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Date: January 24, 2009
Refer To: EP2009-0003

James P. Bearzi, Bureau Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
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Subject: Submittal of the Completion Report for Regional Aquifer Well R-42

Dear Mr. Bearzi:

Enclosed please find two hard copies with electronic files of the Completion Report for Regional Aquifer Well R-42.

If you have any questions, please contact Mark Everett at (505) 667-5931 (meverett@lanl.gov) or Nancy Werdel at (505) 665-3619 (nwerdel@doeal.gov).

Sincerely,

Bruce Schappell for MJG

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Sincerely,

David R. Gregory, Project Director
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MG/DG/PH/ME:sm

Enclosures: 1) Two hard copies with electronic files - Completion Report for Regional Aquifer Well R-42 (LA-UR-09-0217)

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LA-UR-09-0217
January 2009
EP2009-0003

Completion Report for Regional Aquifer Well R-42

Los Alamos
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Prepared by the Environmental Programs Directorate

Los Alamos National Laboratory, operated by Los Alamos National Security, LLC, for the U.S. Department of Energy under Contract No. DE-AC52-06NA25396, has prepared this document pursuant to the Compliance Order on Consent, signed March 1, 2005. The Compliance Order on Consent contains requirements for the investigation and cleanup, including corrective action, of contamination at Los Alamos National Laboratory. The U.S. government has rights to use, reproduce, and distribute this document. The public may copy and use this document without charge, provided that this notice and any statement of authorship are reproduced on all copies.

LA-UR-09-0217
EP2009-0003

Completion Report for Regional Aquifer Well R-42

January 2009

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EXECUTIVE SUMMARY

This well completion report describes the drilling, installation, development, and aquifer testing of Los Alamos National Laboratory (the Laboratory) regional aquifer well R-42, located in Mortandad Canyon, Technical Area 05 (TA-05), 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) as an upgradient well to R-28 to monitor groundwater quality and contaminant movement toward well R-28 (which has consistently shown the highest concentration of chromium in the regional aquifer at the Laboratory).

The R-42 borehole was drilled using dual-rotary air-drilling methods. Drilling fluid additives used included potable water and foam. Foam-assisted drilling was used only in the vadose zone; no drilling-fluid additives other than small amounts of potable water added to the air below 790 ft depth, which is 128 ft above the top of regional saturation. Additive-free drilling provides minimal impacts to the groundwater and aquifer materials. The borehole was successfully completed to total depth using casing-advance drilling methods.

Well R-42 was completed as a single-screen well with a screen within the upper part of the pumiceous sediments within the Santa Fe Group, which is the regional aquifer. The R-42 well is intended to further define the nature and extent of contamination from Mortandad and Sandia Canyon sources and to address key uncertainties in the conceptual model for contaminant fate and transport of known chromium contamination in the vicinity of well R-28. A dedicated submersible pump sampling system was installed in the R-42 well, and groundwater sampling will be performed as part of the facility-wide groundwater-monitoring program.

The well was completed in accordance with an NMED-approved well design. The well was thoroughly developed and all target water-quality parameters were achieved. Hydrogeologic testing indicated that monitoring well R-42 is highly productive and will perform effectively to meet the planned objectives.

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Acronyms and Abbreviations

µS/cm	microsiemen per centimeter
amsl	above mean sea level
ASTM	American Society for Testing and Materials
bgs	below ground surface
DO	dissolved oxygen
EES	Environmental and Earth Sciences Group
ENV-MAQ	Environmental Stewardship–Meterology and Air Quality
EP	Environmental Programs
ICPOES	inductively coupled (argon) plasma optical emissison spectroscopy
ICPMS	inductively coupled (argon) mass spectrometry
I.D.	inside diameter
IDW	investigation-derived waste
IWD	integrated work document
LANL	Los Alamos National Laboratory
mV	millivolt
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxygen-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
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
TOC	total organic carbon
Tpf	Tertiary Puye formation
Tsfu	Tertiary Santa Fe Group undifferentiated
WCSF	waste characterization strategy form

1.0 INTRODUCTION

This completion report summarizes the site preparation, drilling, well construction, well development, and related activities for monitoring well R-42 and was written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005, Compliance Order on Consent (the Consent Order). Well R-42 was drilled and completed from June 2008 to September 2008 at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Water Stewardship Program. Aquifer testing was conducted in November 2008, and results are presented in this completion report.

The R-42 project site is located in Mortandad Canyon upgradient of well R-28 within Technical Area 05 (TA-05), Los Alamos County, New Mexico (Figure 1.0-1). The purpose of the R-42 monitoring well is to provide hydrogeologic- and groundwater-quality data from the regional aquifer to achieve data quality objectives consistent with the Groundwater Protection Program for the Laboratory and the Consent Order, in addition to the New Mexico Environment Department- (NMED-) approved "Work Plan for Geochemical Characterization and Drilling for Fate and Transport of Contaminants Originating in Sandia Canyon" (LANL 2007, 099607). Specifically, well R-42 is intended to further define the nature and extent of contamination from Mortandad and Sandia Canyon sources and to address key uncertainties in the conceptual model for contaminant fate and transport of known chromium contamination in the vicinity of well R-28. Well R-42 will help define source and flowpath immediately upgradient of R-28.

The primary objective of the drilling activities was to drill and install a single-screened regional aquifer monitoring well in the uppermost part of the regional groundwater system. The water table at R-42 is within the upper part of Miocene pumiceous sediments characterized by abundant vitrc-aphyric rhyolitic pumice beneath the Puye Formation. This unit is highly transmissive in many aquifer tests (especially at R-28), and it contains groundwater with elevated chromium concentrations at R-28. Proximal upgradient position and location within a common transmissive unit make this location a critical sampling point for understanding contaminant movement toward well R-28.

The R-42 borehole was drilled to a total depth (TD) of 1047.5 ft below ground surface (bgs). A monitoring well was installed with a screened interval between 931.8 and 952.9 ft bgs. The depth to water after well installation and well development was 918.8 ft bgs. Postinstallation activities included well development, pump testing, surface completion, dedicated sampling system installation, site restoration, and geodetic surveying. Ongoing activities include 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 all activities associated with the R-42 project, as well as supporting figures, tables, and appendixes.

2.0 PRELIMINARY ACTIVITIES

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

2.1 Administrative Preparation

The following documents were prepared to guide the implementation of the scope of work for R-42, "Work Plan for Geochemical Characterization and Drilling for Fate and Transport of Contaminants Originating in Sandia Canyon" (LANL 2007, 099607), "Integrated Work Document for Regional and Intermediate Aquifer

Well Drilling" (LANL 2007, 100972), "Storm Water Pollution Prevention Plan Addendum" (LANL 2006, 092600), "Waste Characterization Strategy Form for Chromium Wells (R-42, SCI-2/R-43) and Corehole Installation" (LANL 2008, 101914).

2.2 Site Preparation

Site preparation was performed between June 19 and 29, 2008, and included clearing and grading a drill pad and access road; excavating and lining a cuttings containment pit; and installing berms, silt fencing, and straw waddles to control stormwater run-on and runoff and prevent erosion. The drill pad area was approximately 200 ft × 150 ft and was covered with base course. The access road was 1600 ft long and was covered with base course. The cuttings pit measured approximately 60 ft × 40 ft with a depth of 8 ft. Radiation control technicians (RCTs) from the Laboratory's Radiation Protection Group-1 performed radiological screening of the site and construction equipment as required.

Office and supply trailers, generators, and general field equipment were moved on-site during mobilization of drilling equipment. Potable water for drilling was trucked to the site by the drilling subcontractor from a Los Alamos County fire hydrant located near municipal well house PM-5. 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 provides a chronological summary of field activities conducted at monitoring well R-42.

3.1 Drilling Approach

The drilling methodology and selection of equipment and drill-casing sizes were designed to ensure successful completion of well R-42. This approach retained the ability to case off perched groundwater and reach TD with sufficiently sized casing to meet the required 2-in. minimum annular thickness of the filter pack. Further, it was anticipated that if perched groundwater was encountered at R-42, the perched zone would be isolated and sealed off with either casing or by cementing to avoid commingling perched groundwater with the regional aquifer.

Dual-rotary air-drilling methods using a Foremost DR-24HD drill rig were employed to drill the R-42 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, one 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. Two sizes of flush-welded mild carbon-steel casing were used on the R-42 project: 16-in.-inside diameter (I.D.) and 12-in.-I.D. The dual-rotary technique at R-42 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 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 bits and lift cuttings from the borehole. Estimated cumulative total of drilling fluids introduced into the borehole and the total fluids recovered are presented in Table 3.1-1. No additives other than municipal water were used for drilling within the lower 128 ft of the vadose zone or within the regional aquifer.

3.2 Chronology of Drilling Activities

Drilling equipment and supplies were mobilized to the site between June 28 and 29, 2008. On June 30, 2008, the R-42 borehole was initiated with dual-rotary methods using 16-in. casing and a 15-in. conventional hammer bit. The 16-in. casing was advanced through the alluvium, the Otowi Member of the Bandelier Tuff, and the upper Puye Formation sediments and landed on July 10, 2008, at 419.4 ft bgs, 4.4 ft into the top of the Cerros del Rio basalt. On July 11, 2008, drilling then continued below the Cerros del Rio basalt using open-hole drilling methods with a 15-in. hammer bit.

Difficulties were encountered at approximately 540 ft bgs, and the 15-in. hammer bit was removed for examination due to lost circulation and poor penetration rates. The internal foot valve in the hammer was malfunctioning and needed to be replaced. The 15-in. hammer bit foot valve was replaced on July 12, 2008, and open-hole drilling continued to approximately 777 ft bgs. At approximately 680 ft bgs, drilling conditions changed with rapid penetration rates, indicating the contact with the lower Puye Formation. Open-hole drilling conditions between 680 and 777 ft bgs were normal and fast because of the soft formation. The decision was made to switch over to 12-in. casing advance at 777 ft bgs because open-hole drilling was not feasible in the poorly consolidated Puye sediments. On July 13 and 14, 2008, the Laboratory's downhole video camera and geophysical tools were run in the borehole to investigate potential perched groundwater in the Puye Formation. On July 14, 2008, several discrete trickles of perched groundwater were identified from 685.9 to 690 ft bgs. The cumulative flow of the observed perched water between 685.9 to 690 ft bgs was estimated to be 1 gpm or less based on visual observation. Perched groundwater accumulation was observed in the bottom of the hole. A pump rig was brought on-site to aid in collecting a groundwater sample from the perched zone. A groundwater sample was collected with a bailer from standing water from 771 to 775 ft bgs and submitted for anion and cation analyses.

On July 14, 2008, the drive shoe was cut off the 16-in. casing, and the perched water zone was sealed using 12-in. casing and bentonite chip seal. On July 15, 2008, a 10-ft thick hydrated bentonite chip seal was installed from 774.9 to 764.2 ft bgs and hydrated with potable water. The 12-in. casing was advanced into the bentonite chip seal to a depth of 778 ft bgs.

Drilling continued using 12-in. casing (using an 11 7/8-in. tricone bit with conventional dual-rotary methods) through the Puye Formation and into sands and gravels of the Santa Fe Group sediments. No drilling additives other than potable water were used below 790 ft bgs. On July 17, 2008, evidence of groundwater was first encountered at 894.5 ft bgs and again at 913 ft bgs. Groundwater samples were collected from these two depths by airlifting the groundwater through the drill string. Drilling operations halted the injection of potable water and circulated only air for approximately 10 min at each of these intervals. Water continued to be observed in the discharge.

Drilling with 12-in. casing advance continued to 970 ft bgs. Collection of additional groundwater samples was attempted at 935 to 950 ft bgs, 960 ft bgs, and 970 ft bgs; however, the formation did not yield enough water for off-site analyses. The decision was made to halt drilling and monitor water levels with an electronic sounder to determine the static water level (SWL) in the borehole and identify the top of the regional aquifer. The SWL was measured at approximately 920 ft bgs. On July 17, 2008, the Laboratory decided to drill an additional 60 ft into the regional aquifer with 12-in. casing advance. Before drilling, a groundwater-screening sample was collected at 970 ft bgs. Additional groundwater-screening samples were collected every 20 ft until TD was reached at 1029ft bgs.

On July 18, 2008, the drilling tools were removed from the borehole, and the Laboratory's gamma tool and camera were run through the 12-in. casing to verify the SWL. The 12-in. casing was lifted 5 ft to help the groundwater equilibrate to a static level more quickly in the hole. The top of the groundwater table

was recorded at 945 ft bgs. After the Laboratory's geophysical tools were run, the casing was pushed back to the bottom of the borehole (1029 ft bgs) and the drilling tools were tripped back in to clean out the hole. Slough was encountered in the 12-in. casing at approximately 980 ft bgs and was cleaned out multiple times back to TD. Formation material continued to heave inside the 12-in. casing, reaching a level of 978 ft (50 ft inside the 12-ft casing). In attempts to clean out the borehole and control the heaving sediments, the borehole was flooded several times with potable water; however, formation sands and sediments continued to heave 10–15 ft up inside the casing. On July 19, 2008, the drilling tools were tripped back out of the borehole in preparation for geophysical logging by Schlumberger. Schlumberger logged the borehole on July 19 and 20, 2008. Formation heave was encountered during the last logging run at 972 ft bgs, which prevented the final log from reaching TD of the borehole.

The Laboratory approved the final well design for R-42 on July 23, 2008. At that time, formation material had surged 56.5 ft up into the 12-in. casing. Before cutting the casing (as discussed below), the tools were tripped back into the borehole and it was cleaned out to 1029.5 ft bgs.

On July 24, 2008, the crew began tripping out the tool string in preparation for cutting the 12-in. casing. While tripping out of the hole, the heaving sands and sediments continued to enter into the 12-in. casing. Formation material rose in the cased hole from 1027 to 994 ft bgs. Into the borehole, 1500 gal. of water was introduced in an attempt to force the formation material out of the 12-in. casing and to regain control of the formation; this attempt was not successful. Well construction activities were stalled until a solution to the heaving problem could be identified. The decision was made to attempt to advance the borehole an additional 20 ft and into undisturbed formation to case off the heaving zone and regain control of the formation so well construction could be accomplished.

On July 25, 2008, the R-42 borehole was advanced to 1047.5 ft bgs and flooded with 2500 gal. of potable water to control formation heave. At the end of the shift, the hole was tagged inside the 12-in. casing at 1039 ft bgs, indicating that the heaving of formation material had slowed. On July 26, 2008, the borehole was tagged at 1028.5 ft bgs. Although the formation heaved slightly overnight, the decision was made to trip out the tool string, cut the 12-in. casing, and begin well construction. An attempt was made to cut the 12-in. casing at 990 ft bgs, but the casing cutter malfunctioned and ultimately broke. On July 27, 2008, the drill string was tripped back in and the hole was cleaned out to 1000 ft bgs. On July 28, 2008, the casing cutter parts were delivered and the casing cutter was repaired. The tool string was tripped out and the casing cutter tripped back in the hole. The 12-in. casing string and drive shoe were successfully cut at 988 ft bgs. A total of 59.5 ft of 12-in. casing and the drive shoe remain in the borehole (988 to 1047.5 ft bgs). The 12-in. casing string was strategically cut to leave a long piece in place to isolate the worst heaving interval. This strategy proved successful, and no formation difficulties were experienced above the cut at 988 ft bgs. Once the 12-in. casing was cut, well installation began.

The field crew generally worked two 12-h shifts per day, 7 d/wk. Most of the drilling and well construction activities were conducted on 24-h workdays. Final well construction and development activities were conducted on single 12-h day shifts. Operations suffered numerous lightning delays throughout the duration of the project. Some technical delays were incurred because of the unexpected heaving formation material encountered in the sediments of the Santa Fe Group in the lower portion of the borehole. Mechanical delays due to a broken foot valve in the hammer bit and a broken casing cutter also affected progress.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities at well R-42. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-42 borehole at 5-ft intervals from ground surface to the TD of 1047.5 ft bgs. At each interval, approximately 500 mL of bulk cuttings were collected from the discharge hose, placed in resealable plastic bags, labeled, and archived in core boxes. Sieved fractions (>#10 and >#35 mesh) were also collected from ground surface to 1047.5 ft bgs and placed in chip trays along with unsieved (whole rock) cuttings. RCTs screened all cuttings before removal from the site.

Most drill cuttings collection methods used at R-42 did not retain a majority of the finest fraction (silt and clay) of the drill cuttings because the high-velocity compressed air required for non-mud-rotary methods made catching samples difficult. Site geologists manually collected samples with a wire mesh basket directly from the discharge hose and discharge velocities forced most of the fines through the basket. In addition, bucket samples were collected at various intervals to capture total formation material: 580–585 ft, 870–875 ft, 890–895 ft, 910–915 ft, 950–955 ft, 990–995 ft, and 1010–1015 ft. Recovery of the coarser fraction of the cuttings samples was excellent in nearly 100% of the borehole. The borehole lithologic log for R-42 is presented in Appendix A.

4.2 Water Sampling

Groundwater-screening samples were collected from the drilling discharge hose at 20-ft intervals from the top of regional aquifer to the TD of 1047.5 ft bgs in the R-42 borehole. Typically upon reaching the bottom of a 20-ft run of casing, the driller stopped water circulation (if injecting water) and circulated air to clean out the borehole. As the discharge cleared, water samples were collected directly from the discharge hose. Not all depth intervals below the top of the regional groundwater table could be captured at the end of each casing run due to lack of water production. Alternatively, some water samples were collected upon start-up of the next casing run after the borehole filled with water.

Perched groundwater samples were collected by bailing or by air-lifting a water sample through the drill string. Two perched groundwater samples (771–775 ft bgs) were collected and analyzed. Additionally, two samples (894 and 913 ft bgs) of indeterminate origin (introduced potable water?) were collected and analyzed.

Regional groundwater samples were also collected at regular intervals (one sample every 2 h) during well development and aquifer testing. The groundwater samples were collected from the surface discharge port on the submersible development pump riser pipe and submitted for analyses.

All groundwater samples were submitted to the Laboratory's Earth and Environmental Sciences groundwater chemistry laboratory for analysis of anions, cations, total organic carbon (TOC) and (for some samples) nitrates, tritium, and chromium. Sampling documentation and containers were provided by the Laboratory and processed through the Laboratory's Sample Management Office. Groundwater analytical results and details of groundwater chemistry at R-42 are presented in Appendix B. Table 4.2-1 presents a summary of all groundwater samples collected during drilling and well development activities.

5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered at R-42 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-42.

5.1 Stratigraphy

The stratigraphy for the R-42 borehole is presented below in order of youngest to oldest geologic units. Lithologic descriptions are based on cuttings samples collected from the discharge hose. Cuttings and borehole geophysical logs were used to identify geologic contacts. Figure 5.1-1 illustrates the stratigraphy at R-42. A detailed lithologic log is presented in Appendix A.

Quaternary Alluvium, Qal (0–70 ft bgs)

Quaternary alluvium consisting of unconsolidated silty sand to sandy silt with pebbles and gravels of tuffaceous sediments was encountered from 0 to 70 ft bgs. No evidence of alluvial groundwater was observed.

Otowi Member of the Bandelier Tuff, Qbo (70–367 ft bgs)

The Otowi Member of the Bandelier Tuff is present in R-42 from 70 to 367 ft bgs. The Otowi Member is a glassy, lithic-bearing, pumiceous, poorly welded ash-flow tuff. It contains reddish gray to gray, subangular to subrounded, intermediate composition volcanic rocks up to 16 mm in diameter and vitric pale yellow to white pumice lapilli with conspicuous phenocrysts of quartz and sanidine. Halos of iron staining occur around pumice.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (367–383 ft bgs)

The Guaje Pumice Bed is present from 367 to 383 ft bgs. The pumice bed contains abundant pumice fragments (up to 95%) with subordinate amounts of volcanic lithics, quartz and sanidine phenocrysts, and fine ash.

Upper Puye Formation, Tpf (383–393 ft bgs)

The upper Puye Formation, from 383 to 393 ft bgs, consists of volcaniclastic sandy silt to silty sand with pebble and gravel deposits. Gravels consist of intermediate composition volcanic rock fragments, volcaniclastic sandstones, pumice clasts, and conspicuous felsic and mafic mineral grains. The formation ranges from yellowish gray to light brown.

Basaltic Colluvium (393-415 ft bgs)

At approximately 393 ft bgs, the upper Puye Formation transitions downward into brown volcaniclastic sediments with 70%–100% basalt clasts. These basalt clasts appear to be derived from the underlying Cerros del Rio basalt.

Cerros del Rio Basalt, Tb4 (415–680 ft bgs)

Cerros del Rio basalt, from 415 to 680 ft bgs, consists of multiple lava flows of vesicular to massive porphyritic basalt with an aphanitic groundmass. Trace to minor olivine and plagioclase phenocrysts and local clay and clay-filled vesicles are evident. Basalt ranges from dark to medium gray to dark reddish gray.

Lower Puye Formation, Tpf (680–900 ft bgs)

The lower Puye Formation consists of poorly sorted volcaniclastic sediments with white clay, silt, sand, gravels, and cobbles. Gravel and cobbles consist of intermediate composition lavas, with conspicuous felsic and mafic phenocrysts, siltstones, sandstones, and conglomerates. The formation ranges from pinkish white to medium gray.

Santa Fe Group, Undivided, Tsfu (900–1047.5 ft bgs)

The Miocene Santa Fe Group is present from 900 ft to TD at 1047.5 ft bgs and consists of (1) upper light tan, generally fine-grained pumiceous sediments (900 to 991 ft) and (2) lower brown riverine deposits (991 to 1047.5 ft). The pumiceous deposits include sands, silts and minor gravels made up of pumice, and other mixed felsic to intermediate volcanic detritus. The upper part of the riverine deposits (991 to 1020 ft) consists of siltstone with fine sand and clay made up primarily of volcanic detritus and up to 15% rounded Precambrian quartzite clasts. Below 1020 ft, the riverine deposits consist of coarse gravel with silt and sand made up of rounded intermediate to felsic volcanic detritus and 5%–10% Precambrian quartz, quartzite, and granite clasts.

5.2 Groundwater

Regional groundwater was believed to be encountered at R-42 during drilling at approximately 913 ft bgs in the Santa Fe Group on July 17, 2008. An SWL of 920.4 ft bgs was measured in the borehole on July 17, 2008. Groundwater-screening samples (section 4.2) were collected during drilling and well development. After well installation and development, the SWL was measured at 918.8 ft bgs. A discussion of groundwater chemistry is presented in Appendix B. Aquifer testing data and interpretation for R-42 are presented in Appendix C. Another show of water occurred during drilling at 894.5 ft bgs, which was initially suspected to be the regional aquifer occurring at a shallower than predicted depth. Water was produced from this zone at a rate of 5 to 10 gpm and a sample was collected. However, this saturated zone could not be further confirmed or characterized through water-level monitoring or borehole geophysics.

Several discrete trickles of perched groundwater were identified from 685.9 to 690 ft bgs. The flow of water entering the borehole between 685.9 to 690 ft bgs was visually estimated at 1 gpm or less. The water accumulated in the bottom of the borehole and a groundwater sample was collected for anion and cation analyses (Appendix B).

6.0 BOREHOLE LOGGING

Several video logs and a limited suite of cased-hole geophysical logs were collected during the R-42 drilling project using Laboratory-owned equipment. An additional suite of geophysical logs was collected by Schlumberger Wireline Services. A summary of video and geophysical logging runs is presented in Table 6.0-1.

6.1 Video Logging

Video logs were run in the uncased borehole to check for the presence of perched groundwater in the Cerros del Rio basalt on July 13 and 14, 2008. Perched water was observed in the video logs in the Puye Formation a short distance below the Cerros del Rio basalt. Several other video logs were run in the borehole to verify conditions. An additional video log was collected in the completed well for inspection.

The July 14, 2008, video log from the borehole is presented on a digital video disc as part of Appendix D included with this document. Table 6.0-1 details individual video logging runs.

6.2 Geophysical Logging

A suite of Schlumberger geophysical logs was run inside the drill casing on July 19 and 20, 2008. At the time of logging, the terminations of the two casing strings in the R-42 borehole were located at the following depths: 16-in. casing at 419.4 ft bgs and the 12-in. casing at 1028.5 ft bgs. The geophysical suite included Triple Detector Lithodensity Tool, Accelerator Porosity Sonde, Natural and Spectral Gamma Logs, and Elemental Capture Sonde. Interpretation and details of the logging will be presented on CD in the Geophysical Logging Report as part of Appendix E.

Additionally, several natural gamma ray and induction tool logs were run in the R-42 borehole and the completed well using the Laboratory's geophysical equipment. Details of the logging operations are presented in Table 6.0-1. The results of the geophysical logging will be presented on plots in Appendix E.

7.0 WELL INSTALLATION

R-42 well casing and annular fill were installed between July 30, 2008, and August 27, 2008.

7.1 Well Design

The R-42 well was designed in accordance with the NMED Consent Order. NMED approved the well design before installation. The well was designed with a single screen interval to monitor groundwater quality in the upper part of the regional aquifer within Santa Fe Group sediments.

7.2 Well Construction

The R-42 monitoring well was constructed of 5.0-in.-I.D./5.56-in.-outside diameter (O.D.) type A304 stainless-steel casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. External couplings (also type A304 stainless steel fabricated to ASTM A312 standards) were used to connect individual casing and screen sections. The screen sections were 12.3 ft long with 10-ft lengths of 5.0-in.-I.D. rod-based 0.020-in. slot wire-wrapped well screen. The coupled unions between threaded sections were approximately 0.7 ft long. The casing and screen were factory-cleaned and steam-cleaned on-site before installation. A 2-in.-I.D. steel-threaded/coupled tremie pipe was used to deliver all backfill and annular fill materials during well construction. A side-discharging cap was installed on the tremie pipe for installation of liquid backfill materials (high solids bentonite grout and cement grout).

A nominal 20-ft screened interval was used for R-42 with the top of the screen set at 931.8 ft bgs. A 20.6-ft stainless-steel sump was placed below the well screen. The dual-rotary drill rig was used for most of the well construction activities. A Semco work-over rig was brought on-site for final well construction activities. Figure 7.2-1 presents an as-built schematic showing construction details for the completed well.

Problems associated with the Santa Fe Group sediments included severe heaving sands and sediments encountered during the initial phase of well construction. Extending the hole 20 ft beyond the proposed TD into undisturbed formation and flooding, the borehole with potable water resolved the problems. As a result of the formation difficulties, the 12-in. casing string and drive shoe was cut at 988 ft bgs, leaving a 59.5-ft section of 12-in. casing in the bottom of the borehole. Once the casing was cut, the process of extracting drill casing and installing the well began.

After the well casing was assembled and lowered into the borehole, installation of annular backfill materials was started. This activity had two components: installing materials and retracting the drill casing. As the annular fill was emplaced, the drill casing was retracted and removed. The well-casing string was hung under full tension throughout well construction. The well installation proceeded normally and few difficulties were encountered. The bottom of the borehole was filled with 10/20 sand from 976.6 to 1047.5 ft bgs. Some sloughing occurred in this interval. The lower bentonite seal was installed around the well sump from 957.8 to 967.6 ft bgs. The primary filter pack of 10/20 silica sand was placed across the screened interval from 926.9 to 957.8 ft bgs. R-42 is screened from 931.8 to 952.9 ft bgs. During and after installation of the primary filter pack, the work-over rig was used to surge the screened interval with a surge block to promote settling and compaction of the filter pack. A fine-grained transition-sand collar of 20/40 silica sand was placed above the primary filter pack from 924.8 to 926.9 ft bgs. After placement of the fine sand collar, a bentonite chip seal was installed from 901.9 to 924.8 ft bgs. A high-solids bentonite grout was then installed from 687.3 to 901.9 ft bgs and another bentonite chip seal was placed from 400.3 to 687.3 ft bgs. The surface seal composed of 96% cement and 4% bentonite was installed from 3 to 400.3 ft bgs. Figure 7.2-1 depicts final depths and volumes used in each interval. Table 7.2-1 details volumes of materials used during well construction.

8.0 POSTINSTALLATION ACTIVITIES

Following well installation, the well was developed and aquifer pumping tests were conducted. A dedicated submersible pump system banded with two transducer tubes was installed after pump testing. The wellhead and surface pad are completed and a geodetic survey of the wellhead was performed. Site restoration activities were 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 September 2 and September 6, 2008. Initially, the screened interval was bailed and swabbed to remove formation fines in the filter pack and 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 screened interval. 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.

During the pumping stage of well development, turbidity, temperature, pH, dissolved oxygen (DO), oxygen-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 measurement at the end of R-42 well development was less than 0.5 ppm and the final turbidity value was 4.9 NTUs. The lowest turbidity measurement during development was 2.3 NTUs.

Approximately 4448 gal. of groundwater was purged at R-42 during initial development activities. Total removed during development and testing was 17,995.5 gal. Table 8.1-1 presents the volume of water removed during well development and the corresponding water-quality parameters. Discussion of analytical results is presented in Appendix B.

8.1.1 Field Parameters

Results for field parameters consisting of pH, temperature, DO, ORP, specific conductance, and turbidity are provided in Table 8.1-1 and in Appendix B. Field parameters were measured at well R-42 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. Measurements of pH and temperature varied from 7.86 to 8.12 and from 19.1°C to 25.4°C, respectively, at well R-42. Percent saturation of DO varied from 45.4 to approximately 100. Regional aquifer groundwater is relatively oxidizing at well R-42 based on DO and ORP measurements, with ORP varying from –78.9 to 175.7 millivolts (mV), with most of the ORP readings greater than +100 mV. Specific conductance ranged from 383 to 418 microsiemens per centimeter (μS/cm). Values of turbidity measured at R-42 ranged from 0.2 to 859 NTUs for the nonfiltered groundwater samples. Ten of the 35 turbidity measurements recorded during well development exceeded 5 NTUs.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-42 between November 12 and November 15, 2008. Several short-duration tests with short-duration recovery periods were performed on the first day of testing followed by a 36-h background data collection period. A 24-h pumping test followed by a 24-h recovery period completed the testing. The same 5-hp Grundfos pump used during well development was used to perform the aquifer tests. The results of the R-42 aquifer test are presented in Appendix C.

8.3 Dedicated Sampling System Installation

A dedicated 3-hp, 4-in.-O.D. environmentally retrofitted Grundfos submersible pump and an In-Situ Level Troll 500 transducer was installed in R-42 following the aquifer tests. Pump riser pipe consisted of threaded and coupled 1-in.-diameter stainless steel. Two 1-in.-diameter polyvinyl chloride (PVC) tubes were installed along with and banded to the pump riser. One tube was for the dedicated pressure transducer and the other for manual water-level measurements. The tubes were 1.0-in.-I.D. flush-threaded schedule 40 PVC pipe. Each PVC tube has a 6-in. long 0.010-in. screen-slot interval at the bottom of the tube with a threaded bottom cap. Postinstallation construction and sampling system component installation details for R-42 are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes for R-42.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 6 in. thick, was installed at the R-42 wellhead. The pad will provide long-term structural integrity for the well. A brass survey pin was embedded in the northwest corner of the pad. A 10-in.-I.D. steel protective casing with a locking lid was installed around the stainless-steel well riser. The concrete pad was slightly elevated above the ground surface and crowned to promote runoff. Base course was graded around the edges of the pad. Details of the wellhead completion are presented in Figure 8.3-1a.

8.5 Geodetic Survey

Geodetic survey data for the stainless-steel well casing top cap, 10.-in. protective casing, brass pin, and ground surface at R-42, were collected on November 5, 2008. The survey data are presented in Figure 8.3-1b and Table 8.5-1. Geodetic surveys were conducted using a Trimble 5700 differential global positioning system. The survey data were collected by a licensed surveyor and conform to Laboratory

Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA-D802, “Geospatial Positioning Accuracy Standard for A/E/C and Facility Management.” All coordinates are expressed as New Mexico State Plane Coordinate System Central Zone (NAD 83); elevation is expressed in feet above mean sea level (amsl) using the National Geodetic Vertical Datum of 1929.

8.6 Waste Management and Site Restoration

Waste generation and characterization for the R-42 project include a small quantity of contact waste, decontamination fluids, drill cuttings, discharged drilling water, cement slurry, and purged groundwater. R-42 waste characterization samples of drill cuttings, purge water, and cement slurry were collected from September 8, 2008, to November 14, 2008. A summary of the waste samples collected for the R-42 well is presented in Table 8.6-1.

Fluids, cuttings, cement slurry, and contact waste produced during drilling and development were containerized and sampled in accordance with the “Waste Characterization Strategy Form for Chromium Wells (R-42, SCI-2/R-43) and Corehole Installation” (LANL 2008, 101914).

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 (WSCF) 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 water 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 waste will be disposed of at an authorized facility.

Cuttings produced during drilling are anticipated to be land-applied after a review of associated analytical results per the WCSF and Environmental Protection Division Resource Conservation Recovery Act 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. The cement slurry waste stream will be managed as industrial nonhazardous waste, pending analytical review. Disposal of this concrete slurry will take place at an authorized disposal facility. Characterization of contact waste will be based upon acceptable knowledge, pending the results of the waste samples collected from the drill cuttings, purge water, and cement slurry.

Site restoration activities will include removing water from the cuttings containment pit and land-applying it on-site (if applicable), removing the polyethylene liner, removing the containment area berms, and backfilling and regrading the containment area. Cuttings will be managed in accordance with SOP-011.0, referenced above. The site will be reseeded with a native seed mix consisting of Indian rice grass, mountain broam, blue stem, sand drop, and slender wheat grass seed. The Laboratory-approved seed mix will be applied at the required rate of 20 lb/acre; Biosol fertilizer will be applied at a rate of 80 lb/acre.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Drilling, sampling, and well construction at R-42 were performed as specified in the “Drilling Work Plan for Regional Aquifer Well R-42” (TerranearPMC 2008, 103940).

10.0 ACKNOWLEDGMENTS

P. Longmire of Los Alamos National Laboratory contributed the geochemistry section of this report (Appendix B).

Boart Longyear drilled the R-42 borehole and installed the well.

S.G. Western, Inc. prepared the site for drilling activities.

Southwest Mountain Survey performed the geodetic survey.

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

11.0 REFERENCES

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

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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. "Work Plan for Geochemical Characterization and Drilling for Fate and Transport of Contaminants Originating in Sandia Canyon," Los Alamos National Laboratory document LA-UR-07-7579, Los Alamos, New Mexico. (LANL 2007, 099607)

LANL (Los Alamos National Laboratory), May 2008. "Waste Characterization Strategy Form for the Chromium Wells (R-42 and SCI-2/R-43) Regional Groundwater Well Installation and Corehole Drilling," Los Alamos, New Mexico. (LANL 2008, 101914)

TerranearPMC, June 2008. "Drilling Plan for Regional Aquifer Well R-42," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2008, 103940)

11.1 Map Data Sources for R-42 Completion Report Location Map

Point Feature Locations of the Environmental Restoration Project Database; Los Alamos National Laboratory, Waste and Environmental Services Division, EP2008-0109; 28 February 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; 06 January 2004; as published 04 January 2008.

Dirt Road Arcs; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 04 January 2008.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; 06 January 2004; as published 04 January 2008.

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

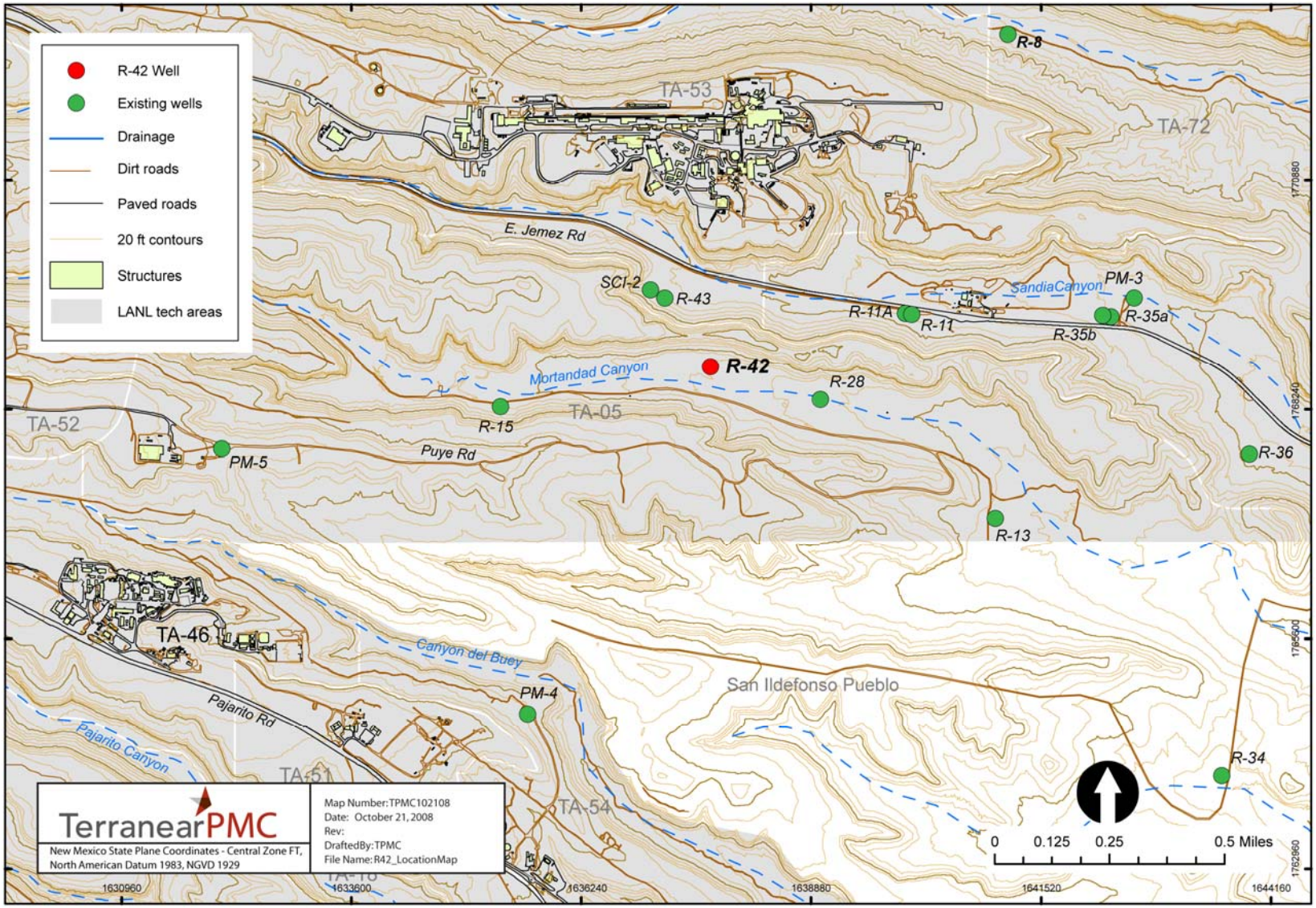

Figure 1.0-1 Location of regional aquifer well R-42 with respect to municipal supply well PM-5 and additional surrounding regional wells

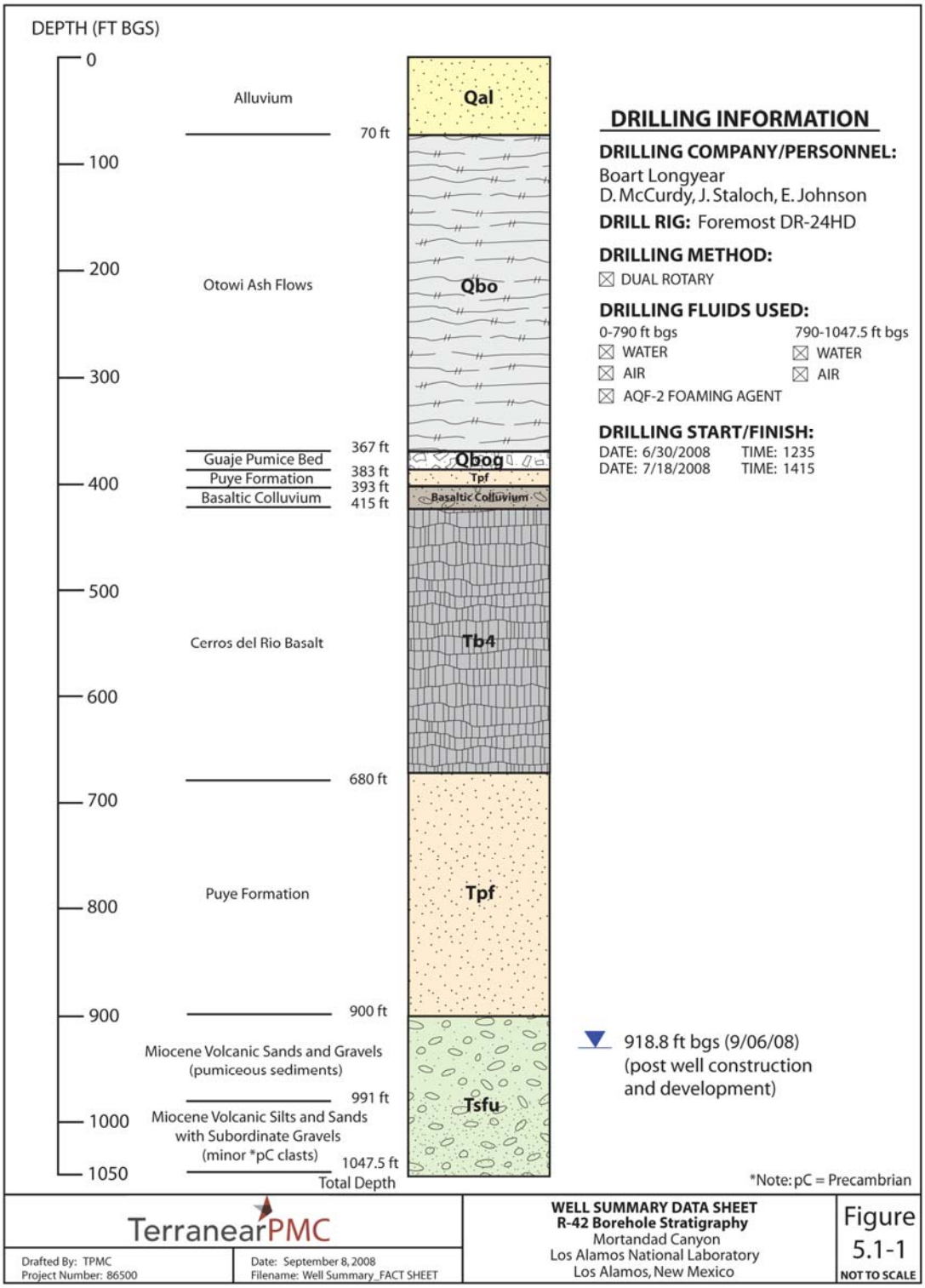

Figure 5.1-1 R-42 borehole stratigraphy

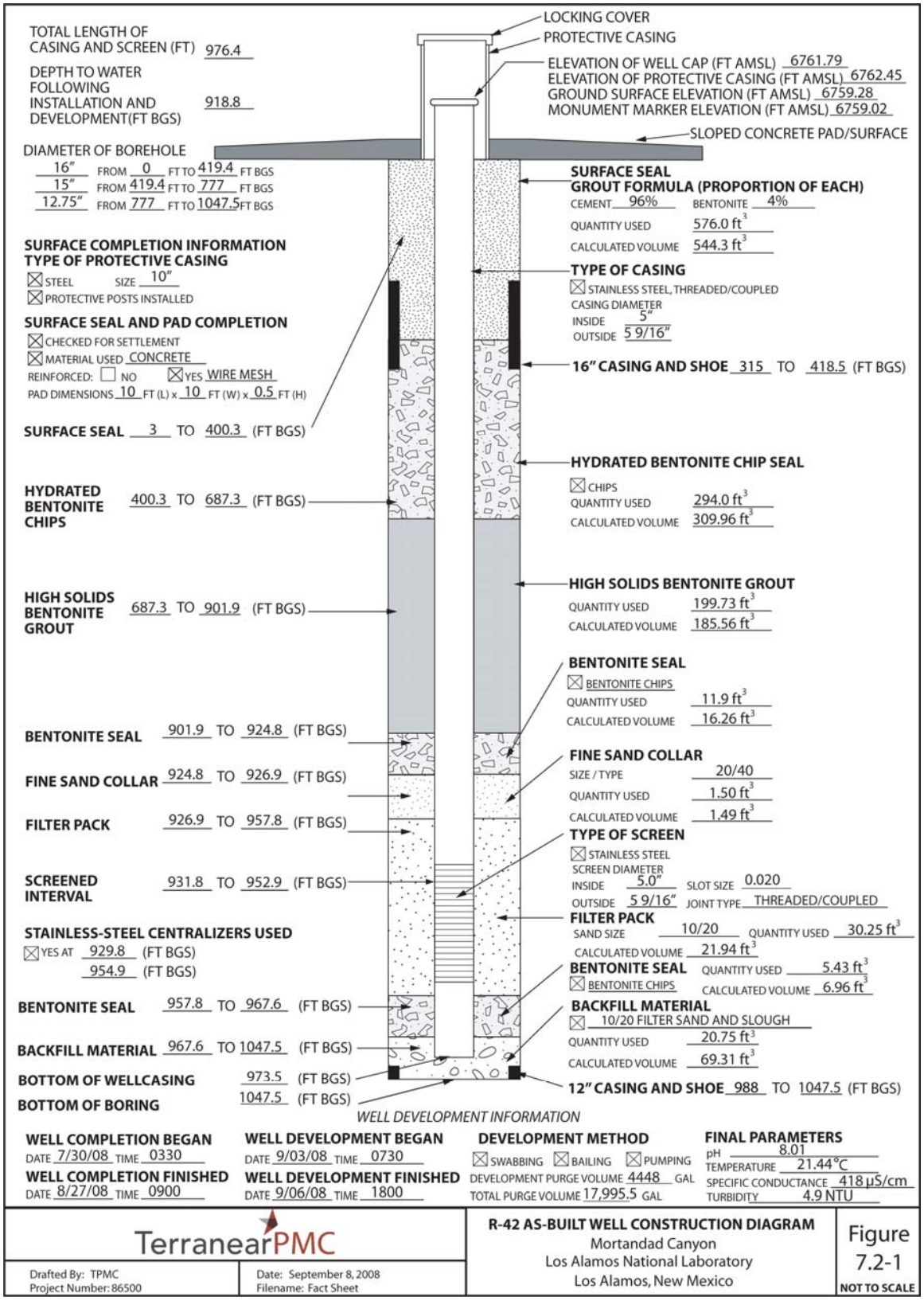

Figure 7.2-1 R-42 as-built well construction diagram

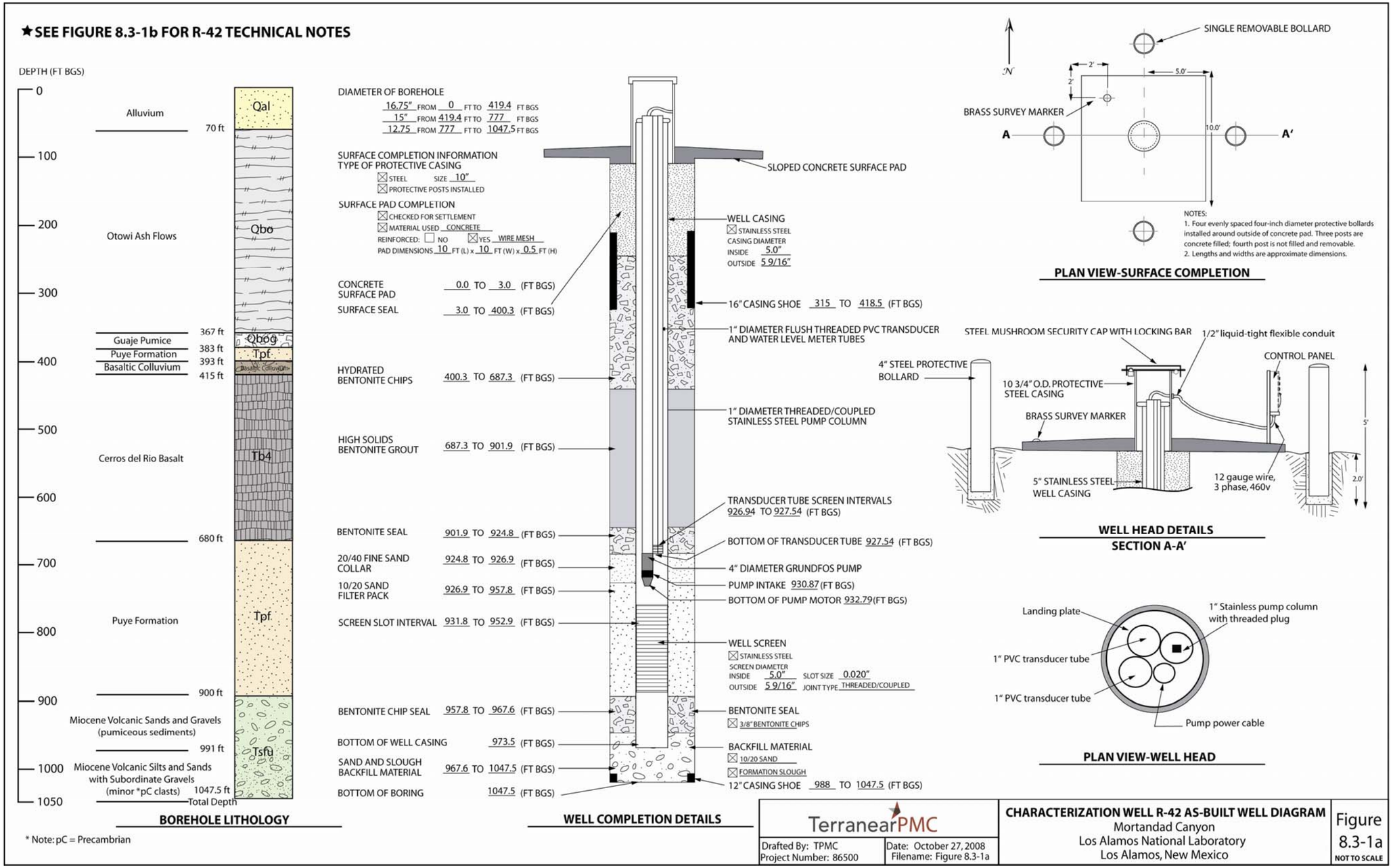

Figure 8.3-1a As-built schematic for regional well R-42

R-42 TECHNICAL NOTES: [1]

SURVEY INFORMATION[2]

Brass Marker

Northing:	1768775.7330
Easting:	1637709.9575
Elevation:	6759.02

Well Casing (top of stainless steel)

Northing:	1768770.2588
Easting:	1637713.6341
Elevation:	6761.79

BOREHOLE GEOPHYSICAL LOGS

LANL Natural Gamma Ray, LANL Induction Tool
Schlumberger Compensated Neutron, Three Detector Litho-Density, Natural Gamma Ray, and Elemental Capture Sonde

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:	06/30/2008
Finished:	07/18/2008

Well Completion

Start:	07/30/2008
Finished:	08/27/2008

Well Development

Start:	09/03/2008
Finished:	09/06/2008

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping

Total Volume Purged:	4,448 gallons

Parameter Measurments (Final)

pH:	8.01
Temperature:	21.44 °C
Specific Conductance:	418 µS/cm
Turbidity:	4.9 NTU

AQUIFER TESTING

Constant Rate Pumping Test

Water Produced:	13,547.5 gallons
Average Flow Rate:	5.2 gpm
Performed on:	11/12–15/2008

DEDICATED SAMPLING SYSTEM

Pump
Grundfos, Type: 5S30-820 CBM
Model: 96023161-P10931004
3 U.S. gpm, intake at 930.8 ft bgs
Environmental Retrofit

Motor
Franklin Electric, model: 2343268602,
3HP, 3-phase

Pump Column
1-inch, schedule 40, 304 stainless steel,
threaded/coupled, check valves every 240 ft

Transducer Tubes
1-inch, schedule 40 PVC, flush threaded,
0.010-inch screen at 927-927.5 ft bgs

Transducer
In-Situ, Level Troll 500, 15 psi vented

NOTES:
1) Additional information available in "Final Completion Report, Characterization Well R-42, Los Alamos National Laboratory, Los Alamos, New Mexico, November 2008.
2) 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	R-42 TECHNICAL NOTES	Figure
Drafted By: TPMC Project Number: 86500 Date: November 20, 2008 Filename: Figure 8.3-1b	Mortandad Canyon Los Alamos National Laboratory Los Alamos, New Mexico	8.3-1b NOT TO SCALE

Figure 8.3-1b As-built technical notes for R-42

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.)	Cumulative Returns in Pit: Fluids (gal.)
Drilling					
6/30/2008	120	1200	8	8	na[a]
7/01/2008	150	2700	10	18	na
7/02/2008	200	4700	9	27	na
7/03/2008	0	4700	0	27	na
7/08/2008	400	5100	10	37	na
7/09/2008	120	6300	25	62	na
7/10/2008	320	8500	55	117	na
7/11/2008	600	9100	30	147	na
7/12/2008	720	16300	60	207	na
7/13/2008	120	17500	40	247	na
7/14/2008	0	17500	0	247	na
7/15/2008	200	17700	10	257	na
7/16/2008	700	18400	25	282	na
7/17/2008	0	18400	0	282	na
7/18/2008	0	18400	0	282	na
7/19/2008	0	18400	0	282	na
7/20/2008	0	18400	0	282	na
Well Construction					
7/22/2008	0	18400	n/a[b] n/a		na
7/23/2008	0	18400	n/a	n/a	na
7/24/2008	150	19900	n/a	n/a	na
7/25/2008	250	22400	n/a	n/a	na
7/26/2008	0	22400	n/a	n/a	na
7/27/2008	0	22400	n/a	n/a	na
7/28/2008	0	22400	n/a	n/a	na
7/29/2008	0	22400	n/a	n/a	na
7/30/2008	0	22400	n/a	n/a	na
7/31/2008	100	23400	n/a	n/a	na
8/01/2008	380	27200	n/a	n/a	na
8/02/2008	260	29800	n/a	n/a	na
8/03/2008	570	35500	n/a	n/a	na
8/04/2008	500	36000	n/a	n/a	na
8/05/2008	135	37350	n/a	n/a	na
8/06/2008	540	37890	n/a	n/a	na

Table 3.1-1 (Continued)

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)	Cumulative Returns in Pit: Fluids (gal.)
8/07/2008	100	37990	n/a	n/a	na
8/08/2008	0	37990	n/a	n/a	na
8/09/2008	0	37990	n/a	n/a	na
8/10/2008	0	37990	n/a	n/a	na
8/11/2008	0	37990	n/a	n/a	na
8/12/2008	0	37990	n/a	n/a	na
8/13/2008	0	37990	n/a	n/a	na
8/14/2008	820	38810	n/a	n/a	na
8/15/2008	283	41640	n/a	n/a	na
8/16/2008	0	41640	n/a	n/a	na
8/17/2008	109	42730	n/a	n/a	na
8/18/2008	240	42970	n/a	n/a	na
8/19/2008	0	42970	n/a	n/a	na
8/20/2008	0	42970	n/a	n/a	na
8/21/2008	115	43085	n/a	n/a	na
8/22/2008	175	43260	n/a	n/a	na
8/23/2008	270	43530	n/a	n/a	na
8/24/2008	675	44205	n/a	n/a	na
8/25/2008	0	44205	n/a	n/a	na
8/26/2008	570	44775	n/a	n/a	na
8/27/2008	330	45105	n/a	n/a	na
Total Volume (gal.)					
R-42	451	05			32484

[a] na = Not available.

[b] n/a = Not applicable. Foam use and pit use discontinued after drilling activities; therefore, no additional fluids were produced.

Table 4.2-1
Summary of Groundwater Screening Samples Collected during Drilling, Well Development, and Aquifer Testing of Well R-42

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type
Drilling				
R-42 GW	42-08-14095	7/14/2008	771–775	Potential perched groundwater
R-42 GW	42-08-14096	7/17/2008	894	Potential perched groundwater
R-42 GW	42-08-14097	7/17/2008	913	Groundwater
R-42 GW	42-08-14098	7/17/2008	970	Groundwater
R-42 GW	42-08-14099	7/17/2008	990–995	Groundwater
R-42 GW	42-08-14100	7/17/2008	1020–1029	Groundwater
Well Development				
R-42 GW	42-08-14109	9/03/2008	932	Groundwater
R-42 GW	42-08-14110	9/05/2008	955.4	Groundwater
R-42 GW	42-08-14111	9/05/2008	955.41	Groundwater
R-42 GW	42-08-14112	9/05/2008	949.41	Groundwater
R-42 GW	42-08-14113	9/05/2008	941.41	Groundwater
R-42 GW	42-08-14114	9/05/2008	933.41	Groundwater
R-42 GW	42-08-14115	9/06/2008	931.41	Groundwater
R-42 GW	42-08-14116	9/06/2008	931.41	Groundwater
R-42 GW	42-08-14117	9/06/2008	966.20	Groundwater
R-42 GW	42-08-14118	9/06/2008	966.20	Groundwater
Aquifer Pump Test				
R-42 GW	42-09-999	11/14/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1000	11/14/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1001	11/14/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1002	11/14/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1003	11/14/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1004	11/14/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1005	11/14/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1006	11/14/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1007	11/14/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1008	11/15/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1009	11/15/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1010	11/15/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1011	11/15/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1014	11/14/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1015	11/14/2008	931.8–952.9	Groundwater
R-42 GW	42-09-1016	11/15/2008	931.8–952.9	Groundwater

Table 6.0-1
R-42 Video and Geophysical Logging Runs

Date	Depth (ft bgs)	Description
7/13/2008 0–7	69	Laboratory video run to view basalt/Puye contact and potential perched water in Puye Formation
7/14/2008 0–7	71	Laboratory video and induction log run to view basalt/Puye contact and potential perched water in Puye Formation
7/18/2008 0–1	029.5	Laboratory gamma tools run through 12-in. casing to TD at 1029.5 ft bgs
7/19/2008 and 7/20/2008	0–1023	Schlumberger complete geophysical suite, including Triple Detector Lithodensity Tool, Accelerator Porosity Sonde, Compensated Neutron Tool, Hostile Natural Gamma Spectroscopy, Elemental Capture Spectroscopy, and cased hole formation resistivity.

Table 7.2-1
R-42 Annular Fill Materials

Material	Volume
Surface seal: cement slurry	576.0 ft^3
Bentonite seal: bentonite chips	294.0 ft^3
Bentonite seal: high solids bentonite grout	199.73 ft^3
Upper annular seal: bentonite chips	11.9 ft^3
Fine sand collar: 20/40 silica sand	1.5 ft^3
Primary filter: 10/20 silica sand	30.25 ft^3
Lower annular seal: bentonite chips	5.43 ft^3
Backfill material: 10/20 silica sand and slough	20.75 ft^3
Potable water used in the regional aquifer (drilling and well construction)	45,105 gal.

Table 8.1-1
Well Development Volumes, Aquifer Pump Test Volumes, and Associated Field Water-Quality Parameters for R-42

Date	pH	Temp (°C)	DO (%)	ORP (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development								
9/05/2008	8.04	21.34	~100	170.0	0.383	859.0	4 4	
	8.14	23.04	80.9	171.7	0.383	638.7	135 139	
	8.12	23.78	81.1	167.8	0.389	733.9	120 259	
	8.07	23.76	80.7	168.3	0.391	673.8	140 399	
	8.09	23.80	79.6	167.4	0.393	9.4	140 539	
	8.05	23.95	80.1	168.0	0.389	7.3	140 679	
	8.04	23.99	79.8	168.4	0.398	2.7	140 819	
	8.04	24.66	78.9	169.0	0.399	2.3	140 959	
	8.02	23.68	80.2	173.3	0.402	1.6	140 109	9
	8.01	24.03	80.0	175.7	0.404	0.7	140 123	9
	8.00	23.79	80.7	181.9	0.402	1.5	140 137	9
	8.01	23.62	80.5	175.6	0.407	1.1	140 151	9
	7.99	23.32	79.6	174.9	0.407	0.2	140 165	9
	8.00	23.75	79.1	175.7	0.409	2.2	140 179	9
	7.99	23.29	79.4	174.6	0.407	2.7	140 193	9
	8.01	23.21	79.2	171.1	0.409	1.4	140 207	9
9/06/08	7.86	19.06	45.4	–78.9	0.397	145.1	164 224	3
	7.95	22.21	56.5	10.1	0.408	6.9	130 237	3
	8.12	22.96	60.3	63.1	0.412	5.9	130 250	3
	8.09	23.25	60.8	78.6	0.412	4.8	130 263	3
	8.08	23.65	65.8	91.2	0.412	4.5	130 276	3
	8.05	24.11	65.8	103.2	0.413	4.2	125 288	8
	8.04	24.28	68.7	112.0	0.413	4.3	120 300	8
	8.03	24.48	67.1	115.9	0.414	5.1	120 312	8
	8.03	25.36	70.8	121.5	0.416	4.7	120 324	8
	8.03	25.39	71.7	125.7	0.412	4.3	120 336	8
	8.12	24.92	62.2	134.6	0.405	29.1	120 348	8
	8.04	23.63	71.1	138.6	0.414	4.4	120 360	8
	8.02	23.60	72.8	144.8	0.415	3.4	120 372	8
	8.01	23.63	73.0	151.2	0.416	2.7	120 384	8
	8.02	23.42	73.9	151.9	0.406	2.3	120 396	8
	8.01	23.10	72.7	152.7	0.417	2.7	120 408	8
	8.01	22.98	74.8	158.8	0.410	2.4	120 420	8
	8.02	23.20	71.9	163.2	0.417	2.3	120 432	8
	8.01	21.44	72.8	169.8	0.418	4.9	120 444	8

Table 8.1-1 (Continued)

Date	pH	Temp (°C)	DO (%)	ORP (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Aquifer Pump Test Volumes								
11/12/08	n/r*	n/r	n/r	n/r	n/r	n/r	413 486	1
11/14/08	8.22	17.68	12.1	–251.3	0.414	187.8	270 513	1
	8.11	20.86	57.5	31.9	0.434	0.6	468 559	9
	8.04	21.04	65.3	54.9	0.434	0.3	624 622	3
	8.04	21.04	66.6	55.8	0.434	0.1	624	6847
	8.05	20.89	68.4	60.8	0.435	0.2	624	7471
	8.06	20.68	68.8	64.8	0.436	0.0	624	8095
	8.07	20.54	68.7	71.1	0.436	0.0	624	8719
	8.08	20.61	70.8	72.3	0.436	0.0	624	9343
	8.07	20.61	71.8	82.0	0.436	0.0	624	9967
11/15/08	8.08	20.50	72.0	87.1	0.437	0.0	624	10591
	8.08	20.46	70.7	92.7	0.437	0.0	624	11215
	8.07	20.46	71.4	94.0	0.437	0.0	624	11839
	8.07	20.68	72.5	95.1	0.438	0.0	572 124	11
Postaquifer Pump Test Purge Volumes								
11/16/08	n/r	n/r	n/r	n/r	n/r	n/r	5589.6 179	95.5

Note: Cumulative purge volumes calculated using average pump discharge rate of 5.2 gpm.

* n/r = Not recorded.

Table 8.5-1
R-42 Survey Coordinates

North	East	Elevation (ft amsl)	Identification
1768775.7330 163	7709.9575	6759.02	R-42 brass pin embedded in pad
1768772.4834 163	7715.2387	6759.28	R-42 ground surface near pad
1768770.1228 163	7713.7024	6762.45	R-42 top of 10-in. protective casing
1768770.2588 163	7713.6341	6761.79	R-42 top of stainless-steel well casing

Note: 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-42

Location ID	Sample ID	Date Collected	Description	Sample Type
WST-600902	GW42-08-14277	9/08/08	Cuttings Pit Solids	Drill Cuttings
WST-600902	GW42-08-14276	9/08/08	Cuttings Pit Solids	Drill Cuttings
WST-600902	GW42-08-14288	9/08/08	Cuttings Pit Fluids	Drill Fluids
WST-600902	GW42-08-14289	9/08/08	Cuttings Pit Fluids	Drill Fluids
WST-600902	GW42-08-14290	9/08/08	Cuttings Pit Fluids	Drill Fluids
WST-600902	GW42-08-14291	9/08/08	Cuttings Pit Fluids	Drill Fluids
WST-600902	RC05-08-15255	10/30/08	Well Development Purge Fluids	Purge Water
WST-600902	RC05-08-15256	10/30/08	Well Development Purge Fluids	Purge Water
WST-600902	RC05-08-15257	10/30/08	Well Development Purge Fluids	Purge Water
WST-600902	RC05-08-15258	10/30/08	Well Development Purge Fluids	Purge Water
R-42 RC05-	09-1268	10/30/08	Decontamination Fluids	Decontamination Water
R-42 RC05-	09-1269	10/30/08	Decontamination Fluids	Decontamination Water
R-42 RC05-	09-1270	10/30/08	Decontamination Fluids	Decontamination Water
R-42 RC05-	09-1271	10/30/08	Decontamination Fluids	Decontamination Water

Appendix A

Well R-42 Lithologic Log

Los Alamos National Laboratory
Regional Hydrogeologic Characterization Project
Borehole Lithologic Log

BOREHOLE IDENTIFICATION (ID): R-42	**TECHNICAL AREA (TA): 05**	**PAGE: 1 of 5**
DRILLING COMPANY: Boart Longyear	**START DATE/TIME:** 6/30/08: 1235	**END DATE/TIME:** 7/17/08: 2030
DRILLING METHOD: Dual Rotary	**MACHINE**: Foremost DR-24 HD	**SAMPLING METHOD:** Grab
GROUND ELEVATION:		**TOTAL DEPTH:** 1047.5 ft below ground surface (bgs)
DRILLERS: D. McCurdy/J. Staloch	**SITE GEOLOGIST:** J.R. Lawrence	

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
0–70	**ALLUVIUM:** Unconsolidated Tuffaceous Sediments—pale red (10R 6/2) to light gray (5YR 7/1), silty sand to sandy silt with few pebbles and gravels, trace clay, unconsolidated, G/S/F = 2%–5%/10%–30%/60%–90%, 3–25-mm pebbles of volcanic rock lithics in silt matrix with fine to coarse-grained sand composed of quartz and sanidine	Qal	Alluvium 0–70 ft bgs, 70 ft thick Qal/Qbo contact at 70 ft bgs based on gamma log and clasts of Tshirege Member in cuttings to at least 70 ft
70–80	**OTOWI MEMBER OF THE BANDELIER TUFF:** Weathered Tuff—orange (5YR 7/6) to pink (5YR 8/3), moderately to poorly welded, mostly ash, with little quartz and sanidine phenocrysts and trace volcanic lithics (mostly dacite)	Qbo	Distinct color change, presence of iron oxide, sample appears fresh, pumice appear weathered Otowi Member Bandelier Tuff (70–369 ft bgs), 299 ft thick
80–145	Tuff—pale orange (5YR 7/6) to white (10YR 8/1), poorly to moderately welded, lithic- and pumice-rich, 25%–30% pumice fragments (weathered to fibrous, vitric), lithics 10%–15% (mostly dacite up to 30 mm), 10%–15% phenocrysts of quartz and sanidine, 15%–50% ash matrix, some iron-staining around pumice		
145–200	Tuff—very pale brown (10YR 8/4), lithic- and pumice-rich, poorly welded, 15%–30% pumice (mostly fibrous vitric, up to 15 mm), 8%–30% lithics (mostly dacite, some andesite and flow-banded rhyolite up to 16 mm), 10%–15% phenocrysts (mostly quartz, some sanidine), 15%–50% ashy matrix, iron staining		
200–345	Tuff—reddish yellow (5YR 6/8) to orange brown (5YR 7/8), more ashy than above, lithic- and pumice-rich, poorly welded, 15%–50% pumice (mostly fibrous, vitric, up to 15 mm), lithics 8%–30% (mostly gray dacite, trace andesite and rhyolite), phenocrysts 10%–15% (mostly quartz, some sanidine), ashy matrix		Pumice are iron stained
345–367	Tuff—reddish yellow (5YR 6/6) to pale orange tan (5YR 7/6), lithic-poor, pumice rich, poorly welded, mostly ash and pumice >50% (mostly fibrous, vitric), <5% lithics (mostly dacite and andesite), phenocrysts 10%–15% (mostly quartz, some sanidine), some iron staining		Decrease in lithics Estimated Qbo/Qbog contact at 367 ft bgs

Borehole Lithologic Log (continued)

BOREHOLE ID: R-42	**TA-05**	**PAGE: 2 of 5**

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
367–383	**GUAJE PUMICE BED:** Pumice Bed—white (5YR 8/1), nonwelded, pumice fragments 80%–95% (white, vitric, fibrous, up to 22 mm), 5%–20% lithics (dacites, andesites, rhyolites, up to 20 mm), 5%–10% quartz and sanidine crystals >5% fine ash	Qbog	Guaje Pumice (367–383 ft bgs), 16 ft thick
383–415	**PUYE FORMATION:** Volcaniclastic Sediments—pink (5YR 7/4), sandy silt to silty sand with pebbles and gravel, gravel component increases with depth, G/S/F = 20%–70%/15%–50%/20%–35%, sand is composed of basalt chips, siltstone, and sandstone, gravels are subrounded clasts of basalt and sandstone, at depth composition of gravels is 100% silt coated basalt chips	Tpf	Base of Guaje Pumice Bed and estimated top of Puye Formation at 383 ft bgs Puye Formation, upper part above Cerros del Rio basalt (383–415 ft bgs), 32 ft thick Section from 393 to 415 ft entirely basaltic detritus; possible flow rubble zone
415–495	**CERROS DEL RIO BASALT:** Basalt—dark to medium gray (GLEY 4/1 to GLEY 4/0), 100% basalt (massive to weakly vesicular, porphyritic with aphanitic groundmass, 3%–5% phenocrysts (clinopyroxene, minor olivine, minor feldspar), cumulophyric	Tb4	Cerros del Rio Basalt (est. 415–680 ft bgs), 265 ft thick Limonitic iron oxides on some fracture surfaces
495–535	Basalt—light medium gray (GLEY1 6/0) to dark gray (GLEY1 4/0), 50%–85% light medium gray basalt chips, 15%–50% dark gray olivine-bearing basalt, (massive, porphyritic with aphanitic groundmass), 10%–15% silt and clay 3%–5% phenocrysts (olivine, brown subhedral clinopyroxene, rare plagioclase)		Olivines strongly altered to iddingsite
535–590	Basalt—light gray (GLEY1 6/0), 100% basalt (nonvesicular, porphyritic with aphanitic groundmass, cumulophyric, groundmass weak to moderately altered and bleached, 3%–5% phenocrysts (green olivine and clinopyroxene)		
590–595	Basalt—very dark gray (GLEY1 3/0) to dark reddish gray (2.5 YR 4/1), 50% massive olivine basalt, 50% dark reddish brown strongly vesicular basalt with strong iron-oxide staining, amygdaloidal white clay, strongly weathered appearance		Strong vesicularity suggests Tb4 flow unit top; apparent contact at 592.5 ft bgs

Borehole Lithologic Log (continued)

BOREHOLE ID: R-42	**TA-05**	**PAGE: 3 of 5**

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
595–676	Basalt—varicolored very dark gray (GLEY1 3/0) to dark reddish gray (2.5 YR 4/1) to white (10YR 8/1), 80%–90% basalt (vesicular to weakly vesicular, porphyritic with aphanitic groundmass), 1%–3% phenocrysts (clinopyroxene and olivine), 10%–20% white clay filling vesicles	Tb4	
676–680	Basaltic detritus—sediments and tephra of Cerros del Rio	Tb4 clastic	Based on gamma, density, and ECS geophysical logs
680–695	**PUYE FORMATION:** Volcaniclastic Sediments—light gray (GLEY1 7/10), sand with gravels and pebbles, mixed varieties of volcanic rocks, 80% mixed volcanic lithics, 10%–15% sandstone fragments, 7%–10% white clay	Tpf	Puye Formation Puye Formation lower part (680–900 ft bgs), 220 ft thick Overall Puye Formation encompassing Cerros del Rio (383–900 ft bgs), 517 ft thick
695–730	Volcaniclastic Sediments—pinkish white (5YR 8/2), gravel with sand and silt, dominantly dacite detritus, 85%–95% light gray to pink hornblende dacite, 10%–15% basalt, 2%–3% sandstone fragments		
730–780	Volcaniclastic Sediments—light gray (GLEY1 7/0), coarse gravel with sand, subrounded detrital clasts composed mostly of gray and pinkish gray dacite, 90%–95% dacite (up to 18 mm), 5%–10% pink and black quartz-bearing rhyolite vitrophyre		
780–795	Volcaniclastic Sediments—brownish gray (10YR 5/2), pebbley gravel with sand and silt, detrital dacites, 80% light gray hornblende dacite, 15% dacite vitrophyre, 5% pumice		
795–820	Volcaniclastic Sediments—pinkish white (5YR 8/2), gravel with sand and minor clay, dacite detritus, 97% dacite, 3% indurated sandstones		
820–845	Volcaniclastic Sediments—pinkish gray (5YR 7/2), gravel with sand and clay, dacite detritus, up to 25% silt and clay matrix, detrital clasts mostly dacite, some quartz bearing rhyodacite		
845–875	Volcaniclastic Sediments—pinkish gray (5YR 6/2), coarse gravel with sand, dacite detritus, composed mostly of light gray biotite-dacite, minor pinkish quartz rhyolite, abundant free quartz crystals, silty matrix		

Borehole Lithologic Log (continued)

BOREHOLE ID: R-42	**TA-05**	**PAGE: 4 of 5**

DEPTH (ft bgs)	LITHOLOGY	LITHOLOGIC SYMBOL	NOTES
875–900	Volcaniclastic Sediments—gray (GLEY1 6/0), coarse gravel with sand, dacite detritus, 100% white to light gray hornblende-dacite clasts (up to 20 mm)	Tpf	Puye Formation continued
900–920	**MIOCENE VOLCANIC SANDS AND GRAVELS:** Pumiceous Sediments—pink tan (5YR 8/3) to light gray (GLEY1 7/10) gravel with pebbles, sand and silt, 40%–75% white vitric aphyric pumices, 25%–60% mixed volcanic clasts (dacite, andesite, basalt and biotite-rhyolite), silty matrix	Tsfu	Santa Fe Group contact at 900 ft bgs
920–945	Pumiceous Sediments—pale yellow tan (10YR 8/3) and light gray (GLEY1 7/0) gravel with sand and abundant silt, pumice and mixed volcanic detritus, 40%–50% white pumice, 40%–50% mixed volcanic rocks, 15%–20% silt		
945–970	Pumiceous Sediments—pale yellowish brown (10 YR 7/3), gravel with pebbles and sand, 90%–95% white pumice fragments (up to 15 mm), 5%–10% light gray dacites, trace sandstone fragments		Note: Sharp increase in % pumice
970–991	Pumiceous Sediments—very pale brown (10YR 7/4), siltstone and mudstone with trace sand and fine gravel, predominantly pumice detritus, 50%–95% silt, pumice and dacite gravels		
991-1020	**MIOCENE VOLCANIC AND PRECAMBRIAN PLUTONIC/METAMORPHIC SILTS AND SANDS:** Volcaniclastic Sediments—very pale brown (10YR 7/4), siltstone with fine sand and clay, predominately volcanic detritus, 50%–90% silt and clay, 10%–20% sand, 20%–30% lithic clasts of indurated fine-grained sandstone, dacite, rhyolite, and andesite, minor to 15% rounded Precambrian quartz clasts		Sharp change in composition of detritus; first appearance of Precambrian quartzite clasts
1020–1047.5	Volcaniclastic Sediments—very pale brown (10YR 7/4) coarse gravel with silt and sand, mixed volcanic and minor Precambrian detrital material, 70%–80% rounded volcanic clasts (dacite, rhyolite, andesite), 5%–10% Precambrian quartzite (varicolored), 10%–20% silt matrix, trace sandstone lithics		
1047.5	Total Depth		

ABBREVIATIONS

5YR 8/1 = Munsell soil color notation where hue (e.g., 5YR), value (e.g., 8), and chroma (e.g.,1) 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.
F = Fines.
F = fines (<62 μm).
G = Gravel (2 to 75 mm).
N = Neutrals.
Qal = Quaternary Alluvium.
Qbo = Otowi Member of Bandelier Tuff.
Qbog = Guaje Pumice Bed.
S = Sand (2 mm to 62 μm).
Tb4 = Cerros del Rio Basalt.
Tpf = Puye Formation.
Tsfu = Santa Fe Group.
YR = Yellow red.

Appendix B

Groundwater Analytical Results

B-1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-42

Seven groundwater-screening samples were collected at borehole R-42 during drilling: two above the regional water table (from 771 to 775 ft below ground surface [bgs]) and five within the regional aquifer (from 894 to 1029 ft bgs). A total of 10 groundwater-screening samples were collected at well R-42 during well development. The samples were collected from the screen interval of 932 to 966 ft bgs within the regional aquifer. The filtered samples were analyzed for total organic carbon (TOC), cations, anions, perchlorate, and metals. A total of 4448 gal. of groundwater was pumped from well R-42 during development and sample collection.

B-1.1 Field Preparation and Analytical Techniques

Chemical analyses of groundwater-screening samples were performed at Los Alamos National Laboratory's (LANL's or the Laboratory's) Earth and Environmental Sciences Group 6 (EES-6). Groundwater samples were filtered (0.45-µm membranes) before preservation and chemical analyses. Samples were acidified at the EES-6 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 in the U.S. Environmental Protection Agency (EPA) SW-846 manual. Ion chromatography was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. Instrument detection limits for perchlorate were 0.002 and 0.005 ppm. Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) was used for analyses of calcium, magnesium, potassium, silica, and sodium. 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). The precision limits (analytical error) for major ions and trace elements were generally less than ±7% using ICPOES and ICPMS. Charge balance errors for total cations and anions were generally less than ±9% for complete analyses of the above inorganic chemicals. The negative cation-anion charge balance values indicate excess anions for the filtered samples. Total carbonate alkalinity was measured using standard titration techniques.

B-1.2 Field Parameters

Table B-1.2-1 provides results of field parameters, consisting of pH, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductance, and turbidity measured during well development. Measurements of pH and temperature varied from 7.86 to 8.12 and from 19.1°C to 25.4°C, respectively, at well R-42. Percent saturation of DO varied from 45.4 to approximately 100, suggesting that DO was measured between 3 and 7 mg/L at the well. This assumes that 6.61 mg/L of DO represents complete (100%) saturation at 6000 ft and 25°C. Regional aquifer groundwater is relatively oxidizing at well R-42 based on DO and ORP measurements, with ORP varying from –78.9 to 175.7 millivolts (mV) (Table B-1.2-1), with most of the ORP readings greater than +100 mV. Elevated above-background concentrations of total dissolved chromium of 0.100 ppm and higher also support relatively oxidizing conditions at well R-42. Specific conductance ranged from 383 to 418 microsiemens per centimeter (µS/cm). Values of turbidity measured at R-42 ranged from 0.2 to 859 nephelometric turbidity units (NTUs) for the nonfiltered groundwater samples. Ten of the 35 turbidity measurements recorded during well development exceeded 5 NTUs (Table B-1.2-1).

B-1.3 Analytical Results for Groundwater-Screening Samples

Table B-1.3-1 provides analytical results for groundwater-screening samples collected at well R-42 during drilling and well development. Calcium and sodium are the dominant cations in groundwater pumped from well R-42. Dissolved concentrations of calcium and sodium in filtered samples ranged from 24.2 to 39.4 ppm (24.2 to 39.4 mg/L) and from 15.4 to 29.4 ppm, respectively. Concentrations of chloride and fluoride in filtered samples ranged from 26.7 to 34.0 ppm and from 0.33 to 0.45 ppm, respectively, during development of well R-42. Dissolved concentrations of nitrate(N) and sulfate ranged from 4.12 to 5.53 ppm and from 42.5 to 58.8 ppm, respectively, at the well. Dissolved concentrations of chloride, nitrate(N), and sulfate at well R-42 exceeded Laboratory background within the regional aquifer (LANL 2007, 095817). Maximum background concentrations for dissolved chloride, nitrate plus nitrite(N), and sulfate in the regional aquifer are 5.95 mg/L, 1.05 mg/L, and 8.63 mg/L, respectively (LANL 2007, 095817). Concentrations of TOC ranged from 0.82 to 1.19 mgC/L at well R-42 (Table B-1.3-1). Concentrations of perchlorate were less than detection (<0.002 and 0.005 ppm) at well R-42.

Dissolved concentrations of iron and manganese ranged from 0.01 to 0.06 ppm (10 to 60 μg/L) and from 0.023 to 0.135 ppm, respectively, in groundwater-screening samples collected at well R-42 (Table B-1.3-1). Dissolved concentrations of iron and manganese are less than the maximum background values for these two trace metals (excluding one sample analyzed for manganese) in the regional aquifer (iron: 0.147 mg/L and manganese: 0.124 mg/L) (LANL 2007, 095817). Detectable concentrations of molybdenum in filtered samples ranged from 0.001 to 0.006 ppm (Table B-1.3-1). Dissolved concentrations of zinc ranged from 0.001 to 0.012 ppm in groundwater-screening samples collected at R-42, with no samples exceeding the maximum background concentration of this trace metal in filtered samples (Table B-1.3-1). Background mean, median, and maximum concentrations of zinc in filtered samples are 3.08 μg/L, 1.45 μg/L, and 32.0 μg/L, respectively, for the regional aquifer (LANL 2007, 095817). Dissolved concentrations of boron ranging from 0.018 to 0.056 ppm at well R-42 typically are less than the Laboratory maximum background value of 51.6 μg/L for the regional aquifer (LANL 2007, 095817). Total dissolved concentrations of chromium ranged from 0.146 to 0.513 ppm (146 to 513 ppb or μg/L) at well R-42 (Table B-1.3-1). 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-2.0 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 number. This information is also included in text citations. ER ID numbers are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; EPA, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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-42

Date	pH	Temp (°C)	DO (%)	ORP (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development								
9/05/2008	8.04	21.34	~100	170.0	383	859.0	4	4
	8.14	23.04	80.9	171.7	383	638.7	135	139
	8.12	23.78	81.1	167.8	389	733.9	120	259
	8.07	23.76	80.7	168.3	391	673.8	140	399
	8.09	23.80	79.6	167.4	393	9.4	140	539
	8.05	23.95	80.1	168.0	389	7.3	140	679
	8.04	23.99	79.8	168.4	398	2.7	140	819
	8.04	24.66	78.9	169.0	399	2.3	140	959
	8.02	23.68	80.2	173.3	402	1.6	140	1099
	8.01	24.03	80.0	175.7	404	0.7	140	1239
	8.00	23.79	80.7	181.9	402	1.5	140	1379
	8.01	23.62	80.5	175.6	407	1.1	140	1519
	7.99	23.32	79.6	174.9	407	0.2	140	1659
	8.00	23.75	79.1	175.7	409	2.2	140	1799
	7.99	23.29	79.4	174.6	407	2.7	140	1939
	8.01	23.21	79.2	171.1	409	1.4	140	2079
9/06/08	7.86	19.06	45.4	–78.9	397	145.1	164	2243
	7.95	22.21	56.5	10.1	408	6.9	130	2373
	8.12	22.96	60.3	63.1	412	5.9	130	2503
	8.09	23.25	60.8	78.6	412	4.8	130	2633
	8.08	23.65	65.8	91.2	412	4.5	130	2763
	8.05	24.11	65.8	103.2	413	4.2	125	2888
	8.04	24.28	68.7	112.0	413	4.3	120	3008
	8.03	24.48	67.1	115.9	414	5.1	120	3128
	8.03	25.36	70.8	121.5	416	4.7	120	3248
	8.03	25.39	71.7	125.7	412	4.3	120	3368
	8.12	24.92	62.2	134.6	405	29.1	120	3488
	8.04	23.63	71.1	138.6	414	4.4	120	3608
	8.02	23.60	72.8	144.8	415	3.4	120	3728
	8.01	23.63	73.0	151.2	416	2.7	120	3848
	8.02	23.42	73.9	151.9	406	2.3	120	3968
	8.01	23.10	72.7	152.7	417	2.7	120	4088
	8.01	22.98	74.8	158.8	410	2.4	120	4208
	8.02	23.20	71.9	163.2	417	2.3	120	4328
	8.01	21.44	72.8	169.8	418	4.9	120	4448

Note: Cumulative purge volumes calculated using average pump discharge rate of 17.2 gpm.

Table B-1.3-1
Analytical Results for Groundwater-Screening Samples Collected at Well R-42

Sample ID	Aquifer	Sample Type	Activity	Date Received	ER/RRES-WQH	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)
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	08-1554	771–775	0.001 U	[a] 0.321		0.001	0.0009	0.000	0 0.059	0.000 0.044	0.000		0.001	U
GW42-08-14095 Perche	d	Borehole	Drilling	7/14/2008	08-1554	771–775	0.001 U		0.304	0.001	0.0008	0.000	0 0.047	0.000 0.043	0.000		0.001	U
GW42-08-14096 Introduce	d Water?	Borehole	Drilling	7/21/2008	08-1577	894	0.001 U		0.685	0.001	0.0006	0.000	0 0.039	0.000 0.052	0.001		0.001	U
GW42-08-14097 Introduce	d Water?	Borehole	Drilling	7/21/2008	08-1577	913	0.001 U		0.008	0.001	0.0004	0.000	0 0.032	0.000 0.059	0.001		0.001	U
GW42-08-14098 Regi	onal	Borehole	Drilling	7/21/2008	08-1577	970	0.001 U		0.009	0.000	0.0005	0.000	0 0.029	0.000 0.073	0.003		0.001	U
GW42-08-14099 Regi	onal	Borehole	Drilling	7/21/2008	08-1577	990–955	0.001 U		0.006	0.000	0.0005	0.000	0 0.032	0.001 0.099	0.000		0.001	U
GW42-08-14100 Regi	onal	Borehole	Drilling	7/21/2008	08-1577	1020–1029	0.001 U		0.054	0.009	0.0006	0.000	0 0.030	0.000 0.070	0.001		0.001	U
GW42-08-14109 Regi	onal	Well	Development	9/8/2008	08-1556	932	0.001 U		0.005	0.000	0.0010	0.000	0 0.026	0.000 0.056	0.000		0.001	U
GW42-08-14110 Regi	onal	Well	Development	9/8/2008	08-1556	955.4	0.001 U		0.005	0.000	0.0010	0.000	1 0.020	0.001 0.062	0.000		0.001	U
GW42-08-14111 Regi	onal	Well	Development	9/8/2008	08-1556	955.41	0.001 U		0.004	0.000	0.0008	0.000	0 0.018	0.000 0.063	0.000		0.001	U
GW42-08-14112 Regi	onal	Well	Development	9/8/2008	08-1556	949.41	0.001 U		0.006	0.000	0.0007	0.000	0 0.056	0.001 0.065	0.001		0.001	U
GW42-08-14113 Regi	onal	Well	Development	9/8/2008	08-1556	941.41	0.001 U		0.005	0.000	0.0008	0.000	0 0.035	0.000 0.067	0.001		0.001	U
GW42-08-14114 Regi	onal	Well	Development	9/8/2008	08-1556	933.41	0.001 U		0.005	0.000	0.0006	0.000	0 0.029	0.001 0.058	0.000		0.001	U
GW42-08-14115 Regi	onal	Well	Development	9/8/2008	08-1556	931.41	0.001 U		0.005	0.000	0.0006	0.000	0 0.026	0.000 0.060	0.000		0.001	U
GW42-08-14116 Regi	onal	Well	Development	9/8/2008	08-1556	931.41	0.001 U		0.005	0.000	0.0006	0.000	1 0.024	0.001 0.059	0.000		0.001	U
GW42-08-14117 Regi	onal	Well	Development	9/8/2008	08-1556	966.2	0.001 U		0.005	0.000	0.0007	0.000	0 0.023	0.001 0.064	0.000		0.001	U
GW42-08-14118 Regi	onal	Well	Development	9/8/2008	08-1857	966.2	0.001 U		0.005	0.000	0.0007	0.000	0 0.021	0.000 0.064	0.001		0.001	U

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	Br^- (ppm)	TOC rslt (ppm)	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	stdev (Cd)	Cl^- (ppm)	ClO_4^- (ppm)	ClO_4^- (U)	Co rslt (ppm)	stdev (Co)	Alk-CO_3 rslt (ppm)	ALK-CO_3 (U)	Cr rslt (ppm)	stdev (Cr)
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	0.43	Not measured	25.4	0.1	0.001	U	37.5	n/a[b]	n/a	0.001	U	0.8	U	0.021	0.000
GW42-08-14095 Perche	d	Borehole	Drilling	7/14/2008	0.41	Not measured	25.0	0.1	0.001	U	37.2	0.005	U 0.001		U 0.8		U	0.021	0.000
GW42-08-14096 Introduce	d Water?	Borehole	Drilling	7/21/2008	0.05	Not measured	14.3	0.1	0.001	U	10.1	0.002	U 0.001		U 0.8		U	0.007	0.000
GW42-08-14097 Introduce	d Water?	Borehole	Drilling	7/21/2008	0.08	Not measured	23.6	0.1	0.001	U	19.3	0.005	U 0.001		U 0.8		U	0.009	0.000
GW42-08-14098 Regi	onal	Borehole	Drilling	7/21/2008	0.20	Not measured	35.8	0.4	0.001	U	42.6	0.005	U	0.001	U 0.8		U	0.005	0.000
GW42-08-14099 Regi	onal	Borehole	Drilling	7/21/2008	0.25	Not measured	43.5	0.1	0.001	U	46.9	0.005	U	0.001	U 0.8		U	0.006	0.000
GW42-08-14100 Regi	onal	Borehole	Drilling	7/21/2008	0.14	Not measured	27.3	0.2	0.001	U	25.4	0.005	U	0.001	U 0.8		U	0.004	0.001
GW42-08-14109 Regi	onal	Well	Development	9/8/2008	0.13	1.19	24.2	0.1	0.001	U	26.7	0.002	U	0.001	0.001 0.8		U	0.158	0.001
GW42-08-14110 Regi	onal	Well	Development	9/8/2008	0.15	1.05	31.3	0.3	0.001	U	29.2	0.002	U	0.001 U		0.8	U	0.459	0.003
GW42-08-14111 Regi	onal	Well	Development	9/8/2008	0.14	0.90	35.3	0.3	0.001	U	33.4	0.002	U	0.001 U		0.8	U	0.492	0.002
GW42-08-14112 Regi	onal	Well	Development	9/8/2008	0.16	0.90	37.9	0.1	0.001	U	31.8	0.002	U	0.001 U		0.8	U	0.509	0.001
GW42-08-14113 Regi	onal	Well	Development	9/8/2008	0.16	0.84	38.6	0.2	0.001	U	32.6	0.002	U	0.001 U		0.8	U	0.513	0.010
GW42-08-14114 Regi	onal	Well	Development	9/8/2008	0.17	0.89	38.8	0.1	0.001	U	33.2	0.005	U	0.001 U		0.8	U	0.238	0.001
GW42-08-14115 Regi	onal	Well	Development	9/8/2008	0.17	0.84	37.9	0.2	0.001	U	33.3	0.005	U	0.001 U		0.8	U	0.177	0.002
GW42-08-14116 Regi	onal	Well	Development	9/8/2008	0.16	0.88	37.9	0.1	0.001	U	33.7	0.002	U	0.001 U		0.8	U	0.146	0.000
GW42-08-14117 Regi	onal	Well	Development	9/8/2008	0.18	0.82	38.9	0.2	0.001	U	33.7	0.002	U	0.001 U		0.8	U	0.265	0.001
GW42-08-14118 Regi	onal	Well	Development	9/8/2008	0.17	0.96	39.4	0.2	0.001	U	34.0	0.002	U	0.001 U		0.8	U	0.274	0.002

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	Cs rslt (ppm)	stdev (Cs)	Cu rslt (ppm)	stdev (Cu)	F^-(ppm)	Fe rslt (ppm)	stdev (Fe)	Alk-CO_3+HCO_3 rslt (ppm)	Hg rslt (ppm)	stdev (Hg)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	stdev (Li)
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	0.001	U	0.003	0.000	0.73	0.50	0.00	142	0.00011	0.00001	3.28	0.01	0.052	0.001
GW42-08-14095 Perched		Borehole	Drilling	7/14/2008	0.001	U	0.003	0.000	0.76	0.50	0.00	145	0.00009	0.00000	3.35	0.01	0.050	0.002
GW42-08-14096 Introduced Water?		Borehole	Drilling	7/21/2008	0.001	U	0.003	0.000	0.70	0.38	0.00	107	0.000	14	0.00001	4.12	0.01	0.054	0.005
GW42-08-14097 Introduced Water?		Borehole	Drilling	7/21/2008	0.001	U	0.001	0.000	0.63	0.01	U	138	0.00005	U	4.66	0.03	0.089	0.001
GW42-08-14098 Regional		Borehole	Drilling	7/21/2008	0.001	U	0.001	U	0.69	0.01	U	98.2	0.00010	0.00000	5.61	0.01	0.110	0.000
GW42-08-14099 Regional		Borehole	Drilling	7/21/2008	0.001	0.001	0.001	U	0.60	0.01	U	105	0.00007	0.00000	6.16	0.02	0.120	0.000
GW42-08-14100 Regional		Borehole	Drilling	7/21/2008	0.001	U	0.001	0.000	0.79	0.01	0.00	112	0.00014	0.00000	5.19	0.03	0.085	0.012
GW42-08-14109 Regional		Well	Development	9/8/2008	0.001	U	0.002	0.000	0.45	0.03	0.00	92.0	0.00007	0.00000	1.25	0.00	0.033	0.000
GW42-08-14110 Regional		Well	Development	9/8/2008	0.001	U	0.001	U	0.34	0.01	0.00	79.8	0.00005	0.00001	2.65	0.02	0.033	0.000
GW42-08-14111 Regional		Well	Development	9/8/2008	0.001	U	0.001	U	0.34	0.01	U	75.1	0.00005	U	2.09	0.01	0.033	0.000
GW42-08-14112 Regional		Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.03	0.00	73.8	0.00005	U	2.11	0.01	0.036	0.000
GW42-08-14113 Regional		Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.03	0.00	73.4	0.00005	U	2.05	0.01	0.035	0.001
GW42-08-14114 Regional		Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.04	0.00	74.2	0.00005	U	2.07	0.01	0.036	0.000
GW42-08-14115 Regional		Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.04	0.00	73.1	0.00005	U	2.07	0.01	0.036	0.000
GW42-08-14116 Regional		Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.04	0.00	73.0	0.00005	U	2.02	0.01	0.035	0.000
GW42-08-14117 Regional		Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.04	0.00	72.3	0.00005	U	2.05	0.01	0.035	0.000
GW42-08-14118 Regional		Well	Development	9/8/2008	0.001	U	0.001	U	0.33	0.06	0.00	72.5	0.00005	U	2.03	0.01	0.035	0.000

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	stdev (Mo)	Na rslt (ppm)	stdev (Na)	Ni rslt (ppm)	stdev (Ni)	NO_2 (ppm)	NO_2-N rslt	NO_2-N (U)	NO_3 (ppm)	NO_3-N rslt
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	7.13	0.02	0.104	0.001	0.093	0.001	52.6	0.2	0.006	0.000	0.01	0.003	U	5.53	1.25
GW42-08-14095 Perched		Borehole	Drilling	7/14/2008	6.91	0.03	0.103	0.001	0.086	0.001	50.4	0.3	0.006	0.000	0.01	0.003	U	5.55	1.25
GW42-08-14096 Introduced Water?		Borehole	Drilling	7/21/2008	3.36	0.02	0.069	0.007	0.179	0.002	21.3	0.1	0.001	0.000	0.23	0.07	[b]	2.20	0.50
GW42-08-14097 Introduced Water?		Borehole	Drilling	7/21/2008	6.10	0.05	0.455	0.002	0.113	0.001	30.7	0.0	0.003	0.000	0.12	0.04	[b] 1.14		0.26
GW42-08-14098 Regional		Borehole	Drilling 7/21/2008		10.7	0.2	0.316	0.002	0.235	0.004	26.3	0.1	0.009	0.000	3.16	0.96	[b] 13.9		3.15
GW42-08-14099 Regional		Borehole	Drilling 7/21/2008		13.4	0.1	0.376	0.002	0.209	0.001	28.5	0.3	0.011	0.000	4.12	1.25	[b] 11.1		2.51
GW42-08-14100 Regional		Borehole	Drilling	7/21/2008	8.76	0.13	0.323	0.002	0.180	0.001	21.8	0.1	0.004	0.000	0.69	0.21	[b] 1.31		0.30
GW42-08-14109 Regional		Well	Development	9/8/2008	7.28	0.02	0.135	0.000	0.006	0.000	29.4	0.1	0.008	0.000	0.01	0.003	U	18.2	4.12
GW42-08-14110 Regional		Well	Development	9/8/2008	8.97	0.06	0.080	0.000	0.003	0.000	21.2	0.0	0.008	0.000	0.01	0.003	U	20.9	4.71
GW42-08-14111 Regional		Well	Development	9/8/2008	9.89	0.07	0.038	0.000	0.002	0.000	17.8	0.0	0.009	0.000	0.01	0.003	U	22.1	4.99
GW42-08-14112 Regional		Well	Development	9/8/2008	10.5	0.2	0.028	0.000	0.001	0.000	15.8	0.2	0.009	0.000	0.01	0.003	U	23.2	5.23
GW42-08-14113 Regional		Well	Development	9/8/2008	10.8	0.1	0.025	0.000	0.001	0.000	15.3	0.2	0.010	0.000	0.01	0.003	U	23.7	5.35
GW42-08-14114 Regional		Well	Development	9/8/2008	11.0	0.1	0.032	0.000	0.001	0.000	15.9	0.1	0.009	0.001	0.01	0.003	U	23.5	5.32
GW42-08-14115 Regional		Well	Development	9/8/2008	10.9	0.1	0.029	0.000	0.002	0.000	17.0	0.1	0.009	0.001	0.01	0.003	U	23.3	5.27
GW42-08-14116 Regional		Well	Development	9/8/2008	10.7	0.1	0.029	0.000	0.002	0.000	16.5	0.1	0.011	0.001	0.01	0.003	U	23.6	5.33
GW42-08-14117 Regional		Well	Development	9/8/2008	11.1	0.1	0.025	0.000	0.001	0.000	15.7	0.2	0.011	0.001	0.01	0.003	U	23.9	5.40
GW42-08-14118 Regional		Well	Development	9/8/2008	11.1	0.0	0.023	0.000	0.001	0.000	15.4	0.1	0.010	0.000	0.01	0.003	U	24.5	5.53

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	C_2O_4 rslt (ppm)	C_2O_4 (U)	Pb rslt (ppm)	stdev (Pb)	pH	PO_4^{3-} rslt (ppm)	PO_4^{3-} (U)	Rb rslt (ppm)	stdev (Rb)	S_2- rslt (ppm)	Sb rslt (ppm)	stdev (Sb)	Se rslt (ppm)	stdev (Se)
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	0.16	SD[c]	0.0014 0.000	1	7.83	0.01	U	0.007 0.000	Not	measured 0.001		U	0.001	0.000
GW42-08-14095 Perche	d	Borehole	Drilling	7/14/2008 0.17		SD	0.0014	0.0000	7.73	0.01	U	0.006 0.000	Not	measured	0.001	U	0.001 0.00	0
GW42-08-14096 Introduce	d Water?	Borehole	Drilling	7/21/2008	0.27	SD 0.000	5	0.0000	7.85	0.01	U	0.007 0.000	Not	measured	0.001	U	0.001 U	
GW42-08-14097 Introduce	d Water?	Borehole	Drilling	7/21/2008	1.14	SD 0.000	2	U	7.41	0.01	U	0.006	0.000 Not	measured	0.001	U	0.001 U	
GW42-08-14098 Regi	onal	Borehole	Drilling	7/21/2008	0.43	SD	0.0002 U		7.64	0.01	U	0.009	0.000	Not measured	0.001	U	0.001	0.000
GW42-08-14099 Regi	onal	Borehole	Drilling	7/21/2008 0.01		U	0.0002	U	7.56	0.01	U	0.011 0.000	Not	measured 0.001		U	0.002	0.000
GW42-08-14100 Regi	onal	Borehole	Drilling	7/21/2008 0.35		SD	0.0003	0.0000	7.86	0.01	U	0.009 0.000	Not	measured	0.001	U	0.001 U	
GW42-08-14109 Regi	onal	Well	Development	9/8/2008 0.01		U	0.0002	U	7.99	0.01	U	0.002 0.000	Not	measured 0.001		U	0.001	0.000
GW42-08-14110 Regi	onal	Well	Development	9/8/2008 0.01		U	0.0002	U	7.92	0.01	U	0.006 0.000	Not	measured 0.001		U	0.002	0.000
GW42-08-14111 Regi	onal	Well	Development	9/8/2008 0.01		U	0.0002	U	7.60	0.01	U	0.004 0.000	Not	measured 0.001		U	0.002	0.000
GW42-08-14112 Regi	onal	Well	Development	9/8/2008 0.01		U	0.0002	U	7.76	0.01	U	0.004 0.000	Not	measured 0.001		U	0.002	0.000
GW42-08-14113 Regi	onal	Well	Development	9/8/2008 0.01		U	0.0002	U	7.75	0.01	U	0.004 0.000	Not	measured 0.001		U	0.002	0.000
GW42-08-14114 Regi	onal	Well	Development	9/8/2008 0.01		U	0.0002	U	7.73	0.01	U	0.004 0.000	Not	measured 0.001		U	0.001	0.000
GW42-08-14115 Regi	onal	Well	Development	9/8/2008 0.01		U	0.0002	U	7.70	0.01	U	0.004 0.000	Not	measured 0.001		U	0.001	0.000
GW42-08-14116 Regi	onal	Well	Development	9/8/2008 0.01		U	0.0002	U	7.65	0.01	U	0.004 0.000	Not	measured 0.001		U	0.002	0.000
GW42-08-14117 Regi	onal	Well	Development	9/8/2008 0.01		U	0.0002	U	7.59	0.01	U	0.004 0.000	Not	measured 0.001		U	0.002	0.000
GW42-08-14118 Regi	onal	Well	Development	9/8/2008 0.01		U	0.0002	U	7.66	0.01	U	0.004 0.000	Not	measured 0.001		U	0.002	0.000

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	Si rslt (ppm)	stdev (Si)	SiO_2 rslt (ppm)	stdev (SiO_2)	Sn rslt (ppm)	stdev (Sn)	SO_4^{2-} rslt (ppm)	Sr rslt (ppm)	stdev (Sr)	Th rslt (ppm)	stdev (Th)	Ti rslt (ppm)	stdev (Ti)	Tl rslt (ppm)
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	24.6 0.2		52.6 0.	4 0.001		U	41.2	0.124	0.001	0.001 U		0.056	0.000	0.001
GW42-08-14095 Pe	rched	Borehole	Drilling	7/14/2008 24.1		0.1	51.5 0.2		0.001	U	40.9	0.120	0.000 0.001	U		0.057	0.000	0.001
GW42-08-14096 Introduce	d Water?	Borehole	Drilling	7/21/2008	21.9	0.1 46.8		0.2	0.001	U	11.4	0.054 0.002	0.001	U		0.010	0.000	0.001
GW42-08-14097 Introduce	d Water?	Borehole	Drilling	7/21/2008	9.35 0.04		20.0 0.1		0.001	U	23.8	0.085 0.000	0.	001 U		0.002	U	0.001
GW42-08-14098 Regi	onal	Borehole	Drilling	7/21/2008	16.5	0.1 35.4		0.1	0.001	U	63.3	0.133	0.001 0.001	U		0.002	U	0.001
GW42-08-14099 Regi	onal	Borehole	Drilling	7/21/2008	19.8	0.0 42.3		0.0	0.001	U	85.0	0.162	0.002 0.001	U		0.002	U	0.001
GW42-08-14100 Regi	onal	Borehole	Drilling	7/21/2008 19.9		0.1	42.7 0.2		0.001	U	49.4	0.105	0.001 0.001	U		0.003	0.000	0.001
GW42-08-14109 Regi	onal	Well	Development	9/8/2008	27.5	0.2	58.8 0.4		0.001	U	42.5	0.139	0.001 0.001	U		0.002	U	0.001
GW42-08-14110 Regi	onal	Well	Development	9/8/2008	32.1	0.1	68.6 0.2		0.001	U	47.7	0.150	0.003 0.001	U		0.002	U	0.001
GW42-08-14111 Regi	onal	Well	Development	9/8/2008	33.6	0.1	71.8 0.2		0.001	U	56.9	0.139	0.001 0.001	U		0.002	U	0.001
GW42-08-14112 Regi	onal	Well	Development	9/8/2008	34.1	0.2	73.1 0.5		0.001	U	53.8	0.142	0.001 0.001	U		0.002	U	0.001
GW42-08-14113 Regi	onal	Well	Development	9/8/2008	34.2	0.4	73.2 0.8		0.001	U	55.8	0.143	0.001 0.001	U		0.002	U	0.001
GW42-08-14114 Regi	onal	Well	Development	9/8/2008	32.9	0.1	70.5 0.2		0.001	U	56.9	0.148	0.002 0.001	U		0.002	U	0.001
GW42-08-14115 Regi	onal	Well	Development	9/8/2008	33.1	0.1	70.9 0.3		0.001	U	57.3	0.145	0.001 0.001	U		0.002	U	0.001
GW42-08-14116 Regi	onal	Well	Development	9/8/2008	32.3	0.3	69.1 0.6		0.001	U	58.1	0.142	0.000 0.001	U		0.002	U	0.001
GW42-08-14117 Regi	onal	Well	Development	9/8/2008	33.8	0.2	72.3 0.5		0.001	U	58.3	0.143	0.001 0.001	U		0.002	U	0.001
GW42-08-14118 Regi	onal	Well	Development	9/8/2008	33.6	0.2	71.9 0.5		0.001	U	58.8	0.144	0.002 0.001	U		0.002	U	0.001

Table B-1.3-1 (continued)

Sample ID	Aquifer	Sample Type	Activity	Date Received	stdev (Tl)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS[d] (ppm)	Cations	Anions	Balance
GW42-08-14095 dup	Perched	Borehole	Drilling	7/14/2008	U	0.0044 0.000	5 0.003		0.000	0.018	0.001 371		4.24	4.41	-0.02
GW42-08-14095 Perche	d	Borehole	Drilling	7/14/2008	U	0.0038	0.0001	0.002 0.000	0.017	0.	001 369		4.11	4.44	-0.04
GW42-08-14096 Introduce	d Water?	Borehole	Drilling	7/21/2008	U	0.0015 0.000	0 0.003		0.000	0.002	0.000 224		2.04	2.40	-0.08
GW42-08-14097 Introduce	d Water?	Borehole	Drilling	7/21/2008	U	0.0004 0.000	0 0.002		0.000	0.003	0.000 270		3.17	3.39	-0.03
GW42-08-14098 Regi	onal	Borehole	Drilling	7/21/2008	U	0.0015	0.0000	0.002 0.000	0.003	0.	000 338		3.99	4.49	-0.06
GW42-08-14099 Regi	onal	Borehole	Drilling	7/21/2008	U	0.0019	0.0001	0.002 0.000	0.003	0.	000 389		4.70	5.15	-0.05
GW42-08-14100 Regi	onal	Borehole	Drilling	7/21/2008	U	0.0018	0.0000	0.002 0.000	0.005	0.	000 297		3.19	3.69	-0.07
GW42-08-14109 Regi	onal	Well	Development	9/8/2008	U	0.0014 0.000	0 0.001		U	0.012	0.000 302		3.13	3.49	-0.06
GW42-08-14110 Regi	onal	Well	Development	9/8/2008	U	0.0012 0.000	0 0.001		U	0.002	0.000 312		3.30	3.51	-0.03
GW42-08-14111 Regi	onal	Well	Development	9/8/2008	U	0.0009 0.000	0 0.001		U	0.004	0.000 327		3.42	3.76	-0.05
GW42-08-14112 Regi	onal	Well	Development	9/8/2008	U	0.0008 0.000	0 0.001		U	0.003	0.000 324		3.51	3.65	-0.02
GW42-08-14113 Regi	onal	Well	Development	9/8/2008	U	0.0008 0.000	0 0.001		U	0.003	0.000 328		3.54	3.71	-0.02
GW42-08-14114 Regi	onal	Well	Development	9/8/2008	U	0.0008 0.000	0 0.001		U	0.001	0.000 328		3.60	3.76	-0.02
GW42-08-14115 Regi	onal	Well	Development	9/8/2008	U	0.0008 0.000	1 0.001		U	0.002	0.000 328		3.59	3.75	-0.02
GW42-08-14116 Regi	onal	Well	Development	9/8/2008	U	0.0009 0.000	0 0.001		U	0.002	0.000 327		3.56	3.78	-0.03
GW42-08-14117 Regi	onal	Well	Development	9/8/2008	U	0.0008 0.000	0 0.001		U	0.002	0.000 330		3.60	3.78	-0.02
GW42-08-14118 Regi	onal	Well	Development	9/8/2008	U	0.0008 0.000	0 0.001		U	0.002	0.000 332		3.61	3.81	-0.03

[a] U = Undetected.
[b] n/a = Not available.
[c] SD = Sample detected.
[d] TDS = Total dissolved solids.

Appendix C

Aquifer Testing Report

C-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests at well R-42 located in Mortandad Canyon within the existing chromium plume beneath the canyon. The tests were conducted in conjunction with testing of cross-gradient well R-43 located in Sandia Canyon near the edge of the chromium plume. The primary objective of the analysis was to determine the hydraulic properties of the formation screened by R-42. A secondary objective was to look for a cross-connection between R-42 and surrounding wells, including R-43.

Testing consisted primarily of constant-rate pumping tests. During the tests, water levels were monitored in the pumped well and both screen zones in R-43. In addition, water-level data were collected from regional wells R-11, R-13, R-15, R-28, and R-33.

Consistent with most of the R-well pumping tests conducted on the plateau, an inflatable packer system was used in R-42 to eliminate the effects of casing storage on the test data.

Conceptual Hydrogeology

R-42 is completed at the top of the regional aquifer within the Miocene pumiceous deposits. It is a single-screen completion with 21.1 ft of screen between 931.8 and 952.9 ft below ground surface (bgs). The static water level (SWL) measured at the onset of testing was 919.8 feet bgs. The estimated ground surface elevation at R-42 was 6759 ft above mean sea level (amsl), putting the groundwater elevation at about 5839 ft amsl.

The original R-42 borehole was advanced to a depth of 1047 ft where tight sediments were encountered. The deeper portion of the borehole was backfilled and the well was completed shallower. The aquifer penetrated by R-42 was considered to be unconfined, extending from the SWL of 919.8 ft to the tight sediments at 1047. Thus, the assumed aquifer thickness was approximately 127 ft. The actual properties of the sediments between the bottom of the well and 1047 ft were not known, so the assignment of an aquifer thickness of 127 ft was somewhat arbitrary and considered only an estimate.

Well R-43 is a dual-screen well completed at the top of the Miocene riverine sediments, with 20.7 ft of screen from 903.9 to 924.6 ft (screen 1) and 10 ft of screen from 969.1 to 979.1 ft (screen 2). At the time of testing R-42, the approximate groundwater elevations in R-43 screens 1 and 2 were 5837 and 5836 ft, respectively.

R-42 Testing

R-42 was tested from November 12 to November 16, 2008. Testing consisted of brief trial pumping on November 12, background data collection, and a 24-h constant-rate pumping test that was begun on November 14.

At the conclusion of formal testing, R-42 was purged an additional 15 h to complete the development process of removing a volume of water equivalent to what was lost to the regional aquifer during the drilling process. Purging was performed on November 16, followed by recovery until November 17. The water-level data recorded during the final development purging were retained for analysis.

After brief pumping to fill the drop pipe and adjust the discharge rate, two trial tests were conducted on November 12. Trial 1 was conducted for 30 min from 10:30 to 11:00 a.m. and was followed by 50 min of recovery until 11:50 a.m. During trial 1, a significant leak was detected in the drop pipe used to hang the pump, forcing removal of a number of joints of drop pipe and replacement of two pipe joints that had leaks.

The water that had leaked from the drop pipe during trial 1 was trapped above the inflatable packer and thus did not reenter the screen zone. Therefore, the metered flow at the surface underestimated the true formation pumping rate by the quantity of water that had leaked from the drop pipe. The effective pumping rate was estimated in two ways: (1) by observing the volume of water above the packer, based on head buildup data recorded after packer deflation, and (2) by applying the specific capacity of the well observed in subsequent pumping episodes. It was estimated that the leakage rate was 3.0 gpm. Adding this to the measured discharge rate of 3.4 gpm resulted in an estimated pumping rate of 6.4 gpm for trial 1.

A second trial test was conducted, but because of the delay caused by removing, examining, and replacing some of the drop pipe, the high-density data collection schedule programmed for trial 2 had expired. The actual data density achieved was not adequate to contribute to the pumping test interpretation. Therefore, the data from trial 2 were not analyzed.

At 8:00 a.m. on November 14, the 24-h pumping test was begun at a rate that was a little over 5 gpm. During the test, the discharge rate fluctuated erratically. Pumping continued until 8:00 a.m. on November 15. Following shutdown, recovery measurements were recorded for 23 h until 7:00 a.m. on November 16.

Final purge development began at 7:00 a.m. on November 16 and continued for 15 h until 10:00 p.m. Pumping was discontinued and recovery data were recorded until 8:00 a.m. on November 17. The purge rate averaged 6.2 gpm, although it was not constant.

Variations in Generator Output

During testing and purge development, the discharge rate from R-42 varied erratically. The generator that was used to power the pump showed slight variations in frequency output during the test, according to visual observations of the electrical meter on the generator control panel. Based on the bowl characteristics of the 4-in. submersible pump used for the testing, an output variation only a small fraction of a cycle per second would have been enough to account for the variation in flow rates measured during testing. It was assumed that this was the cause of the discharge rate fluctuations. There was no evidence of air being discharged in the water stream as had occurred in the R-43 tests, so it was unlikely that entrained air affected the pump operation.

C-2.0 BACKGROUND DATA

The background water-level data collected with running the pumping tests allowed the analyst to see what water-level fluctuations occur naturally in the aquifer and helped 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-42, 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.

The Environmental Division Meteorology and Air Quality (ENV-MAQ) obtained barometric pressure data from the Technical Area (TA-54) tower site. The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead elevation is approximately 6759 ft amsl. The SWL was about 920 ft below land surface, making the water table elevation roughly 5839 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-42.

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

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R} \left(\frac{E_{R42} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R42}}{T_{WELL}} \right) \right] \qquad \textbf{Equation C-1}$$

Where P_{WT} = barometric pressure at the water table inside R-42

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_{R42} = land surface elevation at R-42 site, in feet (6759 ft estimated)

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

E_{WT} = elevation of the water level in R-42, in feet (approximately 5839 ft)

T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 38.6° Fahrenheit or 276.8° Kelvin)

T_{WELL} = air temperature inside R-42, in degrees Kelvin (assigned a value of 64.8° Fahrenheit or 291.4° Kelvin)

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

The corrected barometric pressure data reflecting pressure conditions at the water table were compared with the water-level hydrographs to discern the correlation between the two.

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. Thus, the early data often offer the best opportunity to obtain hydraulic conductivity information because conductivity would equal the earliest-time transmissivity divided by the well screen length.

Unfortunately, in many pumping tests, casing-storage effects dominate the early-time data, 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 of column pipe, in inches

Q = discharge rate, in gallons per minute

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

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, including the R-42 pumping tests. As described below, antecedent drainage of a portion of the filter pack may have left air pockets in place that contributed to a casing-storagelike effect.

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-3**

Where,

$$W(u) = \int_u^\infty \frac{e^{-x}}{x} dx$$ **Equation C-4**

and

$$u = \frac{1.87 r^2 S}{Tt}$$ **Equation C-5**

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-6**

$$S = \frac{Tut}{2693r^2}$$ **Equation C-7**

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-8**

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-9**

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. 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-10**

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. This was of paramount importance in the R-42 pumping tests because variable current output from the electric generator induced discharge rate fluctuations.

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:

$$s_P = \frac{1-\frac{L}{b}}{\frac{L}{b}}\left[\ln\frac{b}{r_w} - 2.948 + 7.363\frac{L}{b} - 11.447\left(\frac{L}{b}\right)^2 + 4.675\left(\frac{L}{b}\right)^3\right] \qquad \textbf{Equation C-11}$$

Where S_p = partial penetration correction, dimensionless

L = well screen length, in feet

b = aquifer thickness, in feet

r_w = radius of the pumping well, in feet

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:

$$K = \frac{264Q}{sb}\left(\log\frac{0.3Tt}{r_w^2 S} + \frac{2s_P}{\ln 10}\right) \qquad \textbf{Equation C-12}$$

Where K = hydraulic conductivity, in feet/day

Q = flow rate, in gallons per minute

T = transmissivity, in gallons per day per foot

t = time, in minutes

S_p = partial penetration correction, dimensionless

s = drawdown, in feet

b = aquifer thickness, in feet

r_w = radius of the pumping well, in feet

S = storage coefficient, dimensionless

To apply this procedure, a storage coefficient value must be assigned. Unconfined conditions were assumed for R-42. Storage coefficient values for unconfined conditions can be expected to range from about 0.01 to 0.25, depending on sediment makeup (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. An assumed value of 0.1 was used for R-42.

The analysis also requires assigning a value for the saturated aquifer thickness, *b*. For calculation purposes, the aquifer thickness of 127 ft cited above was used. The computed result is not particularly sensitive to the exact aquifer thickness because sediments far above or below the screen have little effect

on yield and drawdown response. Therefore, the calculation based on the assumed aquifer thickness value was deemed to be adequate.

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-42 tests were plotted along with barometric pressure to determine the barometric effect on water levels and to look for pumping response in the surrounding observation wells. R-42 screen and R-43 screens 1 and 2 were monitored using nonvented pressure transducers, while the remaining wells—R-11, R-13, R-15, R-28, and R-33—were monitored using vented transducers.

Figure C-7.0-1 shows aquifer pressure data from R-42 along with barometric pressure data from TA-54 that have been corrected to equivalent barometric pressure at the water table in feet of water. The R-42 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-42 pumping tests are included on the figure for reference.

It is apparent that the swings in barometric pressure had little effect on the total aquifer pressure. This meant that if there had been no packer above the transducer, a given change in barometric pressure would have caused an opposite and nearly equal change in the water level in the well, such that the total pressure remained nearly unchanged. This implied a high barometric efficiency for R-42.

The background data recorded from November 12 to 14 showed a slight downward trend—a continuation of the trend observed the previous week during the testing of R-43. On November 10, continuous pumping of County supply well PM-4 was discontinued, allowing general groundwater levels in the area to rebound slightly (described below). Nevertheless, the R-42 water levels continued a downward trend, suggesting that the sediments screened in R-42 are more poorly hydraulically connected to the deep aquifer than other R-well screen zones. This response was consistent with observations made the previous week and a half during testing of R-43. At that time, continuous operation of PM-4 from late October to November 10 caused water levels in other regional wells to decline for the entire 10-d monitoring period from November 1 to 10. During that time, however, the response in R-42 was delayed in that water levels were observed to rise until November 3 before they began to decline in response to operation of PM-4. In summary, the data from both the R-43 and R-42 pumping tests showed a delayed response in R-42 to regional aquifer pumping compared with what was observed in other R-wells.

An alternative explanation to the idea of delayed response to operation of PM-4 is the possibility that the observed lag is a delayed response to large-scale atmospheric pressure fluctuations. Long-term monitoring of R-42 may shed light on this idea.

Figures C-7.0-2 and C-7.0-3 show apparent hydrographs for R-43 screens 1 and 2, respectively. The graphs were similar in that there was negligible change in total aquifer pressure in response to changes in barometric pressure. This implied a barometric efficiency near 100% for both screens 1 and 2 in R-43. The data collected during previous testing of R-43 were inconclusive with respect to determining the barometric efficiency of screen 2. The data in Figure C-7.0-3, however, showed conclusively that the zone is highly barometrically efficient.

Both Figures C-7.0-2 and C-7.0-3 showed tiny diurnal water-level fluctuations throughout the monitoring period (subtle “ripples” in the data plots). These appeared to be unrelated to barometric pressure changes and could not be correlated to cycling of the County supply wells. It is possible that these small water-level perturbations reflect earth tides.

There was no evidence of a response to pumping R-42 in either screen zone in R-43.

Figures C-7.0-4 through C-7.0-8 show comparisons of barometric pressure and hydrograph data from regional wells R-11, R-13, R-15, R-28, and R-33 screen 1, respectively. (Data from R-33 screen 2 showed daily fluctuations of 5 or 6 ft in response to operation of PM-5 and are not presented here.) For all hydrographs, the strong correlation between barometric pressure and water level was clear, showing near 100% barometric efficiencies. In each of these plots, there was a steady rise in water levels compared with the barometric pressure changes, presumably in response to discontinuing operation of PM-4 after November 10.

Examination of the data in Figures C-7.0-4 through C-7.0-8 showed that there was no apparent response to pumping R-42 in any of the monitored wells.

The data from R-33 screen 1 were replotted along with the run times for Los Alamos County supply well PM-5 as shown in Figure C-7.0-9.

Previous background data collection during the R-43 pumping tests revealed possible reverse water-level fluctuations in R-33 screen 1, also called the Noordbergum effect (Wolff 1970, 098242; Rodrigues 1983, 098239; Heish 1996, 098238), in response to operation of PM-5. This effect is occasionally seen in observation wells completed within aquitards or within aquifers adjacent to the pumped aquifer and separated from it by an aquitard. The data obtained during the R-42 test were examined for this effect.

Reverse water-level fluctuations are brought about by poroelastic effects and corresponding pore-pressure changes. When the main aquifer is pumped, it undergoes elastic deformation in response to the change in pore-water pressures, as well as the down thrust on the land surface at the wellhead associated with operating the pump. When the pumped aquifer becomes distorted, adjacent layers of aquitards and aquifers also are distorted. This creates transient pore-pressure changes within these units. At some locations, the pressures decline, while at other locations they rise (reverse water-level fluctuations). As time goes on, these pressure changes are relieved as water moves from high pressure areas to low pressure areas.

To check again for this response, the R-33 screen 1 hydrograph was examined along with the start and stop times for PM-5. As observed previously, a detailed analysis of the data showed that when PM-5 began pumping, the water level in R-33 screen 1 rose by an amount that was disproportionate compared with the barometric pressure change at that time. Likewise, when PM-5 pumping stopped, there was a similar disproportionate drop in the R-33 screen 1 water level. As an example, according to the hydrograph, when PM-5 began pumping just after midnight on November 12, the water level rise in R-33 screen 1 exceeded the corresponding barometric pressure change. When pumping stopped, the dip in the R-33 screen 1 water level again exceeded the corresponding barometric pressure change. Observations consistent with this idea were noted for virtually every cycling event at PM-5 shown in Figure C-7.0-9.

An alternative explanation for the observed response in screen 1 is the possibility that earth tides could have caused the fluctuations observed in the hydrograph. The diurnal pattern of the observed fluctuations is consistent with this idea.

A third possibility is that the observed pressure perturbations could be related to the elasticity of the pump and packer system installed in R-33. For example, when operation of PM-5 lowers or raises the water level in screen 2 at 5 or 6 ft, it is possible that the changing pressure beneath the inflatable packer could cause it to move, expand, contract, deform, etc., giving rise to the exaggerated amplitude of the small oscillations seen in the screen 1 hydrograph.

Finally, the observed response could be caused by a leak in the sampling system equipment, possibly through the screen 2 transducer drop tube. A 5-ft offset in screen 2 water levels has been noted consistently between post-pack-inflation levels and postsampling levels, with a corresponding tiny opposite water-level effect in screen 1. This anomaly and the apparent reverse water-level fluctuations in Figure C-7.0-9 could be related.

In summary, all monitored R-wells presented above showed near 100% barometric efficiency response. None of the wells showed any response to pumping R-42. All wells except R-42 showed water-level recovery in response to discontinuing pumping at PM-4. Levels in R-42 continued their antecedent downward trend from the previous pumping of PM-4, suggesting that the R-42 response was delayed and that the formation screened in R-42 is less well connected to the deep aquifer than the screen zones in the other wells. Finally, R-33 screen 1 showed subtle water-level oscillations coincident with operation of County well PM-5 that could have been caused by either the Noordbergum effect (reverse water-level fluctuations), fortuitously coincident earth tide response, or elastic deformation of components of the pump and packer sampling system.

C-8.0 R-42 DATA ANALYSIS

This section presents the data obtained from the R-42 pumping tests and the results of the analytical interpretations. Data are presented for drawdown and recovery for trial 1, the 24-h constant-rate pumping test, and final purge development.

Trial 1

Figure C-8.0-1 shows a semilog plot of the trial 1 drawdown data. The initial drawdown spike was attributed to antecedent drainage of a portion of the drop pipe through leaky coupling joints at a substantial depth below ground surface (unrelated to the holes discovered in some of the shallow drop pipes). On startup, the pump operated against reduced head briefly until the void in the drop pipe filled. Against reduced head, the pump produced a greater discharge rate momentarily, resulting in exaggerated drawdown.

Note that the effective pumping water level was pulled below the top of the well screen (and below the top of the filter packed annulus as well). The presence of the inflatable packer above the pump ensured that air could not enter the screen zone from inside the well casing. (In fact, the submersible pump intake was positioned 2 ft above the top of the screen. The drawdown indicated on the graph was achieved by the pump pulling a vacuum beneath the packer.) However, there was a possibility that air could have accessed the filter pack and/or well screen through the formation outside the well. This created the possibility of entrained air in either the filter pack or screen/casing that could contribute an effect similar to casing storage.

The drawdown data trace was uneven, indicating discharge rate variations. The unsteady flow rate was probably attributable to nonuniform generator output as described above.

Figure C-8.0-2 shows a semilog plot of the trial 1 recovery data. The transmissivity value computed from the very early data was 390 gpd/ft. Based on the screen length of 21.1 ft, the computed hydraulic conductivity was 18.5 gpd/ft^2, or 2.5 ft/d. Based on the possibility of entrained air in the well or filter pack,

it was possible that the data could have been affected by a storagelike phenomenon similar to casing storage, caused by expansion and contraction of the hypothesized trapped air. If this were the case, the computed hydraulic conductivity value would be an underestimate of the true value. As described below, subsequent testing and analysis showed that this was the case.

As shown in Figure C-8.0-2, after less than a minute of recovery, the data curve flattened steadily. This was likely attributable to vertical expansion of the cone of depression (partial penetration effects) and possibly delayed yield. Other contributing factors also could have included changes (increases) in hydraulic conductivity laterally or vertically around the well.

Figure C-8.0-3 shows an expanded-scale plot of the late recovery data. The line of fit shown on the graph yielded a computed transmissivity value of 26,000 gpd/ft. Because the graph represented a limited recovery time, just 50 min, the extremely flat slope depicted on the graph could represent delayed yield rather than reflect true aquifer coefficients. Also, there was substantial scatter in the data set casting doubt on the reliability of the computed transmissivity value.

Packer Deflation

Following trial 1, the downhole packer was deflated so that the pump string could be lifted to remove and replace defective sections of drop pipe. This allowed the weight of the trapped water above the packer that had leaked through holes in the drop pipe to be delivered to the pressure transducer while the water drained back into the well and formation.

Figure C-8.0-4 shows the resulting head buildup and decay that occurred when the packer was deflated. Also shown on the graph are the computed “injection” rate of water moving from the well casing into the aquifer and the effective injection specific capacity (ratio of inflow rate to head buildup). After packer deflation, the head in the casing above the transducer increased more than 100 ft and then slowly declined. This information helped establish an estimate of the volume of water that had leaked from the drop pipe during trial 1, supporting determination of an estimated discharge rate for the trial 1 test.

Of interest in Figure C-8.0-4 is the depiction of the injection specific capacity. As shown on the graph, the injection specific capacity fell between 0.1 and 0.2 gpm/ft. In contrast, the pumping tests on R-42 produced specific capacities around 0.8 gpm/ft. This supports the generally accepted idea that injection rates tend to be less than extraction rates because of clogging at the borehole face that often occurs during injection, either with solids or air or dynamic changes that occur between the filter pack and borehole face when the flow direction is reversed. Numerous previous pumping tests in R-wells on the plateau utilized injection rather than pumping as the mechanism of stressing the aquifer. The data in Figure C-8.0-4 provide anecdotal evidence that, as suspected, those previous tests may have underestimated hydraulic conductivity in cases where calculations were based either on specific capacity performance or on slug test analysis.

C-8.1 R-42 24-H Constant-Rate Pumping Test

Figure C-8.1-1 shows a semilog plot of the drawdown data recorded during the 24-h constant-rate pumping test conducted at R-42. The early-time drawdown exceeded subsequent drawdown because of antecedent drainage of the drop pipe through leaky threaded joints, as described above. Consistent with this, on startup it took several seconds before water was produced from the discharge pipe at the surface. This was the time required to refill the void in the drop pipe.

Subsequent data showed varying drawdown throughout the test corresponding to changing discharge rates. Some examples of the measured discharge rates are identified on the graph. As stated above, the variable output of the electrical generator likely caused the flow rate fluctuations. The rate gradually increased to 5.5 gpm and stayed close to that level for the last several hours of the test.

Figure C-8.1-2 shows a semilog plot of the recovery data following the 24-h test. The transmissivity value computed from the early data was 450 gpd/ft making the hydraulic conductivity 21.3 gpd/ft^2, or 2.9 ft/d. In general, early recovery data respond according to the last pumping rate of the test, just before pump shutoff. Therefore, calculations shown in Figure C-8.1-2 used the final pumping rate of 5.5 gpm rather than the average rate of 5.2 gpm.

The curvature associated with the first few data points on the recovery graph mimicked what is seen when casing storage affects pumping test data. Care was taken to ensure that all air within the casing beneath the packer was allowed to escape before inflating the packer for the 24-h pumping test. This, coupled with the storagelike response in Figure C-8.1-2, implied a likelihood that air had become entrained in the filter pack. This could have occurred when the effective pumping water level was pulled into the well screen during trial 1. It also could have happened during initial development of the well weeks earlier. The likelihood of storage effects meant that the computed parameter values in Figure C-8.1-2 underestimated the true values.

After about 1 min, the late recovery data showed flattening associated with the combination of delayed yield and partial penetration, as well as perhaps other effects as described earlier. An expanded-scale plot of the late data was prepared as shown in Figure C-8.1-3.

The flattening of the curve followed by an increase in slope at late recovery time lent support to the idea that delayed yield of the unconfined aquifer had occurred. The transmissivity computed from the late data was 10,400 gpd/ft. Because late-recovery data respond according to the average pumping rate of the test, calculations shown in Figure C-8.1-3 were based on the average pumping rate of 5.2 gpm. Assigning the aquifer thickness of 127 ft yielded a hydraulic conductivity of 81.9 gpd/ft2, or 10.9 ft/d. Note that the computed transmissivity value was substantially less than the 26,000 gpd/ft computed from trial 1 (Figure C-8.0-3). This confirmed that the trial 1 analysis was based on delayed yield data, thus overestimating the transmissivity.

C-8.2 Development Purging

Following the recovery from the 24-h pumping test, purge development was performed on R-42 for 15 h followed by 10 h of recovery. Figure C-8.2-1 shows the drawdown data measured during the 15 h of purging the well.

As with other tests on R-42, the drawdown data shown in Figure C-8.2-1 were erratic, in response to variations in pumping rate. The pumping rate was roughly proportional to the observed drawdown so examining the drawdown curve provides insight into the magnitude of the variation in discharge rate. The average rate throughout the purging event was 6.2 gpm.

Figure C-8.2-2 shows recovery data recorded following pump shutdown when purging ceased. The early steep slope shown on the graph reflected the presumed casing-storagelike effect combined with the limited transmissivity of the screened interval. The intermediate portion of the curve became flat in response to a combination of vertical growth of the cone of depression and delayed yield. The late-time slope revealed a transmissivity of 8240 gpd/ft, making the hydraulic conductivity 64.9 gpd/ft^2, or 8.7 f/dt, in fair agreement with the value obtained from the 24-h pumping test.

C-8.3 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound conductivity value for R-42 for comparison to the pumping test values. In addition to specific capacity, other input values used in the calculations included the aquifer thickness of 127 ft (from the SWL to the bottom of the originally advanced borehole), a storage coefficient of 0.1 and a borehole radius of 0.51 ft. The calculations are somewhat insensitive to the assigned aquifer thickness, as long as the selected value is substantially greater than the screen length.

R-42 produced 5.5 gpm with a drawdown of 7.0 ft after 24 h of pumping for a specific capacity of 0.79 gpm/ft. Applying the Brons and Marting method (1961, 098235) to these inputs yielded a lower-bound hydraulic conductivity value for the screened interval of 32.5 gpd/ft^2, or 4.3 ft/d. This was greater than the values obtained from the early recovery data in Figures C-8.0-2 and C-8.1-2. This confirmed that those values were underestimates of aquifer properties, reinforcing the idea that the data on which they were based were storage affected.

The late data in Figures C-8.1-3 and C-8.2-2 yielded an average hydraulic conductivity of 9.8 ft/d, assuming an aquifer thickness of 127 ft. The lower-bound hydraulic conductivity value of 4.3 ft/d was consistent with these data, that is, the value did not exceed it. The discrepancy in the magnitude of these values could indicate that the well is a little less than 50% efficient, certainly a possibility.

On the other hand, if the well is highly efficient, the result could indicate that the average hydraulic conductivity of the overall aquifer is greater than that of the screened portion. Or alternatively, it could imply that the assumed aquifer thickness is incorrect.

C-9.0 SUMMARY

Constant-rate pumping tests were conducted on R-42 in Mortandad Canyon. The tests were conducted to gain an understanding of the hydraulic characteristics of the aquifer. Additionally, several surrounding wells, including cross-gradient well R-43, were monitored to check for hydraulic cross connection to R-42. Numerous observations and conclusions were drawn for the tests as summarized below.

- Water-level data from R-42, R-43 screens 1 and 2, R-11, R-13, R-15, R-28, and R-33 screen 1 showed near 100% barometric efficiencies.
- There was a general water-level rise in all of the surrounding wells, in response to ceasing operation at PM-4. However, levels in R-42 continued to decline, showing a lag in response to PM-4, consistent with what was observed during the previous week and a half of R-43 pumping tests. This suggested that the sediments screened in R-42 may not be as effectively hydraulically connected to the deep aquifer as are the zones penetrated by the other wells.
- There was no observed response to pumping R-42 in any of the monitored wells.
- A defective (leaky) drop pipe used in initial testing allowed the annulus above the inflatable packer to fill with water more than 100 ft above the SWL. Upon packer deflation, the inflow rate of the water back into the aquifer occurred at a specific capacity ranging between 0.1 and 0.2 gpm/ft, compared with a pumping specific capacity of about 0.8 gpm/ft. This supported the idea that previous injection tests on the plateau some years ago may have significantly underestimated hydraulic conductivity values.
- During each test, the discharge rate varied erratically, apparently as a function of subtle variations in the output characteristics of the electric generator.

- During the initial trial test, antecedent drainage of a portion of the drop pipe allowed the pump to produce a high discharge rate briefly, pulling the effective pumping water level below the top of the well screen. This may have introduced air into the filter pack, causing subsequent casing-storagelike effects. Introduction of air into the filter pack also could have occurred during previous well development.
- Early recovery data underestimated the hydraulic conductivity, consistent with what occurs when the data are affected by casing storage. Further, visual appearance of the early recovery curve was consistent with casing storage phenomena.
- Intermediate data showed a subtle delayed yield effect.
- Late data showed an average transmissivity of about 9300 gpd/ft.
- The aquifer thickness was estimated at 127 ft, the distance between the SWL and the maximum depth of the original borehole where tight sediments were encountered. This thickness, combined with the transmissivity cited above, yielded an average hydraulic conductivity of 73 gpd/ft^2, or 9.8 ft/d.
- Specific capacity data yielded a lower-bound hydraulic conductivity of 4.3 ft/d, consistent with the above estimate (about 44%). The difference between the estimates could indicate a well efficiency on the order of 40% to 50% or that the screened interval has a lower hydraulic conductivity than the aquifer average.

C-10.0 REFERENCES

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

Copies of the master reference set are maintained at the New Mexico Environment Department Hazardous Waste Bureau; the U.S. Department of Energy–Los Alamos Site Office; the U.S. Environmental Protection Agency, Region 6; and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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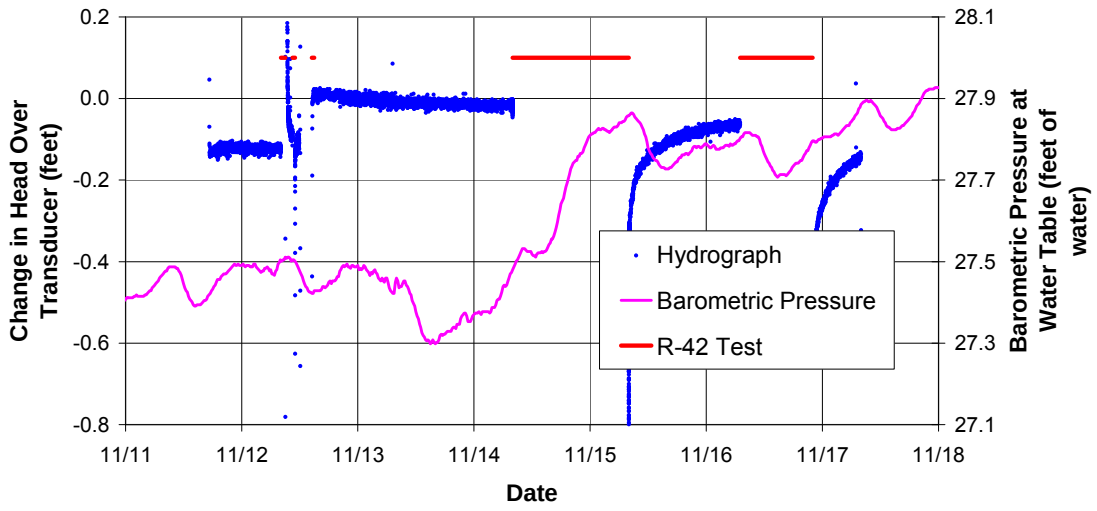

Figure C-7.0-1 Comparison of R-42 apparent hydrograph and adjusted TA-54 barometric pressure

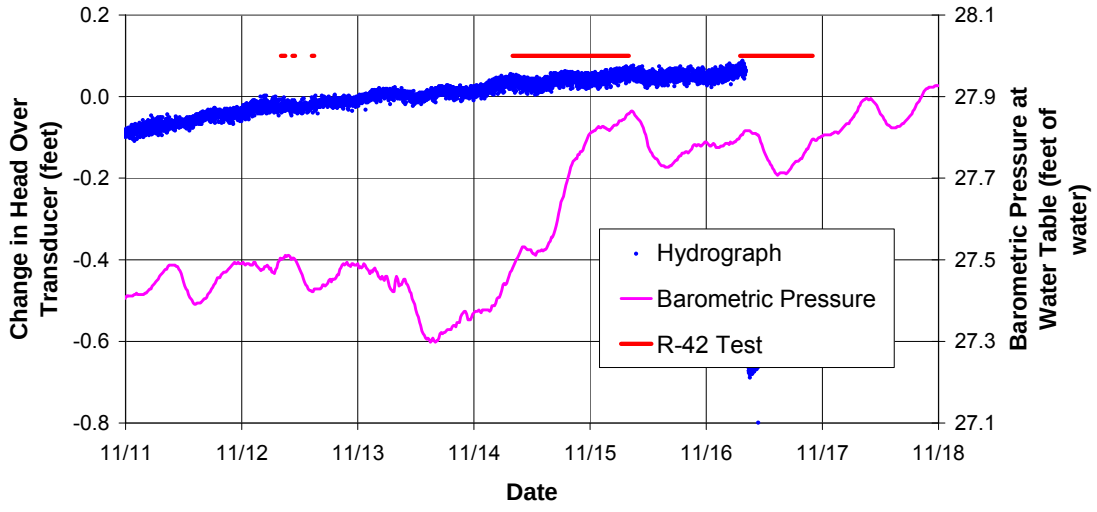

Figure C-7.0-2 Comparison of R-43 screen 1 apparent hydrograph and adjusted TA-54 barometric pressure

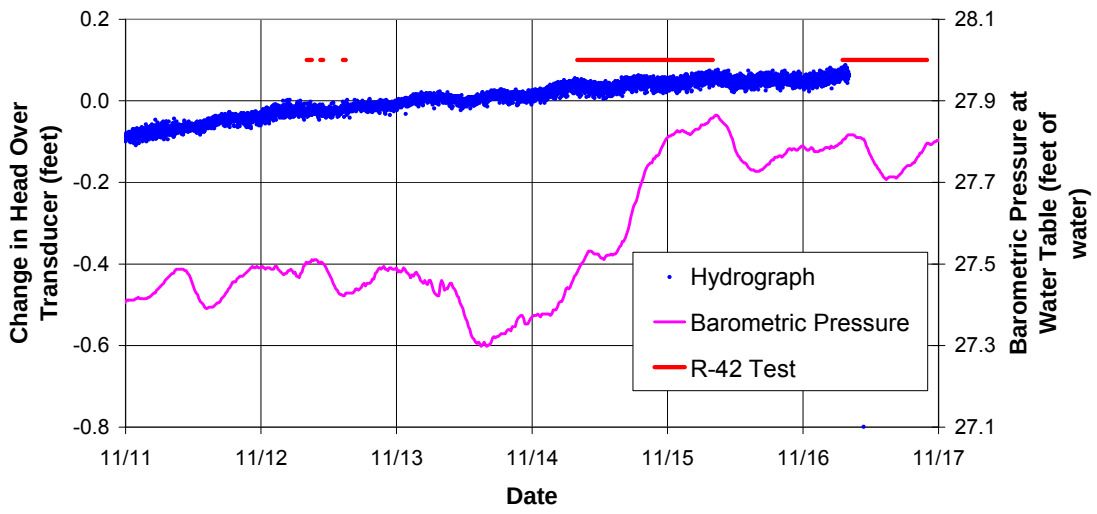

Figure C-7.0-3 Comparison of R-43 screen 2 apparent hydrograph and adjusted TA-54 barometric pressure

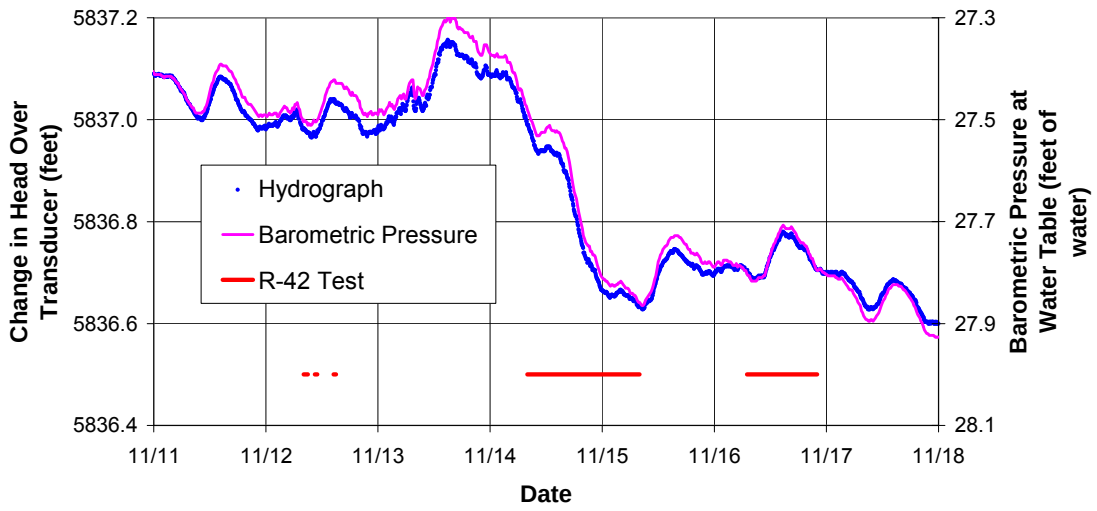

Figure C-7.0-4 Comparison of R-11 hydrograph and adjusted TA-54 barometric pressure

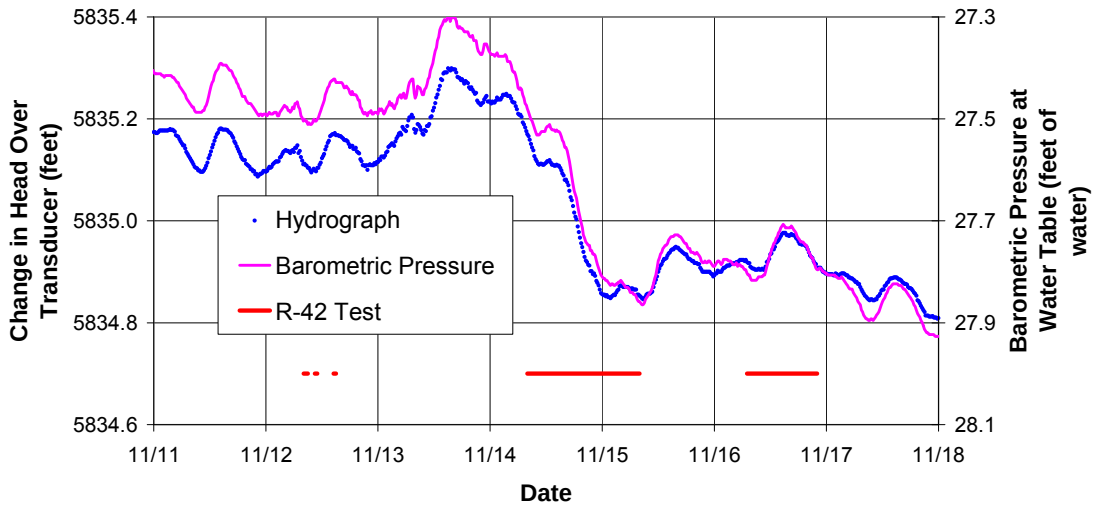

Figure C-7.0-5 Comparison of R-13 hydrograph and adjusted TA-54 barometric pressure

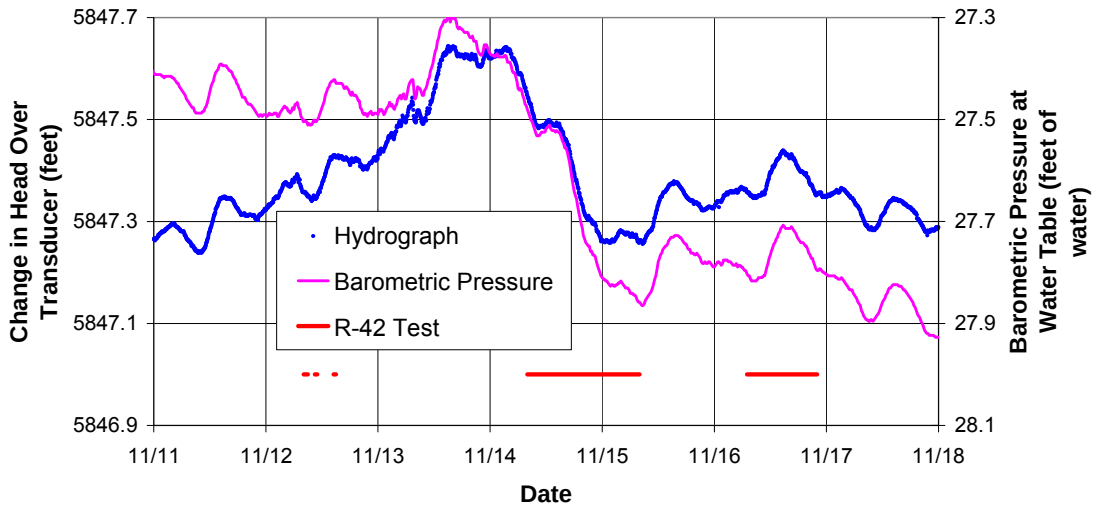

Figure C-7.0-6 Comparison of R-15 hydrograph and adjusted TA-54 barometric pressure

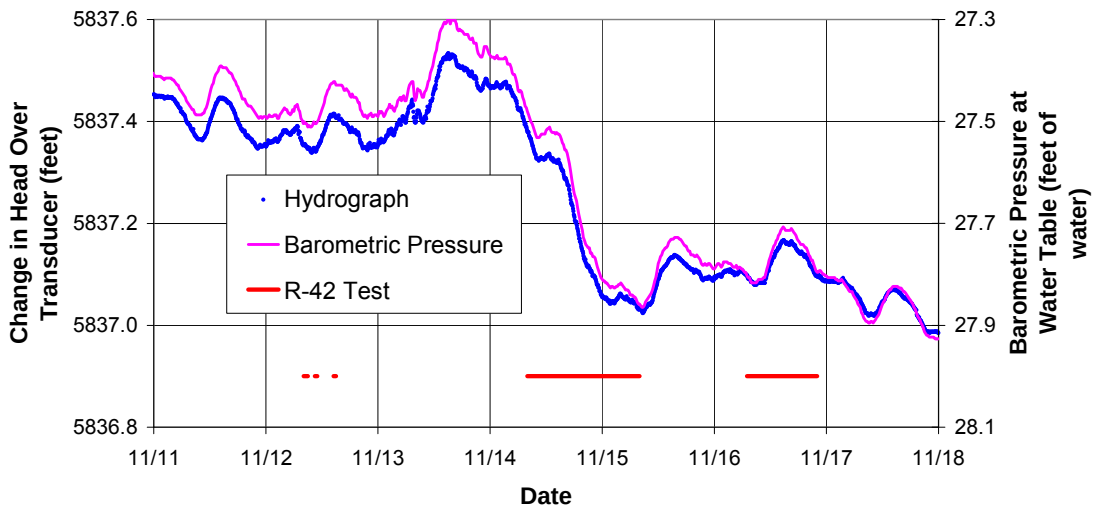

Figure C-7.0-7 Comparison of R-28 hydrograph and adjusted TA-54 barometric pressure

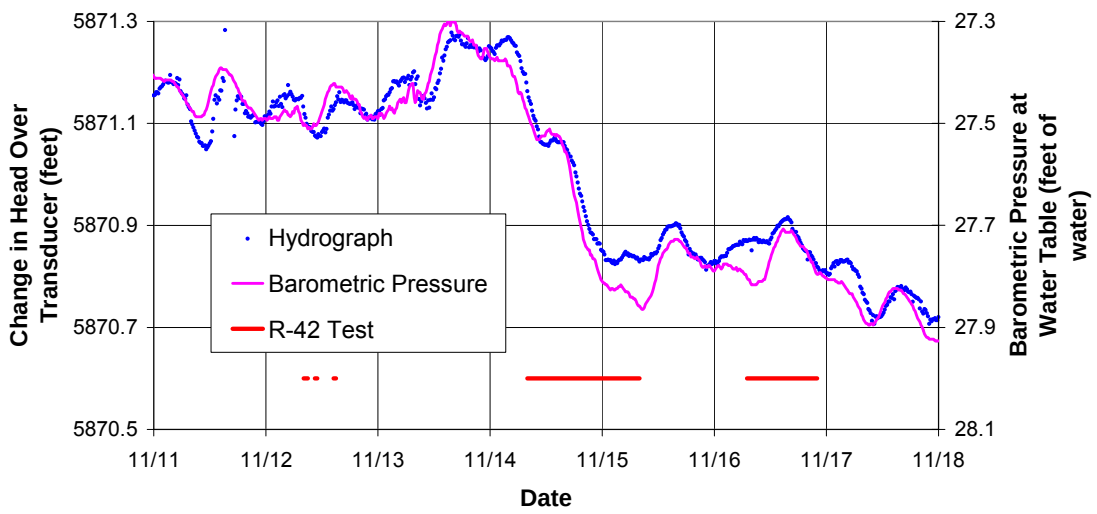

Figure C-7.0-8 Comparison of R-33 screen 1 hydrograph and adjusted TA-54 barometric pressure

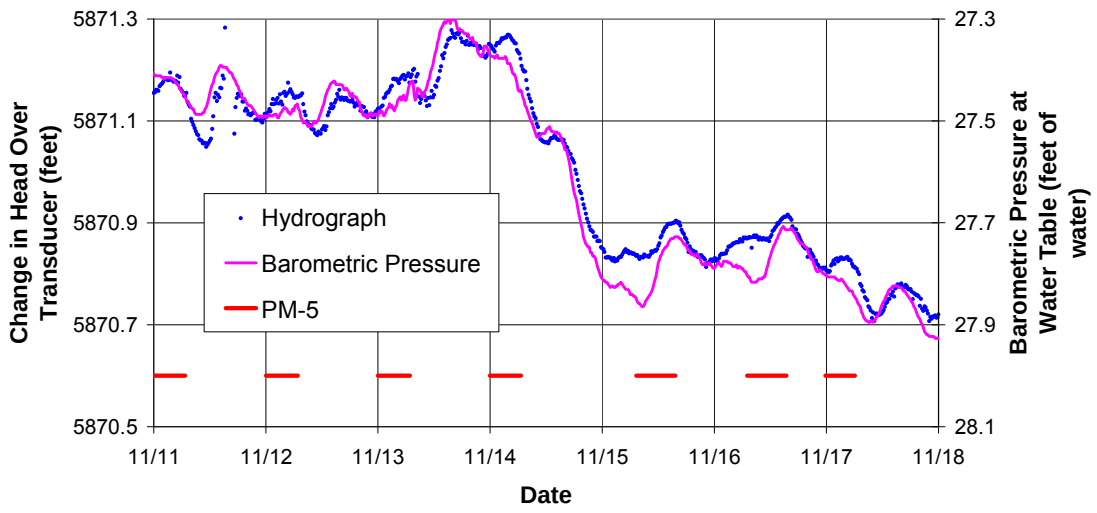

Figure C-7.0-9 Comparison of R-33 screen 1 hydrograph and PM-5 operation

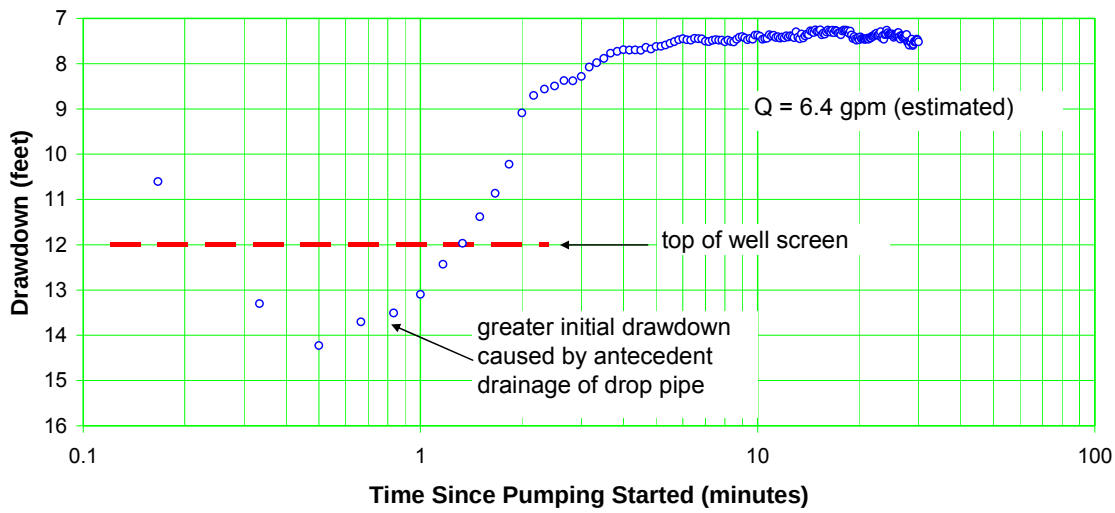

Figure C-8.0-1 Well R-42 trial 1 drawdown

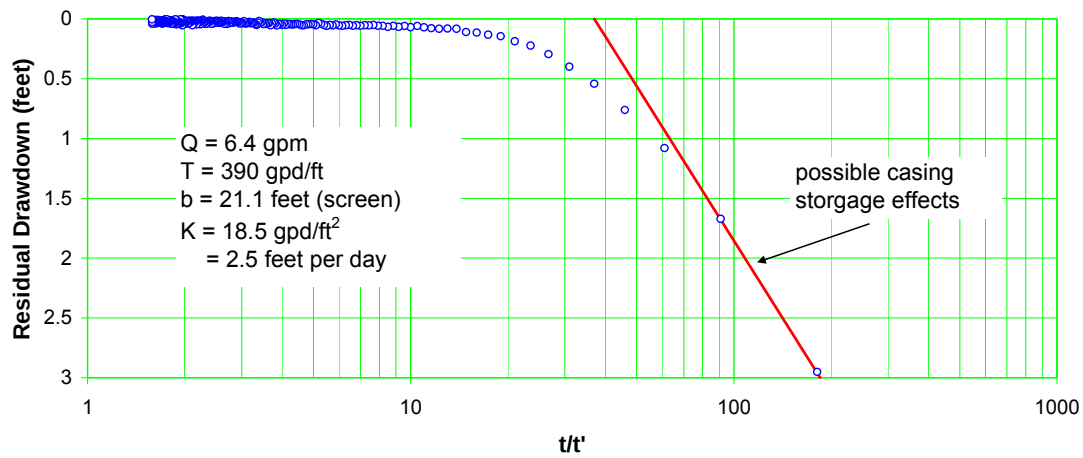

Figure C-8.0-2 Well R-42 trial 1 recovery

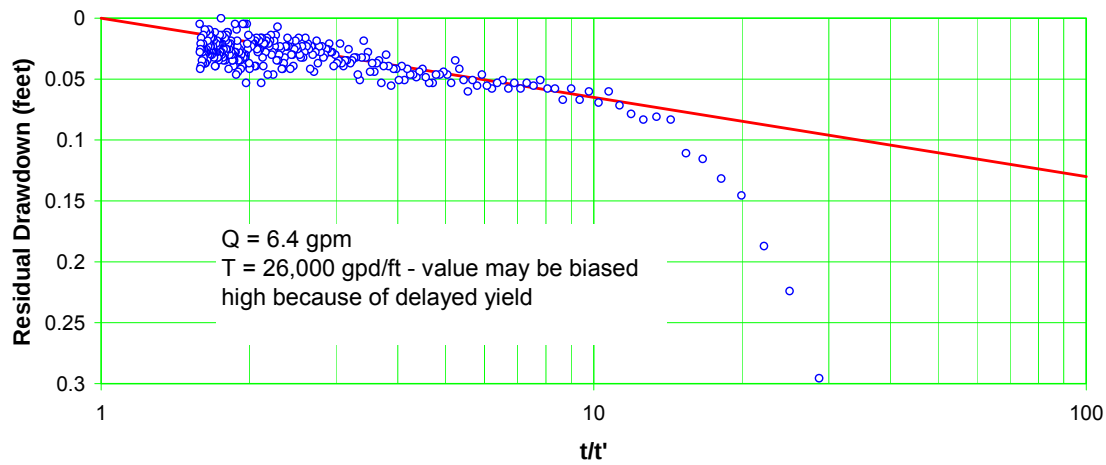

Figure C-8.0-3 Well R-42 trial 1 recovery—late data

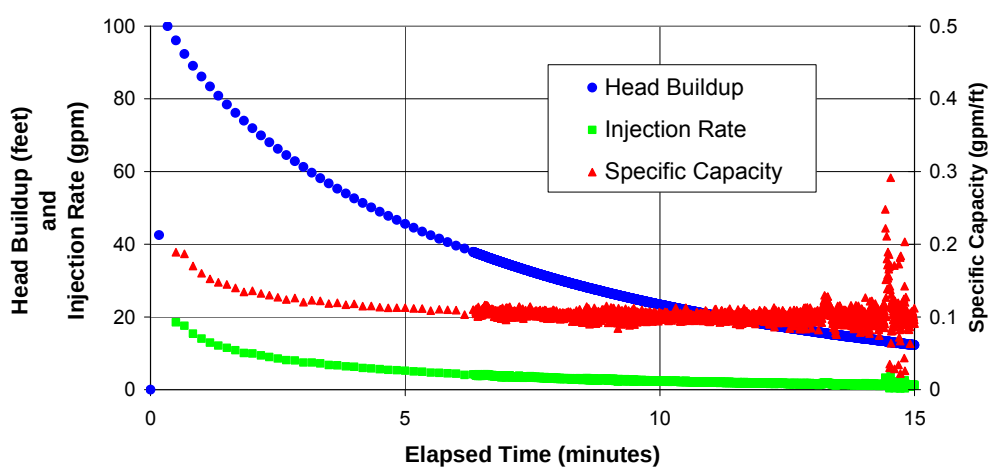

Figure C-8.0-4 Head buildup following trial 1 packer deflation

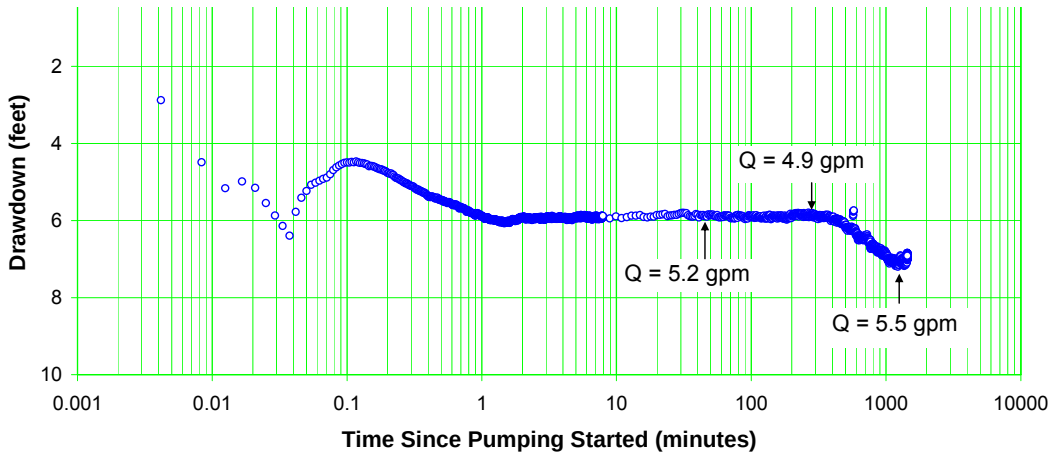

Figure C-8.1-1 Comparison of R-42 drawdown

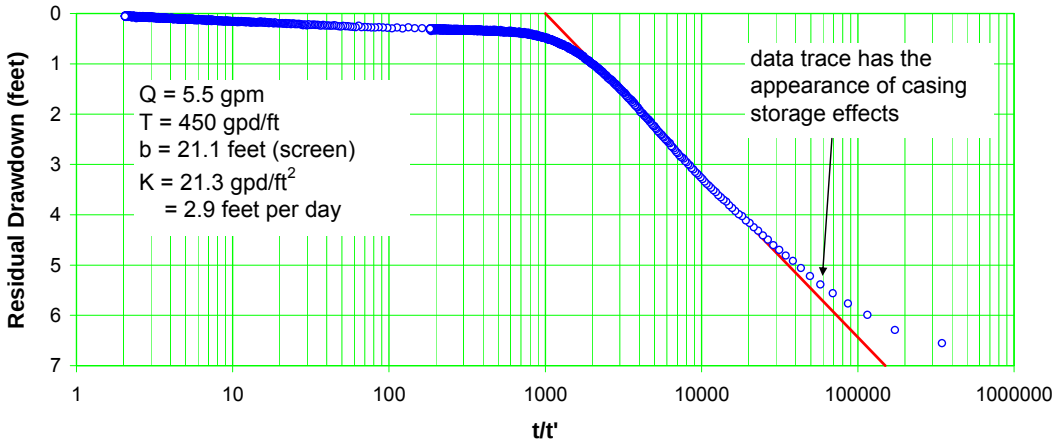

Figure C-8.1-2 Well R-42 recovery—early data

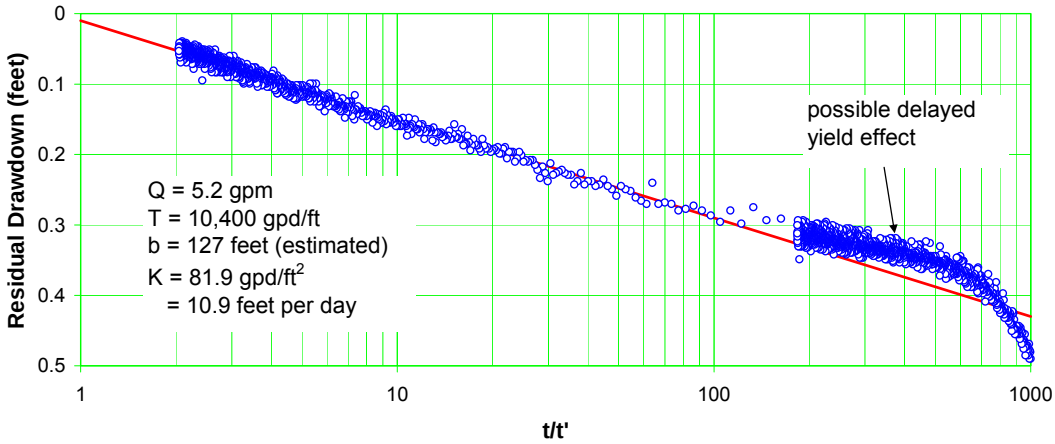

Figure C-8.1-3 Well R-42 recovery—late data

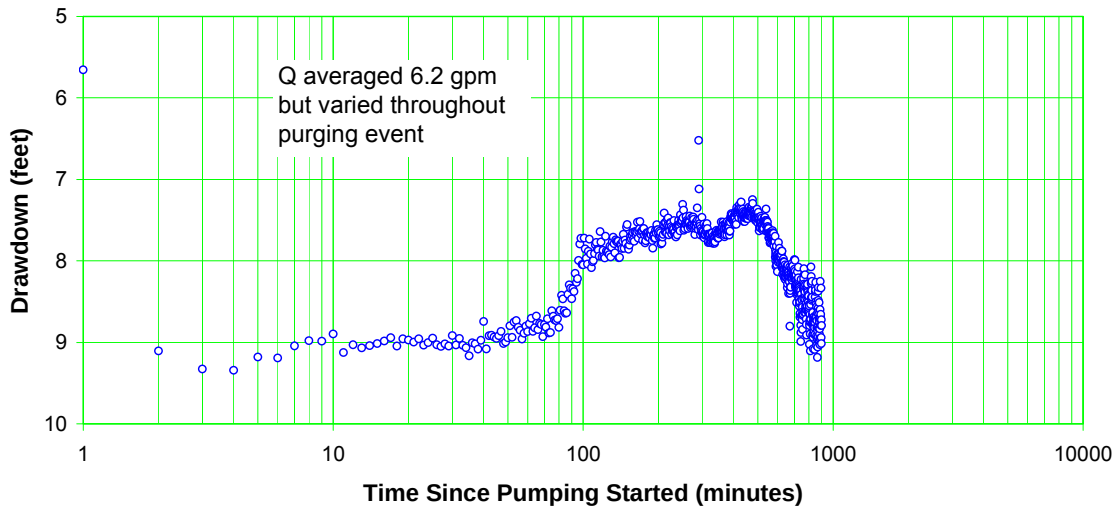

Figure C-8.2-1 Well R-42 purge drawdown

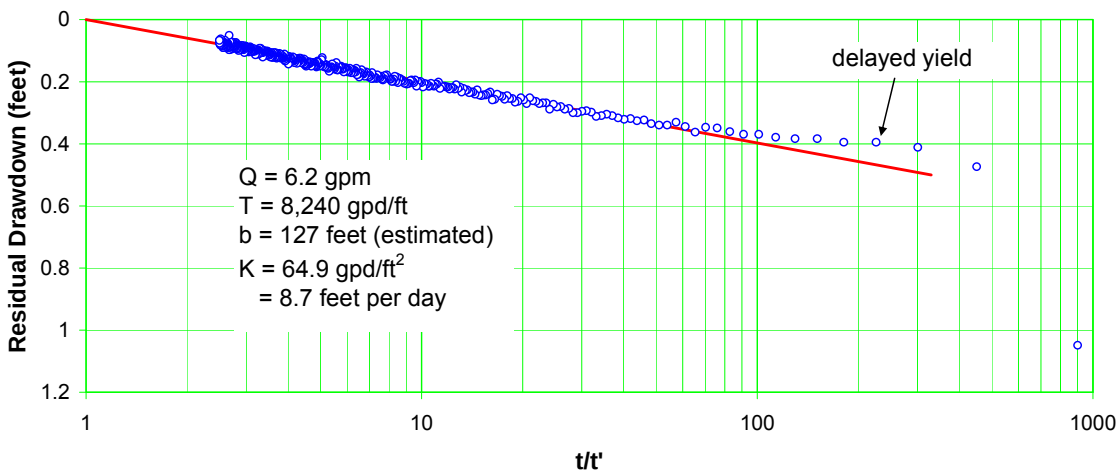

Figure C-8.2-2 Well R-42 purge recovery

Appendix D

July 14, 2008, Borehole Video
(on DVD included with this document)

Appendix E

Los Alamos National Laboratory Geophysical Logs and Schlumberger Geophysical Logging Report (on CD included with this document)