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Completion Report for Intermediate Aquifer Well R-55i

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June 2011

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EXECUTIVE SUMMARY

This completion report describes borehole drilling, well construction, well development, aquifer testing, and dedicated sampling system installation for perched intermediate groundwater well R-55i, located in Cañada del Buey approximately 2000 ft east of Material Disposal Area G in Technical Area 54 at Los Alamos National Laboratory (the Laboratory) in Los Alamos County, New Mexico. The R-55i 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-55i monitoring well borehole was drilled using dual-rotary air-drilling methods. Fluid additives included potable water and foam. Foam-assisted drilling was used only to a depth of 400 ft below ground surface (bgs), approximately 100 ft above the top of the anticipated intermediate groundwater.

The following geologic formations were encountered at R-55i: 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, and the Cerros del Rio volcanic series. R-55i was drilled to a total depth of 565 ft bgs.

Well R-55i was completed as a single-screen well, allowing evaluation of water quality and water levels within the perched intermediate groundwater zone. The 20-ft-long screened interval is set between 510.0 and 531.1 ft bgs within phreatomagmatic deposits of the Cerros del Rio volcanic series. The depth to water before well installation was 498.4 ft bgs.

R-55i was completed in accordance with an NMED-approved well design. The well was thoroughly developed, and the groundwater met target water-quality parameters. Aquifer testing indicates that well R-55i is productive and will perform effectively to meet the planned objectives. A sampling system and transducer have been installed, and groundwater sampling at R-55i will be performed as part of the annual Interim Facility-Wide Groundwater Monitoring Plan.

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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
Eh	oxidation-reduction potential
EP	Environmental Programs
EPA	Environmental Protection Agency
F	filtered
FD	field duplicate
FTB	field trip blank
gpd	gallons per day
gpm	gallons per minute
hp	horsepower
I.D.	inside diameter
LANL	Los Alamos National Laboratory
MDA	material disposal area
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	alluvium
Qbo	Otowi Member of the Bandelier Tuff
Qbog	Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff
Qbt	Tshirege Member of the Bandelier Tuff
RPF	Records Processing Facility
TA	technical area
Tb 4	Cerros del Rio volcanic series
TD	total depth
TOC	total organic carbon

Tpf	Puye Formation
UF	unfiltered
VOC	volatile organic compound
WCSF	waste characterization strategy form
WES-EDA	Waste and Environmental Services Division–Environmental Data and Analysis (Group)
WR	whole rock

1.0 INTRODUCTION

This completion report describes borehole drilling, well construction, well development, aquifer testing, and dedicated sampling system installation for perched intermediate groundwater well R-55i. 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-55i monitoring well borehole was drilled from December 13, 2010, to January 7, 2011, and completed from January 11 to 18, 2011, at Los Alamos National Laboratory (LANL or the Laboratory) for the Environmental Programs (EP) Directorate.

Well R-55i 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). Well R-55i was installed as part of the TA-54 groundwater monitoring network and was primarily drilled to collect representative samples from the perched intermediate groundwater identified within the Cerros del Rio volcanic series during drilling of regional aquifer well R-55. Secondary objectives were to establish water levels for the intermediate groundwater and to characterize the hydrogeologic setting through the collection of drill cutting samples.

The R-55i borehole was drilled to a total depth (TD) of 565 ft below ground surface (bgs). During drilling, cuttings samples were collected at 5-ft intervals in the borehole from ground surface to TD. A monitoring well was installed with a screened interval between 510.0 and 531.1 ft bgs in the Cerros del Rio volcanic series. A depth to water (DTW) of 498.2 ft bgs was recorded on January 24, 2011, after well installation.

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

The information presented in this report was compiled from field reports and daily activity summaries. Records, including field reports, field logs, and survey information, are on file at the Laboratory's Records Processing Facility (RPF). This report contains brief descriptions of activities and supporting figures, tables, and appendixes associated with the R-55i project.

2.0 ADMINISTRATIVE PLANNING

The following documents were prepared to guide activities associated with the drilling, installation, and development of intermediate aquifer well R-55i:

- "Drilling Work Plan for Well R-55i" (LANL 2010, 110488),
- "Drilling Plan for Intermediate Well R-55i" (TerranearPMC 2010, 111582),
- "Integrated Work Document for Regional and Intermediate Aquifer Well Drilling" (LANL 2007, 100972),
- "Storm Water Pollution Prevention Plan for SWMUs and AOCs (Sites) and Storm Water Monitoring Plan" (LANL 2006, 092600), and
- "Waste Characterization Strategy Form for R-55i, Perched-Intermediate Well Installation and Corehole Drilling" (LANL 2010, 111297).

3.0 DRILLING ACTIVITIES

This section describes the drilling approach and provides a chronological summary of field activities conducted at monitoring well R-55i.

3.1 Drilling Approach

The drilling methods and selection of equipment and drill-casing sizes for the R-55i monitoring well were designed to retain the ability to investigate and case off any perched groundwater encountered above the target perched groundwater zone. 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-55i 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. Two sizes of A53 grade B flush-welded mild carbon-steel casing (16-in. and 12-in.-inside diameter [I.D.]) were used for the R-55i project.

The dual-rotary technique at R-55i 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 400 ft bgs, roughly 100 ft above the expected top of the target perched intermediate groundwater zone. No additives other than potable water were used for drilling below 400 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-55i Well

Mobilization of drilling equipment and supplies to the R-55i drill site occurred on December 11 and 12, 2010. Decontamination of the equipment and tooling was performed before mobilization to the site. On December 13, following on-site equipment inspections, the monitoring well borehole was initiated at 1400 h using dual-rotary methods with 16-in. drill casing and a 14.75-in. tricone bit.

Drilling and advancing the 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 at the top of the Cerros del Rio volcanic series on December 14, 2010. No indications of groundwater were observed while the 16-in. casing was advanced.

On December 14, open-hole drilling with a 15-in. hammer bit began. Drilling proceeded through thin, fractured basaltic lava flows to 145 ft bgs. Loose and unstable conditions in the basalt required installing 12-in. drill casing and changing to casing advance drilling methods on December 16.

Starting on December 18, the 12-in. casing string and an underreaming hammer bit were advanced through alternating basaltic flows and scoriaceous deposits below 145 ft. On December 21, the 12-in. casing was advanced to 366.9 ft bgs before drilling operations were suspended between December 22, 2010, and January 3, 2011, for the winter holiday break.

On January 4, 2011, operations resumed. Maintenance on the drill rig was completed on January 5, and the underreaming hammer bit was replaced with an 11.75-in. conventional hammer bit because of slow progress and penetration rates while advancing the 12-in. casing into a massive basalt flow. An open borehole was advanced to a TD of 565 ft bgs on January 6 and 7. Intermediate groundwater was first encountered at a depth of 485 ft bgs based on drill crew observations. The 12-in. casing shoe was cut on January 8 at 356 ft bgs (10.9 ft of 12-in. casing was left in the borehole).

During drilling, field crews worked 12-h shifts, 7 d/wk. Operations were suspended between December 22 and January 3 for the winter 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-55i. All sampling activities were conducted in accordance with applicable quality procedures.

4.1 Cuttings Sampling

Cuttings samples were collected from the R-55i monitoring well borehole at 5-ft intervals from ground surface to the TD of 565 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. Because of lost circulation from 250 to 255 ft bgs and from 295 to 305 ft bgs, samples were not recovered from those intervals. Radiation control technicians screened the cuttings before removal from the site. All screening measurements were within the range of background values. The core boxes were delivered to the Laboratory’s archive at the conclusion of drilling activities.

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

4.2 Water Sampling

Six groundwater screening samples were collected during aquifer testing from the pump’s discharge line and analyzed for total organic carbon (TOC) (Table 4.2-1). The TOC results are presented in Appendix B.

Groundwater characterization samples will be collected from the completed well in accordance with the Consent Order. For the first year, the samples will be analyzed for the full suite of constituents, including radioactive elements; anions/cations; general inorganic chemicals; volatile and semivolatile organic compounds; and stable isotopes of hydrogen, nitrogen, and oxygen. The analytical results will be included in the appropriate periodic monitoring report issued by the Laboratory. After the first year, the analytical suite and sampling frequency at R-55i 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-55i is presented below. The Laboratory’s geology task leader and project site geologist examined cuttings to determine geologic contacts and hydrogeologic conditions. Drilling observations and water-level measurements were used to characterize groundwater occurrences encountered at R-55i.

5.1 Stratigraphy

Rock units for the R-55i borehole are presented below in order of stratigraphic occurrence from youngest to oldest unit. 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-55i. A detailed lithologic log for R-55i is presented in Appendix A.

Alluvium, Qal (0–10 ft bgs)

A thin zone of Quaternary alluvium mixed with base-course gravel fill from drill pad construction was encountered from 0 to 10 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 (10–40 ft bgs)

Unit 1g of the Tshirege Member of the Bandelier Tuff was encountered from 10 to 40 ft bgs. Unit 1g is a poorly welded to nonwelded 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 abundant free quartz and sanidine crystals and minor small (up to 10 mm) volcanic (predominantly dacitic) lithic clasts.

Otowi Member of the Bandelier Tuff, Qbo (40–45 ft bgs)

The Otowi Member ash flows of the Bandelier Tuff were encountered from 40 to 45 ft bgs. The Otowi Member ash flow deposit is a poorly welded pumiceous rhyolitic ash-flow tuff that is crystal- and lithic-bearing. Abundant pumice lapilli are white, glassy, lustrous, and quartz- and sanidine-phyric. Otowi Member drill cuttings contain white, glassy pumices, volcanic lithic clasts (up to 10 mm), and quartz and sanidine crystals. Lithic 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 (45–55 ft bgs)

The Guaje Pumice Bed represents an air fall deposit of rhyolitic pumice and ash that forms the base of the Otowi Member. The Guaje deposit was encountered from 45 to 55 ft bgs. 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 (55–82 ft bgs)

Puye Formation volcaniclastic sediments were encountered from 55 to 82 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 (82–565 ft bgs)

Cerros del Rio volcanic rocks, encountered in R-55i from 82 to 565 ft bgs, form a complex sequence that includes both massive and vesicular basaltic lavas, basaltic scoria deposits, cinders, phreatomagmatic deposits, and both volcaniclastic and quartzo-feldspathic sediments.

No samples were collected from 295 to 305 ft bgs because circulation was lost in a large scoria zone. Basalt lava and scoria were encountered from 305 to 315 ft bgs.

Massive basalt flows were again encountered from 315 to 354 ft bgs, and basaltic cinders deposits and scoria were encountered from 354 to 360 ft bgs. Massive basalt lavas were encountered from 360 to 490 ft bgs, with an underlying breccia zone at 490 to 495 ft bgs. Glassy basalt with larger olivine crystals and dark gray volcanic breccias were encountered at 495 ft bgs; these deposits and associated tephras are interpreted as phreatomagmatic eruption deposits. Drill cuttings surfaces in this section were frequently altered to a yellowish-green color. The phreatomagmatic volcanic deposits were observed to 540 ft bgs.

Volcaniclastic and quartzo-feldspathic sediments were encountered below the phreatomagmatic deposits from 540 to 565 ft bgs at the borehole TD. These gravel and sand deposits contain some phreatomagmatic volcanic clasts and are similar in composition to the Totavi Lentil of the Puye Formation. The gravels are composed of clasts (up to 10 mm) of various volcanic lithologies (dacites, massive basalts, glassy basalts) and Precambrian quartzites. The amount of clay in the sediments increases with depth, and an exceptionally clay-rich interval was encountered from 560 to 565 ft bgs at the bottom of the borehole. A clay-rich interval was also encountered at approximately 565 ft bgs in regional well R-55 (approximately 100 ft southeast of R-55i). This clay-rich zone is interpreted to be the perching horizon for the intermediate groundwater observed at both wells.

5.2 Groundwater

Drilling at R-55i proceeded without any groundwater indications until approximately 485 ft bgs as noted by the drilling crew. After drilling to 550 ft bgs, drilling was paused, and water production was estimated at 20 gallons per minute (gpm). The borehole was then advanced to the TD of 565 ft bgs. Water levels stabilized at 498.4 ft bgs on January 11, 2011, before well installation. The measured DTW in the completed well was 498.2 ft bgs on January 24.

6.0 BOREHOLE LOGGING

No video or geophysical logs were collected in the R-55i borehole because they are available for regional well R-55, located on the same drill pad.

7.0 WELL INSTALLATION R-55i MONITORING WELL

The R-55i well was installed between January 11 and 18, 2011.

7.1 Well Design

The R-55i well was designed in accordance with the Consent Order, and NMED approved the final well design before installation (Appendix D). The well was designed with a screened interval between 510 and 530 ft bgs to monitor the groundwater quality of the perched intermediate groundwater within the Cerros del Rio volcanic series.

7.2 Well Construction

The R-55i 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.

The screened section utilized two 10-ft lengths of 5.0-in.-I.D., rod-based, 0.020-in., wire-wrapped screen. Compatible external stainless-steel couplings (also type A304 stainless steel fabricated to ASTM A312 standards) were used to join the individual casing 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 for delivery of backfill and annular fill materials downhole during well construction. A short length of 12-in. drill casing (10.9-ft casing and shoe, at a depth of 356 to 366.9 ft bgs) remains in the borehole. The 12-in. casing stub was encased in the upper bentonite seal during well completion.

A 10.3-ft-long stainless-steel sump was placed below the bottom of the well screen. Stainless-steel centralizers (two sets of four) were welded to the well casing approximately 2.0 ft above and below the screened interval. 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 9 to 11, 2010. The 5.0-in.-I.D. well casing was started into the borehole on January 11 at 1150 h. The well casing was hung by wireline with the bottom at 541.4 ft bgs.

The installation of annular materials began on January 13 after the bottom of the borehole was measured at 544.4 ft bgs (approximately 21 ft of slough in the borehole). The lower bentonite seal was installed on January 13 from 533 to 544.4 ft bgs using 3.4 ft^3 of 3/8-in. bentonite chips. The lower bentonite seal took 38% less annular fill material than had been calculated, likely due to unstable borehole materials collapsing into the borehole while the bentonite chips were being installed with flowing water.

The filter pack was installed on January 13 from 505.3 to 533 ft bgs using 17.0 ft^3 of 10/20 silica sand. The filter pack was surged to promote compaction. The fine sand collar was installed above the filter pack from 503.3 to 505.3 ft bgs using 1.0 ft^3 of 20/40 silica sand.

From January 13 to 17, the upper bentonite seal was installed from 62.9 to 503.3 ft bgs using 432.2 ft^3 of 3/8-in. bentonite chips. On January 18, a cement seal was installed from 3 to 62.9 ft bgs. The cement seal used 117.6 ft^3 of Portland Type I/II/V cement. This volume exceeded the calculated volume of 81.8 ft^3 by 44% and is likely because of cement loss to the near surface formations.

Operationally, well construction proceeded smoothly, 12 h/d, 7 d/wk, from January 11 through 18, 2011.

8.0 POST-INSTALLATION ACTIVITIES

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

8.1 Well Development

The well was developed between January 24 and 27, 2011. Initially, the screened interval was 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 and filter pack. The bailing tool was a 4.0-in.-O.D. by 21.0-ft-long carbon steel bailer with a total capacity of 12 gal. The tool was lowered by wireline, repeatedly filled, withdrawn from the well, and emptied into the cuttings pit. Approximately 963 gal. of groundwater was removed during bailing activities.

After bailing, a 5-horsepower (hp), 4-in. Berkeley submersible pump was installed in the well for the final stage of well development. On January 25 and 26, the screened interval was pumped from top to bottom and then from bottom to top in 2-ft increments. The pump was then used to purge the well sump. On January 26, the pump intake was set at 508.4 ft bgs for the remainder of purging. Approximately 5969 gal. of groundwater was purged with the submersible pump during well development.

Total Volumes of Introduced and Purged Water

During drilling, approximately 3500 gal. of potable water was added to the borehole in the perched groundwater interval between 485 and 565 ft bgs. An additional 2000 gal. was added during installation of the screened interval filter pack. Thus, approximately 5500 gal. of potable water was introduced into the borehole over the water-bearing interval during drilling and installation.

Approximately 6932 gal .of groundwater was purged at R-55i during well development activities. Another 5619 gal. was purged during aquifer testing. Total groundwater purged during post-installation activities was 12,551 gal.

8.1.1 Well Development Field Parameters

During the pumping stage of well development, turbidity, temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and specific conductance were measured. To indicate adequate well development has occurred, the TOC and turbidity values should be less than 2.0 ppm and less than 5 nephelometric turbidity units (NTU), respectively, at the end of development.

Field parameters were measured by collecting aliquots of groundwater from the discharge pipe with the use of a flow-through cell. The final parameters at the end of well development were pH of 8.21, temperature of 16.96°C, specific conductance of 306 µS/cm, and turbidity of 0.0 NTU. Table B-2.2-1 in Appendix B shows field parameters and purge volumes measured during well development.

8.2 Aquifer Testing

Aquifer pumping tests were conducted at R-55i on January 31 and on February 3 and 4, 2011. Several short-duration tests with short-duration recovery periods were performed on the first day of testing. A 24-h pump test followed by a 24-h recovery period completed the testing of the screened interval.

A 5-hp pump was also used for the aquifer tests. A total of approximately 5619 gal. of groundwater was purged during aquifer testing.

Turbidity, temperature, pH, DO, ORP, and specific conductance were measured during the 24-h test. Measured parameters are presented in Appendix B. The R-55i aquifer test results and analysis are presented in Appendix C.

8.3 Dedicated Sampling System Installation

The dedicated sampling system for R-55i was installed on March 15, 2011. The pumping system utilizes an environmentally retrofitted 4-in., 1.5-hp Grundfos submersible pump set near the bottom of the screened interval. Because of insufficient head above the screen, the pump was set within the screened interval in a stainless-steel pump shroud; the bottom of the shroud is located at 530.1 ft bgs. The pump column is constructed of 1-in. threaded/coupled passivated stainless-steel pipe. A weep valve was installed at the bottom of the uppermost pipe joint to protect the pump column from freezing. To measure water levels in the well, two 1-in.-I.D. schedule 80 polyvinyl chloride (PVC) pipes were installed to sufficient depth to set a dedicated transducer and to provide access for manual water-level measurements. The PVC transducer tubes are equipped with 9-in. sections of 0.010 -in. slotted screen with a threaded end cap on the bottom of each tube. An In-Situ Level Troll 500 30-psig transducer is installed in one of the PVC tubes to monitor the water level in the well's screened interval.

Sampling system details for R-55i 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-55i 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 10-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, were set at the outside edges of the pad to protect the well from traffic. All four bollards were 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 February 15, 2011 (Table 8.5-1). The survey data conform to Laboratory Information Architecture project standards IA-CB02, "GIS Horizontal Spatial Reference System," and IA-D802, "Geospatial Positioning Accuracy Standards 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-55i monitoring well.

8.6 Waste Management and Site Restoration

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

All waste streams produced during drilling and development activities were sampled in accordance with "Waste Characterization Strategy Form for R-55i, Perched-Intermediate Well Installation and Corehole Drilling" (LANL 2010, 111297).

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

Cuttings produced during drilling are anticipated to be land-applied after a review of associated analytical results per the WCSF and ENV-RCRA-QP-011.2, Land Application of Drill Cuttings. If the drill cuttings do not meet the criteria for land application, they will be disposed of at an authorized facility. Decontamination fluid used for cleaning equipment is containerized. The fluid waste was sampled and will be disposed of at an authorized facility. Characterization of contact waste will be based upon acceptable knowledge, pending analyses of the waste samples collected from the drill cuttings, purge water, and decontamination fluid.

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

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Drilling, sampling, and well construction at R-55i were performed as specified in “Drilling Plan for Intermediate Well R-55i” (TerranearPMC 2010, 111582).

10.0 ACKNOWLEDGMENTS

Boart Longyear drilled and installed the R-55i 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), August 2010. “Drilling Work Plan for Well R-55i,” Los Alamos National Laboratory document LA-UR-10-5142, Los Alamos, New Mexico. (LANL 2010, 110488)

LANL (Los Alamos National Laboratory), November 29, 2010. "Waste Characterization Strategy Form for R-55i, Perched-Intermediate Well Installation and Corehole Drilling," Los Alamos National Laboratory, Los Alamos, New Mexico. (LANL 2010, 111297)

TerranearPMC, December 2010. "Drilling Plan for Intermediate Well R-55i," plan prepared for Los Alamos National Laboratory, Los Alamos, New Mexico. (TerranearPMC 2010, 111582)

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.

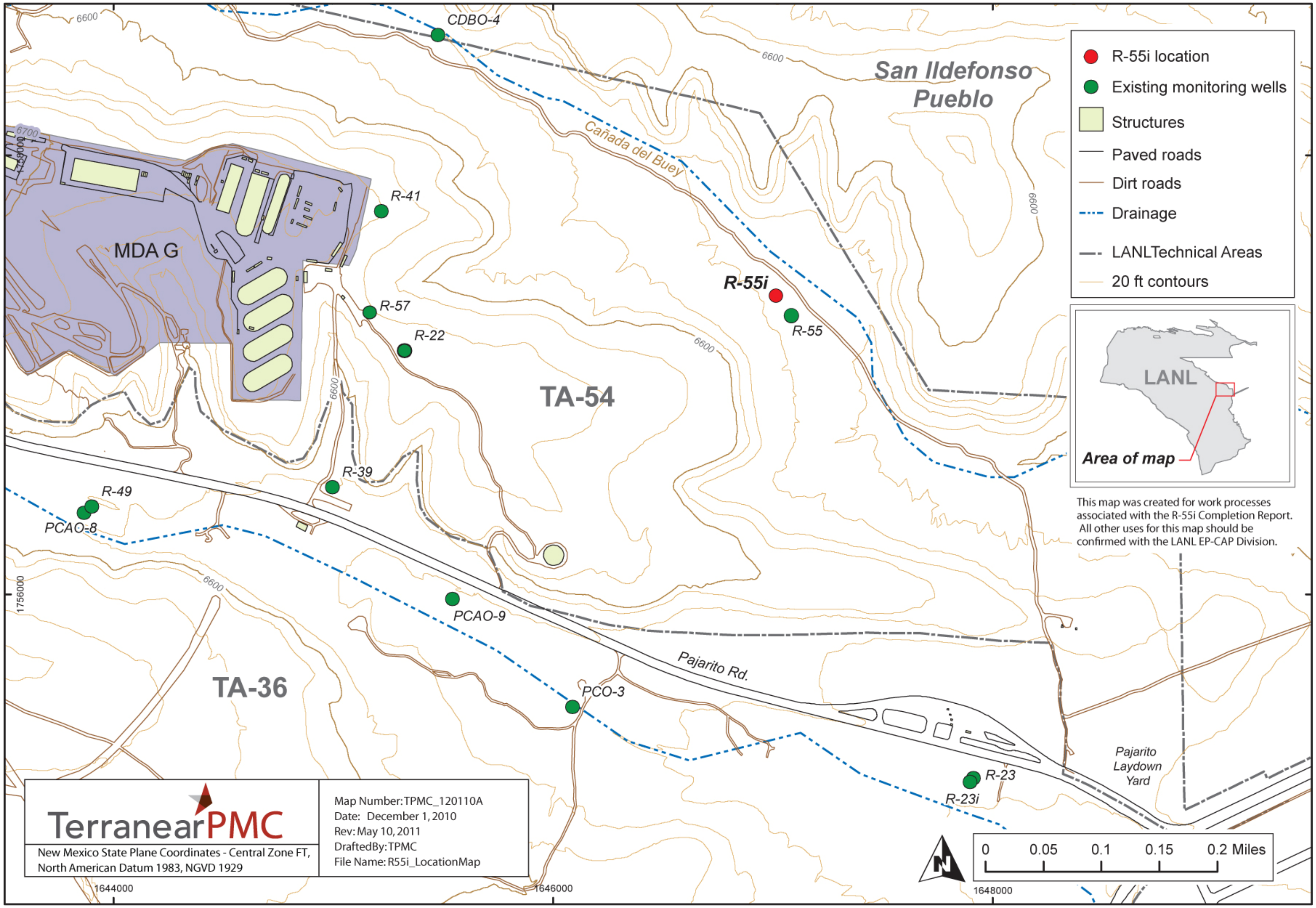


Figure 1.0-1 Location of monitoring well R-55i

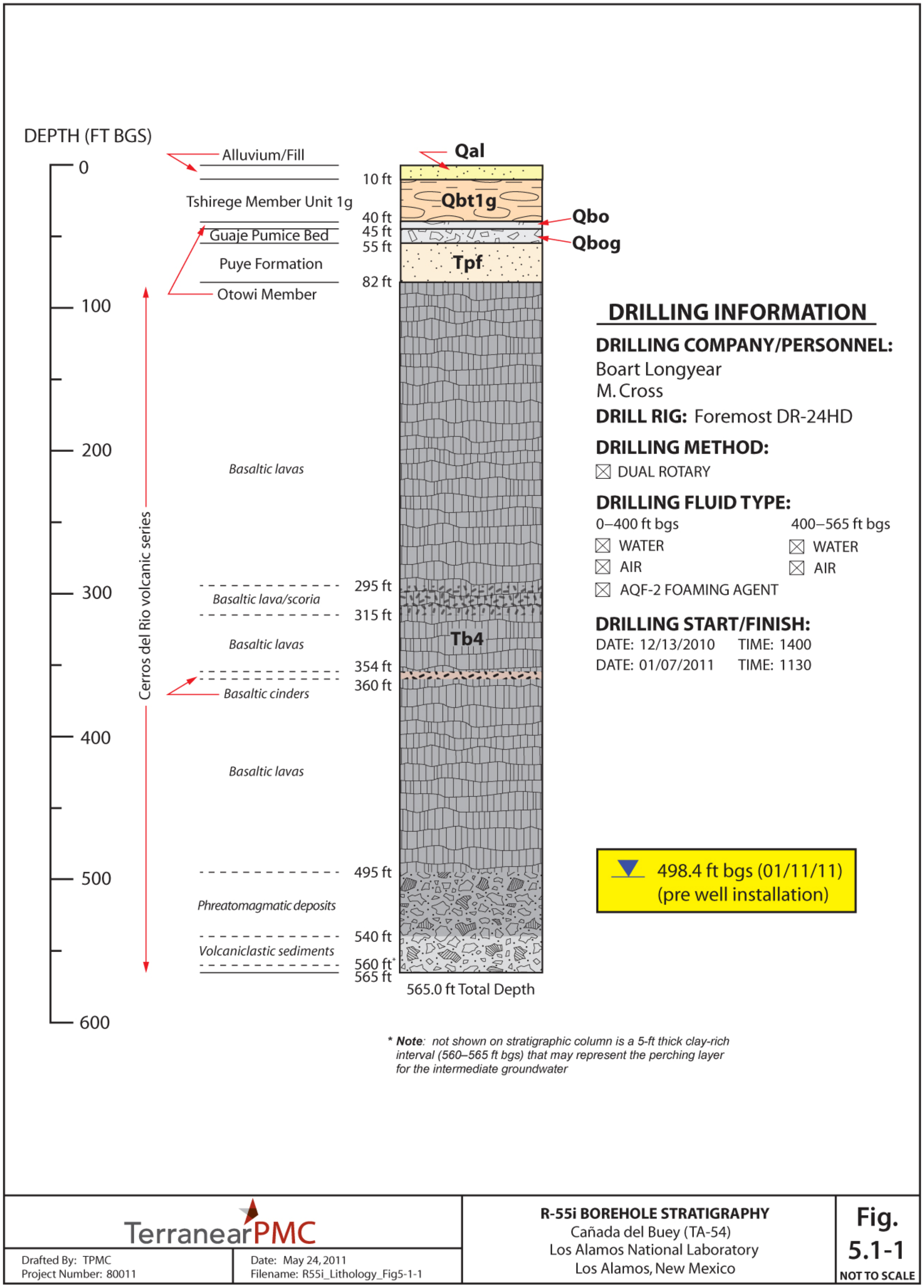


Figure 5.1-1 Monitoring well R-55i borehole stratigraphy

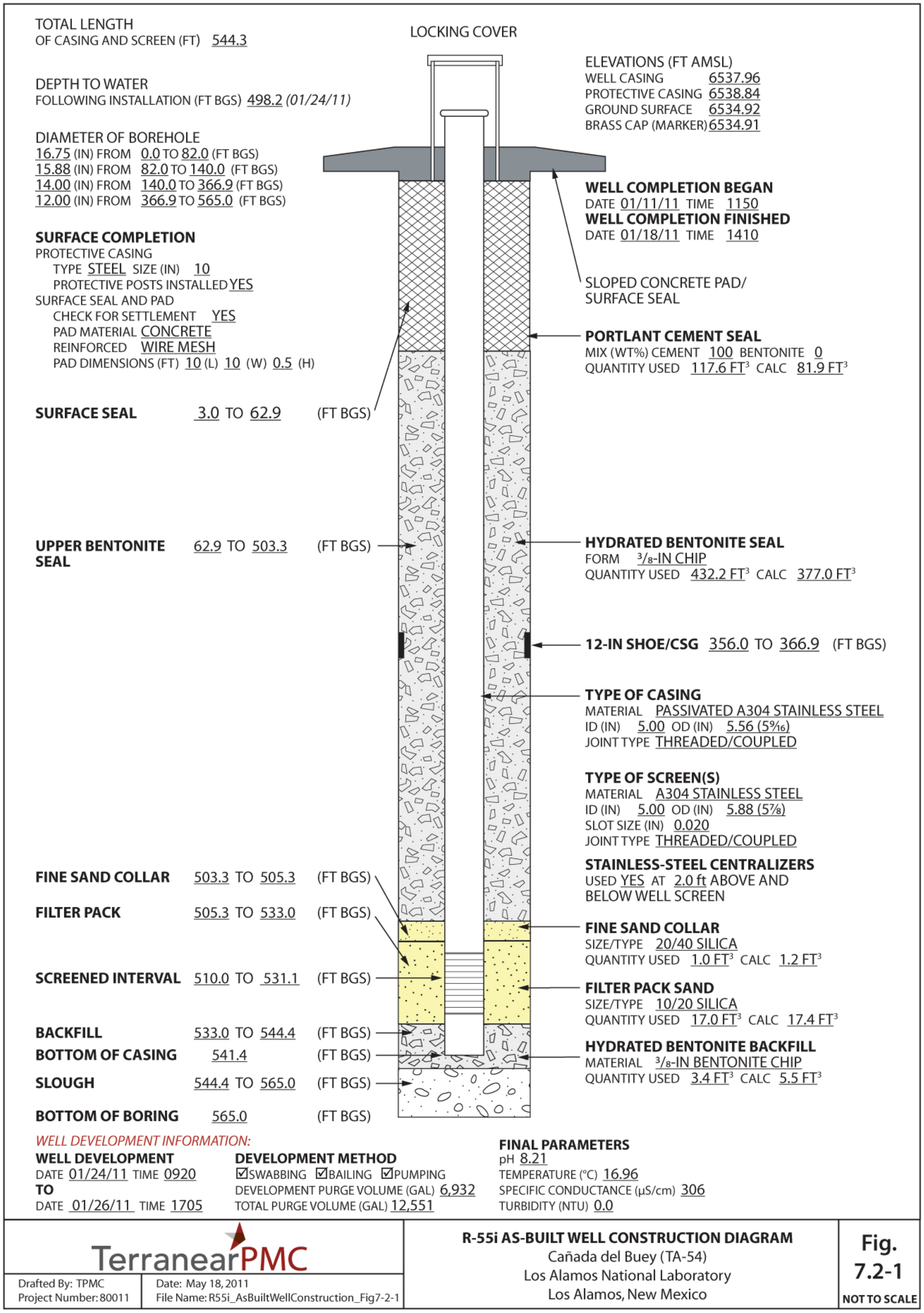


Figure 7.2-1 Monitoring well R-55i as-built well construction diagram

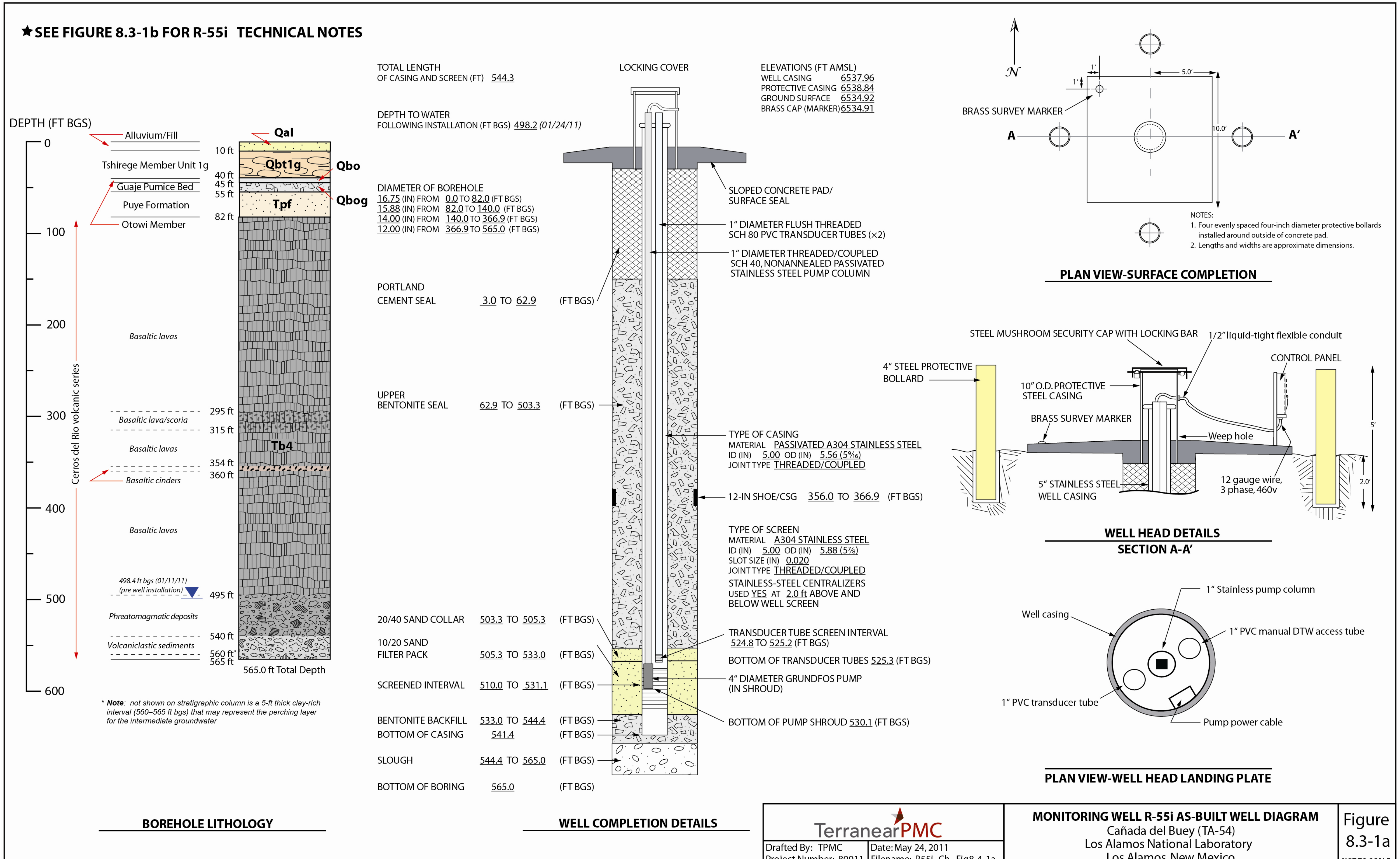


Figure 8.3-1a Monitoring well R-55i as-built diagram with borehole lithology and technical well completion details

R-55i TECHNICAL NOTES:

SURVEY INFORMATION*

Brass Marker

Northing:	1757360.90 ft
Easting:	1647014.67 ft
Elevation:	6534.91 ft AMSL

Well Casing (top of stainless steel)

Northing:	1757355.27 ft
Easting:	1647014.04 ft
Elevation:	6537.96 ft AMSL

BOREHOLE GEOPHYSICAL LOGS

None

DRILLING INFORMATION

Drilling Company
Boart Longyear

Drill Rig
Foremost DR-24HD

Drilling Methods
Dual Rotary
Fluid-assisted air rotary

Drilling Fluids
Air, potable water, AQF-2 Foam (to 400 ft bgs)

MILESTONE DATES

Drilling

Start:	12/13/2010
Finished:	01/07/2011

Well Completion

Start:	01/11/2011
Finished:	01/18/2011

Well Development

Start:	01/24/2011
Finished:	01/26/2011

WELL DEVELOPMENT

Development Methods
Performed swabbing, bailing, and pumping
Total Volume Purged: 6,932 gal

Parameter Measurments (Final)

pH:	8.21
Temperature:	16.96°C
Specific Conductance:	306 µS/cm
Turbidity:	0.0 NTU

AQUIFER TESTING

Constant Rate Pumping Test

Water Produced:	5,619 gal.
Average Flow Rate:	4.2 gpm
Performed on:	01/31–02/04/2011

DEDICATED SAMPLING SYSTEM

Pump (Shrouded)
Make: Grundfos
Model: 5515-26
S/N: B08010026-P10730US
5 U.S. gpm
Bottom pump shroud: 530.1 ft bgs
Environmental retrofit

Motor
Make: Franklin Electric
S/N: 10L14-03-01598C
1.5 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
0.01-in. slot screen at 524.8–525.2 ft bgs

Transducer
Make: In-Situ, Inc.
Model: Level TROLL 500
30 psig range (vented)
S/N: 182072

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

TerranearPMC
Drafted By: TPMC
Project Number: 80011
Date: May 10, 2011
Filename: R55i_TechnicalNotes_Fig8-3-1b

R-55i 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-55i

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

Date	Depth Interval (ft bgs)	Water (gal.)	Cumulative Water (gal.)	AQF-2 Foam (gal.)	Cumulative AQF-2 Foam (gal.)
Drilling					
12/13/10	0–35	300	300	1	1
12/14/10	35–85	800	1100	2	3
12/15/10	85–140	800	1900	5	8
12/18/10	140–200	2500	4400	10	18
12/19/10	200–275	2000	6400	10	28
12/20/10	275–318	1800	8200	20	48
12/21/10	318–363	3600	11,800	20	68
1/4/11	363–366	1500	13,300	10	78
1/6/11	366–480	3000	16,300	5	83
1/7/11	480–565	3000	19,300	0	83
1/8/11	Cut shoe	500	19,800	0	83
Well Construction					
1/13/11	544–491	2000	2000	n/a*	n/a
1/14/11	491–403	500	2500	n/a	n/a
1/15/11	403–360	250	2750	n/a	n/a
1/16/11	360–278	500	3250	n/a	n/a
1/17/11	278–63	1500	4750	n/a	n/a
1/18/11	63–3	400	5150	n/a	n/a
Total Water Volume (gal.)					
R-55i	24,950				

*n/a = Not applicable. Foam use terminated at 400 ft bgs during drilling; none used during well construction.

Table 4.2-1
Summary of Groundwater Screening Samples Collected during Aquifer Testing of Well R-55i

Location ID	Sample ID	Date and Time Collected	Collection Depth (ft bgs)	Sample Type	Analysis
Aquifer Testing					
R-55i	GW55(i)-11-4653	2/3/11; 1200 h	504.9	Groundwater, pumped	TOC
R-55i	GW55(i)-11-4654	2/3/11; 1600 h	504.9	Groundwater, pumped	TOC
R-55i	GW55(i)-11-4655	2/3/11; 2000 h	504.9	Groundwater, pumped	TOC
R-55i	GW55(i)-11-4656	2/4/11; 0000 h	504.9	Groundwater, pumped	TOC
R-55i	GW55(i)-11-4657	2/4/11; 0400 h	504.9	Groundwater, pumped	TOC
R-55i	GW55(i)-11-4658	2/4/11; 0800 h	504.9	Groundwater, pumped	TOC

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

Material	Volume
Upper surface seal: cement slurry	117.6 ft^3
Upper bentonite seal: bentonite chips	432.2 ft^3
Fine sand collar: 20/40 silica sand	1.0 ft^3
Filter pack: 10/20 silica sand	17.0 ft^3
Backfill: bentonite chips/pellets	3.4 ft^3

Table 8.5-1
R-55i Survey Coordinates

Identification	Northing	Easting	Elevation
R-55i brass cap embedded in pad	1757360.90	1647014.67	6534.91
R-55i ground surface near pad	1757353.87	1647009.71	6534.92
R-55i top of stainless-steel well casing	1757355.27	1647014.04	6537.96
R-55i top of 10-in. protective casing	1757355.35	1647013.94	6538.84

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

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

Location ID	Sample ID	Date Collected	Description	Sample Type
R-55i	WST55-11-2806	12/13/2010	Drill cuttings	Solids
R-55i	WST55-11-2856	12/21/2010	Drill cuttings	Solids
R-55i	WST55-11-2855(FTB[a])	12/21/2010	Drill cuttings	Solids
R-55i	WST55-11-2857	1/7/2010	Drill cuttings—3rd VOC[b] sample	Solids
R-55i	WST55-11-2858(FTB)	1/7/2010	Drill cuttings—3rd VOC sample	Solids
R-55i	WST55-11-3796(UF[c])	1/11/2011	R-55i decon[d]: well casing	Liquid
R-55i	WST55-11-3792(F[e])	1/11/2011	R-55i decon: well casing	Liquid
R-55i	WST55-11-3800(FD[f])	1/11/2011	R-55i decon: well casing	Liquid
R-55i	WST55-11-3804(FTB)	1/11/2011	R-55i decon: well casing	Liquid
R-55i	WST55-11-3797(UF)	1/13/2011	R-55i decon: tremie pipe last used/deconned at R-60	Liquid
R-55i	WST55-11-3793(F)	1/13/2011	R-55i decon: tremie pipe last used/deconned at R-60	Liquid
R-55i	WST55-11-3801(FD)	1/13/2011	R-55i decon: tremie pipe last used/deconned at R-60	Liquid
R-55i	WST55-11-3805(FTB)	1/13/2011	R-55i decon: tremie pipe last used/deconned at R-60	Liquid
R-55i	WST55-11-4141	1/20/2011	R-55i drill cuttings	Solids
R-55i	WST55-11-4244(UF)	1/28/2011	Development water	Liquid
R-55i	WST55-11-4243(F)	1/28/2011	Development water	Liquid
R-55i	WST55-11-4245(FD)	1/28/2011	Development water	Liquid
R-55i	WST55-11-4246(FTB)	1/28/2011	Development water	Liquid
R-55i	WST55-11-3798(UF)	1/28/2011	Decon downhole tremie used to backfill and build well	Liquid
R-55i	WST55-11-3794(F)	1/28/2011	Decon downhole tremie used to backfill and build well	Liquid
R-55i	WST55-11-3802(FD)	1/28/2011	Decon downhole tremie used to backfill and build well	Liquid
R-55i	WST55-11-3806(FTB)	1/28/2011	Decon downhole tremie used to backfill and build well	Liquid

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

Appendix A

Borehole R-55i Lithologic Log

Borehole Identification (ID): R-55i		**Technical Area (TA): 54**	**Page:** 1 of 7
Drilling Company: Boart Longyear Company		**Start Date/Time:** 12/13/10; 1400	**End Date/Time:** 01/07/11; 1130
Drilling Method: Dual Rotary		**Machine**: Foremost DR24 HD	**Sampling Method:** Grab
Ground Elevation: 6534.92 ft AMSL			**Total Depth:** 565 ft
Drillers: M. Cross		**Site Geologists:** T. Naibert, M. Jojola	

Depth (ft bgs)	Lithologic description	Lithologic symbol	Notes
0–10	**ALLUVIUM:** Construction Fill and Tuffaceous Sediments—pale orange gray (10YR 8/2), crystal-bearing, lithic-bearing tuff clasts and rounded clasts (quartzite, dacite) in well pad base course. 0–3’ WR: pale brown (5YR 5/2) mixed subrounded to subangular clasts (dacite, quartzite) indicating imported base course gravels used in drill pad construction; powdered tuff and silty ash. Disturbed section no more than 3 ft thick. 3–10’ WR: 85–90% Fine grained tuffaceous sediments; coarse sand to granule sized pumice and tuff grains; few pebble sized tuff clasts and quartzite from construction fill.	Qal	Note: Drill cuttings for descriptive analysis were collected at 5-ft intervals from 0 ft to borehole TD at 565 ft bgs. Alluvial sediments, encountered from 0–10 ft bgs, are approximately 10 ft thick.
10–35	**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, weak to moderately indurated, crystal-rich, lithic-poor, strongly weathered, with white vitric pumice clasts up to 2 mm. 10–35’ WR: 10–15% silt/sand sized fragments of ash flow tuff (i.e., ignimbrite); 70–80% white vitric pumice clasts, color becomes slightly more orange between 30’–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% pumice lapilli (5 to 15 mm); dacite lithic fragments set in a matrix of glassy to weathered volcanic ash.	Qbt 1g	Unit 1g of the Tshirege Member of the Bandelier Tuff (Qbt 1g), encountered from 10–40 ft bgs, is estimated to be 30 ft thick.
35–40	Rhyolitic Tuff and Pumice—white to very light gray (N9–N8) pumice and minor tuff fragments, crystal-poor, lithic-poor. 35–40’ WR: 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 crystal-poor basal zone from 35–40 ft bgs.

Borehole Identification (ID): R-55i	Technical Area (TA): 54	Page: 2 of 7
Drilling Company: Boart Longyear Company	**Start Date/Time:** 12/13/10; 1400	**End Date/Time:** 01/07/11; 1130
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD	**Sampling Method:** Grab
Ground Elevation: 6534.92 ft AMSL		**Total Depth:** 565 ft
Drillers: M. Cross	**Site Geologists:** T. Naibert, M. Jojola	

Depth (ft bgs)	Lithologic description	Lithologic symbol	Notes
40–45	**OTOWI MEMBER OF THE BANDELIER TUFF:** Rhyolite Tuff—white to very light gray (N9–N8) unconsolidated, crystal-rich, lithic–poor pumice fragments. 40–50' WR: 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).	Qbo	
45–55	**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. 50–55' WR: 95–100% white vitric pumice clasts; 1–5% dacitic and rhyolitic lithics.	Qbog	Note: The upper contact of the Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff was determined to be at 45 ft bgs based on a crystal-poor, pumice-rich zone in drill cuttings from 45–55 ft bgs.
55–60	**PUYE FORMATION:** Fine-Grained Sediments—white pumice (N9) and light brown (5YR 6/4) quartz-rich, fine-grained sandstones and siltstones. 55–60' WR: 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.	Tpf	The Puye Fm. was encountered from 55–82 ft bgs.
60–82	Fine-Grained Sediments—light brown (5YR 6/4) quartz-rich fine-grained sandstones and siltstones. 60–75' WR: 75–85% light brown siltstone and fine-grained sandstones containing abundant glassy gray to black volcanic lithic clasts and quartz grains; 5% gray glassy volcanic clasts; 15–25% white lithic-poor pumice clasts. 75–82' WR: 80–90% light brown fine-grained sandstone and siltstone clasts; 2–5% gray glassy rhyolite clasts; 5–10% angular to subangular vesicular basalt clasts.	Tpf	Note: A few vesicular basalt clasts were noted between 75 and 82 ft bgs and are interpreted to be reworked Cerros del Rio basalts. The Puye Fm/Cerros del Rio volcanic series contact is estimated at 82 ft bgs based on a change in drilling penetration rate.

Borehole Identification (ID): R-55i	**Technical Area (TA): 54**	**Page:** 3 of 7
Drilling Company: Boart Longyear Company	**Start Date/Time:** 12/13/10; 1400	**End Date/Time:** 01/07/11; 1130
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD	**Sampling Method:** Grab
Ground Elevation: 6534.92 ft AMSL		**Total Depth:** 565 ft
Drillers: M. Cross	**Site Geologists:** T. Naibert, M. Jojola	

Depth (ft bgs)	Lithologic description	Lithologic symbol	Notes
82–85	**CERROS DEL RIO VOLCANIC Series:** 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. 82–85' WR: 75–85% angular/broken fragments of massive basalt with few vesicles; 10–20% subrounded (i.e., milled during drilling) fragments of yellow/gray to tan very fine-grained tuffaceous ash; 10–20% brown fine-grained sand/siltstones.	Tb 4	The Cerros del Rio volcanic series (Tb 4) was encountered from 82 to the TD of 565 ft bgs.
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: 95–99% angular/broken chips of fine-grained massive olivine/pyroxene-phyric basalt; 1–3% chips of tan tuffaceous ash/siltstone.	Tb 4	
90–120	Basalt Lava—medium dark gray to medium gray (N4–N5). Sample predominantly chips of fine-grained massive basalt. 90–120' WR/+10F/+35F: 97–100% angular/broken chips of massive plagioclase/olivine-bearing basalt	Tb 4	
120–145	Basalt Lava Flows—medium gray (N5) chips of massive basalt, porphyritic with aphanitic groundmass, phenocrysts (5–10% by volume) of plagioclase. 120–125' WR: 85–95% angular/broken chips of massive basalt with 5–10% phenocrysts of plagioclase. 125–130' WR: Massive basalt fragments. 130–135' WR: Slightly oxidized basalt fragments, more vesicular than above. 135–145' WR: Vesicular basalt fragments and large scoria (up to 20 mm).	Tb 4	Note: Basalt is increasingly vesicular with depth suggesting thinner basalt flows or scoria deposits.

Borehole Identification (ID): R-55i	Technical Area (TA): 54	Page: 4 of 7
Drilling Company: Boart Longyear Company	**Start Date/Time:** 12/13/10; 1400	**End Date/Time:** 01/07/11; 1130
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD	**Sampling Method:** Grab
Ground Elevation: 6534.92 ft AMSL		**Total Depth:** 565 ft
Drillers: M. Cross	**Site Geologists:** T. 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 of plagioclase. 145–155' WR: 100% angular chips of vesicular basalt. Minor oxidation has occurred along some vesicles and surfaces. 155–160' WR: Brown/red oxidized vesicular basalt clasts up to 30 mm. Small basalt fragments are weathered to brown clay.	Tb 4	
160–185	Basalt Lava—medium gray (N5) to medium dark gray, predominantly broken chips of vesicular basalt. 160–170' WR: 100% angular chips of vesicular basalt. Oxidation of fragment surfaces increases slightly down section but is uncommon. 170–185' WR: 100% angular chips of medium dark gray, weakly vesicular basalt. Oxidation of surfaces is uncommon. Few phenocrysts are visible in this section.	Tb 4	
185–215	Basalt Lava—medium gray (N5) to medium dark gray (N4), predominantly broken chips of vesicular basalt. 185–190' WR: Small (<0.5 mm) fragments of massive basalt with no oxidation. 190–215' WR: 98–99% angular chips of vesicular plagioclase-olivine basalt; 1–2% fragments of pinkish-white clay (2.5YR 8/2).	Tb 4	
215–250	Basalt Lava—medium gray (N5) chips of basalt. Basalt is phenocryst poor (<2% by volume). 215–250' WR: 99–100% angular chips of medium light gray phenocryst-poor basalt; vesicles slightly oxidized. Clasts up to 40 mm between 225–230 ft; 1% fragments of pinkish-white clay (7.5YR 7/2) below 235 ft.	Tb 4	
250–255	250–255': No cuttings collected; lost circulation.	Tb 4	

Borehole Identification (ID): R-55i	Technical Area (TA): 54	Page: 5 of 7
Drilling Company: Boart Longyear Company	Start Date/Time: 12/13/10; 1400	End Date/Time: 01/07/11; 1130
Drilling Method: Dual Rotary	Machine: Foremost DR24 HD	Sampling Method: Grab
Ground Elevation: 6534.92 ft AMSL		Total Depth: 565 ft
Drillers: M. Cross	Site Geologists: T. Naibert, M. Jojola	

Depth (ft bgs)	Lithologic description	Lithologic symbol	Notes
255–265	Basalt Lava—medium dark gray (N4) chips of vesicular basalt. Basalt is porphyritic with phenocrysts (10% by volume). 255–265' WR: 95% angular chips of medium to medium dark gray to dark red vesicular basalt; 5% orange clay as clasts and in some vesicles.	Tb 4	
265–295	Basalt Lava—medium dark gray (N4) mixed vesicular and massive basalt. 265–270' WR: 99% angular chips of vesicular basalt with olivine phenocrysts; trace amounts of tan siltstone and tuffaceous ash. 270–290' WR: 100% angular chips of basalt (>75% massive) with olivine phenocrysts up to 3 mm. 290–295' WR: 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 (255–295 ft bgs).
295–305	295–305': No cuttings collected; lost circulation.	Tb 4	
305–315	Basalt Lava and Scoria—medium dark gray (N4) vesicular basalt and scoria. 305–315' WR: 100% fragments of partially oxidized vesicular basalt with scoria clasts up to 30 mm.	Tb 4	
315–320	Basalt Lava—medium dark gray (N4) mixed vesicular and massive basalt clasts. 315–320' WR: 100% small (<3 mm), slightly oxidized basalt chips.	Tb 4	Note: Lower penetration rate at ~315 ft suggests change from mixed flows/scoria to mostly massive lava flows below 315 ft.
320–335	Basalt Lava—medium dark gray (N4) massive basalt with few, large vesicles. 320–335' WR: 98% fragments of massive basalt clasts; 2% pink clay clasts up to 15 mm.	Tb 4	
335–355	Basalt Lava—medium gray (N5) massive basalt chips. 335–345' WR: 90–97% massive basaltic chips; 3–10% pink clay/siltstone. 345–350' WR: 100% massive basaltic chips with minor oxidation. 350–355' WR: 95–99% massive basaltic chips; 1–5% pink clay/siltstone.	Tb 4	

Borehole Identification (ID): R-55i	**Technical Area (TA): 54**		**Page:** 6 of 7
Drilling Company: Boart Longyear Company	**Start Date/Time:** 12/13/10; 1400		**End Date/Time:** 01/07/11; 1130
Drilling Method: Dual Rotary	**Machine**: Foremost DR24 HD		**Sampling Method:** Grab
Ground Elevation: 6534.92 ft AMSL			**Total Depth:** 565 ft
Drillers: M. Cross	**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic symbol	Notes
335–355	Basalt Lava—medium gray (N5) massive basalt chips. 335–345' WR: 90–97% massive basaltic chips; 3–10% pink clay/siltstone. 345–350' WR: 100% massive basaltic chips with minor oxidation. 350–355' WR: 95–99% massive basaltic chips; 1–5% pink clay/siltstone.	Tb 4	
355–360	Basaltic Cinders—medium gray (N5) vesicular basalt with minor reddish-gray oxidation. 355–360' WR: 95% angular chips of vesicular olivine-phyric basalt with minor oxidation; 5% pink clay/siltstone.	Tb 4	Note: Drilling penetration rate increased at ~354 ft bgs due to more scoracious deposits.
360–390	Basalt Lava—medium gray (N5) mixed vesicular and massive basalt with minor oxidation and cinder deposits. 360–370' WR: 95% rounded chips of olivine-phyric basalt; 5% pink, ashy clay/siltstone. 370–375' WR: 95–100% angular vesicular basalt clasts; <5% pink clay/siltstone. 375–390' WR: 95–98% mixed vesicular and massive basalt clasts with little alteration; 2–5% pink/orange clay.	Tb 4	
390–490	Basalt Lava—medium to medium light gray (N5–N6) mixed vesicular and massive basalt. 390–400' WR: 80–90% angular chips of mixed vesicular and massive basalt; 10–20% tan ashy siltstone clasts. 400–425' WR: 90–95% angular chips of mixed vesicular and massive basalt; 5–10% tan ashy siltstone clasts. 425–490' WR: 99–100% chips of more massive basalt; <1% tan ashy siltstone clasts.	Tb 4	
490–495	Basalt Breccias—medium to medium light gray (N5–N6) vesicular basalt clasts. 490–495' WR: 100% large (>40 mm) vesicular basalt clasts with very minor oxidation.	Tb 4	

Borehole Identification (ID): R-55i		Technical Area (TA): 54		Page: 7 of 7
Drilling Company: Boart Longyear Company		**Start Date/Time:** 12/13/10; 1400		**End Date/Time:** 01/07/11; 1130
Drilling Method: Dual Rotary		**Machine**: Foremost DR24 HD		**Sampling Method:** Grab
Ground Elevation: 6534.92 ft AMSL				**Total Depth:** 565 ft
Drillers: M. Cross		**Site Geologists:** T. Naibert, M. Jojola		

Depth (ft bgs)	Lithologic description	Lithologic Symbol	Notes
495–540	Phreatomagmatic Deposits—medium to dark gray (N5–N3) olivine-phyric basalt with glassy matrix, basalt surfaces are commonly altered; fine-grained volcanic breccias containing clasts of basalt, obsidian, olivine, and plagioclase. 495–540' WR: 30–40% glassy vesicular basalt with abundant olivine phenocrysts (up to 2 mm), surfaces altered to green; 10–40% volcanic breccias containing angular to rounded clasts of obsidian and detrital quartzite, and grains of olivine and plagioclase and detrital quartz; 10–40% medium gray olivine-phyric massive basalt.	Tb 4	
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 volcanic lithologies (black glassy basalt, fine-grained medium gray basalt, dacite) and Precambrian quartzites. 540–550' WR: 40–50% subrounded to well rounded clasts of dark gray glassy basalt; 40–50% clasts of medium gray (N5) aphanitic basalt.	Tb 4	
550–560	Volcaniclastic Sediments—fine to medium subrounded to well rounded gravels (up to 10 mm) and sand. Proportion of silt and clay increases down section. Detritus composed of variable volcanic lithologies (black glassy basalt, fine-grained medium gray basalt), Precambrian quartzite and pink ashy matrix-supported fine-grained sandstone clasts. 550–560' WR: 30–50% subrounded to well rounded clasts of dark gray glassy basalt; 30–50% clasts of medium gray (N5) aphanitic basalt; 10–20% fine-grained lithic-rich sandstone clasts,<5% Precambrian quartzite clasts	Tb 4	
560–565	560–565' WR: 40–50% clay-rich 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; <10% clay bodies in unsieved samples; 1–2% subrounded to well rounded clasts of dark gray glassy basalt.	Tb 4	Note: The clay-rich interval from 560–565 ft bgs is likely the perching horizon for the intermediate groundwater. TD = 565 ft bgs.

Abbreviations

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

% = estimated percent by volume of a given sample constituent

AMSL = above mean sea level

bgs = below ground surface

Qal = alluvium

Qbo = Otowi Member of the Bandelier Tuff

Qbog = Guaje Pumice Bed

Qbt 1g = unit 1g of the Tshirege Member of the Bandelier Tuff

Tb 4 = Cerros del Rio volcanic series

Tpf = Puye 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

Screening Groundwater Analytical Results

B-1.0 SCREENING GROUNDWATER ANALYSES AT R-55i

R-55i is a perched intermediate groundwater monitoring well with one well screen from 510 to 531.1 ft below ground surface (bgs) set in the Cerros del Rio volcanic series. This appendix presents screening laboratory analytical results for samples collected during aquifer testing at R-55i as well as field parameters measured during well development and aquifer testing.

Laboratory Analyses

Six samples were collected during aquifer testing and analyzed for total organic carbon (TOC). Los Alamos National Laboratory's Earth and Environmental Sciences Group 14 conducted the TOC analyses. Table B-1.0-1 lists the samples submitted for TOC analyses from R-55i.

Field Analyses

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

B-2.0 SCREENING ANALYTICAL RESULTS

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

B-2.1 Total Organic Carbon

TOC concentrations varied from 0.22 to 0.84 mgC/L in six groundwater samples collected during aquifer testing at well R-55i (Table B-2.1-1). These concentrations are below the target concentration of 2.0 mgC/L for TOC at the end of well development.

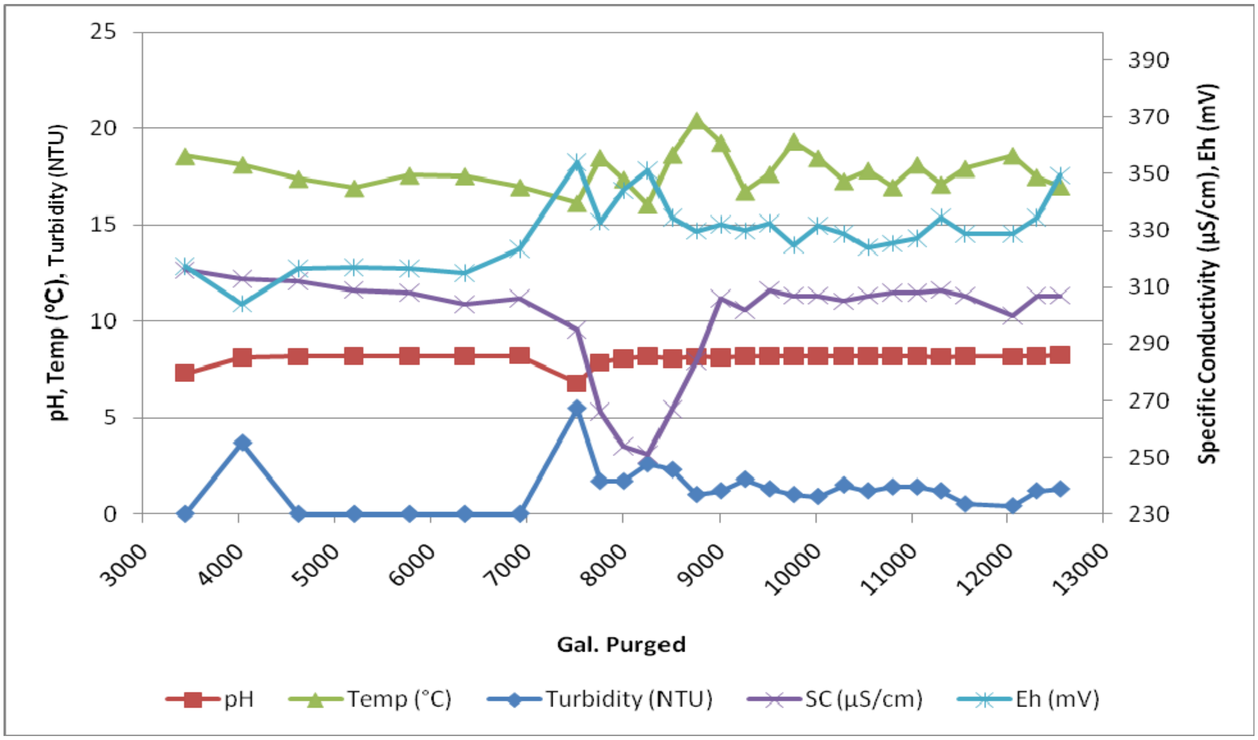
B-2.2 Field Parameters

Field parameters measured during well development and aquifer testing are summarized in Table B-2.2-1. During well development and aquifer testing, pH varied from 6.78 to 8.23, and temperatures ranged from 16.0°C to 20.4°C. DO concentrations varied from 4.0 to 77.2. Specific conductance ranged from 251 to 316 μS/cm, and turbidity values varied from 0 to 5.5 nephelometric turbidity units (NTU). Corrected oxidation-reduction potential (Eh) values, determined from field ORP measurements, varied from 304.1 to 354.1 mV. Two temperature-dependent correction factors were used to calculate Eh values from field ORP measurements: 208.9 and 203.9 mV, at 15°C and 20°C, respectively. Figure B-2.2-1 shows the field parameters measured over the course of well development and aquifer testing.

The final parameters measured at the end of the aquifer testing period were pH of 8.23, temperature of 17.0°C, DO of 6.58 mg/L, specific conductance of 307 μS/cm, and turbidity of 1.3 NTU.

B-3.0 SUMMARY OF SCREENING ANALYTICAL RESULTS

TOC concentrations were below the target level of 2.0 mgC/L at the end of aquifer testing, and turbidity was below 5 NTU at the end of development and aquifer testing. R-55i will be sampled quarterly for 1 yr, and then data will be assessed and incorporated into the Interim Facility-Wide Groundwater Monitoring Plan. Data from ongoing sampling at R-55i will be analyzed and presented in the appropriate periodic monitoring report.



Note: Well development ended when 6932 gal. of groundwater had been purged. An additional 560 gal. was removed during a brief aquifer test 5 d later (no parameters were measured). The 24-h aquifer test commenced at the 7492-gal. purge mark 8 d after development ended.

Figure B-2.2-1 Field parameters during R-55i well development and aquifer testing

Table B-1.0-1
Summary of Groundwater Screening Samples Collected during Aquifer Testing at Well R-55i

Location ID	Sample ID	Date and Time Collected	Collection Depth (ft bgs)	Sample Type	Analysis
R-55i	GW55(i)-11-4653	2/3/11; 1200 h	504.9	Groundwater, pumped	TOC
R-55i	GW55(i)-11-4654	2/3/11; 1600 h	504.9	Groundwater, pumped	TOC
R-55i	GW55(i)-11-4655	2/3/11; 2000 h	504.9	Groundwater, pumped	TOC
R-55i	GW55(i)-11-4656	2/4/11; 0000 h	504.9	Groundwater, pumped	TOC
R-55i	GW55(i)-11-4657	2/4/11; 0400 h	504.9	Groundwater, pumped	TOC
R-55i	GW55(i)-11-4658	2/4/11; 0800 h	504.9	Groundwater, pumped	TOC

Table B-2.1-1
TOC Results

Sample ID	EPA* Method	TOC Concentration (mgC/L)
GW55(i)-11-4653	415.1	0.84
GW55(i)-11-4654	415.1	0.31
GW55(i)-11-4655	415.1	0.22
GW55(i)-11-4656	415.1	0.29
GW55(i)-11-4657	415.1	0.34
GW55(i)-11-4658	415.1	0.35

*EPA = U.S. Environmental Protection Agency.

Table B-2.2-1
Purge Volumes and Field Parameters during Well Development and Aquifer Testing at R-55i

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge Volume (gal.)
Well Development									
1/24/11	n/r*; bailing							963	963
1/25/11	n/r, pumping while swabbing screen							1220	2183
1/26/11	n/r, pumping while swabbing screen							801	2984
1/26/11	7.31	18.58	77.2	113.4	317.3	316	0.0	456	3440
	8.11	18.13	7.49	100.2	304.1	313	3.7	600	4040
	8.16	17.39	11.41	107.7	316.6	312	0.0	582	4622
	8.20	16.91	11.44	108.0	316.9	309	0.0	582	5204
	8.18	17.57	9.52	112.8	316.7	308	0.0	576	5780
	8.20	17.54	9.54	111.0	314.9	304	0.0	576	6356
	8.21	16.96	11.14	114.5	323.4	306	0.0	576	6932

Table B-2.2-1 (continued)

Date	pH	Temp (°C)	DO (mg/L)	ORP (mV)	Eh (mV)	Specific Conductivity (µS/cm)	Turbidity (NTU)	Purge Volume between Samples (gal.)	Cumulative Purge volume (gal.)
Aquifer Pump Test									
1/31/11	n/r, pumping, mini-tests							560	560
2/3/11 to 2/4/11	6.78	16.12	4.00	145.2	354.1	295	5.5	33	593
	7.86	18.50	5.20	129.1	333.0	266	1.7	240	833
	8.08	17.37	5.23	135.2	344.1	254	1.7	248	1081
	8.19	16.03	6.01	142.2	351.1	251	2.6	248	1329
	8.05	18.65	6.34	130.6	334.5	267	2.3	248	1577
	8.16	20.44	5.89	125.9	329.8	284	1.0	252	1829
	8.14	19.26	6.34	128.2	332.1	306	1.2	252	2081
	8.19	16.73	6.92	121.0	329.9	302	1.8	252	2333
	8.17	17.64	6.39	128.6	332.5	309	1.3	256	2589
	8.17	19.34	6.25	121.0	324.9	307	1.0	252	2841
	8.19	18.47	6.22	127.8	331.7	307	0.9	252	3093
	8.19	17.27	6.36	119.9	328.8	305	1.5	270	3363
	8.20	17.84	6.34	120.2	324.1	307	1.2	252	3615
	8.20	16.96	6.26	116.5	325.4	308	1.4	256	3871
	8.18	18.12	6.41	123.3	327.2	308	1.4	252	4123
	8.15	17.09	6.34	125.8	334.7	309	1.2	248	4371
	8.18	17.93	6.58	125.0	328.9	307	0.5	252	4623
	8.16	18.61	6.38	124.9	328.8	300	0.4	496	5119
	8.17	17.49	6.57	125.5	334.4	307	1.2	248	5367
	8.23	17.00	6.58	140.5	349.4	307	1.3	248	5615

Note: Temperature-dependent correction factors of 203.9 mV at 20°C and 208.9 mV at 15°C were used to convert field ORP values to Eh values.

*n/r = Not recorded.

Appendix C

Aquifer Testing Report

C-1.0 INTRODUCTION

This appendix describes the hydraulic analysis of pumping tests conducted during January and February 2011 at R-55i, an intermediate perched zone well located in Cañada del Buey downgradient of Material Disposal Area G. The tests on R-55i were conducted to characterize the saturated materials and quantify the hydraulic properties of the screened interval. Testing consisted of brief trial pumping, background water level data collection, and a 20.5-h constant-rate pumping test. A 24-h test was planned originally for R-55i. However, extremely cold temperatures on the morning of the test (near –20°F) interfered with starting on-site equipment, including power generators, resulting in a delay of about 3.5 h.

As in most of the pumping tests conducted on the Pajarito Plateau, an inflatable packer system was used in R-55i to try to eliminate casing storage effects on the test data. This approach was successful in obtaining useful early data from the recovery portion of the tests. The early drawdown data, however, was affected by variable discharge rates caused by leaky joints in the contractor's drop pipe that allowed drainage of a portion of the drop pipe between tests. On startup, the discharge rate was momentarily elevated while the void in the drop pipe caused by antecedent drainage refilled. This limited the usefulness of the early portions of the drawdown data plots. This was not a significant limitation, however, because the subsequent recovery data provided the needed information.

Conceptual Hydrogeology

The R-55i screened interval is set within unconsolidated materials associated with basaltic lava flows of the Cerros del Rio volcanic series. The well screen extends from 510.0 to 531.1 ft below ground surface (bgs). The static water level measured on January 31, 2011, before testing was 498.0 ft bgs. The brass cap elevation at the well is 6534.9 ft above mean sea level (amsl), making the water level elevation 6036.9 ft amsl. Because of the proximity of the water table to the well screen (just 12 ft above it), unconfined conditions were assumed for the perched intermediate zone in R-55i.

Drill cuttings obtained from R-55i and nearby R-55 suggested angular, yet permeable, vesicular basalt fragments from approximately 495 to 540 ft bgs. From 540 to 550 ft bgs, the materials became rounded and also appeared to be permeable. Below 550 ft, the silt content increased steadily, likely limiting the permeability of the sediments. The permeable perched interval was assumed to extend from the water table at 498 ft to the bottom of the non-silt-bearing sediments at 550 ft for a total saturated thickness of 52 ft.

R-55i Testing

R-55i was tested briefly on January 31 and again on February 3 and 4, 2011. On January 31, the pump was landed above the top of the well screen and operated long enough to set the discharge rate to a level that would avoid dewatering the screen. Then, the pump was lowered an additional 10 ft to position the inflatable packer below the static water level. Testing began with brief trial pumping on January 31, followed by background data collection, and a 20.5-h constant-rate pumping test that was started on February 3. Following shutdown of the 20.5-h test on February 4, recovery data were recorded for 24 h until February 5.

Trial testing of R-55i began at 4:00 p.m. on January 31 at a discharge rate of 4.9 gallons per minute (gpm) and continued for 30 min. Following shut down, recovery data were recorded for 30 min until 5:00 p.m. when trial 2 pumping began at a discharge rate of 4.8 gpm. Following 60 min of pumping, the pump was shut down, and recovery/background data were collected for 3930 min until 11:30 a.m. on February 3.

At 11:30 a.m. on February 3, the 20.5-h pumping test was begun, with an average discharge rate during the test of 4.1 gpm. Pumping continued for 1230 min until 8:00 a.m. on February 4. Following shutdown, recovery data were recorded for 1440 min until 8:00 a.m. on February 5 when the pump was pulled from the well.

C-2.0 BACKGROUND DATA

The background water level data collected before the pumping tests help distinguish the naturally occurring water level fluctuations from those caused by the pumping test.

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 Pajarito 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 wells drilled on the plateau, 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, with this difference being the true height of water above the transducer.

Subsequent pumping tests, including at R-55i, 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. An example is 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 the Technical Area 54 (TA-54) tower site from the Waste and Environmental Services Division–Environmental Data and Analysis (WES-EDA) Group. The TA-54 measurement location is at an elevation of 6548 ft amsl, whereas the wellhead elevation is at 6534.9 ft amsl. The static water level in R-55i was 498.0 ft bgs, making the water-table elevation 6036.9 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-55i.

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

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

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

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)

$E_{R\text{-}55i}$ = land surface elevation at R-55i site, in feet (6534.9 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-55i, in feet (6036.9 ft)

T_{TA54} = air temperature near TA-54, in degrees kelvin (assigned a value of 10.8°F or 261.4 K)

T_{WELL} = air temperature inside R-55i, in degrees kelvin (assigned a value of 62.4°F or 290.0 K)

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

$$t_c = \frac{0.6\left[\left(D^2 - d^2\right) + S_y\left(D_B^2 - D_C^2\right)\right]}{\frac{Q}{s}}$$ **Equation 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, which is 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 largely successful in the testing performed on R-55i.

C-4.0 TIME-DRAWDOWN METHODS

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

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

where

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

and

$$u = \frac{1.87r^2 S}{Tt}$$ **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 matched 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 (dimensionless)

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

r = distance from center of pumpage, in feet

An alternate 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 the following:

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

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

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

In this equation all terms are expressed in consistent units.

The terms 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 Rothschild (1985, 098234).

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

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

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

$$K = \frac{264Q}{sb} \left(\log \frac{0.3Tt}{r_w^2 S} + \frac{2s_P}{\ln 10} \right)$$ **Equation C-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 R-55i, and a storage coefficient of 0.10 was arbitrarily assigned. 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 R-55i, an estimated thickness of 52 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.

C-7.0 BACKGROUND DATA ANALYSIS

Background aquifer pressure data collected during the R-55i 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-55i 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-55i 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-55i pumping tests are included in the figure for reference.

R-55i showed significant pressure change in response to barometric pressure fluctuations, suggesting a moderate barometric efficiency. There appeared to be a substantial lag in aquifer pressure response to changes in barometric pressure, resulting in a muted, delayed hydrograph response.

For example, following the trial tests on January 31, aquifer pressure increased for a time, then reversed and began to slightly decrease later that same day, even though the barometric pressure was rising at the time. The decrease in aquifer pressure appeared to be a delayed and muted response to an antecedent barometric pressure decline that occurred earlier on January 31. Likewise, the “saw-tooth” barometric pressure pattern observed on February 1, in which the rise in barometric pressure was reversed for several hours and then restored, did not cause a similar aquifer pressure response. Instead, the hydrograph showed only a subtle “ripple” effect some hours later. Finally, the dramatic rise in barometric pressure on February 1 and 2 was reversed on February 3, and yet the aquifer pressure continued to rise throughout the morning of February 3, albeit at a reduced rate, presumably a continuing delayed and muted response to the antecedent barometric pressure rise.

Over a period of many hours, the aquifer pressure appeared to exhibit a change of about 60% of the barometric pressure change, implying an approximate barometric efficiency of 40% (100% minus 60%). Because of the severe attenuation and delay of the aquifer pressure response to changes in atmospheric conditions, it is not possible to generate a simple algorithm for adjusting the water level data for changes in barometric pressure based on the limited background data set.

C-8.0 WELL R-55i DATA ANALYSIS

This section presents the data obtained from the R-55i pumping tests and the results of the analytical interpretations. Data are presented for drawdown and recovery from trial 1, trial 2, and the 20.5-h constant-rate test.

C-8.1 Well R-55i Trial 1 Test

Figure C-8.1-1 shows a semilog plot of the drawdown data collected from the trial 1 test on R-55i at a discharge rate of 4.9 gpm. As shown in the figure, there was exaggerated drawdown for the first several seconds of pumping, indicating a brief period during which the discharge rate was elevated. The pump had been lowered 10 ft just before testing, so the upper 10 ft of the drop pipe was empty on startup. It took several seconds for water to fill the added drop pipe and reach the discharge valve. Once water reached the valve, the backpressure increased, reducing the flow rate.

The later data were plotted for analysis on the expanded-scale graph shown in Figure C-8.1-2. The transmissivity obtained from the graph was 9820 gallons per day (gpd)/ft. It was assumed that this value reflects the full saturated thickness of permeable materials from 498 to 550 ft. This results in a computed average hydraulic conductivity 189 gpd/ft^2, or 25.2 ft/d.

Figure C-8.1-3 shows the recovery data collected following shutdown of the trial 1 pumping test. The very early data suggest a transmissivity of 1010 gpd/ft—presumably reflective of just the 21.1-ft screened interval. The corresponding computed hydraulic conductivity is 47.9 gpd/ft^2, or 6.4 ft/d. This value is substantially below the formation average of 25.2 ft/d cited above.

There are two possible explanations for this. First, it is possible that the rounded, transported sediments below about 540 ft are far more permeable than the angular, irregular breccia fragments in which the screen is installed and thus compose the bulk of the transmissivity of the perched zone. A second possibility is that the very early data reflect a slight storage effect associated with trapped air in the filter pack that may have been introduced there during well development. If any portion of the screen had been dewatered during pump development (such as during pump startup when the drop pipe was empty, and the discharge rate of the pump was at a maximum), air could have entered the filter pack and remained trapped above the screened zone behind the blank casing. Trapped air would expand and contract during pumping and recovery, causing a transient storage-like effect. These two explanations are equally valid and indistinguishable based on the observed data, and either one explains the observed water level response.

Figure C-8.1-4 shows an expanded-scale plot of the trial 1 recovery data, yielding an overall perched zone transmissivity of 8300 gpd/ft and a hydraulic conductivity value of 160 gpd/ft^2, or 21.3 ft/d. These values are similar to those obtained from the drawdown analysis.

C-8.2 Well R-55i Trial 2 Test

Figure C-8.2-1 shows a semilog plot of the drawdown data collected from the trial 2 test on R-55i at a discharge rate of 4.8 gpm. The first few seconds of data showed temporarily exaggerated drawdown because of minor drainage of water from the drop pipe that occurred during the 30-min shutdown between trials 1 and 2. The drainage was attributable to a worn thread in the drop pipe string. Because of a small void in the drop pipe, the pump started against reduced head (just the height of water between the static water level and the void in the drop pipe), resulting in an elevated discharge rate. Once the void refilled, the effective head on the pump increased to the sum of the full height of filled drop pipe and the effect of the constriction imposed by the backpressure valve, reducing the flow rate.

Figure C-8.2-2 shows an expanded-scale plot of the trial 2 drawdown data. The transmissivity estimated from the data plot is 8810 gpd/ft, making the average hydraulic conductivity 169 gpd/ft^2, or 22.7 ft/day.

Figure C-8.2-3 shows the recovery data collected following shutdown of the trial 2 pumping test. The early data yield a calculated transmissivity of 840 gpd/ft, corresponding to a screened interval hydraulic conductivity value of 39.8 gpd/ft^2, or 5.3 ft/d. This result is similar to that obtained from the trial 1 recovery data. As before, it could reflect the true characteristics of the screened interval or simply be a manifestation of a minor storage effect.

Figure C-8.2-4 shows an expanded-scale graph of the recovery data, suggesting an overall perched zone transmissivity of 7840 gpd/ft and average hydraulic conductivity of 151 gpd/ft^2, or 20.2 ft/d, in good agreement with previous results.

The late data show a brief reversal of water levels followed by an abrupt rise above the original static level. Both of these effects were induced by barometric pressure changes as discussed earlier.

C-8.3 Well R-55i 20.5-h 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 an average discharge rate of 4.1 gpm. The early data on the graph showed exaggerated drawdown for more than a minute of pumping attributable to an elevated discharge rate associated with antecedent drainage of a portion of the drop pipe.

In fact, pumping proceeded for approximately 1.25 min before water was produced at the surface. During this period, the pumping rate was likely on the order of 15 gpm because of the reduced backpressure on the pump. This corresponds to a drained volume of nearly 19 gal., implying that about 110 ft of drop pipe had drained during the 65.5-h background monitoring period. This was consistent with observations made when the pump was pulled from the well after 24 h of recovery. At that time, nearly 40 ft of drop pipe was empty. Thus, the leakage rates (110 ft in 65.5 h and 40 ft in 24 h) were similar.

Figure C-8.3-2 shows an expanded-scale plot of the drawdown data. The transmissivity computed from this graph was 5340 gpd/ft—noticeably lower than previous values. It is likely that the steady decline in barometric pressure during this period (Figure C-7.0-1) results in an exaggerated slope on the drawdown graph, reducing the computed transmissivity value. Thus, the transmissivity computed from the extended pumping test is not considered representative of actual formation characteristics.

Figure C-8.3-3 shows the recovery data collected following shutdown of the 20.5-h constant-rate pumping test. As with previous recovery graphs, the early steep slope shown in Figure C-8.3-3 could reflect actual screened interval characteristics or could be an artifact of a minor storage effect associated with trapped air in the filter pack above the screen. The slope of the line of fit through the early data suggests a transmissivity of 960 gpd/ft and an average hydraulic conductivity for the screened interval of 45.5 gpd/ft^2, or 6.1 ft/d.

Figure C-8.3-4 shows an expanded-scale plot of the recovery data following the 20.5-h pumping test. The transmissivity computed from the line of fit shown on the graph is 7460 gpd/ft, making the overall perched zone hydraulic conductivity 143 gpd/ft^2, or 19.2 ft/d, consistent with previous results.

The late recovery data show continuous flattening over time and eventual water level reversal, consistent with aquifer response to the ongoing decline in barometric pressure (Figure C-7.0-1).

Following 24 h of recovery, the packer was deflated to prepare for pulling the pump. Figure C-8.3-5 shows water level changes observed when the packer was deflated. The enormous spike in water level was caused by trapped water above the packer that had leaked into the annulus above the packer through the leaky drop pipe joint(s) during the test period. Once the packer deflated, this trapped water flowed downward into the well screen causing the observed head buildup seen on the graph.

C-8.4 Well R-55i 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-55i. This was done to provide a frame of reference for evaluating the foregoing analyses.

At the end of the 20.5-h pumping test, the discharge rate was 4.1 gpm, with a resulting drawdown of 3.82 ft, for a specific capacity of 1.07 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 0.50 ft (inferred from the volume of filter pack required to backfill the screened zone), a screen length of 21.1 ft, and an estimated saturated thickness of 52 ft.

Applying the Brons and Marting method to these inputs yields a lower-bound hydraulic conductivity value of 47.3 gpd/ft^2, or 6.3 ft/d. The average hydraulic conductivity value from the foregoing pumping test analyses is 44.4 gpd/ft^2 for the early data (screened interval) and 162 gpd/ft^2 for the late data (entire saturated zone). As described earlier, there are two alternate and plausible interpretations of the data. First, it is possible that the screened zone has a lower conductivity (44.4 gpd/ft^2) than the formation average (163 gpd/ft^2) and that the computed lower-bound estimate implies a highly efficient well. Alternatively, it is possible that the early test data were storage-affected, making the calculated average hydraulic conductivity of the screened interval of 44.4 gpd/ft^2 erroneous. In that case, the expected average hydraulic conductivity would be 162 gpd/ft^2, and the lower bound estimate of 47.3 gpd/ft^2 would suggest a modest well efficiency of about 30%.

C-9.0 SUMMARY

Constant-rate pumping tests were conducted on R-55i. The tests were performed to gain an understanding of the hydraulic characteristics of the screened interval and perched zone.

A comparison of barometric pressure and R-55i water level data shows the water level response was delayed and highly muted with a barometric efficiency of approximately 40%.

Incorporating an inflatable packer into the pumping string was largely effective in eliminating casing storage effects. However, it is unclear whether or not trapped air in the filter pack above the screen may have contributed a minor storage-like effect.

Worn drop pipe threads contributed to leakage of water from the pipe during testing and background monitoring, altering the discharge rate and drawdown during startup of each of the pumping tests. This was not a serious limitation, as good early data were obtained from the recovery data sets.

The saturated perched zone was estimated to include 52 ft of permeable sediments from the water table at 498 ft to the base of the clean, silt-free zone at about 550 ft. Analysis of the R-55i pumping tests shows an average transmissivity of 8440 gpd/ft, making the average hydraulic conductivity of this interval 162 gpd/ft^2, or 21.7 ft/d.

Early data from the tests suggested a possible average hydraulic conductivity of the screened interval of 44.4 gpd/ft^2, or 5.9 ft/d. It cannot be determined whether this value is valid or an artifact of trapped air in the filter pack causing a storage-like effect.

R-55i produced 4.1 gpm for 1230 min with 3.82 ft of drawdown for a specific capacity of 1.07 gpm/ft. The lower-bound hydraulic conductivity computed from this information is 47.3 gpd/ft^2, or 6.3 ft/d, fairly consistent with the pumping test values. The interpretation of a screened interval conductivity of 44.4 gpd/ft^2 would imply a well efficiency near 100% and also that most of the formation transmissivity is concentrated in the unscreened sediments, likely the rounded deposits below 540 ft. On the other hand, if the early data were storage affected, the lower-bound hydraulic conductivity value would imply a lower well efficiency of around 30%. These two interpretations are equally valid based on the available response data.

The data do not show the presence of aquifer boundaries, implying that the highly transmissive perched zone is also laterally extensive.

C-10.0 REFERENCES

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

Bradbury, K.R., and E.R. Rothschild, March-April 1985. "A Computerized Technique for Estimating the Hydraulic Conductivity of Aquifers from Specific Capacity Data," *Ground Water,* Vol. 23, No. 2, pp. 240-246. (Bradbury and Rothschild 1985, 098234)

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Theis, C.V., 1934-1935. "The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage," *American Geophysical Union Transactions,* Vol. 15-16, pp. 519-524. (Theis 1934-1935, 098241)

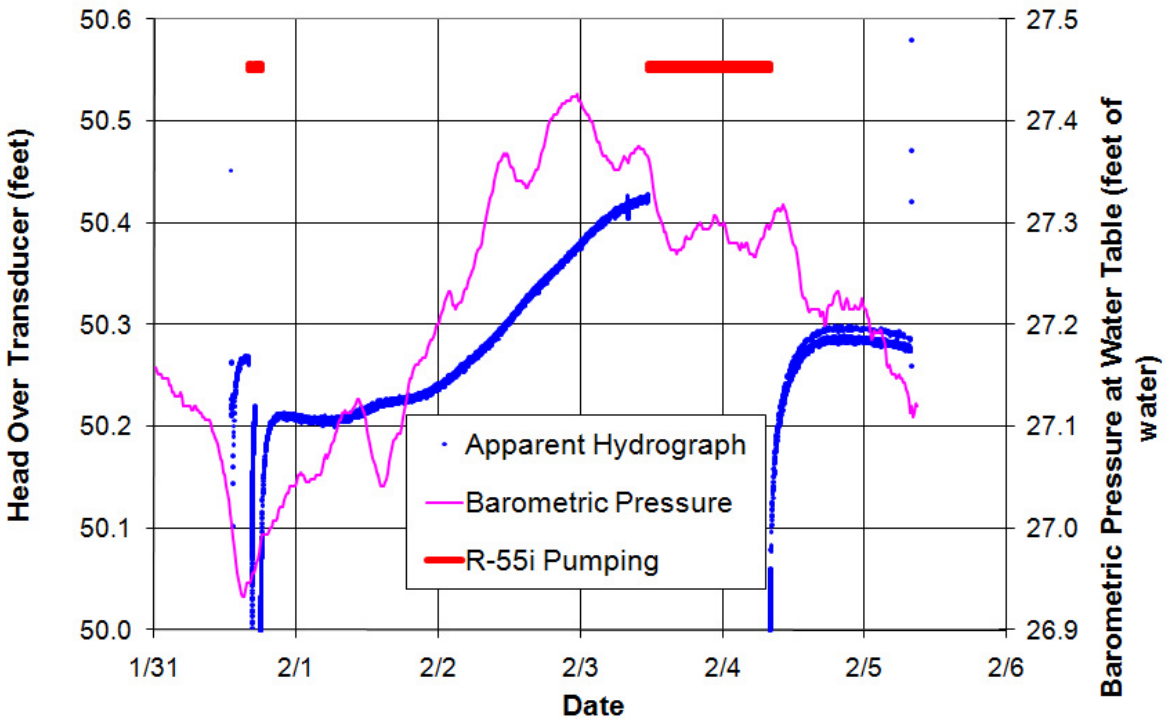


Figure C-7.0-1 Well R-55i apparent hydrograph

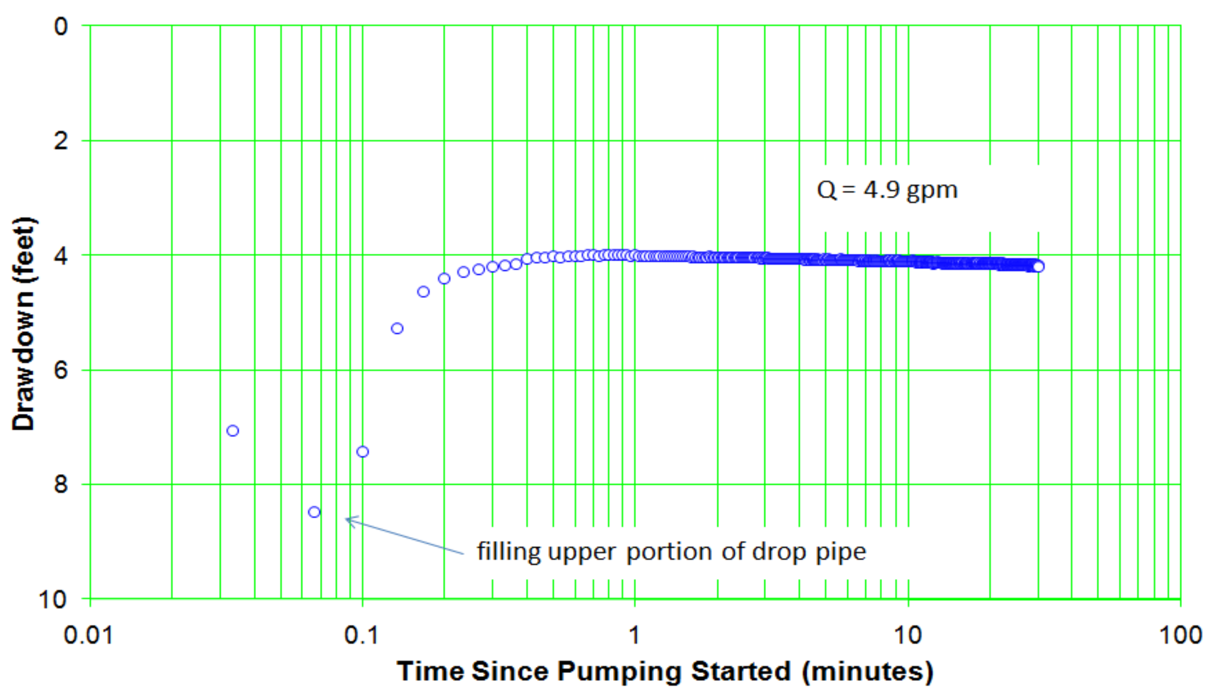


Figure C-8.1-1 Well R-55i trial 1 drawdown

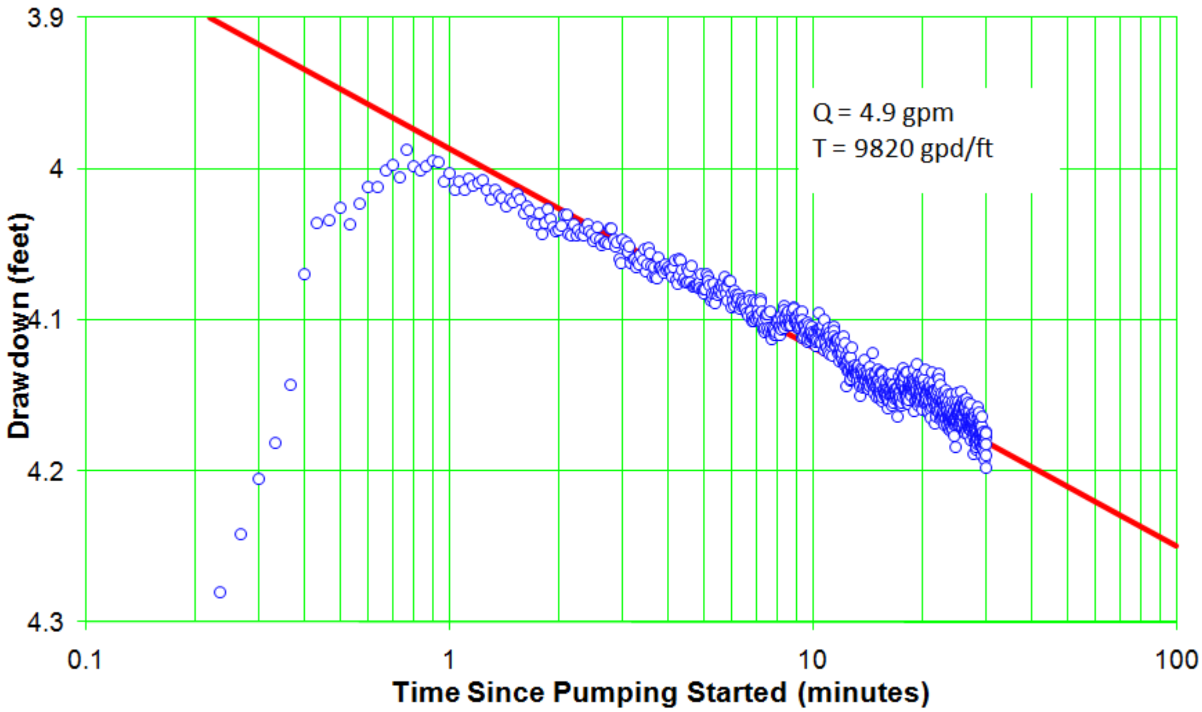


Figure C-8.1-2 Well R-55i trial 1 drawdown—expanded scale

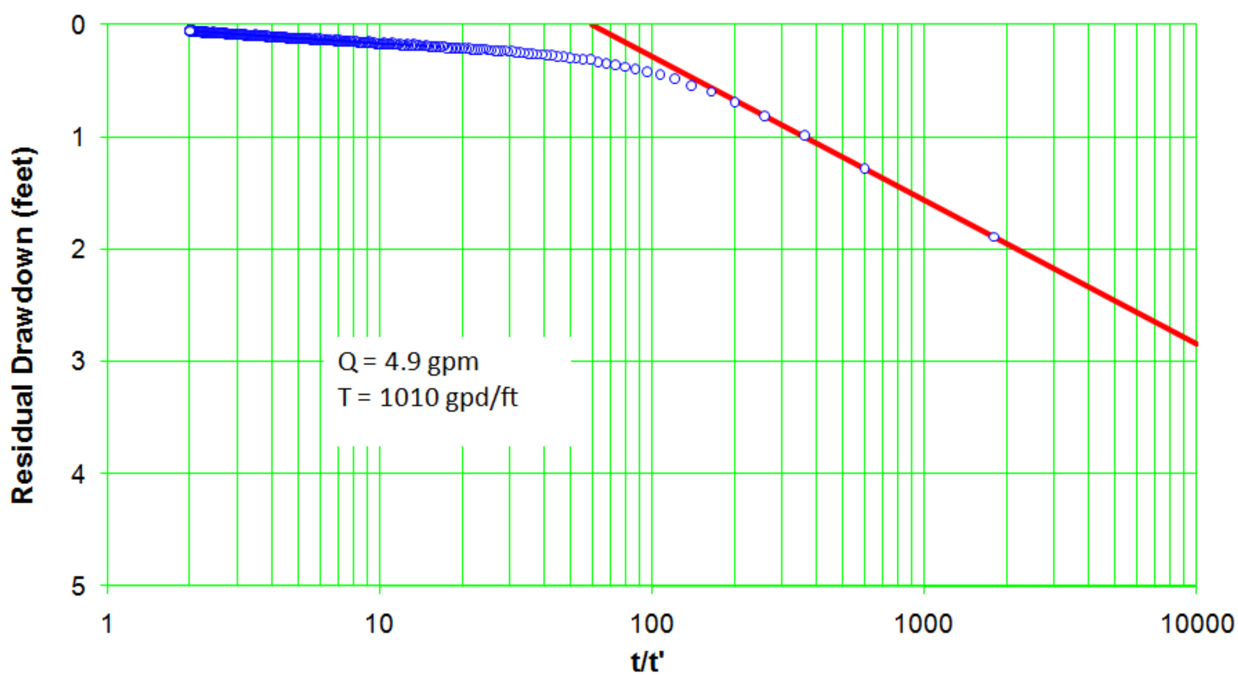


Figure C-8.1-3 Well R-55i trial 1 recovery

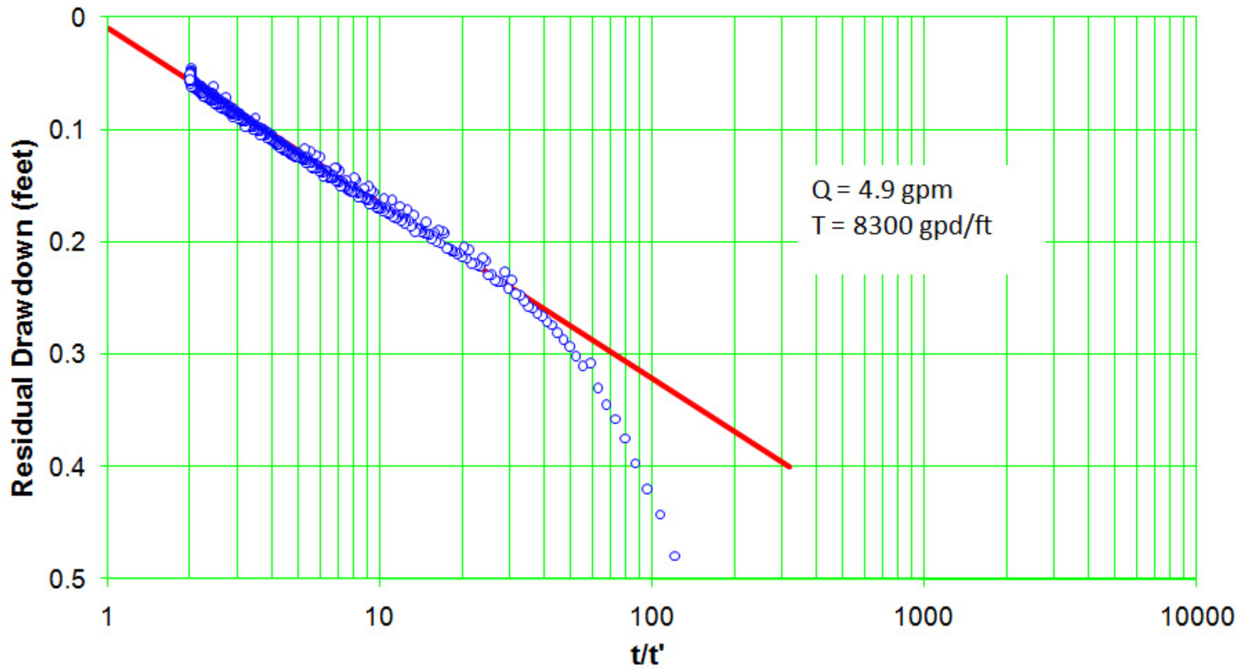


Figure C-8.1-4 Well R-55i trial 1 recovery—expanded scale

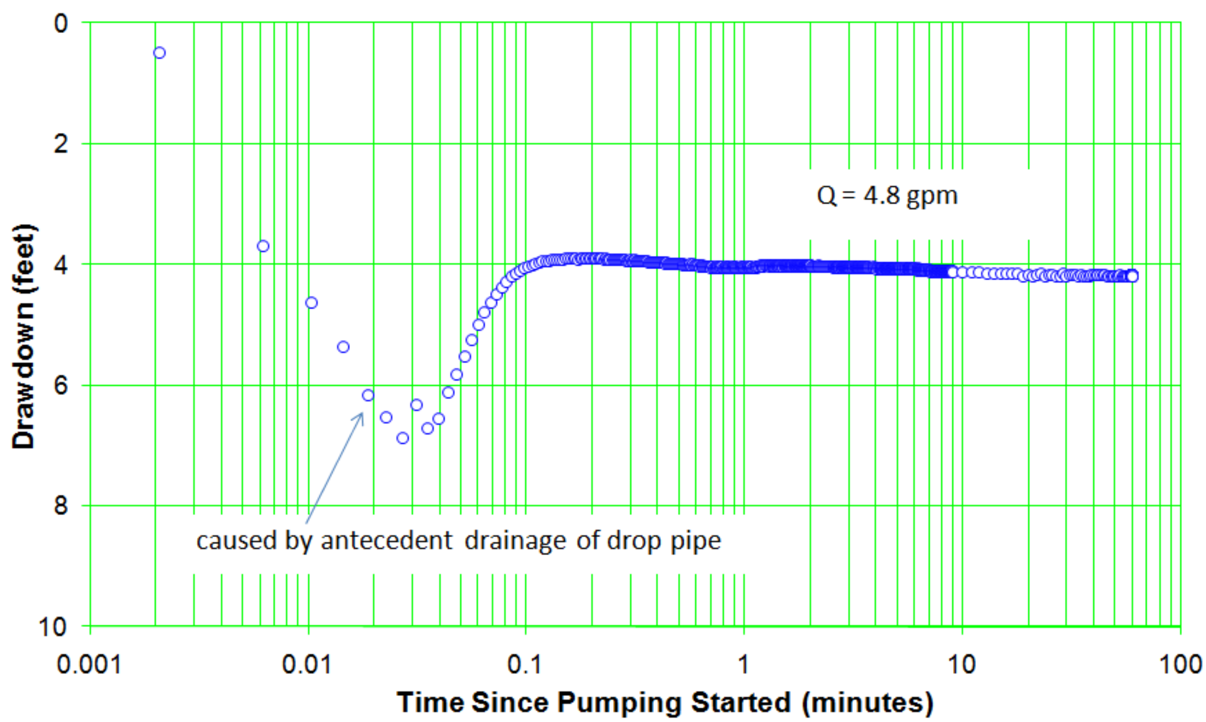


Figure C-8.2-1 Well R-55i trial 2 drawdown

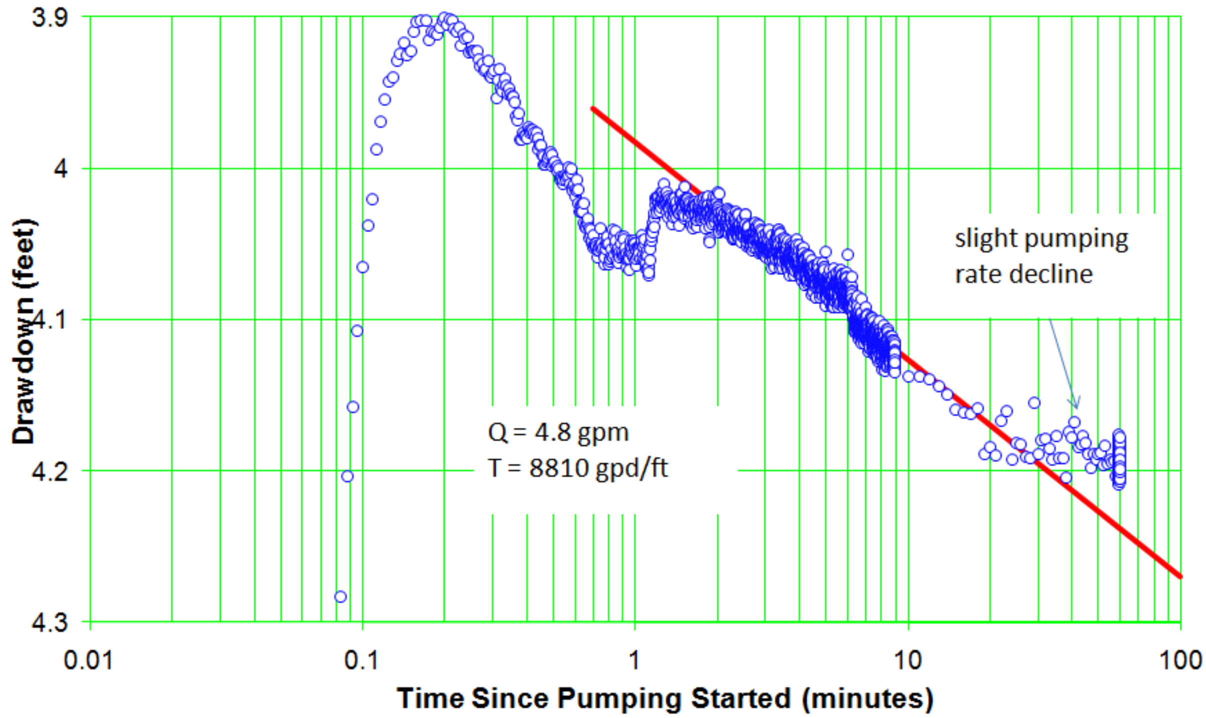


Figure C-8.2-2 Well R-55i trial 2 drawdown—expanded scale

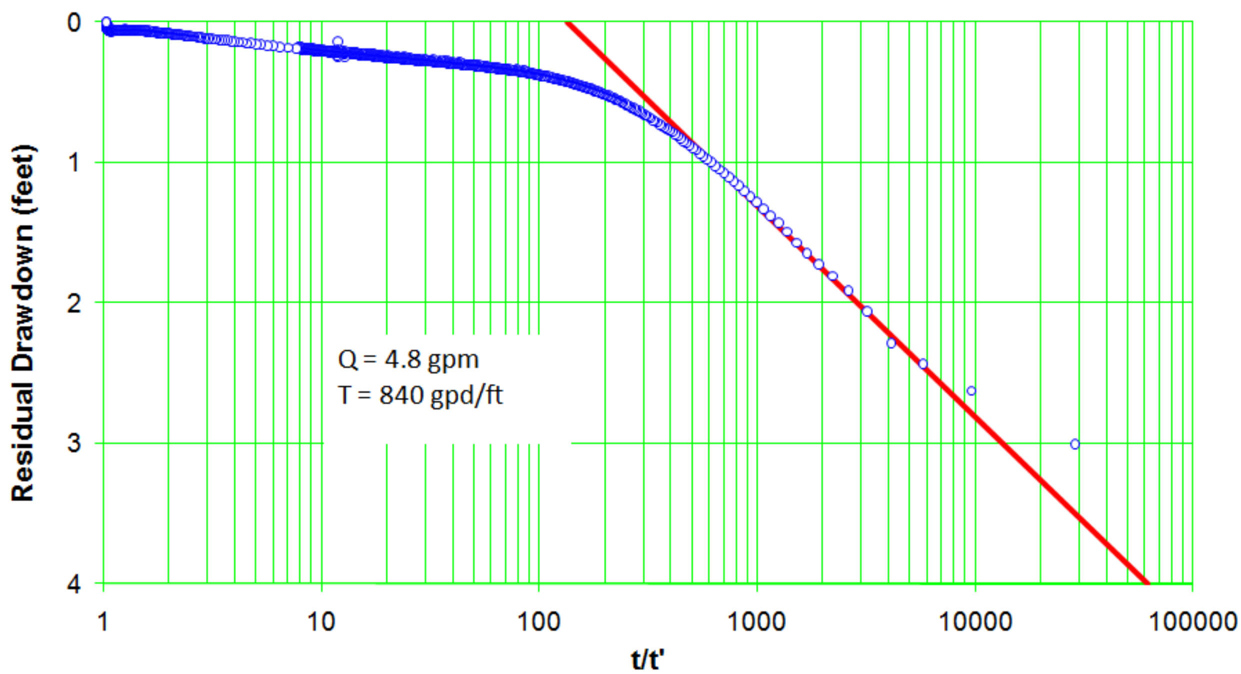


Figure C-8.2-3 Well R-55i trial 2 recovery

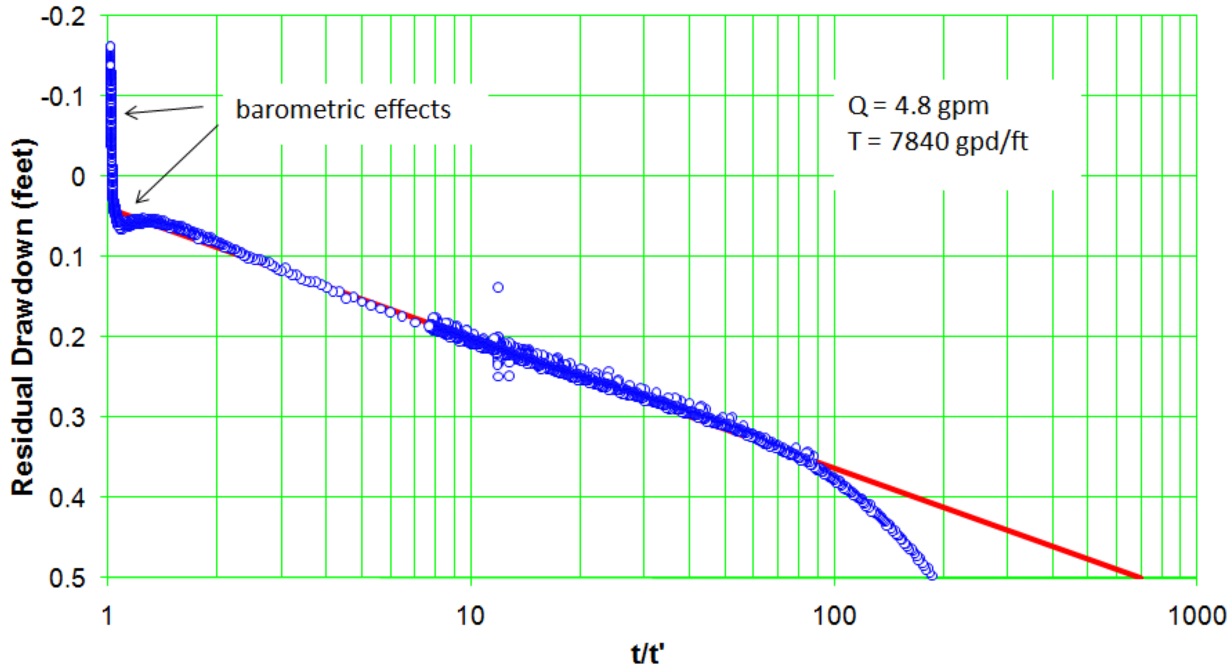


Figure C-8.2-4 Well R-55i trial 2 recovery – expanded scale

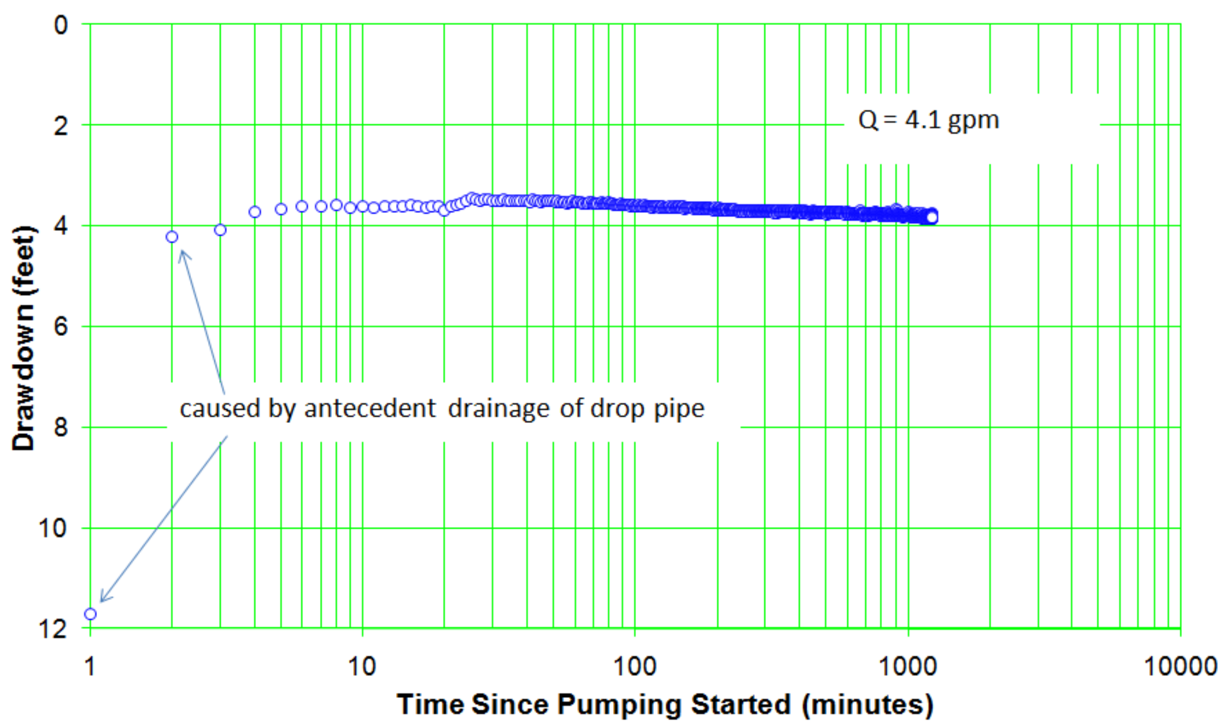


Figure C-8.3-1 Well R-55i drawdown

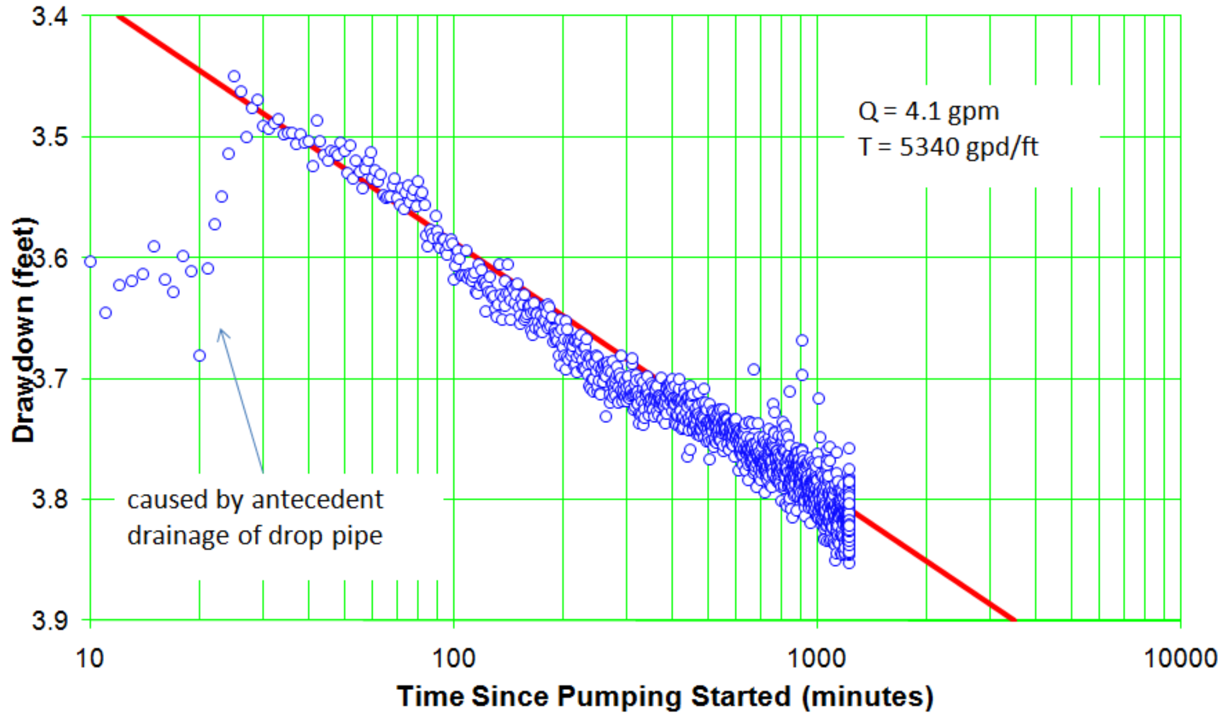


Figure C-8.3-2 Well R-55i drawdown—expanded scale

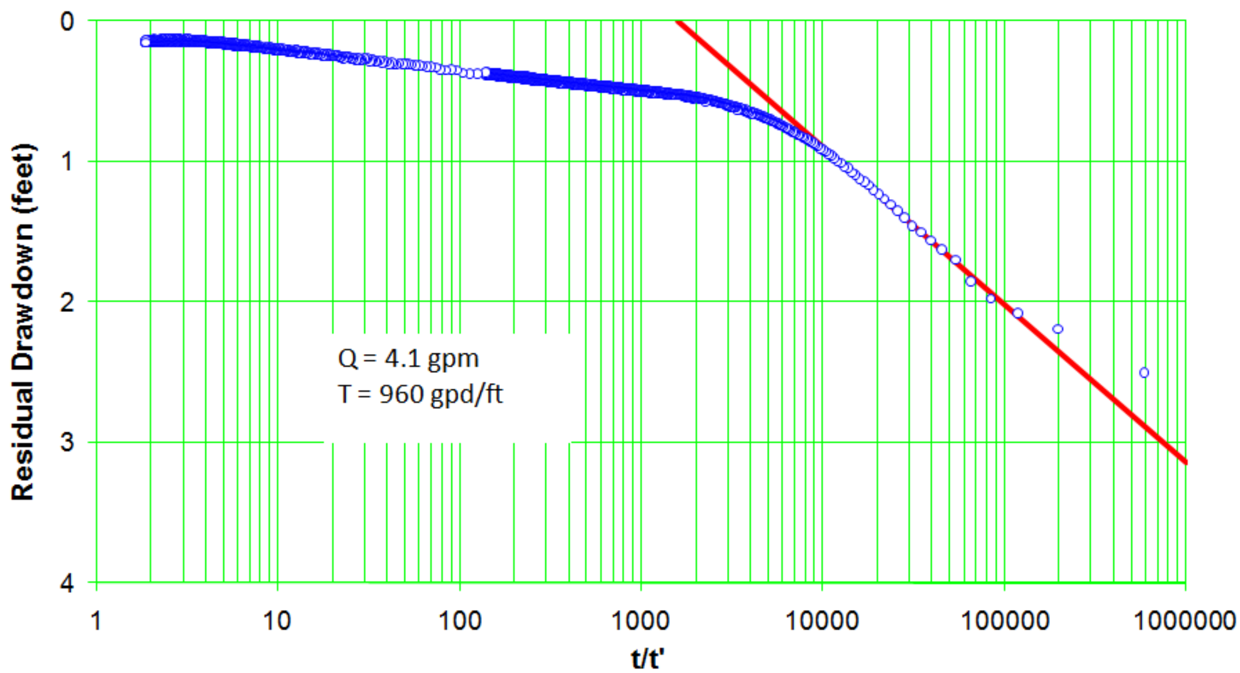


Figure C-8.3-3 Well R-55i recovery

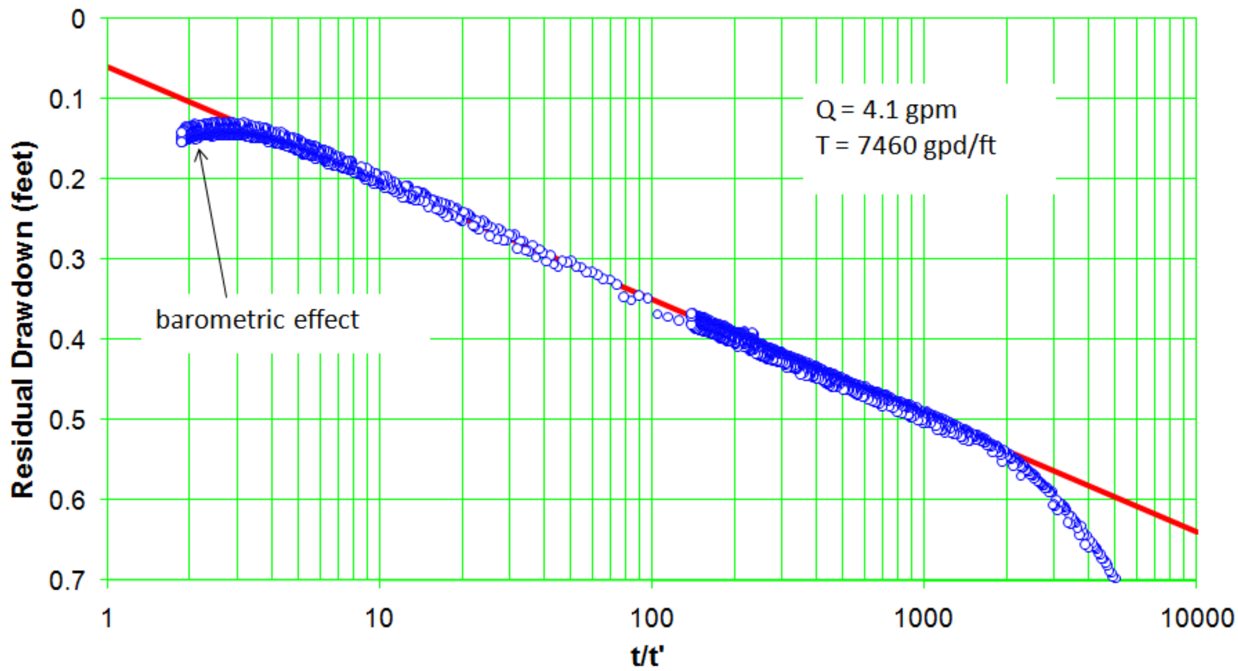


Figure C-8.3-4 Well R-55i recovery—expanded scale

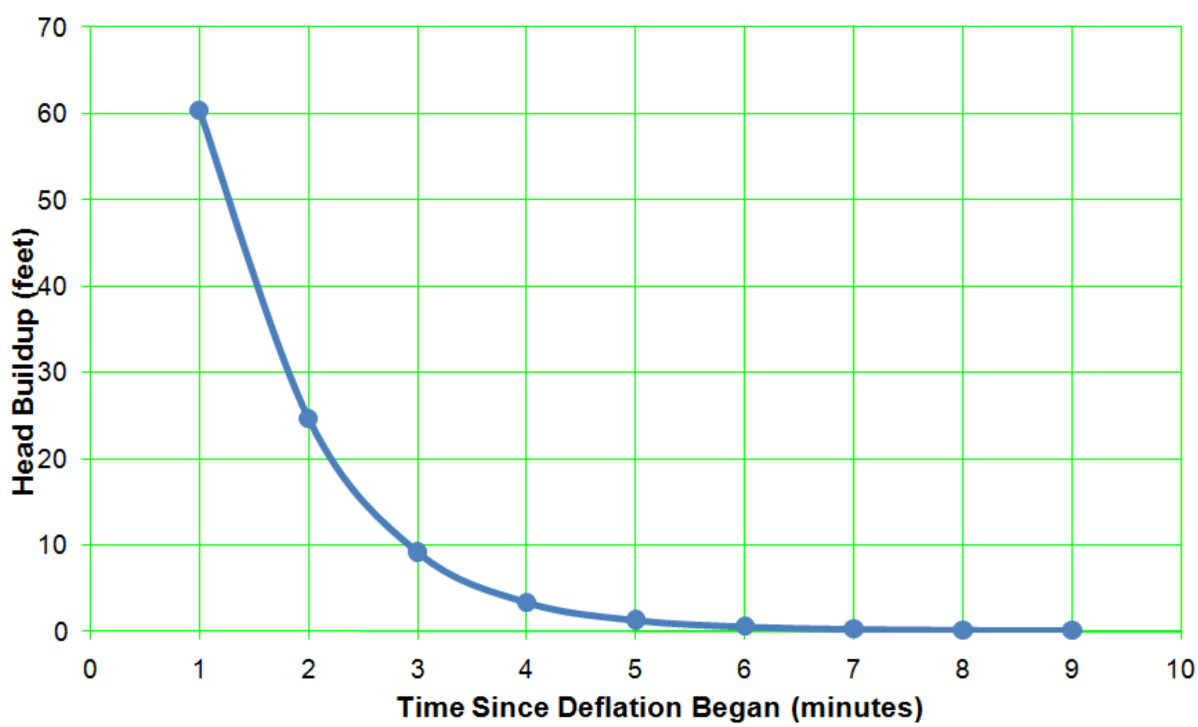


Figure C-8.3-5 Well R-55i packer deflation response

Appendix D

R-55i Final Well Design and
New Mexico Environment Department Approval

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

R-55i WELL PROPOSED WELL DESIGN

Well Objectives

Well R-55i is located east of MDA G in Cañada del Buey (Figure 1). Perched intermediate groundwater was first identified at this location when the R-55 regional well was drilled on the same drill pad. The principal objective of R-55i is to monitor water quality of perched intermediate groundwater east of potential contaminant release sites at TA-54. Data from R-55i will be compared to water-quality data from other perched-groundwater wells such as R-23i and R-10i (planned) to determine the nature and extent of perched groundwater in the area. The R-55i well objectives are best met by installing a well with a single screen placed near the top of the perched intermediate groundwater zone.

Recommended Well Design

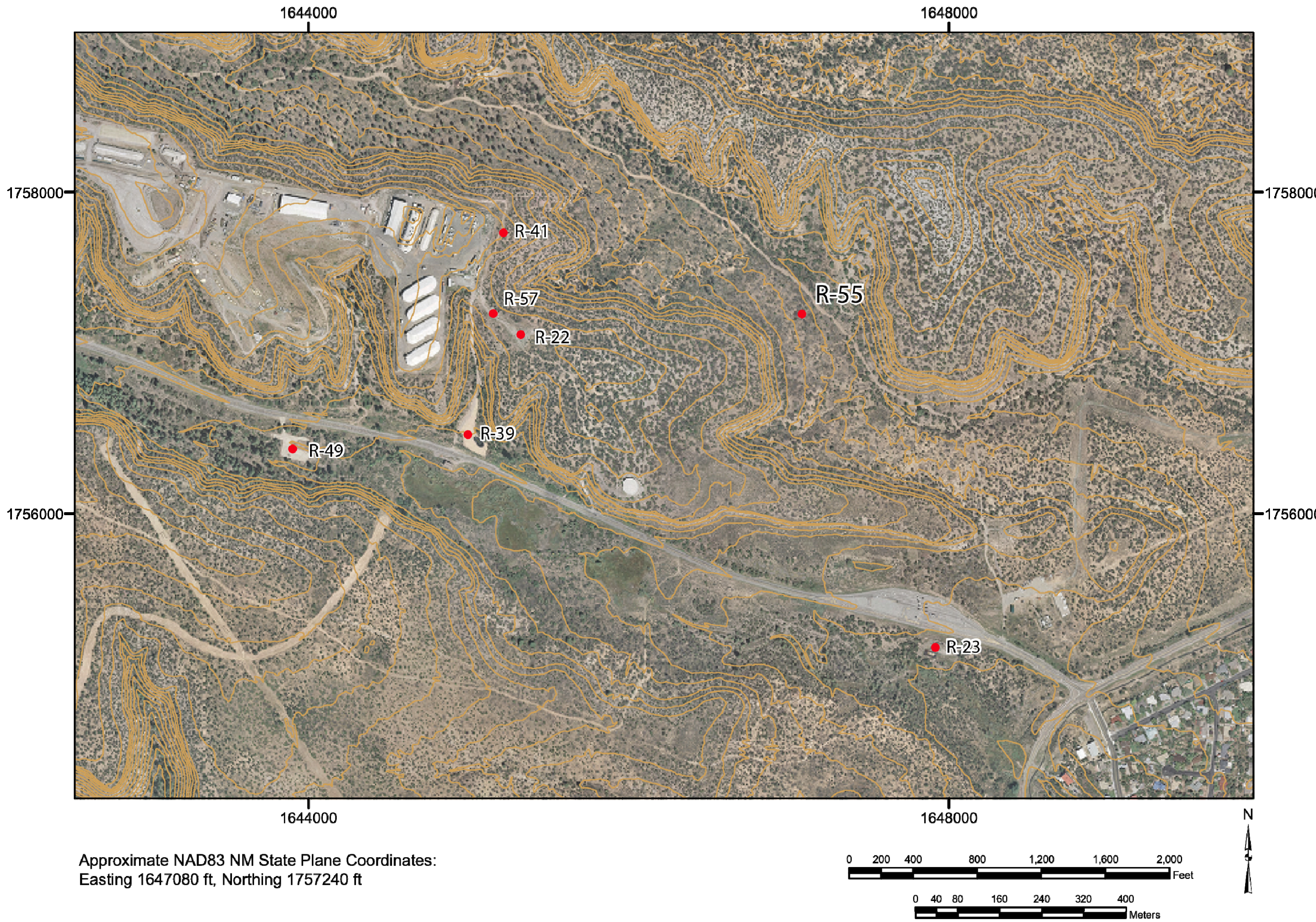
It is recommended that R-55i be installed with a single 20-ft stainless-steel, 20 slot, wire-wrapped well screen extending from 510 to 530 ft bgs. The depth to top of perched saturation is about 498 feet (see discussion below). The primary filter pack for the screen will consist of 10/20 sand extending 5 ft above and 5 ft below the screen openings. A 2-ft secondary filter pack will be placed above the primary filter pack. 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.

Well Design Considerations

Preliminary lithological logs indicate that the geologic contacts are, in descending stratigraphic order: Bandelier Tuff (0–55 ft), Puye Formation (55–80 ft), and basaltic lavas of the Cerros del Rio field with associated scoria, cinder, phreatomagmatic, and sedimentary deposits (80–565 ft TD).

At R-55, perched intermediate groundwater was encountered within phreatomagmatic and riverine deposits located between two Cerros del Rio basalt lava sequences; the units encountered at R-55 indicated that this perched interval occurs above clay-rich sediment that extended 565 to 605 ft bgs. At R-55i a reliable water level for this zone was determined to be 498 ft bgs in repeated water-level soundings. The phreatomagmatic deposits at R-55i extend from about 500 to 535 ft bgs and fine-grained quartzo-feldspathic riverine deposits occur from about 535 to 560 ft bgs. Clay-rich lacustrine beds occur below 560 ft bgs, forming a perching horizon for the groundwater. Although the clay aquitard is fully developed below 560 ft, some clay zones could extend higher, possibly to 545 ft bgs. The borehole video log from adjacent well R-55 indicates that the phreatomagmatic deposits are made up of relatively porous beds of highly stratified coarse- to fine-grained basaltic clasts. The R-55 video shows that the underlying riverine deposits are made up of massive beds of silt and fine sand that may represent overbank or floodplain deposits. The R-55i well screen targets the phreatomagmatic deposits because they appear to have better permeability characteristics than the fine-grained riverine deposits.



Approximate NAD83 NM State Plane Coordinates:
Easting 1647080 ft, Northing 1757240 ft

Figure 1 **Location map for R-55 showing locations of nearby monitoring wells. Proposed well R-55i is on the same drill pad as well R-55.**

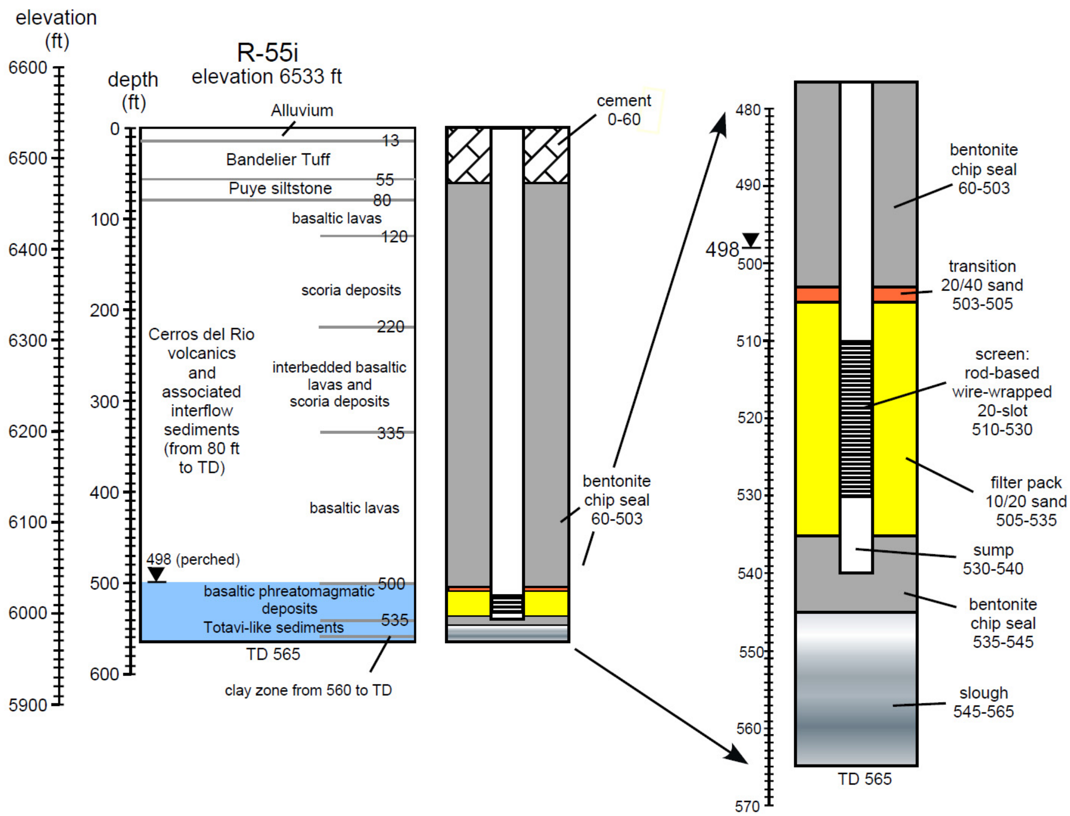


Figure 2 Proposed well design for R-55i

LANL REQUEST FOR FINAL WELL DESIGN APPROVAL AND NMED'S APPROVAL

---------- Forwarded message ----------
From: "Dale, Michael, NMENV" <Michael.Dale@state.nm.us>
To: "Everett, Mark C" <meverett@lanl.gov>
Date: Mon, 10 Jan 2011 06:58:54 -0700
Subject: RE: R-55i proposed well design
Mark,

This e-mail serves as NMED approval for installation of intermediate aquifer well R-55i as proposed in the document attached to the original e-mail received by NMED yesterday, January 09, 2011, at 5:08 PM. 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 sampling, any modifications to the well design proposed in the above-mentioned e-mail, and any additional information related to the installation of well R-55i 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. Thank you.

Michael Dale, NMED HWB

Hazardous Waste Bureau
New Mexico Environment Department
2905, Rodeo Park Drive East, Building 1
Santa Fe, NM 87505
Phone (505) 476-6052 / Fax (505) 476-6030
Main HWB Phone (505) 476-6000
Los Alamos Phone (505) 661-2673 / Cell 660-1679

From: Everett, Mark C [meverett@lanl.gov]
Sent: Sunday, January 09, 2011 5:08 PM
To: Dale, Michael, NMENV; Kulis, Jerzy, NMENV; Cobrain, Dave, NMENV
Cc: Drilling Team (drilling@lanl.gov); Shen, Hai; Broxton, David E; Vaniman, David T; Katzman, Danny
Subject: R-55i proposed well design

Michael,

Here is our proposed well design for intermediate well R-55i. Please take a look and if it is acceptable, respond with your concurrence. Please call me on my cell phone if you would like to discuss further.

Thanks,

Mark Everett
ADEP ET-EI
(505) 667-5931