LANL

DEPARTMENT OF ENERGY
National Nuclear Security Administration
Los Alamos Site Office
Los Alamos, New Mexico 87544

TA/S

MAR 23 2006

CERTIFIED MAIL/RETURN RECEIPT

Mr. James P. Bearzi, Chief
NMED-Hazardous Waste Bureau
2905 Rodeo Park Drive East,
Building 1
Santa Fe, NM 87505-6303

RECEIVED
MAR 2006
NMED Hazardous Waste Bureau

Dear Mr. Bearzi:

Subject: Completion Report for Characterization Well R-27

Enclosed are two copies of the Final Completion Report for Characterization Well R-27. If you have any questions regarding this report, please contact me at (505)667-1968, or Tom Whitacre at (505)665-5042.

Sincerely,

Eugene T. Rodriquez
Acting Assistant Manager
Office of Environmental Stewardship

ES: 2TW-027

Enclosures

cc w/o enclosures:
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Los Alamos Site Office
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Los Alamos, NM 87544-2201

4264

FINAL
COMPLETION REPORT
CHARACTERIZATION WELL R-27
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO
PROJECT NO. 49436

Prepared for:

The US Department of Energy and the
National Nuclear Security Administration through the
US Army Corps of Engineers
Sacramento District

Prepared by:

KLEINFELDER

8300 Jefferson NE, Suite B
Albuquerque, New Mexico 87113

March 2006

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LIST OF ACRONYMS AND ABBREVIATIONS

amsl	above mean sea level
bgs	below ground surface
BMPs	best management practices
DOE	US Department of Energy
DTW	depth to water
EES-6	Earth and Environmental Sciences Division, Group 6
ft	foot/feet
ft^3	cubic feet
gal.	gallon/gallons
HE	high explosives
ID	inner diameter
in.	inch/inches
Kleinfelder	Kleinfelder, Inc.
LANL	Los Alamos National Laboratory
µS/cm	microSiemens per centimeter
NA	not applicable
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
OD	outer diameter
pH	percentage of hydrogen ions
ppm	parts per million
Qal	Quaternary Alluvium
Qbo	Otowi Member of the Bandelier Tuff
Qbt	Tshirege Member of the Bandelier Tuff
Qct	Cerro Toledo interval
Qbog	Guaje Pumice Bed
RCT	radiation control technician
Spectrum	Spectrum Exploration, Inc.
TA	Technical Area
TD	total depth
TOC	total organic carbon
Tb4	Cerros del Rio basalt
Tpf	Puye Formation
WDC	WDC Exploration & Wells, Inc.

ABSTRACT

Characterization Well R-27 was installed in accordance with the "Drilling Work Plan for Characterization Well R-27, Final" (Kleinfelder 2005a). Drilling activities were funded and directed by the US Department of Energy. Kleinfelder, Inc, under contract to the US Army Corps of Engineers, conducted the drilling, installation and sampling at R-27. Los Alamos National Laboratory personnel provided technical assistance.

R-27 is located in Water Canyon within Technical Area (TA) 36 in the south-central portion of Los Alamos National Laboratory. The well was installed to monitor regional groundwater for potential contamination from TA-16 and other nearby sites.

R-27 was drilled to 987 feet (ft) below ground surface (bgs) using air rotary and foam-assist air rotary drilling methods. The stratigraphy encountered during borehole drilling included, in descending order, Quaternary Alluvium, Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, Otowi Member of the Bandelier Tuff, Guaje Pumice Bed of the Otowi Member, upper Puye Formation, Cerros del Rio basalt and lower Puye Formation. The well was installed with a screened interval from 852 to 875 ft bgs within the regional aquifer in the lower Puye Formation. The depth to water after well installation was 810.83 ft bgs.

A separate corehole was cored at the R-27 site to a depth of 272.8 ft bgs. Core samples were collected at 10-ft intervals to 100 ft and at 50-ft intervals thereafter and submitted for laboratory analysis of anions, moisture content, stable isotopes, radionuclides and tritium.

Three screening groundwater samples were collected during drilling, one from perched intermediate zone groundwater at approximately 630 ft bgs (from the upper Puye Formation above the Cerros del Rio basalt), one from perched intermediate zone groundwater at approximately 790 ft bgs (possibly from the lower Puye Formation), and one from the regional aquifer at approximately 820 ft bgs; these samples were submitted for analysis of anions, cations, perchlorate and metals. Three additional screening samples from the same zones were submitted for high explosives analyses. A final groundwater sample was collected from the regional aquifer at 862.5 ft bgs after the well was installed and developed.

Perchlorate was tentatively detected in the 790 ft bgs sample at a concentration of 0.0076 parts per million; it was not detected in the 630 ft bgs sample or the two samples from the regional aquifer. Nitrate (as N) was detected in the 630 ft bgs sample and in both of the regional aquifer samples at concentrations ranging between 0.10 and 0.29 parts per million. High explosive compounds were not detected in the three screening samples.

Aquifer testing has not been conducted at R-27 because both cuttings pits are near their fluid volume capacities. When waste characterization analytical data have been received and the New Mexico Environment Department has granted permission to discharge drilling fluids, the pits can be drained and the aquifer test will be conducted. An addendum to this report will be issued to summarize the aquifer test results, pump installation information, discharge approval and site restoration activities.

1.0 INTRODUCTION

This completion report summarizes the site preparation, drilling, well construction, well development and related activities for Characterization Well R-27 drilled in October 2005 at Los Alamos National Laboratory (LANL). The well was specified in the Compliance Order on Consent (New Mexico Environment Department [NMED] 2005). Drilling activities were funded and directed by the US Department of Energy (DOE) and contracted by the US Army Corps of Engineers. Kleinfelder, Inc. (Kleinfelder) was responsible for the drilling, installation and sampling activities with technical assistance from LANL. Activities were conducted according to the "Drilling Work Plan for Characterization Well R-27, Final" (Kleinfelder 2005a).

R-27 is located in Water Canyon within Technical Area 36 (TA-36), as shown in Figure 1.0-1. The well was installed to monitor regional groundwater for potential high explosives (HE) contamination from TA-16 or other nearby sites (Kleinfelder 2005a).

The R-27 Drilling Work Plan specified that a corehole would be drilled to approximately 300 feet (ft) below ground surface (bgs) and that a borehole for the R-27 well would be drilled to 1,100 ft bgs, approximately 300 ft into the regional aquifer. Coring ceased at 272.8 ft bgs because the core rig developed mechanical problems. The R-27 borehole was drilled to a total depth (TD) of 987 ft bgs when drilling stopped because of borehole instability and concerns that the drill string might become stuck. R-27 was installed with a single screened interval between 852 and 875 ft bgs in the regional aquifer within the lower Puye Formation. Post-installation activities included well development groundwater sampling and wellhead surveying. Aquifer testing and permanent pump installation will be completed at a later date when fluids can be removed from the cuttings pits.

The information presented in this report was compiled from field reports and activity summaries generated by Kleinfelder, LANL and subcontractor personnel. Original records, including field reports, field logs and survey records, are on file in Kleinfelder's Albuquerque office and will be provided to the LANL Records Processing Facility at the completion of the project. This report contains brief descriptions of all activities associated with R-27 as well as supporting figures, tables and appendices. Detailed analysis and interpretation of geologic, geochemical and aquifer data will be included in separate technical documents to be prepared by LANL.

2.0 PRELIMINARY ACTIVITIES

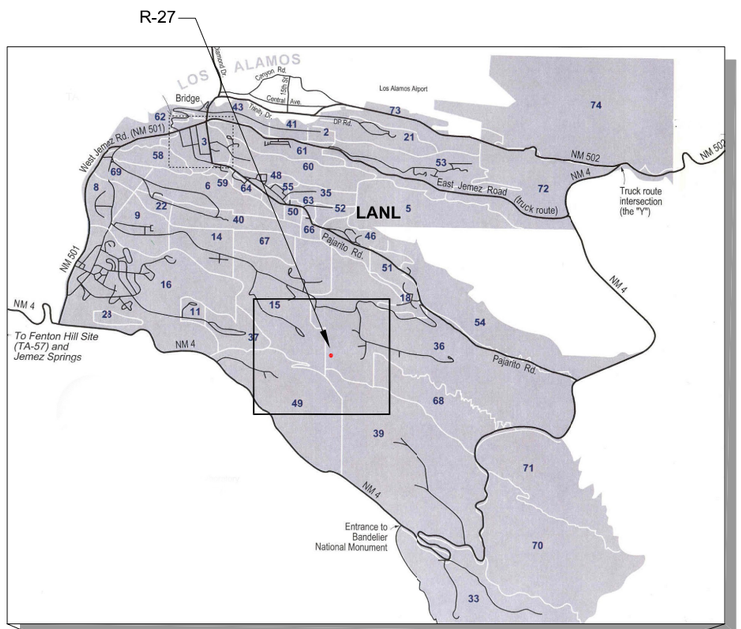
Preliminary activities included preparing administrative planning documents and constructing the drill site.

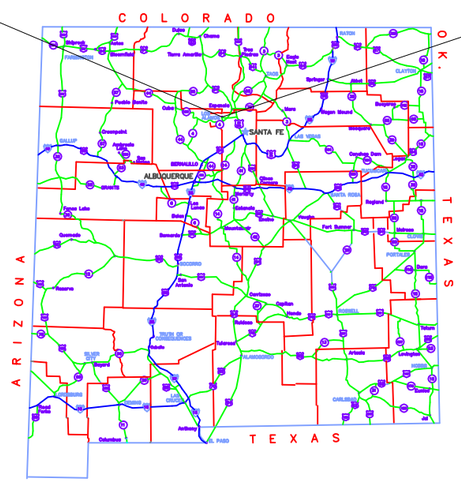
2.1 Administrative Preparation

Kleinfelder received contractual authorization as a notice to proceed on May 27, 2005. The following documents were prepared to guide the implementation of the scope of work for this well: Drilling Work Plan (Kleinfelder 2005a), Contractor's Quality Management Plan (Kleinfelder 2005b), Site-Specific Health and Safety Plan (Kleinfelder 2005c) and Storm Water Pollution Prevention Plan (Kleinfelder 2005d).

Legend

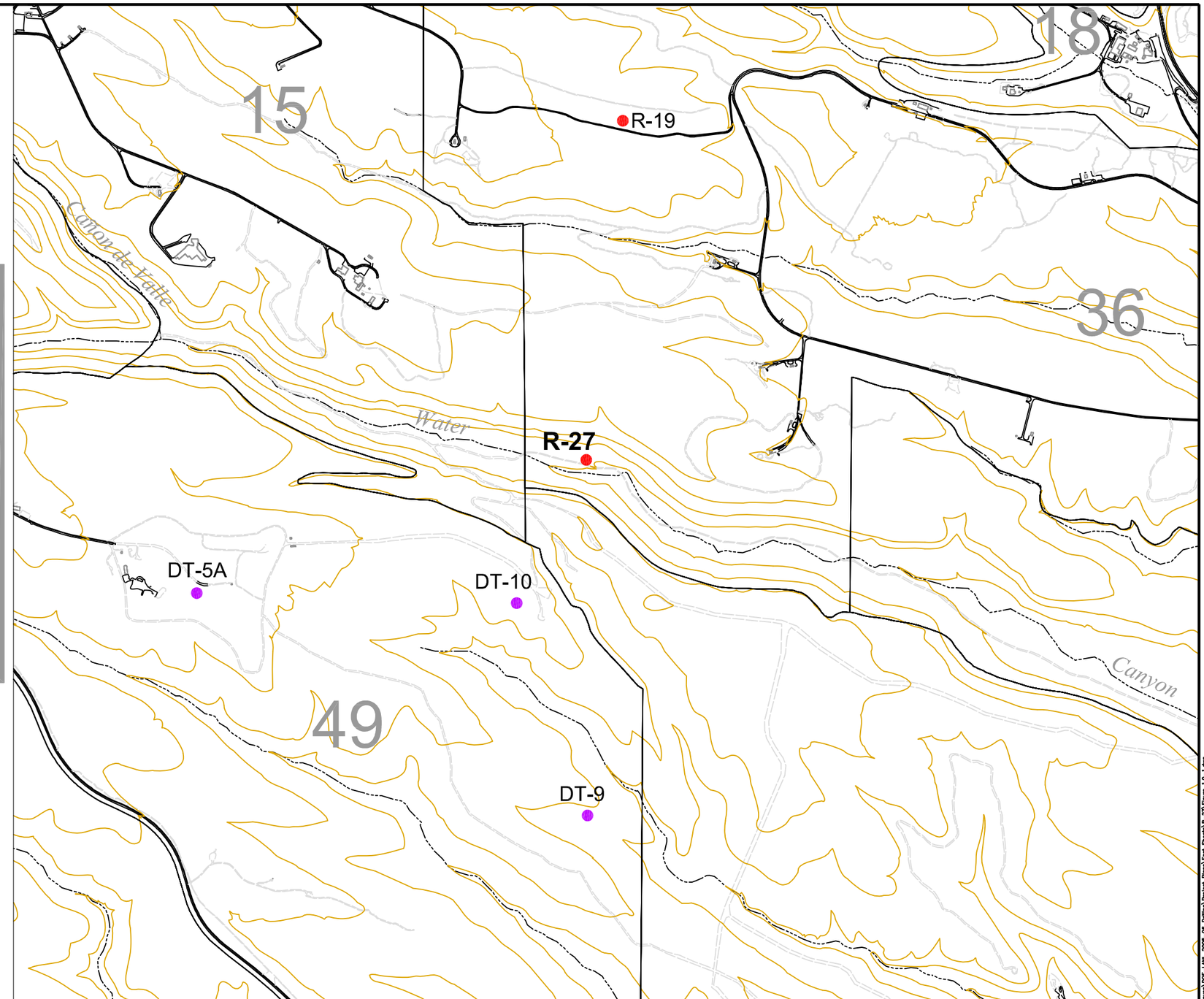
- = Regional aquifer wells
- = Older test wells
- 58 = Technical area identification
- = 100-ft contours





VICINITY MAP

NOT TO SCALE



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FEET

KLEINFELDER

Drawn By: C. Bhongir	Date: February 2006
Project No.: 49436	Filename: Figure 1.0–1.dwg
Scale: 1" = 1200'	Revision: –

SITE LOCATION MAP
Characterization Well R-27
Water Canyon
Los Alamos, New Mexico

FIGURE
1.0-1

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2.2 Site Preparation

Site preparation consisted of grading the access road, installing temporary grates across stream crossings, clearing the drill site of vegetation, installing silt fencing to prevent erosion and runoff from the drill site, preparing the cuttings pit and setting up the exclusion zone. Best management practices, also known as BMPs, were installed as specified in the Storm Water Pollution Prevention Plan (Kleinfelder 2005d). EnviroWorks, Inc. completed these tasks from July 29 to August 9, 2005. Final road grading and site preparation were accomplished from October 3 through 5, 2005. A radiation control technician (RCT) from LANL's Health, Safety, and Radiation Protection Group-1 screened the access road and drill site before site preparation activities. A geology trailer, generator, compressor and safety lighting equipment were moved to the site during the subsequent mobilization of drilling equipment.

3.0 DRILLING ACTIVITIES

Spectrum Exploration, Inc. (Spectrum) drilled the corehole between September 22 and 27, 2005, with a Delta Base 540 track-mounted HQ coring rig to a TD of 272.8 ft bgs. Coring ceased due to mechanical problems with the rig. No groundwater was encountered and core samples were collected as specified in the Drilling Work Plan (Kleinfelder 2005a).

WDC Exploration & Wells, Inc. (WDC) used a Speedstar 50K rig to drill the R-27 borehole between October 5 and 22, 2005 to 987 ft bgs. A well was completed with one 23-ft screened interval in the regional aquifer from 852 to 875 ft bgs. The drill crew and two site geologists conducted the drilling in 10-hour night shifts that typically began about 5:00 P.M. each day and continued to approximately 3:00 A.M. the following day. This schedule was used in order to avoid the TA-36 daytime shot schedule, which would have required drill site evacuations. Depth-to-water (DTW) measurements were taken at the beginning and end of most shifts to check for the presence of groundwater. A chronology of drilling and associated activities for R-27 is presented in Table 3.0-1. Table 3.0-2 shows the fluid volumes introduced and recovered during drilling.

WDC mobilized to the drill site between October 3 and 5, 2005. On the evening of October 5 and into the morning of October 6, WDC began drilling and advanced the borehole with a 12¼-inch (in.) outer diameter (OD) chisel-tooth button bit to 43 ft bgs. The borehole was enlarged with a 24-in. reamer bit to 25 ft bgs so that surface casing could be set.

On the October 6 and 7 shift, 16-in. OD surface casing was cemented to 19.7 ft bgs. On October 7 and 8, the crew used a 15-in. OD button bit to drill to 28 ft bgs. The surface casing slipped and was re-cemented in place.

On October 8 and 9, the borehole was advanced to 63 ft bgs with a 12¼-in. chisel tooth bit. On October 9 and 10, the crew drilled to 470 ft bgs, and on the 10th and 11th they drilled to 640 ft bgs. LANL personnel ran a video camera downhole during the day on October 11 and water was observed to be entering the borehole at approximately 616 ft bgs. On the evening of October 11, the DTW was measured at 628.0 ft bgs and groundwater samples were collected for analysis of anions, cations, metals, perchlorate and HE.

On October 11 and 12, the drill crew tripped in a 12¼-in. down-the-hole hammer bit and drilled to 747 ft bgs. On the evening of October 12, the crew advanced the hole to 757 ft bgs. About

Table 3.0-1
Chronology of Activities

TASK	R-27 DATES																			
	Jul-05	Aug-05		Sep-05		Oct-05				Nov-05				Dec-05		Jan-06		Feb-06	
SITE PREPARATION ACTIVITIES	7/29 - 8/9					10/3-5													
COREHOLE DRILLING/SAMPLING																			
Mobilization				9/21-22															
Coring					9/22-27														
Geophysical Logging					9/28	10/2													
BOREHOLE DRILLING/SAMPLING																			
Mobilization						10/3-5													
Air-Rotary Drilling							10/5 - 22												
Groundwater Screening Sampling							10/11, 20, 21												
BOREHOLE LOGGING																			
Geophysical Logging								10/21,25											
Video Logging							10/11	10/20											
WELL CONSTRUCTION									10/30 - 11/7										
WELL DEVELOPMENT											11/9-14								
GROUNDWATER WELL SAMPLING											11/14								
AQUIFER TESTING[a]																			
PUMP INSTALLATION[a]																			
SITE RESTORATION[a]																			

[a]Aquifer testing, pump installation and site restoration will be conducted after NMED has granted permission to drain the cuttings pit. An addendum will be issued to document those activities.

Table 3.0-2
Introduced and Recovered Fluids

Material		Amount (gallons)
Introduced	QUIK-FOAM®	424
	EZ-MUD®	13
	Potable Water	18,127
	Total Introduced Fluids[a]	18,564
Recovered	Total Recovered Fluids[b]	68,713

[a]Represents the fluids introduced during drilling.
[b]Represents the estimated fluid volume recovered during drilling and well development.

9:30 P.M., the crew tripped the drill string out of the hole and discovered that the bottom of the hammer bit had broken off and was left in the hole. Because the crew was leaving for scheduled days off at the end of the shift, they secured the site and made plans to mobilize equipment to retrieve the bit upon their return on October 17. DTW was measured at 710 ft bgs.

On October 17, the DTW in the borehole was 632.4 ft bgs and the bottom of the borehole was tagged at approximately 730 ft bgs. WDC tripped in the drill string and a 12¼-in. chisel-tooth bit to clean out the slough in the bottom of the borehole. The crew cleaned out the hole to 752 ft bgs and began tripping out when a fray was noted in the ¾-in. rig cable. Drilling was stopped to repair the cable.

On October 18 and 19, the crew replaced the ¾-in. rig cable and made two unsuccessful attempts to retrieve the hammer bit. On October 19 and 20, WDC successfully retrieved the bit and then advanced the borehole with a 12¼-in. hammer bit to 807 ft bgs. DTW at the end of the shift was approximately 674.4 ft bgs. During the day on October 20, LANL personnel ran a video camera downhole and encountered standing water at approximately 789.5 ft bgs.

On October 20, groundwater samples were collected at the beginning of the shift and WDC drilled to 947 ft bgs. On October 21 and 22, the crew tripped the drill string out of the borehole and tagged the bottom at 911 ft bgs. Groundwater samples were collected from the open borehole and gamma and induction logs were run. At the beginning of the shift on the evening of October 22, DTW was 813.6 ft bgs. WDC advanced the borehole to the TD of 987 ft bgs, then tripped out of the hole and tagged bottom at 911 ft bgs. Drilling was terminated at that point due to borehole instability and concerns that the drill string might become stuck.

4.0 SAMPLING ACTIVITIES

This section describes the core, cuttings and groundwater sampling at R-27. Sampling activities were generally conducted in accordance with the Drilling Plan (Kleinfelder 2005a).

4.1 Core Sampling

Lithologic core was continuously collected from the corehole with a 2.0-in. OD split-spoon sampler. The Drilling Plan specified that core samples were to be collected for laboratory

analysis every 10 ft to a depth of 100 ft bgs and at 50-ft intervals thereafter. Radiological screening samples were to be collected every 50 ft.

Table 4.1-1 shows the core samples collected and submitted for laboratory analysis. The core from R-27 was labeled and archived in core boxes and submitted to the Field Sampling Facility. LANL RCTs screened all cuttings before they were removed from the site.

Table 4.1-1
Core Samples

Sample ID	Date	Interval (ft bgs)	Radio-logical Screening	Anions, Moisture, $N^{14}N^{15a}$	H^{3b}	D^2H + $O^{18}O^{16c}$	Am^{241} + GS + ISO Pu + Sr^{90d}
GW27-05-61954	9/22/05	5.8-7.3	X	X	X	X	X
GW27-05-61955	9/22/05	22.8-25.1	X	X	X	X	X
GW27-05-61956	9/22/05	30.3-32.8	X	X	X	X	X
GW27-05-61957	9/22/05	40.3-42.8	X	X	X	X	X
GW27-05-61958	9/23/05	50.3-52.8	X	X	X	X	X
GW27-05-61959	9/23/05	60.3-62.8	X	X	X	X	X
GW27-05-61960	9/23/05	70.3-72.8	X	X	X	X	X
GW27-05-61961	9/23/05	79.2-81.7	X	X	X	X	X
GW27-05-61962	9/23/05	90.3-92.8	X	X	X	X	X
GW27-05-61963	9/23/05	98.4-100.9	X	X	X	X	X
GW27-05-61964	9/23/05	149.4-152.0	X	X	X	X	X
GW27-05-61965	9/23/05	200.3-202.8	X	X	X	X	X
GW27-05-61966	9/26/05	250.5-252.8	X	X	X	X	X
GW27-05-61967	9/27/05	265.3-267.4	X	X	X	X	X

[a] nitrogen 14 and 15 isotopes
[b] tritium
[c] deuterium and oxygen isotopes
[d] americium-241, gamma spectroscopy, plutonium isotopes and strontium-90

4.2 Cuttings Sampling

Bulk cuttings were collected in plastic bags from the R-27 borehole at 10-ft intervals from 0 to 250 ft bgs. From 250 to 987 ft bgs, bulk cuttings and sieved cuttings were collected at 5-ft intervals and processed in the following manner. Approximately 500 to 700 milliliters of bulk cuttings were collected from the discharge hose, sealed in Ziploc® bags, labeled and transferred to the LANL geology task leader. Sieved fractions (>#10 and >#35 mesh) were placed in chip trays along with unsieved (whole rock) cuttings. The sieved fractions were placed in labeled plastic bags and submitted to LANL. The remaining cuttings were sealed in Ziploc® bags, labeled and archived in core boxes. LANL RCTs screened all cuttings before they were removed from the site.

4.3 Water Sampling

Six screening groundwater samples were collected with bailers from several feet below the standing water level in the open borehole during drilling at R-27. The screening groundwater samples with sample identification numbers beginning with EU were submitted to the LANL Earth and Environmental Sciences Division, Group 6 (EES-6) for anions, cations, perchlorate and metals analyses; the screening samples with numbers beginning with GU were submitted to GEL Laboratories for HE analyses. Table 4.3-1 summarizes the sample numbers, dates,

collection depths and analyses for the groundwater samples. A final groundwater sample was collected via a submersible pump from 862.5 ft bgs after development and submitted for anions, cations, perchlorate and metals analyses.

Table 4.3-1
Groundwater Samples

Sample Number	Date	DTW (ft bgs)	Borehole Depth (ft bgs)	Analyses	Water-bearing Unit
EU05070GR2701	10/11/05	628 [a]	640	Anions, cations, metals, ClO_4 [d]	Puye Formation
GU05070GR2701	10/11/05	628 [a]	640	HE	Puye Formation
EU05070GR2702	10/20/05	789.5 [a]	807	Anions, cations, metals, ClO_4	Puye Formation
GU05100GR2702	10/20/05	789.5 [a]	807	HE	Puye Formation
EU05070GR2703	10/21/05	814 [a]	847	Anions, cations, metals, ClO_4	Puye Formation
GU05100GR2703	10/21/05	814 [a]	847	HE	Puye Formation
EU05070GR2705	11/14/05	862.5 [b]	878.7	Anions, cations, metals, ClO_4	Puye Formation

[a] Sample collected with bailer just below water level in open borehole.
[b] Sample collected from completed well after well development.
[c] Depth of completed well
[d] Perchlorate

5.0 COREHOLE AND BOREHOLE LOGGING

Natural gamma and induction logs were run in the corehole at the TD of 272.8 ft bgs; augers were in the corehole to 200.8 ft bgs. After the augers were removed, site geologists made two attempts to run induction logs on the upper portion of the corehole, but the induction logging equipment did not work properly.

Video and Schlumberger geophysical logs were run at R-27 borehole. Table 5.0-1 summarizes the dates and types of logging. A DVD of the October 11 and 20, 2005 video logs (combined

Table 5.0-1
Borehole Logging

Operator	Date	Tools	Cased Footage (ft bgs)	Open hole Interval (ft bgs)	Logged Interval (ft bgs)	Remarks
LANL	10/11/05	Video	0-19.7	19.7-640	0-629	Water visible at 616 ft bgs. DTW measured after logging at 627.95 ft bgs.
Kleinfelder	10/20/05	Video	0-19.7	10.7-807	629-789.5	Minor water entering from basalt fractures at 670, 695, 709 and 762 ft bgs. Standing water at 789.5 ft bgs.
Kleinfelder	10/21/05	Gamma and induction	0-19.7	19.7-947	30-911	DTW at 814 ft bgs
Schlumberger	10/25/05	Geophysics	0-19.7	19.7-987	24-923	Triple LithoDensity, Compensated Neutron, Array Induction, Natural Gamma Ray, Formation Micro-imager, Combinable Magnetic Resonance, Caliper, Elemental Capture Sonde

logged interval 0 to 789.5 ft bgs) is presented in Appendix A. Appendix B contains the Schlumberger geophysical logging report. The Excel spreadsheets and charts from the gamma and induction corehole and borehole logs are included in Appendix B on the report CD.

6.0 HYDROGEOLOGY

This section contains a brief description of the hydrogeologic features encountered at R-27. The stratigraphy section discusses geologic units at R-27 as identified by the site geologists and LANL's EES-6 staff. The groundwater section describes groundwater encountered at R-27 and is based on drilling observations, open-hole video logging and water level measurements.

6.1 Stratigraphy

This section presents a brief summary of the lithology encountered at R-27. The following formations were present in order of youngest to oldest: Quaternary Alluvium, Tshirege Member of the Bandelier Tuff, Cerro Toledo interval, Otowi Member of the Bandelier Tuff, Guaje Pumice Bed of the Otowi Member, upper Puye Formation, Cerros del Rio basalt and lower Puye Formation. Figure 6.1-1 summarizes the local stratigraphy at R-27. A detailed lithologic log for R-27 is presented in Appendix C.

Quaternary Alluvium, Qal (0 to 21 ft bgs)

The surficial alluvial deposits were primarily unconsolidated, yellowish brown silty/clayey sand and gravel. The sand was composed of rounded felsic crystals with minor amounts of silt/clay and gravel. The gravel deposits were poorly sorted, subangular to angular and predominantly intermediate composition volcanic lithics.

Tshirege Member of the Bandelier Tuff, Qbt 1g (21 to 80 ft bgs)

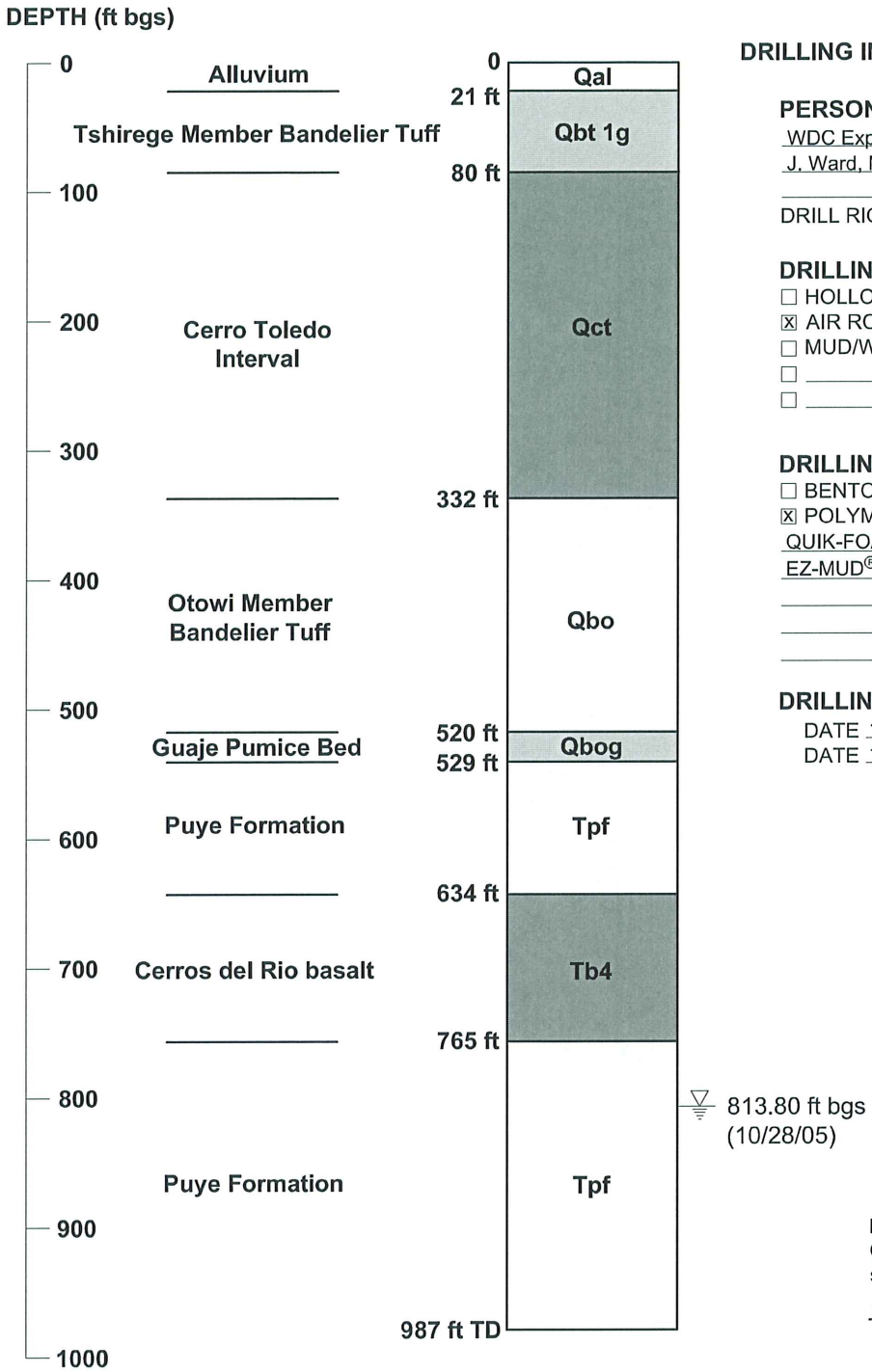
The Tshirege Member was present from 21 to 80 ft bgs and was primarily a very pale orange to grayish orange pink poorly welded tuff. It was composed of felsic crystals and vitric pumice fragments in a fine to coarse ash matrix, representing the lower vitric ash flows of the member.

Cerro Toledo interval, Qct (80 to 332 ft bgs)

The Cerro Toledo interval was encountered from 80 to 332 ft bgs and contained grayish orange to pale yellowish brown gravelly siltstone and claystone in the upper portion (approximately 200 ft), with light to medium gray fluvial gravel deposits in the lower 55 ft. The siltstone and claystone deposits are typically non-indurated and moderately sorted, with between 10 and 25% subangular pumice and intermediate composition volcanic gravel, up to 15 millimeters in size. The gravel in the lower portion of the interval was composed of 50 to 80% subangular intermediate composition volcanic lithics and 20 to 50% subangular to subrounded vitric pumice.

Otowi Member of the Bandelier Tuff, Qbo (332 to 520 ft bgs)

The ash flows of the Otowi Member of the Bandelier Tuff were present from 332 to 520 ft bgs. The orange-pink to very light gray, poorly welded tuff contained 30 to 60% intermediate composition volcanic lithic fragments and 40 to 70% vitric pumice fragments in a fine ash matrix.



DRILLING INFORMATION

PERSONNEL

WDC Exploration & Wells
J. Ward, M. Tycksen, Q. Stevens, M. Daniel

DRILL RIG Speedstar 50k

DRILLING METHOD

- ☐ HOLLOW-STEM AUGER
- ☒ AIR ROTARY
- ☐ MUD/WATER ROTARY
- ☐
- ☐

DRILLING FLUID TYPE

- ☐ BENTONITE
- ☒ POLYMER
- ☒ WATER
- ☒ AIR

QUIK-FOAM®
EZ-MUD®

DRILLING START / FINISH

DATE 10/05/05 TIME 22:50
DATE 10/22/05 TIME 22:55

Note:
Geologic contacts are preliminary and subject to change.

▽ Depth to water prior to well construction

KLEINFELDER		BOREHOLE SUMMARY DATA SHEET **Characterization Well R-27** Water Canyon Los Alamos, New Mexico	FIGURE **6.1-1**
Drawn By: C. Bhongir	Date: January 2006		
Project No.: 49436	Filename: 49436_01_0.dwg		
Scale: not-to-scale	Revision: –		

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Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (520 to 529 ft bgs)

The Guaje Pumice Bed was present from 520 to 529 ft bgs. The pumice was very light gray and contained 60 to 70% white, vitric pumice and 30 to 40% intermediate composition volcanic lithics in a fine ash matrix.

Puye Formation, Tpf (529 to 634 ft bgs)

An upper sequence of the sedimentary Puye Formation, from 529 to 634 ft bgs, contained fanglomerate deposits comprised of pale red to medium dark gray volcaniclastic gravel that was subangular to subrounded, poorly sorted and poorly indurated. The formation contained between 2 and 15% sand.

Cerros del Rio basalt, Tb4 (634 to 765 ft bgs)

Lavas of the Cerros del Rio basalt extended from 634 to 765 ft bgs. The basalt lavas consisted of predominantly medium gray basalt with an aphanitic groundmass and 2 to 7% reddish brown to yellowish green olivine phenocrysts. The basalt is highly brecciated from 634 to 670 ft bgs and massive from 670 to 765 ft bgs. The lower massive zone contains two interflow breccia zones from 700 to 704 ft bgs and from 748 to 752 ft bgs.

Puye Formation, Tpf (765 to 987 ft bgs)

A lower sequence of the Puye Formation was present from 765 ft bgs to the TD of 987 ft bgs and consisted of gravelly silt and sand in the upper portion with sandy gravel and silty/clayey gravel in the lower part. The silt and sand deposits were very pale orange to light brown, moderately sorted and poorly indurated with 5 to 20% intermediate composition volcanic and basalt gravel. The gravel deposits were brownish gray to light gray, moderately sorted and poorly indurated. They contained 80 to 95% subangular to subrounded, intermediate composition volcanics with up to 20% scoria clasts. Basalt and scoria fragments may represent intermixing from the overlying Cerros del Rio basalt during drilling. Silty/clayey gravel deposits were encountered in the bottom part of the borehole; these sediments contained 60 to 65% sand, 20 to 35% gravel and 5 to 15% silt/clay.

6.2 Groundwater

During video logging, perched intermediate groundwater was observed to be entering the borehole at 616 ft bgs near the base of the upper Puye Formation above the Cerros del Rio basalt. At the borehole depth of 640 ft bgs, or 6 ft into the Cerros del Rio basalt, standing water was measured at 627.95 ft bgs. At the borehole depth of 807 ft bgs, in the lower Puye Formation, minor water was observed to be entering the borehole from fractures in the Cerros del Rio basalt at 670, 695, 709 and 762 ft bgs. The DTW was measured at 789.5 ft bgs at the borehole depth of 807 ft bgs; it is unclear if this water was from the upper zone above the Cerros del Rio basalt, or from a lower perched interval within the Cerros del Rio basalt or the lower Puye Formation.

The following interpretations regarding perched intermediate zone groundwater were made in the Schlumberger geophysical logging report (Appendix B). The processed logs indicate no significant zones with high water saturation were observed above 676 ft bgs. The interval from 676 to 764 ft bgs in the Cerros del Rio basalt contains very low porosity; however, the log results indicate that this zone is mostly saturated. It is possible this largely competent, impermeable

basalt section is retaining whatever water it can hold, although the water saturation estimate is very sensitive and may possibly be inaccurate at such low porosity values. The interval from 764 to 818 ft bgs in the lower Puye Formation was logged as unsaturated.

The regional aquifer static water level in the borehole during geophysical logging was approximately 815 ft bgs and shortly after well installation, the water level was measured at 810.83 ft bgs. The geophysical report contains the following information regarding the regional aquifer at R-27. The processed geophysical logs indicate that the geologic section is fully saturated from 818 to 924 ft bgs (the bottom of the logged interval) within the Puye Formation fanglomerate. The measured porosity across this interval is highly variable – mostly ranging from 12 to 48% of total rock/sediment volume, although it is higher in areas with borehole washouts. The most productive aquifer zones reliably estimated from the processed logs are 818 to 825, 844 to 847, 869.5 to 882 and 911 to 915 ft bgs. In addition, the zones 830 to 833, 851 to 862, 893 to 900 and 919.5 to 924 ft bgs appear to have a high production potential, but the borehole contained washouts across these intervals and, thus, the log results are not reliable.

6.3 Preliminary Groundwater Analytical Results

Three screening groundwater samples were collected during drilling, one from perched intermediate zone groundwater at approximately 630 ft bgs (from the upper Puye Formation above the Cerros del Rio basalt), one from perched intermediate zone groundwater at approximately 790 ft bgs (possibly from the lower Puye Formation), and one from the regional aquifer at approximately 820 ft bgs. These samples were submitted for analysis of anions, cations, perchlorate and metals. Three additional screening samples from the same zones were submitted for high explosives analyses. A final groundwater sample was collected from the regional aquifer at 862.5 ft bgs after the well was installed and developed. Appendix D presents the results in table form and contains a brief summary.

Perchlorate was tentatively detected in the 790 ft bgs sample at a concentration of 0.0076 parts per million (ppm); it was not detected in the 630 ft bgs sample or the two samples from the regional aquifer. Nitrate (as N) was detected in the 630 ft bgs sample and in both of the regional aquifer samples at concentrations ranging between 0.10 and 0.29 ppm. High explosive compounds were not detected in the three screening samples. Total organic carbon (TOC) was measured at 1.23 ppm near the end of well development on November 13, 2005. Appendix D contains the analytical data for the groundwater samples collected from R-27.

7.0 WELL INSTALLATION

Data from geophysical logs, drill cuttings, drillers' observations regarding water production and water level measurements were evaluated to determine the placement of the screened interval for the well. The well was installed between October 30 and November 7, 2005.

7.1 Well Design

The well was designed in accordance with LANL Standard Operating Procedure for Well Construction, Revision 3 (LANL 2001); DOE and LANL provided an approved well design to Kleinfelder. NMED approved the well design prior to well installation. The design called for a single screened interval from 852 to 875 ft bgs to monitor groundwater quality near the top of the regional aquifer within the lower Puye Formation.

7.2 Well Construction

R-27 was constructed of 4.5-in. inner diameter (ID)/5.0-in. OD, type A304 stainless steel casing fabricated to American Society for Testing and Materials A312 standards. Two nominal 10-ft lengths of 5.0-in. OD compatible, rod-based, 0.020-in. wire-wrapped well screen were used. The casing and screen were factory-cleaned before shipment and were also steam-cleaned on-site.

The screened interval chosen for the well was 852 to 875 ft bgs. A 3.7-ft-deep sump of stainless steel casing was placed below the well screen. Figure 7.2-1 is an as-built schematic showing construction details for R-27.

Prior to construction, the borehole bottom was tagged at 925 ft bgs, indicating that 62 ft of slough had accumulated above the borehole TD of 987 ft bgs. Tremie pipe was used to deliver the annular fill materials to the annular space. The well casing, screen and sump were lowered into the borehole. A 50:50 mixture of coarse bentonite pellets and 10/20 silica sand was added to the bottom of the borehole to 885 ft bgs. The primary filter pack of 10/20 silica sand was installed between 885 and 842 ft bgs. After emplacement of the filter pack, the drillers used a swabbing tool to settle the filter pack along the screened interval. A fine sand collar of 20/40 silica sand was then placed from 842 to 840.5 ft bgs. Medium bentonite chips and 10/20 silica sand were installed above the fine sand collar to 626 ft bgs. From 626 to 78 ft bgs, medium bentonite chips were placed. The cement grout surface seal was poured from 78 to 2 ft bgs and consisted of 95% cement and 5% bentonite. Table 7.2-1 summarizes the volumes of annular fill materials used to complete R-27. Note that the volumes of annular fill materials required for the 885 to 925 ft bgs interval and the 626 to 840.5 ft bgs interval were significantly larger than the calculated volumes; the additional materials were required in zones where the borehole was washed-out or oversized.

Table 7.2-1
Annular Fill Materials

Material	Volume
Surface seal: cement slurry	81.0 ft^3
Bentonite seal: bentonite chips	586.5 ft^3
Bentonite seal: bentonite chips+10/20 silica sand	144.0 ft^3
Fine sand collar: 20/40 silica sand	1.5 ft^3
Primary filter: 10/20 silica sand	32.5 ft^3
Backfill material: Bentonite+10/20 silica sand	128.8 ft^3
Potable water	28,389 gallons

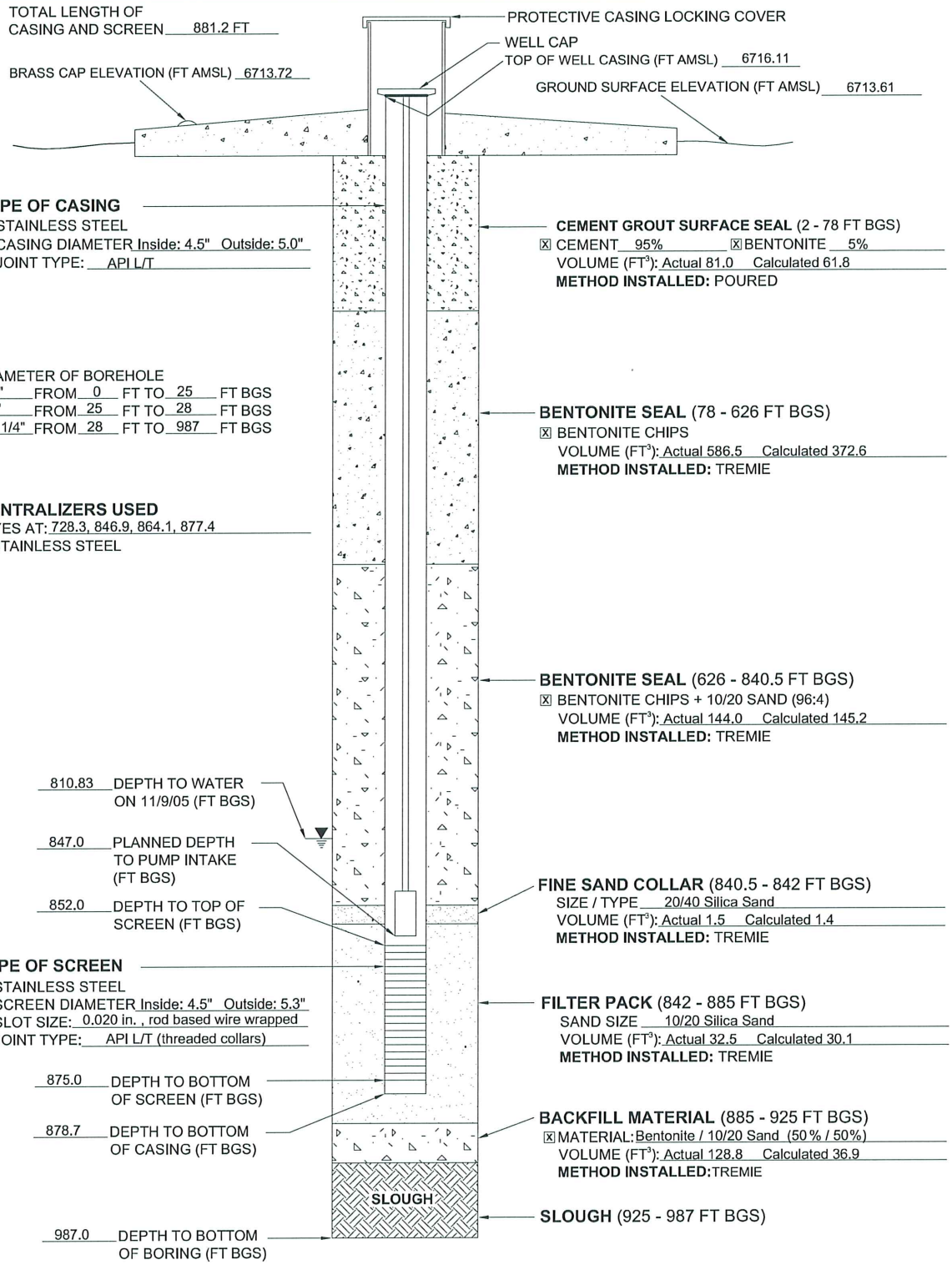
ft^3 = cubic ft

8.0 POST-INSTALLATION ACTIVITIES

Following well installation, the well was developed and the wellhead was completed. Surveying, aquifer testing and the permanent pump installation have not been completed. Site restoration activities will commence when NMED permission to discharge fluids has been received.

8.1 Well Development

R-27 was developed between November 9 and 14, 2005. The development crew initially bailed and swabbed the screened interval to help remove formation fines and filter pack sand from the



WELL DEVELOPMENT INFORMATION

WELL COMPLETION BEGAN
DATE 10/30/05 TIME 08:12
WELL COMPLETION FINISHED
DATE 11/07/05 TIME 08:48

WELL DEVELOPMENT BEGAN
DATE 11/09/05 TIME 06:30
WELL DEVELOPMENT FINISHED
DATE 11/14/05 TIME 16:23

DEVELOPMENT METHOD
☒ SWABBING ☒ BAILING ☒ PUMPING
☒ TOTAL PURGE VOLUME 38,792.5 GALLONS

FINAL PARAMETERS
pH 8.31
TEMPERATURE 17.2 °C
SPECIFIC CONDUCTANCE 118 µS/cm
TURBIDITY 3.1 NTUs

KLEINFELDER		WELL SCHEMATIC **Characterization Well R-27** Water Canyon Los Alamos, New Mexico	FIGURE **7.2-1**
Drawn By: C. Bhongir	Date: February 2006		
Project No.: 49436	Filename: 49436_02_0.dwg		
Scale: not-to-scale	Revision: –		

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well. Approximately 230 gallons (gal.) of water were removed during swabbing and bailing. A 3-in. Grundfos submersible pump was used for the final stage of well development. The pump intake was set within the screened interval at 862.5 ft bgs and 38,562.5 gal. of water were removed.

Turbidity, pH, temperature and specific conductance were measured during development. Additionally, TOC was measured; the target concentration for TOC was <2.0 ppm, which indicates that drilling fluids have been removed from the well. The final turbidity reading was 3.1 nephelometric turbidity units (NTUs) and the TOC level near the end of development was 1.23 ppm. Table 8.1-1 shows the volume of water removed during well development and the resultant water quality parameters and TOC concentration. Figure 8.1-1 shows the water quality parameters measured during the course of well development.

Table 8.1-1
Final Water Quality Parameters

Method	Water Removed (gal.)	pH	Temper-ature (°Celsius)	Specific Conductance (µS/cm)	Turbidity (NTUs)	Total Organic Carbon (ppm)
Bailing/Swabbing	230	8.1	18.2	148	Off scale	Not measured
Pumping	38,562.5	8.3	17.2	118	3.1	1.23

µS/cm = microSiemens per centimeter

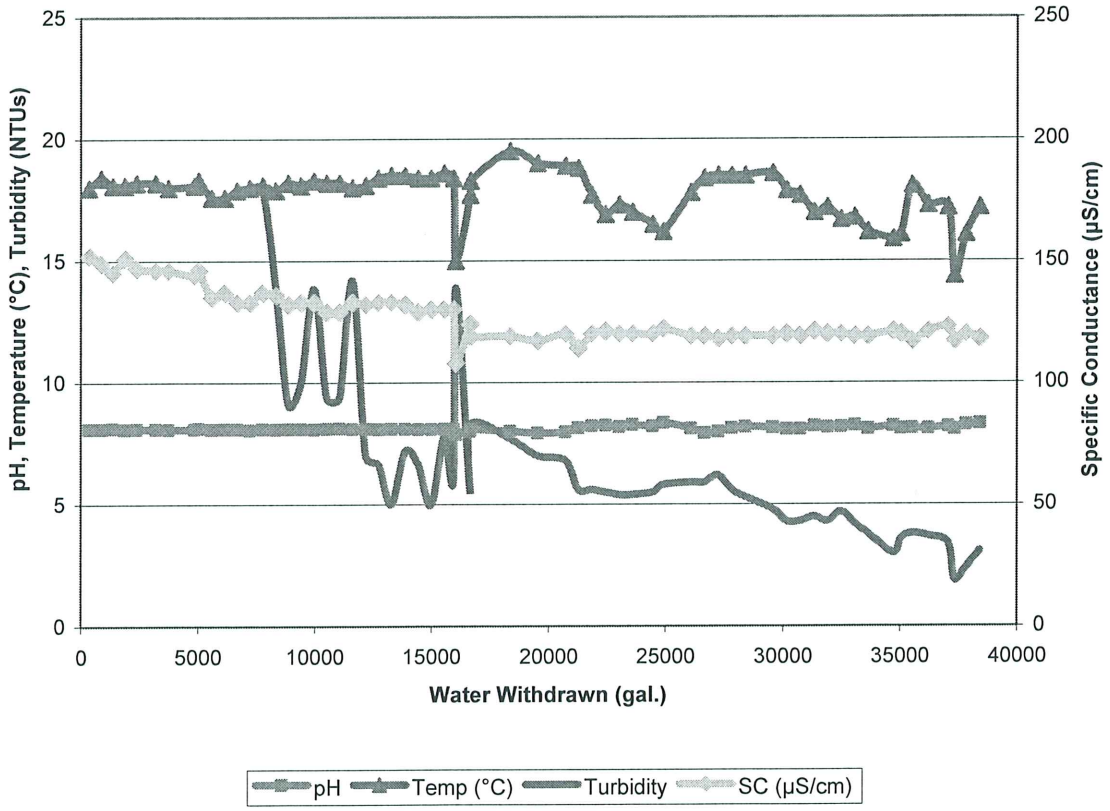

Figure 8.1-1. Water Quality Parameters During Development

8.2 Aquifer Testing

Aquifer testing has not been conducted at R-27 to date because both cuttings pits are near their fluid volume capacities. When NMED permission to discharge cuttings fluids is obtained and the pits can be drained, then the aquifer test will be conducted. An addendum to this report will be issued to present the aquifer test results.

8.3 Dedicated Sampling System Installation

A dedicated pump has not been installed at R-27 because information from the aquifer test is typically used to size the pump. Details of the pump installation will be included in the addendum along with the aquifer test report.

8.4 Wellhead Completion

A reinforced 2,500 pounds per square inch concrete pad, 5 ft by 5 ft by 6 in. thick, was installed around the well casing to provide long-term structural integrity for the well and to prevent surface water from flowing down the outside of the casing. A brass survey pin was embedded in the northwest corner of the pad. A 10.75-in. OD diameter steel casing with a locking lid was installed to protect the well riser. The concrete pad was elevated slightly above the ground surface, with base course gravel graded up around the edges.

8.5 Geodetic Survey

ASTS Inc. of Albuquerque, New Mexico conducted the geodetic survey at R-27 and the survey data are provided in Table 8.5-1.

Table 8.5-1
Geodetic Data

Description	Northing	Easting	Elevation[a]
COREHOLE	1756294.09	1629263.09	6713.76
R-27 WELLHEAD			
Brass cap in R-27 pad	1756296.28	1629230.52	6713.72
Top of stainless steel casing	1756294.75	1629231.73	6716.11
Ground surface beside pad	1756298.27	1629230.44	6713.61

[a] Measured in ft above mean sea level relative to the National Geodetic Vertical Datum of 1929.

8.6 Site Restoration

Fluids produced during drilling and development were containerized and sampled in accordance with the July 12, 2005 "Waste Characterization Strategy Form" prepared for the 2005 well drilling program at LANL (Appendix C in Kleinfelder 2005a). Fluid sample results will be compared to the State of New Mexico Water Quality Control Commission Regulation 3103 groundwater standards and applicable Resource Conservation and Recovery Act regulatory limits. Water generated during drilling, development and aquifer testing will be discharged in accordance with the "Workplan Notice of Intent Decision Tree," revised July 15, 2002, and in

coordination with NMED. Site restoration will include removing the silt fencing and reseeding the site.

Site restoration activities have not started at R-27. When NMED permission to discharge fluids has been obtained, a memorandum will be issued to document discharge approval and site restoration activities.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Appendix E compares the actual drilling and well construction activities at R-27 with the planned activities described in the Drilling Work Plan. In general, drilling, sampling and well construction were performed as specified in the Drilling Work Plan. The main deviations from planned activities were:

- Planned Borehole Depth – The Drilling Work Plan called for the borehole to be drilled to a target TD of 1,100 ft bgs; it was drilled to a TD of 987 ft bgs because of borehole instability.
- Planned Corehole Depth – The target depth for the corehole was 300 ft bgs; it was cored to 272.8 ft bgs because the core rig developed mechanical problems.
- Groundwater Analyses – Although not specified in the drilling plan, high explosives analyses were added to the analytical suite for three of the samples.
- Aquifer Test – An aquifer test will be performed when there is room in the cuttings pits for pumped water. An addendum to this report will be issued when the test is complete.

10.0 ACKNOWLEDGEMENTS

D. Broxton and D. Vaniman of LANL worked with site geologists to identify the geologic contacts.

EnviroWorks, Inc. prepared the drill site.

P. Longmire of LANL evaluated the hydrochemistry.

Spectrum drilled the R-27 corehole.

WDC drilled the R-27 borehole and installed the monitoring well.

11.0 REFERENCES

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Kleinfelder 2005b, Contractor Quality Management Program for the DOE Monitoring Well Installation at Los Alamos National Laboratory, W91238-04-F-0096, Revision 3, May 20, 2005.

Kleinfelder 2005c, Site-Specific Health and Safety Plan, Monitoring Well Installation R-27, Los Alamos National Laboratory, Los Alamos, New Mexico, July 14, 2005.

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LANL 2001, Standard Operating Procedure for Well Construction, Revision 3, Los Alamos National Laboratory SOP-05.01, Los Alamos, New Mexico, April 2001.

NMED 2005, Compliance Order on Consent between New Mexico Environment Department and Los Alamos National Laboratory and the University of California, March 2005.

Appendix A

Borehole Video Log

Borehole video log DVD will be included with the final report.

TO VIEW THE VIDEO THAT ACCOMPANIES THIS DOCUMENT, PLEASE CALL THE HAZARDOUS WASTE BUREAU AT 505-476-6000 TO MAKE AN APPOINTMENT

Appendix B

Geophysical Logging Report

Schlumberger Water Services

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1.0 SUMMARY

This report describes borehole geophysical logging measurements from characterization well R-27, performed by Schlumberger in October 2005 before well completion. The report (1) summarizes the technology, measurements, and procedures employed; and (2) presents the processed results from these measurements and discusses their interpretation. The logging measurements were acquired from 24 to 923 feet (ft) below ground surface (bgs), when the borehole was open (uncased) from 20 to 925 ft (bottom of hole, as measured by the logs), drilled with a 12.25-inch (in.) diameter bit size.

The primary purpose of the geophysical logging was to characterize the geologic/hydrogeologic section intersected by the well, with emphasis on determining regional aquifer groundwater level, perched groundwater zones, moisture content, capacity for flow, and the stratigraphy/mineralogy of geologic units. A secondary purpose of the geophysical logging was to evaluate the borehole conditions such as borehole diameter versus depth, deviation versus depth, and degree of drilling fluid invasion. These objectives were accomplished by measuring, nearly continuously, along the length of the well (1) total and effective water-filled porosity and pore-size distribution from which an estimate of hydraulic conductivity is made; (2) bulk density (sensitive to total water plus air-filled porosity and grain density); (3) bulk electrical resistivity at multiple radial depths of investigation; (4) neutron induced gamma ray spectroscopy, providing bulk concentrations of a number of important mineral-forming elements, as well as hydrogen; (5) spectral natural gamma ray, including potassium, thorium, and uranium concentrations; (6) bedding and fracture orientation, fracture aperture, and geologic texture; (7) borehole inclination and azimuth; and (8) borehole diameter.

Preliminary results of these measurements were generated in the logging truck at the time the geophysical services were performed and are documented in field logs provided on site. However, the measurements presented in the field results are not fully corrected for borehole conditions and are provided as separate, individual logs. The field results were reprocessed by Schlumberger to (1) correct/improve the measurements, as well as possible, for borehole/formation environmental conditions; (2) perform an integrated analysis of the log measurements so that they are all coherent; and (3) combine the logs in a single presentation, enabling integrated interpretation. The reprocessed log results provide better quantitative property estimates that are consistent for all applicable measurements, as well as estimates of properties that otherwise could not be reliably estimated from the single measurements alone (e.g., total porosity inclusive of all water and air present, water saturation, mineralogy).

The geophysical log measurements from R-27 provide, overall, good quality results that are consistent with each other through most of the borehole. The quality of some measurements was degraded across intervals where the borehole contains large washouts and/or rugose hole (across the intervals 54–84, 152–182, 314–344, 530–646, 852–855, 876–883, 893–899, and 920–925 ft bgs, in varying degrees of severity). The measurements most affected by the adverse borehole conditions were ones that have a shallow depth of investigation and that require close contact to the borehole wall – the bulk density, photoelectric effect, and the porosity measurements (particularly from the magnetic resonance tool). The greatest impact on the log processing was erroneously high air-filled and/or water-filled porosity in the problem zones – as estimated from the logs. Through the integrated analysis and interpretation of all the logs, the individual

shortcomings of the specific measurements are reduced. Thus, the results derived from integrated log analysis (e.g., the optimized water-filled porosity log) are the most robust single representation of the geophysical log measurements, providing a wealth of valuable high-resolution information on the geologic and hydrogeologic environment of the R-27 area.

Important results from the processed geophysical logs in R-27 include the following:

1. The standing water level in R-27 was stable throughout the logging acquisition, remaining between 814 and 816 ft bgs for all four logging runs.

2. The processed logs indicate that the intersected geologic section is fully saturated with water from the bottom of the log interval (924 ft bgs) to 818 ft bgs, which lies within Puye Formation fanglomerate. The measured porosity across this interval is highly variable, mostly ranging 12–48% of total rock/sediment volume, although it is higher in borehole washouts. The most productive aquifer zones reliably estimated from the processed logs are 818–825, 844–847, 869.5–882, and 911–915 ft bgs. In addition, the zones 830–833, 851–862, 893–900, and 919.5–924 ft bgs appear to have a high production potential, but the borehole contained washouts across these intervals and, thus, the log results are not reliable.

3. The processed logs indicate that the interval from 764 to 818 ft bgs is unsaturated. The very low porosity section above this interval (676 to 764 ft bgs) appears to be mostly saturated from the log results. It is possible this very competent, largely impermeable basalt section is retaining what little water it can hold, although the water saturation estimate is very sensitive and possibly inaccurate at such low porosity values. Above 676 ft bgs the processed logs indicate no significant zones with high water saturation.

4. A basalt zone is clearly delineated from the geophysical log results, located from 639 to 764 ft bgs. This basalt zone contains both competent, low porosity sections (676–700.5, 704–748, and 752–764 ft bgs) and high porosity breccia/rubble sections (639–676, 700.5–704, and 748–752 ft bgs). The log results clearly delineate that the basalt is underlain by Puye Formation fanglomerate to the bottom of the borehole (925 ft bgs); the texture and bedding below the well standing water level (815 ft bgs) is determined from the borehole electrical image and integrated log analysis results. The log results show that the basalt is also overlain by fanglomerate to a depth of 530 ft bgs, above which lies a thick volcanic tuff/pumice sequence. The geophysical log response in the zone 522 to 530 ft bgs is characteristic of the Guaje Pumice Bed, with very high total porosity (48% of total rock volume), relatively high water-filled porosity at the bottom (20%) that decreases in the upward direction, and a large increase in thorium and uranium concentrations. The pumice bed is overlain by a thick section of slightly less-porous volcanic tuff. The log results suggest volcanic tuff extends to near the top of the log interval (22 ft bgs).

5. Interpreted planar bedding features across the electrically imaged interval 815 to 921 ft bgs have dip azimuths (direction beds are dipping to) primarily to the northeast and secondarily to the southwest, with a mean bedding dip azimuth of 51.6 degrees (northeast). Bedding feature dip angles (angle from horizontal) are mostly less than 30

degrees and almost all less than 40 degrees, with a mean bedding dip angle of 3.1 degrees. No natural fractures were identified across this interval.

2.0 INTRODUCTION

Schlumberger logged well R-27 in October 2005 before the well was completed. The purpose of these services is to acquire in-situ measurements to help characterize the borehole, near-borehole, and adjacent geologic environment. The primary objective of the geophysical logging is to provide in-situ evaluation of formation properties (hydrogeology and geology) intersected by the well. Los Alamos National Laboratory (LANL) scientists, engineers, and project managers involved in the drilling program use the information to design the well completion, to better understand subsurface site conditions, and to assist in overall decision-making.

The primary geophysical logging tools used by Schlumberger in well R-27 were the

- Combinable Magnetic Resonance (CMR*) tool, which measures the nuclear magnetic resonance response of the formation to evaluate total and effective water-filled porosity of the shallow formation and to estimate pore size distribution and in-situ hydraulic conductivity;
- Compensated Neutron Tool (CNT*), which measures volumetric water content of the formation to evaluate moist/porous zones;
- Triple Detector Litho-Density (TLD*) tool, which measures formation bulk density and photoelectric factor to estimate total porosity and lithology, as well as micro-resistivity and borehole diameter;
- Array Induction Tool (AIT*), which measures formation electrical resistivity at five depths of investigation and borehole fluid resistivity to evaluate drilling fluid invasion into the formation (a qualitative indicator of permeability and water saturation), presence of moist zones far from the borehole wall, and presence of clay-rich zones;
- Formation Micro-Imager (FMI*) tool, which measures electrical conductivity images of the borehole wall in fluid-filled open-hole and borehole diameter with a two-axis caliper to evaluate geologic bedding and fracturing, including strike and dip of these features and fracture apertures, and rock/sediment texture;
- General Purpose Inclinometry Tool (GPIT*), which measures borehole deviation and azimuth in open-hole to evaluate borehole position versus depth and to orient FMI images;
- Natural Gamma Spectroscopy (NGS) tool, which measures gross natural gamma and spectral natural gamma ray activity, including potassium, thorium, and uranium concentrations, to evaluate geology/lithology, particularly the amount of clay and potassium-bearing minerals; and

*Mark of Schlumberger

- Elemental Capture Spectroscopy (ECS*) tool, which measures neutron-induced spectral gamma ray activity; this determines elemental weight fraction concentrations of a number of key rock-forming elements used to characterize geochemistry, mineralogy, and lithology of the formation.

In addition, calibrated gross gamma ray (GR) was recorded with every service for the purpose of correlating depths between the different logging runs. Table 2.1 summarizes the geophysical logging runs performed in R-27.

Table 2.1
Geophysical Logging Services, Their Combined Tool Runs and Intervals Logged, As Performed by Schlumberger in Borehole R-27

Date of Logging	Borehole Status	Run #	Tool 1	Tool 2	Tool 3	Tool 4	Depth Interval
25-Oct-2005	Open hole below 20 ft Bit size of 12.25 in. Steel surface casing above 20 ft. Casing ID of 16 in.	1	AIT (Bottom)	TLD	CNT	NGS (Top)	20–920 ft
Same	Same	2	FMI	GR			20–920 ft
26-Oct-2005	Same	3	CMR	GR			46–923 ft
Same	Same	4	ECS	GR			24–919 ft

A more detailed description of these geophysical logging tools can be found on the Schlumberger website (http://www.hub.slb.com/index.cfm?id=id11618).

3.0 METHODOLOGY

This section describes the methods Schlumberger employed for geophysical logging of R-27, including the following stages/tasks:

- Measurement acquisition at the well site
- Quality assessment of logs
- Reprocessing of field data

3.1 Acquisition Procedure

Once the well drilling project team notified Schlumberger that R-27 was ready for geophysical well logging, the Schlumberger district in Farmington, New Mexico (NM), mobilized a wireline logging truck, the appropriate wireline logging tools and associated equipment, and crew to the job site. Upon arriving at the site, the crew completed site-entry paperwork and received a site-specific safety briefing.

After arriving at the well site, the crew proceeded to rig up the wireline logging system, including:

1. Parking and stabilizing the logging truck in a position relative to the borehole that is best for performing the surveys

2. Setting up a lower and an upper sheave wheel (the latter attached to, and hanging above, the borehole from the drilling rig/mast truck)
3. Threading the wireline cable through the sheaves
4. Attaching to the end of the cable the appropriate sonde(s) for the first run

Next, pre-logging checks and any required calibrations were performed on the logging sondes, and the tool string was lowered into the borehole. If any of the tools required active radioactive sources (in this case, a neutron and gamma source for the CNT/ECS and TLD, respectively) the sources were taken out of their carrying shields and placed in the appropriate tool source-holding locations using special source-handling tools just before lowering the tool string. The tool string was lowered to the bottom of the borehole and brought up at the appropriate logging speed as measurements were made. At least two logging runs (one main and one repeat) were made with each tool string.

Upon reaching the surface, any radioactive sources were removed from the tools and were returned to their appropriate storage shields, thus eliminating any radiation hazards. Any post-logging measurement checks were performed as part of log quality control and assurance. The tool string was cleaned as it was pulled out of the hole, separated, and disconnected.

The second tool string was attached to the cable for another logging run, followed by subsequent tool strings and logging runs. After the final logging run was completed, the cable and sheave wheels were rigged down.

Before departure, the logging engineer printed field logs and created a compact disc containing the field log data for on-site distribution and sent the data via satellite to the Schlumberger data storage center. The Schlumberger data processing center was alerted that the data were ready for post-acquisition processing.

3.2 Log Quality Control and Assessment

Schlumberger has a thorough set of procedures and protocols for ensuring that the geophysical logging measurements are of very high quality. This includes full calibration of tools when they are first built, regular recalibrations and tool measurement/maintenance checks, and real-time monitoring of log quality as measurements are made. Indeed one of the primary responsibilities of the logging engineer is to ensure, before and during acquisition, that the log measurements meet prescribed quality criteria.

A tool-specific base calibration that directly relates the tool response to the physical measurement using the designed measurement principle is performed on all Schlumberger logging tools when first assembled in the engineering production centers. This is accomplished through a combination of computer modeling and controlled measurements in calibration models with known chemical and physical properties.

The base calibration for most Schlumberger tools is augmented through regular "master calibrations" typically performed every one to six months in local Schlumberger shops (such as Farmington, NM), depending on tool design. Master calibrations consist of controlled measurements using specially designed calibration tanks/jigs and internal calibration devices that

are built into the tools, both with known physical properties. The measurements are used to fine-tune the tool's calibration parameters and to verify that the measurements are valid.

In addition, on every logging job, before and after on-site "calibrations" are executed for most Schlumberger tools directly before/after lowering/removing the tool string from the borehole. For most tools, these represent a measurement verification instead of an actual calibration used to confirm the validity of the measurements directly before acquisition and to ensure that they have not drifted or been corrupted during the logging job.

All Schlumberger logging measurements have a number of associated depth-dependent quality control (QC) logs and flags to assist with identifying and determining the magnitude of log quality problems. These QC logs are monitored in real-time by the logging engineer during acquisition and are used in the post-acquisition processing of the logs to determine the best processing approach for optimizing the overall validity of the property estimates derived from the logs.

Additional information on specific tool calibration procedures can be found on the Schlumberger web page (http://www.hub.slb.com/index.cfm?id=id11618).

3.3 Processing Procedure

After the geophysical logging job was completed in the field and the data were archived, the data were downloaded to the Schlumberger processing center. There, the data were processed in the following sequence: (1) the measurements were corrected for near-wellbore environmental conditions and the measurement field processing for certain tools (CMR and ECS) was redone using better processing algorithms and parameters; (2) the log curves from different logging runs were depth matched and spliced; and (3) the near-wellbore substrate lithology/mineralogy and pore fluids were modeled through integrated log analysis. Separately, the FMI electrical image was processed to produce scaled and normalized high-resolution images that were interpreted to identify geologic features and compute fracture apertures. Afterwards, an integrated log montage was built to combine and compile all the processed log results.

3.3.1 Environmental Corrections and Raw Measurement Reprocessing

If required, the field log measurements were processed to correct for conditions in the well, including fluid type (water or air), presence of steel casing (not applicable for this well since the top of all logs is below the surface casing), and (to a much lesser extent) pressure, temperature, and fluid salinity. Basically, these environmental corrections entail subtracting from the measurement response the known influences of the set of prescribed borehole conditions. In R-27, the log measurements requiring these corrections are the CNT porosity, ECS elemental concentrations, and NGS spectral gamma ray logs.

Two CNT neutron porosity measurements are available – one that measures thermal ("slow") neutrons, and one that measures epithermal ("fast") neutrons. Measurement of epithermal neutrons is required to make neutron porosity measurements in air-filled holes. In water/mud-filled holes, both the CNT epithermal and thermal neutron measurements are valid, but the thermal neutron porosity has better statistical precision. Both epithermal and thermal neutron porosity measurements were made in R-27 since the borehole was partly water-filled (below 815

ft during the CNT logging) and partly air-filled (above 815 ft during the logging). Epithermal neutron porosity was processed at the field site for borehole fluid type (air versus water) and other environmental conditions and didn't require any further processing. The thermal neutron porosity measurement was reprocessed for borehole conditions, although the results were very similar to the field logs. For further processing and analysis (e.g., integrated log analysis), the reprocessed thermal neutron porosity log was used.

The raw ECS elemental yield measurements include the contribution of iron from steel casing and hydrogen from fluid in the borehole. The processing consists of subtracting this unwanted contribution from the raw normalized yield, then performing the normal elemental yields-to-weight fraction processing. The contribution to subtract is a constant baseline amount (or zoned constant values if there are bit/casing size changes), usually determined by comparing the normalized raw yields in zones directly below/above the borehole casing/fluid change. The ECS logs did not require any casing corrections since the log interval was entirely in uncased borehole. At the time of the ECS logging in R-27 the borehole contained water from bottom to 815 ft; no hydrogen correction was required in the air-filled section above 815 ft and the difference between the hydrogen yield above and below this depth was used to determine the baseline borehole hydrogen correction to apply below.

The NGS spectral gamma ray is affected by the material (fluid, air, and casing) in the borehole because different types and amounts of these materials have different gamma ray shielding properties; the NGS measures incoming gamma rays emitted by radioactive elements in the formation surrounding the borehole. The processing algorithms try to correct for the damping influence of the borehole material. The NGS logs from R-27 were reprocessed to fully account for the environmental effects of the borehole fluid (water below 815 ft and air above) and hole size.

The measurements cannot be fully corrected for borehole washouts or rugosity since the specific characteristics (e.g., geometry) of these features are unknown and their effects on the measurements are often too significant to account for. Thus, the compromising effects of these conditions on the measurements should be accounted for in the interpretation of the log results.

3.3.2 Depth-Matching and Splicing

Once the logs were environmentally corrected for the conditions in the borehole and the raw measurement reprocessing was completed, the logs from different tool runs were depth-matched to each other using the FMI tool run as the base reference. Gross gamma ray was used as the common correlation log measurement for depth-matching the different runs. The depth reference for all the processed logs is ground surface.

3.3.3 Integrated Log Analysis

An integrated log analysis, using as many of the processed logs as possible, was performed to model the near-wellbore substrate lithology/mineralogy and pore fluids. This analysis was performed using the Elemental Log Analysis (ELAN*) program (Mayer and Sibbit, 1980;

*Mark of Schlumberger

Quieren et al, 1986) – a petrophysical interpretation program designed for depth-by-depth quantitative formation evaluation from borehole geophysical logs. ELAN estimates the volumetric fractions of user-defined rock matrix and pore constituents at each depth based on the known log measurement responses to each individual constituent by itself[1]. ELAN requires an a priori specification of the volume components present within the formation, i.e., fluids, minerals, and rocks. For each component, the relevant response parameters for each measurement are also required. For example, if one assumes that quartz is a volume component within the formation and the bulk density tool is used, then the bulk density parameter for this mineral is well known to be 2.65 grams per cubic centimeter (g/cc).

The logging tool measurements, volume components, and measurement response parameters used in the ELAN analysis for R-27 are provided in Table 3.1. The final results of the analysis – an optimized mineral-fluid volume model – are shown on the integrated log montage, 3rd track from the right (inclusive of the depth track). In addition, the ELAN program provides a direct comparison of the modeled versus the actual measured geophysical logs, as well as a composite log of all of the key ELAN-derived results. To make best use of all the measurement data and to perform the analysis across as much of the well interval as possible (24 to 924 ft bgs), as many as possible of the processed logs were included in the analysis, with less weighting applied to less robust logs. Not all of the tool measurements shown in Table 3.1 and the ELAN modeled versus measured log display are used for the entire interval analyzed, as not all the measurements are available, or of good quality, across certain sections of the borehole. To accommodate fewer tool measurements, certain model constituents are removed from the analysis in some intervals. Most notably, above 46 ft bgs capillary bound water had to be removed because no CMR measurement is available (CMR has the only measurement that is independently sensitive to bound water).

The ELAN analysis was performed with as few constraints or prior assumptions as possible. A considerable effort was made to choose a set of minerals or mineral types for the model that is representative of Los Alamos area geology and its volcanic origins. For the ELAN analysis, the log interval from 24 to 530 ft bgs was assumed to be tuff or pumice, and a mineral suite considered representative of this volcanic tuff, based on LANL cuttings mineral analysis, was used (primary "minerals" silica glass/cristobalite/tridymite [indistinguishable from the log measurements], quartz, potassium feldspar, and montmorillinite, with accessory minerals augite, calcite, and pyrite). The log intervals 530 to 637 and 764 to 924 ft bgs were assumed to be in the Puye Formation, or fanglomerate, with similar composition, and a mineral suite considered representative of this geology, based on LANL cuttings mineral analysis, was used (primary "minerals" silica glass/cristobalite/tridymite [indistinguishable from the log measurements], plagioclase and potassium feldspar; quartz at a defined small fraction of the silica glass content; variable amounts of montmorillinite clay; with possible accessory/trace minerals biotite, hematite, augite, hypersthene, heavy mafic minerals, and pyrite). The log interval 637 to 764 ft bgs was assumed to be basaltic lava flows/material with a possible mineral suite of plagioclase and potassium feldspar, augite, hypersthene, heavy mafic minerals (such as magnetite), montmorillinite, quartz, hematite, and pyrite – also guided by LANL cuttings mineral analysis.

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[1]Mathematically this corresponds to an inverse problem – solving for constituent volume fractions from an (over)determined system of equations relating the measured log results to combinations of the tool measurement response to individual constituents.

Table 3.1
Tool Measurements, Volumes, and Respective Parameters Used in the R-27 ELAN Analysis

Volume / Tool Measurement	Air	Capillary Bound Water	Water	Hypersthene	Hematite	Labradorite	Silica Glass, Cristo., Tridy.	Heavy Mafic Minerals	Augite	Montmorillinite	Biotite	Pyrite	Orthoclase	Calcite	Quartz
Bulk density (g/cc)	-0.19	1.00	1.00	3.55	5.161	2.68	2.33	4.4	3.08	2.02	3.04	4.99	2.54	2.71	2.64
Thermal neutron poro. (nonlinear) (ft^3/ft^3)	0	1.00	1.00	0.036	0.126	-0.01	-0.03	0.07	0.015	0.65	0.15	0.01	-0.01	0.0	-0.02
Epithermal neutron poro. (ft^3/ft^3)	0	1.00	1.00	0.012	0.055 6	-0.01	0.0	0.022	-0.01	0.5	0.14	0.165	-0.01	0.0	-0.05
Volumetric photoelectric effect (unitless)	0	0	0.40	20.2	107.3	7.32	4.2	83	23.8	4.4	21.6	82.1	7.3	14.1	4.78
Total CMR porosity (ft^3/ft^3)	0	1.0	1.0	0	0	0	0	0	0	0.5	0	0	0	0	0
CMR bound fluid volume (ft^3/ft^3)	0	1.0	0	0	0	0	0	0	0	0.5	0	0	0	0	0
Resistivity (ohm-m)	Very high	9.76	4.88	Very high	Very high	Very high	Very high	Very high	Very high	Com-puted	Very high	Very high	Very high	Very high	Very high
Dry weight silicon (lbf/lbf)	0.0	0.0	0.0	0.24	0.0	0.247	0.468	0.184	0.225	0.242	0.178	0.0	0.3	0.0	0.468
Dry weight calcium (lbf/lbf)	0.0	0.0	0.0	0.0	0.0	0.09	0.0	0.0	0.10	0.012	0.007	0.0	0.0	0.405	0.0
Dry weight iron (lbf/lbf)	0.0	0.0	0.0	0.20	0.699	0.023	0.0	0.22	0.112	0.02	0.199	0.466	0.015	0.0	0.0
Dry weight aluminum (lbf/lbf)	0.0	0.0	0.0	0.0	0.0	0.162	0.0	0.0	0.018	0.103	0.081	0.0	0.104	0.0	0.0
Dry weight sulfur (lbf/lbf)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.535	0.0	0.0	0.0
Dry weight titanium (lbf/lbf)	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.0	0.048	0.001	0.016	0.0	0.0	0.0	0.0
Wet weight potassium (lbf/lbf)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.003	0.004	0.070	0.0	0.12	0.0	0.0
Weight hydrogen (lbf/lbf)	0.0	0.111	0.111	0.0	0.0	0.0	0.01	0.0	0.0	0.022	0.003	0.0	0.0	0.0	0.0
Wet weight thorium (ppm)	0	0	0	13.5	0	1.75	2	4	13.5	24	25	0	5	0	0
Clay bound water volume (ft^3/ft^3)	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0
Magnetic field variation (mT)	0	0	0	0	10	0	0	2	0	0	0	1	0	0	0

gAPI = gamma ray API (American Petroleum Institute) standard unit
ft^3 = cubic feet
ppm = parts per million
mT = milli-Tesla
lbf = pounds force
ohm-m = ohm x meters
g/cc = grams per cubic centimeter

The results of laboratory analyses of Bandelier Tuff and Puye Formation samples from around the LANL site were also used to constrain the proportion of quartz versus the combination of glass/cristobalite/tridymite in the ELAN analysis.

No prior assumption is made about water saturation – where the boundary between saturated and unsaturated zones lies (e.g., the depth to the top of the regional aquifer or perched zones). Thus, the presence and amount of air in the pore space is unconstrained. Total porosity and water-filled porosity are also left unconstrained throughout the analysis interval, despite the obvious influence on the log response of borehole washouts. There is no way to objectively correct for the adverse effect on the log measurements from these borehole conditions; therefore the decision was made to perform the ELAN analysis so as to honor the log measurements. Accordingly, interpretations should be made from the ELAN results with the understanding that the mineral-fluid model represents a mathematically optimized solution that is not necessarily a physically accurate representation of the native geologic formation. Within this context, the ELAN model is a robust estimate of the bulk mineral-fluid composition that accounts for the combined response from all the geophysical measurements.

4.0 RESULTS

Preliminary results from the wireline geophysical logging measurements acquired by Schlumberger in R-27 were generated in the logging truck at the time the geophysical services were performed and were documented in the field logs provided on site. However, the measurements presented in the field results are not fully corrected for undesirable (from a measurement standpoint) borehole and geologic conditions and are provided as separate, individual logs. The field log results have been processed (1) to correct/improve the measurements, as much as possible, for borehole/formation environmental conditions, and (2) to depth-match the logs from different tool runs in the well. Additional logs were generated from integrated analysis of processed measured logs, providing valuable estimates of key geologic and hydrologic properties.

The processed log results are presented as continuous curves of the processed measurement versus depth and are displayed as (1) a one-page, compressed summary log display for selected directly related sets of measurements (see Figures 4.1, 4.2, and 4.3); and (2) an integrated log montage that contains all the key processed log curves, on depth and side by side. The summary log displays address specific characterization needs, such as moisture content, water saturation, and lithologic changes. The purpose of the integrated log montage is to present, side by side, all the most salient processed logs and log-derived models, depth-matched to each other, so that correlations and relationships between the logs can be identified.

Important results from the processed geophysical logs in R-27 are described below.

4.1 Well Fluid Level

The standing water level in R-27 was stable during the October 25-26, 2005 logging, remaining between 814 and 816 ft bgs for all four logging runs.

4.2 Regional Aquifer

The processed geophysical logs indicate fully-water saturated conditions below 818 ft bgs. The estimated pore volume water saturation (fraction of the total pore volume containing water) computed from the ELAN analysis is very high (90-100%, mostly above 95%) from 818 ft bgs to the bottom of the log interval (924 ft bgs), compared with primarily 30-60% in the interval directly above (762 to 816 ft bgs). The estimate is similarly high when computed directly from bulk density and ELAN water-filled porosity for a grain density range of 2.35 to 2.55 g/cc (tuff section), 2.45 to 2.65 g/cc (fanglomerate sections), and 2.75 to 2.95 g/cc (basalt section). The processed log results indicate that the water saturation increases again above 762 ft bgs – ranging mostly 60-100% from 676 to 762 ft bgs. Based on the logs, this zone is composed of very competent, mostly low porosity basaltic rock that could retain small amounts water (enough to be fully-water saturated). Thus, this zone is likely not part of the regional aquifer. Above 676 ft bgs the processed logs show an increase in total porosity and a corresponding decrease in estimated water saturation, the latter remaining well below 100% (mostly below 60%) all the way up to the top log interval.

These overall results suggest that the regional aquifer groundwater level likely resides at approximately 818 ft bgs in this location, with the regional aquifer itself below.

The log-derived estimates of water-filled and total porosity[2], which are equivalent in the fully-water saturated section, vary widely (12-70%), but predominantly range 20-40%, across the section of the log interval that intersects the apparent Regional Aquifer (818 to 924 ft bgs). Key hydrogeologic characteristics observed from the processed continuous logs across this depth section are described below, zoned based on intervals that have similar characteristics (referenced to depth below ground surface):

- **818–825 ft:** This zone has low to moderate total and water-filled porosity (18-27% of total rock volume, as estimated from the ELAN integrated log analysis), although much of the pore space appears to be effective (estimated effective porosity of 10-20% of total rock volume). As a result of the high effective porosity, the estimated hydraulic conductivity is also quite high. Based on the ELAN results and visual inspection of the FMI electrical image log, this interval is composed of very large-grained and well-sorted alluvial sediments.

- **825–830 ft:** Total and water-filled porosity is significantly lower than the directly adjacent section above (16-21% of total rock volume), as is estimated effective porosity (8-16% of total rock volume). Based on the ELAN results and FMI image log, this interval is a continuation of the fanglomerate sequence from above, but has visually smaller and not as well-sorted grain size.

- **830–833 ft:** This thin zone is characterized by a localized peak in total and water-filled porosity (maximum of 32% of total rock volume), as well as estimated effective

[2] Water-filled porosity is defined in this report as the fraction of the total rock volume occupied by water. Total porosity is defined as fraction of the total rock volume occupied by water plus air, plus any other fluid or gas (non-solid).

porosity (maximum of 22% of total rock volume). These values may be elevated due to a washout across the zone. Based on the ELAN results and FMI image log, this interval is a continuation of the fanglomerate sequence from above, with visibly well-rounded pebbles and cobbles.

- **833–837 ft:** This zone is a continuation of the saturated fanglomerate sequence from above, with relatively low total and water-filled porosity (21-25% of total rock volume) and estimated effective porosity that increases steadily with depth from 8 to 14%(top to bottom). The FMI image visually shows that this zone has a smaller grain size than the zone above.

- **837–840 ft:** This zone has similar total and water-filled porosity to the zone above (23% of total rock volume), but higher estimated effective porosity (maximum of 19% of total rock volume). Based on the ELAN results and FMI image log, this interval is a continuation of the saturated fanglomerate sequence from above, with visibly very large angular cobbles/boulders below 838.5 ft bgs.

- **840–844 ft:** This zone is characterized by a significant low in total/water-filled and estimated effective porosity (minimum of 12% and 0% of total rock volume, respectively). The ELAN results and FMI image indicate the zone is a continuation of the saturated fanglomerate sequence above, with very large angular cobbles/boulders.

- **844–847 ft:** This thin zone is a characterized by a localized peak in total/water-filled and estimated effective porosity (maximum 28% and 18% of total rock volume, respectively). The processed FMI image visually shows this zone is continuation of the saturated fanglomerate sequence above, with large sub-angular to rounded cobbles/boulders.

- **847–851 ft:** This thin zone is a continuation of the saturated fanglomerate sequence from above, with relatively low total/water-filled and estimated effective porosity (20-23% and 7-12% of total rock volume, respectively). The processed FMI image visually shows large angular to sub-angular cobbles and boulders.

- **851–855 ft:** This zone is characterized by a large peak in total/water-filled and effective porosity (maximum of 47% and 39% of total rock volume, respectively). These values may be elevated due to a washout across the zone. Based on the ELAN results and FMI image log, this interval is a continuation of the saturated fanglomerate sequence from above, with visibly smaller grain size than the zone above, but more rounded cobbles and pebbles.

- **855–862 ft:** This zone is a continuation of the saturated fanglomerate sequence from above, with moderate total/water-filled porosity (22-32% of total rock volume) and high estimated effective porosity (15-25% of total rock volume). The estimated hydraulic conductivity, based on these porosity values, is relatively high. The processed FMI image visually shows this zone has a large well-sorted grain size, with well-rounded pebbles and cobbles.

- **862–869.5 ft:** This zone is characterized by a significant decrease in total/water-filled and estimated effective porosity (20-25% and 8-11% of total volume, respectively) – compared to the zone directly above. The ELAN analysis model results and the FMI image indicate that this zone is a continuation of the saturated fanglomerate sequence from above, but with visibly smaller and less well-sorted grain size.

- **869.5–882 ft:** This zone has high total/water-filled and estimated effective porosity (32-43% and 15-27% of total rock volume, respectively) and moderately high estimated effective porosity (10-19% of total rock volume). Based on the ELAN results and processed FMI image log, this interval is a continuation of the saturated fanglomerate sequence from above, with no visually identifiable cobbles or boulders, but scattered well-rounded pebbles.

- **882–893 ft:** This zone has similar total/water-filled porosity as the zone above (33-40% of total rock volume), but significantly lower estimated effective porosity (12-18% of total rock volume). The ELAN analysis model results and the FMI electrical image log indicate that this zone has visually smaller grain size than zones above, contains clay (clay is identifiable on the FMI image by lower resistivity and darker image color), and, thus, is likely not very productive.

- **893–899 ft bgs:** This zone is characterized by unrealistically high total/water-filled and effective porosity (maximum of about 90% and 75% of total rock volume, respectively). These values are undoubtedly elevated due to a very large washout across this zone. Thus, actual formation properties are very difficult to determine from the log results.

- **899–907 ft bgs:** Total/water-filled and estimated effective porosity decrease steadily with depth from a high of 43% and 28% of total rock volume, respectively, at the top to 22% and 12%, respectively, at the bottom. Based on the ELAN results and processed FMI image log, this interval is a continuation of the saturated fanglomerate sequence from above, with no visually identifiable cobbles or boulders, but scattered rounded pebbles.

- **907–911 ft bgs:** This zone is characterized by a low in total/water-filled and estimated effective porosity (minimum of 20% and 6% of total rock volume, respectively). The ELAN analysis model results and the FMI electrical image log indicate that this zone has visibly smaller grain size than zones above, contains clay, and, thus, is likely not very productive.

- **911–915 ft bgs:** This zone is a continuation of the saturated fanglomerate from above and is characterized by a localized peak in total/water-filled and estimated effective porosity (maximum of 40% and 22% of total rock volume, respectively). The processed FMI image visually shows this zone has a large grain size, with rounded pebbles and cobbles.

- **915–919.5 ft bgs:** This zone has moderate total/water-filled porosity (28% of total rock volume), but relatively low estimated effective porosity (10-12% of total rock

volume). The processed FMI image delineates a visibly clay-rich bed from 917.5 to 919.5 ft bgs.

- **919.5–924 ft bgs:** This zone is characterized by unrealistically high total/water-filled and effective porosity (maximum of 63% and 60% of total rock volume, respectively). These values are undoubtedly elevated due to a very large washout across this zone. Thus, actual formation properties are very difficult to determine from the log results.

4.3 Vadose Zone Perched Water

Above 818 ft bgs (the estimated apparent regional aquifer ground water level from the processed geophysical logs), the processed geophysical logs indicate highly variable total and water-filled porosity, ranging from 4 to 67% of total rock volume. Most of the zones that have unrealistically high porosity values (above 50% of total rock volume) contain large borehole washouts, where the porosity measurements are severely influenced by the large volume of air-filled borehole surrounding the sensors on the logging tools. The estimated water saturation is also highly variable, ranging from 8 to 100%. Key vadose zone hydrogeologic characteristics observed from the processed continuous logs across the vadose zone depth section of the valid log interval (22 to 818 ft bgs) are described below, zoned based on intervals that have similar characteristics (referenced to depth below ground surface):

- **815–818 ft bgs:** Total porosity and water-filled porosity range 20-23% and 15-23% of total rock volume, respectively, resulting in water saturations of 58-100% (full water saturation occurring at 818 ft bgs.

- **812–815 ft bgs:** This thin zone is characterized by very low total and water-filled porosity, dropping to 10% and 6% of total rock volume, respectively. Based on the ELAN mineralogy/lithology analysis results this zone appears to be within the fanglomerate/fanglomerate section. Possibly the low porosity is a result of significant cementation of the sediments.

- **806–812 ft bgs:** Total porosity and water-filled porosity range 21-30% and 10-17% of total rock volume, respectively, resulting in water saturations of 33 to 63%.

- **764–806 ft bgs:** This zone is characterized by relatively high total porosity (30-50% of total rock volume, mostly around 35%) and higher water-filled porosity than the directly adjacent section (10-20% of total rock volume, mostly around 17%). Corresponding water saturation ranges 22-62%, mostly around 45%.

- **752–764 ft bgs:** Total and water-filled porosity are dramatically lower in this zone compared to the section below, averaging about 11% and 7% of total rock volume, respectively. The ELAN results indicate this zone is part of competent basalt lava section. Estimated water saturation ranges 50-90%.

- **748–752 ft bgs:** This thin zone is characterized by a localized increase in total porosity to 21% of total rock volume. Water-filled porosity is about 5% of total volume, resulting in a water saturation of about 27%. The ELAN results indicate this zone is a continuation of the basalt lava section from below, the higher porosity

possibly related to more fractures in the basalt at this depth than in the surrounding section.

- **704–748 ft bgs:** This zone is a continuation of the basalt lava section from below and is characterized by very low total and water-filled porosity (6-12% and 6-9%, respectively). Estimated water saturation ranges 60-100%. At these low porosities the water saturation estimate is very sensitive to slight variations in water content. The results may indicate that the solid, largely impermeable basalt is retaining what little water it can hold.

- **700.5–704 ft bgs:** This thin zone is characterized by a localized increase in total porosity to about 33% of total rock volume. Water-filled porosity remains at about 8% of total volume, resulting in a drop in water saturation to 25%. The ELAN results indicate this zone is a continuation of the basalt lava section from below, the higher porosity possibly related to more fractures in the basalt at this depth than in the surrounding section.

- **676–700.5 ft bgs:** This zone is a continuation of the basalt lava section from below and is characterized by low total and water-filled porosity (11-19% and 10%, respectively). Estimated water saturation ranges 57-100%, mostly below 90%. At these low porosities the water saturation estimate is very sensitive to slight variations in water content. The results may indicate that the solid, largely impermeable basalt is retaining what little water it can hold.

- **639–676 ft bgs:** This zone is characterized by a significant increase in total and water-filled porosity (21-45% and 15-19% of total rock volume, respectively) compared to the section directly below. Estimated water saturation ranges 50-78%. The ELAN results indicate this zone is a continuation of the basalt lava sequence from below, but is likely a rubble/breccia zone based on the high porosity. The results also show the zone contains a significant amount of clay.

- **634–639 ft bgs:** This zone is characterized by a peak in water-filled porosity (reaching 30% of total rock volume), along with high total porosity (37-50% of total rock volume), resulting in an estimated water saturation high of close to 80%. The ELAN results indicate a clay-rich basalt lithology at this depth, which could account for the high water content (clay acting to retain water).

- **578–634 ft bgs:** This zone is characterized by highly variable total porosity (29-67% of total rock volume) that likely is related to/exasperated by severe, highly irregular borehole washouts that occur across this interval. Water-filled porosity ranges 6-20% of total rock volume, resulting in an estimated water saturation range of 13-38%. The ELAN results indicate the lithology across this zone is heterogeneous fanglomerate containing clay, with higher clay content correlating with higher water content.

- **573–578 ft bgs:** Water-filled porosity is much higher in this zone (25-30% of total rock volume) compared with the directly surrounding section. Total porosity ranges 43-55% of total volume and water saturation peaks at 68%. As with the zone below,

severe, highly irregular washouts occur across this interval – likely causing elevated total porosity results from the geophysical logs. The ELAN results indicate the lithology is a continuation of the heterogeneous fanglomerate containing clay from below.

- **530–573 ft bgs:** This zone is characterized by highly variable total porosity (30-63% of total rock volume) that likely is related to/exasperated by severe, highly irregular borehole washouts that occur across this interval. Water-filled porosity is low, ranging 5-12% of total rock volume, resulting in an estimated water saturation range of 12-43%. The ELAN results indicate the lithology across this zone is a continuation of the heterogeneous fanglomerate containing clay from below.

- **526–530 ft bgs:** This zone is characterized by a peak in water-filled porosity (reaching 34% of total rock volume) and very high total porosity (43-48% of total rock volume), resulting in a water saturation of 78%. The geophysical log response, seen in many other Los Alamos wells, is characteristic of the bottom of the Guaje Pumice bed. The ELAN results indicate the lithology is a high porosity, siliceous volcanic tuff.

- **522–526 ft bgs:** This zone is distinguished by very high porosity (47% of total rock volume) that is slightly higher than the section above – possibly representing the top of the Guaje Pumice Bed. Water-filled porosity is 20% of total rock volume, resulting in a water saturation of 43%. The ELAN results indicate the lithology is the continuation of a high porosity, siliceous volcanic tuff from below.

- **387–522 ft bgs:** This zone is characterized by fairly uniform, very high porosity (42-48% of total rock volume) and fairly uniform, moderate water-filled porosity that generally trends slightly lower with decreasing depth (20% of total volume at bottom and 18% at the top). Water saturation ranges 30-43%. The ELAN results indicate the lithology is the continuation of a high porosity, siliceous volcanic tuff from below.

- **346–387 ft bgs:** This zone is very similar to the zone directly below, but can be distinguished by a slight increase in water-filled porosity (20-21% of total volume near the bottom decreasing to 18% at the top). Total porosity ranges 43-47% of the total volume and water saturation averages about 42%. The ELAN results indicate the lithology is the continuation of a high porosity, siliceous volcanic tuff from below.

- **336–346 ft bgs:** Total porosity is highly variable, reaching 61% of the total rock volume across the depth interval where there is a severe borehole washout; otherwise total porosity is around 41%. Water-filled porosity is significantly lower in this zone (6-17% of total volume) than in the surrounding section – also possibly a consequence of the large washout. The ELAN results indicate the lithology is the continuation of a high porosity, siliceous volcanic tuff from below.

- **225–336 ft bgs:** This zone is characterized by fairly uniform, very high porosity (45% of total rock volume) and water-filled porosity that generally trends higher with decreasing depth (around 12% of total volume at bottom and 22% at the top). Water

saturation ranges 30-50%. The ELAN results indicate the lithology is the continuation of a high porosity, siliceous volcanic tuff from below.

- **160–225 ft bgs:** This zone is characterized by very high porosity that generally trends lower with decreasing depth (around 44% of total volume at bottom and 40% near the top). Water-filled porosity follows the same trend – decreasing from 23% at the bottom to 10% at the top. Water saturation ranges 23-50%. The ELAN results indicate the lithology is the continuation of a high porosity, siliceous volcanic tuff from below.

- **82–160 ft bgs:** This zone is characterized by fairly uniform, very high porosity (40-43% of total rock volume) and fairly uniform water-filled porosity (11-15% of total rock volume) that generally trends higher with decreasing depth (around 12% of total volume at bottom and 22% at the top). Water saturation ranges 25-47%. The ELAN results indicate the lithology is the continuation of a high porosity, siliceous volcanic tuff from below.

- **29–82 ft bgs:** This zone is distinguished by very high porosity (44-54% of total rock volume) that is slightly higher than the section below. Water-filled porosity mostly ranges 12-16% of total rock volume, resulting in a water saturation range of 20-42%. The ELAN results indicate the lithology is most likely a continuation of the high porosity, siliceous volcanic tuff from below.

- **24–29 ft bgs:** This zone is characterized by a decrease in total porosity (32-40% of total rock volume) and an increase in water-filled porosity (20-32% of total rock volume) compared to the section directly below. Consequently, the estimated water saturation is much highly, mostly ranging from 70% to close to 100%. The processed geochemical logs and ELAN results seem to indicate that there is a change in lithology from the underlying section, most interestingly showing a large increase in calcium/calcite concentration. These results suggest that the zone may contain a large amount of calcite cementation – quite possibly related to the installation of the surface casing directly above.

4.4 Geology

The processed geophysical log results clearly delineate the geologic material and most of the formation contacts intersected by R-27 across the log interval (from 24 to 923 ft bgs). The generalized geologic stratigraphy observed from the logs across the measured interval is as follows (depth below ground surface):

- **24–29 ft bgs (top of processed log interval): Relatively high porosity calcium-rich material (possibly related to installation of the surface casing directly above)** – characterized by relatively high total porosity (32-40% of total rock volume) and high calcite content (or other calcium-bearing minerals)

- **29–82 ft bgs: Very high porosity volcanic tuff** – characterized by very high total porosity (44-54% of total rock volume); high silica glass/tridymite/cristobalite and potassium feldspar content; minor amounts of quartz, augite (or similar minerals) and

calcite (or other calcium-bearing minerals); and variably minor amounts of clay (particularly from 78 to 82 ft bgs)

- **82–225 ft bgs: Homogeneous, very high porosity volcanic tuff** – characterized by uniformly very high total porosity (40-44% of total rock volume); high silica glass/tridymite/cristobalite and potassium feldspar content; and minor amounts of quartz, augite (or similar minerals) and calcite (or other calcium-bearing minerals)

- **225–336 ft bgs: Homogeneous, very high porosity volcanic tuff** – characterized by uniformly very high total porosity (45% of total rock volume); high silica glass/tridymite/cristobalite and potassium feldspar content; and minor amounts of quartz, augite (or similar minerals) and calcite (or other calcium-bearing minerals)

- **336–346 ft bgs: Variable, very high porosity volcanic tuff** – characterized by very high, highly varying total porosity (41-61% of total rock volume, but anomalously high porosity likely associated with washouts); high silica glass/tridymite/cristobalite and potassium feldspar content; minor amounts of quartz, augite (or similar minerals) and calcite (or other calcium-bearing minerals); and variably trace amounts of clay

- **346–522 ft bgs: Homogeneous, very high porosity volcanic tuff** – characterized by very high total porosity (43-48% of total rock volume); high silica glass/tridymite/cristobalite and potassium feldspar content; and minor amounts of quartz, augite (or similar minerals) and calcite (or other calcium-bearing minerals)

- **522–530 ft bgs: Very high porosity volcanic tuff/pumice** – characterized by very high total porosity (43-48% of total rock volume); high silica glass/tridymite/cristobalite and potassium feldspar content; and minor amounts of quartz, augite (or similar minerals) and calcite (or other calcium-bearing minerals)

- **530–614 ft bgs: Very high and variable porosity heterogeneous fanglomerate** – characterized by highly variable total porosity (29-67% of total rock volume, but anomalously high porosity likely associated with washouts); high silica glass/tridymite/cristobalite content; variably moderate plagioclase and potassium feldspar content; variably minor to small amounts of clay, augite, hypersthene, and/or heavy mafic minerals; and variably trace to minor amounts of quartz, biotite, and/or hematite

- **614–639 ft bgs: Very high and variable porosity heterogeneous, clay-rich fanglomerate** – characterized by highly variable total porosity (2-50% of total rock volume, but anomalously high porosity likely associated with washouts); high silica glass/tridymite/cristobalite content; variably moderate to high clay and plagioclase and potassium feldspar content; and variably minor amounts of augite, hypersthene, heavy mafic minerals, biotite, quartz, and/or hematite

- **639–676 ft bgs: Relatively high porosity, clay-rich basalt (likely fractured breccia/rubble zone)** – characterized by relatively high total porosity (21-45% of total rock volume); high plagioclase feldspar content; small to moderate potassium

feldspar, clay, augite, hypersthene, and/or heavy mafic minerals content; and variably trace amounts of hematite

- **676–700.5 ft bgs: Low porosity basalt** – characterized by relatively low total porosity (11-19% of total rock volume); high plagioclase feldspar content; small to moderate potassium feldspar, augite, hypersthene, and/or heavy mafic minerals content; and variably trace amounts of hematite
- **700.5–704 ft bgs: High porosity basalt (likely fractured breccia/rubble zone)** – characterized by high total porosity (33% of total rock volume); high plagioclase feldspar content; small to moderate potassium feldspar, augite, hypersthene, and/or heavy mafic minerals content; and variably trace amounts of hematite
- **704–748 ft bgs: Very low porosity basalt** – characterized by very low total porosity (6-12% of total rock volume); high plagioclase feldspar content; small to moderate potassium feldspar, augite, hypersthene, and/or heavy mafic minerals content; and variably trace amounts of hematite and/or clay
- **748–752 ft bgs: Relatively high porosity basalt (likely fractured zone)** – characterized by relatively high total porosity (21% of total rock volume); high plagioclase feldspar content; small to moderate potassium feldspar, augite, hypersthene, and/or heavy mafic minerals content; and variably trace amounts of hematite and/or clay
- **752–764 ft bgs: Low porosity basalt** – characterized by low total porosity (11% of total rock volume); high plagioclase feldspar content; small to moderate potassium feldspar, augite, hypersthene, and/or heavy mafic minerals content; and variably trace amounts of hematite and/or clay
- **764–798 ft bgs: High porosity fanglomerate** – characterized by high total porosity (30-40% of total rock volume); high silica glass/tridymite/cristobalite and plagioclase feldspar content; moderate potassium feldspar content; minor to small amounts of augite and clay; and variably trace to minor amounts of hypersthene, biotite, heavy mafic minerals, and/or quartz
- **798–807 ft bgs: High and variable porosity fanglomerate containing clay)** – characterized by highly variable total porosity (30-50% of total rock volume); variably moderate to high silica glass/tridymite/cristobalite and plagioclase and potassium feldspar content; small to moderate clay content; and variably minor to small amounts of augite; hypersthene, biotite, heavy mafic minerals, and/or quartz
- **807–812 ft bgs: Moderate porosity (fanglomerate)** – characterized by moderate total porosity (21-30% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>812–815 ft bgs</u>: Very low porosity (fanglomerate)** – characterized by very low total porosity (10% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>815–825 ft bgs</u>: Moderate porosity (likely fanglomerate)** – characterized by moderate total porosity (18-27% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>825–830 ft bgs</u>: Relatively low porosity (likely fanglomerate)** – characterized by relatively low total porosity (16-21% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>830–833 ft bgs</u>: Relatively high porosity (likely fanglomerate)** – characterized by relatively high total porosity (32% of total rock volume, possibly elevated due to presence of washout); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>833–840 ft bgs</u>: Moderate porosity (likely fanglomerate)** – characterized by moderate total porosity (21-25% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>840–844 ft bgs</u>: Very low porosity (likely fanglomerate)** – characterized by very low total porosity (12% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>844–847 ft bgs</u>: Relatively high porosity (likely fanglomerate)** – characterized by relatively high total porosity (28% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>847–851 ft bgs</u>: Moderate porosity (likely fanglomerate)** – characterized by moderate total porosity (20-23% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>851–855 ft bgs</u>: Very high porosity (likely fanglomerate)** – characterized by very high total porosity (47% of total rock volume, possibly elevated due to presence of washout); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>855–862 ft bgs</u>: Relatively high porosity (likely fanglomerate)** – characterized by relatively high total porosity (22-32% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>862–869.5 ft bgs</u>: Moderate porosity (likely fanglomerate)** – characterized by moderate total porosity (20-25% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>869.5–882 ft bgs</u>: High porosity (likely fanglomerate)** – characterized by high total porosity (32-43% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>882–893 ft bgs</u>: High porosity (likely fanglomerate containing clay)** – characterized by high total porosity (33-40% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; small amounts of clay; and variably trace to minor amounts of augite, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>893–899 ft bgs</u>: Large borehole washout (likely in fanglomerate)** – characterized by unrealistically high total porosity (90% of total rock volume, elevated due to presence of washout); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>899–907 ft bgs</u>: High porosity (likely fanglomerate)** – characterized by high total porosity (28-43% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **<u>907–911 ft bgs</u>: Relatively low porosity (likely fanglomerate containing clay)** – characterized by relatively low total porosity (20% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; small amounts of clay; and variably trace to minor amounts of augite, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **911–915 ft bgs: High porosity (likely fanglomerate)** – characterized by high total porosity (40% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **915–919.5 ft bgs: Relatively high porosity (likely fanglomerate)** – characterized by relatively high total porosity (28% of total rock volume); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

- **919.5–924 ft bgs (bottom of log interval): Large borehole washout (likely in fanglomerate)** – characterized by unrealistically high total porosity (63% of total rock volume, elevated due to presence of washout); high silica glass/tridymite/cristobalite content; moderate plagioclase and potassium feldspar content; and variably trace to minor amounts of augite, clay, hypersthene, biotite, heavy mafic minerals, and/or quartz

4.5 Summary Logs

Three summary log displays have been generated for R-27 to highlight the key hydrogeologic and geologic information provided by the processed geophysical log results:

- Porosity summary log showing continuous hydrogeologic property logs, including total and moveable water content and water saturation; highlights hydrologic information obtained from the integrated log results (Figure 4.1)

- Density and clay content summary showing a continuous logs of formation bulk density and estimated grain density, as well as photoelectric factor (sensitive to mineralogy) and estimated clay volume; highlights key geologic rock matrix information obtained from the log results (Figure 4.2)

- Spectral natural gamma ray and lithology summary showing a high vertical resolution, continuous volumetric analysis of formation mineral and pore fluid composition (based on an integrated analysis of the logs), and key lithologic/stratigraphic correlation logs from the spectral gamma ray measurement (concentrations of gamma-emitting elements); highlights the geologic lithology, stratigraphy, and correlation information obtained from the log results (Figure 4.3)

4.6 Integrated Log Montage

This section summarizes the integrated geophysical log montage for R-27. The montage is provided on the report CD. A description of each log curve in the montage follows, organized under the heading of each track, starting from track 1 on the left-hand side of the montage. Note that the descriptions in this section focus on what the curves are and how they are displayed; the specific characteristics and interpretations of the R-27 geophysical logs are provided in the previous section.

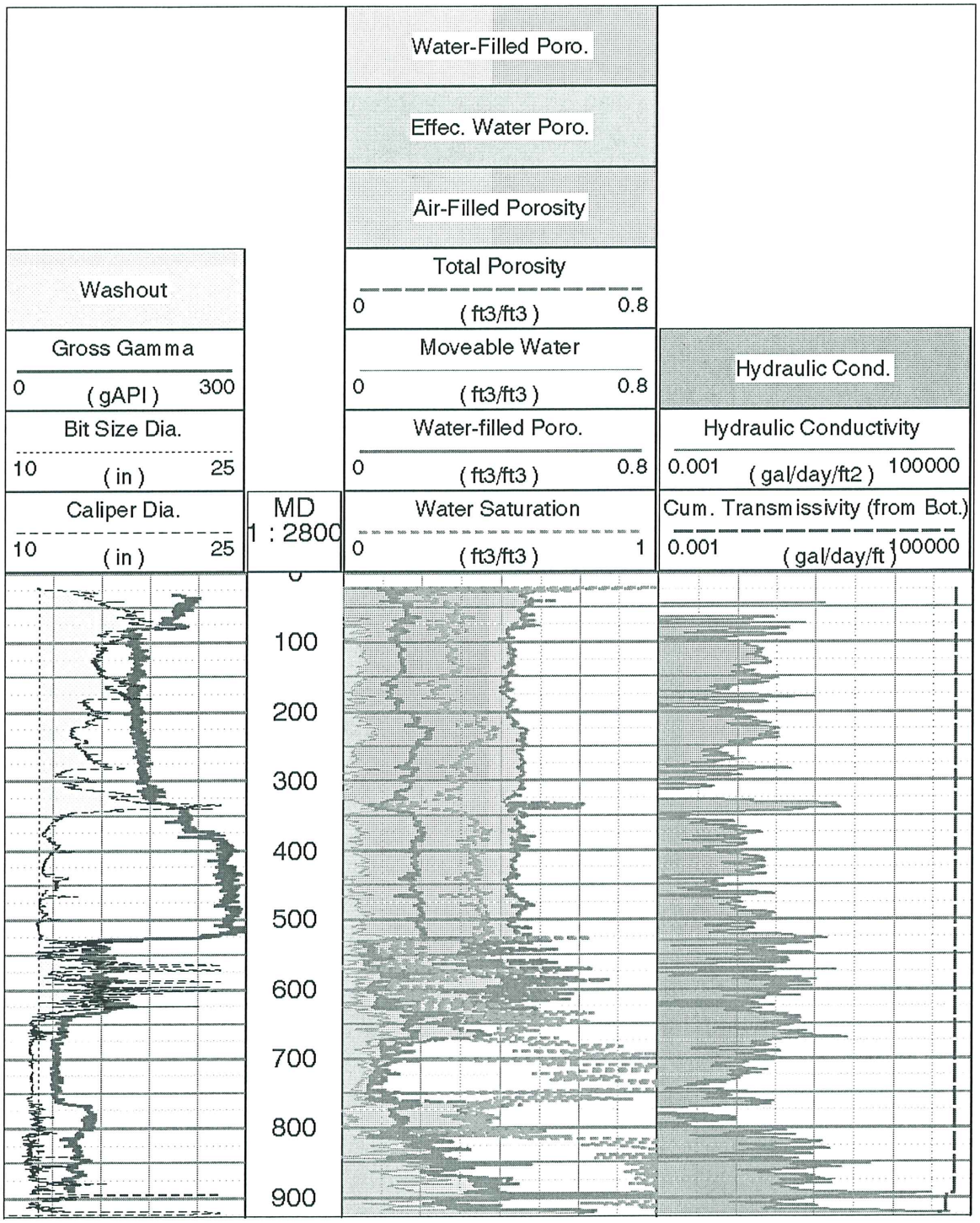

Figure 4.1. Summary of porosity logs in R-27 borehole from processed geophysical logs, interval of 24 to 923 ft bgs, with caliper, gross gamma, water saturation, water hydraulic conductivity, and transmissivity logs. Porosity, water saturation, and hydraulic conductivity logs are derived from the ELAN integrated log analysis.

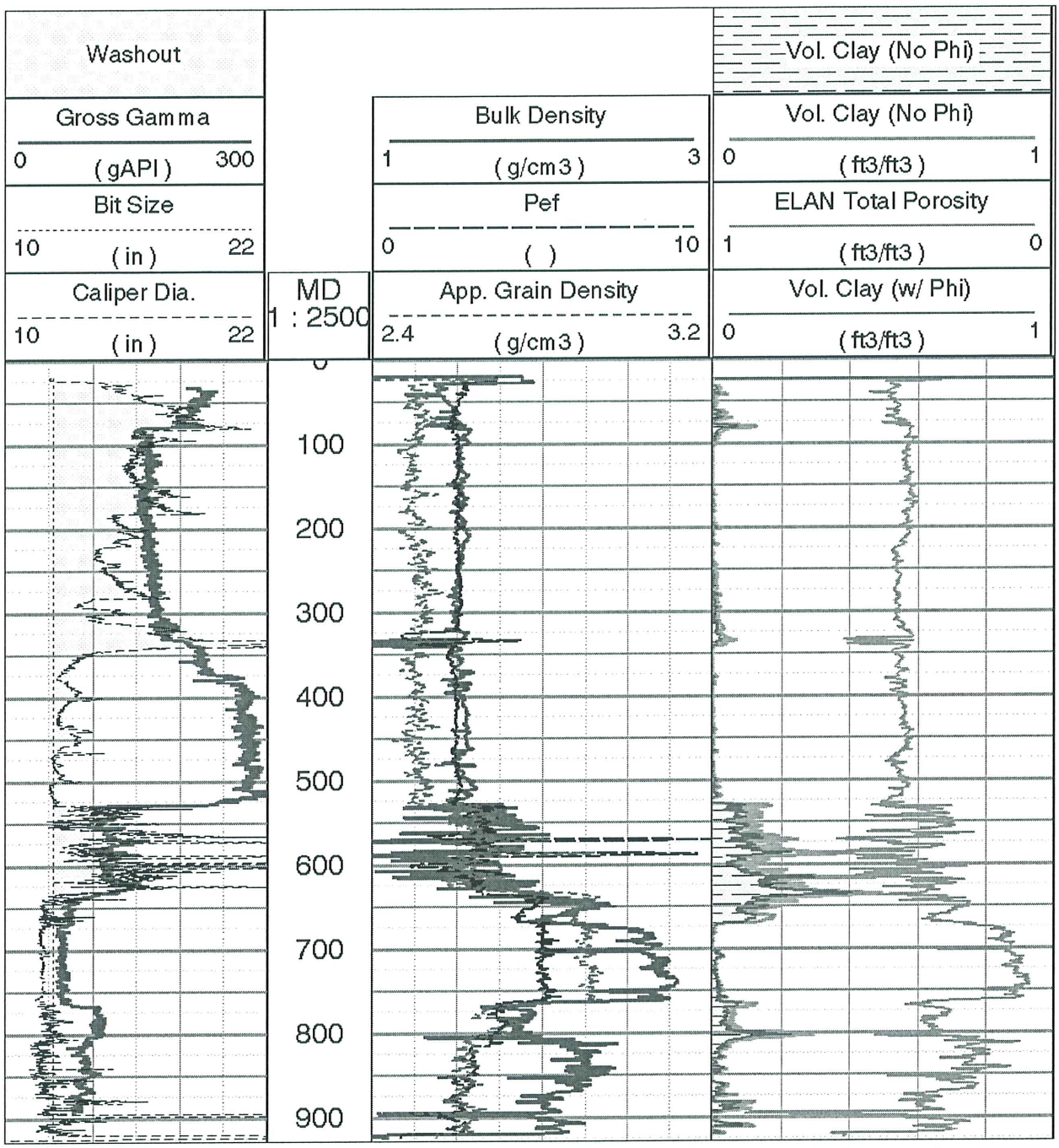

Figure 4.2. Summary of bulk density and volume clay logs in R-27 borehole from processed geophysical logs, interval of 26 to 920 ft bgs. Also shown are caliper, gross gamma, apparent grain density, and total porosity logs (the latter two derived from the ELAN analysis).

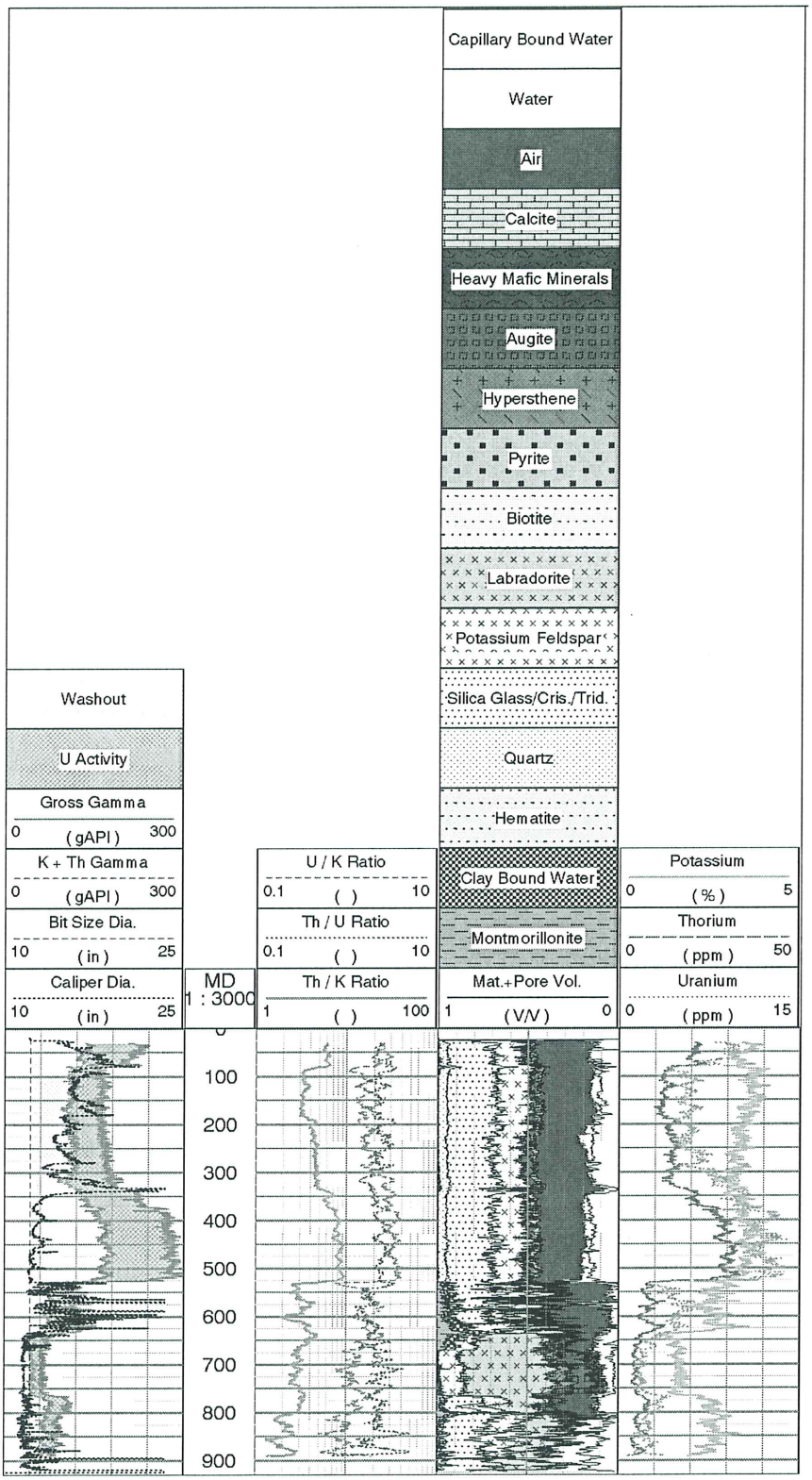

Figure 4.3. Summary of spectral natural gamma ray logs and ELAN mineralogy/lithology and pore fluid model volumes derived from the ELAN integrated log analysis for R-27 borehole, interval 24 to 924 ft bgs. Caliper log is also shown.

4.6.1 Track 1–Depth

The first track on the left contains the depth below ground surface in units of feet, as measured by the geophysical logging system during the FMI logging run. All the geophysical logs are depth-matched to the gross gamma log acquired with this logging run.

4.6.2 Track 2–Basic Logs

The second track on the left (inclusive of the depth track) presents basic curves:

- gamma ray (thick black), recorded in American Petroleum Institute gamma ray standard units (gAPI) and displayed on a scale of 0 to 300 gAPI units;
- two orthogonal calipers from the FMI (thin dotted and dashed pink) and one from the TLD (thin solid pink) with bit size as a reference (dashed-dotted black) to show washout (pink shading), recorded as hole diameter in inches and displayed on a scale of 10 to 25 in.;
- borehole deviation displayed as a tadpole every ten feet (light blue dots and connected line segments) – the "head" marks the angular deviation from vertical at that particular depth, on a scale of 0 to 5 degrees, and the "tail" shows the azimuth of the deviation, true north represented by the tail facing straight towards the top of the page.

Two gamma ray curves from the NGS are:

- total gross gamma (thick solid black curve) and
- gross gamma minus the contribution of uranium (dashed black).

4.6.3 Track 3–Resistivity

The third track displays the resistivity measurements from the AIT, spanning most of the open hole section at the time of the logging. All the resistivity logs are recorded in units of ohmmeters (ohm-m) and are displayed on a logarithmic scale of 2 to 2000 ohm-m.

The six resistivity logs from the AIT that are displayed are

- Borehole fluid resistivity (solid orange curve)–only valid in water-filled hole
- Bulk electrical resistivity at five median depths of investigation–10 in. (black solid), 20 in. (long-dashed blue), 30 in. (short-dashed red), 60 in. (dashed-dotted green), and 90 in. (solid purple)–each having a 2-foot vertical resolution.

The area between the 10 in. and 90 in. resistivity curves, representing radial variations in bulk resistivity (potentially from invasion of drilling fluids), is shaded

- blue when the 10-in. resistivity is greater than the 90-in. resistivity (labeled "resistive invasive") and
- yellow when the 90-in. resistivity is greater than the 10-in. resistivity (labeled "conductive invasive").

A high vertical resolution (~8 in.), shallow-reading (~2 in.) micro-resistivity log from the TLD is also displayed in this track (solid pink curve) – only valid in the fluid-filled, uncased section of the borehole.

4.6.4 Track 4–Porosity

The fourth track displays the primary porosity log results. All the porosity logs are recorded in units of volumetric fraction and are displayed on a linear scale of 0.75 (left side) to -0.1 (right side). Specifically, these logs consist of

- CNT epithermal neutron porosity (solid light blue curve) – epithermal neutron porosity processed for zoned air-filled and water-filled hole;
- CNT water-filled thermal neutron porosity (solid sky blue curve) – thermal neutron porosity valid only in the fluid-filled borehole;
- CMR total water-filled porosity (solid black);
- CMR effective water-filled porosity (dashed green);
- CMR bound water porosity (light blue area shading) – representing by the area between the CMR total and effective water-filled porosities;
- Total porosity derived from bulk density and ELAN water-filled porosity using a grain density of 2.55/2.65/2.95 g/cc (dotted red curve), 2.35/2.45/2.75 g/cc (long-dashed red curve), and 2.45/2.55/2.85 g/cc (dashed red curve)–with red shading between the 2.35/2.45/2.75 g/cc and 2.55/2.65/2.95 g/cc porosity curves to show the range (the highest grain density range used across the basalt interval [637–764 ft], the middle grain density range used across the fanglomerate intervals [530–637 ft and 764–924 ft], and the lowest grain density range used across the tuff/pumice interval [24–530 ft]); and
- ELAN total water and air-filled porosity (dashed-dotted cyan)–derived from the ELAN integrated analysis of all log curves to estimate optimized matrix and pore volume constituents.

4.6.5 Track 5–Density

The fifth track displays the

- bulk density (thick solid maroon curve) on a scale of 1 to 3 g/cc;
- photoelectric effect (P_e) (long-dashed black curve) on a scale of 0 to 10 non-dimensional units;
- density correction (dashed orange curve) on a scale of -0.75 to 0.25 g/cc; and
- apparent grain density (dashed-dotted brown curve), derived from the ELAN analysis, on a scale of 2.4 to 3.2 g/cc.

Gray area shading is shown where the Pe increases above 3 (indicating the presence of heavy, possibly mafic, minerals), and orange shading is shown where the density correction is greater

than the absolute value of 0.25 (indicating that the density processing algorithm had to perform a major correction to the bulk density calculation).

4.6.6 Track 6–NGS Spectral Gamma

The sixth track from the left displays the spectral components of the NGS measurement results as wet weight concentrations:

- potassium (solid green curve) in units of percent weight fraction and on a scale of -5% to 5%;
- thorium (dashed brown) in units of parts per million (ppm) and on a scale of 50 to -50 ppm; and
- uranium (dotted blue) in units of ppm and on a scale of 20 to 0 ppm.

4.6.7 Track 7–CMR Porosity

Track 7 displays various CMR water-filled porosities along with measurement quality flags – valid only in the open-hole section. The porosity and measurement quality logs are presented on a scale of 0.5 to 0 volume fraction and discrete blocks originating from the left side, respectively. Specifically, the CMR logs shown in this track are

- High vertical resolution total water-filled porosity (solid black curve) – representing the total water volume fraction measured by the CMR;
- Three millisecond (ms) porosity (short-dashed brown) – representing the water volume fraction corresponding to the portion of the CMR measured T2 distribution that is above 3 ms, a cutoff that is considered to be representative of the break between clay-bound water (less than 3 ms) and all other types of water (greater than 3 ms);
- High vertical resolution effective water-filled, or free-fluid, porosity (solid pink) – representing the water volume fraction that is moveable (can flow), based on a 33 ms T2 distribution cutoff that is considered representative of the break between bound water (less than 33 ms) and moveable water (greater than 33 ms) in clastic rocks;
- Clay-bound water (brown area shading between total and 3 ms porosity logs) – representing the water volume fraction that is bound within clays;
- Capillary-bound water (pink area shading between 3 ms and effective porosity logs) – representing the water volume fraction that is bound within matrix pores by capillary forces;
- CMR magnetic field variation (dotted yellow) – representing the variation in the measured magnetic field versus the baseline magnetic field used for the logging (used as an indicator of the presence of magnetic minerals which requires a lower T2 cutoff)
- CMR wait-time flag (red area shading) – activates when there is significant measurement response at late T2 times, corresponding to large amounts of completely free ("bathtub") water and often associated with washouts or very large pores;

- CMR measurement noise flag (yellow and orange area shading) – activates when there is potentially detrimental amounts of measurement noise detected by the tool, at moderate (yellow) and high (orange) levels.

4.6.8 Track 8–Pore Size Distribution

Track 8 displays the water-filled pore size distribution as determined by the CMR – shown as binned water-filled porosities and valid only in the open-hole section. The binned porosity logs are presented on a scale of 0.5 to 0 volume fraction with colored area shading corresponding to the different bins:

- Clay-bound water–brown area shading
- Micro-pore and small-pore water (the sum comprising capillary-bound water)–gray and blue area shading, respectively
- Medium-pore, large-pore, and late-decay (the sum comprising effective water-filled porosity)–yellow, red, and green area shading, respectively

In addition, hydroxyl hydrogen is approximated as the difference between the CMR total porosity and environmentally corrected thermal neutron porosity (shaded as diagonal purple stripes).

4.6.9 Track 9–CMR T2 Distribution (Waveforms)

The CMR T2 distribution is displayed in Track 9 as green waveform traces at discrete depths. The horizontal axis, corresponding to relaxation time in milliseconds, is on a logarithmic scale from 0.3 to 3000 ms. Also plotted are the:

- T2 logarithmic mean (solid blue curve) and
- T2 cutoff time used for differentiating between bound and free water (solid red line) – chosen as 33 ms

4.6.10 Track 10–CMR T2 Distribution (Heated Amplitude)

Track 10 displays the T2 distribution in another way – on a heated color scale where progressively "hotter" color (green to yellow to red) corresponds to increasing T2 amplitude. The remaining aspects of the display are the same as in Track 9, except that the high vertical resolution T2 logarithmic mean is shown as a solid white curve and the T2 cutoff is displayed as a solid black line.

4.6.11 Track 11–CMR Hydraulic Conductivity

Track 11 displays several estimates of hydraulic conductivity (K) derived from the CMR measurement and the ELAN integrated log analysis (the latter primarily sensitive to the CMR measurement of moveable water), presented on a logarithmic scale of 10^{-4} to 10^{6} gallons per day per feet squared (gal./day/ft^2):

- A K-versus-depth estimate derived from using the SDR permeability equation applied to the processed CMR results, converted to hydraulic conductivity (dashed purple curve);

- A K-versus-depth estimate derived from using the Timur-Coates permeability equation with total and moveable water content derived from the ELAN analysis, converted to hydraulic conductivity (solid blue curve); and
- An intrinsic K-versus-depth estimate (assuming full saturation) using the Timur-Coates permeability equation with total porosity and matrix mineral weight fraction values derived from the ELAN analysis, converted to hydraulic conductivity (dotted cyan).

In addition, an estimate of cumulative transmissivity from the bottom of the log interval is display (bold dashed-dotted green curve) – computed by integrating from bottom to top the ELAN Timur-Coates hydraulic conductivity estimate.

4.6.12 Track 12– FMI Image (Dynamic Normalization)

Track 12 displays the FMI image, processed with dynamic normalization so that small-scale electrical resistivity features are amplified in the image. (With dynamic normalization, the range of electrical resistivity amplitudes – colors in the image – is normalized across a small moving depth window.) The image is fully oriented and corresponds to the inside of the borehole wall unwrapped, such that the left-hand side represents true north, half-way across the image is south, and the right-hand side is north again. The four color tracks in the image correspond to portions of the borehole wall contacted by the four FMI caliper pads; the blank space in between is the portion of the borehole wall not covered by the pads.

Also displayed are interpreted planar bedding features (thin blue sinusoids).

4.6.13 Track 13– FMI Bedding and Fractures

Track 13 displays the interpreted planar bedding features picked from the FMI image, shown in two ways:

- Individually, as tadpoles at the depths the bedding plane or fracture plane crosses the midpoint of the borehole – where the "heads" (circles/triangles) represent the dip angle, and the "tails" (line segments) represent the true dip azimuth (direction the bed is dipping towards). Bedding features are shown as circular headed blue tadpoles.
- Summed, as dip azimuth fan plot histograms (green colored fan plots for bed boundaries) – where the number of bedding features having a dip direction within a particular sector are summed and normalized, thus highlighting the predominant dip directions.

4.6.14 Track 14– FMI Image (Static Normalization)

Track 14 displays the FMI image again, but in a different way – processed with static normalization to highlight larger scale features and trends. (With static normalization, the range of electrical resistivity amplitudes – colors in the image – is normalized across the entire length of the log interval.) Also shown is the high-resolution scaled resistivity from one of the FMI pads.

4.6.15 Track 15– High Resolution Porosity

Track 15 displays the high resolution thermal neutron porosity log (solid dark blue), the high resolution CMR total porosity (solid light blue), and the high resolution density porosity (dotted red), the latter computed using the matrix grain density computed from the ELAN integrated log analysis and pore fluid density of 1.0 g/cc. The epithermal neutron porosity log from above the well water level is spliced to the high-resolution thermal neutron porosity, since thermal neutron porosity is not valid in air-filled borehole. All these logs have an approximately 8 in depth resolution (except the epithermal neutron porosity log, since there is no high resolution log) and have been depth-matched to the FMI image. Where the density porosity is greater than the neutron porosity the area between the two logs is shaded yellow. The yellow shading is an indication of possible air in the pore space (less than 100% water saturation).

4.6.16 Tracks 16 to 20 – Geochemical Elemental Measurements

The narrow tracks 18 to 22 present the geochemical measurements iron (Fe) and silicon (Si), sulfur (S) and calcium (Ca), estimated aluminum (Al) and potassium (K), titanium (Ti) and gadolinium (Gd), and hydrogen (H) and bulk chlorinity (Cl) — from left to right respectively, in units of dry matrix weight fraction (except K and H in wet-weight fraction, and Cl in ppk).

4.6.17 Track 21 – ELAN Mineralogy Model Results (Dry Weight Fraction)

Track 23 displays the results from the ELAN integrated log analysis (the matrix portion)–presented as dry-weight fraction of mineral types chosen in the model:

- Montmorillonite clay (brown/tan)
- Hematite (orange with small black dots)
- Quartz (yellow with closely spaced small black dots)
- Combined silica glass, tridymite, and cristobalite (yellow with widely spaced large black dots)
- Orthoclase or other potassium feldspar (lavender)
- Labradorite or similar plagioclase feldspar (pink)
- Biotite (light green)
- Pyrite (orange-tan with black squares)
- Hypersthene (purple)
- Augite (maroon)
- Heavy mafic/ultramafic minerals, such as magnetite or olivine (dark green)
- Calcite (cyan)

4.6.18 Track 22–ELAN Mineralogy and Pore Space Model Results (Wet Volume Fraction)

Track 24 displays the results from the ELAN integrated log analysis–presented as wet mineral and pore fluid volume fractions:

- Montmorillonite clay (brown/tan)
- Clay-bound water (checkered gray-black)
- Hematite (orange with small black dots)
- Quartz (yellow with closely spaced small black dots)
- Combined silica glass, tridymite, and cristobalite (yellow with widely spaced large black dots)
- Orthoclase or other potassium feldspar (lavender)
- Labradorite or similar plagioclase feldspar (pink)
- Biotite (light green)
- Pyrite (orange-tan with black squares)
- Hypersthene (purple)
- Augite (maroon)
- Heavy mafic/ultramafic minerals, such as magnetite or olivine (dark green)
- Calcite (cyan)
- Air (red)
- Moveable water (white)
- Capillary-bound water (light blue)
- Moved air (orange)
- Moved water (blue)

4.6.19 Track 23–Summary Logs

Track 25, the second track from the right, displays several summary logs that describe the fluid and air-filled volume measured by the geophysical tools, including water saturation, which show

- Optimized estimate of total volume fraction water from the ELAN analysis (solid dark blue curve and area shading);
- Optimized estimate of moveable volume fraction water (effective porosity in fully saturated conditions) from the ELAN analysis (dashed cyan curve and green area shading);
- Optimized estimate of total volume fraction of air-filled porosity from the ELAN analysis (solid red curve and dotted red area shading);
- Optimized estimate of water saturation (percentage of pore space filled with water) from the ELAN analysis (dashed-dotted purple curve);
- Water saturation as calculated directly from the bulk density and ELAN-estimated porosity using a grain density of 2.55/2.65/2.95 g/cc (dotted light blue curve),

2.35/2.45/2.75 g/cc (long-dashed light blue curve), and 2.45/2.55/2.85 g/cc (dashed light blue curve) – with light blue shading between the 2.35/2.45/2.75 g/cc and 2.55/2.65/2.95 g/cc porosity curves to show the range (the highest grain density range used across the basalt interval [637–764 ft], the middle grain density range used across the fanglomerate intervals [530–637 ft and 764–924 ft], and the lowest grain density range used across the tuff/pumice interval [24–530 ft]);

- Integrated estimated relative water flow profile from the ELAN water permeability log that mimics a flow meter (spinner) acquired under flowing conditions (solid green line coming from left-hand side at bottom of logged interval);
- Predicted cumulative volumetric flow rate from bottom during pumping (dotted light green line coming from left-hand side at bottom of logged interval) – computed using the Thiem steady state well flow equation with the ELAN Timur-Coates hydraulic conductivity estimate and a number of assumptions about well size, pulled drawdown, and aquifer horizontal extent;
- Potential for water flow indicator from the CMR log (block cyan coming from the right-hand side of the track).

The porosity scale is from 0 to 1 total volume fraction, left to right; the water saturation scale is from 0 to 1 volume fraction of pore space, from left to right. The relative water flow is on a scale of 0 to 1 relative volumetric flow rate from left to right. The predicted cumulative flow rate is on a scale of 0 to 1,000,000 gallons per day (gal/day) from left to right. The flow indicator is a binary-valued flag that rises to halfway through the first division from the right on the x-axis when the CMR measurement indicates a potential for flow.

4.6.20 Track 24–Depth

The final track on the right, the same as the first track on the left, displays the depth below ground surface in units of feet, as measured by the geophysical logging system during the FMI logging run.

5.0 REFERENCES

Mayer, C. and A. Sibbit, 1980. "GLOBAL, A New Approach to Computer-Processed Log Interpretation." Paper SPE 9341 presented at the 1980 SPE Annual Technical Conference and Exhibition.

Quirein, J., S. Kimminau, J. LaVigne, J. Singer, and F. Wendel, 1986. "A Coherent Framework for Developing and Applying Multiple Formation Evaluation Models." Paper DD in 27th Annual Logging Symposium Transactions: Society of Professional Well Log Analysts.

Appendix C

Lithologic Log

Geologic Unit	**Lithologic Description** *Lithologic descriptions are based upon core from 0 to 272.8 ft bgs, and on cuttings from 272.8 ft bgs to total depth.*	Interval (ft bgs)	Elevation (ft amsl)
Quaternary Alluvium (Qal)	Gravelly silty/clayey sand, dusky yellowish brown (10YR 2/2), moderately sorted, non-indurated. Composed of: 80-85% sand, predominantly felsic crystals, rounded; 10-15% silt/clay; 5% gravel, inter. comp. volcanics, up to 5mm, subangular to subrounded. Damp.	0-2.0	6713.6-6711.6
	Gravelly silty/clayey sand, moderate yellowish brown (10YR 5/4), moderately sorted, non-indurated. Composed of: 80% sand, fine to very coarse, predominantly felsic crystals, broken to round to subrounded; 10% silt/clay; 10% gravel, inter. comp. volcanics, moderate yellowish brown to medium gray to yellowish gray, subangular to subrounded, reworked welded tuff noted. Damp.	2.0-7.8	6711.6-6713.6
	Gravel, pale yellowish brown (10YR 6/2), poorly sorted, non-indurated. Composed of: 60-80% gravel, predominantly inter. comp. volcanics (olive gray to yellowish gray to dark gray, up to 60 mm, subangular to angular), common felsic crystals (pale yellowish brown, up to 5 mm, subangular,); 20-30% sand, predominantly felsic crystals, subangular to subrounded, quartz and sanidine noted; 5-10% silt/clay. Damp. • 10.5 - 12.8 ft, No recovery. • 14.5 - 15.1 ft, Gravel, as above, tuff boulder encountered: grayish orange pink (5YR 7/2), poorly welded. Composed of: fine ash matrix; 10% pumice, vitric, fibrous, white, up to 15 mm, trace felsic phenocrysts; 7% felsic crystals, predominantly quartz, 1 mm, subhedral; 5% lithics, medium dark gray, up to 0.5 mm, subangular. Dry. • 15.1 - 17.8 ft, No recovery. • 17.8 - 18.3 ft, Gravel, as above, gravels to 80%, common pumice. • 18.3 – 21.0 ft, No recovery.	7.8-21.0	6713.6-6692.6

Geologic Unit	**Lithologic Description** *Lithologic descriptions are based upon core from 0 to 272.8 ft bgs, and on cuttings from 272.8 ft bgs to total depth.*	Interval (ft bgs)	Elevation (ft amsl)
Tshirege Member of the Bandelier Tuff Unit 1g (Qbt1g)	Tuff, very pale orange (10YR 8/2), poorly welded. Composed of: fine ash matrix; 5-15% pumice, vitric, white to pale orange, up to 18 mm, subrounded, trace felsic phenocrysts (clear, up to 1 mm), common manganese/iron (Mn/Fe) oxide specks; 5-15% felsic phenocrysts in groundmass, predominantly quartz, up to 3 mm, euhedral to subhedral, bipyramidal quartz noted; 1-3% lithics, inter. comp. volcanics, medium dark gray to reddish brown, up 20 mm, subangular; 1-3% mafic phenocrysts, black, up to 1 mm, rectangular to square. Dry. Note: The top of the Qbt1g is 21 ft bgs based on geophysical logs. • 21.0 – 22.8 ft, No recovery. • 25.1-26.4 ft, Tuff, as above, grayish orange pink (10Y 8/2), trace clay alteration of pumices. • 37.8 - 47.5 ft, Tuff, as above, non-welded. • 47.5 - 68.5 ft, Tuff, as above, grayish orange pink (10Y 8/2), increase in pumice with common felsic phenocrysts. • 68.5 - 69.5 ft, Tuff, as above, near vertical and horizontal fractures, filled with waxy clay, grayish brown (5YR 3/2) to moderate brown (5YR 3/4), aperture width 10 mm. Moist.	21.0-72.8	6692.6-6640.8
	Tuff, light brown (5YR 6/4), non-welded. Composed of: coarse ash matrix; 3-5% felsic crystals, 2 mm, subhedral to anhedral, bipyramidal quartz noted; 3% pumice, vitric, white and orange, 3-5 mm, rounded to elongate, altered, minor felsic phenocrysts; 3-5% lithics, inter. comp. volcanics, dark gray, 3-10 mm, angular to round.	72.8-73.7	6640.8-6639.9
	Tuff, pale yellowish orange (10YR 8/6), poorly welded. Composed of: 50-60% vitric pumice white, up to 15 mm, minor Mn/Fe oxide dendritic staining, trace felsic phenocrysts; 40-50% felsic phenocrysts, minor pitting on surfaces, minor discontinuous coatings of brown waxy clay on phenocrysts, bipyramidal quartz noted; minor coarse ash. Damp.	73.7-77.8	6639.9-6635.8
	Tuff, grayish orange pink (5YR 7/2), poorly to moderately welded. Composed of: fine ash matrix; 10% inter. comp. volcanics, up to 20 mm, dark gray, subangular to subrounded; 10% pumice, vitric, dark yellow orange, up to 8 mm, subrounded to elongate or broken, common felsic phenocrysts (clear, up to 2 mm); 3-5% felsic phenocrysts in groundmass, 1-2 mm, subhedral to anhedral, bipyramidal quartz and chatoyance noted. Damp.	77.8-80.0	6635.8-6633.6

Geologic Unit	**Lithologic Description** *Lithologic descriptions are based upon core from 0 to 272.8 ft bgs, and on cuttings from 272.8 ft bgs to total depth.*	Interval (ft bgs)	Elevation (ft amsl)
Cerro Toledo Interval (Qct)	Gravelly sandy siltstone/claystone, light brown (5YR 6/4) to grayish orange (10YR 7/4), poorly sorted, non-indurated. Composed of: 60-65% silt/clay; 15-20% gravel, predominantly inter. comp. volcanics (dark gray, up to 20 mm, subangular), common pumice (grayish orange to white, vitric, up to 15 mm, rounded, common felsic phenocrysts); 10-15% sand, predominantly felsic crystals (clear, subangular to subrounded). Damp. Note: The top of the Qct is 80.0 ft bgs based on geophysical logs. • 83.5-98.0 ft, Gravelly sandy siltstone/claystone, as above, marked decrease in gravel percentage and size.	80.0-95.5	6633.6-6618.1
	Gravelly siltstone/claystone, light brown, moderately sorted, non-indurated. Composed of: 65-70% silt/clay; 20-25% gravel, predominantly inter. comp. volcanics (dark gray, up to 40 mm, generally 5-15 mm, subangular), common pumice (light brown to white, vitric, increasing occurrence of white pumice with depth, up to 25 mm, generally 5-10 mm, subrounded to rounded, common felsic phenocrysts (clear, up to 3 mm, sanidine and quartz noted); 5-10% sand, predominantly felsic crystals (clear, 1 mm, subangular to broken, quartz and sanidine noted) with common inter. comp. volcanics (dark gray, subangular). Damp. • 120.3-126.8 ft, Gravelly sandy siltstone/claystone, as above, orange pumice with altered sugary texture, breaks easily.	95.5-147.8	6618.1-6565.8

Geologic Unit	**Lithologic Description** *Lithologic descriptions are based upon core from 0 to 272.8 ft bgs, and on cuttings from 272.8 ft bgs to total depth.*	Interval (ft bgs)	Elevation (ft amsl)
	Gravelly siltstone/claystone, grayish orange (10YR 7/4) to moderate yellowish brown (10YR 5/4), moderately sorted, non-indurated. Composed of: 75-80% silt/clay; 10-15% gravel, composed predominantly of pumice (dark yellowish orange to dark gray, vitric, up to 12mm, common felsic phenocrysts (clear, 2mm, round to elongate)), and inter. comp. volcanics (dark gray, up to 10mm, subangular); 5-7% sand, predominantly felsic crystals (clear, up to 2mm, subhedral/ broken), common inter. comp. volcanics (dark gray, subangular); trace mafic crystals. Damp to dry. • 154.2-154.8 ft, Gravelly siltstone/claystone, as above, sugary texture observed in pumices. • 169.3-169.9, Gravelly siltstone/claystone, as above, altered pumice, lithic fragments up to 40 mm. • 174.8-176.8, Gravelly siltstone/claystone, as above, very light gray, altered pumice. • 192.2-192.5 ft, Gravelly siltstone/claystone, as above, altered pumice. • 197-200 ft, Gravely siltstone/claystone, as above, inter. comp. volcanic fragments up to 50 mm, subrounded. Overall core color change to pale yellowish brown (10YR 6/2).	147.8-200.0	6565.8-6513.6
	Gravelly siltstone/claystone, pale yellowish brown (10YR 6/2), well to moderately sorted, non- to poorly indurated. Composed of: 75-80% silt/clay; 10-15% gravel, predominantly inter. comp. volcanics (dark gray, up to 15 mm, subangular), common pumice (vitric, very dense, hard, up to 15 mm, subrounded, felsic phenocrysts common); 5-10% sand, predominantly felsic crystals (clear, up to 2 mm, subhedral), common inter. comp. volcanics (dark gray, subangular). Overall altered texture of core. Dry. • 215.0 - 226.0 ft, Gravelly sandy siltstone/claystone, as above, relative increase of inter. comp. volcanics. • 226 – 272.8 ft, Gravelly sandy siltstone/claystone, as above, slight increase in sand to 10 –15%, slight decrease in gravels to 10%. • 260.4 - 262.8 ft, No recovery. • 262 - 267.9 ft, Gravelly sandy siltstone/claystone, as above, slightly damp. • 267.9 - 272.8 ft, No recovery. Dry at 272.8 ft bgs (corehole total depth).	200.0-272.8	6513.6-6440.8

Geologic Unit	**Lithologic Description** *Lithologic descriptions are based upon core from 0 to 272.8 ft bgs, and on cuttings from 272.8 ft bgs to total depth.*	Interval (ft bgs)	Elevation (ft amsl)
	Fluvial, gravel, very light gray (N8) to medium dark gray (N4), moderately sorted, poorly indurated. **WR**: 60-70% gravel, up to 10 mm; 30-40% sand. **10+F:** 100% gravel, composed of 50-80% inter. comp. volcanics, (medium light gray to medium dark gray to grayish red, up to 16 mm, subangular, minor biotite and hornblende phenocrysts, trace felsic phenocrysts, common reddish gray alteration/staining), 20-50% pumice (white, vitric, fibrous, subangular to subrounded, minor felsic phenocrysts, trace Mn/Fe oxide specks), trace dark vitric pumice fragments. **35+F:** 100% sand, composed of 30-35% inter. comp. volcanics as described for 10+F, 30-35% pumice as described for 10+F, 30-35% loose felsic crystals (clear to white, up to 2 mm, angular to subrounded, common crystals faces and partial bipyramidal quartz, common frosted surfaces, trace rounded grains, sanidine noted). • 285-290 ft, Fluvial, sandy gravel, as above, 10+F: vitric pumice up to 28 mm; 35+F: loose felsic crystals to 50%. • 300-315 ft, Fluvial, sandy gravel as above, 10+F: trace Mn/Fe oxide staining (dendritic pattern) on inter. comp. volcanics; 35+F: decrease in felsic crystals.	272.8-330	6440.8-6383.6
Otowi Member of the Bandelier Tuff (Qbo)	Tuff, moderate orange pink (5YR 8/4), poorly welded. **WR:** fine ash with common vitric pumice, lithics, and felsic crystals. **10+F:** 50-70% pumice, vitric, fibrous, moderate orange pink to pale yellow to light gray, common pinkish orange oxidized surfaces, minor felsic phenocrysts, common Mn/Fe oxide specks; 30-50% lithics, inter. comp. volcanics, dark brown to very dark gray, up to 10 mm, broken to subrounded surfaces. **35+F:** 40-50% felsic crystals, clear, up to 1 mm, broken; 25-30% lithics, inter. comp. volcanics as for 10+F; 25-30% vitric pumice as for 10+F. **Note:** The top of the Qbo is 332 ft bgs based on geophysical logs. • 330-340 ft, Tuff, as above, trace orange vitric pumice highly intermixed with overlying formation.	330-375	6383.6-6338.6

Geologic Unit	**Lithologic Description** *Lithologic descriptions are based upon core from 0 to 272.8 ft bgs, and on cuttings from 272.8 ft bgs to total depth.*	Interval (ft bgs)	Elevation (ft amsl)
	Tuff, very light gray (N8), poorly welded. **WR:** fine ash matrix with common vitric pumice, lithics, and felsic crystals. **10+F:** 50-60% lithics, inter. comp. volcanics, dark brown to dark gray to moderate reddish brown, up to 10 mm, broken to subangular, trace reddish brown alteration/staining; 40-50% pumice, vitric, fibrous texture, generally very light gray, up to 25 mm, broken with subangular surfaces, minor felsic phenocrysts, trace alteration of pumice from 375 to 440 ft, trace Mn/ Fe oxide specks. **35+F:** 40-50% felsic crystals, clear, up to 1 mm, broken, minor crystal faces, trace bipyramidal quartz and sanidine chatoyance; 25% lithics as for 10+F; 25-35% pumice as for 10+F; trace obsidian from 390 to 440 ft, possibly intermixed from overlying Qct. • 375- 390 ft, Tuff, as above, 10+F: minor very pale orange pumice. • 400-440 ft, Tuff, as above, 35+F: few returns. • 435-440 ft, Tuff, as above, 10+F: 3-5% red inter. comp. volcanics, single coarse sandstone fragment noted from up hole (10 mm, subrounded); 35+F: 5% red inter. comp. volcanics.	375-520	6338.6-6193.6
Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (Qbog)	Pumice bed, very light gray (N8) to light gray (N7), poorly welded. **WR:** Predominantly pumice and lithics, trace felsic crystals, and ash. **10+F:** 60-70% pumice, white, vitric, fibrous, up to 12 mm, subangular to subrounded, minor felsic phenocrysts (clear, up to 2 mm, subhedral), trace Mn/Fe oxide specks; 30-40% inter. comp. volcanics, grayish red to medium dark gray, up to 10 mm, subangular; trace coarse sandstone clasts and trace vesicular clasts from up hole. **35+F:** Few returns. 50-60% pumice as for 10+F; 10-20% inter. comp volcanics as for 10+F; 10-20% felsic crystals (clear, up to 1 mm, broken, bipyramidal quartz noted). Note: The top of the Qbog is 520 ft bgs based on geophysical logs.	520-530	6193.6-6183.6

Geologic Unit	**Lithologic Description** *Lithologic descriptions are based upon core from 0 to 272.8 ft bgs, and on cuttings from 272.8 ft bgs to total depth.*	Interval (ft bgs)	Elevation (ft amsl)
Puye Formation (fanglomerate) (Tpf)	Fanglomerate, gravel, pale red (10R 6/2), to medium dark gray (N4), poorly sorted, poorly indurated. **WR:** 85-98% gravel, up to 25 mm; 2-15% sand. **10+F:** 97-100% gravel composed of predominantly inter. comp. volcanics (varied colors – pale green to pale red to medium dark gray, up to 15 mm, subangular to subrounded, Mn/Fe oxide staining, trace hornblende dacite); trace vitric pumice from overlying formation. **35+F:** 100% sand, composed of 90-95% inter. comp. volcanics as for 10+F; 5-10% loose felsic crystals likely from up hole (clear, up to 2 mm, broken with common crystal faces). Note: The top of the Tpf is 529 based on geophysical logs. • 540-555 ft, Fanglomerate, as above, 35+F: few returns. • 570-585 ft, Fanglomerate, as above, WR: increase in sand fraction to 30-40%; 10+F: increase in smaller, rounded gravels; single scoria clast at 570-575 ft. • 585-590 ft, Fanglomerate, as above, 10+F: trace sandstone, very pale orange, up to 12 mm, subrounded, composed of fine to coarse sand, predominantly felsic grains. • 585-635 ft, Fanglomerate, as above, predominantly large gravel clasts up to 35 mm. 35+F: few returns.	530-634	6183.6-6079.6
Cerros del Rio Basalt (Tb4)	Basalt, medium gray (N5) to medium dark gray (N6), weakly to moderately vesicular. **WR:** Basalt with intermixing of inter. comp. volcanics and sandstone from overlying formation. **10+F:** 90-95% basalt, aphanitic groundmass, 2-5% olivine phenocrysts (medium yellowish green to reddish brown, up to 2 mm, anhedral), clay lined vesicles (light orange/tan to reddish tan); trace tan clay fragments; 5-10% intermixing with inter. comp. volcanics (gray to pale red, up to 15 mm, subangular), and sandstone (very pale orange, up to 18 mm, predominantly felsic grains, subrounded) from overlying formation. **35+F:** 90-95% basalt as described for 10+F: 5-10% intermixing with felsic crystals (white to clear, up to 2 mm, broken with trace crystal faces observed), and inter. comp. volcanics from overlying formation. Note: The top of the Tb4 is 634 ft bgs based on geophysical logs.	634-675	6079.6-6038.6

Geologic Unit	**Lithologic Description** *Lithologic descriptions are based upon core from 0 to 272.8 ft bgs, and on cuttings from 272.8 ft bgs to total depth.*	Interval (ft bgs)	Elevation (ft amsl)
	Basalt, medium gray (N5), massive. **WR:** Basalt with trace vesicular basalt and sandstone from up hole. **10+F:** Basalt, microcrystalline groundmass, 3-5% olivine phenocrysts (reddish brown to pale green, up to 3 mm, anhedral); trace intermixing of sandstone (very pale orange, up to 8 mm, rounded, predominantly fine grained). **35+F:** 97% basalt as for 10+F; 1-2% sandstone; trace intermixing of inter. comp. volcanics and loose felsic crystals (clear to white, broken fragments with trace crystal faces observed, up to 2 mm); trace loose olivine crystals (reddish brown to pale green, up to 2 mm, broken/anhedral). • 675-685 ft, Basalt, as above, trace microcrystalline groundmass fragments with predominantly aphanitic groundmass fragments from up hole as described for 635-675 ft interval. • 700 ft, Basalt, as above, less resistant drilling. 10+F: trace intermixing of inter. comp. volcanics from overlying formation. • 735-745 ft, Basalt, as above, increase in olivine phenocrysts to 5-7%. • 745-765 ft, No recovery.	675-765	6038.6-5948.6
Puye Formation (Tpf)	Fanglomerate, silt, very pale orange (10YR 8/2) moderately sorted, poorly indurated. **WR:** silt with trace gravel. **10+F:** Few returns. 100% gravel predominantly inter. comp. volcanics (varied colors, up to 10 mm, subangular), with trace basalt and vitric pumice fragments from overlying formation. **35+F:** 100% sand composed of 40% felsic crystals (clear, 1 mm, broken fragments with minor crystal faces observed), 35% basalt from overlying formation, 25% inter. comp. volcanics. Note: The top of the Tpf is 765 ft bgs based on geophysical logs. • 770-775 ft, No recovery. • 775-780 ft, Fanglomerate, as above, few returns. WR: silty gravelly sand, medium light gray (N6) with continued intermixing of basalt from overlying formation. 10+F: as above with trace red brown vesicular lava (up to 5 mm, subangular) with clay lining on surfaces. • 780-785 ft, No recovery.	765-785	5948.6-5928.6

Geologic Unit	**Lithologic Description** *Lithologic descriptions are based upon core from 0 to 272.8 ft bgs, and on cuttings from 272.8 ft bgs to total depth.*	Interval (ft bgs)	Elevation (ft amsl)
	Fanglomerate, gravelly sand, light brown (5YR 5/6), moderately sorted, poorly indurated. **WR:** 75-90% sand; 5-20% gravel, up to 7 mm; 5-10% silt. **10+F:** Few returns. 100% gravel, composed of 50-60% basalt (microcrystalline groundmass) from overlying formation, 20-30% inter. comp. volcanics (pale red to grayish red, up to 5 mm, subangular), 5% scoria/vesicular lava (light brown to red, up to 3 mm, rounded, weathered), 5% siltstone/sandstone (reddish brown, up to 4 mm, subrounded). **35+F:** 100% sand, composed of 30-40% siltstone/sandstone as for 10+F; 30-40% basalt as for 10+F; 10-20% inter. comp. volcanics as for 10+F: 0-5% loose felsic crystals likely from up hole (clear, up to 2 mm, broken fragments with trace crystal faces observed); trace scoria; trace loose olivine crystals (pale green up to 1 mm, anhedral). • 795-800 ft, No recovery. • 810-835 ft, No recovery.	785-835	5928.6-5878.6
	Fanglomerate, sandy gravel to gravel, medium gray (N5) to brownish gray (5YR 4/1), moderately sorted, poorly indurated. **WR:** 40-80% gravel, generally larger clasts up to 35 mm; 15-50% sand; 5-10% silt/clay. **10+F:** 100% gravel, composed of 80-100% inter. comp. volcanics (medium gray to grayish red, up to 35 mm, subangular to subrounded), 0-20% scoria (pale red to dark gray, up to 20 mm, subrounded), trace rhyolitic clasts, trace siltstone/sandstone (light brownish gray, up to 25 mm, subrounded). **35+F:** 100% sand composed of 95% inter. comp. volcanics (up to 2 mm) as in 10+F, 2-5% felsic crystals (clear to white, up to 2 mm, broken with trace crystal faces observed), 0-2% scoria (up to 2 mm) as in 10+F, trace mafic crystals (black, up to 2 mm, square to rectangular to platy, hornblende and biotite noted). • 845-855 ft, No recovery. • 865-880 ft, No recovery. • 880-885 ft, Fanglomerate, as above, trace 35+F returns. • 885-895 ft, No recovery. • 895-900 ft, Fanglomerate, as above, 10+F: trace quartzite.	835-905	5878.6-5808.6

Geologic Unit	**Lithologic Description** *Lithologic descriptions are based upon core from 0 to 272.8 ft bgs, and on cuttings from 272.8 ft bgs to total depth.*	Interval (ft bgs)	Elevation (ft amsl)
	Fanglomerate, sandy gravel, medium light gray (N6) to light brownish gray (5YR 6/1), poorly sorted, poorly indurated. **WR:** 65% sand; 25-30% gravel, up to 7 mm; 5-10% silt/clay. **10+F:** 100% gravel, composed of 90-95% inter. comp. volcanics, (medium gray to grayish red, up to 10 mm, subangular to subrounded, biotite dacite noted), trace siltstone/sandstone, trace scoria/vesicular lava (dark gray, up to 3 mm, subrounded). **35+F:** 100% sand, composed of 98 - 100% inter. comp. volcanics (up to 2 mm) as in 10+F, 0-2% felsic crystals (clear, broken fragments), trace mafic crystals (black, rectangular to platy, biotite noted). • 910-955 ft, No recovery.	905-975	5808.6-5738.6
	Fanglomerate, silty/clayey sandy gravel to gravelly silty/clayey sand, medium light gray (N6), poorly sorted, poorly indurated. **WR:** 60-65% sand; 20-35% gravel, up to 10 mm; 5-15% silt/clay. **10+F:** 100% gravel, composed of, 95-100% inter. comp. volcanics (medium light gray to pale red, up to 17 mm, subangular, dacite noted), trace vitrophyre (black, up to 10 mm, subangular), trace intermixing of pumice from up hole (very pale orange, vitric, 10 mm, subrounded). **35+F:** 100% sand, composed of 98-100% inter. comp volcanics (up to 2 mm) as in 10+F, 0-2% felsic crystals (clear to white, up to 1 mm, broken fragments).	975-987	5738.6-5726.6
	TOTAL DEPTH OF BOREHOLE WAS 987 FT BGS.		

References

Dutro, J. T., Dietrich, R. V., and Foose, R. M., 1989, American Geological Institute. Data Sheets, 3rd Edition.
Geological Society of America, 1995, Rock-Color Chart, 8th Printing.
Tucker, M.E., 1991, Sedimentary Petrology, An Introduction to the Origin of Sedimentary Rocks, Blackwell Science Limited.

Classification System

Field geologists used principles identified in the AGI Data Sheets (Dutro, J. T, et al., 1989) to describe lithology. Specifically, AGI Data Sheets 32.1, 32.2 as well 29.1 (the modified Wentworth scale for grain-size classification) were used for sedimentary units. The AGI approach was augmented by the classification system presented in Sedimentary Petrology, An Introduction to the Origin of Sedimentary Rocks (Tucker, 1991).

Note that rotary drill cuttings present an inherently false skew of the grain-size distribution in sedimentary units. In order to avoid this bias, the formation depositional name or rock type (e.g., fanglomerate, alluvium, siltstone/sandstone, etc.) was used as the primary descriptor. The primary term is then followed by a description of the grain-size distribution of the unsieved cuttings. This approach was taken to more accurately reflect the true stratigraphy rather than just describing the fine particle size distribution inherent in rotary drilling.

Cuttings Descriptions

Cuttings were collected at nominal 5-ft intervals and divided into three sample splits:

(1) **WR** (whole rock) - unsieved cuttings obtained from the discharge line;
(2) **>10+F** sieved fraction (greater than 2.0 mm);
(3) **>35+F** sieved fraction (greater than 0.5 mm and less than 2.0 mm).

If the cuttings sample contained finer size fractions, the sample was divided into a 35+F sieved fraction and a 60+F sieved fraction.

Groundwater
Please refer to section 6.2 of the report for a description of groundwater encountered at R-27.

Appendix D

Groundwater Analytical Results

1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT R-27

Perched intermediate and regional groundwater was encountered at R-27. Two screening groundwater samples were collected from the perched intermediate zone water during drilling. One screening sample and one final sample were collected from the regional aquifer. The screening samples were analyzed for anions, cations, perchlorate and metals. Split samples were taken from the three screening samples and submitted for high explosives (HE) analyses. A final groundwater sample was collected from the completed well at approximately 865 feet (ft) below ground surface (bgs) following well development. The final sample was analyzed for anions, cations, perchlorate and metals. During development, a water sample was also submitted for total organic carbon (TOC) analysis.

1.1 Analytical Techniques

Groundwater samples were filtered prior to analysis for metals, trace elements, and major cations and anions. Aliquots of the samples were filtered through 0.45-micrometer Gelman filters. Samples were acidified with analytical grade nitric acid to a pH of 2.0 or less for metal and major cation analyses. Total carbonate alkalinity was measured at Los Alamos National Laboratory's Earth and Environmental Sciences Group 6 (EES-6) using standard titration techniques. The sample collected for TOC analysis was not filtered.

Groundwater samples were analyzed by EES-6 using techniques specified in the US Environmental Protection Agency SW-846 manual. Ion chromatography (IC) was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. The instrument detection limits (IDLs) for perchlorate analyses were 0.001 and 0.0005 parts per million (ppm) for R-27 samples.

Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) was used for calcium, magnesium, potassium, silica, and sodium. Aluminum, antimony, arsenic, barium, beryllium, cadmium, cesium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, nickel, rubidium, selenium, silver, thallium, thorium, tin, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS). The precision limits (analytical error) for major ions and trace elements were generally less than ±10% using ICPOES and ICPMS.

1.2 Analytical Results

Cation, anion and metal analytical results for groundwater samples collected at R-27 are provided in Table 1.2-1; high explosives analytical data are presented in Table 1.2-2. Perchlorate was tentatively detected in the deeper perched intermediate zone screening sample at a concentration of 0.0076 ppm; it was not detected in the shallower perched intermediate zone screening sample or the two samples from the regional aquifer. Nitrate (as N) was detected in the shallower perched intermediate zone sample and in both of the regional aquifer samples at concentrations between 0.10 and 0.29 ppm. HE compounds were not detected in the three screening samples (Table 1.2-2). TOC was measured in a sample collected near the end of well development on November 13, 2005 at 1.23 ppm.

Table 1.2-1
Hydrochemistry of Groundwater Samples Collected from Perched Intermediate and Regional Aquifer Groundwater at R-27 (filtered samples)

SAMPLE ID	**EU05070GR2701**	**EU05070GR2702**	**EU05070GR2703**	**EU05070GR2705**
SAMPLE TYPE	**During drilling**	**During drilling**	**During drilling**	**After development**
DEPTH (ft bgs)	**DTW = 628**	**DTW = 789.5**	**DTW = 814**	**862.5**
AQUIFER	**Perched intermediate**	**Perched intermediate**	**Regional aquifer**	**Regional aquifer**
GEOLOGIC UNIT	**upper Puye Formation**	**lower Puye Fm (?)**	**lower Puye Formation**	**lower Puye Formation**
DATE	**10/11/05**	**10/20/05**	**10/21/05**	**11/14/05**
Charge Balance (%)	-0.65	-7.00	+7.02	+5.48
pH (Lab)	7.81	6.61	6.86	7.57
Ag (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Al (ppm)	0.013	0.020	0.014	0.0029
Alkalinity (ppm $CaCO_3$/L)	54.8	41.1	53.0	48.4
As (ppm)	0.0004	0.0004	0.0008	0.0009
B (ppm)	0.081	0.20	0.096	0.012
Ba (ppm)	0.16	0.24	0.32	0.023
Be (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Br (ppm)	0.02	0.03	0.03	0.03
Ca (ppm)	7.91	4.45	9.18	9.25
Cd (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Cl (ppm)	1.91	1.58	1.49	1.64
ClO_4 (ppm)	U [0.0005]	0.0076	U [0.001]	U [0.0005]
Co (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]
CO_3 (ppm)	0	0	0	0
Cr (ppm)	0.0016	U [0.001]	0.0020	U [0.001]
Cs (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Cu (ppm)	U [0.001]	0.0010	U [0.001]	U [0.001]
F (ppm)	0.17	0.21	0.18	0.20
Fe (ppm)	0.01	0.02	0.05	0.01
HCO_3 (ppm)	66.9	50.2	64.7	59.1
Hg (ppm)	0.00017	0.00086	U [0.00005]	U [0.00005]
K (ppm)	0.72	3.24	0.93	1.30
Li (ppm)	0.010	0.019	0.021	0.034
Mg (ppm)	1.95	1.29	2.71	2.74
Mn (ppm)	0.011	0.053	0.010	0.0023
Mo (ppm)	0.0019	0.0048	0.0029	0.0011
Na (ppm)	13.8	16.8	15.9	10.7
Ni (ppm)	U [0.001]	0.0017	U [0.001]	U [0.001]
NO_2(as N) (ppm)	U [0.002]	U [0.002]	U [0.002]	U [0.002]
NO_3(as N) (ppm)	0.10	U [0.003]	0.29	0.17
C_2O_4 (ppm)(oxalate)	U [0.01]	0.09	0.03	U [0.01]
Pb (ppm)	U [0.0002]	U [0.0002]	U [0.0002]	U [0.0002]
PO_4 (ppm)	0.06	U [0.001]	U [0.001]	0.03
Rb (ppm)	U [0.001]	0.013	0.0014	0.0024
Sb (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Se (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]
SiO_2 (ppm)	66.3	65.1	67.3	65.9
SO_4 (ppm)	1.21	21.4	4.11	1.48
Sn (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Sr (ppm)	0.040	0.026	0.048	0.047
Th (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Ti (ppm)	U [0.001]	0.002	0.001	U [0.001]
Tl (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]
U (ppm)	0.0003	U [0.0002]	0.0003	0.0005
V (ppm)	0.002	0.002	0.005	0.005
Zn (ppm)	0.057	0.32	0.094	0.053
TDS (calculated)	161.9	165.3	168.5	153.3

Notes: U = Undetected at the IDL shown in brackets. Bicarbonate concentrations (HCO_3) were calculated from measured alkalinity.

Table 1.2-2
High Explosives Analytical Results -
Perched Intermediate and Regional Aquifer Groundwater at R-27
(from GEL Laboratories)

SAMPLE ID	EU05070GR2701	GU05100GR2701	GU05100GR2702
SAMPLE TYPE	During drilling	During drilling	During drilling
DEPTH (ft bgs)	DTW = 628	DTW = 789.5	DTW = 814
AQUIFER	Perched intermediate	Perched intermediate	Regional aquifer
GEOLOGIC UNIT	upper Puye Formation	lower Puye Fm (?)	lower Puye Formation
DATE	10/11/05	10/20/05	10/21/05
2,4-Diamino-6-nitrotoluene (ppb)	U [1.3}	U [1.3}	U [1.3}
2,6-Diamino-4-nitrotoluene (ppb)	U [1.3}	U [1.3}	U [1.3}
3,5-dinitroaniline (ppb)	U [1.3}	U [1.3}	U [1.3}
Amino-2,6-dinitrotoluene[4-] (ppb)	U [0.325]	U [0.325]	U [0.325]
Amino-4,6-dinitrotoluene[2-] (ppb)	U [0.325]	U [0.325]	U [0.325]
Dinitrobenzene[1,3-] (ppb)	U [0.325]	U [0.325]	U [0.325]
Dinitrotoluene[2,4-] (ppb)	U [0.325]	U [0.325]	U [0.325]
Dinitrotoluene[2,6-] (ppb)	U [0.325]	U [0.325]	U [0.325]
HMX (ppb)	U [0.325]	U [0.325]	U [0.325]
Nitrobenzene (ppb)	U [0.325]	U [0.325]	U [0.325]
Nitrotoluene[2-] (ppb)	U [0.325]	U [0.325]	U [0.325]
Nitrotoluene[3-] (ppb)	U [0.325]	U [0.325]	U [0.325]
Nitrotoluene[4-] (ppb)	U [0.649]	U [0.649]	U [0.649]
PETN (ppb)	U [1.3]	U [1.3]	U [1.3]
RDX (ppb)	U [0.325]	U [0.325]	U [0.325]
TATB (ppb)	U [1.3]	U [1.3]	U [1.3]
Tetryl (ppb)	U [0.649]	U [0.649]	U [0.649]
Trinitrobenzene[1,3,5-] (ppb)	U [0.325]	U [0.325]	U [0.325]
Trinitrotoluene[2,4,6-] (ppb)	U [0.325]	U [0.325]	U [0.325]
Tri-o-cresylphosphate (ppb)	U [1.3]	U [1.3]	U [1.3]

All results are in micrograms per liter or parts per billion (ppb).

Appendix E

Deviations from Planned Activities

Activity	Drilling Work Plan for R-27 (Kleinfelder 2005a)	R-27 Actual Work
Planned Depth	Target total depth was 1,100 feet (ft) below ground surface (bgs).	R-27 was drilled to 987 ft bgs.
Drilling Method	Air rotary technique	R-27 was drilled with an air rotary rig.
Corehole	A nearby corehole was to be cored to 300 ft bgs.	Corehole was drilled to 272.8 ft bgs.
Screening Water Samples for Contaminant Analysis	If perched water was encountered in the unsaturated zone, groundwater samples were to be collected from each perched zones for screening analysis.	Two screening groundwater samples were collected from intermediate perched groundwater during drilling. One screening sample was also collected from the regional aquifer.
Post-Well Development Groundwater Sample	One groundwater sample to be collected following well development	A final water sample was collected immediately after well development from the regional aquifer.
Water Sample Analysis	Groundwater samples to be analyzed for perchlorate, anions, cations, and metals.	Screening and final groundwater samples were submitted for analysis of anions, cations, metals, and perchlorate. Additionally, three of the screening samples were submitted for high explosives analysis.
Field Hydraulic-Property Tests	Constant rate pumping test or slug test.	A constant rate pumping test has not been performed to date. After fluids can be discharged from the cuttings pit, an aquifer test will be conducted and an addendum to this report will be issued.