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Completion Report for Regional Aquifer Well R-55

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EXECUTIVE SUMMARY

This well completion report describes the drilling, well construction, development, aquifer testing, and dedicated sampling system installation for regional aquifer well R-55, located in Cañada del Buey, approximately 2000 ft east of Material Disposal Area G, within Los Alamos National Laboratory (LANL or the laboratory) Technical Area 54 (TA-54) in Los Alamos County, New Mexico. The R-55 monitoring well is intended to provide hydrogeologic and groundwater quality data to achieve specific data quality objectives consistent with the Groundwater Protection Program for the Laboratory, the Compliance Order on Consent (March 2005, revised 2008), and the New Mexico Environment Department– (NMED-) approved drilling work plan.

The R-55 monitoring well borehole was drilled using dual-rotary air-drilling methods. Fluid additives used included potable water and foam. Foam-assisted drilling was used only to a depth of 682 ft below ground surface (bgs), approximately 100 ft above the anticipated regional aquifer.

The following geologic formations were encountered at R-55: alluvium, the Tshirege Member of the Bandelier Tuff, the Otowi Member ash flows of the Bandelier Tuff, the Guaje Pumice Bed of the Otowi Member, the Puye Formation, the Cerros del Rio volcanic series, the Totavi Lentil of the Puye Formation, and the Chamita Formation. R-55 was drilled to a total depth of 1035.2 ft bgs.

Well R-55 was completed as a dual-screen well, allowing evaluation of water quality and water levels at two discrete depth intervals within the regional aquifer. The upper 20-ft-long screened interval is set between 860.0 and 880.6 ft bgs near the bottom of the Puye Formation, while the lower 20-ft-long screened interval is set between 994.4 and 1015.4 ft bgs within the Chamita Formation. The composite depth to water before well installation was 843.5 ft bgs. The well screens are separated by a packer to ensure isolation of the screened intervals.

The well was completed in accordance with an NMED-approved well design. The well was thoroughly developed and target water quality parameters were met at both screened intervals. Aquifer testing indicates both screened intervals at monitoring well R-55 are productive and will perform effectively to meet the planned objectives. A sampling system and transducers will be placed in the upper and lower screened intervals, and groundwater sampling at R-55 will be performed as part of the facility-wide groundwater monitoring program.

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Acronyms and Abbreviations

amsl	above mean sea level
ASTM	American Society for Testing and Materials
bgs	below ground surface
Consent Order	Compliance Order on Consent
DO	dissolved oxygen
DTW	depth to water
EES-14	Earth and Environmental Sciences Group 14
Eh	oxidation-reduction potential
EP	Environmental Programs Directorate
gpd	gallons per day
gpm	gallons per minute
hp	horsepower
I.D.	inside diameter
LANL	Los Alamos National Laboratory
LH3	low-level tritium
MDA	material disposal area
mV	millivolt
NAD	North American Datum
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
O.D.	outside diameter
ORP	oxidation-reduction potential
PVC	polyvinyl chloride
Qal	Quaternary alluvium
Qbo	Otowi Member of the Bandelier Tuff
Qbog	Guaje Pumice Bed of Otowi Member of the Bandelier Tuff
Qbt	Tshirege Member of the Bandelier Tuff
RPF	Records Processing Facility
SOP	standard operating procedure
TA	technical area
Tb 4	Cerros del Rio volcanic series
Tcar	Chamita Formation
TD	total depth

TOC	total organic carbon
Tpf	Puye Formation
Tpt	Totavi Lentil of the Puye Formation
VOC	volatile organic compound
WCSF	waste characterization strategy form
WES-EDA	Waste and Environmental Services Division–Environmental Data and Analysis
wt%	weight percent

1.0 INTRODUCTION

This completion report summarizes borehole drilling, well construction, well development, aquifer testing, and planned dedicated sampling system installation for regional aquifer well R-55. The report is written in accordance with the requirements in Section IV.A.3.e.iv of the March 1, 2005 (revised 2008), Compliance Order on Consent (the Consent Order). The R-55 monitoring well borehole was drilled from May 9 to June 29, 2010, and completed from July 28 to August 25, 2010, at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Directorate.

Well R-55 is located in Cañada del Buey, east of Material Disposal Area (MDA) G, within the Laboratory's Technical Area 54 (TA-54) in Los Alamos County, New Mexico (Figure 1.0-1). R-55 was installed to satisfy a requirement by the New Mexico Environment Department (NMED) for a dual-screen monitoring well in the uppermost part of the regional groundwater aquifer downgradient of MDA G at the eastern end of TA-54. Secondary objectives were to establish water levels and flow characteristics in the regional aquifer, to collect drill-cutting samples, and to conduct borehole geophysical logging.

The R-55 borehole was drilled to a total depth (TD) of 1035.2 ft below ground surface (bgs). During drilling, cuttings samples were collected at 5-ft intervals in the borehole from ground surface to TD. The monitoring well was installed with two screens. The upper 20-ft-long screened interval is between 860.0 and 880.6 ft bgs in the Puye Formation, and the lower 20-ft-long screened interval is between 994.4 and 1015.4 ft bgs in the Chamita Formation. The composite depth to water (DTW) before well installation and well development was recorded on June 30, 2010, at 843.5 ft bgs. A dedicated sampling system will be installed with an inflatable packer isolating the two well screens. The dedicated sampling system will allow discrete sampling and water-level monitoring of both screened intervals. Water-level transducers will be placed in the upper and lower screened intervals to evaluate hydraulic relationships between this well and other nearby wells.

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

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the Laboratory's Records Processing Facility (RPF). This report contains brief descriptions of activities and supporting figures, tables, and appendices associated with the R-55 project. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to the NMED in accordance with U.S. Department of Energy policy.

2.0 PRELIMINARY ACTIVITIES

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

2.1 Administrative Preparation

The following documents helped guide the implementation of the scope of work for the R-55 project:

- "Drilling Work Plan for Regional Aquifer Well R-55" (LANL 2010, 109616);
- "Drilling Plan for Regional Aquifer Well R-55" (TerranearPMC 2010, 109941);
- "Integrated Work Document for Regional and Intermediate Aquifer Well Drilling (Mobilization, Site Preparation and Setup Stages)" (LANL 2007, 100972);
- "Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan" (LANL 2006, 092600);
- "Waste Characterization Strategy Form for Regional Wells R-56 and R-57 at TA-54, Regional Well Installation and Corehole Drilling" (LANL 2010, 108753); and
- "Amendment #1 to the Waste Characterization Strategy Form (WCSF) for Regional Wells R-56 and R-57 at TA-54 (EP2010-0085)" (LANL 2010, 109431).

2.2 Site Preparation

Site preparation and access road construction were performed by Laboratory personnel before rig mobilization. The drill rig, air compressors, trailers, and support vehicles were mobilized to the drill site on May 7, 2010. Staging of alternative drilling tools and construction materials occurred at the Pajarito Road lay-down yard.

All potable water was obtained from a fire hydrant on East Jemez Road. 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 approach and provides a chronological summary of field activities conducted at monitoring well R-55.

3.1 Drilling Approach

The drilling method and selection of equipment and drill-casing sizes for the R-55 monitoring well were designed to retain the ability to investigate and case off any perched groundwater encountered above the regional aquifer. Further, the drilling approach ensured that a sufficiently sized drill casing was used to meet the required 2-in.-minimum annular thickness of the filter pack around a 5.56-in.-outside-diameter (O.D.) well casing.

Dual-rotary air-drilling methods using a Foremost DR-24HD drill rig were employed to drill the R-55 borehole. Dual-rotary drilling has the advantage of simultaneously advancing and casing the borehole. The Foremost DR-24HD drill rig was equipped with conventional drilling rods, tricone bits, downhole hammer bits, a deck-mounted air compressor, and general drilling equipment. Auxiliary equipment included two Ingersoll Rand trailer-mounted air compressors. Three sizes of A53 grade B flush-welded mild carbon-steel casing (16-in.-, 12-in.-, and 10-in.-inside diameter [I.D.]) were used for the R-55 project.

The dual-rotary technique at R-55 used filtered compressed air and fluid-assisted air to evacuate cuttings from the borehole during drilling. Drilling fluids, other than air, used in the borehole (all within the vadose zone) included potable water and a mixture of potable water with Baroid AQF-2 foaming agent. The fluids were used to cool the bit and help lift cuttings from the borehole. Use of the foaming agent was terminated at 682 ft bgs, roughly 100 ft above the expected top of the regional aquifer. No additives other than potable water were used for drilling below 682 ft bgs. The total amounts of drilling fluids introduced into the borehole are presented in Table 3.1-1.

3.2 Chronological Drilling Activities for the R-55 Well

Mobilization of drilling equipment and supplies to the R-55 drill site occurred on May 7, 2010. Decontamination of the equipment and tooling was performed before mobilization to the site. On May 9, following on-site equipment inspections, the monitoring well borehole was initiated at 1255 h using dual-rotary methods with 16-in. drill casing and a 14.75-in. tricone bit.

Drilling and advancing 16-in. casing proceeded through canyon-bottom alluvium, the Tshirege Member of the Bandelier Tuff, the Otowi Member ash flows of the Bandelier Tuff, the Guaje Pumice Bed, and the Puye Formation. Drilling continued to 82 ft bgs where the 16-in. drill casing was landed in the upper 2 ft of the Cerros del Rio volcanic series on May 10. No indications of groundwater were observed while the 16-in. casing was advanced.

On May 20, open-hole drilling commenced using a 15-in. hammer bit. Drilling proceeded through thin, fractured basaltic lava flows to 220 ft bgs. Loose and unstable conditions in the basalt necessitated cementing to gain stability and help with circulation. A video log was run by the drilling subcontractor in the open portion of the borehole on May 22. The borehole was cemented from 220 to 61 ft bgs using a total of 16.5 yd^3 of sand grout (Portland cement with a minor amount of silica sand) on May 22 and 23 and again after the Memorial Day holiday break, on June 1. Open-hole drilling continued on June 2 through the basaltic tephra and basaltic lava flows of the Cerros del Rio volcanic series to 300 ft bgs, where circulation was lost and unstable conditions were encountered. The borehole was cemented from 300 to 204 ft bgs using 9 yd^3 of sand grout on June 4. Open-hole drilling continued on June 4 and 5 to 565 ft bgs. Mixed volcaniclastic and quartzo-feldspathic sediments were encountered at 540 ft bgs.

On June 6, perched groundwater was identified by the drilling crew while cleaning slough from the borehole at approximately 565 ft bgs, and the perched water was sampled. Laboratory personnel logged the open borehole with video, natural gamma, and induction tools on June 7 to a depth of 545 ft bgs and the top of the perched water was measured at 499.7 ft bgs.

The 16-in. casing shoe was cut off on June 8 at 77 ft bgs. On June 9, 12-in. drill casing was started into the borehole. The 12-in. casing string was advanced through slough in the bottom of the borehole to 568 ft bgs on June 12. On June 13, the water inside the casing was airlifted with the bottom of the casing at 568 ft bgs. After 15 min, the discharge was dry, indicating the casing was below the perched aquifer and sealed by the surrounding formation. A bentonite seal (18 ft^3 of ¼-in. coated pellets) was poured into the casing while the casing was retracted to 540 ft bgs. A tricone bit was then used to readvance the casing through the bentonite seal and a layer of clay (565 to 605 ft bgs) below the perched aquifer. On June 14, lava was again encountered below the clay layer at 605 ft bgs. The tricone bit was removed, and an underreaming hammer bit was used to advance the casing through the remainder of the lava and into Totavi Lentil sediments to a depth of 835 ft bgs. The underreaming hammer bit was removed because of soft drilling conditions, and a tricone bit was used to advance 12-in. casing below 835 ft bgs.

On June 19, the 12-in. casing became difficult to rotate, possibly because of swelling of the clay interval between approximately 565 and 605 ft bgs. Drilling continued to 845 ft bgs and the casing continued to become tighter in the borehole. The driller reported the conditions were such that it was unlikely the anticipated TD of 1000 ft bgs would be reached with the 12-in. casing, and 10-in. casing would be necessary to finish the borehole. At this point in the drilling operation, there was no evidence that regional groundwater had been encountered. After the tool string was removed in preparation for cutting the 12-in. casing, multiple water-level measurements were recorded, indicating the top of the aquifer was located at a depth of approximately 834.5 ft bgs. Some uncertainty existed at the time regarding the validity of this measurement and whether it was indeed the top of the aquifer or if it was drilling water. To better determine if the regional aquifer had been reached and to mitigate any potential connectivity between the perched intermediate water and the regional aquifer, an attempt was made to retract 20 ft of the 12-in. casing string. Several attempts to retract the 12-in. casing resulted in the extraction of 5.1 ft of casing before the 12-in. casing string stopped moving altogether. The decision was made to cut the casing just below the top of the clay interval so at least the upper half of the 12-in. casing string could be removed during well installation. The 12-in. casing was cut on June 21 at a depth of 570 ft bgs, approximately 5 ft below the top of the clay interval. The bottom of the 12-in. casing was located at a depth of 839.4 ft bgs. Starting on June 21, 10-in. casing was hung in the borehole.

The 10-in. casing was advanced from 842 to a TD of 1035.2 ft bgs using a 9.75-in. tricone bit between June 21 and 29. On June 29, Laboratory personnel ran a natural gamma log of the borehole. The 10-in. casing shoe was cut at 1025 ft bgs on June 30 and the composite DTW was measured at 843.5 ft bgs.

During drilling, field crews worked 12-h shifts, 7 d/wk. Operations were suspended between May 24 and June 1 for the Memorial Day holiday break. All associated activities proceeded normally without incident or delay.

4.0 SAMPLING ACTIVITIES

This section describes the cuttings and groundwater sampling activities for monitoring well R-55. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-55 monitoring well borehole at 5-ft intervals from ground surface to the TD of 1035.2 ft bgs. At each interval, approximately 500 mL of bulk cuttings was collected by the site geologist from the drilling discharge cyclone, placed in resealable plastic bags, labeled, and archived in core boxes. Sieved fractions (>#10 and >#35 mesh) were also collected from ground surface to TD and placed in chip trays along with unsieved (whole rock) cuttings. Radiation control technicians screened the cuttings before removal from the site. All screening measurements were within the range of background values. The core boxes and chip trays were delivered to the Laboratory's archive at the conclusion of drilling activities.

The stratigraphy of R-55 is summarized in section 5.1, and a detailed lithologic log is presented in Appendix A.

4.2 Water Sampling

A groundwater sample was collected from the drilling discharge at 550 ft bgs, within the perched intermediate aquifer. The sample was collected after the bottom of a 20-ft run of casing was reached, where the driller stopped water circulation and circulated air. As the discharge cleared, the water sample was collected directly from the discharge cyclone and analyzed for anions, cations, metals, volatile organic compounds (VOCs), and low level tritium (LH3). Table 4.2-1 presents a summary of screening samples collected during the R-55 monitoring well installation. Groundwater chemistry and field water-quality parameters are discussed in Appendix B.

Each screened interval was sampled once during well development from the development pump's discharge line. The development samples were analyzed only for total organic carbon (TOC). Additionally, nine groundwater-screening samples were collected during aquifer testing from the pump's discharge line and analyzed for TOC only.

Groundwater characterization samples will be collected from the completed well in accordance with the Consent Order. For the first year, the samples will be analyzed for the full suite of constituents, including radioactive elements; anions/cations; general inorganic chemicals; VOCs and semivolatile organic compounds; and stable isotopes of hydrogen, nitrogen, and oxygen. The analytical results will be included in the appropriate periodic monitoring report issued by the Laboratory. After the first year, the analytical suite and sample frequency at R-55 will be evaluated and presented in the annual "Interim Facility-Wide Groundwater Monitoring Plan."

5.0 GEOLOGY AND HYDROGEOLOGY

A brief description of the geologic and hydrogeologic features encountered at R-55 is presented below. The Laboratory's geology task leader and project site geologist 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-55.

5.1 Stratigraphy

Rock units for the R-55 borehole are presented below in order of youngest to oldest in stratigraphic occurrence. Lithologic descriptions are based on binocular microscope analysis of drill cuttings collected from the discharge hose. Figure 5.1-1 illustrates the stratigraphy at R-55. A detailed lithologic log for R-55 is presented in Appendix A.

Quaternary Alluvium, Qal (0–12 ft bgs)

Thin Quaternary alluvium mixed with base-course gravel from drill pad construction was encountered from 0 to 12 ft bgs. The alluvium consists of unconsolidated, poorly sorted gravel and sand and is composed of vitric nonwelded tuffaceous detritus. No evidence of alluvial groundwater was observed.

Unit 1g, Tshirege Member of the Bandelier Tuff, Qbt 1g (12–40 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff was encountered from 12 to 40 ft bgs and is locally about 28 ft thick. Unit 1g is a poorly welded to welded rhyolitic ash-flow tuff that is poorly to moderately indurated, strongly pumiceous, and crystal-bearing. White to pale orange, lustrous, glassy pumice lapilli that are quartz- and sanidine-phyric are characteristic of Unit 1g. Cuttings contain minor fragments of abundant free quartz and sanidine crystals and minor small (up to 10 mm) volcanic (predominantly dacitic) lithic inclusions.

Otowi Member of the Bandelier Tuff, Qbo (40–43 ft bgs)

The Otowi Member ash flows of the Bandelier Tuff, estimated to be 3 ft thick, were encountered from 40 to 43 ft bgs. The Otowi Member ash flow deposit is a poorly welded rhyolitic ash-flow tuff that is pumiceous, crystal- and lithic-bearing. Typically abundant pumice lapilli are white, glassy, lustrous, and quartz- and sanidine-phyric. Qbo drill cuttings contain white glassy pumices, volcanic lithic clasts (up to 10 mm) and quartz and sanidine crystals. Lithic fragments, representing tuff-hosted xenoliths, are commonly subangular to subrounded and generally of intermediate volcanic composition, including porphyritic dacites and andesites.

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (43–54 ft bgs)

The Guaje Pumice Bed represents an air-fall tephra deposit of rhyolitic pumice that forms the base of the Otowi Member. The Guaje deposit, encountered from 43 to 54 ft bgs, is estimated to be 11 ft thick. Drill cuttings in this interval contain abundant (up to 95% by volume), lustrous, vitric pumice lapilli (up to 15 mm in diameter) with trace occurrences of small volcanic lithic fragments. The deposit is nonwelded and unconsolidated.

Puye Formation, Tpf (54–80 ft bgs)

Puye Formation volcaniclastic sediments were encountered from 54 to 80 ft bgs. The deposits in this interval are light brown, fine-grained, quartz-dominated sandstones and siltstones, including glassy volcanic clasts and sanidine crystals. Sand-sized volcanic clasts are typically subangular to subrounded, and fine quartz grains are subrounded to well rounded. Sandstones and siltstones are well cemented.

Cerros del Rio Volcanic Series, Tb 4 (80–685 ft bgs)

Cerros del Rio volcanic rocks, encountered in R-55 from 80 to 685 ft bgs, form a complex sequence that includes both massive and vesicular basaltic lavas, basaltic scoria deposits, and glassy volcanic breccias and tephras interpreted as phreatomagmatic eruption products. The sequence at R-55 also includes reworked volcanic sediments mixed with quartzo-feldspathic sediments and a 40-ft-thick clay bed. The sequence has a cumulative thickness of about 605 ft. The upper 40-ft interval, from 80 to 120 ft bgs, consists of massive olivine-phyric basalt lava flows. From 120 to 220 ft bgs, the basalt is more vesicular and partially oxidized, suggesting multiple thin lava flows and scoria deposits. Basalts in this sequence are generally porphyritic with phenocrysts (up to 5% by volume) of olivine and plagioclase enclosed in an aphanitic groundmass. Massive medium dark gray basalt was encountered from 220 to 245 ft bgs, and oxidized vesicular basalt scoria was encountered from 245 to 270 ft bgs. The interval from 270 to 390 ft bgs contains alternating basalt cinder and mixed vesicular and massive basalt fragments. This 120-ft section represents alternating thin basalt lava flows and scoria deposits and also contains pale orange claystone layers interpreted to be sediments deposited between flows. No samples were collected from 300 to 325 ft bgs because circulation was lost in a large scoria zone. Oxidized basaltic cinders were encountered on both sides of this missing interval. From 350 to 505 ft bgs, basalt chips from massive olivine-bearing lava flows were collected. Phreatomagmatic tephra, glassy basalt, and dark gray glassy volcanic breccias were encountered from 505 to 540 ft bgs. These deposits also contain rounded sedimentary quartz grains and quartzites entrained during eruption.

A section of mixed volcaniclastic and quartzo-feldspathic sediments was encountered below the phreatomagmatic deposits from 540 to 605 ft bgs. Gravels and sands similar to the Puye Formation extend from 540 to 565 ft bgs and are composed of clasts (up to 10 mm) of various volcanic lithologies (dacites, massive basalts, glassy basalts) and Precambrian quartzites. The abundance of quartzite increases down section. No samples were recovered from 565 to 575 ft bgs. Below the gravels, from 565 to 605 ft bgs, 40 ft of light brown to gray clay beds was encountered. The clays locally contain quartz and sanidine grains.

The lower 80 ft of the Cerros del Rio volcanic series from 605 to 685 ft bgs is characterized by mixed massive and vesicular olivine-bearing lava flows with few phenocrysts. Whole-rock x-ray fluorescence analyses of two samples in this sequence indicate these lavas are basaltic trachyandesites. This interval also includes small percentages (<5%) of pale orange ashy claystone, representing sedimentary deposits between individual lava flows.

Totavi Lentil of the Puye Formation, Tpt (685–890 ft bgs)

Totavi Lentil clastic sediments were encountered from 685 to 890 ft bgs. These poorly sorted, heterogeneous deposits are fine to coarse gravels with silty fine- to coarse-grained sandstones. The subrounded to well-rounded gravels are largely composed of Precambrian quartzite and granite with varying amounts of subrounded to rounded intermediate to mafic lava clasts. A 25-ft-thick silt- and clay-rich zone was encountered within the gravels from 755 to 780 ft bgs.

Chamita Formation, Tcar (890–1035.2 ft bgs)

Chamita Formation sediments were encountered from 890 ft bgs to the bottom of the R-55 borehole at 1035.2 ft bgs. These deposits consist of interstratified fine-grained sugar sands of quartz and microcline, silty sands, well-rounded volcanic lithic sands, and rounded intermediate volcanic gravels with up to 3% Precambrian quartzite. From 955 ft bgs to the bottom of the borehole, the gravels are dominated by abundant mixed volcanic clasts including rhyolites, porphyritic dacites, basalts, and andesites. Gravel and sand-sized white pumice clasts (up to 35%) were encountered at 990 ft bgs, but the amounts decreased with depth.

5.2 Groundwater

A zone of perched water was encountered from 499 ft bgs to approximately 565 ft bgs while drilling within the Cerros del Rio volcanic series. The water level was measured at 499 ft bgs in a video log from June 7 and five times with a water-level meter between June 7 and 12. The perched zone is within phreatomagmatic deposits and gravelly sediments from 500 to 565 ft bgs. The bottom of the perched aquifer is likely sealed by clay beds below 565 ft bgs. Casing was advanced through a 28-ft-thick bentonite seal placed at the bottom of the perched aquifer to prevent the perched groundwater from affecting the regional aquifer.

Casing advance drilling proceeded below the perched aquifer without any groundwater indications until 845 ft bgs, where the regional groundwater was subsequently measured at 834.5 ft bgs. The composite DTW at the beginning of well development was 834.4 ft bgs.

6.0 BOREHOLE LOGGING

One video log, one induction log, and two gamma ray logs were collected during the R-55 drilling project using Laboratory-owned equipment. A video log was also collected using the drilling subcontractor’s camera. A summary of video and geophysical logging runs is presented in Table 6.0-1.

6.1 Video Logging

A video log from surface to 200 ft bgs was made in the R-55 borehole with the drilling subcontractor’s equipment on May 22, 2010, to investigate a fractured basalt section before the borehole was cemented.

The second video log was run in the R-55 borehole on June 7, 2010, from ground surface to 545.0 ft bgs. The video recorded a water level at 499 ft bgs. The video logs are presented on a DVD as Appendix D included with this document.

6.2 Geophysical Logging

Natural gamma ray and induction surveys were collected on June 7, 2010, between ground surface and 545 ft bgs to document conditions in the open portion of the borehole before 12-in. casing was installed.

A final natural gamma ray survey was obtained on June 29, 2010, from ground surface to 1035.2 ft bgs inside the drill casing before well construction. Geophysical logging data are presented on CD as part of Appendix E included with this document.

7.0 WELL INSTALLATION R-55 MONITORING WELL

The R-55 well was installed between July 28 and August 25, 2010.

7.1 Well Design

The R-55 well was designed in accordance with the Consent Order. NMED approved the well design before installation. The well was designed with an upper screened interval between 860.0 and 880.6 ft bgs and a lower screened interval between 994.4 and 1015.4 ft bgs. The R-55 well was designed with dual screens to monitor groundwater quality near the top of the regional aquifer within the Puye Formation and deeper in the regional aquifer within the Chamita Formation. The final well design, the Laboratory’s request for approval, and NMED’s concurrence are included in Appendix F.

7.2 Well Construction

The R-55 monitoring well was constructed of 5.0-in.-I.D./5.56-in.-O.D., type A304 passivated stainless-steel threaded casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. Screened sections utilized four 10-ft lengths of 5.0-in.-I.D. rod-based 0.020-in. wire-wrapped screens to make up the 20-ft-long upper and lower well screen intervals. Compatible external stainless-steel couplings (also type A304 stainless steel fabricated to ASTM A312 standards) were used to join all individual casing and screen sections. The coupled unions between threaded sections were approximately 0.7 ft long. All casing, couplings, and screens were steam and pressure washed on-site before installation. A 2-in.-I.D. threaded/coupled steel tremie pipe (decontaminated before use) was utilized to deliver backfill and annular fill materials downhole during well construction. Short lengths of 10-in. drill casing (1025 to 1035.2 ft bgs), 16-in. drill casing (77 to 82 ft bgs), and 12-in. drill casing (570 to 839.4 ft bgs) remain in the borehole. The 10-in. casing stub was encased in slough, and the 16-in. casing stub was encased in the upper bentonite seal during well completion. The lower 261.5 ft of 12-in. casing length was filled with bentonite; the upper 7.9 ft was encased in an intermediate cement below the perched aquifer.

A 5.6-ft-long stainless-steel sump was placed below the bottom of the lower well screen. Stainless-steel centralizers (four sets of four) were welded to the well casing approximately 2.0 ft above and below each screen. A Pulstar work-over rig was used for all well construction activities. Figure 7.2-1 presents an as-built schematic showing construction details for the completed well.

Decontamination of the stainless-steel well casing, screens, and tremie pipe along with mobilization of the Pulstar work over rig and initial well construction materials to the site took place from July 24 to 26, 2010. On July 26 to 27, heaving sands were bailed out of the bottom of the borehole. The 5.0-in.-I.D. well casing was started into the borehole on July 28 at 0750 h. The well casing was hung by wireline with the bottom at 1021 ft bgs.

The installation of annular materials began on July 30 after the bottom of the borehole was measured at 1028.6 ft bgs (approximately 6.6 ft of slough in borehole). From July 30 to July 31, the lower bentonite seal was installed from 1020.7 to 1028.6 ft bgs using 4.0 ft^3 of 3/8-in. bentonite chips.

From July 31 to August 4, the lower filter pack was installed from 990 to 1020.7 ft bgs using 17.5 ft^3 of 10/20 silica sand. The filter pack was then surged to promote compaction. Installation of annular fill material was suspended on August 5 to deploy an inflatable packer inside the well casing, above the lower screen, to isolate the screens during installation of the middle bentonite seal. On August 6, the lower fine sand collar was installed above the lower filter pack from 988.4 to 990.0 ft bgs using 1.0 ft^3 of 20/40 silica sand.

From August 6 to 9, the middle bentonite seal was installed from 891.3 to 988.4 ft bgs above the lower filter pack/sand collar using a combination of 3/8-in. bentonite chips and ¼-in. coated bentonite pellets. Because the formation was heaving, 27.5 ft^3 of bentonite was used for the middle seal, which was 40% less than the calculated volume of 45.6 ft^3. However, the bentonite volume closely matched the calculated volume immediately above the lower transition sand and immediately below the upper filter pack. (Note that the subsequent aquifer pumping test results demonstrate the screens do not respond to one another when pumped, indicating the middle bentonite seal is adequate.) From August 10 to 11, the upper filter pack was installed from 855.2 to 891.3 ft bgs using 18.1 ft^3 of 10/20 silica sand and then surged to promote compaction. On August 11, the inflatable packer was removed from the well casing, and the upper fine sand collar was installed above the upper filter pack from 851.6 to 855.2 ft bgs using 1.0 ft^3 of 20/40 silica sand.

From August 12 to 16, the upper bentonite seal was installed below the perched aquifer from 577.9 to 851.6 ft bgs inside the 12-in. casing using 139.4 ft^3 of 3/8-in. bentonite chips and ¼-in. coated bentonite pellets. On August 17, a cement seal was installed from 577.9 to 565 ft bgs, inside and above the abandoned 12-in. casing and up to the bottom of the perched aquifer. The cement seal consists of 13.4 ft^3 of Portland Type I/II/V cement. From August 18 to August 24, the upper bentonite seal was installed from 59.2 to 577.9 ft bgs using 469.7 ft^3 of 3/8-in. bentonite chips and ¼-in. coated bentonite pellets. The surface seal was installed on August 25 from 2 to 59.2 ft bgs using 93.6 ft^3 of Portland Type I/II/V cement. Installation of the cement surface seal on August 25, at 1635 h, marked the end of well construction. Table 7.2-1 itemizes volumes of all materials used during well construction, and Figure 7.2-1 shows the completed well schematic.

Operationally, well construction proceeded smoothly, 12 h/d, 7 d/wk, from July 28 to August 25, 2010.

8.0 POSTINSTALLATION ACTIVITIES

Following well installation at R-55, the well was developed and aquifer tests were conducted. The wellhead and surface pad were constructed, a geodetic survey was performed, and a dedicated sampling system will be installed. Site restoration activities will be completed following the final disposition of contained drill cuttings and groundwater, per the NMED-approved waste-disposal decision trees.

8.1 Well Development

Well development was conducted between August 28 and September 3, 2010. Initially, both screened intervals were bailed and swabbed to remove formation fines in the filter pack and well sump. Bailing continued until water clarity visibly improved. Final development was then performed with a submersible pump.

The swabbing tool employed was a 4.5-in.-O.D., 1-in.-thick nylon disc attached to a weighted steel rod. The wireline-conveyed tool was drawn repeatedly across the screened interval, causing a surging action across the screen/filter pack. The bailing tool employed was a 4.0-in.-O.D. by 21-ft-long carbon steel bailer with a total capacity of 12 gal. The tool was lowered by wireline and repeatedly filled, withdrawn from the well, and dumped into the cuttings pit. Approximately 737 gal. of composite groundwater was removed during bailing activities. After bailing, a 10-horsepower (hp), 4-in.-diameter Berkeley submersible pump with inflatable packers located above and below the pump was installed in the well for the final stage of well development of each screen.

During the pumping stage of well development, turbidity, temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and specific conductance parameters were measured. In addition, water samples for TOC analysis were collected. The required TOC and turbidity values for adequate well development are less than 2.0 ppm and less than 5 nephelometric turbidity units (NTU), respectively.

Table B-1.2-1 presents a summary of volumes purged during each phase of development as well as measured and calculated water quality parameters.

Upper Screened Interval

On August 30 and August 31, the development pump was used to purge the upper screen from top to bottom in 2-ft increments from 860 to 882 ft bgs. On September 3, the pump intake was set at 857.7 ft bgs with the packers inflated. Purged water from the upper screen interval displayed turbidity values less than 5 NTU. Approximately 8877 gal. of groundwater was purged during development of the upper screen.

Lower Screened Interval

On August 31, the development pump was used to purge the lower screen from top to bottom in 2 ft increments from 994 to 1016 ft bgs. After pumping throughout the lower screened interval, the pump was set at 991 ft bgs, and the packers were inflated to ensure discrete water-quality-parameter sampling on September 1. Turbidity values for purged water from the lower screened interval were above 50 NTU at the start of parameter measurement and dropped to less than 5 NTU for three consecutive measurements on September 2. Approximately 8599 gal. of groundwater was purged during development of the lower screen.

Water Introduced and Removed within the Regional Aquifer

The top of the regional aquifer was encountered at 834.5 ft bgs during drilling. An approximate total of 24,050 gal. of water was introduced into the regional aquifer during drilling and well-construction activities: 6800 gal. for drilling between June 19 and 29, and 17,250 gal. during well construction between July 26 and August 12. Based on average water usage within the regional aquifer per foot, these volumes represent approximately 7200 gal. of water used across the upper screen and 6140 gal. used across the lower screen during drilling and construction.

Approximately 18,213 gal. of groundwater was purged from both screened intervals in the regional aquifer during well-development activities: 737 gal. of composite water, 8877 gal. from the upper screen, and 8599 gal. from the lower screen. Another 30,813 gal. was purged during aquifer testing: 24,985 gal. from the upper screen and 3519 gal. from the lower screen. Total groundwater purged during postinstallation activities from both screen intervals combined was 49,026 gal.

8.1.1 Well Development Field Parameters

Field parameters during well development were measured at well R-55 by collecting aliquots of groundwater from the discharge pipe with the use of a flow-through cell. The final parameters measured at the upper screen at the end of well development were pH of 7.90, temperature of 23.71°C, specific conductance of 186 µC/cm, and turbidity of 0.2 NTU. The final parameters measured at the lower screen at the end of well development were pH of 8.0, temperature of 25.02°C, specific conductance of 180 µC/cm, and turbidity of 2.8 NTU.

Well development field parameters are discussed further in Appendix B. Table B-1.2-1 in Appendix B lists the field parameters measured during development and aquifer testing.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-55 between September 4 and 14, 2010. Several short-duration tests with short-duration recovery periods were performed on the first day of testing for each of the two screened intervals.

A 10-hp pump was used for the aquifer test on the upper screened interval. A 24-h test, followed by a 24-h recovery period, completed the testing of the upper screened interval. Approximately 24,985 gal. of groundwater was purged from the upper screened interval at a flow rate of approximately 17.4 gallons per minute (gpm).

A 5-hp pump was used for the aquifer test on the lower screened interval. The pump's flow rate was set to approximately 2.5 gpm. Approximately 3519 gal. of groundwater was purged from the lower screened interval. A 24-h recovery period completed the testing of the lower screened interval.

Turbidity, temperature, pH, DO, ORP, and specific conductance were measured during the 24-h tests. In addition, water samples were collected for TOC analysis. TOC results and field parameters are presented in Appendix B. The R-55 aquifer test results and analysis are presented in Appendix C.

Approximately 30,813 gal. of groundwater was purged during aquifer testing activities.

8.3 Dedicated Sampling System Installation

The dedicated sampling system for R-55 will be installed in late January 2011. The system, manufactured by Baski, Inc., utilizes a single 2-hp, 4-in.-O.D. environmentally retrofitted Grundfos submersible pump capable of purging each screened interval discretely via pneumatically actuated access port valves. The system includes a viton-wrapped isolation packer between the screened intervals. The pump riser pipe consists of threaded and coupled nonannealed 1-in.-diameter stainless steel. Two 1-in.-diameter schedule 80 polyvinyl chloride (PVC) tubes for dedicated transducers were banded to the pump riser. The upper PVC transducer tube is equipped with a 6-in. section of 0.010-in. slot screen with a threaded end cap at the bottom of the tube. The lower PVC transducer tube is equipped with a flexible nylon tube that extends from a threaded end cap at the bottom of the PVC tube through the isolation packer and measures water levels in the lower screened interval. Two In-Situ Level Troll 500 transducers were installed in the PVC tubes to monitor water levels in each screened interval.

Sampling system components for R-55 are presented in Figure 8.3-1a. Figure 8.3-1b presents technical notes for the well.

8.4 Wellhead Completion

A reinforced concrete surface pad, 10 ft × 10 ft × 6 in. thick, was installed at the R-55 wellhead. The concrete pad was slightly elevated above the ground surface and crowned to promote runoff. The pad will provide long-term structural integrity for the well. A brass survey pin was embedded in the northwest corner of the pad. A 16-in.-I.D. steel protective casing with a locking lid was installed around the stainless-steel well riser. A total of four bollards, painted yellow for visibility, are set at the outside edges of the pad to protect the well from traffic. All four bollards are designed for easy removal to allow access to the well. Details of the wellhead completion are presented in Figure 8.3-1a.

8.5 Geodetic Survey

A New Mexico licensed professional land surveyor conducted a geodetic survey on September 22, 2010 (Table 8.5-1). The survey data collected conform to Laboratory Information Architecture project standards IA-CB02, “GIS Horizontal Spatial Reference System,” and IA-D802, “Geospatial Positioning Accuracy Standard for A/E/C and Facility Management.” All coordinates are expressed relative to the New Mexico State Plane Coordinate System Central Zone (North American Datum [NAD] 83); elevation is expressed in feet above mean sea level (amsl) using the National Geodetic Vertical Datum of 1929. Survey points include ground-surface elevation near the concrete pad, the top of the brass pin in the concrete pad, the top of the well casing, and the top of the protective casing for the R-55 monitoring well.

8.6 Waste Management and Site Restoration

Waste generated from the R-55 project included drilling fluids, purged groundwater, drill cuttings, decontamination water, New Mexico Special Waste, and contact waste. A summary of the waste characterization samples collected during drilling, construction, and development of the R-55 well is presented in Table 8.6-1.

All waste streams produced during drilling and development activities were sampled in accordance with “Amendment #1 to the Waste Characterization Strategy Form (WCSF) for Regional Wells R-56 and R-57 at TA-54 (EP2010-0085)” (LANL 2010, 109431).

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 (WCSF) and the Standard Operating Procedure (SOP) 010.0, Land Application of Groundwater. If it is determined the drilling fluids are nonhazardous but cannot meet the criteria for land application, they will be evaluated for treatment and disposal at one of the Laboratory’s six wastewater treatment facilities. If analytical data indicate the drilling fluids are hazardous/nonradioactive or mixed low-level waste, the drilling fluids will be disposed of at an authorized facility.

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

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

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Drilling, sampling, and well construction at R-55 were performed as specified in "Drilling Plan for Regional Aquifer Well R-55" (TerranearPMC 2010, 109941).

10.0 ACKNOWLEDGMENTS

Boart Longyear drilled and installed the R-55 monitoring well.

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

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

11.0 REFERENCES AND MAP DATA SOURCES

11.1 References

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

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

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

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

LANL (Los Alamos National Laboratory), February 24, 2010. "Waste Characterization Strategy Form for Regional Wells R-56 and R-57 at TA-54, Regional Well Installation and Corehole Drilling," Los Alamos, New Mexico. (LANL 2010, 108753)

LANL (Los Alamos National Laboratory), May 2010. "Drilling Work Plan for Regional Aquifer Well R-55," Los Alamos National Laboratory document LA-UR-10-2788, Los Alamos, New Mexico. (LANL 2010, 109616)

LANL (Los Alamos National Laboratory), May 5, 2010. "Amendment #1 to the Waste Characterization Strategy Form (WCSF) for Regional Wells R-56 and R-57 at TA-54 (EP2010-0085)," Los Alamos, New Mexico. (LANL 2010, 109431)

TerranearPMC, May 2010. "Drilling Plan for Regional Aquifer Well R-55," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2010, 109941)

11.2 Map Data Sources

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

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

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

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

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

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

Technical Area Boundaries; Los Alamos National Laboratory, Site Planning & Project Initiation Group, Infrastructure Planning Division; 4 December 2009.

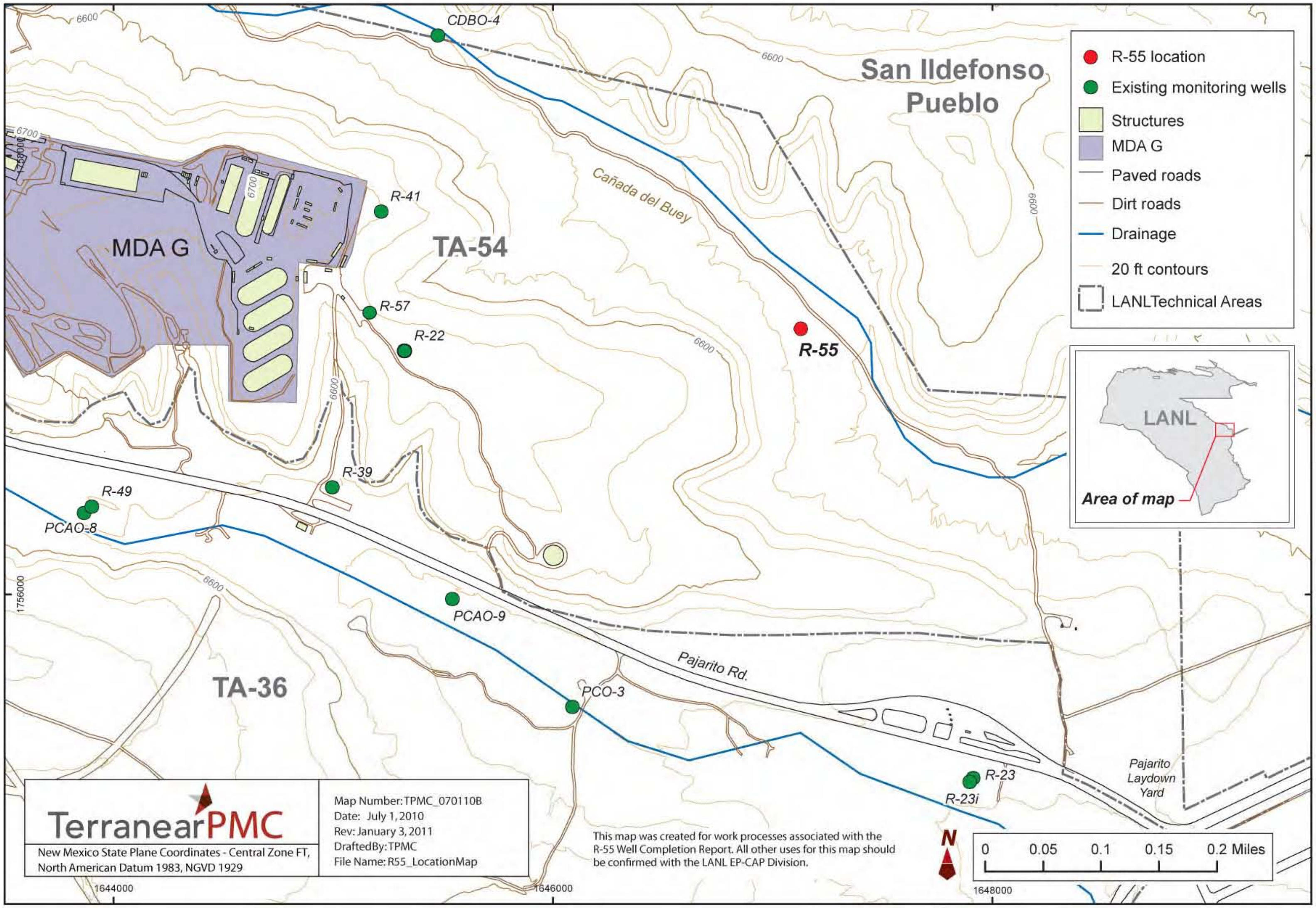

Figure 1.0-1 Location of monitoring well R-55

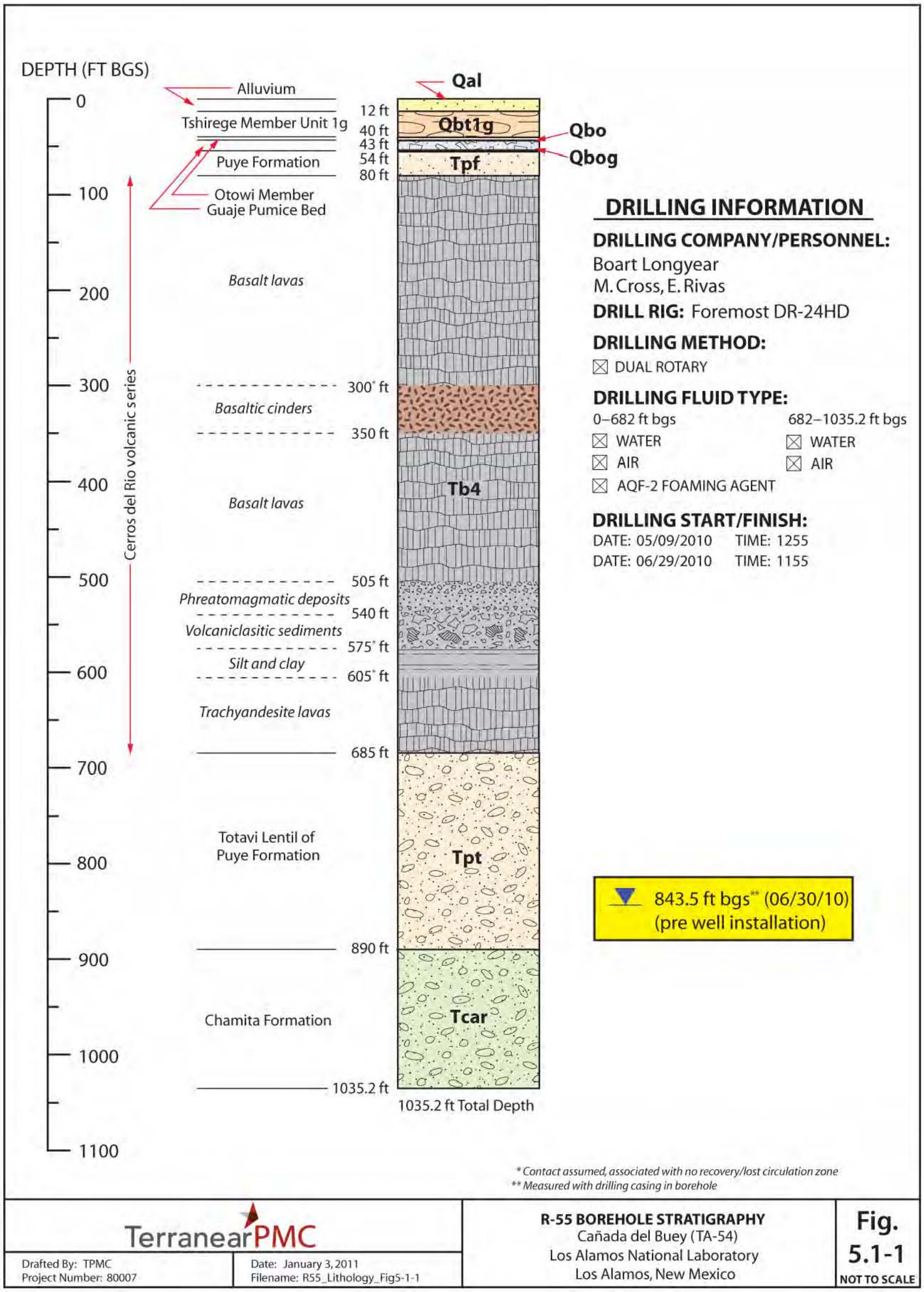

Figure 5.1-1 Monitoring well R-55 borehole stratigraphy

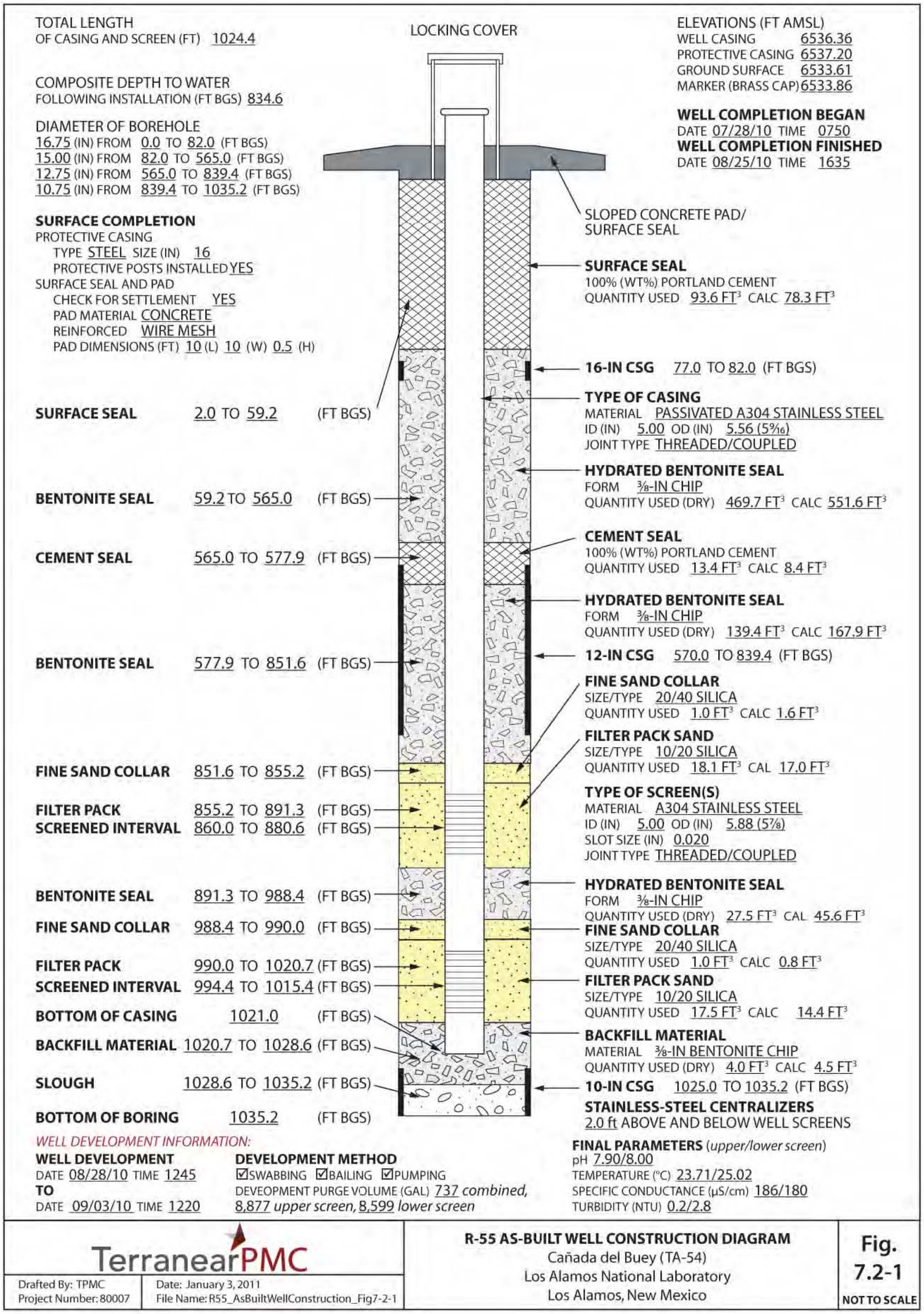

Figure 7.2-1 Monitoring well R-55 as-built well construction diagram

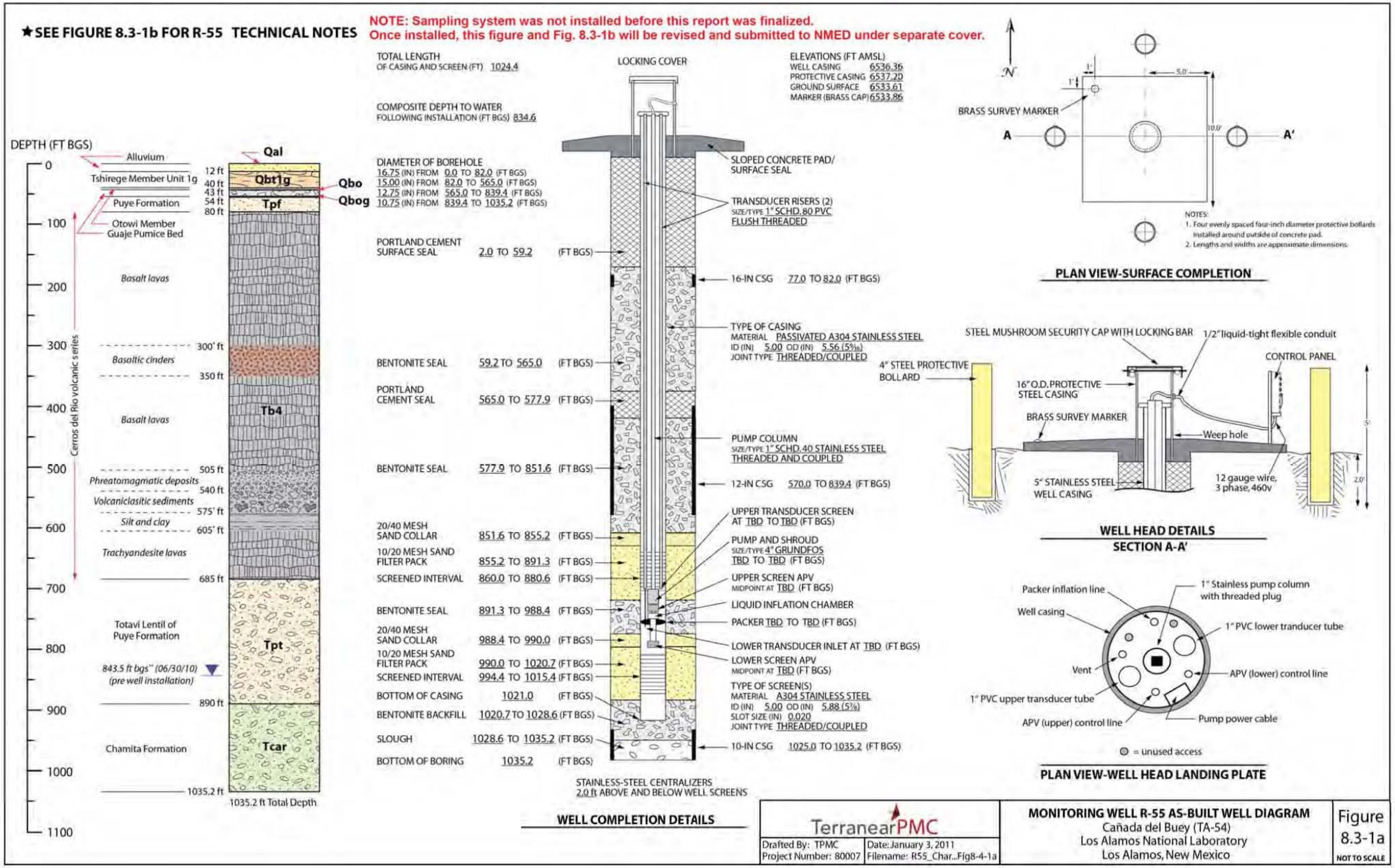

Figure 8.3-1a As-built schematic for regional water monitoring well R-55

R-55 TECHNICAL NOTES:

SURVEY INFORMATION*

Brass Marker

Northing:	1757272.15 ft
Easting:	1647083.52 ft
Elevation:	6533.86 ft AMSL

Well Casing (top of stainless steel)

Northing:	1757266.52 ft
Easting:	1647082.80 ft
Elevation:	6536.36 ft AMSL

BOREHOLE GEOPHYSICAL LOGS

LANL: Natural gamma ray (×2), induction, video

DRILLING INFORMATION

Drilling Company
Boart Longyear

Drill Rig
Foremost DR-24HD

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

Drilling Fluids
Air, potable water, AQF-2 Foam (to 682 ft bgs)

MILESTONE DATES

Drilling

Start:	05/09/2010
Finished:	06/29/2010

Well Completion

Start:	07/28/2010
Finished:	08/25/2010

Well Development

Start:	08/28/2010
Finished:	09/03/2010

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Total Volume Purged (gal): 737 combined, 8,877 upper screen, 8,599 lower screen

Parameter Measurements (Final, upper screen/lower screen)

pH:	7.90/8.00
Temperature:	23.71/25.02°C
Specific Conductance:	186/180 µS/cm
Turbidity:	0.2/2.8 NTU

AQUIFER TESTING

Constant Rate Pumping Test

Upper Screen

Water Produced:	24,985 gal
Average Flow Rate:	17.4 gpm
Performed on:	09/08–09/2010

Lower Screen

Water Produced:	3519 gal
Average Flow Rate:	2.5 gpm
Performed on:	09/13–14/2010

DEDICATED SAMPLING SYSTEM

Pump
Make: Grundfos
Model: TBD
TBD U.S. gpm, APVs (Acccess Port Valves) midpoints at TBD (upper) and TBD (lower) ft bgs
Environmental retrofit

Motor
Make: Franklin Electric
Model: TBD
TBD hp, 3-phase

Pump Column
1-in. threaded/coupled schd. 40, ASTM pickled and passivated A312 stainless steel tubing

Transducer Tubes
2 × 1-in. flush threaded schd. 80 PVC tubing
Upper 0.01-in. slot screen at TBD–TBD ft bgs,
Lower flexible tube from transducer set at TBD ft bgs

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

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

NOTE: Sampling system had not been installed by the time this report was submitted. Once installed, this figure and Fig. 8.3-1a will be revised and submitted to NMED under separate cover.

TerranearPMC
Drafted By: TPMC
Project Number: 80007
Date: January 3, 2011
Filename: R55_TechnicalNotes_Fig8-3-1b

R-55 TECHNICAL NOTES
Cañada del Buey (TA-54)
Los Alamos National Laboratory
Los Alamos, New Mexico

Figure 8.3-1b
NOT TO SCALE

Figure 8.3-1b As-built technical notes for monitoring well R-55

Table 3.1-1
Fluid Quantities Used during R-55 Drilling and Well Construction

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
Drilling				
5/9/10	600	600	1	1
5/10/10	900	1500	10	11
5/20/10	600	2100	20	31
5/21/10	1000	3100	55	86
5/22/10	180	3280	0	86
5/23/10	480	3760	0	86
6/02/10	1300	5060	30	116
6/03/10	1500	6560	40	156
6/04/10	2000	8560	60	216
6/05/10	3500	12,060	125	341
6/12/10	400	12,460	10	351
6/13/10	600	13,060	20	371
6/15/10	1200	14,260	30	401
6/16/10	2000	16,260	10	411
6/17/10	1500	17,760	0	411
6/18/10	1000	18,760	0	411
6/19/10	500	19,260	0	411
6/21/10	500	19,760	0	411
6/26/10	2300	22,060	0	411
6/27/10	2000	24,060	0	411
6/28/10	1000	25,060	0	411
6/29/10	500	25,560	0	411
Well Construction				
7/26/2010	300	300	n/a*	n/a
7/27/10	400	700	n/a	n/a
7/30/10	100	800	n/a	n/a
7/31/10	1200	2000	n/a	n/a
8/01/10	250	2250	n/a	n/a
8/03/10	150	2400	n/a	n/a
8/04/10	50	2450	n/a	n/a
8/06/10	300	2750	n/a	n/a
8/07/10	1700	4450	n/a	n/a
8/08/10	6000	10,450	n/a	n/a
8/09/10	3500	13,950	n/a	n/a

Table 3.1-1 (continued)

Date	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
Well Construction (cont.)				
8/10/10	1500	15,450	n/a	n/a
8/11/10	1000	16,450	n/a	n/a
8/12/10	800	17,250	n/a	n/a
8/15/10	1000	18,250	n/a	n/a
8/16/10	500	18,750	n/a	n/a
8/17/10	60	18,810	n/a	n/a
8/18/10	2000	20,810	n/a	n/a
8/19/10	5500	26,310	n/a	n/a
8/20/10	3000	29,310	n/a	n/a
8/21/10	1000	30,310	n/a	n/a
8/22/10	2200	32,510	n/a	n/a
8/24/10	1500	34,010	n/a	n/a
8/25/10	372	34,382	n/a	n/a
Total Water Volume (gal.)				
R-55	59,942			

Note: Foam use terminated at 862.0 ft bgs during drilling; none used during well construction.
* n/a = Not applicable.

Table 4.2-1
Summary of Groundwater Screening Samples Collected during Drilling, Well Development, and Aquifer Testing of Well R-55

Location ID	Sample ID	Date Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Drilling					
R-55	GW55-10-17161	6/06/10	550.0	Groundwater; Airlifted	Anions, metals, LH3 VOC
Well Development					
R-55	GW55-10-17170	9/01/10	991.0	Groundwater, Pumped	TOC
R-55	GW55-10-17171	9/03/10	857.7	Groundwater, Pumped	TOC
Aquifer Testing					
R-55	GW55-10-17172	9/08/10	854.2	Groundwater, Pumped	TOC
R-55	GW55-10-17173	9/08/10	854.2	Groundwater, Pumped	TOC
R-55	GW55-10-17174	9/09/10	854.2	Groundwater, Pumped	TOC
R-55	GW55-10-17175	9/09/10	854.2	Groundwater, Pumped	TOC
R-55	GW55-10-17176	9/13/10	914.8	Groundwater, Pumped	TOC
R-55	GW55-10-17177	9/13/10	914.8	Groundwater, Pumped	TOC
R-55	GW55-10-17178	9/13/10	914.8	Groundwater, Pumped	TOC
R-55	GW55-10-17179	9/14/10	914.8	Groundwater, Pumped	TOC
R-55	GW55-10-17180	9/14/10	914.8	Groundwater, Pumped	TOC

Table 6.0-1
R-55 Logging Runs

Date	Type	Depth (ft bgs)	Description
5/22/10	Video	Surface to 200 (open hole from 82 to 200)	The drilling subcontractor ran video log after the 15-in. open borehole was drilled to 220 ft bgs to observe fractured basalt section before sealing it off. Drilling fluids in borehole at 200 ft bgs blocked video log below that depth.
6/07/10	Video, gamma, induction	Surface to 545 (open hole from 82 to 545).	LANL personnel ran video, gamma, and induction logs after the 15-in. open borehole was drilled to 565 ft bgs. Slough in the borehole prevented logging past 545 ft bgs. DTW was 499 ft bgs.
6/29/10	Gamma	Surface to 1035.2	LANL personnel ran gamma log in the 10-in. casing after drilling and advancing casing to 1035.2 ft bgs (TD).

Table 7.2-1
R-55 Monitoring Well Annular Fill Materials

Material	Volume
Upper surface seal: cement slurry	93.6 ft^3
Upper bentonite seal: bentonite chips	469.7 ft^3
Perched zone seal: cement slurry	13.4 ft^3
Upper bentonite seal: bentonite chips	139.4 ft^3
Fine sand collar: 20/40 silica sand	1.0 ft^3
Filter pack: 10/20 silica sand	18.1 ft^3
Middle bentonite seal: bentonite chips	27.5 ft^3
Fine sand collar: 20/40 silica sand	1.0 ft^3
Filter pack: 10/20 silica sand	17.5 ft^3
Backfill: bentonite chips/pellets	4.0 ft^3

Table 8.5-1
R-55 Survey Coordinates

Identification	Northing	Easting	Elevation
R-55 brass cap embedded in pad	1757272.15	1647083.52	6533.86
R-55 ground surface near pad	1757269.85	1647076.93	6533.61
R-55 top of stainless-steel well casing	1757266.52	1647082.80	6536.36
R-55 top of 16-in. protective casing	1757266.23	1647082.93	6537.20

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

Table 8.6-1
Summary of Waste Samples Collected during Drilling and Development of R-55

Location ID	Sample ID	Date Collected	Description	Sample Type
R-55	WST55-10-19299	7/29/10	Decontamination water: tremie pipe (unfiltered)	Liquid
R-55	WST55-10-19298	7/29/10	Decontamination water: tremie pipe (filtered)	Liquid
R-55	WST55-10-19300	7/29/10	Decontamination water: tremie pipe (duplicate)	Liquid
R-55	WST55-10-19301	7/29/10	Decontamination water: tremie pipe	Liquid
R-55	WST55-10-19303	7/29/10	Decontamination water: R-55 well casing (unfiltered)	Liquid
R-55	WST55-10-19302	7/29/10	Decontamination water: R-55 well casing (filtered)	Liquid
R-55	WST55-10-19304	7/29/10	Decontamination water: R-55 well casing (duplicate)	Liquid
R-55	WST55-10-19305	7/29/10	Decontamination water: R-55 well casing	Liquid
R-55	WST55-10-19112	9/09/10	Development water (unfiltered)	Liquid
R-55	WST55-10-19111	9/09/10	Development water (filtered)	Liquid
R-55	WST55-10-19113	9/09/10	Development water (duplicate)	Liquid
R-55	WST55-10-19114	9/09/10	Development water	Liquid
R-55	WST55-10-19120	9/15/10	Drill fluids (unfiltered)	Liquid
R-55	WST55-10-19117	9/15/10	Drill fluids (filtered)	Liquid
R-55	WST55-10-19119	9/15/10	Drill fluids (duplicate)	Liquid
R-55	WST55-10-19118	9/15/10	Drill fluids	Liquid

Appendix A

Borehole R-55 Lithologic Log

Borehole Identification (ID): R-55	**Technical Area (TA): 54**	**Page :** 1 of 15
Drilling Company: Boart Longyear Company	**Start Date/Time: 5-9-10/1257**	**End Date/Time :** 6-29-10/1235
Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD	**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl		**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola	

Depth (ft bgs)	**Lithologic description**	**Lithologic Symbol**	**Notes**
0–12	**ALLUVIUM:** Construction Fill and Tuff Sediments—pale orange gray (10YR 8/2), poorly welded, weakly indurated, strongly pumiceous, crystal-bearing, lithic-bearing tuff clasts and rounded clasts (quartzite, dacite) in well pad base course. 0'–3' WR/+10F/+35F: pale brown (5YR 5/2) mixed chips of indurated Qbt 1g tuff, quartz crystals, and exotic subrounded to subangular clasts (dacite, quartzite) indicating imported base-course gravels used in drill pad construction; silty ash matrix. Disturbed section no more than 3 ft thick. 3'–12' WR/ +10F: 85–90% large fragments (up to 15 mm) of pinkish-orange glassy, fibrous-textured, quartz- and sanidine-phyric pumices [pumices becoming more lustrous (vitreous) with depth]; 10–15% rounded to angular/broken quartzite clasts (from construction fill). +35F: 30–70% glassy pumice fragments; 30–70% quartz crystals (increasing crystals lower in section); 2–3% volcanic lithics and glass.	Qal	Note: Drill cuttings for binocular microscope descriptive analysis were collected at 5-ft intervals from 0 ft to borehole TD at 1035.2 ft bgs. Alluvial sediments, encountered from 0 ft to 12 ft, are approximately 12 ft thick.
12–35	**UNIT 1g OF THE TSHIREGE MEMBER OF THE BANDELIER TUFF:** Rhyolitic Tuff and Pumice—pale orange (10YR 8/2) to white (N9) tuff fragments, poorly welded, weakly to moderately indurated, crystal-rich, lithic-poor, strongly weathered and white vitric pumice clasts up to 2mm. 15'–35' WR/+10F: 10–15% fragments of crystal-bearing ash flow tuff (i.e., ignimbrite); 70–80% white vitric pumice clasts, color becomes slightly more orange between 25'–35'; 10–15% dacitic and andesitic lithics (up to 10 mm); trace quartz crystals. The ash-flow tuff is composed of 15–20% quartz and sanidine crystals, 10–15% small (up to 4 mm) pumice lapilli, dacitic lithic fragments set in a matrix of glassy to weathered volcanic ash. +35F: 45–50% white vitric pumice clasts; 45–50% quartz crystals; 5% volcanic lithic fragments; trace of obsidian.	Qbt 1g	Unit 1g of the Tshirege Member of the Bandelier Tuff (Qbt 1g), encountered from 12 ft to 40 ft bgs, is estimated to be a minimum of 28 ft thick. Top contact of Tshirege Member determined based on gamma log.

Borehole Identification (ID): R-55	**Technical Area (TA): 54**		**Page :** 2 of 15
Drilling Company: Boart Longyear Company	**Start Date/Time: 5-9-10/1257**		**End Date/Time :** 6-29-10/1235
Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD		**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl			**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola		

Depth (ft bgs)	**Lithologic description**	**Lithologic Symbol**	**Notes**
35–40	Rhyolitic Tuff and Pumice—white to very light gray (N9 to N8) pumice and minor tuff fragments, crystal-poor, lithic-poor. 35’–40’ WR/+10F/+35F: 70–80% white vitric pumice clasts; 10–20% quartz and sanidine crystals; 5–15% volcanic lithic fragments.	Qbt 1g	Note: Lower contact of Qbt 1g was determined by decrease in crystal content from 35–40 ft bgs and using gamma log.
40–43	**ASH FLOWS OF THE OTOWI MEMBER OF THE BANDELIER TUFF:** Rhyolite Tuff—white to very light gray (N9-N8) unconsolidated, crystal-rich, lithic–poor pumice fragments. 40’–43’ WR/+10F: 85–95% white vitric pumice clasts; 5–10% dacitic and rhyolitic lithics (up to 10 mm); 1–5% fragments of crystal-bearing ash flow tuff (i.e., ignimbrite); 40’–43’ +35F: 50% quartz and sanidine crystals; 35% white vitric pumice clasts; 15% volcanic lithic fragments.	Qbo	Note: The upper contact of the basal Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff was determined to be at 43 ft bgs based on gamma log interpretation, supported by a relatively crystal-poor, pumice rich zone in drill cuttings from 50’–55’ bgs.
43-54	**GUAJE PUMICE BED OF THE OTOWI MEMBER OF THE BANDELIER TUFF:** Rhyolite Tuff—white to very light gray (N9-N8) unconsolidated, crystal-poor pumice fragments. 43’–54’ WR/+10F: 95–100% white vitric pumice clasts; 1–5% dacitic and rhyolitic lithics. 43’–54’ +35F: 60–75% white vitric pumice clasts; 5–10% quartz and sanidine crystals; 10–15% lithic fragments; 10–15% brown-orange ash flow tuff fragments.	Qbog	Note: Basal contact of Qbog defined by gamma log. The presence of light brown silty fine-grain sandstone clasts in the +35F from 50’–55’ is consistent with a contact between the Bandelier Tuff and Puye Formation sediments at approximately 54 ft bgs.
54–60	**PUYE FORMATION:** Fine-grained Sediments—white pumice (N9) and light brown (5YR 6/4) quartz-rich fine-grained sandstones and siltstones. 54’–60’ WR/+10F: 50–60% white vitric pumice clasts; 40–50% light brown siltstone and fine-grained sandstones containing abundant glassy gray to black volcanic lithic clasts and quartz grains. +35F: 80–85% light brown siltstones and fine-grained sandstone clasts; 5–10% white vitric pumice clasts; 5% gray to black glassy volcanic lithic clasts; 1–5% quartz and sanidine crystals.	Tpf	Puye Formation sediments were encountered from 54 to 80 ft bgs. Fine-grained sandstones and siltstones are 26 ft thick above Cerros del Rio volcanic series.

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Drilling Company: Boart Longyear Company	**Start Date/Time: 5-9-10/1257**		**End Date/Time :** 6-29-10/1235
Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD		**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl			**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola		

Depth (ft bgs)	**Lithologic description**	**Lithologic Symbol**	**Notes**
60–80	Fine-grained Sediments—light brown (5YR 6/4) quartz-rich fine-grained sandstones and siltstones. 60'–75' WR/+10F: 75–85% light brown siltstone and fine-grained sandstones containing abundant glassy gray to black volcanic lithic clasts and quartz grains; 15–25% gray glassy volcanic clasts; 1–5% white lithic-poor pumice clasts. +35F: 90–95% light brown fine-grained sandstone and siltstone clasts; 5–10% obsidian and gray rhyolite clasts; 1–5% quartz and sanidine crystals; 1–3% white vitric pumice clasts. 75'–80' WR/+10F: 80–90% light brown fine-grained sandstone and siltstone clasts; 2–5% gray glassy rhyolite clasts; 5–10% angular to subangular vesicular basalt clasts with carbonate-coated vesicles.	Tpf	Note: The few vesicular basalt clasts between 75 and 80 ft bgs are interpreted as detritus/rips-ups from the underlying Cerros del Rio basalts.
80–85	**CERROS DEL RIO VOLCANIC ROCKS:** Tuffaceous Ash and Basalt Lava—varicolored, light brown (5YR 6/4), and medium dark gray (N4). Sample contains mixed fragments of basalt lava, and tuffaceous ash/siltstone. 80'–85' WR/+10F: 60–80% angular/broken fragments of massive basalt with few vesicles; 20–40% subrounded (i.e., milled during drilling) fragments of yellow/gray to tan, very fine grained tuffaceous ash; traces (<2%) of white pumice and quartz crystals. +35F: 60–70% chips of olivine/plagioclase-phyric basalt; 25–35% fragments of yellow-gray to tan very fine grained tuffaceous ash; 2–5% quartz crystals; traces (<2%) of white pumice fragments and carbonate grains.	Tb 4	The Cerros del Rio volcanic series (Tb 4), encountered from 80 to 685 ft bgs, is estimated to have a cumulative thickness of 605 ft.
85–90	Basalt Lava—medium dark gray (N4). Sample predominantly made up of chips of massive basalt and lesser fragments of tan tuffaceous ash/siltstone. 85'–90' WR/+10F+35F: 95–99% angular/broken chips of fine grained massive olivine/pyroxene-phyric basalt; 1–3% chips of tan tuffaceous ash/siltstone; 1–2% chips of very fine grained, subangular quartz and lithic-rich sandstone in +35F.	Tb 4	

Borehole Identification (ID): R-55	**Technical Area (TA): 54**		**Page :** 4 of 15
Drilling Company: Boart Longyear Company	**Start Date/Time: 5-9-10/1257**		**End Date/Time :** 6-29-10/1235
Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD		**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl			**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola		

Depth (ft bgs)	**Lithologic description**	**Lithologic Symbol**	**Notes**
90–120	Basalt Lava—medium dark gray to medium gray (N4 to N5). Sample predominantly chips of fine-grained massive basalt with trace amounts of tan tuffaceous ash/siltstone and amygdaloidal brown clay and carbonate. 90'–120' WR/+10F/+35F: 97–100% angular/ broken chips of massive plagioclase/olivine-bearing basalt with few vesicles and traces of amygdaloidal brown clay and white carbonate; <1–3% chips of tan tuffaceous siltstone (ash) decreasing down section. Plagioclase phenocryst abundance increases down section from 5 to 15% by volume.	Tb 4	
120–140	Basalt Lava flows—medium gray (N5) chips of massive basalt, porphyritic with aphanitic groundmass, phenocrysts (5–10% by volume) of plagioclase (euhedral to anhedral, up to 0.5 mm), and anhedral olivine (up to 1 mm); dark red-gray vesicular porphyritic basalt with phenocrysts (3–5% by volume) of plagioclase (euhedral, up to 2.5 mm). 120'–125' WR/+10F: 85–95% angular/broken chips of massive basalt with 5–10% phenocrysts of plagioclase and traces of olivine; 5–15% large (5–30mm) angular fragments of reddish-gray vesicular basalt containing plagioclase phenocrysts (up to 2 mm) oxidized on primary fracture surfaces and in vesicles. +35F: 97–99% massive basalt; 1–3% reddish-gray vesicular basalt fragments as described in larger size fractions. 125'–130' WR/+10F/+35F: 65–75% massive basalt fragments; 25–35% reddish-gray vesicular basalt fragments. 130'–140' WR/+10F/+35F: 20–30% massive basalt fragments; 70–80% reddish-gray vesicular basalt fragments	Tb 4	
140–145	Basalt Lava—medium gray (N5) broken chips of massive (nonvesicular) plagioclase-olivine basalt exhibiting oxidation along some surfaces. 140'–145' WR/+10F/+35F: 100% angular chips of massive plagioclase-olivine basalt. Olivine crystals are altered to iddingsite to various degrees. Secondary quartz present on surfaces of some fragments in +35F.	Tb 4	

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Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD	**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl		**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists** : Travis J. Naibert, M. Jojola	

Depth (ft bgs)	**Lithologic description**	**Lithologic Symbol**	**Notes**
145–160	Basalt Lava—medium gray (N5), predominantly broken chips of vesicular basalt. Basalt is porphyritic with aphanitic groundmass and contains phenocrysts (3–5% by volume) of plagioclase (anhedral, up to 1.5 mm) and olivine (subhedral, commonly altered to iddingsite). 145'–160' WR/+10F/+35F: 99–100% angular chips of vesicular basalt, commonly with white-yellow crystals lining vesicles. Minor oxidation has occurred along some vesicles and surfaces.	Tb 4	
160–185	Basalt Lava—medium gray (N5) to medium dark gray, predominantly broken chips of massive basalt. Basalt is weakly porphyritic with phenocrysts (2–3% by volume) of plagioclase (subhedral, up to 1 mm) and green olivine (anhedral, up to 0.5 mm) set in an aphanitic groundmass that is weakly altered (possibly zeolitized). 160'–170' WR/+10F/+35F: 100% angular chips of massive basalt. Oxidation of fragment surfaces increases slightly down section but is uncommon. 170'–185' WR/+10F/+35F: 100% angular chips of medium dark gray, weakly vesicular basalt. Oxidation of surfaces is uncommon. Few olivine phenocrysts are visible in this section.	Tb 4	
185–220	Basalt Lava—medium gray (N5) to medium dark gray (N4), predominantly broken chips of massive basalt. Basalt is weakly porphyritic with phenocrysts (2–3% by volume) of plagioclase (subhedral, up to 1 mm) and green olivine (anhedral, up to 0.5 mm). 185'–220' WR/+10F/+35F: 98–99% angular chips of plagioclase-olivine basalt; vesicles lined with yellowish-brown or pinkish-white clay; 1–2% fragments of pinkish-white mudstone (2.5YR 8/2) similar to clay filling basalt vesicles.	Tb 4	

Borehole Identification (ID): R-55	Technical Area (TA): 54	Page : 6 of 15
Drilling Company: Boart Longyear Company	**Start Date/Time: 5-9-10/1257**	**End Date/Time :** 6-29-10/1235
Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD	**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl		**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola	

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
245–260	Basalt Lava—medium dark gray (N4) chips of vesicular olivine-basalt. Basalt is porphyritic with phenocrysts (10 % by volume) of olivine (subhedral, up to 2 mm), and smaller black euhedral pyroxene and plagioclase in an aphanitic groundmass that is partially oxidized (dark red) along vesicles and surfaces; groundmass has glassy appearance. 245'–260' WR/+10F/+35: angular chips of medium to medium dark gray to dark red vesicular basalt with phenocrysts of olivine, pyroxene, and plagioclase. Surfaces and vesicles are largely oxidized.	Tb 4	
260–265	Basalt Lava—medium dark gray (N4) olivine-basalt, as described in the interval 245'–260'. Minor amounts of pale orange (10YR 8/2) tuffaceous ash and siltstone. 260'–265' WR/+10F/+35F: 95–98% angular chips of olivine-basalt exhibiting groundmass that is moderately oxidized; 2–5% tan siltstone and tuffaceous ash; trace quartz grains in +35F fraction.	Tb 4	
265–300	Basalt Lava—medium dark gray (N4) mixed vesicular and massive olivine-phyric (partially altered to iddingsite) basalt. 265'–270' WR/+10F/+35F: 98–99% angular chips of vesicular basalt with olivine phenocrysts up to 3 mm, partially iddingsitized; trace amounts of tan siltstone and tuffaceous ash. 270'–290' WR/+10F: 100% angular chips of basalt (>75% massive) with olivine phenocrysts up to 3 mm. 270'–275' +35F: 99% angular chips of basalt (>75% massive) with olivine phenocrysts; trace amounts of pale orange siltstone and tuffaceous ash. 275'–290' +35F: 100% angular chips of basalt (>75% massive) with olivine phenocrysts. 290'–300' WR/+10F/+35F: 100% chips of mixed vesicular (>50%) and massive olivine-phyric basalt, increasingly oxidized (deep red) with depth.	Tb 4	Note: Alternating vesicular and massive basalt intervals of similar mineralogy indicate multiple flows in this zone (265–300 ft bgs).

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Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD	**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl		**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola	

Depth (ft bgs)	**Lithologic description**	**Lithologic Symbol**	**Notes**
300–325	300'–325': No cuttings collected; lost circulation.	Tb 4	
325–350	Basalt Cinder Deposits—medium gray (N5) to reddish-gray (5R 4/2) vesicular cinders of olivine/pyroxene-phyric basalt. 325'–335' WR/+10F: 100% partially oxidized basaltic cinders with plagioclase and olivine phenocrysts up to 1 mm. 335'–345' WR/+10F: 95–98% light gray, partially oxidized (less than above) basaltic cinders with plagioclase and olivine phenocrysts up to 1 mm; 2–5% tan siltstone fragments; trace rounded quartzite granules. 345'–350' WR/+10F: 98–99% angular chips of partially oxidized cinders; 1–2% rounded quartzite grains. 325'–350' +35F: 90–95% partially oxidized olivine-phyric basaltic cinders; 2–5% tan siltstone fragments; 2–5% quartz grains; 1–2% rounded quartzite grains.	Tb 4	
350–380	Basalt Lava—medium gray (N5) mixed vesicular and massive olivine-phyric (partially altered to iddingsite) basalt. 350'–380' WR/+10F: 100% angular chips of olivine-phyric basalt. 350'–370' +35F: 100% angular chips of olivine-phyric basalt. 370'–380' +35F: 99% angular chips of olivine-phyric basalt; 1% pale orange ashy siltstone clasts.	Tb 4	
380–390	Basalt Lava—medium gray (N5) olivine-phyric (partially altered to iddingsite) basalt with angular clasts of oxidized vesicular basalt and cinders. 380'–390' WR/+10F: 80–90% angular chips of olivine-phyric basalt; 10–20% angular chips of reddish-gray, oxidized, vesicular basalt; trace ashy siltstone. +35F: 60–70% angular chips of olivine-phyric basalt; 30–40% angular chips of reddish-gray to red hematite-stained oxidized basalt.	Tb 4	

Borehole Identification (ID): R-55	**Technical Area (TA): 54**		**Page :** 8 of 15
Drilling Company: Boart Longyear Company	**Start Date/Time: 5-9-10/1257**		**End Date/Time :** 6-29-10/1235
Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD		**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl			**Total Depth :** 1035.2 ft
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Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
390–490	Basalt Lava—medium to medium light gray (N5 to N6) olivine-phyric (partially altered to iddingsite) basalt. 390'–490' WR/+10F: 98–100% angular chips of olivine-phyric basalt; 0–2% tan ashy siltstone clasts. +35F; 95–100% angular chips of olivine-phyric basalt; 0–5% tan ashy siltstone clasts; 0–5% quartz grains.	Tb 4	
490–505	Basalt Lava—medium to medium light gray (N5 to N6) olivine-phyric (partially altered to iddingsite) basalt. 490'–505' WR/+10F/+35F: 70–80% angular chips of olivine-phyric basalt; 20–25% dark gray glassy vesicular basalt clasts; 0–5% olivine grains in +35F.	Tb 4	
505–540	Phreatomagmatic Deposits—medium to dark gray (N5 to N3) olivine-phyric basalt with glassy matrix and abundant small plagioclase phenocrysts (<0.5mm), basalt surfaces are commonly altered; fine-grained volcanic breccias containing clasts of basalt, obsidian, olivine, and plagioclase and detrital grains of quartzite and quartz. 505'–540' WR/+10F: 40–60% glassy vesicular basalt with abundant olivine phenocrysts (up to 2 mm); 20–30% volcanic breccias containing angular to rounded clasts of obsidian and detrital quartzite, and grains of olivine and plagioclase and detrital quartz; 10–30% medium gray olivine-phyric massive basalt; trace quartzite clasts; trace reddish oxidized fine-grained vesicular basalt. +35F: 60–70% glassy vesicular basalt with abundant olivine phenocrysts; 15–25% obsidian clasts; 5–15% olivine grains; 2–5% medium light gray aphanitic basalt clasts; trace quartzite crystals; trace quartz grains.	Tb 4	

Borehole Identification (ID): R-55	**Technical Area (TA): 54**	**Page :** 9 of 15
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Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD	**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl		**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola	

Depth (ft bgs)	**Lithologic description**	**Lithologic Symbol**	**Notes**
540–550	Volcaniclastic sediments—fine to medium subrounded to well rounded gravels (up to 10 mm) and sand with fine silt matrix, poorly sorted, moderately indurated. Detritus composed of variable lithologies (black glassy basalt, fine-grained medium gray basalt, minor Precambrian quartzite). 540'–550' WR/+10F: 40–50% subrounded to well rounded clasts of dark gray glassy basalt; 40–50% clasts of medium gray (N5) aphanitic basalt; 5–10% quartzite clasts. +35F: 60–70% subrounded to rounded basalt clasts; 25–35% quartzite clasts; 5–10% quartz and olivine grains; trace oxidized basalt clasts; trace sandstone clasts.	Tb 4	
550–565	Volcaniclastic sediments—fine to medium subrounded to well-rounded gravels (up to 10 mm) and sand with fine sand and silt matrix, poorly sorted, moderately indurated. Detritus composed of variable lithologies (black glassy basalt, fine-grained medium gray basalt, Precambrian quartzite; pink ashy matrix supported fine grained sandstone clasts). 550'–565' WR/+10F: 40–50% tan/pink ashy sandstones containing very fine quartz and feldspar grains and quartzite and obsidian clasts; 20–30% clasts of medium light gray aphanitic basalt; 20–30% quartzite clasts; 1–2% subrounded to well-rounded clasts of dark gray glassy basalt; +35F: 30–40% subrounded to rounded basalt clasts; 30–40% quartzite clasts; 20–30% orange/pink (10YR 8/2) ashy sandstones containing very fine quartz and feldspar grains and quartzite and obsidian clasts; 5–10% quartz grains; trace olivine grains.	Tb 4	
565–575	565'–575': No cuttings collected; lost circulation.	Tb 4	
575–600	Silt/Clay—Light brown to gray clay (10YR 7/1) including some pale brown (5YR 6/4) ashy clay, which includes very fine-grain quartz and sanidine. 575'–600' WR/+10F/+35F: 80–100% clasts of light brown to gray claystone; 0–20% clasts of pink claystone including silt-sized quartz grains.	Tb 4	Note: This clay zone is likely the perching layer beneath perched water at approximately 568 ft bgs.

Borehole Identification (ID): R-55	Technical Area (TA): 54		Page : 10 of 15
Drilling Company: Boart Longyear Company	**Start Date/Time: 5-9-10/1257**		**End Date/Time :** 6-29-10/1235
Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD		**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl			**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
600–605	600'–605': No cuttings collected; lost circulation.	Tb 4	
605–640	Basaltic Trachyandesite Lava—Medium gray (N5) vesicular, aphanitic basaltic lava with few olivine phenocrysts (up to 1mm). 605'–640' WR/+10F/+35F: 90–95% vesicular aphanitic basalt chips; 5–10% tan to pale orange ashy claystone clasts; trace very fine-grained sandstone; trace quartzite clasts.	Tb 4	Note: presence of 5–10% of tan/pale orange claystone in basalt cuttings from 605–670 ft bgs suggests multiple thin flows separated by clay deposits. Lava composition determined by X-ray fluorescence analyses of two cuttings samples.
640–670	Basaltic Trachyandesite Lava—variegated vesicular, aphanitic basaltic lava with few olivine phenocrysts (up to 1 mm). Basalt is partially oxidized from medium gray to gray-red. 640'–670' WR/+10F/+35F: 90–95% vesicular aphanitic basalt chips; 5–10% tan to pale orange ashy claystone clasts; trace to ~5% very fine grained sandstone.	Tb 4	
670–685	Basaltic Trachyandesite Lava—medium to medium dark gray (N5 to N4) olivine-phyric fine-grained basalt. 670'–680' WR/+10F: 100% angular chips of olivine-phyric basalt; +35F: 95–98% angular chips of olivine-phyric basalt (<5% oxidized); 2–5% tan to pale orange (10YR 8/2) ashy claystone clasts; trace olivine grains. 680'–685' WR/+10F: 85–95% angular chips of olivine-phyric basalt; 5–15% tan to pale orange ashy claystone clasts. +35F: 95–98% angular chips of olivine-phyric basalt; 2–5% tan to pale orange ashy claystone clasts; trace olivine grains.	Tb 4	
685–690	**TOTAVI LENTIL OF THE PUYE FORMATION:** Quartzo-feldspathic Sediments—medium gray (N5) olivine-phyric fine-grained basalt; basalt- and quartzite-clast sandstones and granule conglomerate pieces. 685'–690' WR/+10F: 30–40% well-rounded aphanitic basalt clasts; 30–40% well-rounded quartzite clasts; 20–30% well-rounded clasts of fine-grained quartz sandstone. +35F: 90–95% angular chips of olivine-phyric basalt; 5–10% tan to pink ashy claystone clasts.	Tpt	Puye volcaniclastic sediments (Tpf), intersected from 685 ft to 890 ft bgs, have a minimum thickness of 205 ft. The lower Cerros del Rio basalt contact was identified by first appearance of Puye sediments in drill cuttings and confirmed with the gamma log.

Borehole Identification (ID): R-55	**Technical Area (TA): 54**	**Page :** 11 of 15
Drilling Company: Boart Longyear Company	**Start Date/Time: 5-9-10/1257**	**End Date/Time :** 6-29-10/1235
Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD	**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl		**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola	

Depth (ft bgs)	**Lithologic description**	**Lithologic Symbol**	**Notes**
690–695	690'–695': No cuttings collected; lost circulation.	Tpt	
695–720	Quartzo-feldspathic Sediments—gray/orange (10YR 7/4 to 10YR 8/2) silty fine- to medium-grained sandstone and sandstone with fine gravel, well-sorted, weakly to moderately indurated. Detritus predominantly of quartz, microcline feldspar and Precambrian quartzite, and lesser volcanic rocks of basaltic composition. 695'–720' WR: abundant silt matrix. +10F/+35F: 10–15% fragments of silty fine-grained quartzo-feldspathic sandstone; 75–85% subrounded to angular clasts/fragments of quartzite, quartz, microcline; 5–10% subrounded basaltic.	Tpt	
720–735	Quartzo-feldspathic Sediments—fine to medium gravels (up to 12 mm) with medium- to coarse-grained sandstone, weakly to moderately cemented with tan silt/clay. Detritus of mixed quartzo-feldspathic and various volcanic lithologies. 720'–735' WR/+10F: well-rounded to angular/broken clasts composed of 70–80% Precambrian quartzo-feldspathic rocks (quartz, quartzite, microcline); 10–15% clasts of various volcanic rocks (hornblende- and biotite-dacites, basalt, andesite); 5–10% clasts of medium to fine-grained quartz/microcline sandstone. +35F: 80–90% grains of quartzite and quartz; 5–10% grains of various volcanic rocks; 5–10% microcline grains.	Tpt	
735–755	Quartzo-feldspathic Sediments—fine to medium gravels (up to 25 mm) with medium- to coarse-grained sandstone, weakly to moderately cemented with tan silt/clay. Detritus of mixed quartzo-feldspathic and various volcanic lithologies. 735'–755' WR/+10F: well-rounded to angular/broken clasts composed of 70–80% Precambrian quartzo-feldspathic rocks (quartz, quartzite, microcline); 10–15% clasts of various volcanic rocks (hornblende- and biotite-dacites, basalt, andesite); 5–10% clasts of medium to fine-grained quartz/microcline sandstone. +35F: 70–80% grains of quartzite and quartz; 15–25% grains of various volcanic rocks.	Tpt	

Borehole Identification (ID): R-55	**Technical Area (TA): 54**	**Page :** 12 of 15
Drilling Company: Boart Longyear Company	**Start Date/Time: 5-9-10/1257**	**End Date/Time :** 6-29-10/1235
Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD	**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl		**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola	

Depth (ft bgs)	**Lithologic description**	**Lithologic Symbol**	**Notes**
755–780	Quartzo–feldspathic Sediments—fine to medium gravels (up to 25 mm) with fine-grained silty sandstone, silt/claystone. Detritus of mixed quartzo-feldspathic with lesser volcanic lithologies. 755’–780’ WR/+10F/+35F: well-rounded to angular/broken clasts composed of 60–70% Precambrian quartzo-feldspathic rocks (quartz, quartzite, microcline); 10–15% light brown silt/claystone; 10–15% clasts of various volcanic rocks (hornblende- and biotite-dacites, basalt, andesite); 5–10% clasts of medium to fine-grained quartz/microcline sandstone.	Tpt	Note: this interval is much more silt/clay-rich than intervals above or below.
780–815	Quartzo-feldspathic Sediments—fine to medium gravels (up to 12 mm) with medium- to coarse-grained sandstone, weakly to moderately cemented with tan silt/clay. Detritus of mixed quartzo-feldspathic and various volcanic lithologies. 780’–815’ WR/+10F: well-rounded to angular/broken clasts composed of 90–95% Precambrian quartzo-feldspathic rocks (quartz, quartzite, microcline); 5–10% clasts of various volcanic rocks (hornblende- and biotite-dacites, basalt, andesite). +35F: 90–95% grains of quartzite and quartz; 1–5% grains of various volcanic rocks.	Tpt	
815–820	Quartzo-feldspathic Sediments- quartzite gravels (up to 10 mm) with fine- to medium-grained sandstone, moderately cemented. 815’–820’ WR/+10F: 70–80% well-rounded quartzite gravels; 20–30% clasts of moderately cemented poorly sorted sandstone clasts. +35F: 95–98% quartzite and quartz grains; 2–5% grains of various volcanic rocks.	Tpt	

Borehole Identification (ID): R-55	**Technical Area (TA): 54**	**Page :** 13 of 15
Drilling Company: Boart Longyear Company	**Start Date/Time: 5-9-10/1257**	**End Date/Time :** 6-29-10/1235
Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD	**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl		**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola	

Depth (ft bgs)	**Lithologic description**	**Lithologic Symbol**	**Notes**
820–855	Quartzo-feldspathic Sediments—fine to medium gravels (up to 30 mm) with fine- to coarse-grained sandstone. Detritus mostly quartzite. 820'–850' WR/+10F: well-rounded to angular/broken clasts composed of 95–98% Precambrian quartzo-feldspathic rocks (quartz, quartzite, microcline); 2–5% clasts of various volcanic rocks (dacites, andesites). 850'–855' WR/+10F: same composition as 820'–850', finer gravel (<10 mm). 820'–855' +35F: 90–95% fine to coarse sand-sized grains of quartzite and quartz; 5–10% microcline, orthoclase, white mica grains; trace grains of various volcanic rocks.	Tpt	
855–880	Quartzo-feldspathic Sediments—fine to medium gravels (up to 30 mm) with fine- to coarse-grained sandstone. Detritus mostly quartzite, with minor granite and volcanic (andesitic and basaltic) clasts. 855'–880' WR/+10F: subrounded to well-rounded clasts composed of 85–90% quartzites; 5–10% granite clasts; 2–5% well-rounded hornblende-bearing andesite and vesicular basalt clasts; 2–5% fine-grained quartz sandstone clasts. +35F: 90–95% quartzite clasts and quartz grains; 5% granite clasts; 2–5% microcline and orthoclase grains; trace volcanic clasts.	Tpt	Note: First appearance of granitic clasts.
880–885	Quartzo-feldspathic Sediments—quartzite gravels (up to 10 mm) with fine- to medium-grained sandstone, moderately cemented. 880'–885' WR/+10F/+35F: subrounded to well-rounded clasts composed of 75–80% quartzites; 10–50% moderately cemented poorly sorted sandstone clasts (similar lithology to loose sample); 2–5% granite clasts; 2–5% well rounded hornblende-bearing andesite and vesicular basalt clasts.	Tpt	

Borehole Identification (ID): R-55	Technical Area (TA): 54	Page : 14 of 15
Drilling Company: Boart Longyear Company	Start Date/Time: 5-9-10/1257	End Date/Time : 6-29-10/1235
Drilling Method : Dual Rotary	Machine : Foremost DR24 HD	Sampling Method OD: Grab
Ground Elevation : 6533.61 ft amsl		Total Depth : 1035.2 ft
Drillers: M. Cross, E. Rivas	Site Geologists : Travis J. Naibert, M. Jojola	

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
885–890	Quartzo-feldspathic Sediments—fine to medium gravels (up to 30 mm) with fine- to coarse-grained sandstone. Detritus mostly quartzite, with minor granitic and volcanic (andesitic and basaltic) clasts. 855'–880' WR/+10F: subrounded to well rounded clasts composed of 85–90% quartzites; 5–10% granite clasts; 2–5% well rounded hornblende-bearing andesite and vesicular basalt clasts; 2–5% fine-grained quartz sandstone clasts. +35F: 90–95% quartzite clasts and quartz grains; 5% granite clasts; 2–5% microcline and orthoclase grains; trace volcanic clasts.	Tpt	
890–945	**CHAMITA FORMATION:** Quartzo-feldspathic Sediments—fine to medium gravels (up to 30 mm) with fine- to coarse-grained sand. Detritus mostly quartzite with common volcanic (andesitic and basaltic) clasts. 890'–945' WR/+10F: subrounded to rounded clasts composed of 75–80% quartzite clasts; 15–20% clasts of various volcanic lithologies (andesite, dacite, plagioclase-phyric basalt); 5–10% granitic clasts. 890'–925' +35F: 80–85% quartzite clasts; 10–15% volcanic clasts; 1–2% granite clasts; 2–5% quartz grains. 925'–945' +35F: 60–70% quartzite clasts; 20–30% quartz grains (very fine sand sized); 5–10% volcanic clasts; 5% granite clasts.	Tcar	Chamita Formation sediments (Tcar), intersected from 890 ft to the bottom of the borehole at 1035.2 ft bgs, have a minimum thickness of 145.2 ft. The lower Puye contact was identified based on gamma log. Note: +35F size fraction contains fewer quartz grains than the Totavi section above, but the quartz sand in Tcar is generally finer ("sugar sand") than found in Tpt.
945–955	Quartzo-feldspathic Sediments—fine to medium gravels (up to 25 mm) with fine- to coarse-grained sand. Detritus mostly quartzite with common volcanic (andesitic and basaltic) clasts and clasts of fine-grained quartz sandstone. 945'–955' WR/+10F: 70–80% quartzite clasts; 20–30% volcanic clasts; 5–10% clasts of fine-grained sandstone; trace granitic clasts. +35F: 70–80% quartzite and quartz grains; 20–30% volcanic clasts (mostly dacite and andesite, minor oxidized basalt).	Tcar	

Borehole Identification (ID): R-55	**Technical Area (TA): 54**	**Page :** 15 of 15
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Drilling Method : Dual Rotary	**Machine** : Foremost DR24 HD	**Sampling Method OD:** Grab
Ground Elevation : 6533.61 ft amsl		**Total Depth :** 1035.2 ft
Drillers: M. Cross, E. Rivas	**Site Geologists :** Travis J. Naibert, M. Jojola	

Depth (ft bgs)	**Lithologic description**	**Lithologic Symbol**	**Notes**
955–990	Volcaniclastic Sediments—fine to coarse sands and gravels (up to 30 mm) composed of volcanic clasts of various lithologies (andesite, dacite, rhyolite) and Precambrian quartzite clasts. 955'–990' WR/+10F: 70–80% volcaniclastic gravels, including hornblende-bearing dacites and minor rhyolite clasts; 15–20% quartzite clasts; 10–15% clasts of fine-grained tan sandstone. +35F 50–70% volcaniclastic clasts; 20–35% quartzite grains; 15–25% quartz grains; trace sandstone clasts; trace granitic clasts.	Tcar	Note: This interval is dominated by volcanic lithologies as opposed to the above quartzite-dominated intervals, implying a depositional switch from local alluvial contributions from the Jemez volcanic field to axial trunk streams of the Española Basin.
990–1035	Volcaniclastic Sediments—fine to coarse sands and gravels (up to 30 mm) composed of volcanic clasts of various lithologies (andesite, dacite, rhyolite). 990'–1000' WR/+10F: 65–75% volcanic clasts including hornblende-bearing dacites, fine-grained rhyolites, andesites; 25–35% white pumice clasts; 1–2% quartzite clasts. 1000'–1030' WR/+10F: 95% volcanic clasts including dacites, fine-grained rhyolites, banded rhyolites, minor andesites/basalts, and volcanic breccias. Feldspar-bearing clasts are partially altered to clay minerals; 5% white pumice clasts decreasing downsection. 1030'–1035' WR/+10F: 80–90% volcanic clasts; 10–20% fine- to medium-grained, poorly sorted, moderately cemented sandstone clasts containing quartz and volcanic sand grains. 990'–1035' +35F: 40–50% volcanic clasts of various lithologies (as in WR/+10F); 40–50% quartzite and quartz grains; 0–10% dacite clasts altered to clay minerals; 0–5% feldspar grains.	Tcar	
1035–1035.2	Quartzo-feldspathic Sediments—fine to coarse sands and gravels (up to 20 mm) composed of volcanic clasts, fine-grained sandstone clasts and quartzite clasts. 1035'–1035.2' WR/+10F: 60–70% clasts of poorly sorted, quartz and lithic-rich sandstone (well cemented); 20–30% quartzite clasts; 10–20% volcanic clasts (fine grained rhyolites and dacites). +35F: 90–95% quartzite and quartz grains; 5–10% volcanic grains.	Tcar	

ABBREVIATIONS

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

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

TD = total depth

amsl = above mean sea level

bgs = below ground surface

ft = feet

GM = groundmass

Qal = Quaternary alluvium.

Qbo = Otowi Member of Bandelier Tuff

Qbog = Guaje Pumice Bed

Qbt = Tshirege Member of the Bandelier Tuff

Qbt 1g = Unit 1g of the Tshirege Member of the Bandelier Tuff (vitric nonwelded unit)

Tb 4 = Cerros del Rio volcanic series

Tpt = Totavi Lentil of the Puye Formation

Tcar = Chamita Formation

+10F = plus No. 10 sieve sample fraction

+35F = plus No. 35 sieve sample fraction

WR = whole rock (unsieved sample)

1 mm = 0.039 in

1 in. = 25.4 mm

Appendix B

Groundwater Analytical Results

B-1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-55

One borehole water sample was collected during drilling at well R-55 from 550 ft below ground surface (bgs) in perched zone saturation within the Cerros del Rio volcanic series. This sample was analyzed for inorganic solutes, low-level tritium (LH3), and volatile organic compounds (VOCs). The solute analyses (anions and cations) were conducted by Los Alamos National Laboratory's (LANL's or the Laboratory's) Earth and Environmental Sciences Group 14 (EES-14). The LH3 and VOC analyses were conducted by an off-site laboratory.

Ten groundwater samples collected during development and aquifer testing at R-55 were analyzed for total organic carbon (TOC).

B-1.1 Analytical Techniques

Groundwater samples were filtered (0.45-µm membranes) before preservation and chemical analyses. Samples were acidified at the EES-14 wet chemistry laboratory with analytical grade nitric acid to a pH of 2.0 or less for metal and major cation analyses.

Groundwater samples were analyzed using techniques specified by the U.S. Environmental Protection Agency (EPA) methods for water analyses. Ion chromatography (EPA Method 300, Rev. 2.1) was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. The instrument detection limit for perchlorate was 0.005 ppm using EPA Method 314.0, Rev. 1. Total carbonate alkalinity (EPA Method 310.1) was measured using standard titration techniques.

Inductively coupled (argon) plasma optical emission spectroscopy (EPA Method 200.7, Rev. 4.4) was used for analyses of dissolved aluminum, barium, boron, calcium, total chromium, iron, lithium, magnesium, manganese, potassium, silica, sodium, strontium, titanium, and zinc. Dissolved aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, cesium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, rubidium, selenium, silver, thallium, thorium, tin, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (EPA Method 200.8, Rev. 5.4). For metals analyzed by both techniques, EES-14 reports the analytical result from the technique with the lower detection limit.

TOC analyses were performed per EPA Method 415.1.

B-1.2 Field Parameters

B-1.2.1 Well Development

Water samples collected during development and aquifer testing were drawn from the pump discharge line into sealed containers, and field parameters were measured using a YSI multimeter. Results of field parameters, consisting of pH, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), specific conductance, and turbidity measured during development and aquifer testing at well R-55 are provided in Table B-1.2-1.

Upper screen

During development of the upper screen, pH and temperature varied from 7.87 to 7.94 and from 21.16 to 23.99°C, respectively. Concentrations of DO varied from 7.10 to 8.05 mg/L. Corrected oxidation-reduction potential (Eh) values determined from field ORP measurements varied from 252.3 to 345.9 millivolts (mV) (Table B-1.2-1). Two temperature-dependent correction factors for calculating Eh values from field ORP measurements were based on an Ag/AgCl, KCl-saturated filling solution contained in the ORP electrode. The correction factors are 203.9 and 198.5 mV at 20ºC and 25ºC, respectively. Specific conductance varied slightly from 183 to 187 μS/cm, and turbidity varied from 0.1 to 3.8 nephelometric turbidity units (NTU) during development of well R-55 screen 1 (Table B-1.2-1).

Lower screen

During development of the lower screen, pH and temperature varied from 6.85ºC to 7.93ºC and from 20.09ºC to 26.27°C, respectively. Concentrations of DO varied from 3.60 to 5.01 mg/L. Corrected Eh values determined from field ORP measurements decreased from 279.3 to 399.3 mV (Table B-1.2-1). Measurements of specific conductance varied from 96 to 282 μS/cm, and turbidity values generally decreased from 53.3 to 1.4 NTU (Table B-1.2-1).

B-1.2.2 Aquifer Testing

Upper screen

During aquifer testing of the upper screen, nineteen measurements of pH and temperature varied from 7.34ºC to 7.98ºC and from 19.53ºC to 25.14°C, respectively. Concentrations of DO varied from 6.99 to 8.04 mg/L. Corrected Eh values determined from field ORP measurements varied from 337.4 to 419.3 mV (Table B-1.2-1). Specific conductance slightly varied from 180 to 189 μS/cm, and turbidity values decreased from 1.4 to 0 NTU (Table B-1.2-1).

Lower screen

During aquifer test of the lower screen, pH and temperature varied from 8.02ºC to 8.29ºC and from 19.50ºC to 27.32°C. Concentrations of DO varied from 2.79 to 6.35 mg/L. Corrected Eh values determined from field ORP measurements varied from 334.4 to 413.3 mV (Table B-1.2-1). Specific conductance varied from 178 to 196 μS/cm, and all turbidity values were 0.0 NTU (Table B-1.2-1).

B-1.3 Analytical Results for Groundwater Samples

Analytical results from LANL EES-14 and external analytical laboratories are presented below. Select analytical results for the borehole sample only are screened against background concentrations developed for the Laboratory as a whole (LANL 2007, 095817). It should be noted that, because of localized variations in geochemistry, background concentrations for the area upgradient of well R-55 may vary.

B-1.3.1 Volatile Organic Compounds and Low-level Tritium

Acetone was detected at a concentration of 65.7 ppb in the borehole water sample GW55-10-17161. The VOCs 1-butanol and 2-butanone were detected at estimated concentrations of 257 ppb and 1.31 ppb, respectively. LH3 was not detected in the borehole water sample from the perched zone. Off-site laboratory analytical results for VOCs and LH3 are shown in Table B-1.3-1.

B-1.3.2 Cations, Anions, Perchlorate and Metals

Anion and cation analytical results for the borehole sample GW55-10-17161 collected during drilling are provided in Table B-1.3-2. The sample consisted of disaggregated colloidal aquifer material, drilling material, water used during drilling, and native groundwater. The charge balance error for total cations and anions for the borehole water sample was +5%. The positive cation-anion charge balance value indicates excess cations for the filtered sample.

Dissolved concentrations for select analytes detected in the borehole water sample during drilling are presented below; complete results are shown in Table B-1.3-2.

- The molybdenum concentration was elevated (20 ppb versus a maximum background concentration of 4.3 ppb), suggesting that the sample contains a component of drilling lubricant used during drilling.
- Chromium was detected at 13 ppb. The maximum background concentrations of total dissolved chromium 2.4 ppb for perched intermediate groundwater (LANL 2007, 095817).
- Uranium was detected at 1.2 ppb, which slightly exceeds the maximum background concentration of 0.60 ppb for perched intermediate groundwater (LANL 2007, 095817).
- Fluoride was detected at 0.37 ppm. The maximum background concentration of dissolved fluoride is 0.20 mg/L (LANL 2007, 095817).
- Chloride was detected at 24.80 ppm. The maximum background concentration for dissolved chloride is 6.43 ppm for perched intermediate groundwater (LANL 2007, 095817).
- Perchlorate was not detected (<0.005 ppm) in the borehole sample.

B-1.3.3 Total Organic Carbon

TOC concentrations from both screens varied from 0.3 to 0.6 mgC/L during development and aquifer testing, with the exception of one sample from the lower screen that was reported at 4.0 mgC/L during aquifer testing (Table B.1-3-3).

B-1.4 SUMMARY

In summary, dissolved concentrations of chloride, fluoride, chromium, and uranium from the borehole water sample slightly exceed background concentrations for perched intermediate groundwater from developed water samples. Acetone was reported at 65.7 ppb in the borehole water sample. Perchlorate and tritium were not detected in the borehole sample

Concentrations of TOC were typically less than 0.6 mgC/L in samples collected during development and aquifer testing at well R-55.

Groundwater at well R-55 is relatively oxidizing, based on corrected positive Eh values and measurable concentrations of DO recorded during well development and aquifer testing. Redox conditions based on corrected field ORP measurements at well R-55 are similar to other previously wells drilled in the Pajarito watershed, including R-21 and R-23.

B-2.0 REFERENCE

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

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

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

Table B-1.2-1
Purge Volumes and Water Quality Parameters during Well Development and Aquifer Testing at R-55

Date	pH	Temp (°C)	DO (mg/L)	ORP[a], Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development Composite Water from Both Screens								
8/28/10	n/r[b]; bailing						242	242
8/29/10	n/r, bailing						495	737
Well Development Upper Screen								
8/30/10	n/r, pumping while swabbing screen						1193	1930
8/31/10	n/r, pumping while swabbing screen						3575	4313
Well Development Lower Screen								
8/31/10	n/r, pumping while swabbing screen						2664	6977
	n/r, pumping sump						296	7273
	n/r, pump rate stabilization						1771	9044
	8.44	20.09	3.60	195.4, 399.3	184	53.3	209	9253
	6.66	23.30	3.82	178.2, 376.7	282	52.7	204	9457
	8.13	24.04	3.90	130.0, 328.5	187	52.6	108	9565
	8.19	24.40	4.23	147.8, 346.3	185	43.1	102	9667
9/1/10	n/r, pumping while swabbing screen						851	10518
	8.11	26.27	4.78	130.0, 328.5	184	21.3	400	10918
	8.14	25.80	4.70	131.6, 330.1	182	28.3	60	10978
	8.18	25.88	4.57	146.0, 344.5	182	12.7	60	11038
	8.15	25.73	4.65	118.6, 317.1	181	10.7	60	11098
	8.20	26.68	4.57	109.9, 308.4	182	9.2	60	12058
	8.19	25.60	4.46	130.1, 328.6	181	7.5	60	12118
	8.20	25.37	4.45	80.8, 279.3	182	6.5	60	12178
9/2/10	8.17	21.64	4.50	119.3, 323.4	180	11.1	225	12403
	8.08	24.11	4.53	138.6, 337.1	182	13.4	101	12504
	8.05	24.27	4.79	124.4, 322.9	96	5.9	102	12606
	8.00	24.70	4.71	107.5, 306.0	182	4.9	102	12708
	8.01	24.81	4.98	138.6, 337.1	181	1.4	102	12810
	8.00	25.02	5.01	132.9, 331.4	180	2.8	102	12912
Well Development Upper Screen								
9/3/10	n/r, pump rate stabilization						585	13497
	7.87	21.54	7.10	142.0, 345.9	185	3.8	525	14022
	7.94	21.16	7.24	105.0, 308.9	187	1.1	522	14544
	7.94	21.68	7.64	123.4, 327.3	185	0.5	522	15066
	7.92	22.27	7.80	113.4, 317.3	183	0.7	522	15588
	7.93	22.52	7.83	80.5, 279.0	185	0.4	525	16113
	7.89	23.99	7.78	53.8, 252.3	186	0.1	1050	17163
	7.89	23.58	8.05	111.6, 310.1	186	0.2	525	17688
	7.90	23.71	7.83	114.1, 312.6	186	0.2	525	18213

Table B-1.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP[a], Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Aquifer Pumping Test Upper Screen								
9/7/10	n/r, pumping, mini-test preparation						1719	19932
9/8/10 to 9/9/10	7.34	22.90	7.65	196.8, 395.3	183	1.4	4261	24193
	7.92	22.75	8.04	177.9, 376.4	187	0.5	1008	25201
	7.96	23.84	8.04	138.9, 337.4	189	0.0	1038	26239
	7.95	25.14	7.91	160.6, 359.1	189	0.0	1038	27277
	7.94	22.93	7.00	179.2, 377.7	186	0.0	1038	28315
	7.93	22.86	7.47	183.7, 382.2	185	0.0	1038	29353
	7.95	22.97	7.22	184.3, 382.8	184	0.0	1038	30391
	7.95	22.74	7.65	189.1, 387.6	185	0.0	1038	31429
	7.95	20.96	7.58	198.8, 402.7	186	0.0	1044	32467
	7.96	21.86	7.08	198.6, 402.5	181	0.0	1044	33511
	7.97	21.07	7.18	203.3, 407.2	180	0.0	1044	34555
	7.98	22.60	7.20	195.1, 393.6	186	0.0	1044	35599
	7.95	21.91	7.87	206.0, 409.9	185	0.0	1044	36643
	7.97	22.66	7.74	203.2, 401.7	185	0.0	966	37609
	7.97	22.63	7.57	207.2, 405.7	186	0.0	1044	38653
	7.97	19.57	7.81	213.5, 417.4	186	0.0	1044	39697
	7.96	19.53	7.57	214.3, 418.2	184	0.0	1044	40741
	7.98	19.82	7.73	215.4, 419.3	185	0.0	1044	41785
	7.98	22.45	6.99	205.1, 409.0	186	0.0	3132	44917

Table B-1.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP[a], Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Aquifer Pumping Test Lower Screen								
9/11/10	n/r, pumping, mini-test						382	45299
9/13/10 to 9/14/10	8.02	19.50	2.79	175.0, 378.9	193	0.0	208	45507
	8.29	25.19	3.12	135.9, 334.4	196	0.0	153	45660
	8.28	25.54	3.80	148.0, 346.5	193	0.0	153	45813
	8.18	25.53	3.79	158.8, 357.3	189	0.0	153	45966
	8.16	25.87	4.60	163.8, 362.3	183	0.0	153	46119
	8.15	26.95	5.24	154.7, 353.2	178	0.0	153	46272
	8.13	26.16	5.40	159.5, 358.0	188	0.0	153	46425
	8.12	26.32	5.08	161.1, 359.6	186	0.0	153	46578
	8.10	26.76	5.73	158.4, 356.9	184	0.0	153	46731
	8.10	27.32	5.59	161.4, 359.9	183	0.0	153	46884
	8.07	25.82	5.50	174.8, 373.3	189	0.0	153	47037
	8.12	25.55	5.65	181.1, 379.6	186	0.0	153	47190
	8.12	25.44	5.59	187.7, 386.2	187	0.0	153	47343
	8.12	25.45	5.85	191.4, 389.9	186	0.0	153	47496
	8.13	25.41	5.77	196.0, 394.5	185	0.0	153	47649
	8.12	25.33	6.35	197.5, 396.0	183	0.0	153	47802
	8.13	24.91	5.61	198.5, 397.0	187	0.0	153	47955
	8.13	25.45	5.74	200.0, 398.5	186	0.0	153	48108
	8.13	22.13	5.86	205.7, 409.6	182	0.0	153	48261
	8.14	24.98	6.21	202.0, 400.5	183	0.0	153	48414
	8.14	19.73	5.86	209.4, 413.3	184	0.0	153	48567
	8.15	24.80	5.71	199.9, 398.4	186	0.0	153	48720
	8.13	23.26	5.80	205.0, 403.5	183	0.0	306	49026

[a] Eh (mV) is calculated from a Ag/AgCl saturated KCl electrode filling solution at 20ºC and 25ºC by adding temperature-sensitive correction factors of 203.9 mV and 198.5 mV, respectively.

[b] n/r = Not recorded.

Table B-1.3-1
Off-site Laboratory Analytical Results

Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Result	Validation Qualifier Code
GW55-10-17161	VOC	SW-846:8260B	Ethylbenzene	1.0	µg/L	U[a]
GW55-10-17161	VOC	SW-846:8260B	Styrene	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichloropropene[cis-1,3-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichloropropene[trans-1,3-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Propylbenzene[1-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Butylbenzene[n-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Chlorotoluene[4-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichlorobenzene[1,4-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dibromoethane[1,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Acrolein	5.0	µg/L	R[b]
GW55-10-17161	VOC	SW-846:8260B	Chloro-1-propene[3-]	5.0	µg/L	UJ[c]
GW55-10-17161	VOC	SW-846:8260B	Dichloroethane[1,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Propionitrile	5.0	µg/L	R
GW55-10-17161	VOC	SW-846:8260B	Acrylonitrile	5.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Vinyl acetate	5.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Methyl-2-pentanone[4-]	5.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Trimethylbenzene[1,3,5-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Bromobenzene	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Toluene	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Chlorobenzene	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Trichlorobenzene[1,2,4-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Chlorodibromomethane	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Methacrylonitrile	5.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Chloro-1,3-butadiene[2-]	1.0	µg/L	UJ

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Result	Validation Qualifier Code
GW55-10-17161	VOC	SW-846:8260B	Tetrachloroethene	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Butylbenzene[sec-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichloropropane[1,3-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichloroethene[cis-1,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichloroethene[trans-1,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Methyl tert-Butyl Ether	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichlorobenzene[1,3-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Carbon Tetrachloride	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichloropropene[1,1-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Hexanone[2-]	5.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichloropropane[2,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Diethyl Ether	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Tetrachloroethane[1,1,1,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Acetone	65.7	µg/L	NQ[d]
GW55-10-17161	VOC	SW-846:8260B	Chloroform	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Butanol[1-]	257.0	µg/L	J[e]
GW55-10-17161	VOC	SW-846:8260B	Benzene	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Trichloroethane[1,1,1-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Bromomethane	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Chloromethane	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Iodomethane	5.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dibromomethane	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Bromochloromethane	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Chloroethane	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Vinyl Chloride	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Acetonitrile	25.0	µg/L	R

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Result	Validation Qualifier Code
GW55-10-17161	VOC	SW-846:8260B	Methylene Chloride	10.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Carbon Disulfide	5.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Bromoform	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Bromodichloromethane	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichloroethane[1,1-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichloroethene[1,1-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Trichlorofluoromethane	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichlorodifluoromethane	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Trichloro-1,2,2-trifluoroethane[1,1,2-]	5.0	µg/L	UJ
GW55-10-17161	VOC	SW-846:8260B	Isobutyl alcohol	50.0	µg/L	R
GW55-10-17161	VOC	SW-846:8260B	Dichloropropane[1,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Butanone[2-]	1.3	µg/L	J
GW55-10-17161	VOC	SW-846:8260B	Trichloroethane[1,1,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Trichloroethene	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Tetrachloroethane[1,1,2,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Methyl Methacrylate	5.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Trichlorobenzene[1,2,3-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Hexachlorobutadiene	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Naphthalene	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Xylene[1,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Chlorotoluene[2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dichlorobenzene[1,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Trimethylbenzene[1,2,4-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Dibromo-3-Chloropropane[1,2-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Trichloropropane[1,2,3-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Ethyl Methacrylate	5.0	µg/L	U

Table B-1.3-1 (continued)

Sample Name	Analytical Suite Code	Analytical Method Code	Analyte Description	Lab Result	Result	Validation Qualifier Code
GW55-10-17161	VOC	SW-846:8260B	Butylbenzene[tert-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Isopropylbenzene	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Isopropyltoluene[4-]	1.0	µg/L	U
GW55-10-17161	VOC	SW-846:8260B	Xylene[1,3-]+Xylene[1,4-]	2.0	µg/L	U
GW55-10-17161	H3	Generic:Low_Level_Tritium	Tritium	-0.2	TU	U

U = The analyte was analyzed for but not detected.
R = The data are rejected as a result of major problems with quality assurance/quality control parameters.
UJ = The analyte was not positively identified in the sample, and the associated value is an estimate of the sample-specific detection or quantitation limit.
NQ = Not qualified; data are valid.
J = The analyte was positively identified, and the associated numerical value is estimated to be more uncertain than would normally be expected for that analysis.

Table B-1.3-2
EES-14 Analytical Results

Sample ID	Sample Type	Depth (ft)	Ag rslt (ppm)	stdev (Ag)	Al rslt (ppm)	stdev (Al)	As rslt (ppm)	stdev (As)	B rslt (ppm)	stdev (B)	Ba rslt (ppm)	stdev (Ba)	Be rslt (ppm)	stdev (Be)	Br(-) ppm	Ca rslt (ppm)	stdev (Ca)	Cd rslt (ppm)	stdev (Cd)	Cl(-) ppm	ClO4(-) ppm	Co rslt (ppm)	stdev (Co)	Alk-CO3 rslt (ppm)	Cr rslt (ppm)	stdev (Cr)
GW55-10-17161	Borehole	550	0.001	U	0.019	0.000	0.0015	0.0000	0.056	0.000	0.097	0.002	0.001	U	0.13	32.47	0.13	0.001	U	24.80	0.005, U	0.001	U	8	0.013	0.000

Table B-1.3-2 (continued)

Sample ID	Sample Type	Depth (ft)	Cs rslt (ppm)	stdev (Cs)	Cu rslt (ppm)	stdev (Cu)	F(-) ppm	Fe rslt (ppm)	stdev (Fe)	Alk-CO3+HCO3 rslt (ppm)	Hg rslt (ppm)	stdev (Hg)	K rslt (ppm)	stdev (K)	Li rslt (ppm)	stdev (Li)	Mg rslt (ppm)	stdev (Mg)	Mn rslt (ppm)	stdev (Mn)	Mo rslt (ppm)	stdev (Mo)	Na rslt (ppm)	stdev (Na)	Ni rslt (ppm)
GW55-10-17161	Borehole	550	0.001	U	0.001	U	0.37	0.01	0.00	106	0.00012	0.00000	4.77	0.01	0.023	0.000	6.65	0.03	0.001	U	0.020	0.000	30.12	0.13	0.001

Table B-1.3-2 (continued)

Sample ID	Sample Type	Depth (ft)	stdev (Ni)	NO2 (ppm)	NO2-N rslt	NO2-N (U)	NO3 ppm	NO3-N rslt	C2O4 rslt (ppm)	C2O4 (U)	Pb rslt (ppm)	stdev (Pb)	Lab pH	PO4(-3) rslt (ppm)	Rb rslt (ppm)	stdev (Rb)	Sb rslt (ppm)	stdev (Sb)	Se rslt (ppm)	stdev (Se)	Si rslt (ppm)	stdev (Si)	SiO2 rslt (ppm)	stdev (SiO2)	Sn rslt (ppm)	stdev (Sn)
GW55-10-17161	Borehole	550	U	0.01	0.003	U	7.85	1.77	0.01	U	0.0002	U	8.26	0.01, U	0.005	0.000	0.001	U	0.003	0.000	21.06	0.12	45.08	0.25	0.001	U

Table B-1.3-2 (continued)

Sample ID	Sample Type	Depth (ft)	SO4(-2) rslt (ppm)	Sr rslt (ppm)	stdev (Sr)	Th rslt (ppm)	stdev (Th)	Ti rslt (ppm)	stdev (Ti)	Tl rslt (ppm)	stdev (Tl)	U rslt (ppm)	stdev (U)	V rslt (ppm)	stdev (V)	Zn rslt (ppm)	stdev (Zn)	TDS (ppm)	Cations	Anions	Balance
GW55-10-17161	Borehole	550	20.36	0.204	0.001	0.001	U	0.002	U	0.001	U	0.0012	0.0000	0.010	0.000	0.010	0.000	288	3.61	3.29	0.05

Note: U = not detected.

Table B-1.3-3
TOC Analytical Results

Sample ID	Sample Type	Depth (ft)	TOC (ppm)
GW55-10-17170	Development	994.4-1015.4	0.3
GW55-10-17171	Development	860.0-880.6	0.4
GW55-10-17172	Aquifer testing	860.0-880.6	0.5
GW55-10-17173	Aquifer testing	860.0-880.6	0.6
GW55-10-17174	Aquifer testing	860.0-880.6	0.4
GW55-10-17175	Aquifer testing	860.0-880.6	0.3
GW55-10-17176	Aquifer testing	994.4-1015.4	Not reported
GW55-10-17177	Aquifer testing	994.4-1015.4	0.3
GW55-10-17178	Aquifer testing	994.4-1015.4	4.0
GW55-10-17179	Aquifer testing	994.4-1015.4	0.3
GW55-10-17180	Aquifer testing	994.4-1015.4	0.3

Appendix C

Aquifer Testing Report

C-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted in September 2010 at R-55, a dual-screen regional aquifer well located in Cañada del Buey downgradient of Material Disposal Area G. The tests on R-55 were conducted to quantify the hydraulic properties of the two zones in which the well is screened, evaluate the hydraulic interconnection of the zones, and check for interference effects at neighboring wells.

Testing planned for each screen interval consisted of brief trial pumping, background water-level data collection, and a 24-h constant-rate pumping test. Water levels were monitored in both zones during each of the pumping tests in each screen.

As in most of the R-well pumping tests conducted on the Pajarito Plateau, an inflatable packer system was used in R-55 to both hydraulically isolate the screen zones and to try to eliminate casing storage effects on the test data. The implementation of the inflatable packer system was largely successful in eliminating storage effects from the screen 1 tests. It was unclear, however, whether screen 2 exhibited storage effects. It was possible that accumulation of air or gas beneath the packer during the screen 2 tests may have caused a minor storage-like effect that masked early-time recovery response, although the data supported multiple interpretations, as described below.

Both screen zones produced slightly aerated water. The gas content in the water in screen 1 may have contributed to odd pump performance observed during the screen 1 tests, although this effect is not certain. When the pump was first installed at screen 1, numerous startup attempts were made without producing water at the surface or moving a detectable quantity of air from the drop pipe. When the pump was pulled for examination, it was discovered that about 25 ft of drop pipe had filled with water during the startup attempts, meaning that the pump had produced just a “trickle” of water when it was running.

When the pump was removed from the well and tested, it performed appropriately both inside the tight-fitting stainless-steel shroud and when it was removed from the shroud. When the pump was reinstalled in the shroud and rerun to screen 1, more than a dozen start attempts were needed before water was produced at a significant rate (determined from the rate that air was expelled from the drop pipe as it filled with water). Two days later, when trial testing was attempted, the first time the pump was started, it produced just a “trickle” of water. It was shut down and restarted, producing water at a significant rate. The following day, when the 24-h test was begun, the same thing occurred—just a trickle was produced the first time the pump was started, with an adequate yield produced immediately on restart.

Another oddity associated with running the pump in screen 1 was that a different discharge rate was produced each time the pump was run, even though the valve setting in the discharge line was left unchanged. When the drop pipe was filled initially, the rate was throttled back to 15.7 gallons per minute (gpm) by adjusting the valve. When the pump was restarted for trial 1, it produced 16.9 gpm, then 14.1 gpm during trial 2 and, finally, 17.4 gpm during the 24-h test. There was no apparent explanation for this unusual performance. Curiously, the discharge rate during each test remained constant and stable.

It is possible that the pump bowls were defective, contributing to the erratic performance (pumping just a trickle initially, then different rates during each of the tests when it was restarted). It is also possible that variable gas content in the pumped water might have affected the bowl efficiency in such a way as to exhibit the observed symptoms.

Conceptual Hydrogeology

Both screens in R-55 lie within sands and gravels—screen 1 in the Totavi Lentil and screen 2 in the underlying Chamita Formation. Screen 1 is 20.6 ft long, extending from 860.0 to 880.6 ft below ground surface (bgs). Screen 2 is 21.0 ft long and is positioned about 114 ft beneath screen 1, extending from 994.4 to 1015.4 ft bgs.

The composite static water level measured on September 4, 2010, before testing was 834.67 ft bgs. The brass cap elevation at the well was 6533.86 ft above mean sea level (amsl), making the composite water level elevation 5699.19 ft amsl.

When the screen zones were isolated using an inflatable packer, the water level in screen 1 rose 0.11 ft, to a depth of 834.56 ft bgs and an elevation of 5699.30 ft amsl. At the same time, the water level in screen 2 declined 2.66 ft, making its depth to water 837.33 ft bgs at an elevation of 5696.53 ft amsl. Thus, the water levels showed a head difference of 2.77 ft and a significant downward hydraulic gradient, implying the likelihood of resistive sediments separating the two screen zones.

R-55 Screen 1 Testing

Screen 1 was tested from September 5 to 10, 2010. After running the pump and filling the drop pipe on September 5 and monitoring background water levels for nearly 2 d, testing began with brief trial pumping on September 7 followed by a 24-h constant-rate pumping test that was started on September 8. Following shutdown of the 24-h test on September 9, recovery data were recorded for 24 h until September 10.

Trial testing of screen 1 began at 8:03 a.m. on September 7, after the pump failed to produce water at a significant rate when it was started initially at 8:00 a.m. The discharge rate of 16.9 gpm was maintained for 57 min until 9:00 a.m. Recovery data were recorded for 60 min until 10:00 a.m. when trial 2 pumping began at a discharge rate of 14.1 gpm. Following shutdown at 11:00 a.m., trial 2 recovery data were collected for 1230 min until 8:00 a.m. on September 8.

At 8:02 a.m. (restart after failure to produce significant flow during the 8:00 a.m. startup attempt) on September 8, the 24-h pumping test was initiated at a discharge rate of 17.4 gpm. Pumping continued for 1438 min until 8:00 a.m. on September 9. Following shutdown, recovery data were recorded for 1440 min until 8:00 a.m. on September 10 when the pump was pulled from the well.

R-55 Screen 2 Testing

Screen 2 was tested from September 10 to 15, 2010, using a smaller pump than that used for testing screen 1. After filling the drop pipe on September 10, testing began with brief trial pumping on September 11, background data collection, and a 24-h constant-rate pumping test that was begun on September 13.

Two trial tests were conducted on September 11. Trial 1 was conducted at an initial apparent discharge rate of 2.5 gpm starting at 8:00 a.m. After 30 min, the discharge was increased to a measured rate of 4.3 gpm for 30 min, then set back to 2.5 gpm for an additional 10 min. At 9:10 a.m., trial 1 recovery began, continuing for just 20 min until 9:30 a.m., when the packer was deflated briefly as a precaution to expel any gas or air that may have accumulated beneath the packer.

The discharge rates are termed apparent/measured because, as described below, examination of the data showed that a portion of the pumped water from screen 2 leaked from the drop pipe and was injected into screen 1. Thus, the actual discharge from screen 2 was greater than the rate measured at the surface through the flow meter. Based on the specific capacity of screen 1 and the observed rise in head at screen 1 when screen 2 was pumped, it was estimated that up to 1.8 gpm may have discharge into screen 1 whenever screen 2 was pumped. Thus, the effective water removal rate from screen 2 may have been up to 1.8 gpm greater than the apparent values measured at the surface. (Note that any clogging of screen 1 associated with injection may have contributed to an artificial rise in head, meaning that the actual leakage/injection rate could have been less than the theoretical estimate of 1.8 gpm.)

It was expected that the leak may have occurred through the crossover assembly above the packer where the submersible pump wires pass from outside the discharge pipe to the inside and are sealed via O-rings. The pump wire pass through assembly had been rebuilt just before the R-55 pumping tests, so it is possible that improperly sized O-rings, or an insufficient number of them, may have been installed.

Curiously, no such leakage was observed during the screen 1 pumping tests. Had leakage occurred then, the leaked water would have accumulated above the packer during the tests and would have raised water levels in the well when the packer eventually was deflated at the conclusion of testing. No such water level rise was observed. Of note is that the estimated hydraulic pressure within the drop pipe and packer assembly during the screen 1 tests was about 450 psi versus 700 psi during the screen 2 tests. Thus, it is possible that the greater pressure imposed during the screen 2 tests may have triggered the O-ring failure.

Trial 2 on screen 2 was conducted for 60 minutes from 10:00 to 11:00 a.m. at an apparent rate of 2.5 gpm (possible actual rate of 4.3 gpm). Following shutdown, recovery/background data were recorded for 2700 minutes until 8:00 a.m. on September 13.

At 8:00 a.m. on September 13, the 24-h pumping test was begun at an apparent rate of 2.5 gpm (possible actual rate of 4.3 gpm). Pumping continued for 1440 min until 8:00 a.m. on September 14. Following shutdown, recovery measurements were recorded for 1440 min until 8:00 a.m. on September 15 when the pump was tripped out of the well.

Aerated Water

Consistent with observations in many of the recent R-well pumping tests, presence of gas or air was observed in the groundwater pumped from both screens during the R-55 pumping tests. It is possible the observed gas is natural. On the other hand, it is possible high-pressure compressed air used in the drilling process invaded the aquifer zones during drilling, collecting in the formation pore spaces and/or dissolving in the groundwater. When water is pumped from the aquifer, trapped gas or air in the formation pores can move with the pumped water as well as expand and contract in response to pressure changes. Also, pressure reduction associated with pumping can allow dissolved gas or air to come out of solution. The gas or air present in the formations in recently tested wells has had several effects, including (1) interfering with pump operating efficiency, (2) causing transient changes in aquifer permeability, (3) inducing pressure transients as the gas or air expands and contracts, and (4) causing storage-like effects associated with changes in gas or air volume in the formation voids, filter pack and/or well casing.

The gas or air content in R-55 may have contributed to inconsistent pumping rates observed when screen 1 was tested and possibly a minor storage effect when screen 2 was pumped, although neither of these is certain.

C-2.0 BACKGROUND DATA

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

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

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

Subsequent pumping tests, including tests at R-55, have utilized nonvented transducers. These devices simply record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated “apparent” hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When monitored using a vented transducer, an increase in barometric pressure of 1 unit causes a decrease in recorded downhole pressure of 0.9 unit because the water level is forced downward 0.9 unit by the barometric pressure change. However, using a nonvented transducer, the total measured pressure increases by 0.1 unit (the combination of the barometric pressure increase and the water-level decrease). Thus, the resulting apparent hydrograph changes by a factor of 100, minus the barometric efficiency, and in the same direction as the barometric pressure change, rather than in the opposite direction.

Barometric pressure data were obtained from Technical Area 54 (TA-54) tower site from the Waste and Environmental Services Division–Environmental Data and Analysis (WES-EDA). The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead elevation is at 6533.86 ft amsl. The static water level in R-55 was 834.67 ft below land surface, making the water-table elevation 5699.19 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-55.

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

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R} \left(\frac{E_{R-55} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{R-55}}{T_{WELL}} \right) \right]$$ **Equation C-1**

where, P_{WT} = barometric pressure at the water table inside R-55

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/degrees Kelvin (287.04 J/kg/degrees Kelvin)

$E_{R\text{-}55}$ = land surface elevation at R-55 site, in feet (6533.86 ft)

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

E_{WT} = elevation of the water level in R-55, in feet (5699.19 ft)

T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 69.0 degrees Fahrenheit, or 293.7 degrees Kelvin)

T_{WELL} = air temperature inside R-55, in degrees Kelvin (assigned a value of 66.0 degrees Fahrenheit, or 292.0 degrees Kelvin)

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

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

C-3.0 IMPORTANCE OF EARLY DATA

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

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

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

Equation 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

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

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

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

Equation C-3

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

D_B = diameter of borehole, in inches

D_C = outside diameter of well casing, in inches

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

In some instances, it is possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval before conducting the test. This approach was mostly successful in the R-55 pumping test effort.

C-4.0 TIME-DRAWDOWN METHODS

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

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

where,

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

and

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

and where, s = drawdown, in feet

Q = discharge rate, in gallons per minute

T = transmissivity, in gallons per day per foot

S = storage coefficient (dimensionless)

t = pumping time, in days

r = distance from center of pumpage, in feet

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

$$T = \frac{114.6Q}{s} W(u)$$

Equation C-7

$$S = \frac{Tut}{2693r^2}$$

Equation C-8

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

S = storage coefficient

Q = discharge rate, in gallons per minute

$W(u)$ = match-point value

s = match-point value, in feet

u = match-point value

t = match-point value, in minutes

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

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

Equation C-9

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

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

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

Equation C-10

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

Q = discharge rate, in gallons per minute

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

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

Equation C-11

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

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

b = aquifer thickness

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

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

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

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

K_z = vertical hydraulic conductivity

K_r = horizontal hydraulic conductivity

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

$$\beta = \sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b}$$ **Equation C-12**

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

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-13**

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

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

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:

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

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:

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

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

To apply this procedure, a storage coefficient value must be assigned. Storage coefficient values generally range from 10^{-5} to 10^{-3} for confined aquifers and 0.01 to 0.25 for unconfined aquifers (Driscoll 1986, 104226). Unconfined conditions were assumed for screen 1 and a storage coefficient of 0.10 was arbitrarily assigned. A value of 5×10^{-4} was used for the calculations for screen 2 where confined conditions were assumed. The calculation result is not particularly sensitive to the choice of storage coefficient value, so a rough estimate is generally adequate to support the calculations.

The analysis also requires assigning a value for the saturated aquifer thickness, b. For screen 1, an arbitrary thickness of 100 ft was used in the calculations. For partially penetrating conditions, the calculations are not particularly sensitive to the choice of aquifer thickness because sediments far above or below the screen typically contribute little flow. For screen 2, a different tack was taken in which the early response data were extrapolated to predict the drawdown that would have resulted for fully penetrating conditions. The lower-bound hydraulic conductivity was then calculated on this basis as explained below.

C-7.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-55 tests were plotted along with barometric pressure to determine the barometric effect on water levels.

Figure C-7.0-1 shows aquifer pressure data from R-55 screen 1 during the test period along with barometric pressure data from TA-54 that have been corrected to equivalent barometric pressure in feet of water at the water table. The R-55 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-55 pumping tests are included in the figure for reference.

R-55 screen 1 showed no significant pressure change in response to barometric pressure fluctuations, suggesting a barometric efficiency near 100%.

The data in Figure C-7.0-1 showed that when screen 2 was pumped, the water level in screen 1 rose about 0.1 ft. As described above, this effect was likely attributable to a leaky O-ring in the pump wire pass-through assembly above the inflatable packer. Based on the screen 1 specific capacity of nearly 18 gpm/ft, the flux rate into screen 1 was estimated at about 1.8 gpm. It is common for injection specific capacities to be less than pumping specific capacities because of inherent clogging tendencies when injecting. Any clogging in this instance would have contributed to artificially raising the water level in screen 1 and meaning that the true injection rate might have been less than estimated from the pumping specific capacity (i.e., less than 1.8 gpm).

Figure C-7.0-2 shows aquifer pressure data collected from R-55 screen 2 during the pumping test effort. As with screen 1, screen 2 aquifer pressure did not show a distinct correlation with barometric pressure changes, suggesting a high barometric efficiency. For example, the large barometric pressure decline from September 7 to 9 did not appear to induce a similar trend in aquifer pressure. The data did show a sinusoidal diurnal effect, having a magnitude of several hundredths of a ft, likely an Earth-tide effect.

The data did not show a response in screen 2 to pumping screen 1, confirming the idea of tight sediments separating the two zones and the lack of a hydraulic connection.

The hydrograph showed an anomalous offset in screen-2 water levels during the screen 2 tests, better illustrated on the expanded-scale graph on Figure C-7.0-3. The general levels observed from September 10 to 11 suddenly dropped more than 0.1 ft after the first trial test and appeared to stabilize at the lower level. Then, when the packer was deflated briefly and promptly reinflated between the trial tests, the water level rose back to the pre-pumping levels and appeared to stabilize there. Subsequent pumping during trial 2, as well as the 24-h test (Figure C-7.0-2), caused the levels to drop again and fail to rebound to the higher level even after extensive recovery time. Stretching of the drop pipe string was ruled out as a possible cause because there was no equivalent pattern in the screen 1 transducer output.

It is possible that the leaky O-ring seal above the packer may have caused the toggling of the water level position. The water level was always lower after pumping screen 2 (twice on September 11 and again on September 14) and higher after equalizing the water levels above and below the packer by deflating/inflating the packer (on September 9 and 11). The higher level would have been an indication of a tiny amount of cross-flow migrating from screen 1 to screen 2, presumably passing through the leaky seal. It appears that operating the pump at screen 2 and shutting it off left the O-rings in a position to support the head difference of 2.77 ft between the screen zones and block flow, while equalizing the heads may have allowed the O-rings to move slightly permitting a small leak. Based on the head rise of about 0.12 ft and the specific capacity of screen 2 of 0.11 gpm/ft (discussed below), the estimated leakage rate was about 0.013 gpm (0.78 gallons per hour). (Note: it is possible the seal leaked at all times and the 0.013 gpm was the difference in leakage rate associated with movement of the O-rings.)

Hydrograph data from additional nearby R-wells were downloaded to check for a possible pumping response to the R-55 tests. Screen zones examined included R-23 (2259 ft away), R-39 (2208 ft), R-41 screen 2 (1839 ft), and R-49 screens 1 and 2 (3311 ft). None of the monitored zones showed any response to pumping R-55. The hydrographs for these wells are not included in this report.

C-8.0 WELL R-55 SCREEN 1 DATA ANALYSIS

This section presents the data obtained from the R-55 screen 1 pumping tests and the results of the analytical interpretations. Data are presented for drawdown and recovery from trial 1, trial 2, and the 24-h constant-rate test.

C-8.1 Well R-55 Screen 1 Trial Test

Figure C-8.1-1 shows a semilog plot of the drawdown data collected from the trial 1 test on screen 1. The transmissivity estimated from the very early data was 25,000 gpd/ft. As described below, subsequent testing that recorded earlier data showed a lower transmissivity initially followed by a slight flattening consistent with the slope shown in Figure C-8.1-1. This suggested that the lower transmissivity value was representative of the actual screened interval and that the transmissivity shown in Figure C-8.1-1 likely reflected a slightly greater, unknown, effective, contiguous aquifer thickness.

After just a few minutes of pumping, the water levels reached near steady state. This recharge-like response was likely a combination of partial-penetration effects (vertical growth of the cone of depression), leakage from above or below the screened interval, and/or delayed yield associated with vertical movement of the phreatic surface of the unconfined aquifer.

Figure C-8.1-2 shows the recovery data collected following shutdown of the trial 1 pumping test. The transmissivity computed from the line of fit shown on the plot was 26,500 gallons per day (gpd) per foot, in good agreement with the time-drawdown value. Again, exceedingly early data were not recorded during trial 1 recovery, so the graph does not show the initial straight line trend observed in subsequent testing described below.

The late recovery data showed the same flattening effect seen in the drawdown data, consistent with leakage, vertical growth of the cone of depression, and/or delayed yield.

C-8.2 Well R-55 Screen 1 Trial 2 Test

Figure C-8.2-1 shows a semilog plot of the drawdown data collected from the trial 2 test on screen 1 at a discharge rate of 14.1 gpm. The transmissivity estimated from the earliest portion of the data plot was 19,300 gpd/ft. This was interpreted as the transmissivity of the screened interval. Based on the screen length of 20.6 ft, the computed hydraulic conductivity was 937 gpd/ft^2, or 125 ft/d. Data immediately following the initial slope showed a slight flattening of the curve and a transmissivity of 28,400 gpd/ft, consistent with that computed from trial 1. It was assumed this value represented a somewhat greater (and unknown) thickness of sediment corresponding to modest vertical growth of the cone of depression.

Within minutes the drawdown curve flattened, consistent with vertical growth of the cone of depression, leakage, and/or delayed yield.

Figure C-8.2-2 shows the recovery data collected following shutdown of the trial 2 pumping test. The very early data suggested a transmissivity of 18,700 gpd/ft for the screened interval, with a corresponding hydraulic conductivity of 908 gpd/ft^2, or 121 ft/d.

The late data showed the same flattening observed in previous plots.

C-8.3 Well R-55 Screen 1 24-Hour Constant-Rate Test

Figure C-8.3-1 shows a semilog plot of the drawdown data collected from the 24-h constant-rate pumping test conducted at 17.4 gpm. The analysis shown on the graph suggested a screen interval transmissivity of 19,400 gpd/ft with a corresponding hydraulic conductivity of 942 gpd/ft^2, or 126 ft/d.

The late drawdown data showed steady flattening and near steady-state water levels for several hours of pumping. Subsequent data showed a slight increase in slope, perhaps signaling the end of the transient stabilization period associated with delayed yield. The final slope was still very flat, consistent with either (a) the cone of depression penetrating a vertical sequence of sediments having enormous transmissivity or (b) some continuing, persistent drainage of the phreatic surface.

Figure C-8.3-2 shows the recovery data collected following shutdown of the 24-h constant-rate pumping test. As indicated on the plot, the earliest slope suggested a transmissivity of 21,300 gpd/ft, making the hydraulic conductivity of 1034 gpd/ft^2, or 138 ft/d.

The late recovery data showed the same flattening observed in the other tests.

C-8.4 Well R-55 Screen 1 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound hydraulic conductivity value for the permeable zone penetrated by R-55 screen 1. This analysis was done to provide a frame of reference for evaluating the foregoing analyses.

At the end of the 24-h pumping test, the discharge rate was 17.4 gpm with a resulting drawdown of 0.97 ft for a specific capacity of 17.9 gpm/ft. In addition to specific capacity and pumping time, other input values used in the calculations included a storage coefficient value of 0.10, a borehole radius of 0.46 ft (inferred from the volume of filter pack required to backfill the screen zone), a screen length of 20.6 ft, a pumping time of 1438 min, and an arbitrary saturated thickness of 100 ft.

Applying the Brons and Marting method to these inputs yielded a lower-bound hydraulic conductivity value of 843 gpd/ft^2, or 113 ft/d. The average hydraulic conductivity value from the foregoing pumping test analyses was 955 gpd/ft^2, or 128 ft/d, consistent with the lower-bound value and suggesting a high well efficiency.

C-9.0 WELL R-55 SCREEN 2 DATA ANALYSIS

This section presents the data obtained from the R-55 screen 2 pumping tests and the results of the analytical interpretations. Data are presented for drawdown and recovery from trial 1, trial 2 and the 24-h constant-rate test.

C-9.1 Well R-55 Screen 2 Trial 1

Figure C-9.1-1 shows a semilog plot of the screen 2 drawdown data collected from trial 1. The initial measured discharge rate was 2.5 gpm for 30 min. Then the rate was increased to 4.3 gpm for an additional 30 min and set back to 2.5 gpm for the final 10 min of the 70-min trial test. As described above, up to 1.8 gpm may have leaked out of the drop pipe into screen 1 during the test, so the actual withdrawal rates from screen 2 during the three phases were probably around 4.3, 6.1, and 4.3 gpm, respectively.

The early data showed exaggerated drawdown likely caused because of antecedent drainage of a trivial volume of drop pipe. (This effect was observed during each of the tests on screen 2.) This would have allowed the pump to operate briefly against reduced head as the void refilled, thus producing a greater rate initially with correspondingly greater drawdown. The presumed drop pipe leakage would have been unrelated to the leaky O-ring seal at the packer described earlier. There were two check valves immediately above the packer and pump wire crossover assembly isolating the packer from the drop pipe above. With this configuration, it would have been impossible for water beneath these check valves to drain from the packer and pass through assembly. The antecedent drainage likely occurred through coupling joints elsewhere in the drop pipe. Some of the stainless-steel drop pipe used for the R-55 tests has been used frequently, and thus, the threads are probably worn significantly and subject to slight leakage.

When the discharge rate was increased to a measured value of 4.3 gpm (presumed actual rate of 6.1 gpm), there was a substantial, ongoing increase in drawdown over time, as shown on the figure. Because this effect was not reproduced in the recovery data set (described next), the water level change did not reflect head changes within the aquifer, but only within the well itself. This implied that the increased drawdown was probably attributable to a steady decline in well efficiency. This, in turn, may have been caused by gradual hydraulic compaction of the sediments near the wellbore caused by the enormous drawdown applied to the well (more than 60 ft). This phenomenon has been observed in other wells on the plateau that have been subjected to large drawdowns (tens of feet of drawdown or more). The effect is often progressive: increasing applied drawdown creates greater hydraulic compression forces, further reducing the aquifer permeability and causing even greater drawdown, etc.

Figure C-9.1-2 shows the recovery data collected following shutdown of the trial 1 pumping test. The transmissivity estimated from the early data was 41 gpd/ft, making the computed hydraulic conductivity of the 21-ft screened interval 2.0 gpd/ft^2, or 0.26 ft/d—very low values.

The recovery response was odd in that nearly complete recovery was achieved in well under a minute. This response is symptomatic of a highly inefficient well in a permeable formation. However, the transmissivity computation contradicts this idea. Typical response for a low-efficiency well (large skin factor) in a permeable formation would show much greater recovery in the first couple of data points than shown on Figure C-9.1-2.

The initial “sluggish” response shown during the first few seconds of recovery after trial 1 has two possible explanations. First, this type of response could be explained by storage effects, perhaps caused by air or gas coming out of solution and becoming trapped beneath the inflatable packer. In this scenario, the computed transmissivity value would be erroneous.

Second, absent storage effects, the slow initial recovery may reflect the transmissivity of a substantial block of very tight sediment around the well. For example, the screened interval could be a low-permeability zone, overlain or underlain by highly permeable strata that provide rapid recharge to the pumped interval. Alternatively, there could be an extensive zone of tight material around the well, even though the geologic interval in which the screen was placed may be permeable. This could come about, for example, if there were a tremendous amount of caving and sediment movement and displacement during drilling of the borehole leaving a damaged zone reaching many feet away from the borehole. If one of these scenarios applies, the computed transmissivity value would be valid and represent the properties of the material adjacent to the well screen. (This alternative scenario may be applicable: the contractor indicated that caving of the lower portion of the borehole was a continual problem during well construction, while the stratigraphy appeared to be consistent in the lower portion of the borehole.)

These two possible explanations—(1) storage effects, or (2) large zone of tight sediment (including the possibility that the screen was located in a tight formation)—are indistinguishable from one another so it was not possible to determine the true cause of the unusual recovery response. Suffice it to say, however, that a thin, low-permeability skin could not explain the observed data.

The earliest data point on Figure C-9.1-2 did not fall on the straight line of best fit, possibly because the *u*-value condition associated with semilog plots was not met. To check this, the recovery data were plotted on a log-log graph and analyzed by Theis curve matching as shown on Figure C-9.1-3. The resulting early data match was good, producing a transmissivity value of 39 gpd/ft.

Storage effects typically result in an early data plot showing a straight line having unit slope when plotted on a log-log graph—an effect not seen on Figure C-9.1-3. However, the predicted unit slope is applicable to open wells exposed to constant (atmospheric) pressure. In screen 2, the hypothesized storage effect would have been caused by trapped gas beneath the packer. During recovery, compression of the trapped gas would cause a response the deviates from the predicted straight line and, thus, its absence on the figure does not rule out storage effects.

C-9.2 Well R-55 Screen 2 Trial 2

Figure C-9.2-1 shows a semilog plot of the drawdown data collected from the trial 2 test at a measured discharge rate of 2.5 gpm and an actual rate presumed to be 4.3 gpm. The initial response showed the effects of minor antecedent drainage of the drop pipe.

The late drawdown data showed a steady increase in slope not duplicated in the recovery data set, described below. Thus, the increased drawdown over time was most likely a result of ongoing permeability reduction of sediments near the borehole, as observed in trial 1.

Figure C-9.2-2 shows the recovery data collected following shutdown of the trial 2 pumping test. The transmissivity estimated from the early data was 61 gpd/ft, making the computed hydraulic conductivity 2.9 gpd/ft^2, or 0.39 ft/d—possibly erroneous or, absent storage effects, possibly representative of sediments near the well. As observed in trial 1, nearly complete water level recovery occurred in well under a minute, suggesting an immediate hydraulic connection to highly permeable strata.

The earliest recovery data points fell off the line of fit shown on the graph, so the data were plotted on the log-log graph shown on Figure C-9.2-3 and analyzed by Theis curve matching. The computed transmissivity value from the curve match was 65 gpd/ft. Again, the early data did not show a straight line trend having unit slope, but this did not necessarily rule out storage effects.

C-9.3 Well R-55 Screen 2 24-Hour Constant-Rate Test

Figure C-9.3-1 shows a semilog plot of the drawdown data collected from the 24-h constant-rate pumping test conducted at a measured discharge rate of 2.5 gpm and an actual rate presumed to be 4.3 gpm. The initial response showed the effects of minor antecedent drainage of the drop pipe for a few seconds.

The late drawdown data showed a steady increase in slope not duplicated in the recovery data set, described next. Thus, the increased drawdown over time was most likely a result of ongoing permeability reduction of sediments near the borehole, as observed in trials 1 and 2.

Figure C-9.3-2 shows the recovery data collected following shutdown of the trial 2 pumping test. The transmissivity estimated from the early data was 36 gpd/ft, making the computed hydraulic conductivity 1.7 gpd/ft^2, or 0.23 ft/d—erroneous if storage affected or, absent storage effects, possibly representative of sediments near the well. As observed in trials 1 and 2, nearly complete water-level recovery occurred in well under a minute, suggesting an immediate hydraulic connection to highly permeable strata.

The late recovery data were plotted on an expanded scale as shown on Figure C-9.3-3. The straight-line trend shown on the graph corresponded to a transmissivity of 20,600 gpd/ft. There is no way to know what sediment thickness contributed to this response, but the calculation confirmed that the screened horizon is in immediate hydraulic connection to highly permeable sediments.

The earliest recovery data points on Figure C-9.3-2 fell off the line of fit shown on the graph, so the data were plotted on the log-log graph shown on Figure C-9.3-4 and analyzed by Theis curve matching. The computed transmissivity value from the curve match was 32 gpd/ft. Again, the early data did not show a straight line trend having unit slope, but this did not necessarily rule out storage effects.

C-9.4 Well R-55 Screen 2 Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound hydraulic conductivity value for the permeable zone penetrated by R-55 screen 2. This analysis was done to provide a frame of reference for evaluating the foregoing analyses. However, the data were not analyzed assuming partial penetration of a uniform, homogeneous aquifer because of the extreme contrast in permeability suggested by the data—very tight sediments near the well and highly permeable sediments immediately adjacent.

Instead, the initial drawdown trend was extrapolated to 24 h of pumping time, implicitly assuming fully penetrating conditions. Then, the Cooper-Jacob equation was iterated to estimate a lower-bound hydraulic conductivity. This procedure was actually performed based on the recovery because the recovery data set was smoother than the drawdown data and not obscured by the variable pumping rate associated with antecedent drainage of a portion of the drop pipe. In doing this, the observed recovery was extrapolated and served as a surrogate for projected drawdown.

At the end of the 24-h pumping test, the discharge rate was estimated to be 4.3 gpm with a drawdown of 40.1 ft making the actual specific capacity of 0.11 gpm/ft. However, extrapolating the recovery type curve on Figure C-9.3-4 to 1440 min (off the scale of the graph shown on the figure) produced a predicted recovery of 175 ft. This is considered to be equivalent to the drawdown that would have been observed for a fully penetrating well, assuming homogeneous conditions and no recharge effect from the more-permeable adjacent sediments. In addition to pumping rate, projected recovery and pumping time, other input values used in the calculations included a storage coefficient of 5×10^{-4}, a borehole radius of 0.49 ft (inferred from the volume of filter pack required to backfill the screen zone), a pumping time of 1440 min, and an arbitrary saturated thickness of 100 ft.

Iterating the Cooper-Jacob equation for these inputs yielded a lower-bound transmissivity value for the screened interval of 32 gpd/ft, consistent with the pumping test calculations.

C-10.0 SUMMARY

Constant-rate pumping tests were conducted on R-55 screens 1 and 2. The tests were performed to gain an understanding of the hydraulic characteristics of the screen zones and the degree of interconnection between them. Numerous observations and conclusions were drawn for the tests as summarized below.

The static water level observed in screen 1 was 2.77 ft higher than that in screen 2, showing a downward hydraulic gradient, highly resistive sediments separating the screen zones, and little hydraulic connection between the screens. Testing confirmed this, with no response observed in screen 2 when pumping screen 1 at 17.4 gpm for 24 h.

A comparison of barometric pressure and R-55 water level data showed a high barometric efficiency for each zone. Screen 2 showed a small diurnal effect, probably a result of Earth tides.

Pumping screen 1 at 17.4 gpm for 1438 min had no discernable effect on water levels in screen 2. It also had no effect on water levels monitored at R-23, R-39, R-41, and R-49.

Analysis of the screen 1 pumping tests showed an average hydraulic conductivity value of 955 gpd/ft^2, or 128 ft/d for the screened interval. Early on, the drawdown/recovery curves flattened almost completely, consistent with partial penetration effects (vertical growth of the cone of depression) or leakage from highly transmissive overlying and/or underlying sediments and likely delayed yield of the unconfined aquifer.

Screen 1 produced 17.4 gpm for 1438 min with 0.97 ft of drawdown for a specific capacity of 17.9 gpm/ft. The lower-bound hydraulic conductivity computed from this information was 843 gpd/ft^2 or 113 ft/d, consistent with the pumping tests values.

Pumping screen 2 at 4.3 gpm for 1440 min caused a water level rise of 0.10 ft in screen 1, presumably because of a leaky O-ring seal above the inflatable packer. Pumping screen 2 had no effect on water levels monitored at R-23, R-39, R-41 and R-49.

Pumping screen 2 with substantial drawdown (tens of feet) appeared to cause a slight permeability reduction in the vicinity of the well, likely from hydraulic compaction of the sediments near the borehole in response to the applied drawdown. This was evidenced by steadily increasing drawdown inside the well, even though the drawdown in the aquifer outside the well likely remained nearly constant (deduced from the observed recovery response). This effect has been observed in other R-wells subjected to large drawdown stress.

Analysis of the screen 2 pumping tests suggested a very low near-well screen-zone transmissivity of roughly 30 to 60 gpd/ft. The data showed an immediate recharge boundary effect indicating that the near-well sediments are in immediate contact with highly transmissive sediments. It is possible that the low computed value of transmissivity was erroneous, being influenced by slight storage effects associated with trapped gas/air beneath the inflatable packer. On the other hand, the value may have been a valid representation of the zone in which the screen is placed. These two scenarios would produce the same (observed) response and were therefore indistinguishable.

Screen 2 produced 4.3 gpm for 1440 min with 40.1 ft of drawdown for a very low specific capacity of 0.11 gpm/ft. Extrapolating the very early recovery data supported a lower-bound transmissivity value estimate of 32 gpd/ft, not inconsistent with the pumping test calculations.

C-11.0 REFERENCES

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

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

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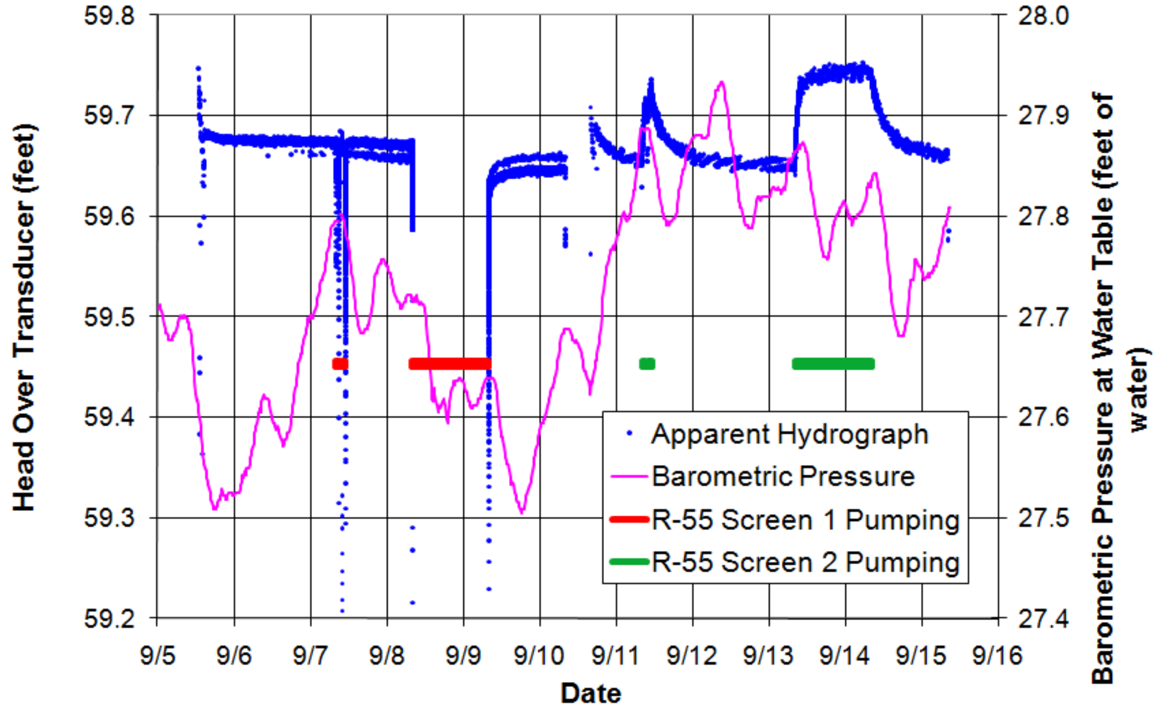


Figure C-7.0-1 Well R-55 screen 1 apparent hydrograph

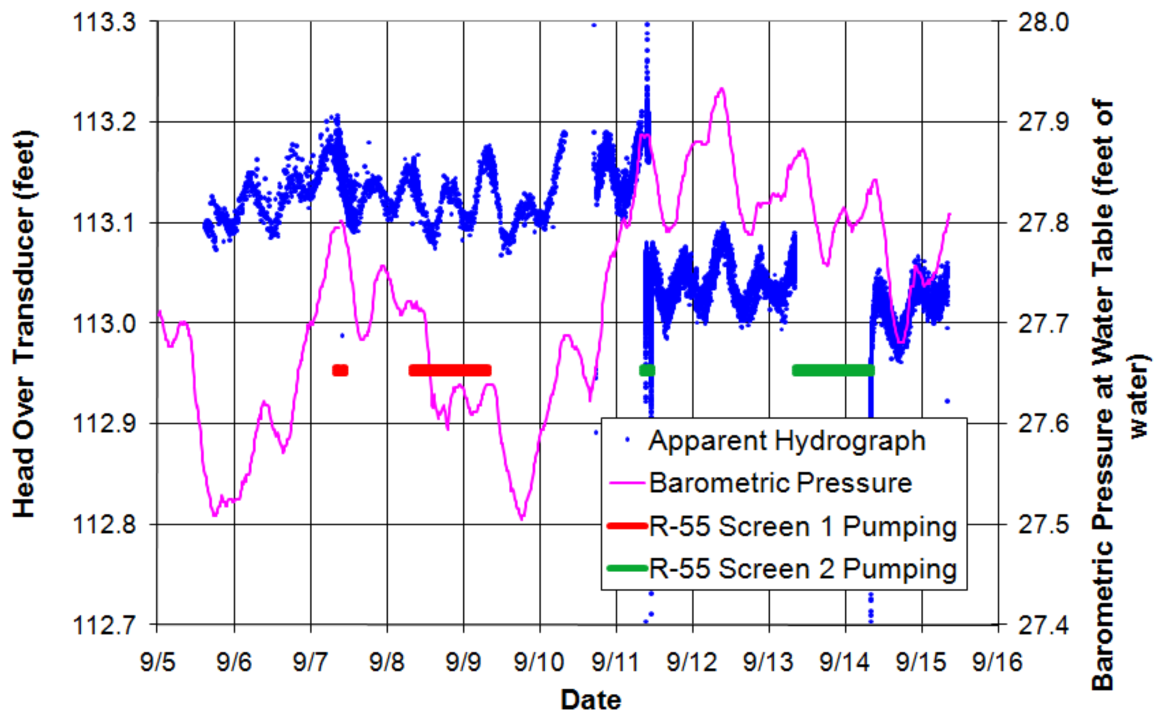


Figure C-7.0-2 Well R-55 screen 2 apparent hydrograph

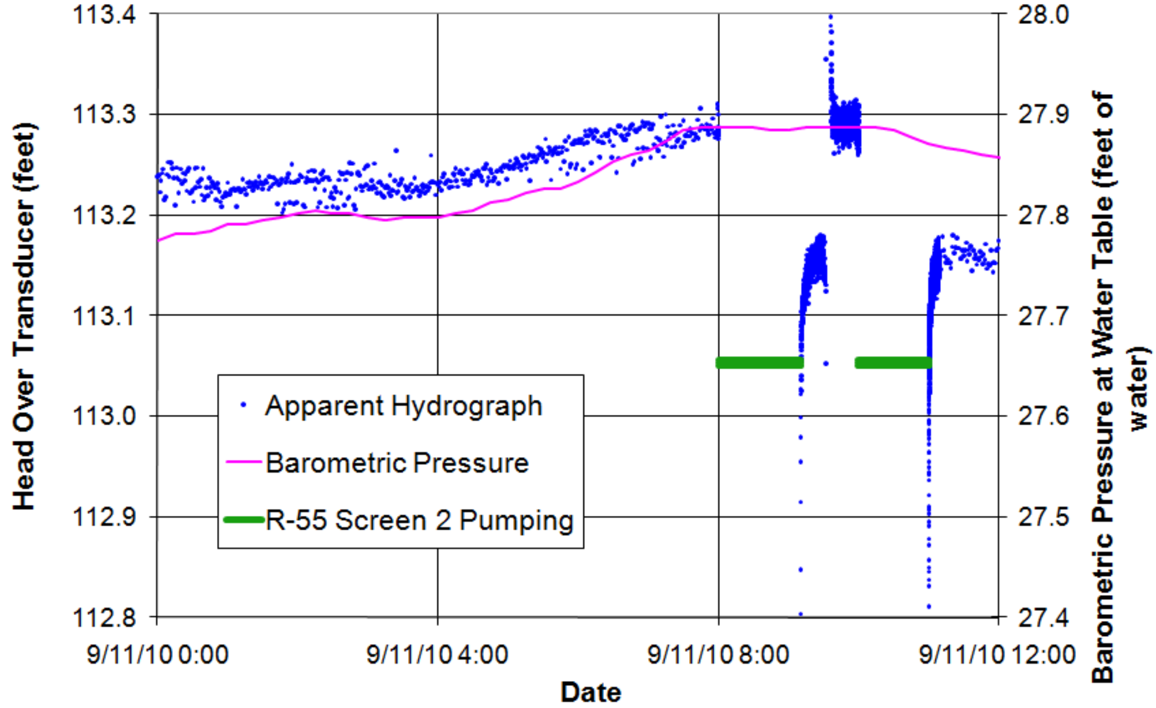


Figure C-7.0-3 Well R-55 screen 2 apparent hydrograph—expanded scale

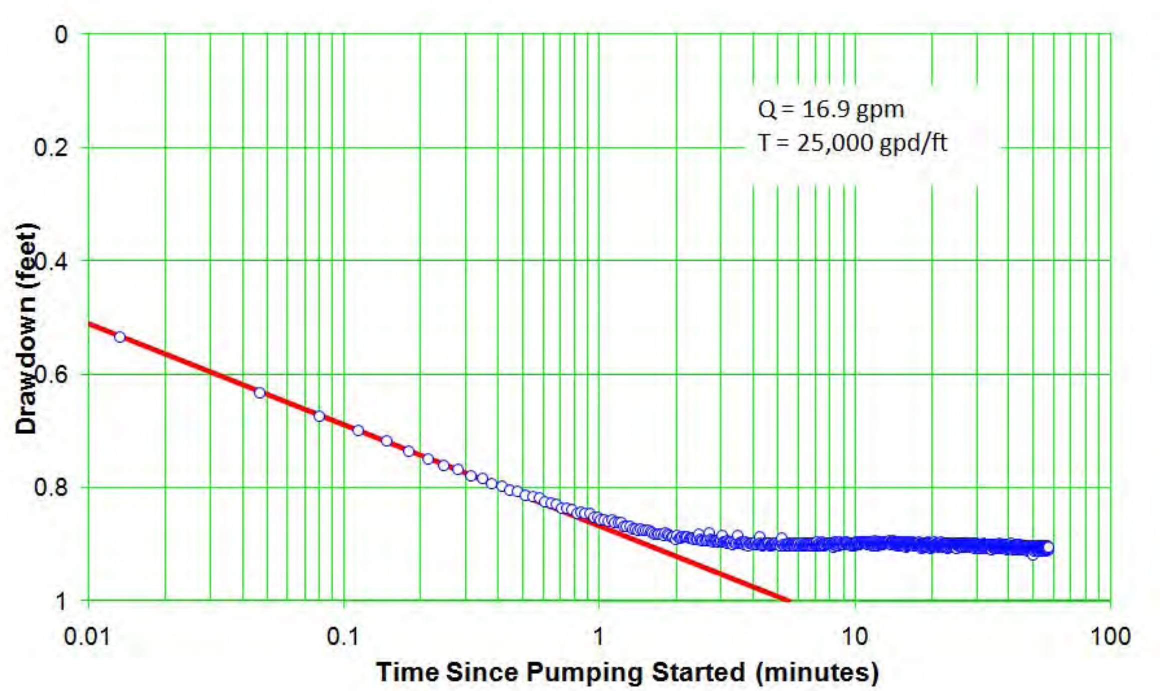


Figure C-8.1-1 Well R-55 screen 1 trial 1 drawdown

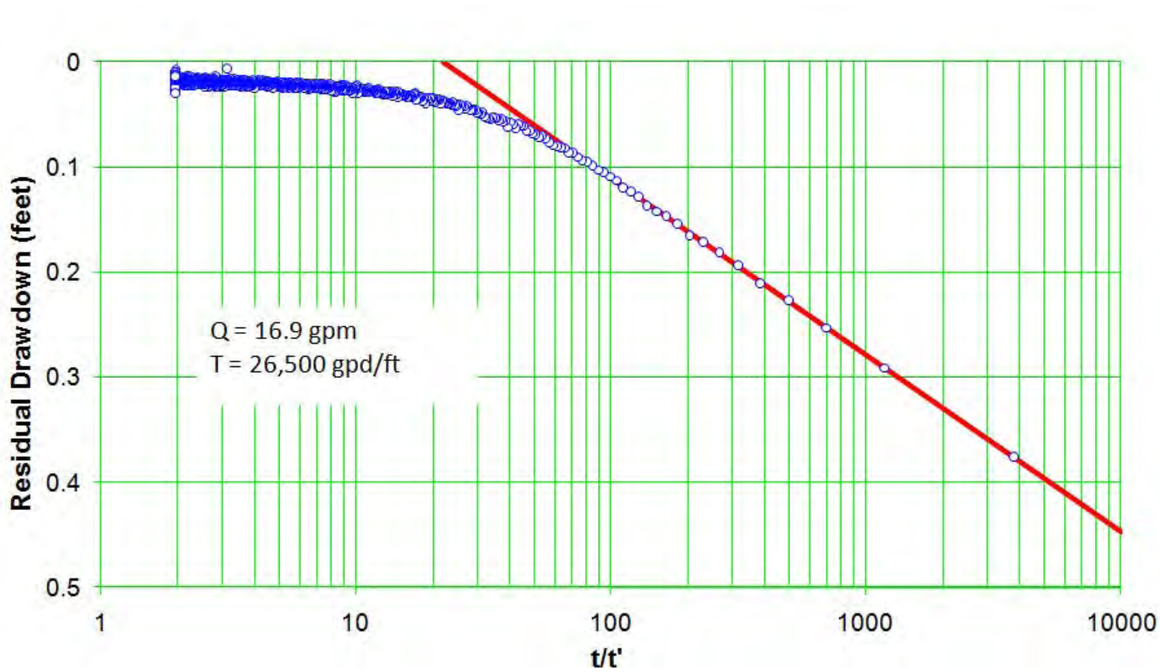


Figure C-8.1-2 Well R-55 screen 1 trial 1 recovery

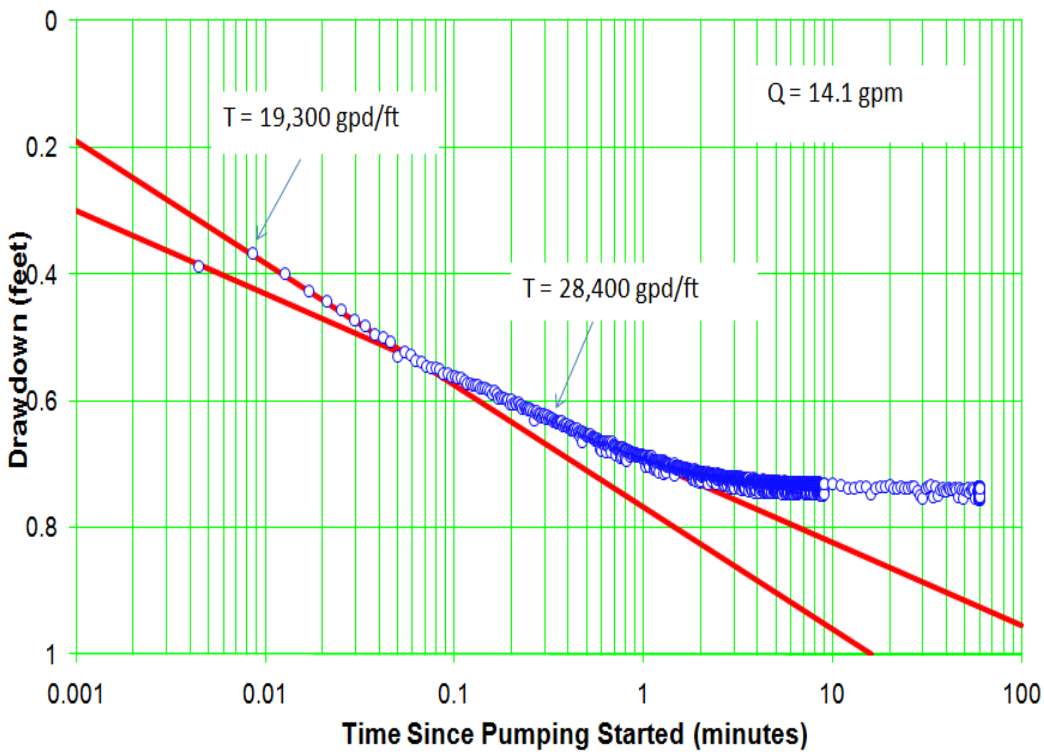
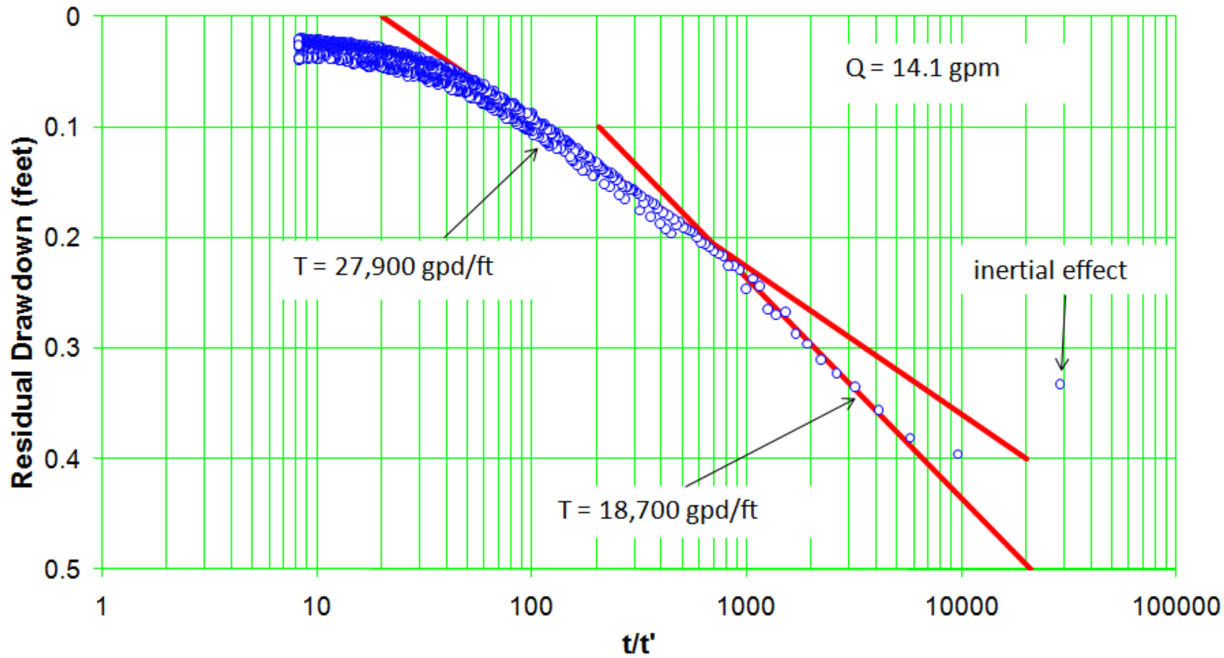


Figure C-8.2-1 Well R-55 screen 1 trial 2 drawdown



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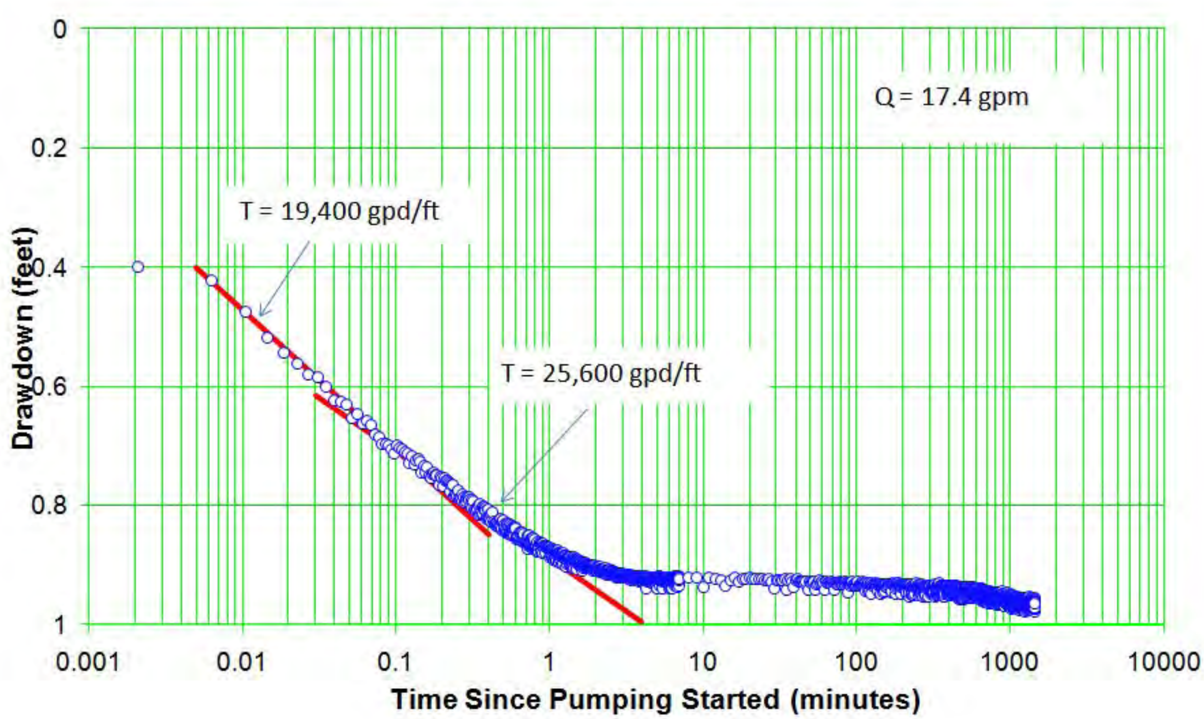
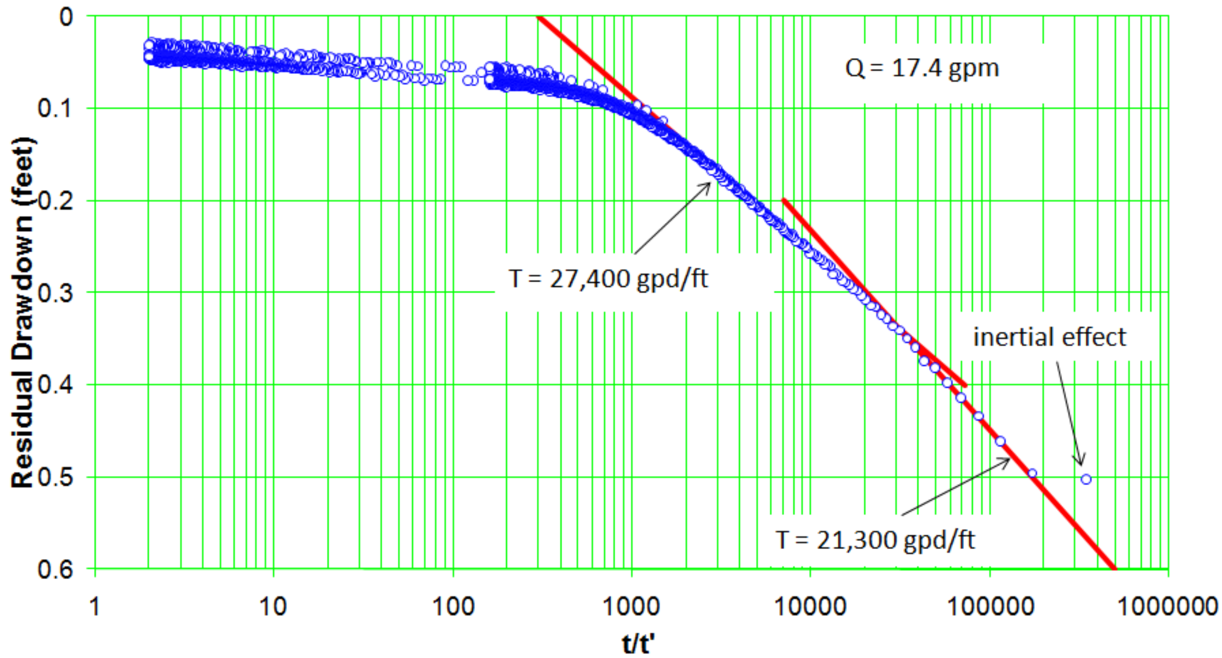


Figure C-8.3-1 Well R-55 screen 1 drawdown



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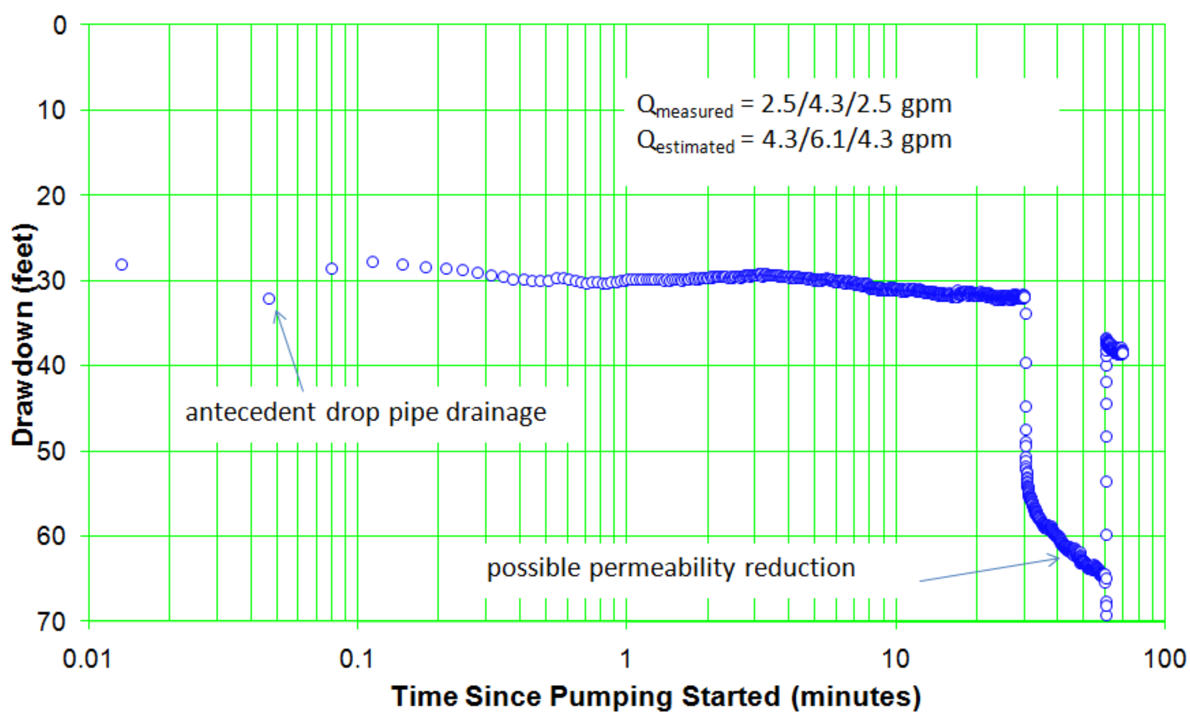


Figure C-9.1-1 Well R-55 screen 2 trial 1 drawdown

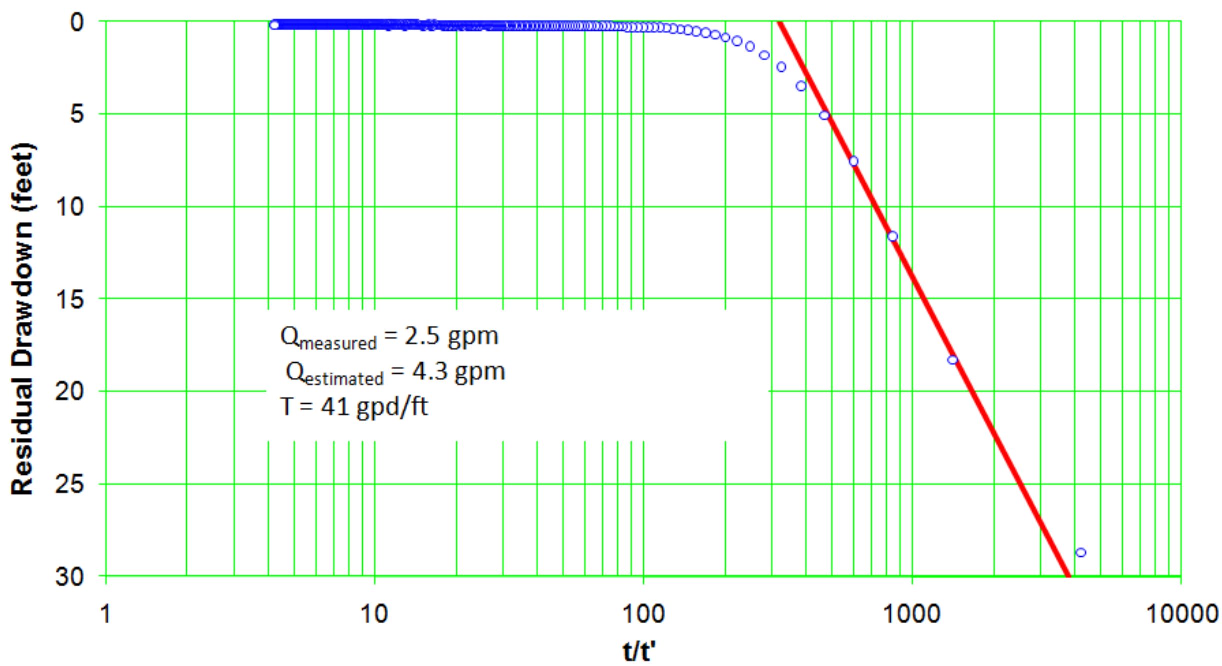


Figure C-9.1-2 Well R-55 screen 2 trial 1 recovery

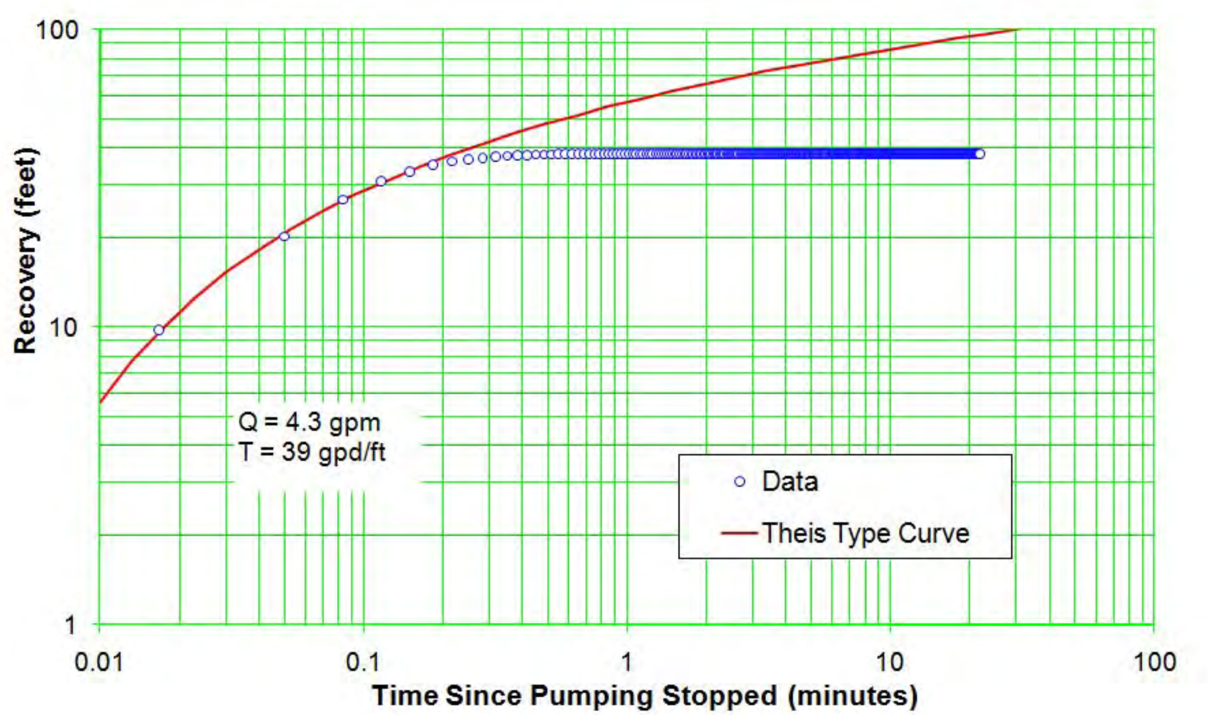


Figure C-9.1-3 Theis analysis of well R-55 screen 2 trial 1 recovery

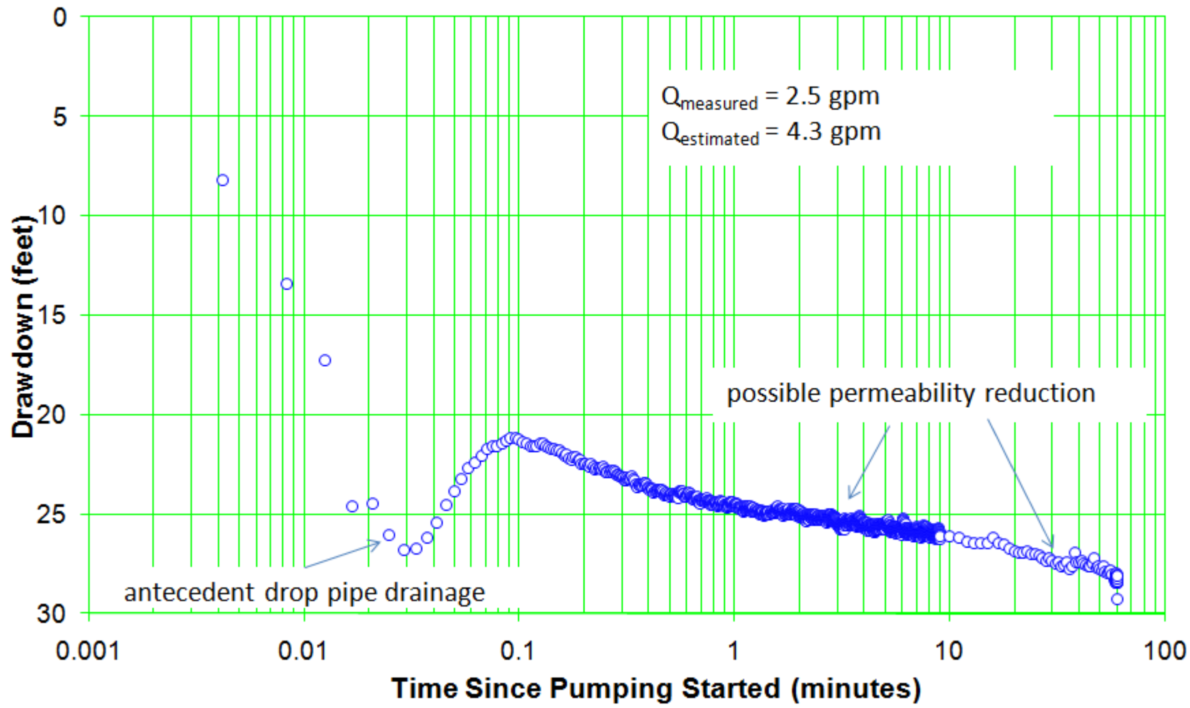
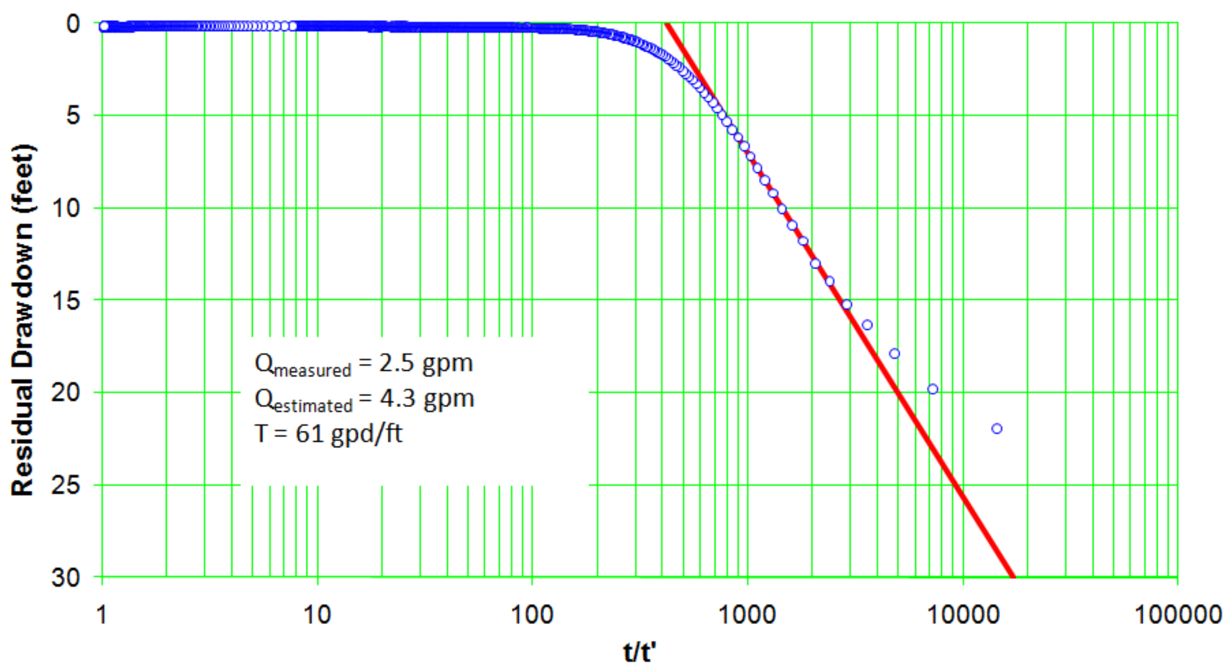


Figure C-9.2-1 Well R-55 screen 2 trial 2 drawdown



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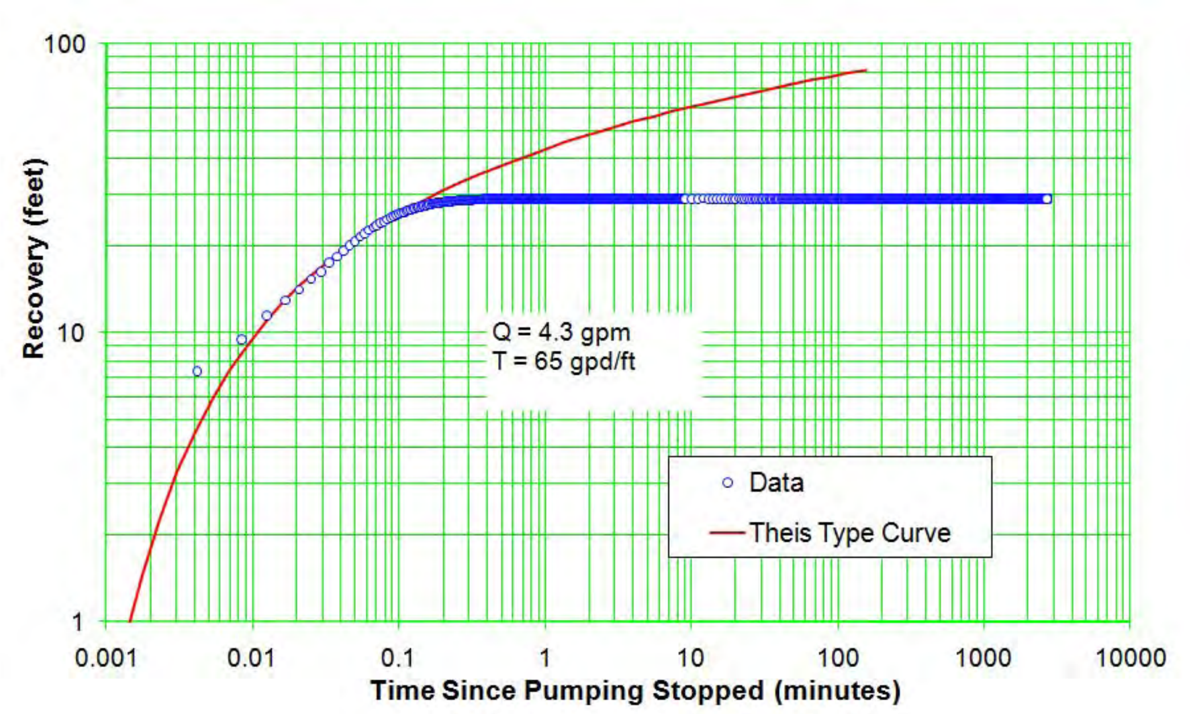

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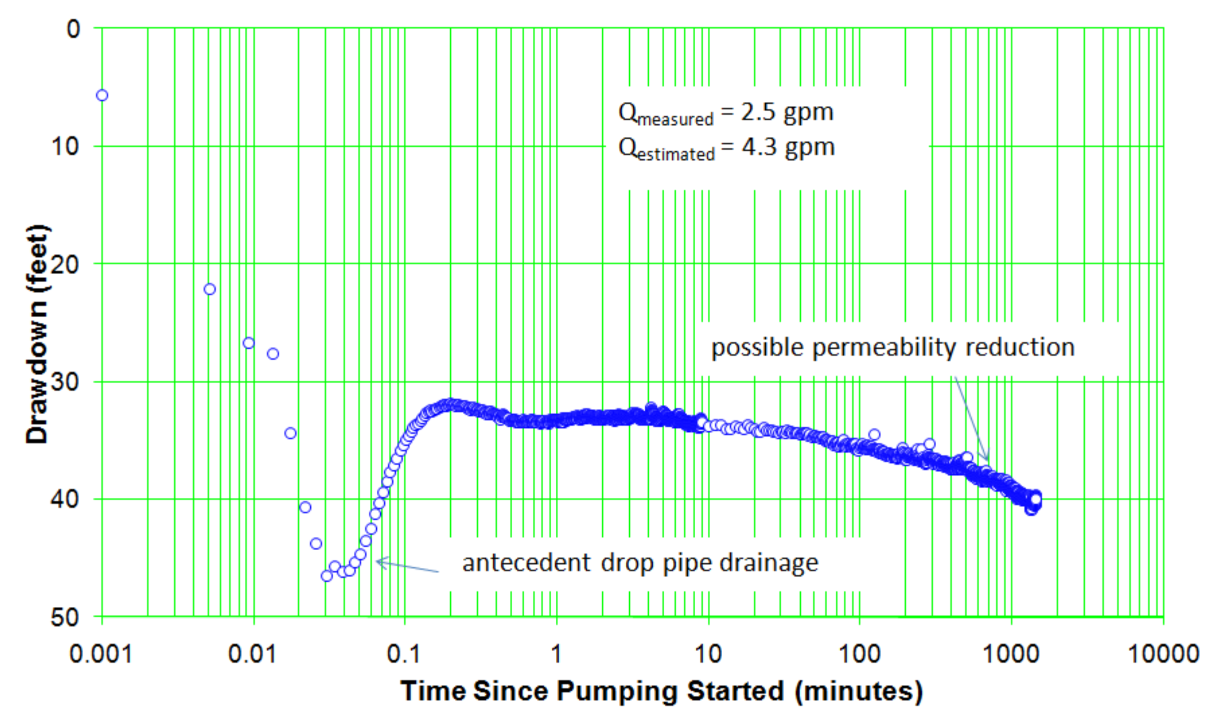

Figure C-9.3-1 Well R-55 screen 2 drawdown

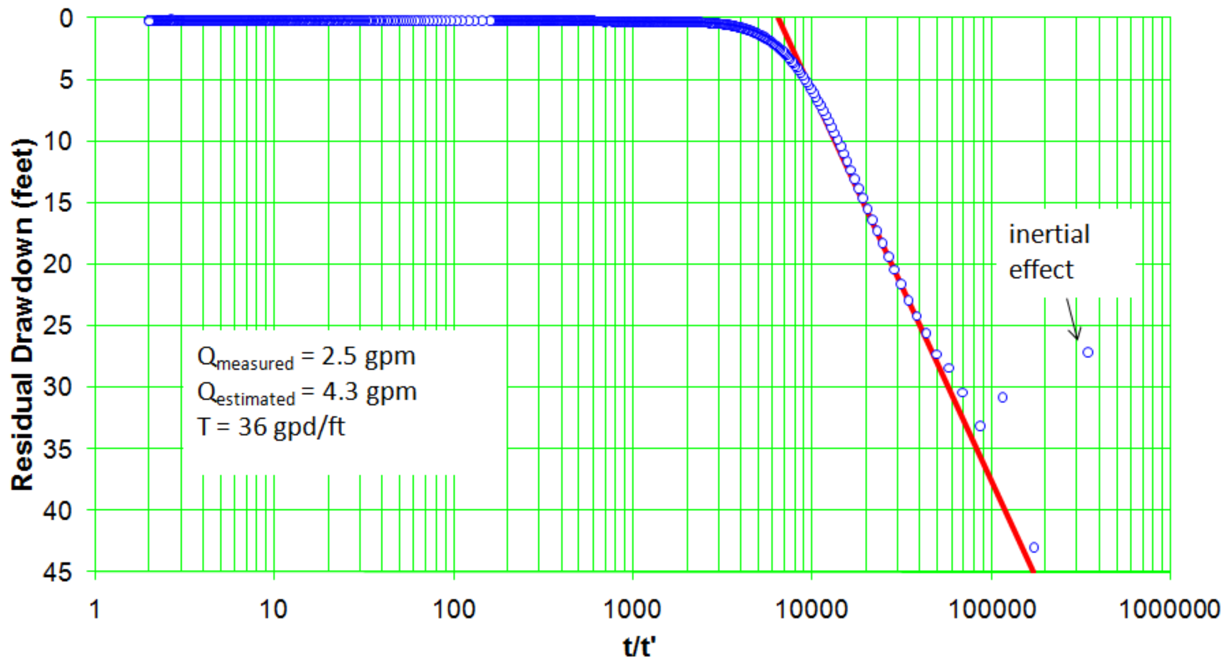

Figure C-9.3-2 Well R-55 screen 2 recovery

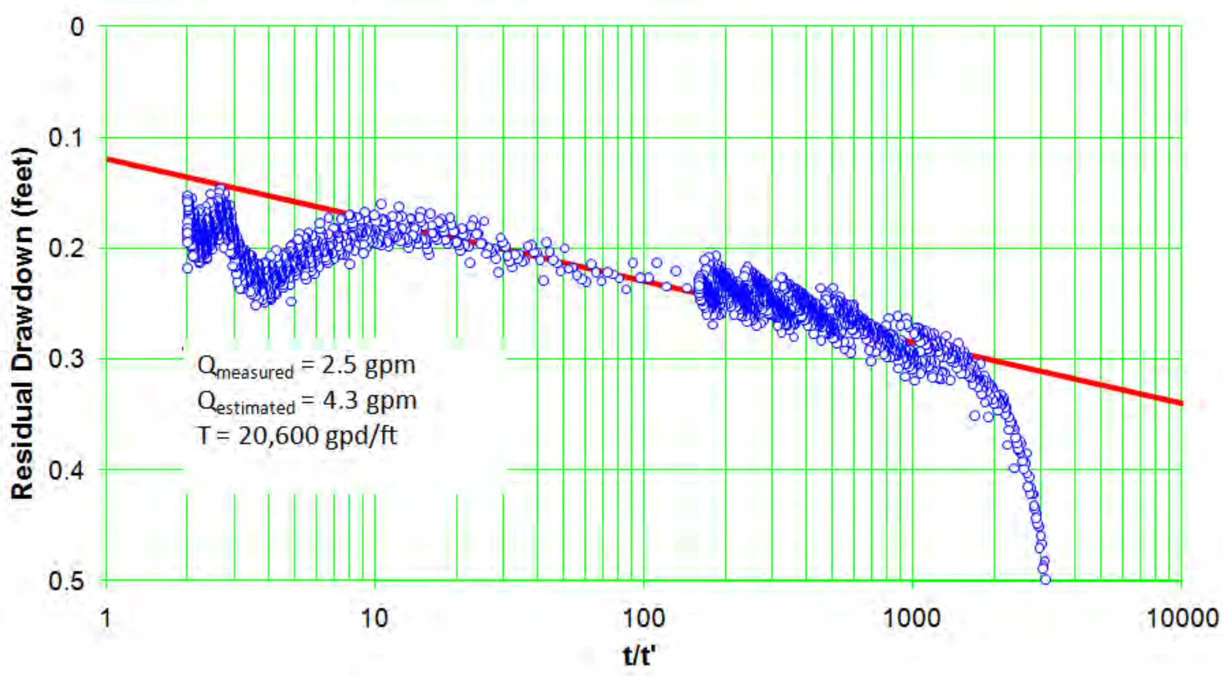

Figure C-9.3-3 Well R-55 screen 2 recovery—expanded scale

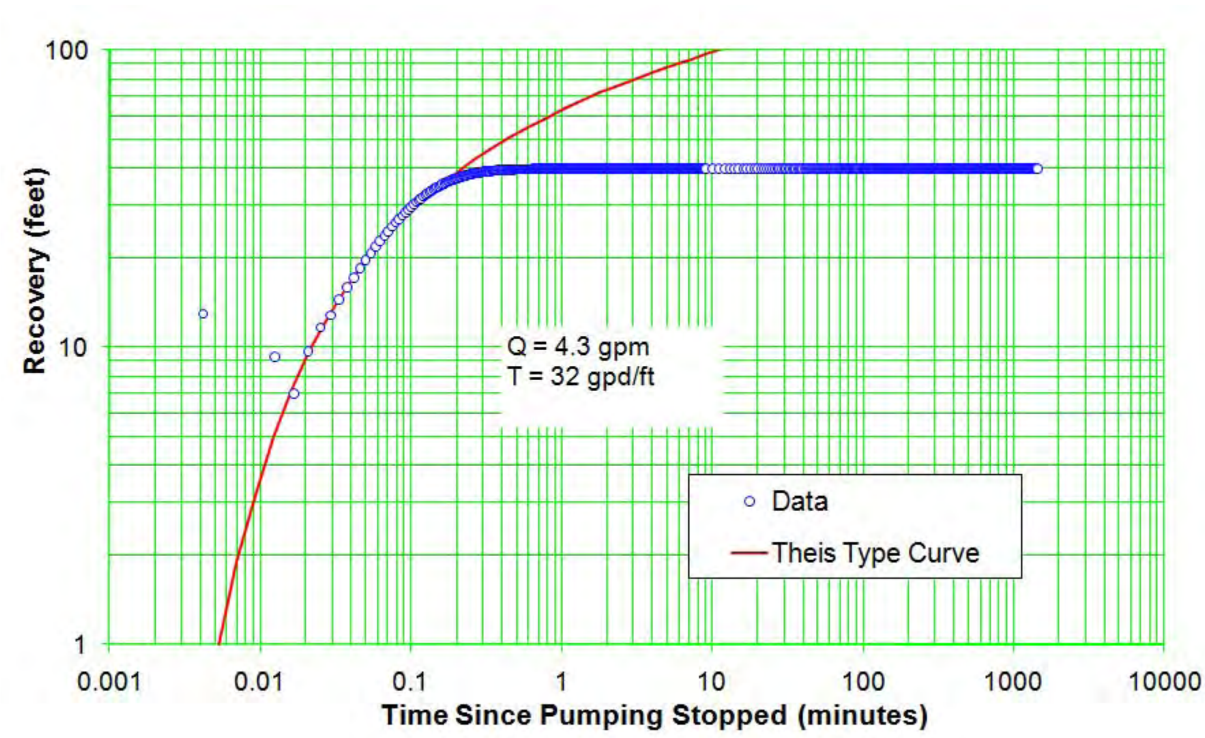

Figure C-9.3-4 Theis analysis of well R-55 screen 2 recovery

Appendix D

Borehole Video Logging
(on DVD included with this document)

Appendix E

Geophysical Logging
(on CD included with this document)

Appendix F

R-55 Proposed Final Well Design and
New Mexico Environmental Department Approval

Note: The information in this final well design package was developed at the completion of borehole drilling. The formation depths and water levels presented herein were based on preliminary information and may differ slightly from the postinstallation lithologic interpretations and data and details presented in the well completion report.

R-55 Well Objectives

The primary purpose of R-55 is to monitor regional groundwater down gradient of MDA G at the eastern end of TA-54 (Figure 1). Well R-55 will supplement groundwater monitoring for MDA G provided by wells R-22, R-23, R-39, R-41, R-49, and R-57. Secondary objectives for well R-55 include establishing water levels for the regional aquifer in this area, determining if perched-intermediate groundwater occurs in the vicinity of MDA G, and characterizing rock units that can impact contaminant pathways in the vadose zone and regional aquifer.

Transport of potential contaminants reaching the regional aquifer is expected to occur primarily by lateral groundwater flow within the upper part of the regional aquifer. Near MDA G, water levels observed in the Cerros del Rio basalt are higher than those observed in the sedimentary deposits beneath the basalts. The water-level data suggest there are steep gradients in the basalts and relatively flat gradients in sedimentary deposits, especially to the east and southeast of MDA G. The proposed location of R-55 targeted the sedimentary deposits east of MDA G.

The R-55 well objectives are best met by installing a two-screen well to monitor water quality and water levels in the sedimentary deposits that make up the upper part of the regional aquifer east of MDA G.

R-55 Recommended Well Design

It is recommended that R-55 be completed as a two-screen well with a 20-ft stainless-steel, 20-slot, wire-wrapped well screen in the lavas extending from 860 ft to 880 ft (screen 1) and a 20-ft stainless-steel, 20-slot, wire-wrapped well screen in the sedimentary deposits extending from 995 to 1015 ft (screen 2). The primary filter pack will consist of 10/20 sand extending 5 ft above and 5 ft below both well screen openings. A 2-ft secondary filter pack consisting of 20/40 sand will be placed above the primary filter pack of both well screens. A Baski system with a submersible pump and isolating packers will be installed to sample the two well screens. The proposed well design is shown in Figure 2.

This well design is based on the objectives stated above and on the information summarized below.

R-55 Well Design Considerations

Preliminary lithological logs indicate that the geologic contacts are, in descending stratigraphic order: Alluvium (0–13 ft), vitric ash-flows of the Bandelier Tuff (13–55 ft), Puye Formation siltstone (57–80 ft) basaltic lavas of the Cerros del Rio volcanic series and associated scoria, cinder, maar, and sedimentary deposits (80–687 ft), and silts, sands, and gravels of the Totavi Lentil (687–890 ft), and sands and gravels of the Chamita Formation (890–1035.2 ft TD).

Perched intermediate groundwater was identified in the R-55 borehole with a water level of 500 ft below ground surface. The saturated interval occurs within highly stratified phreatomagmatic deposits overlying Totavi-like riverine sediments that were deposited between two Cerros del Rio lava flows. The groundwater appears to be perched above olive-green clay deposits extending from 565 to 605 ft. A screening sample was collected and has been submitted for major ion chemistry analysis on site, and VOA and tritium off site. The screening sample results will be shared with NMED when available.

Because of uncertainties associated with the water table map for the area, regional groundwater was predicted to occur between depths of approximately 795 and 835 ft. During drilling, multiple water levels ranging between 833 and 835 ft were obtained over a several day period. The water table is within deposits of sands and gravels of the Totavi Lentil beneath the Cerros del Rio volcanic series.

The measured water level of 833-835 ft is consistent with the elevation of the water table in sedimentary deposits east of MDA G.

While drilling into the top of the regional aquifer, the 12-in drill casing became stuck at a depth of 845 ft. Multiple attempts were made to free the casing, but it could be retracted only to 839 ft where it now permanently rests. This places the bottom of the drill casing 4 to 6 ft into the top of the regional aquifer. It is believed that clay deposits between 565 and 605 ft have plastically deformed around the casing, locking it into place. The 12-in casing was cut at 570 ft, successfully freeing the casing above that level. The freed casing currently remains in place to provide stable borehole conditions, and it will be removed during well construction. The 12-in casing from 570–839 ft will be encased in bentonite during well construction to isolate it from the upper part of the regional aquifer and to prevent corrosion from affecting the representativeness of waters collected from the upper well screen. The clay deposits between 570 and 605 ft should provide a tight seal around the outside of the 12-in drill casing, preventing perched groundwater from migrating downward towards the regional aquifer.

The upper well screen, at 860 ft to 880 ft depth, targets riverine sands and gravels of the Totavi Lentil in the uppermost part of the regional aquifer down gradient of MDA G. The sand fraction contains abundant quartz and microcline and the well-screen interval appears to be largely free of silts and clays. The gravels consist of well-rounded clasts of quartzite and granite with lesser amounts of mafic to intermediate lavas and chert. A 20-ft well screen is recommended for this interval to increase the likelihood that transmissive intervals within these heterogeneous, stratified deposits are intercepted by the well screen. The top of the well screen is 25 to 27 ft below the water table to ensure that the well screen remains submerged during pumping development and aquifer testing, and to provide separation between the well screen and the bottom of the 12-in drill casing that will remain in place.

The lower well screen, at 995 to 1015 ft depth, targets riverine sands and gravel deposits of the Chamita Formation. This interval is dominantly lithic sands and gravels made up of rounded intermediate to felsic lavas with lesser amounts of altered white pumice and cemented sandstone clasts. The well screen is proposed to be 20 ft long to ensure that it includes a number of productive beds in these heterogeneous deposits. Because this well is over 2000 ft east of MDA G, potential contaminants should be well dispersed in the aquifer, and more discrete zonal sampling is not needed. The top of the well screen is placed 115 ft below the bottom of the upper screen. The well screen is placed as deep as possible within the Chamita Formation to provide information about vertical hydraulic gradients in the sedimentary deposits making up the regional aquifer east of MDA G. Maximizing the screen separation also facilitates the evaluation of whether pumping from the Pajarito and Buckman well fields produce different water levels responses at different levels in the aquifer at R-55.

Other Zones and Designs Considered for R-55 Well Screens

The upper screen is placed as close to the water table as possible, consistent with observations during drilling and development and aquifer testing considerations. Placing the well screen closer to the water table was considered, but that option was rejected because it would put the screen in closer proximity to the bottom of the entombed 12-in drill casing.

There were numerous possibilities for siting the lower screen because the lithologies within the Chamita Formation have generally favorable characteristics for water production. Shallower screen locations between 900 and 955 ft depth were rejected because those sedimentary deposits contain abundant fine-grain sands that heaved upwards as much as 40 ft into the casing during drilling (flowing-sands). These unstable conditions could adversely affect well construction during placement of annular materials and lead to long-term turbidity issues in the well.

Other zones between 955 and 995 were also considered for screen 2, but they did not provide as much separation between the two well screens for determining vertical hydraulic gradients and evaluating pumping effects from nearby municipal well fields.

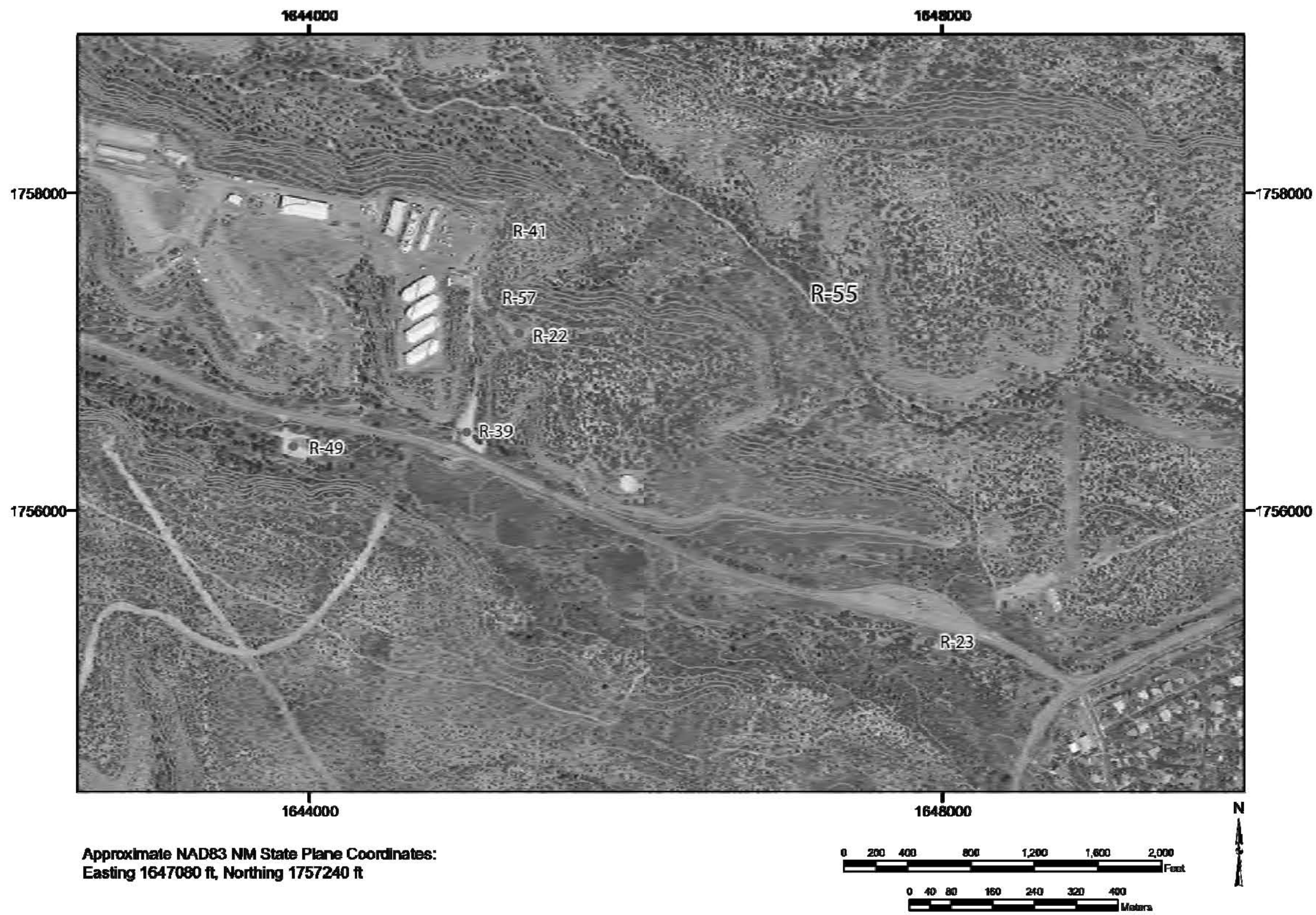

Figure 1. Location map for R-55 showing locations of nearby monitoring wells.

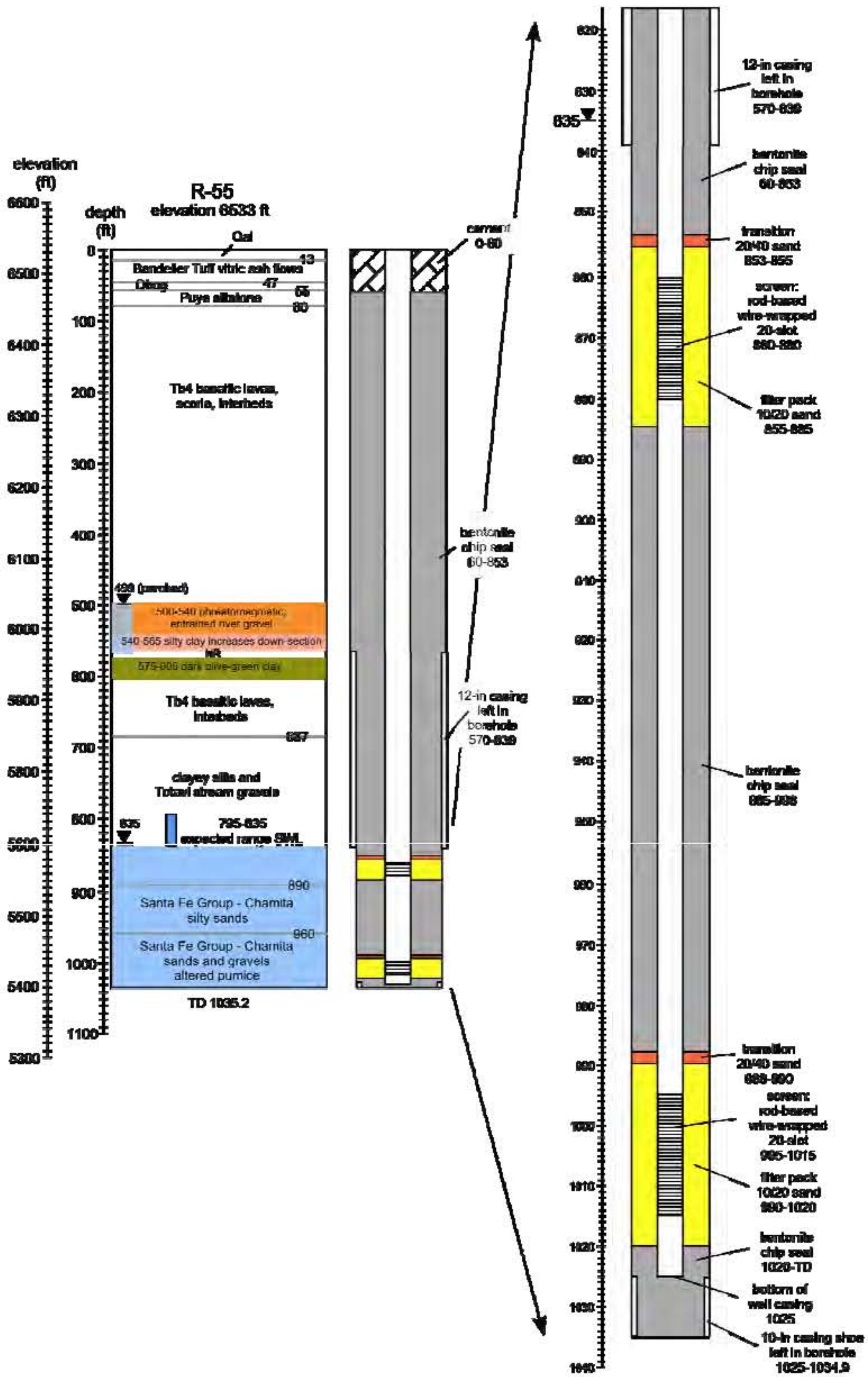

Figure 2. Proposed well design for R-55.

From:	Kulis, Jerzy, NMENV
To:	Everett, Mark C; Cobrain, Dave, NMENV; Dale, Michael, NMENV
Cc:	Ball, Theodore T; Katzman, Danny; Shen, Hai; Mignardot, Edward R Jr; Whitacre, Thomas J; Lynnes, Kathryn D
Subject:	RE: R-55 proposed well design
Date:	Friday, July 02, 2010 2:59:38 PM

Mark,

This e-mail serves as NMED approval for installation of regional aquifer well R-55 as proposed in your e-mail sent on July 1, 2010 at 4:32 PM, with the following condition.

> The presence of a long section of abandoned drill casing in the R-55 borehole between the intermediate perched zone and the regional aquifer creates a possibility of a cross-flow of perched intermediate groundwater into the regional aquifer. If, based on groundwater analytical data, aquifer testing data, and/or other available information, NMED determines that such cross-flow is likely occurring, LANL must undertake a corrective action to prevent further leakage. The corrective action must include overdrilling the R-55 well to remove or grind-out the abandoned drill casing and installation of a replacement well in the same or a new borehole, unless an alternate solution, acceptable to NMED, is proposed by LANL.

This approval is based on the information available to NMED at the time of the approval. NMED understands that LANL will provide the results of preliminary water-quality sampling, any modifications to the proposed well design, and any additional information related to the installation of well R-55 as soon as such information becomes available. LANL shall give notice of this installation to the New Mexico Office of the State Engineer as soon as possible.

Thanks,

Jerzy Kulis
Environmental Scientist
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Bldg 1
Santa Fe, NM 87505-6303
Phone: 505-476-6039
Fax: 505-476-6030

From: Everett, Mark C [mailto:meverett@lanl.gov]
Sent: Thursday, July 01, 2010 4:32 PM
To: Cobrain, Dave, NMENV; Kulis, Jerzy, NMENV; Dale, Michael, NMENV
Cc: Ball, Theodore T; Katzman, Danny; Shen, Hai; Mignardot, Edward R Jr; Whitacre, Thomas J; Lynnes, Kathryn D
Subject: R-55 proposed well design

Attached please find LANL's proposed design for well R-55. The field crew will not be ready to begin construction until next week at the earliest, so we have the luxury of time for a change. Please review and respond at your earliest convenience. As always, feel free to contact me with questions.

Thanks,

Mark Everett, PG
Drilling Project Technical Lead
EP-WSP
LANL
(505) 667-5931 (office)
(505) 231-6002 (mobile)