen 2. This was done to provide a frame of reference for evaluating the foregoing analyses.

In addition to specific capacity, other input values used in the calculations included a storage coefficient value of 0.001, a borehole radius of 0.51 ft, and an arbitrary aquifer thickness of 100 ft. To minimize the effect of the nearby highly transmissive sediments that caused flattening of the drawdown curve, an early drawdown data point was used in the calculations. These effects appeared after just a few minutes of pumping. Therefore, data corresponding to a pumping time of 3 min were used to estimate the lower-bound transmissivity.

During the 24-h pumping test, R-49 was pumped at a rate of 23.4 gpm for the first 3 min with 6.98 ft of drawdown for an estimated specific capacity of 3.35 gpm/ft. Applying the Brons and Marting method (1961, 098235) to these inputs yielded lower-bound hydraulic conductivity of 140 gpd/ft^2, or 18.7 ft/d. This result was consistent with the value of 175 gpd/ft^2 determined from the pumping test, having slightly lower magnitude than the pumping test value as would be expected for a less than 100% efficient well. This result reinforced the validity of the pumping test hydraulic conductivity value. After pumping for 24 h at 23.4 gpm, the drawdown was about 7 ft for a specific capacity of 3.34 gpm/ft.

C-9.6 R-39 Response to Pumping R-49 Screen 2

As indicated in Figure C-7.0-5, pumping R-49 screen 2 caused a drawdown of about 0.06 ft in R-39. The Theis equation (1934–1935, 098241) was used to simulate R-39 response to investigate what aquifer parameters might be consistent with this observation. The calculations described here treated the hydraulic regime as a single continuous, uniform aquifer. The actual makeup of the subsurface could be very different than this, incorporating ample heterogeneity, stratification, faulting, and other variations. Nevertheless, it was instructive to perform the analysis for this simplified scenario.

For the simplified assumption of a single uniform aquifer, several combinations of aquifer coefficients were quantified that were consistent with the observation of 0.06 ft of drawdown at R-39 after 1440 min of pumping R-49 at 23.4 gpm. Figure C-9.6-1 shows a typical scenario in which the storage coefficient was fixed at 5 × 10–4, and the transmissivity was varied until the predicted 24-h drawdown was 0.06 ft. The resulting hydrograph was not unlike the actual R-39 response seen in Figure C-7.0-5. The transmissivity required to produce this simulation was 211,000 gpd/ft, a strikingly large value. It should be pointed out that if R-49 screen 2 and R-39 are not in the same contiguous aquifer but instead are hydraulically separated to some degree by stratification or faulting, a lower value of transmissivity would be sufficient to produce the observed drawdown of 0.06 ft.

The analysis presented in Figure C-9.6-1 was repeated for a range of storage coefficient values to determine the corresponding range of transmissivities. Calculations were performed for storage coefficient values ranging from 2 × 10–5 to 2 × 10–3. Figure C-9.6-2 shows the results of the analysis with the corresponding transmissivity values ranging between about 100,000 and 400,000 gpd/ft. Most of the these values seemed unrealistically large, suggesting that the connection between R-49 screen 2 and R-39, while good, may not be consistent with the screens being installed in the same contiguous aquifer zone. Nevertheless, the rapid response to pumping R-49 screen 2 observed in R-39 (Figure C-7.0-5) implied a strong hydraulic connection and a fairly large aquifer transmissivity.

C-9.7 Aquitard Leakance

Data from the R-49 screen 2 pumping test were used to estimate the leakance of the aquitard separating screens 1 and 2. During pumping at screen 2, the drawdown at screen 1 was about 0.06 ft. To accomplish this, computer modeling was used to replicate the screen 2 pumping test while the simulated drawdown response in the model in screen 1 was noted. Then, the leakance of the aquitard separating screens 1 and 2 was adjusted until the simulated screen 1 zone drawdown equaled the observed value of 0.06 ft (Figure C-7.0-1).

The modeling was performed using MODLFOW, implemented under Schlumberger's Visual MODFLOW. The model grid consisted of 116 rows and 116 columns. To minimize boundary effects, the model domain was large, 20,000 ft × 20,000 ft. The model utilized five layers as follows:

1. layer 1—the screen 1 zone (transmissivity = 50 gpd/ft)
2. layer 2—aquitard separating screens 1 and 2
3. layer 3—the screen 2 contiguous aquifer zone (transmissivity = 19,000 gpd/ft)
4. layer 4—aquitard separating the screen 2 pumped aquifer from an underlying leakage source
5. layer 5—leakage source to screen 2 zone (transmissivity = 250,000 gpd/ft)

Because of the uncertainty in the screen 1 zone storage coefficient, simulations were performed for multiple values to gauge the sensitivity of the results to this parameter. The layer 1 storage coefficient was varied between 10–4 and 10–2 in the simulations. No other sensitivity analyses were performed.

Figure C-9.7-1 shows the results of the model simulations. Calculations showed that for storage coefficient values ranging from 10–4 to 10–2, the computed leakance of the aquitard between screens 1 and 2 ranged from 1.4 × 10–4 to 3.1 × 10–3 inverse days, respectively.

It is important to point out that the foregoing analysis is based on the assumption that the drawdown response observed in screen 1 when pumping screen 2 is a true hydraulic response rather than an elastic one. Indeed, a cursory examination of Figure C-7.0-1 showed that the drawdown and recovery effects tended to be persistent rather than fleeting, consistent with hydraulic, as opposed to elastic, response.

C-10.0 SUMMARY

Constant-rate pumping tests were conducted on R-49 screens 1 and 2. The tests were conducted to gain an understanding of the hydraulic characteristics of the two screen zones and the intervening aquitard, as well as possible cross-connection to well R-39 located just over 1100 ft east of R-49.

Numerous observations and conclusions were drawn for the tests as summarized below.

R-49 screen 1 lies in a zone of dacitic lavas and breccias. The saturated interval responded to barometric pressure with approximately 75% barometric efficiency and a 7-h lag time.

R-49 screen 2 is installed in coarse-grained sedimentary deposits just beneath the lava flows as is nearby well R-39. R-49 screen 2 showed near 100% barometric efficiency.

The screen 1 zone was tight, producing 1.5 gpm with about 20 ft of drawdown for a specific capacity of 0.075 gpm/ft after 24 h. Pumping test analysis of screen 1 data produced transmissivity estimates of about 50 gpd/ft and less.

However, calculations based on specific capacity suggested a lower-bound transmissivity of 50 gpd/ft or greater, possibly in contradiction to the pumping test analysis. This may have been an indication that the pumping test transmissivity values were underestimated because of storage effects. It is possible that the filter pack around screen 1 was dewatered at some point during well development, trapping air in the pack behind the blank casing above the top of the screen. Such trapped air would have expanded and contracted during pumping and recovery, causing a storagelike effect.

The screen 1 data showed an asymmetry between drawdown and recovery. This included (1) relatively greater transmissivity values from the drawdown data and relatively lower values from recovery and (2) an early, brief (seconds) stabilized drawdown of 6 to 8 ft during pumping versus an early, brief stabilized recovery of just 1 ft or so. This unusual asymmetry may have been a further indication of storage effects associated with trapped air in the filter pack.

Screen 2 was high-yielding, producing 23.4 gpm with about 7 ft of drawdown for a specific capacity of 3.34 gpm/ft after 24 h.

Very early drawdown and recovery data (about 1 s) suggested a screen interval transmissivity of 3630 gpd/ft and a hydraulic conductivity of 175 gpd/ft^2, or 23.3 ft/d. The lower-bound hydraulic conductivity computed from the specific capacity data was entirely consistent with this at about 140 gpd/ft^2, or 18.7 ft/d.

Subsequent drawdown and recovery data (a few minutes) showed an average transmissivity value of 19,000 gpd/ft for the contiguous aquifer in which screen 2 is placed. The thickness of this zone could not be determined with certainty, although if uniform hydraulic conductivity were assumed (175 gpd/ft), the projected aquifer thickness would compute to 109 ft.

After just a few minutes of pumping, screen 2 water levels nearly stabilized, indicating hydraulic connection to highly transmissive sediments. Late-recovery data suggested that this transmissivity is in excess of 100,000 gpd/ft.

Pumping screen 2 at 23.4 gpm for 24 h caused a drawdown of 0.06 ft in screen 1. Computer model simulations suggested that for a range of screen 1 zone storage coefficient values from 10–4 to 10–2, the corresponding aquitard leakance ranged from 1.4 × 10–4 to 3.1 × 10–3 inverse days, respectively

Pumping screen 2 at 23.4 gpm for 24 h also caused a drawdown of 0.06 ft in well R-39 located just over 1100 ft to the east. Assuming that R-49 screen 2 and R-39 are completed in the same contiguous aquifer, this drawdown response implied a formation transmissivity ranging from about 100,000 gpd/ft to 400,000 gpd/ft, depending on the assumed value of the storage coefficient. On the other hand, if R-49 screen 2 and R-39 are not directly hydraulically connected via the same contiguous aquifer, that is, if there is intervening stratification, heterogeneity, or faulting, a lower value of transmissivity could prevail.

C-11.0 REFERENCES

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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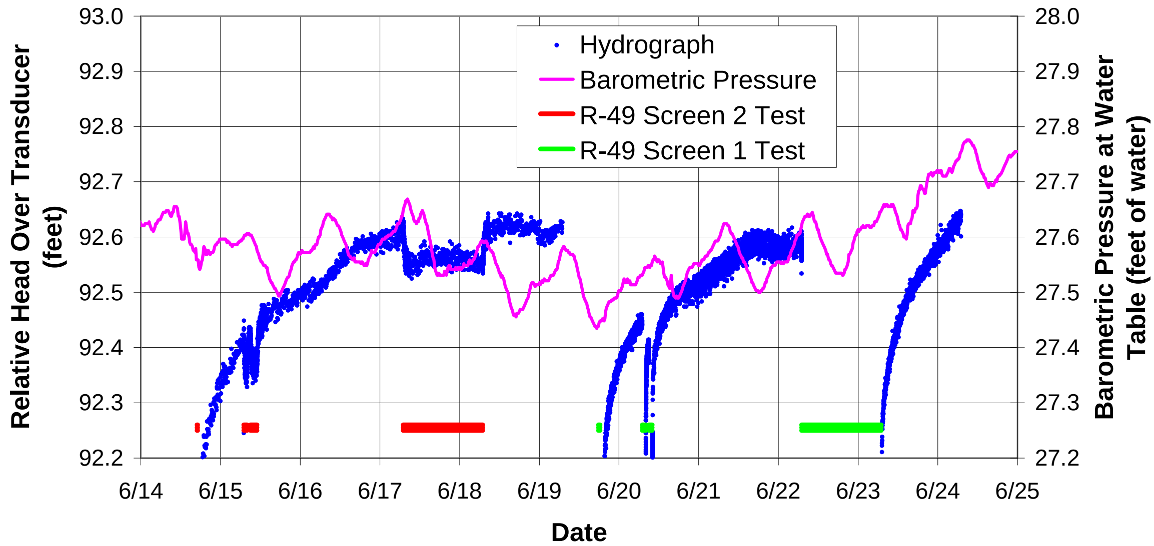

Figure C-7.0-1 Well R-49 screen 1 apparent hydrograph

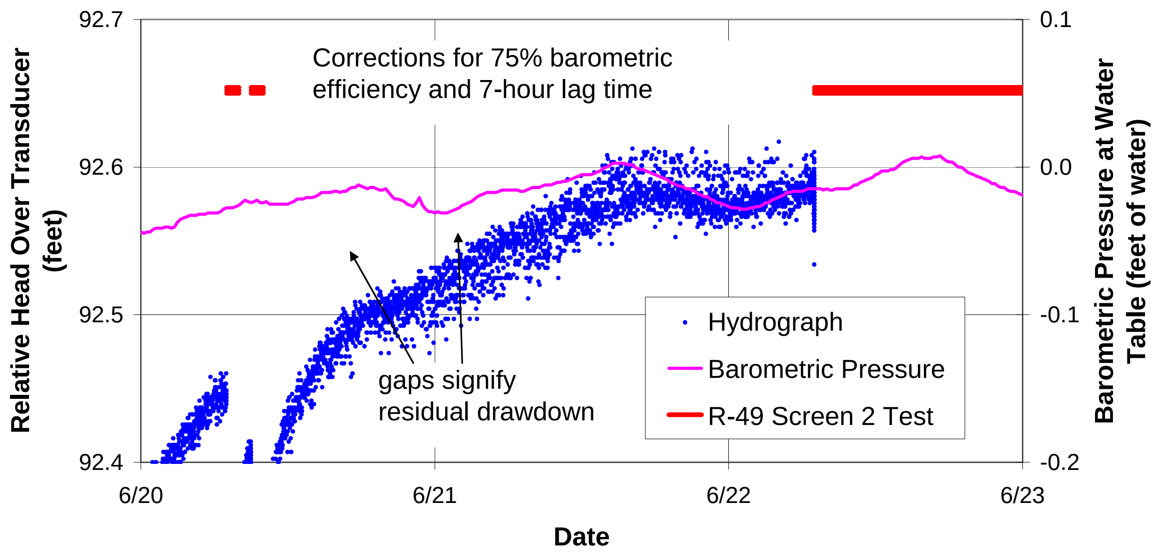

Figure C-7.0-2 Well R-49 apparent hydrograph and modified barometric pressure

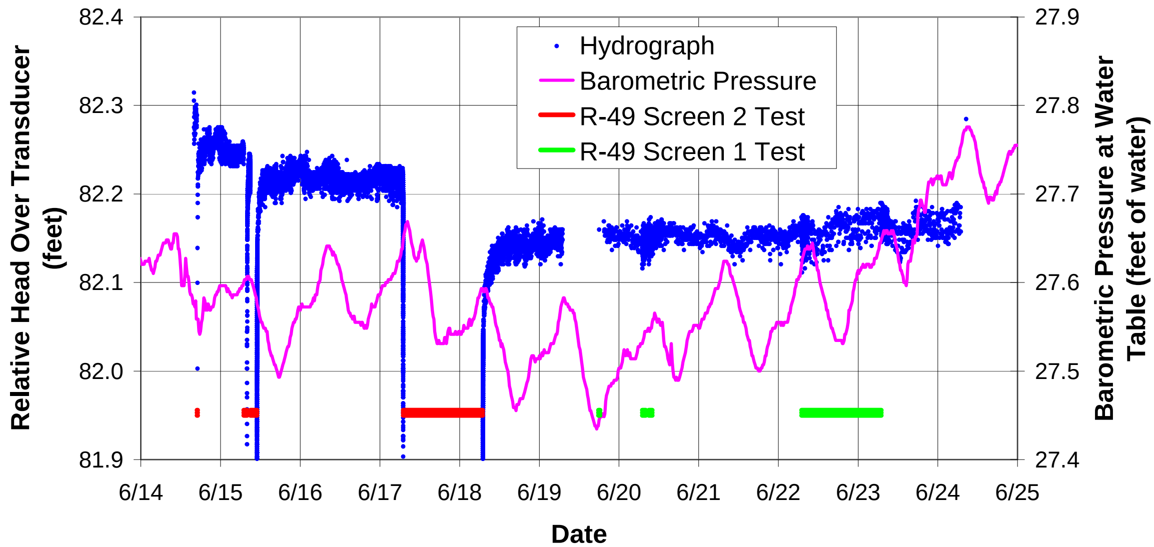

Figure C-7.0-3 Well R-49 screen 2 apparent hydrograph

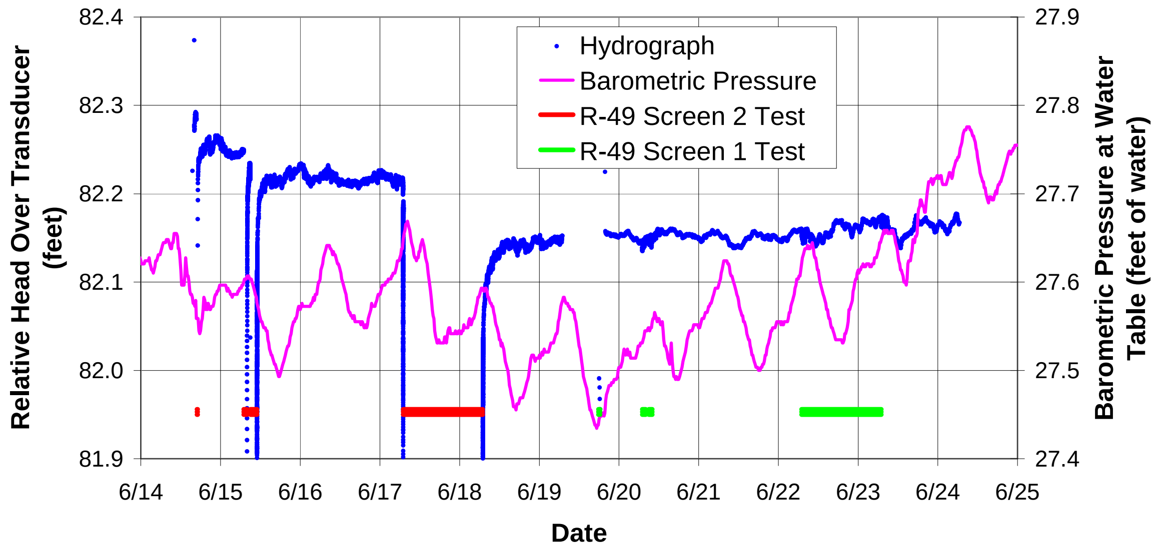

Figure C-7.0-4 Well R-49 screen 2 rolling average apparent hydrograph

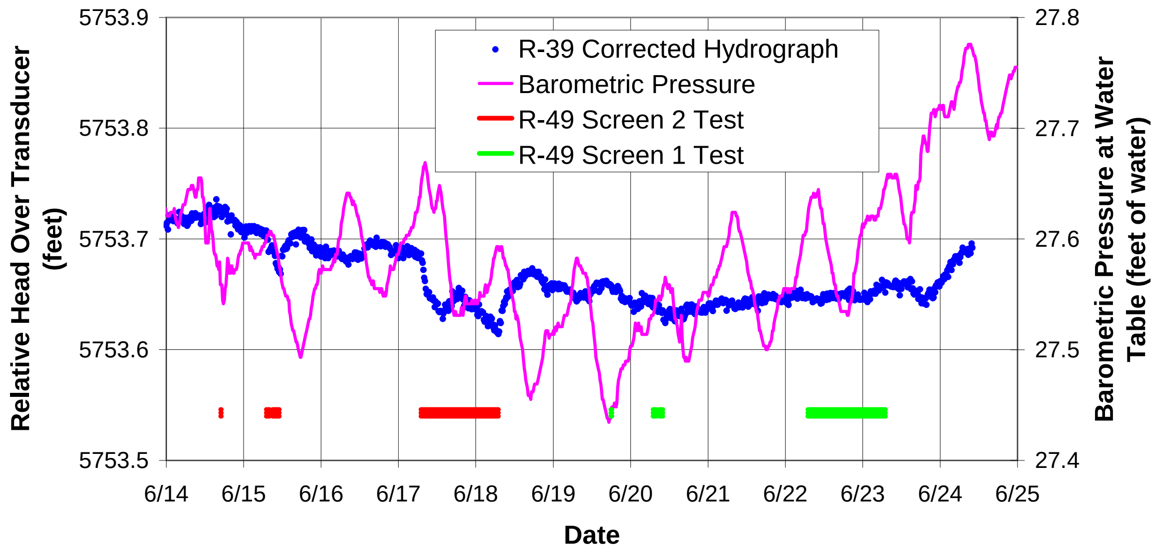

Figure C-7.0-5 Well R-39 hydrograph with BETCO correction

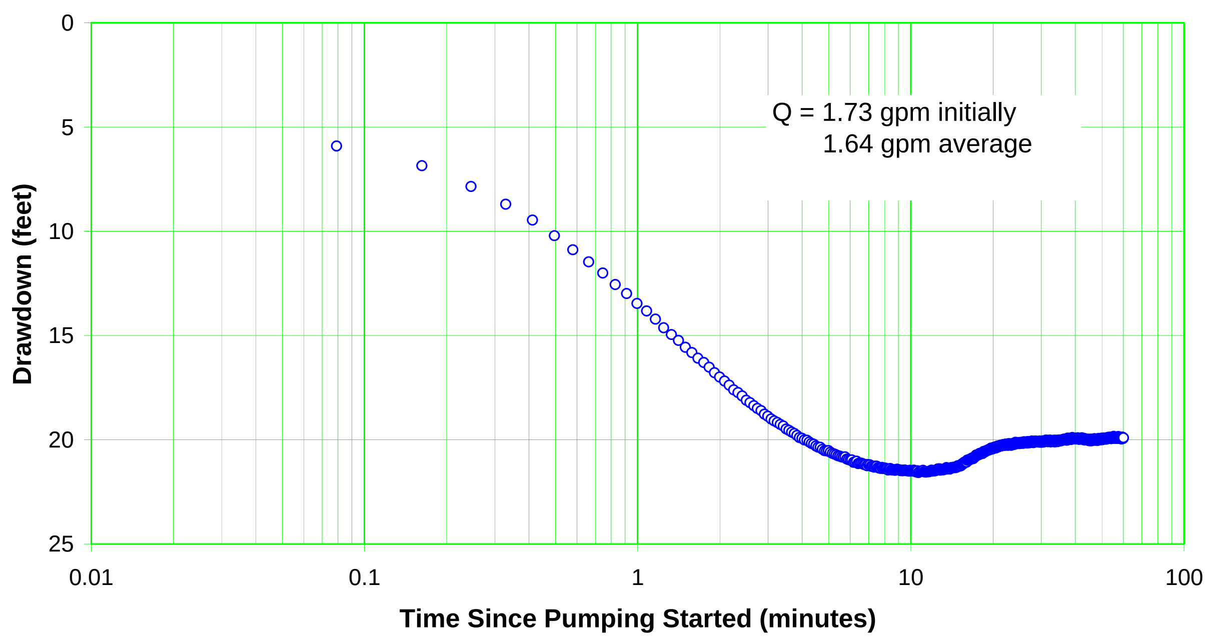

Figure C-8.1-1 Well R-49 screen 1 trial 1 drawdown

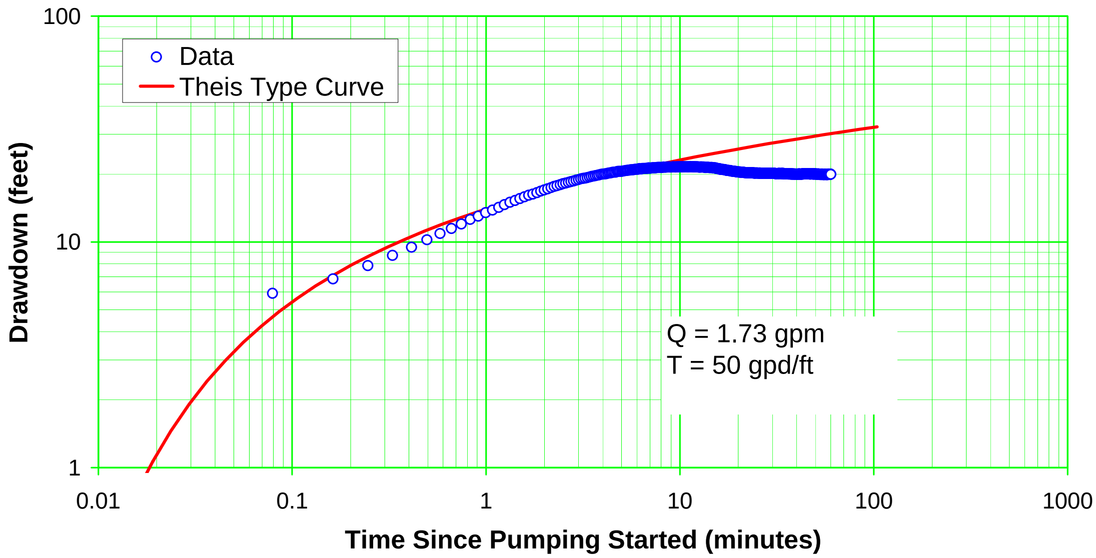

Figure C-8.1-2 Well R-49 screen 1 trial 1 drawdown—Theis analysis

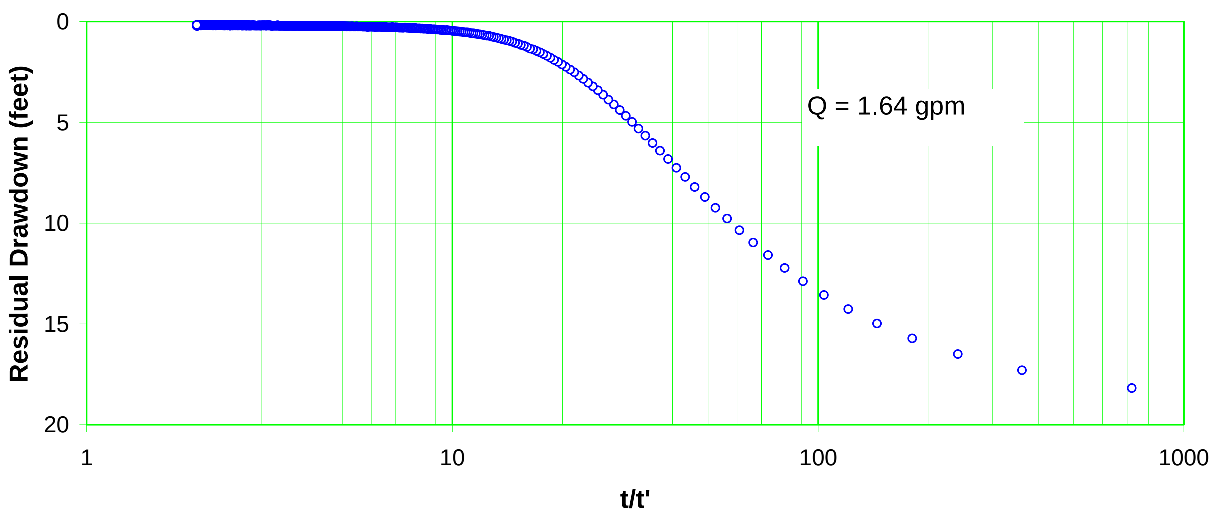

Figure C-8.1-3 Well R-49 screen 1 trial 1 recovery

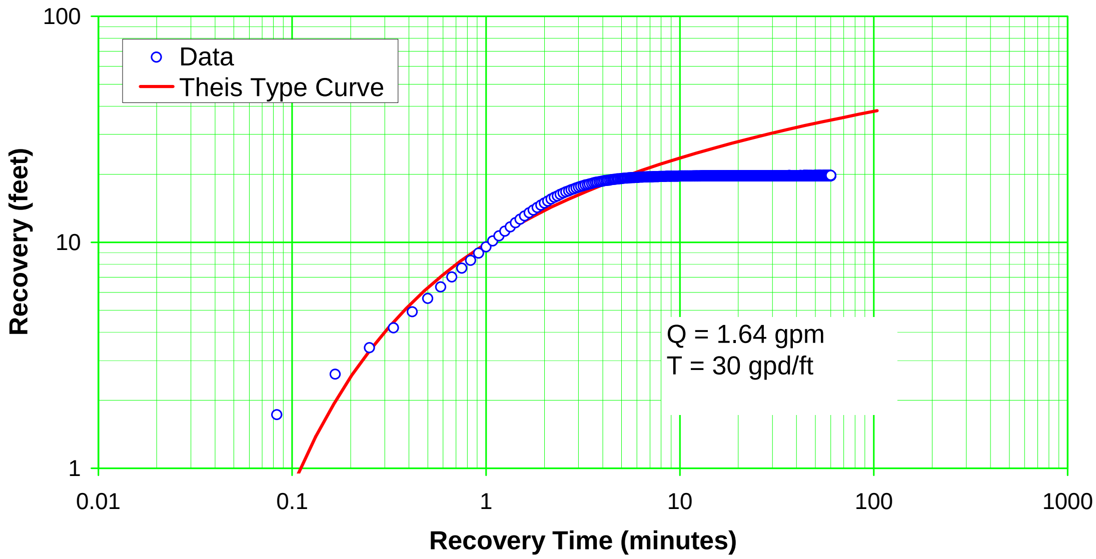

Figure C-8.1-4 Well R-49 screen 1 trial 1 recovery—Theis analysis

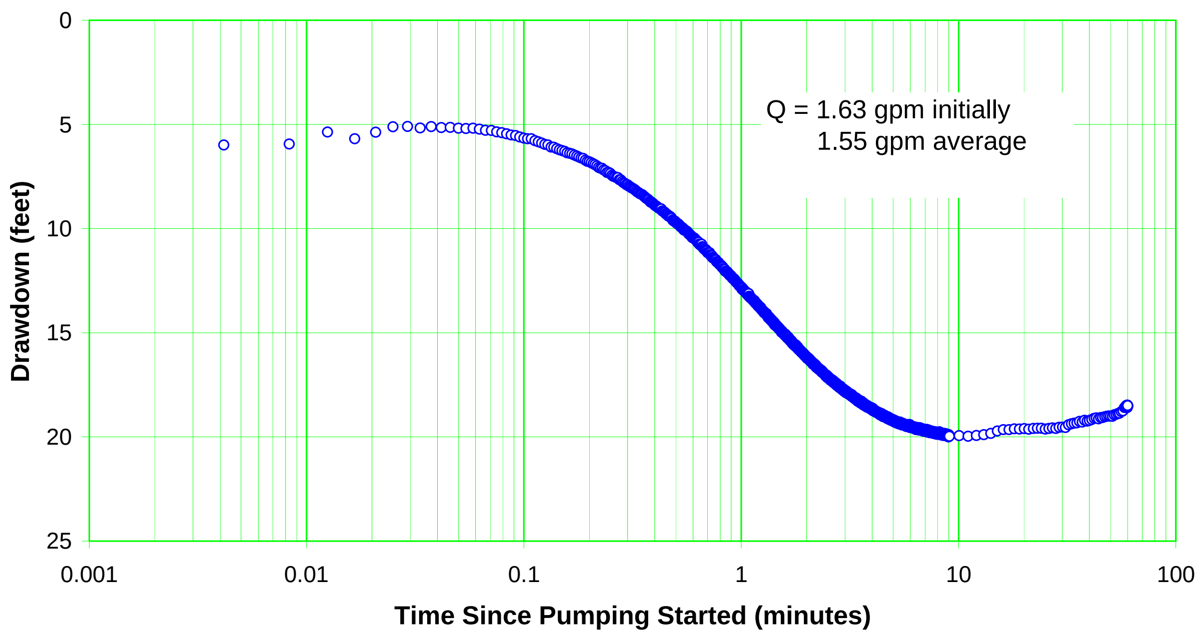

Figure C-8.2-1 Well R-49 screen 1 trial 2 drawdown

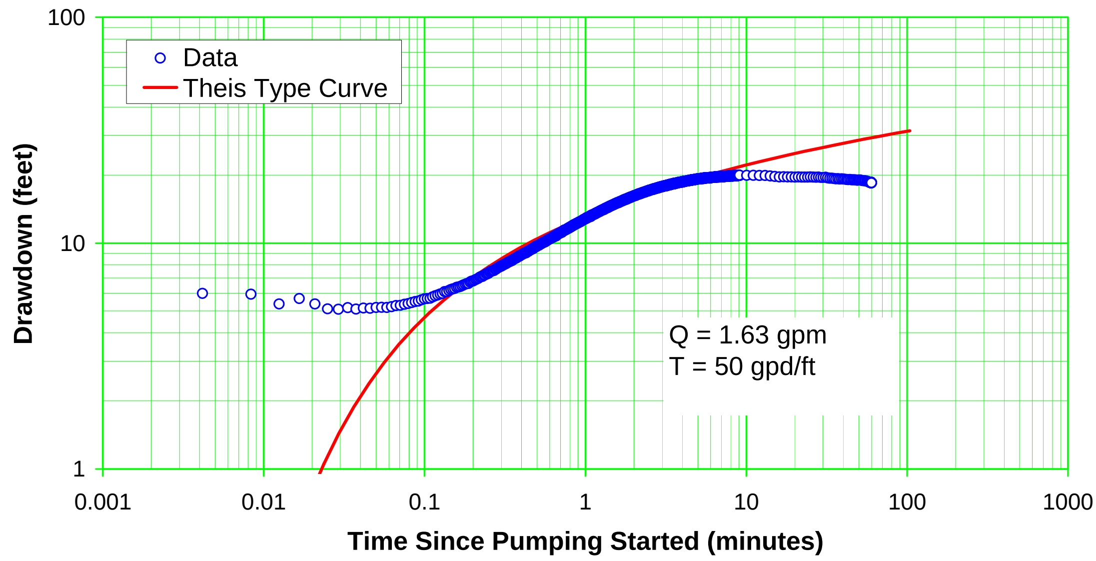

Figure C-8.2-2 Well R-49 screen 1 trial 2 drawdown—Theis analysis

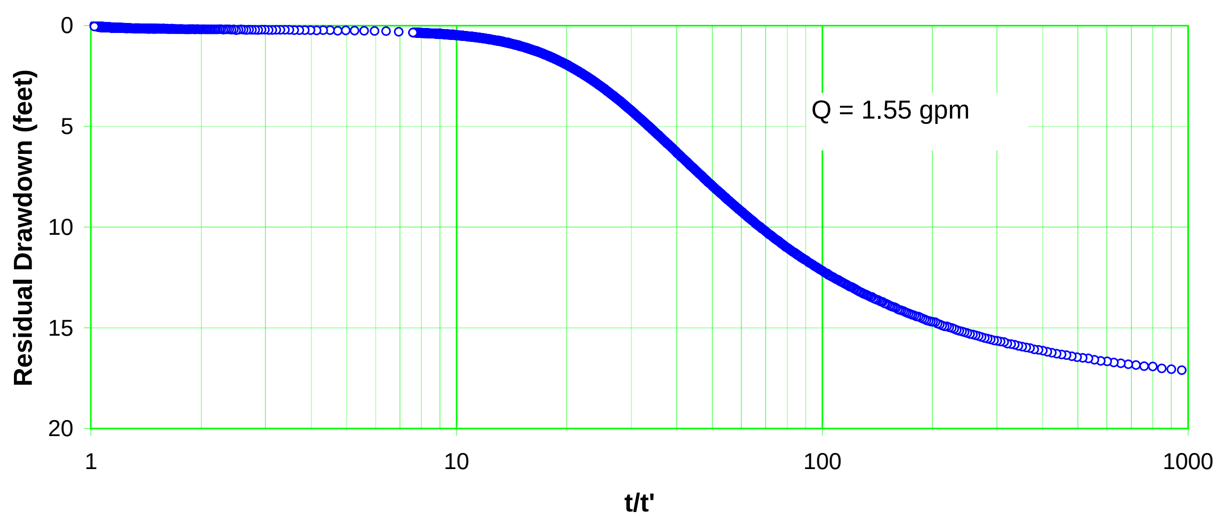

Figure C-8.2-3 Well R-49 screen 1 trial 2 recovery

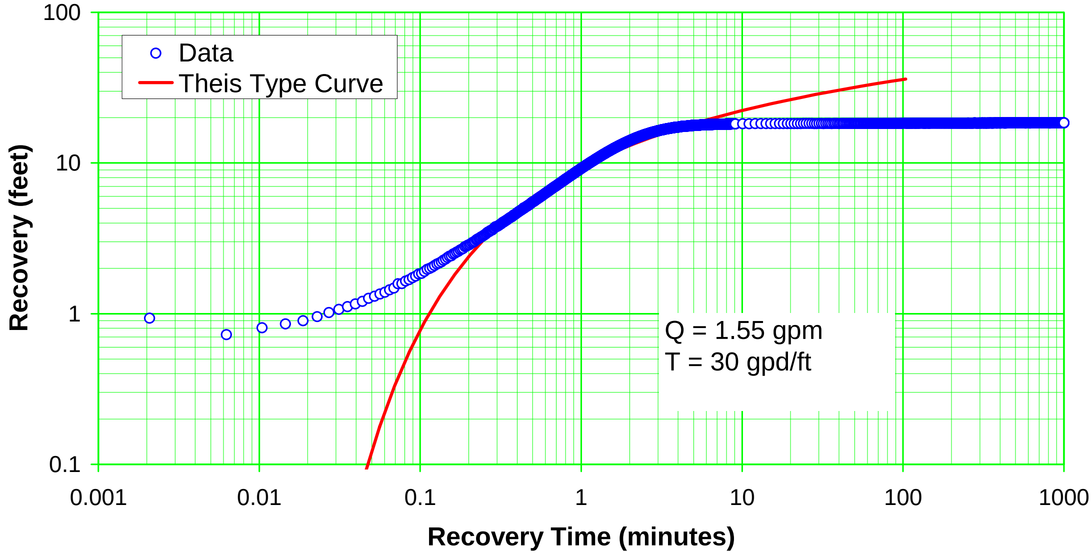

Figure C-8.2-4 Well R-49 screen 1 trial 2 recovery—Theis analysis

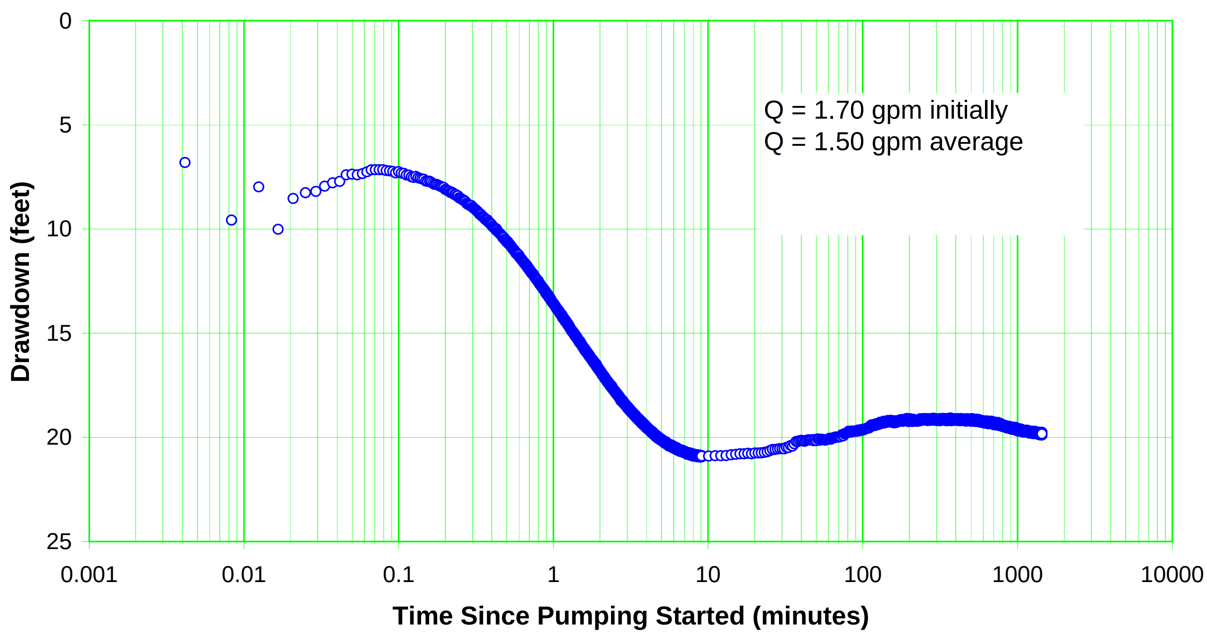

Figure C-8.3-1 Well R-49 screen 1 drawdown

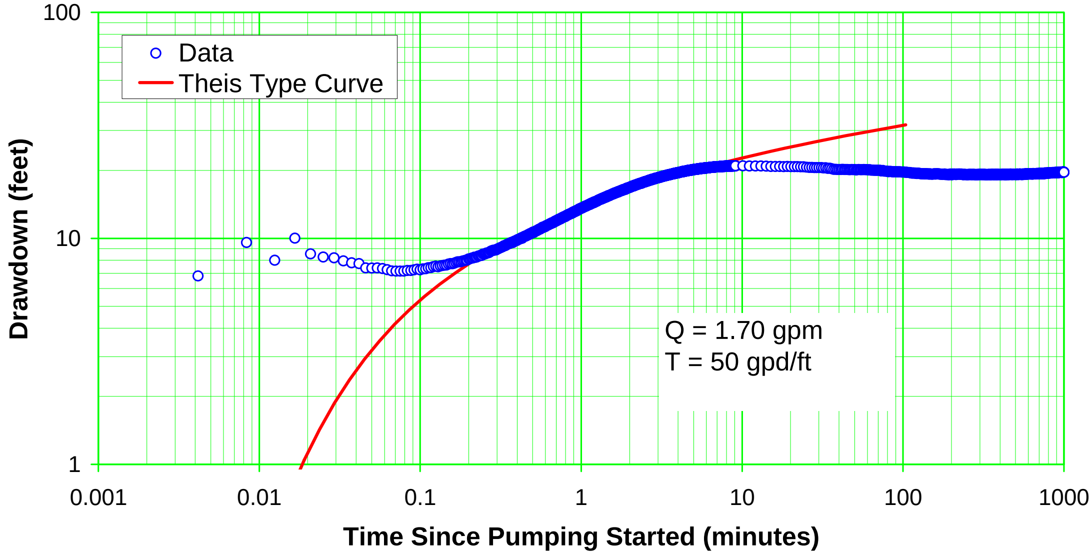

Figure C-8.3-2 Well R-49 screen 1 drawdown—Theis analysis

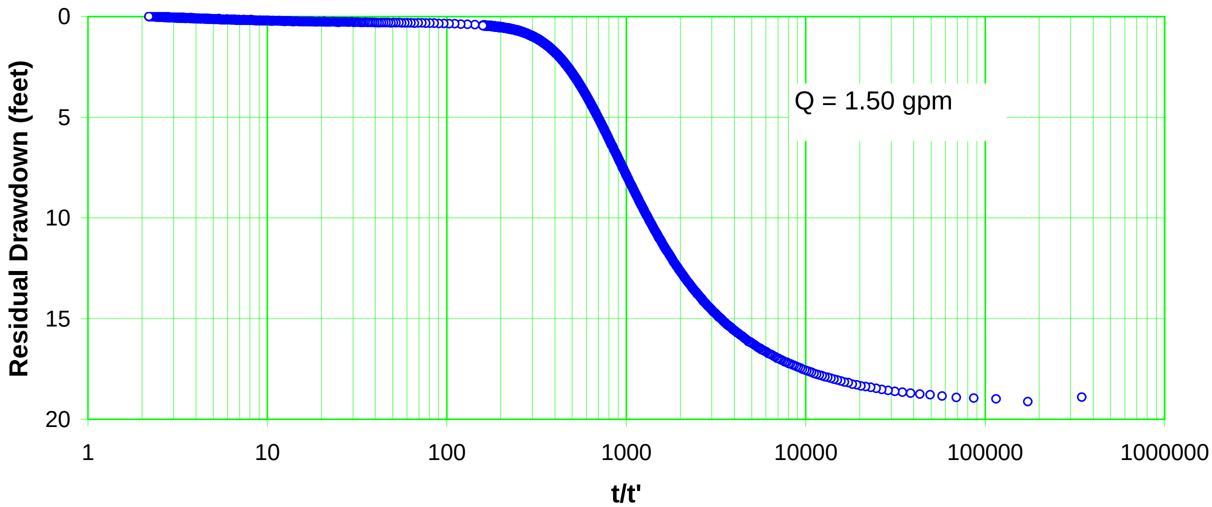

Figure C-8.3-3 Well R-49 screen 1 recovery

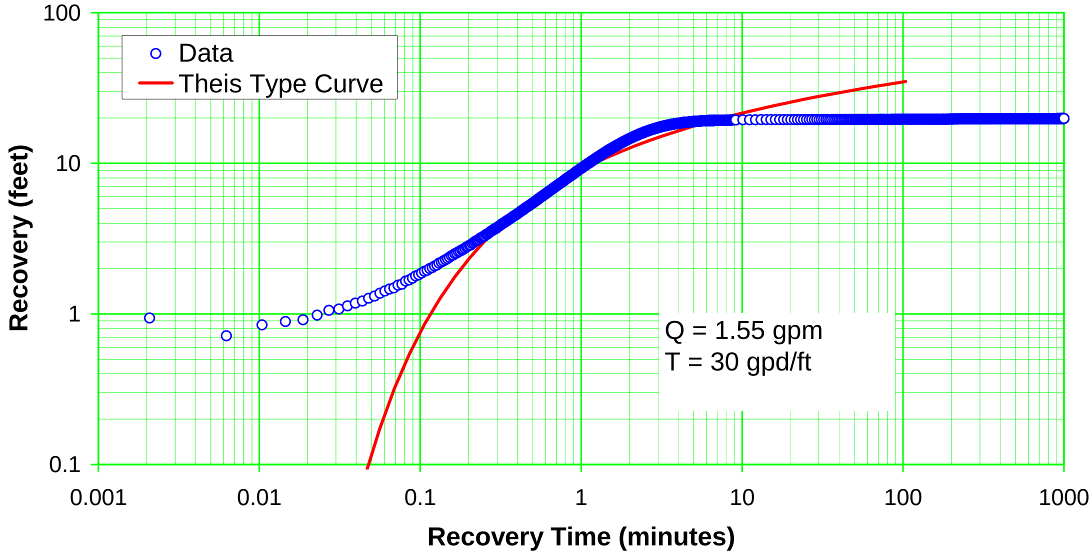

Figure C-8.3-4 Well R-49 screen 1 recovery—Theis analysis

Figure C-8.4-1 Well R-49 screen 1 zone lower-bound transmissivity

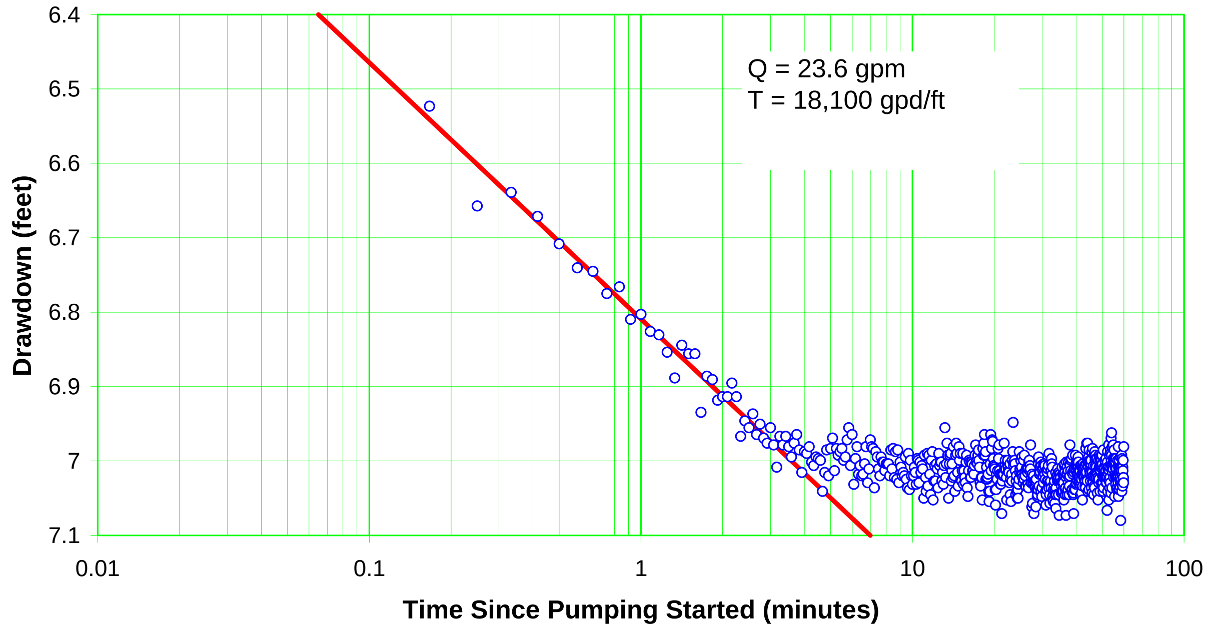

Figure C-9.1-1 Well R-49 screen 2 trial 1 drawdown

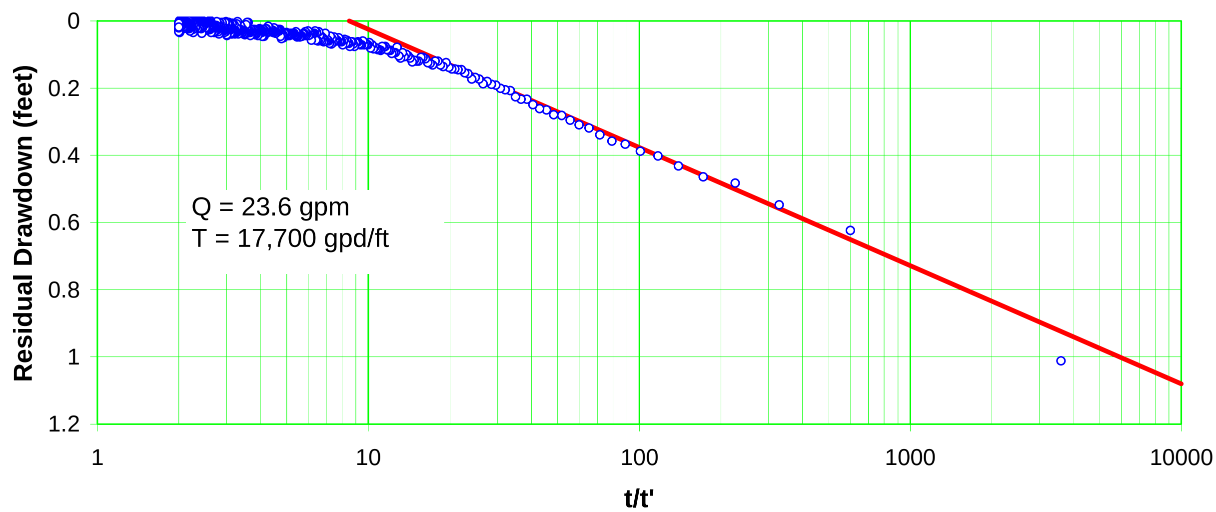

Figure C-9.1-2 Well R-49 screen 2 trial 1 recovery

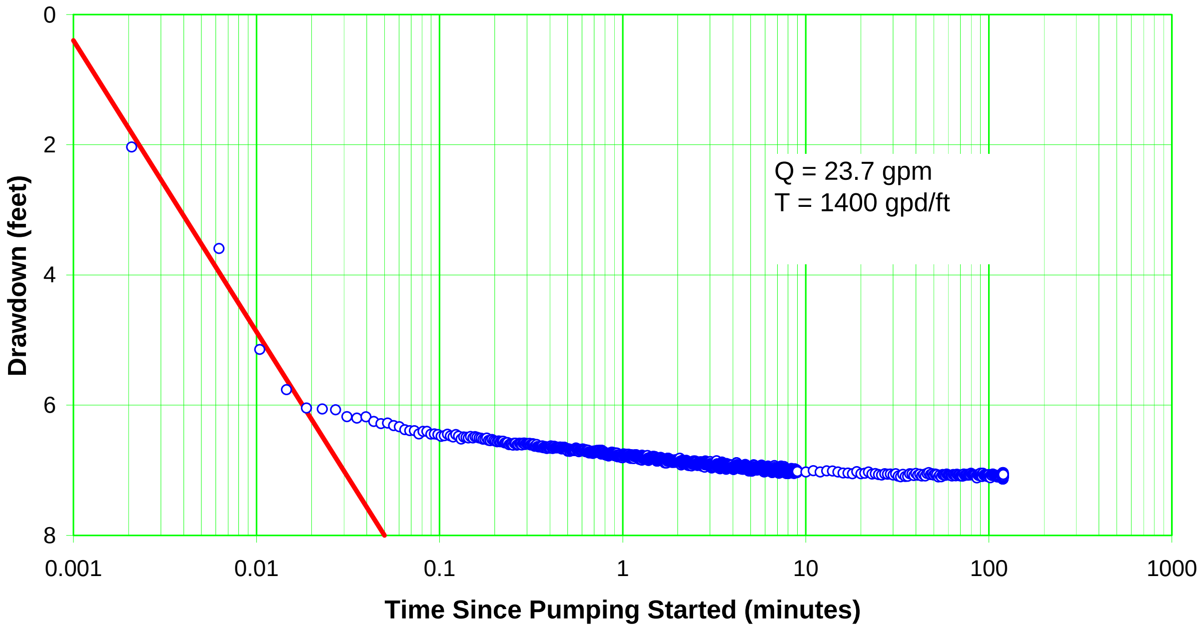

Figure C-9.2-1 Well R-49 screen 2 trial 2 drawdown

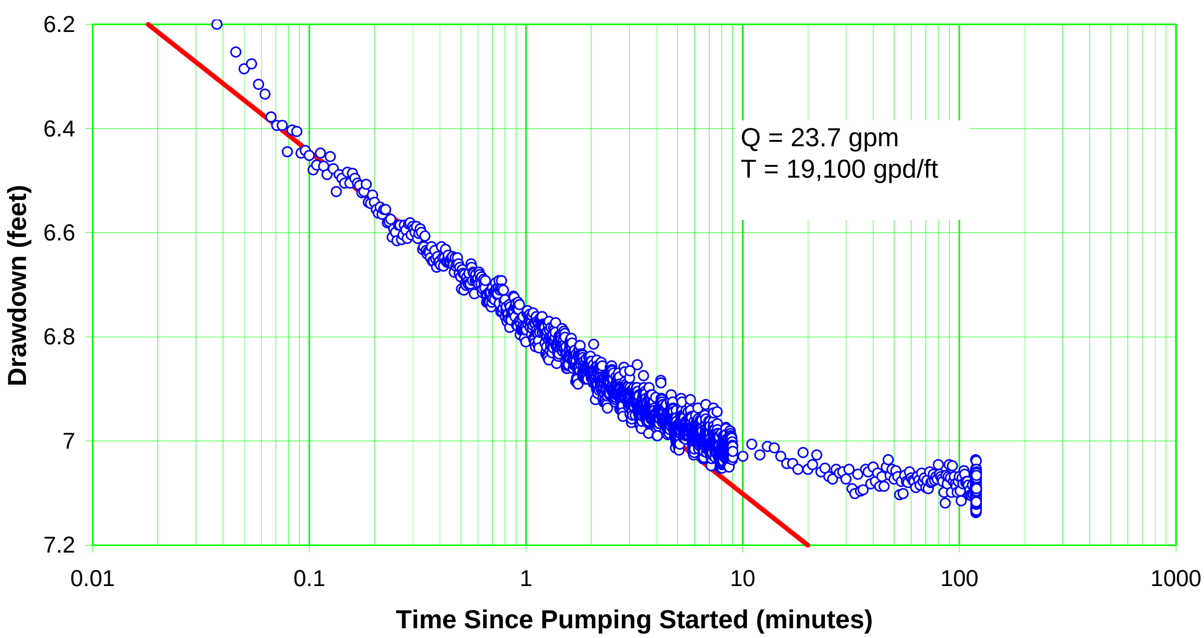

Figure C-9.2-2 Well R-49 screen 2 trial 2 drawdown—expanded scale

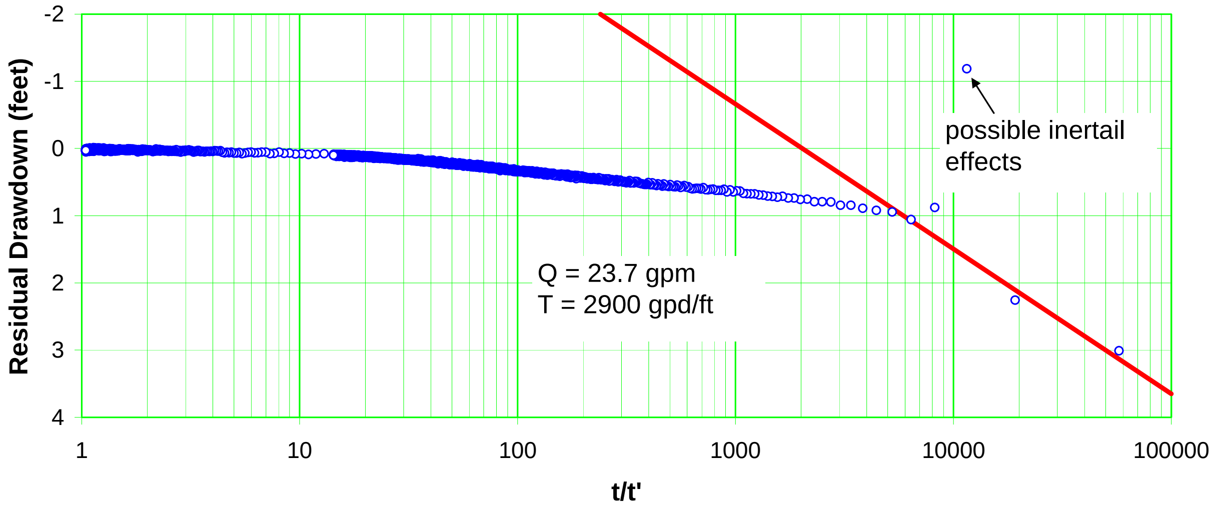

Figure C-9.2-3 Well R-49 screen 2 trial 2 recovery

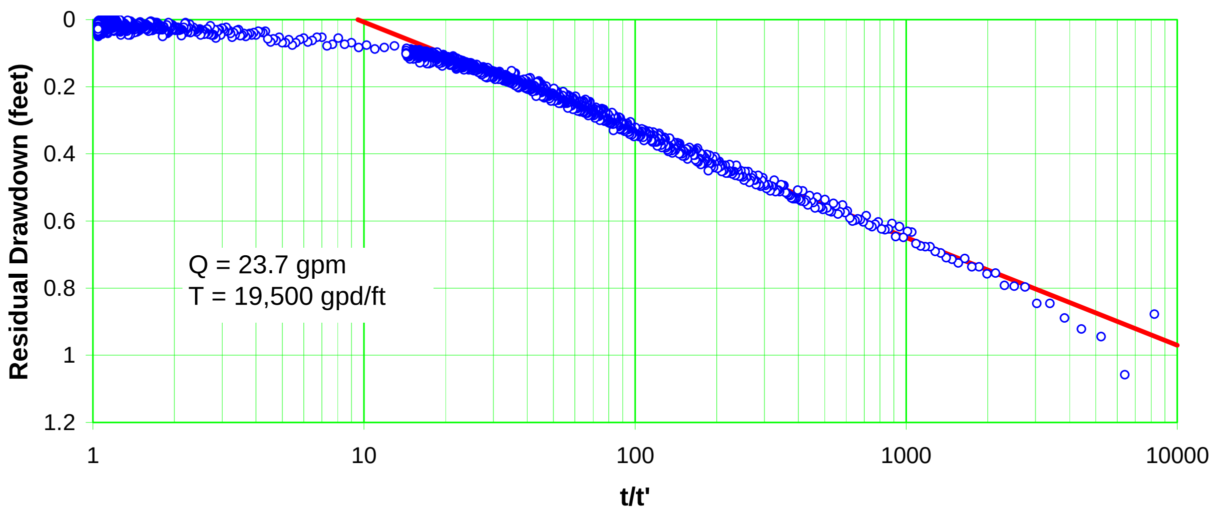

Figure C-9.2-4 Well R-49 screen 2 trial 2 recovery—expanded scale

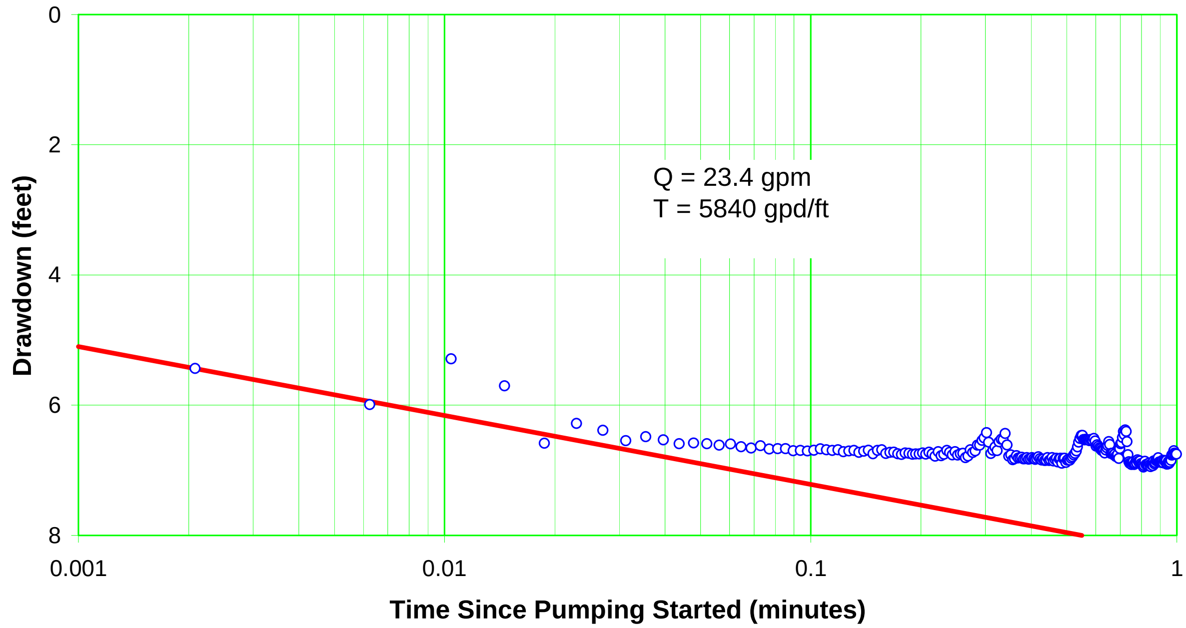

Figure C-9.3-1 Well R-49 screen 2 drawdown—false start

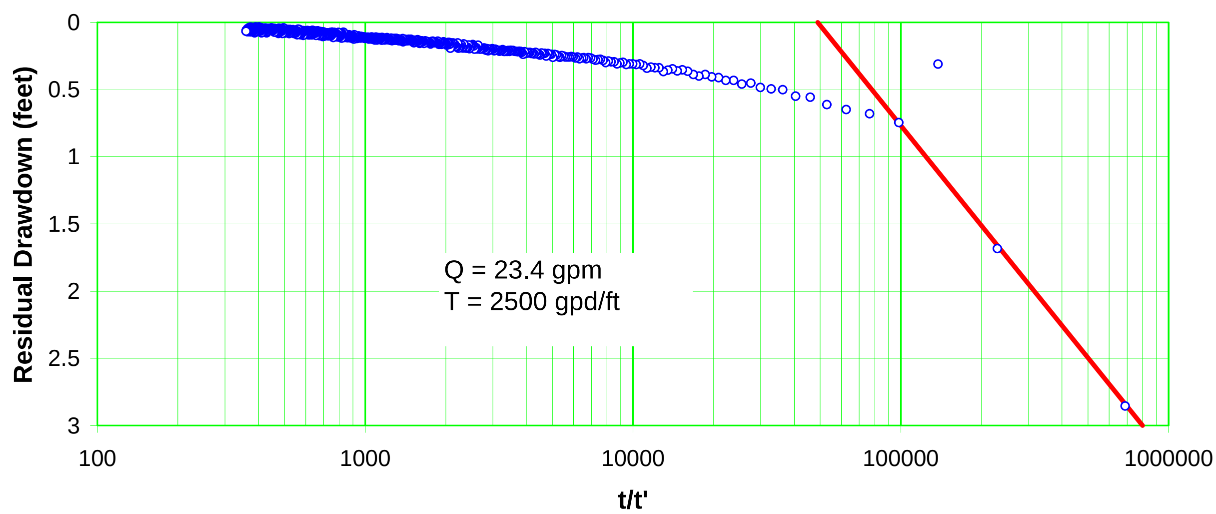

Figure C-9.3-2 Well R-49 screen 2 recovery—false start

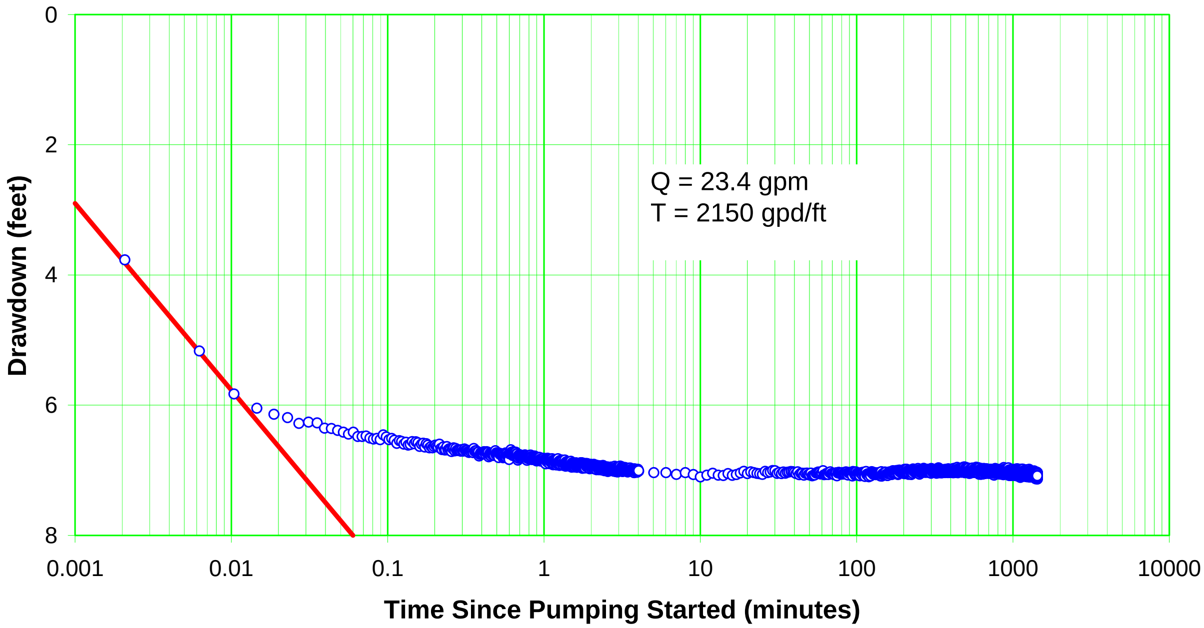

Figure C-9.3-3 Well R-49 screen 2 drawdown—restart

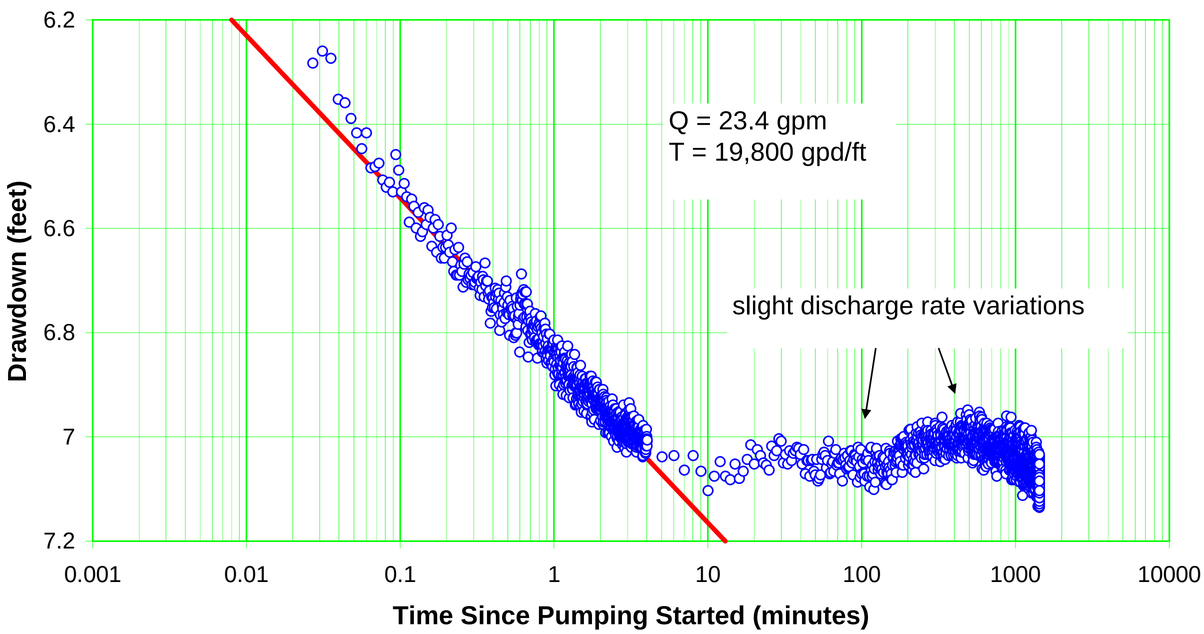

Figure C-9.3-4 Well R-49 screen 2 drawdown—expanded scale

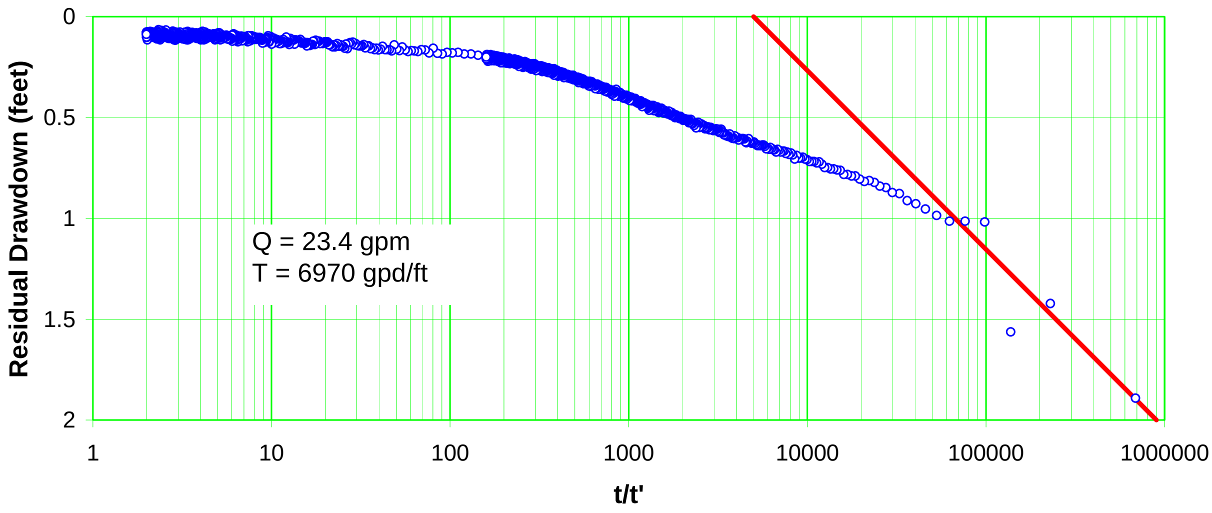

Figure C-9.3-5 Well R-49 screen 2 recovery

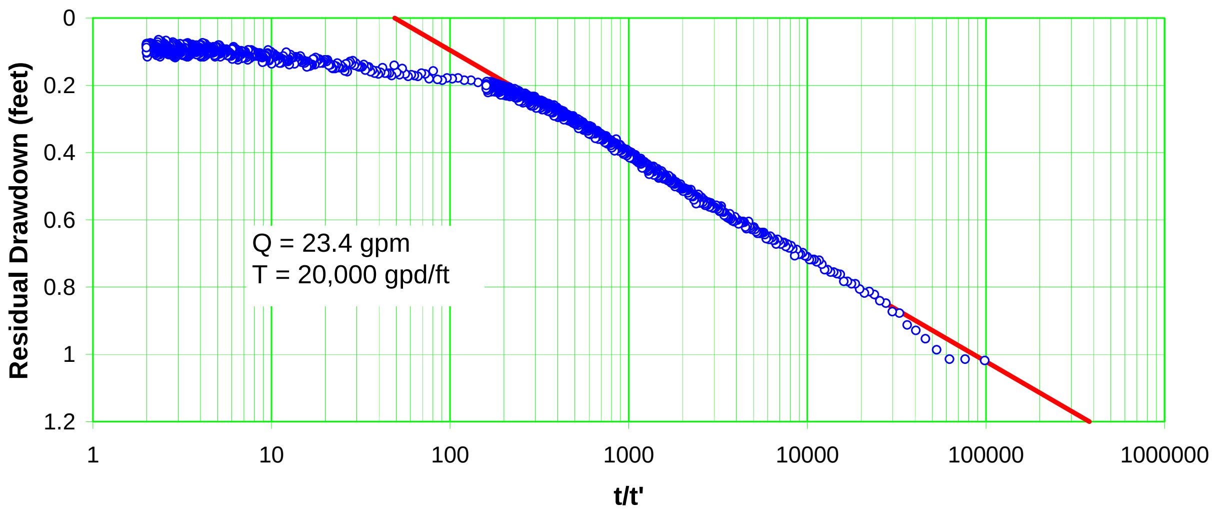

Figure C-9.3-6 Well R-49 screen 2 recovery—expanded scale

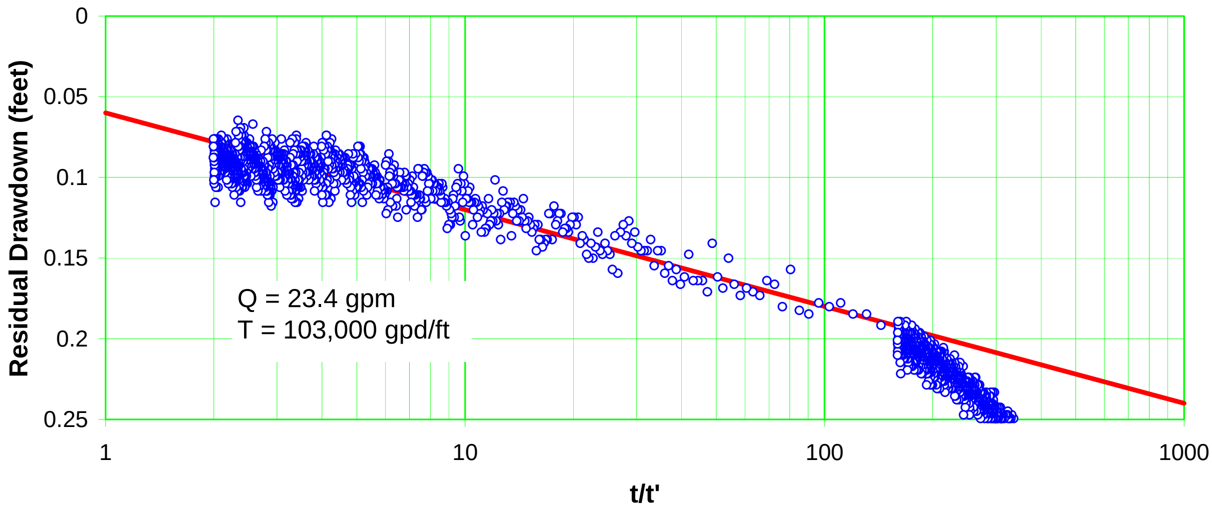

Figure C-9.3-7 Well R-49 screen 2 recovery—late data

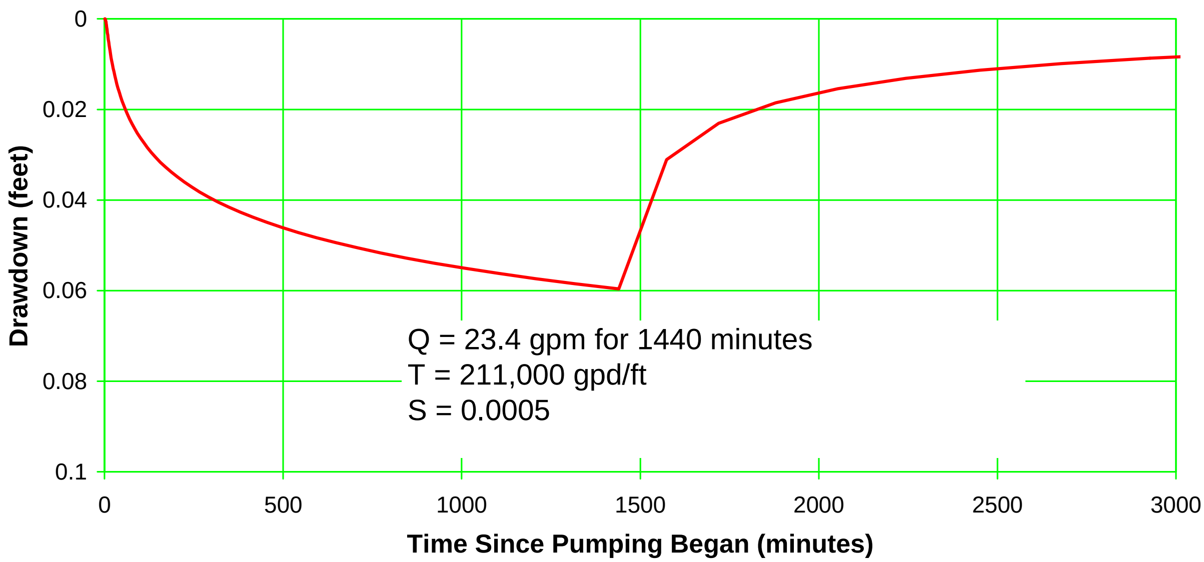

Figure C-9.6-1 Well R-49 screen 2 simulated effect on R-39

Figure C-9.6-2 Combinations of transmissivity and storage coefficient simulating R-39 drawdown

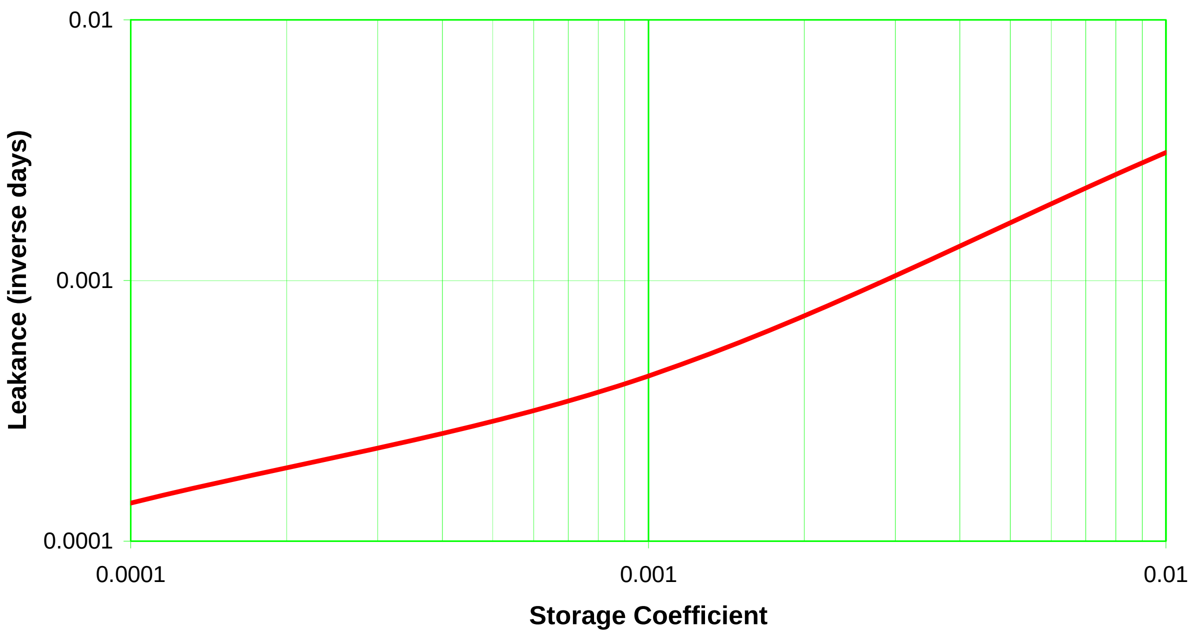

Figure C-9.7-1 Modeled leakance between R-49 screens 1 and 2

Table C-9.4-1
R-49 Screen 2 Transmissivity Values

Test	Analysis	1-*s* T (gpd/ft)	Several-Min T (gpd/ft)
Trial 1	Drawdown	n/a*	18,000
Trial 1	Recovery	n/a	17,700
Trial 2	Drawdown	1400	19,100
Trial 2	Recovery	2900	19,500
24-H False Start	Drawdown	5840	n/a
24-H False Start	Recovery	2500	n/a
24-H Restart	Drawdown	2150	19,800
24-H Restart	Recovery	6970	20,000
Average		3630	19,000

*n/a = Not applicable.

Appendix D

Borehole Video Logging (on DVDs included with this document)

Appendix E

Geophysical Logs and
Schlumberger Geophysical Logging Report
(on CD included with this document)