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Remediation Program

RRES

Characterization Well R-16 Completion Report

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Produced by the Groundwater Protection Program, Risk Reduction & Environmental Stewardship Division

CONTENTS

1.0 INTRODUCTION 1

2.0 PRELIMINARY ACTIVITIES 2

3.0 SUMMARY OF DRILLING ACTIVITIES 3

4.0 SAMPLING AND ANALYSIS OF DRILL CUTTINGS AND GROUNDWATER 4

5.0 BOREHOLE GEOPHYSICS 7
5.1 Geophysical Logging Using LANL Tools 10
5.2 Schlumberger Geophysical Logging 10

6.0 LITHOLOGY AND HYDROGEOLOGY 11
6.1 Stratigraphy and Lithologic Logging 11
6.2 Groundwater Occurrence and Characteristics 14

7.0 WELL DESIGN AND CONSTRUCTION 14
7.1 Well Design 14
7.2 Well Construction 15
7.2.1 Well Installation 15
7.2.2 Annular Fill Placement 15

8.0 WELL DEVELOPMENT AND HYDROGEOLOGIC TESTING 17
8.1 Well Development 17
8.2 Hydrologic Testing 19
8.3 Installation of Westbay™ Monitoring System 19

9.0 WELLHEAD COMPLETION AND SITE RESTORATION 20
9.1 Wellhead Completion 20
9.2 Geodetic Survey of Completed Well 20
9.3 Site Restoration 20

10.0 DEVIATIONS FROM THE R-16 SAP 22

11.0 ACKNOWLEDGEMENTS 22

12.0 REFERENCES 23

Appendixes

Appendix A Activities Planned for R-16 Compared with Work Performed

Appendix B Drill-Additive Product Specifications (CD attached to inside back cover)

Appendix C Lithology Log

Appendix D LANL Borehole Video Log (CD attached to inside back cover)

Appendix E Schlumberger Geophysical Report/Montage (CD attached to inside back cover)

Appendix F Westbay™ Multi-Level Sampling Diagram (CD attached to inside back cover)

Appendix G Waste Characterization Data

List of Figures

Figure 1.0-1 Location map, characterization well R-16 1
Figure 3.0-1 Well summary data sheet, characterization well R-16 5
Figure 3.0-2 Operations chronology diagram, characterization well R-16 6
Figure 7.2-1 As-built configuration diagram, characterization well R-16 16
Figure 9.1-1 Surface completion configuration diagram, characterization well R-16 21

List of Tables

Table 3.0-1 Fluid Additives Used, Characterization Well R-16 3
Table 4.1-1 Hydrochemistry of Regional Aquifer Samples at R-16 8
Table 5.0-1 Borehole and Well Logging Surveys, Characterization Well R-16 10
Table 7.1-1 Well Screen Information, Characterization Well R-16 15
Table 7.2-1 Annular Fill Materials, Characterization Well R-16 17
Table 8.1-1 Development of Characterization Well R-16 18
Table 9.2-1 Geodetic Data, Characterization Well R-16 22

List of Acronyms and Abbreviations

AITH	array induction tool, Model H
ASTM	American Society for Testing and Materials
bgs	below ground surface
CNTG	compensated neutron tool, model G
DOE	US Department of Energy
DR	dual rotation
ECS	elemental capture spectroscopy
EES	Earth and Environmental Science Group
ESH	Environmental, Safety and Health
FMI	formation microimager
FSF	Field Support Facility (part of the Risk Reduction and Environmental Stewardship Division)
GPS	global positioning system
GR	gamma radiation
hp	horsepower
HSA	hollow-stem auger
ICPES	inductively coupled plasma emission spectroscopy
ICPMS	inductively coupled plasma mass spectrometry

ID	inner diameter
LANL	Los Alamos National Laboratory
NAD 83	North American Datum, 1983
NGS	natural gamma spectroscopy
NMED	New Mexico Environmental Department
NTU	nephelometric turbidity unit
OD	outer diameter
PFD	phosphate-free dispersant
RC	reverse circulation
RRES	Risk Reduction and Environmental Stewardship Division
SAP	sampling and analysis plan
SSHASP	site-specific health and safety plan
TA	technical area
TD	total depth
TKN	total Kjeldahl nitrogen
TLD	Triple detector Litho-Density
UR-DTH	under-reaming down-the-hole
VOC	volatile organic compound
WCSF	waste characterization strategy form
XRD	x-ray diffraction
XRF	x-ray fluorescence

Metric to US Customary Unit Conversions

Multiply SI (Metric) Unit	by	To Obtain US Customary Unit
kilometers (km)	0.622	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.281	feet (ft)
meters (m)	39.37	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.394	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns (µm)	0.0000394	inches (in.)
square kilometers (km^2)	0.3861	square miles (mi^2)
hectares (ha)	2.5	acres
square meters (m^2)	10.764	square feet (ft^2)
cubic meters (m^3)	35.31	cubic feet (ft^3)
kilograms (kg)	2.2046	pounds (lb)
grams (g)	0.0353	ounces (oz)
grams per cubic centimeter (g/cm^3)	62.422	pounds per cubic foot (lb/ft^3)
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
micrograms per gram (µg/g)	1	parts per million (ppm)
liters (L)	0.26	gallons (gal.)
milligrams per liter (mg/L)	1	parts per million (ppm)
degrees Celsius (°C)	9/5 + 32	degrees Fahrenheit (°F)

CHARACTERIZATION WELL R-16 COMPLETION REPORT

ABSTRACT

Characterization well R-16 was installed by Los Alamos National Laboratory (LANL or the Laboratory) under implementation of its hydrogeologic work plan. Well R-16 is located just south of Cañada del Buey near White Rock Overlook Park and immediately upstream from the sanitary sewage treatment plant. The primary purpose of this well is to provide water-quality, geochemical, hydrologic, and geologic information that would contribute to understanding the hydrogeologic setting beneath the Laboratory. In addition, this well was designed to monitor regional groundwater near potential contaminant release sites at Technical Area (TA)-54 and to act as a monitoring point between TA-54 and the Rio Grande.

In addition, hydrologic, geologic, geochemical, and geophysical information obtained during completion and subsequent sampling of R-16 will provide data for the Laboratory's hydrologic and geologic conceptual models and contribute to implementing a Laboratory-wide groundwater monitoring network. Monitoring of this network of wells supports the Laboratory's Groundwater Protection Management Program Plan.

The R-16 borehole was drilled to a total depth of 1287 ft using fluid-assisted air-rotary and conventional mud-rotary drilling methods. No core drilling was conducted at R-16. Samples of drill cuttings were collected at regular intervals for stratigraphic, petrographic, and geochemical analyses. Geologic strata encountered during drilling operations at R-16 included, in descending order, alluvial sediments, the Otowi Member of the Bandelier Tuff, basaltic sediments, Puye Formation lake deposits, Cerros del Rio lavas, more Puye lake deposits, older alluvium, more Cerros del Rio lavas, Totavi axial gravels interspersed with Puye fanglomerates, and sediments of the Santa Fe Group.

The zone of regional groundwater saturation was encountered at a depth of 642 ft below ground surface. Well installation was completed with four screened intervals installed within the regional aquifer. Although no groundwater samples were taken during drilling, water samples were collected during well development activities and following hydrologic testing. A Westbay™ multiport system for groundwater sampling was installed inside the well casing.

1.0 INTRODUCTION

This completion report for characterization well R-16 describes the site preparation, drilling, well construction, well development, hydrologic testing and related activities conducted from July 30 to December 4, 2002. Well R-16 is located on the south rim of Cañada del Buey, near White Rock Overlook Park, and immediately upstream from the sanitary sewage treatment plant (Figure 1.0-1). This well was installed as outlined in the "Hydrogeologic Workplan" (LANL 1998, 59599), in support of Los Alamos National Laboratory's (LANL or the Laboratory) "Groundwater Protection Management Program Plan" (LANL 1996, 70215).

Figure 1.0-1. Location map, characterization well R-16

Well R-16 was funded by the Nuclear Weapons Infrastructure, Facilities, and Construction Program and installed by the Laboratory's former Environmental Restoration Project, now part of the Risk Reduction and Environmental Stewardship (RRES) Division. Washington Group International, Inc. (WGII), under contract to the Laboratory, was responsible for executing drilling activities.

Information presented in this report was compiled from field reports and activity summaries generated by the Laboratory and the drilling subcontractor. Geophysical data and geodetic survey information are also included. Data from R-16 and similar wells support the Laboratory's "Groundwater Protection Management Program Plan" (LANL 1996, 70215).

The primary purpose of this characterization well is to provide water-quality, geochemical, hydrologic, and geologic information that would contribute to understanding regional subsurface characteristics and distribution of contaminants downgradient of Laboratory releases from Technical Area (TA)–54 and from Laboratory activities in the Mortandad Canyon watershed. Additionally, data from R-16 will be used to update the sitewide hydrologic and geologic conceptual models for the Laboratory.

This report focuses on operational activities associated with drilling, sampling, and completing well R-16. Detailed analysis and interpretation of geologic, geochemical, geophysical, and hydrologic data, included as part of previous well completion reports, will be discussed in separate technical documents to be prepared by the Laboratory.

2.0 PRELIMINARY ACTIVITIES

WGII received contractual authorization to start administrative preparatory tasks on June 6, 2002. As part of these tasks, WGII prepared a modification to the existing site-specific health and safety plan (No. 271) to include well R-16. WGII also prepared the R-16 waste characterization strategy form (WCSF). The Laboratory prepared "Sampling and Analysis Plan (SAP) for the Drilling of Characterization Wells R-16, R-20, R-21, R-23, and R-32 in the Vicinity of TA-54" (LANL 2002, 73390) to guide field personnel in executing R-16 field activities. Appendix A of this completion report compares activities planned in the sampling and analysis plan (SAP) with the work performed. An agreement to provide access to R-16 on Los Alamos County land was approved on July 25, 2002, to accommodate sampling activities. This access agreement will terminate on December 31, 2017.

A readiness review meeting was held July 9, 2002, to discuss all administrative documents, permits, agreements, and plans pertaining to drilling and installing the R-16 drill pad. The Groundwater Investigations Focus Area project leader signed the readiness review checklist on July 29, 2002, giving authorization to begin work.

K. R. Swerdfeger Construction, Inc., was subcontracted by WGII to conduct site preparation activities, including clearing the site and removing vegetation, placing gravel on the access road, grading and compacting the drill pad, and constructing a lined cuttings-containment area. A temporary chainlink fence was also installed around the site for security. Site preparation was completed between July 30 and August 2, 2002.

The site initially was cleared of vegetation, and portions of the access road were graded and improved. Initial construction involved leveling the designated area with a grader and then compacting the subgrade. Base-course gravel was graded and compacted across the site to complete the drill pad. To store drilling fluids and cuttings, an 18-ft-wide by 85-ft-long by 12-ft-deep cuttings-containment area was excavated along the north end of the site. A 3-ft-high berm was constructed around the containment area, and the entire excavation was lined with a 4-mil polyethylene liner. A secondary fluids-containment area was

graded and lined with a 6-mil polyethylene liner to accommodate two 20,000-gal. tank trailers used for storing drilling fluids pumped from the cuttings-containment area. Safety barriers and signs were installed around the cuttings-containment area and other appropriate locations. Office and supply trailers, generators, and safety lighting equipment were also set up on the site.

3.0 SUMMARY OF DRILLING ACTIVITIES

Dynatec Drilling Company, Inc. (Dynatec), conducted R-16 drilling activities. Drilling operations involved drilling with reverse circulation (RC) air-rotary/fluid-assist to approximately 783 ft and then switching to conventional mud-rotary methods to the total depth (TD) of 1287ft. Coring was not performed at this site. Dynatec provided a Foremost™ dual rotary (DR)-24 drill rig, along with RC drilling rods, conventional mud-drilling equipment, and other support equipment. RRES Division's Field Support Facility (FSF) provided additional equipment and fabrication support for drilling activities.

Open-hole and casing-advance techniques were employed during air-rotary drilling, as determined by changing geologic and drilling conditions. Various additives were mixed with municipal water to improve borehole stability, minimize fluid loss, and facilitate removing cuttings from the borehole. RC air-rotary drilling was assisted with a foam mixture that consisted of municipal water mixed with soda ash, QUICK-GEL®, LIQUI-TROL™, and QUICK-FOAM®. The fluid mixture that was used during mud-rotary drilling typically consisted of municipal water mixed with QUICK-GEL® and LIQUI-TROL™. Magma-Fiber and N-seal were used in the mud mixture to help maintain or regain circulation within the borehole (Appendix B, in a CD attached to the back cover of this document). Table 3.0-1 summarizes quantities of additives and fluids used in the drilling of R-16.

Table 3.0-1
Fluid Additives Used, Characterization Well R-16

Additive	Amount	Unit of Measure
Interval Drilled (0–729 ft)		
Water	35,800	gal.
Quick-Gel®	20,000	lb
Liqui-Trol™	100	gal.
Foam	650	gal.
Soda ash	400	lb
Interval Drilled (729–1287 ft)		
Water	38,350	gal.
Quick-Gel®	31,100	lb
EZ-Mud®	25.5	gal.
Liqui-Trol™	5	gal.
Magma Fiber	800	lb
Pac-L	50	lb
N-Seal	800	lb
Soda ash	100	lb

Dynatec supplied the conventional mud drilling equipment, including a mixing tank and pump assembly, a generator to power the mixing unit, a de-sander unit for removing solids from the discharged drilling fluids, and a large auxiliary pump.

Drilling objectives were to collect groundwater samples for contaminant analysis, produce samples for geologic characterization, and provide a borehole for installation of the well in the regional aquifer. However, no perched water was detected during drilling. Also, because of the type of drilling performed, water samples could not be collected from the regional aquifer. The R-16 borehole was completed to a TD of 1287 ft below ground surface (bgs).

Sections 3.1 and 3.2 below discuss drilling activities. Figure 3.0-1 summarizes well data and depicts groundwater and geologic conditions encountered in well R-16. Figure 3.0-2 is a diagram of the chronology of drilling and other on-site activities.

Drilling Activities

The drill rig was mobilized to the R-16 site on August 16, 2002. Dynatec began drilling with a 16-in. tricone bit to 15 ft below ground surface (bgs), then reamed the borehole with a 22-in. quadcone drill bit. An 18-in. diameter steel conductor casing was then installed and landed at 15 ft bgs on August 17, 2002. Open-hole drilling continued with the 16-in. tricone bit from 15 ft bgs into the Otowi Member of the Bandelier Tuff. While drilling at 84 ft bgs, the driller noticed that the 18-in. conductor casing was subsiding. Dynatec added a 5-ft extension to the conductor casing and then reamed the casing down to 20 ft bgs, where it was landed and cemented in place. On August 18, 2002, open-hole drilling continued with the 16-in. tricone bit from 84 ft bgs. Over the next several days, the borehole was advanced down to the top of the Santa Fe Group sediments at 728 ft bgs on August 21, 2002.

Dynatec then tripped out the drill stem to install surface casing to stabilize the open portion of the borehole before drilling into the regional saturated zone. While tripping out the down-hole tools, the drillers encountered obstructions at various depths in the borehole, indicating collapse and/or swelling of formations with high clay content. After the tools were tripped out, a bridge in the open borehole was measured at 117 ft bgs. From August 21 through August 24, 2002, Dynatec made two unsuccessful attempts to ream out the borehole. After each attempt, bridges were measured at 130 and 107 ft bgs, respectively. An attempt to video log on August 22, 2002, showed bridging at 117 ft bgs. To alleviate the unstable borehole conditions, the decision was made to advance 11.75-in. diameter drill casing the entire bored interval. Dynatec reamed the borehole with a 12.5-in. under-reaming down-the-hole (UR-DTH) hammer bit and landed the 11.75-in. drill casing at 729 ft bgs on August 26, 2002.

Open-hole drilling continued on August 27, 2002, using a 10.625-in. tricone bit from 728 to 867 ft bgs, where drilling was temporarily stopped to monitor the depth to groundwater. A static water level was measured at 621 ft bgs. After switching over to conventional mud-rotary drilling, the borehole was advanced to a total depth (TD) of 1287 ft bgs on August 29, 2002. Drilling operations at R-16 were completed on August 30, 2002. The rig was demobilized on September 8 and 9, 2002.

4.0 SAMPLING AND ANALYSIS OF DRILL CUTTINGS AND GROUNDWATER

Drill cuttings were collected at 5-ft intervals as specified in the R-16, R-20, R-23, R-32 SAP (LANL 2002, 73390). A portion of the cuttings was sieved (at >#10 and >#35 mesh) and placed in chip tray bins along with an unsieved portion. These samples were used to prepare lithologic logs (Appendix C). The remaining cuttings were placed in ziplock bags and set in core boxes for curation. Before curation, 16 sample splits were removed for use in mineralogy, petrography, and geochemical analyses.

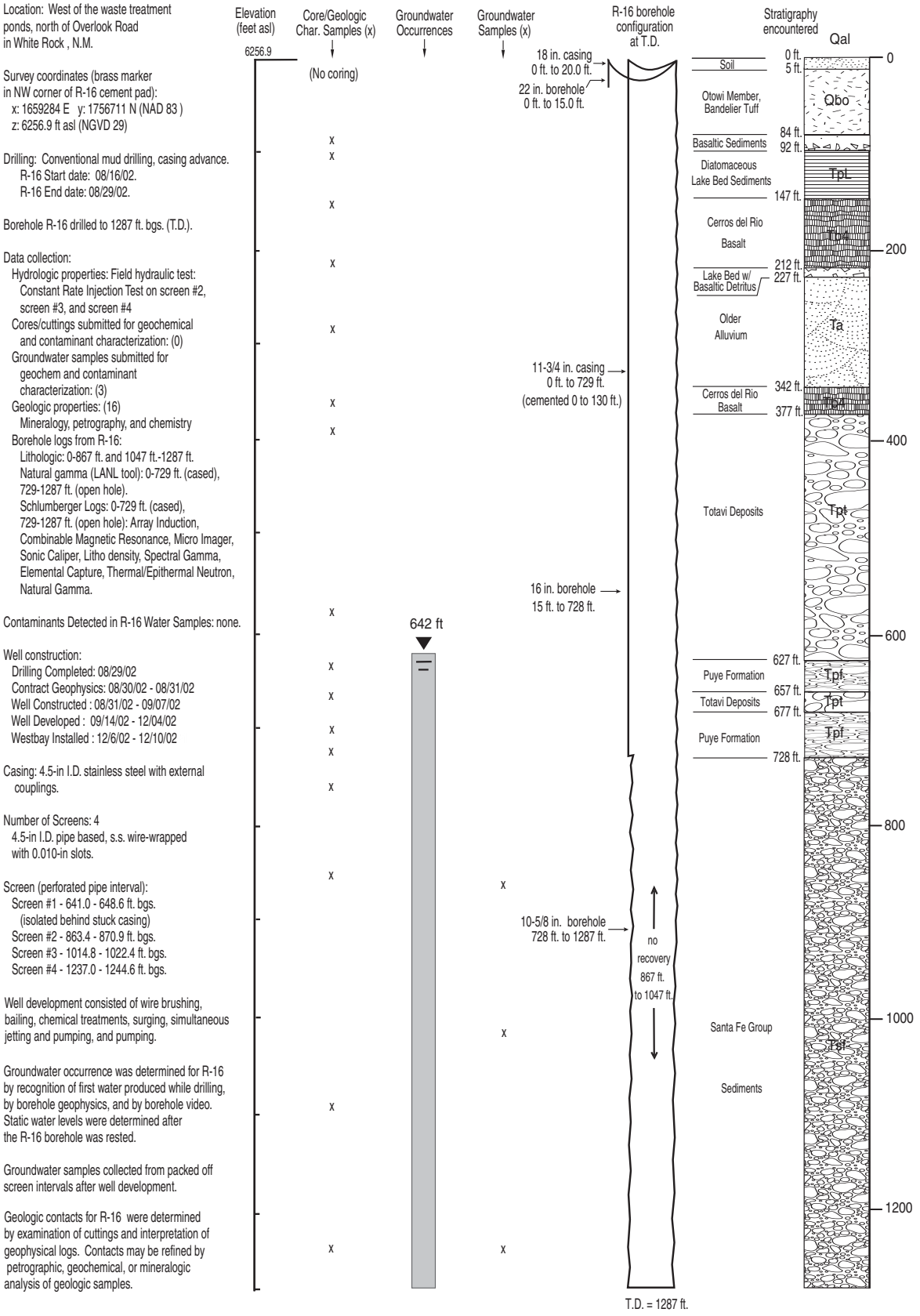


Figure 3.0-1. Well summary data sheet, characterization well R-16

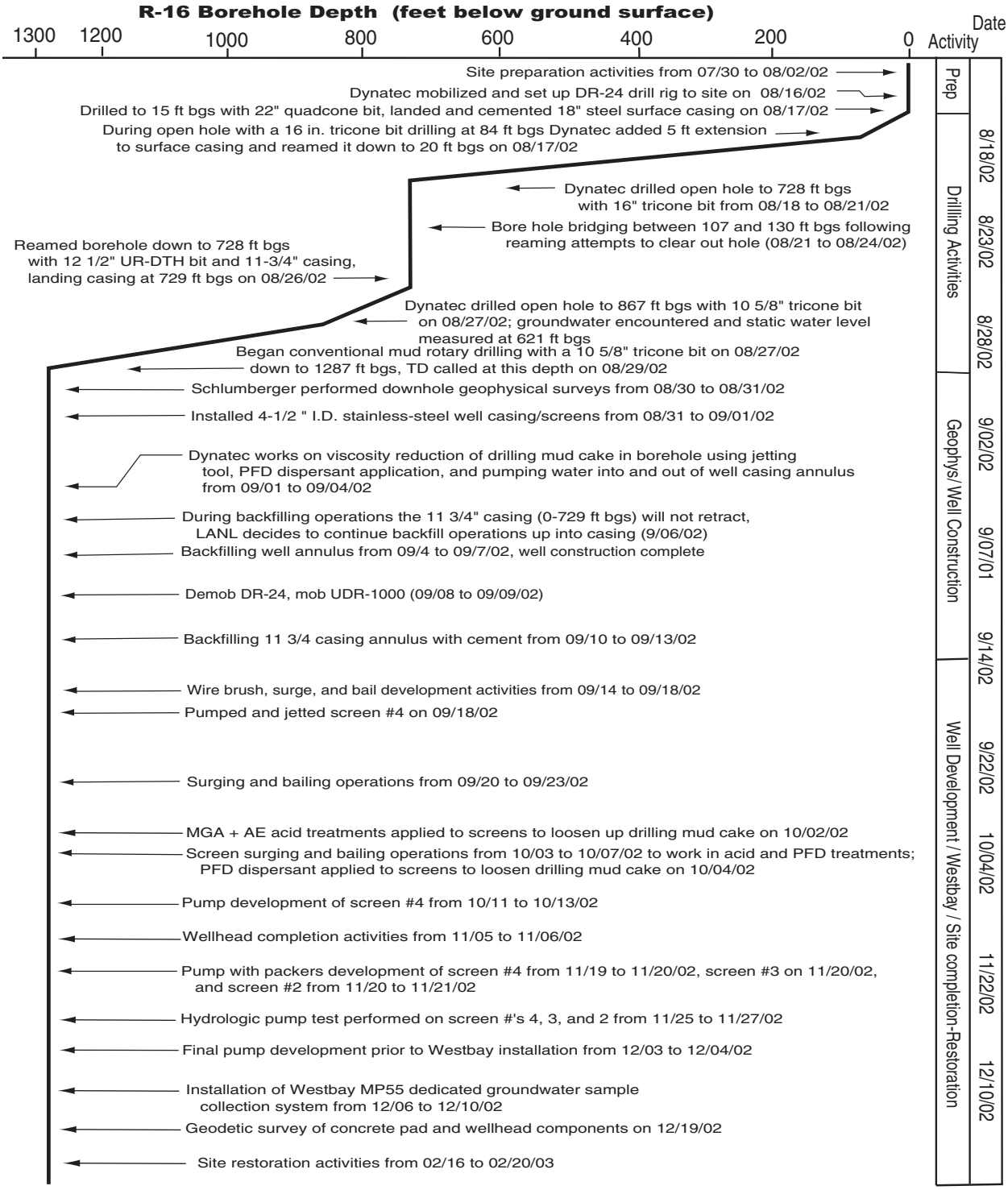


Figure 3.0-2. Operations chronology diagram, characterization well R-16

Groundwater samples were not collected from the open borehole during drilling due to the adverse impact of drilling mud and additives to the groundwater chemistry. However, three samples were collected from screened intervals at 863.4 to 870.9 ft bgs, 1014.8 to 1022.4 ft bgs, and 1237.0 to 1244.6 ft bgs in the regional aquifer after well development. The results are reported below.

Geochemistry of Sampled Waters

Groundwater samples were analyzed to investigate the presence of constituents from laboratory releases. Major potential contaminants of concern at R-16 include perchlorate, nitrate, and tritium.

Groundwater samples were collected using a packer/pump assembly that straddled each screen interval and analyzed for inorganic, organic, and radionuclide constituents. Water was collected and filtered for metal, trace-element, major-cation and major anion analysis. Nonfiltered water was collected for stable isotope, organics, tritium, and radiochemical analysis. Filtered samples were passed through a 0.45-µm Gelman cartridge filter. Samples were acidified as needed with the appropriate analytical-grade acid to a pH of 2.0 or less for metal, major cation, and volatile organic compound (VOC) analyses. All groundwater samples collected in the field were stored at 4°C until they were analyzed.

Groundwater samples were analyzed by laboratories under contract to the Laboratory under the University of California Los Alamos National Laboratory statement of work for analytical laboratories and at the Laboratory's Earth and Environmental Science (EES)-6 laboratory LANL 2000, 71233), using techniques specified in the US Environmental Protection Agency SW-846 manual (available at http://clu-in.org/char1.cfm). Ion chromatography was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. Inductively coupled (argon) plasma emission spectroscopy (ICPES) was used for aluminum, arsenic, barium, chromium, cobalt, copper, iron, manganese, nickel, selenium, silver, calcium, magnesium, potassium, silica, sodium, and zinc. Antimony, beryllium, cadmium, lead, thallium, vanadium, and uranium were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS). Tritium activity in a groundwater sample was determined by electrolytic enrichment at the University of Miami. Americium-241 was analyzed according to (HASL)-300; cesium-137 by generic gamma spectroscopy; plutonium-238 and plutonium-239 by isotopic plutonium (HASL-300); strontium-90 by beta counting; and uranium-234, uranium-235, and uranium–238 by isotopic uranium (HASL-300). Delta deuterium and oxygen 18/16 ratios were determined at Geochron Laboratory. VOC analysis was performed by gas chromatography mass spectroscopy. The precision limits (analytical error) for major ions and trace elements generally were less than ±10% using ICPES and ICPMS.

Table 4.1-1 provides results of screening analyses for regional groundwater samples collected from the Santa Fe Group in well R-16. Based on analytical results for three samples, contamination from Laboratory discharges does not appear to be present in the regional aquifer at this well site.

5.0 BOREHOLE GEOPHYSICS

Using Laboratory tools and Schlumberger geophysical logging services (Schlumberger), WGII performed borehole-logging operations at R-16. Table 5.0-1 lists borehole and well logging surveys performed.

Table 4.1-1
Hydrochemistry of Regional Aquifer Samples at R-16

Analysis/Analyte (location/unit of measure)	863.4–870.9 (ft bgs) 11/21/02	1014.8-1022.4 (ft bgs) 11/20/02	1237.0–1244.6 (ft bgs) 11/19/02
Inorganics (EES-6 laboratory)			
Alkalinity (field; mg $CaCO_3$/L)	71	81	72
Conductivity (field; µS/cm)	170	194	179
pH (field)	8.03	7.82	7.98
Temperature (field; ^oC)	24.3	24.6	23.5
Turbidity (field; NTU)	1.32	0.87	0.9
Al (mg/L)	0.002	0.002	0.002
Sb (mg/L)	[0.0001], U	0.0001	[0.0001], U
As (mg/L)	0.0024	0.0028	0.0026
Ba (mg/L)	0.013	0.018	0.015
Be (mg/L)	[0.001], U	[0.001], U	[0.001], U
B (mg/L)	0.012	0.011	0.011
Br (mg/L)	0.03	0.02	0.04
Cd (mg/L)	[0.001], U	[0.001], U	[0.001], U
Ca (mg/L)	19.1	23.3	20.4
Cl (mg/L)	2.57	2.56	2.57
ClO_4 (mg/L)	[0.002], U	[0.002], U	[0.002], U
ClO_3 (mg/L)	[0.02], U	[0.02], U	[0.02], U
Cr (mg/L)	0.0036	0.0034	0.0040
Co (mg/L)	[0.001], U	[0.001], U	0.0015
Cu (mg/L)	0.0038	[0.001], U	0.0015
F (mg/L)	0.33	0.29	0.28
Fe (mg/L)	0.01	0.01	0.02
Pb (mg/L)	0.0004	0.0001	0.0002
Mg (mg/L)	1.76	2.04	1.92
Mn (mg/L)	0.0019	0.0022	0.0056
Mo (mg/L)	0.0012	0.0012	0.0013
Ni (mg/L)	[0.001], U	[0.001], U	[0.001], U
NO_3 (mg/L; as N)	1.02	0.53	1.02
NO_2 (mg/L; as N)	[0.01], U	[0.01], U	[0.01], U
C_2O_4 (mg/L) (oxalate)	[0.02], U	[0.02], U	[0.02], U
P (mg/L)	[0.006], U	0.075	0.007
K (mg/L)	2.55	3.13	2.48
Se (mg/L)	[0.001], U	[0.001], U	[0.001], U
Ag (mg/L)	0.0004	[0.0001], U	[0.0001], U
Na (mg/L)	13.5	15.4	15.7

Table 4.1-1 (continued)

Analysis/Analyte (location/unit of measure)	863.4–870.9 (ft bgs) 11/21/02	1014.8-1022.4 (ft bgs) 11/20/02	1237.0–1244.6 (ft bgs) 11/19/02
Inorganics (EES-6 laboratory) (continued)			
SiO_2 (mg/L)	56.3	53.3	54.8
SO_4 (mg/L)	4.09	4.13	4.10
Tl (mg/L)	[0.001], U	[0.001], U	[0.001], U
U (mg/L)	0.0010	0.0020	0.0013
V (mg/L)	0.014	0.014	0.014
Zn (mg/L)	0.063	0.25	0.52
δD (permil; Geochron Lab))	-75	-75	-78
D18O (permil; Geochron Lab)	-10.8	-10.8	-10.8
Organics (contract laboratory; additional VOC results were below detection)			
Toluene (mg/L)	BDL	0.002	0.022
Radiochemistry (contract laboratory)			
Am^{241} (pCi/L) (nonfiltered)	[-3.34], U	[5.37], U	[-6.96], U
Cs^{137} (pCi/L) (nonfiltered)	[0.296], U	[-0.524], U	[0.759], U
Gross alpha/beta (pCi/L) (nonfiltered)	[0.519], U	[0.325], U	[0.461], U
Gross beta (pCi/L) (nonfiltered)	[2.42], U	[3.95], U	[2.56], U
Gross gamma (pCi/L) (nonfiltered)	[40.9], U	[70.9], U	[147], U
Pu^{238} (pCi/L) (nonfiltered)	[0.0023], U	[0], U	[0.0062], U
Pu^{239} (pCi/L) (nonfiltered)	[0.0023], U	[0.002], U	[-0.0041}
Sr^{90} (pCi/L) (nonfiltered)	[0.010], U	[0.093], U	[0.048], U
Tritium (pCi/L) (nonfiltered)	[-0.22], U	[0.22], U	[0.48], U
U^{234} (pCi/L) (nonfiltered)	0.719	1.16	0.669
U^{235} (pCi/L) (nonfiltered)	[0.023], U	0.061	[0.026], U
U^{238} (pCi/L) (nonfiltered)	0.391	0.707	0.428

Notes: All samples collected from Santa Fe Group.

BDL = below detection limits.

U = not detected.

J = Analyte is classified as “detected” but reported concentration value is expected to be more uncertain than usual.

Table 5.0-1
Borehole and Well Logging Surveys, Characterization Well R-16

Surveyor	Date	Method	Cased Interval (ft bgs)	Open-Hole Interval (ft bgs)	Remarks
WGII/LANL	August 22, 2002	Video	0–20	20–729 (728)	Conducted to observe borehole conditions; bridging at 117 ft prevented logging to TD
Schlumberger	August 30 to 31, 2002	Logging suite[a]	0–729	729–1287	Schlumberger conducted logging in borehole prior to well design and construction
WGII/LANL	August 31, 2002	Natural gamma	0–729	729–1287	LANL conducted logging in borehole prior to well design and construction
WGII/LANL	November. 13, 2002	Video	0–1276.7	NA[b]	Conducted to document and verify interior well condition prior to Westbay™ installation

[a] Schlumberger's suite of borehole logging surveys included array induction, lithodensity, spectral gamma, elemental capture, compensated neutron, formation microimager, magnetic resonance, caliper, and natural gamma.

[b] NA = Not applicable.

5.1 Geophysical Logging Using LANL Tools

On August 31, 2002, a natural gamma log was run in borehole R-16 using a down-hole tool provided by the Laboratory. The gamma log was run to provide lithologic and stratigraphic information that complement data gathered from cuttings. Natural gamma logs have proven successful in discriminating between geologic units containing varying concentrations of uranium, thorium, and potassium. The gamma log was run prior to well construction inside the 18-in. surface casing from the surface to 20 ft bgs, in the 11.75-in. conductor casing to 729 ft bgs, and in open-hole conditions from 729 to 1287 ft bgs. Measurements of natural gamma activity were obtained every 0.1 ft as the logging tool was raised upward in the hole at a rate of about 15 ft/min.

One open-hole video was run to inspect borehole conditions and slough/bridging problems. Another video was run to view the interior of the installed well as a quality control procedure to inspect the condition of casing and screens after well development but before installation of the Westbay™ system. The Laboratory open borehole video logs are in Appendix D (on CD attached to the inside back cover of this report).

5.2 Schlumberger Geophysical Logging

Schlumberger conducted borehole geophysical logging activity from August 30 through 31, 2002, in the R-16 borehole. Prior to well construction, a suite of logging surveys was performed inside the 18-in. surface casing from the surface to 20 ft bgs, in the 11.75-in. conductor casing to 729 ft bgs, and in open-hole conditions from 729 to 1287 ft bgs.

The primary purpose of the Schlumberger logging was to characterize hydrogeologic conditions in the units penetrated by the R-16 borehole, with an emphasis on determining moisture distribution in the regional saturated zones, measuring flow capacity, and obtaining lithologic/stratigraphic data. Secondary

objectives included evaluating borehole geometry and assessing the degree of drilling-fluid invasion into the borehole walls.

The Schlumberger suite of geophysical logging tools included the following:

- Array Induction Tool, Version H (AITH™) measures formation electrical resistivity and borehole fluid resistivity, evaluates drilling fluid invasion into the formation, and assesses the presence of moist zones far from the borehole wall and the presence of clay-rich zones.
- Fullbore Formation Micro Imager (FMI™) measures electrical conductivity images of the borehole wall and the borehole diameter with a two-axis caliper, thus evaluating geologic bedding and fracturing, including strike-and-dip of these features, fracture apertures, and rock textures.
- Sonic Delta T Borehole Caliper measures acoustic impedance of sonic wave propagation by the surrounding borehole, thus evaluating variations in borehole dimensions and identifying fractures.
- Triple detector Litho-Density (TLD™) measures total porosity and bulk density of a formation, photoelectric effects, and borehole diameter and characterizes lithology.
- Natural Gamma Spectroscopy (NGS™) measures gross natural and spectral gamma-ray activity (including potassium, thorium, and uranium concentrations) in open- and cased-hole conditions to help characterize geology and lithology, in particular the amount of clay present.
- Elemental Capture Sonde (ECS™) measures elemental weight concentrations of a variety of elements (iron, sulphur, silicon, calcium, thallium, gadolinium, chlorine, and hydrogen) to characterize formation mineralogy and lithology and determine water content.
- Compensated (thermal-epithermal) Neutron Tool, Model G (CNTG™) measures volumetric water content outside the casing to evaluate formation moisture content and porosity.

In addition, a calibrated natural gamma tool was used to record gross natural gamma-ray activity with every logging method (except NGS™) to correlate depth runs between each survey.

The Schlumberger logging summary report for borehole R-16 and the geophysical logs for all Schlumberger methods, compiled as a montage, are in Appendix E (on CD attached to the back inside cover of this report).

6.0 LITHOLOGY AND HYDROGEOLOGY

A preliminary assessment of the hydrogeologic features encountered in borehole R-16 is presented below, including a description of the geologic units identified during cuttings characterization. Groundwater occurrence is discussed and evaluated by drilling evidence and geophysical data.

6.1 Stratigraphy and Lithologic Logging

Lithologic descriptions are based on cuttings samples collected from the R-16 borehole from ground surface to a TD of 1287 ft. The samples were collected at 5-ft intervals and prepared by washing and sieving. Because circulation was lost while drilling, no cuttings were recovered from 867 to 1047 ft (within the Santa Fe Group). Sieved samples were examined microscopically to complete the field lithologic log that is presented as Appendix C. A generalized stratigraphic column is shown in the well data summary sheet for R-16 (Figure 3.0-1).

Rock units and stratigraphic relationships, interpreted primarily from data collected during visual examination of drill cuttings samples, are discussed in order of younger-to-older occurrences. Such interpretations may be refined upon future detailed analysis of petrographic, geochemical, mineralogical, and geophysical data.

Alluvium (0 to 5 ft bgs)

Unconsolidated tuffaceous sands and gravels derived from the Bandelier Tuff were noted in the interval from 0 to 5 ft bgs. These sediments represent soil and alluvium on the canyon rim south of Cañada del Buey.

Otowi Member of the Bandelier Tuff (5 to 84 ft bgs)

The Quaternary-age Otowi Member of the Bandelier Tuff was intersected in the R-16 borehole from 5 to 84 ft bgs. Drill cuttings indicate that this unit is composed of vitric pumice, quartz and sanidine crystals, and abundant volcanic xenoliths. Little of the ash matrix is preserved in chip samples, indicating the poorly welded to nonwelded nature of this rhyolitic ash-flow unit. Pumice fragments are generally glassy with a fibrous structure and commonly are stained with iron oxides. Coarse chip samples are frequently 40% to 60% by volume dacite and basalt lithics. Cuttings and geophysical logs leave some uncertainty as to whether the Guaje Pumice Bed of the Otowi Member is present.

Basaltic Sediments (84 to 92 ft bgs)

Basalt-rich volcaniclastic gravels and sands were encountered from 84 to 92 ft bgs. This sedimentary interval has not been assigned to any unit in the stratigraphic section in the vicinity of R-16. Up to 50% of the cuttings in this interval contain chips of vesicular and massive basalt that probably derive from Cerros del Rio basalt sources. Other sample components include clasts of dacite, silicified dacite, black vitrophyre, and clay nodules.

Puye Formation—Diatomaceous Lakebed Sediments (92 to 147 ft bgs)

A complex, 636-ft-thick sequence of sedimentary deposits and intercalated basaltic lavas was intersected in borehole R-16 below a depth of 92 ft. The sequence is made up of subunits of the Puye Formation and Cerros del Rio basalt, both of Tertiary age. The uppermost subunit in the sequence is discussed here.

An interval of clays and clay-rich sands and gravels occurs from 92 to 147 ft bgs. These sediments are interpreted to represent lakebed deposits associated with a lacustrine depositional environment in the upper part of the Puye Formation. Cuttings are locally (e.g., notably from 92.2 to 107.2 ft bgs) made up of white clay fragments containing microscopic siliceous tubules. Scanning-electron-microscope analysis shows these fragments are the fossil remains of fresh-water diatoms. Basaltic clasts, preserved in the basal part of this unit, exhibit orange-colored, limonite-clay rinds, suggesting palagonite alteration.

Upper Cerros del Rio Basalt (147 to 212 ft bgs)

Two intervals of the Tertiary-age Cerros del Rio basalt are recognized in R-16. These volcanic units are intercalated with sedimentary deposits of the Puye Formation. The upper basalt occurs in the interval from 147 to 212 ft bgs. Evidence from cuttings suggests that this unit represents a discrete flow made up of massive-to-vesicular, porphyritic olivine basalt with an aphanitic groundmass. In general, this basalt is sparsely altered as characterized by iddingsite replacement of olivine phenocrysts, iron-oxide and clay coatings on fractures, and groundmass minerals that are variably altered.

Lakebed Sediments with Basalt Detritus (212 to 227 ft bgs)

Additional lakebed deposits containing basaltic detrital sediments are interpreted to occur in the interval from 212 to 227 ft bgs. Samples in this interval contain abundant altered basalt chips and fragments of clay-cemented sandstone.

Older Alluvium (212 to 342 ft bgs)

A 115-ft-thick sequence of clastic sediments intersected from 212 to 342 ft bgs is interpreted to be "older" (i.e., pre-Quaternary) alluvium (as defined by Griggs [1964, 8795]) intercalated within the Puye Formation. Sands and gravels of this interval contain abundant fragments of quartzo-feldspathic sandstone and subrounded coarser clasts dominantly composed of quartz, feldspars, and granitic rocks derived from Precambrian sources.

Lower Cerros del Rio Basalt (342 to 377 ft bgs)

The interval from 342 to 377 ft bgs represents a stratigraphically lower flow of the Cerros del Rio basalt interlayered with Puye sediments. Cuttings indicate that this clay-rich interval is made up of abundant chips (up to 60% by volume) of olivine basalt and fine-to-coarse quartzo-feldspathic detrital sediments. Samples also contain 30% to 40% by volume quartzo-feldspathic detritus.

Totavi Lentil (377 to 627 ft bgs)

R-16 encountered a 250-ft-thick section of quartzite-rich clastic sediments in the interval from 377 to 627 ft bgs that represents the Totavi Lentil. As described by Dethier (1997, 49843), the Totavi Lentil consists of axial channel deposits of the ancestral Rio Grande that occur as lenses within the Puye Formation. Totavi deposits are predominantly quartzite, granite, and other Precambrian materials. The interval is locally made up of clay-rich sands and gravels containing subangular to subrounded clasts derived from Precambrian and, to a lesser degree, volcanic sources. The proportion of Precambrian source materials in these sediments typically ranges from 60% to 80% by volume. Clasts are composed of quartzite, quartz, feldspars, and granitic and metamorphic lithics, and include abundant fragments of indurated quartzo-feldspathic sandstone. Volcanic detritus (20% to 40% by volume) consists mainly of dacite and minor basalt.

Puye Formation and Intercalated Totavi Deposits (627 to 728 ft bgs)

The interval from 627 to 728 ft bgs is composed of detritus from both volcanic and Precambrian sources. These are fanglomerate deposits in which coarse volcanic detritus occurs as the dominant component, typically in the range of 60% to 80% by volume. The volcanic clasts generally are subrounded to rounded and are composed mainly of pink and grayish dacites with minor basalt. Characteristic percentages of coarse quartzite and granitic detritus range from 10% to 40% by volume. The interval from 657 to 677 ft bgs has been interpreted as representing Totavi-related axial river gravels with little or no Puye fanglomerate.

Santa Fe Group Sediments (728 to 1287 ft bgs)

R-16 penetrated a 559-ft-thick section of clay-rich sandstones and gravels in the lowermost drilled interval, from 728 to 1287 ft (TD), that represent sedimentary deposits of the Tertiary-age Santa Fe Group. These sediments are moderately indurated, as evidenced by locally abundant fragments of quartzo-feldspathic sandstone in chip samples. In general, they are composed of materials from both

volcanic and Precambrian sources in variable, though overall equal, proportions. Volcanic clasts are predominantly dacitic; however, basalt, latite, rhyodacite, black vitrophyre (obsidian), and tuffaceous quartz crystals are also evident. Precambrian lithologies include quartz, pink (microcline) and white (plagioclase) feldspars, quartzite, and granite. Quartzo-feldspathic grains commonly exhibit frosted, well-rounded surfaces.

6.2 Groundwater Occurrence and Characteristics

It was anticipated that the regional water table at R-16 would be encountered at approximately 783 ft bgs in the Santa Fe Group, and no perched groundwater zones were predicted. Drilling was performed throughout the entire depth using either air-rotary methods with foam additives or conventional mud-rotary techniques, substantially reducing the ability to detect and observe perched groundwater zones, when they were present.

The regional water table was encountered on August 27, 2002, while drilling through relatively coarse-grained Santa Fe Group sediments. The increase in water production at the end of the discharge line was first observed when the depth of the borehole was at 867 ft bgs, with 11.75-in. drill casing lining the borehole to 729 ft bgs. The water level in the borehole stabilized at 621 ft bgs. No water samples were collected for chemical analysis during the drilling phase of operations. Drilling continued after the presence of regional groundwater was verified, using conventional mud-rotary and casing advance techniques, thus precluding observation of groundwater characteristics. On November 25, 2002, after well development but before hydrologic testing, the water level in the well was measured at 642 ft bgs.

7.0 WELL DESIGN AND CONSTRUCTION

Well R-16 was designed to provide hydrogeologic, geochemical, and water-quality data for the regional aquifer. Sections 7.1 and 7.2 describe the R-16 well design and construction, respectively.

7.1 Well Design

The design for well R-16 was completed jointly by the Laboratory and WGII, in consultation with the New Mexico Environment Department (NMED) and the US Department of Energy (DOE). Geophysical logs, video logs, borehole geologic samples, water-level data, field water-quality data, and drillers' observations were reviewed by the Groundwater Integration Team to plan screen placement intervals for the well. The well design specified four screens to monitor the distribution and concentration of contaminants in the regional aquifer. The number and placement of the screens were designed to

- monitor the top of the regional zone of saturation (screen 1) and
- monitor deeper, more productive zones within the regional aquifer (screens 2, 3, and 4).

Productive intermediate perched groundwater zones were not encountered during drilling; therefore, no screens were placed above the regional water table. The planned and actual screen locations are given in Table 7.1-1.

Table 7.1-1
Well Screen Information, Characterization Well R-16

Screen	Planned Depth (ft)	Actual Depth (ft)	Geologic/Hydrologic Setting
1	640.6–647.4	641.0–648.6	Spans regional water table in the Puye Formation
2	861.2–868.0	863.4–870.9	Within the regional aquifer in the Santa Fe Group
3	1011.9–1018.7	1014.8–1022.4	Within the regional aquifer in the Santa Fe Group
4	1232.5–1239.3	1237.0–1244.6	Within the regional aquifer in the Santa Fe Group

7.2 Well Construction

The well casing and pipe-based screens in well R-16 used 4.5-in. inner diameter (ID)/5.0-in. outer diameter (OD) type 304 stainless steel fabricated to American Society for Testing and Materials (ASTM) standard A554. External couplings also were type 304 stainless steel fabricated to ASTM standards A312 and A511, thereby exceeding the tensile strength of the threaded casing ends. The pipe-based screens were fabricated by Weatherford Well Screens (Johnson Screens, Inc.) from 10-ft sections of blank well casing by drilling a series of 0.5-in.-diameter holes (168 holes/ft) and then welding a stainless steel wire-wrap (with 0.010-in. spacing) over the perforated interval. The final OD of the screens was 5.53 in.

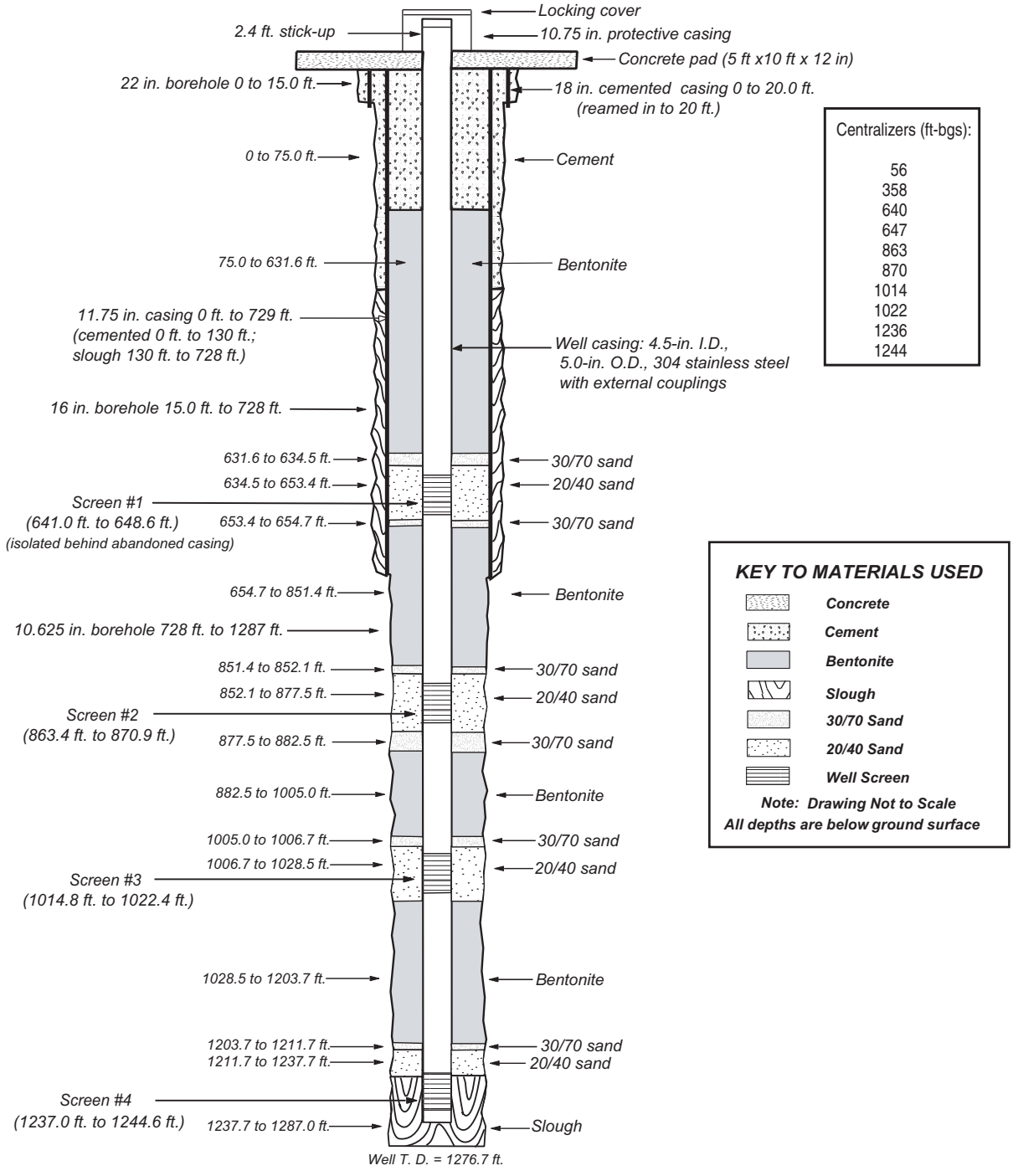
Before installation, all stainless steel well components were cleaned at the well site using a high-pressure steam cleaner and scrub brushes. All annular fill materials were placed in the borehole/well casing annulus through a tremie pipe.

7.2.1 Well Installation

Well installation consisted of connecting joints of stainless steel screens and stainless steel casing joints as specified in the well design (Section 7.1). Dynatec installed the well casing on August 31 and September 1, 2002 (Figure 3.0-2). The base of the well was set at 1276.7 ft bgs. Stainless steel centralizers were installed above and below each screen and in several locations above the zone of regional saturation to centralize the well within the borehole during and after backfill placement. Figure 7.2-1 shows the final well casing configuration and the depths of the various well components from ground surface.

7.2.2 Annular Fill Placement

Before the annular fill material was placed, from September 1 through September 2, 2002, municipal water was pumped into the well annulus at a rate of 20 gal./min to reduce the viscosity of the drilling mud and to enhance placement of backfill material. A jetting tool was used to help remove drill mud cake from the borehole wall. The jetting tool consisted of a tremie rod with a capped end and three evenly spaced 5-mm-diameter holes drilled into the pipe approximately 0.5 ft from the end of the pipe. Municipal water was jetted into the borehole from 730 to 1240 ft bgs. After jetting, approximately 5 gal. of phosphate-free dispersant (PFD) mixed with 2000 gal. of municipal water were injected at 900 ft bgs. An additional 2 gal. of PFD mixed with 1000 gal. of municipal water were injected while the tremie pipe was raised and lowered through the screen 2 interval (863 to 871 ft bgs). Water from the borehole annulus then was airlifted from the borehole, and additional water was pumped in to ensure the viscosity of the borehole fluid was low enough to begin annular fill placement.



Note: 1. Each screen interval lists the footage of the pipe perforations, not the top and bottom of screen joints.
2. All screens are pipe-based 304 stainless steel, 4.5 in. I.D., 5.563 in. O.D., with s.s. 0.010 in. wire wrap slots.
3. The interval of slough consists of sands and gravel of the Santa Fe Group Sediments.
4. Westbay multiport sampling system (MP-55) casing not shown.
5. 11.75 in. casing abandoned in borehole rendered screen #1 non-functional.
6. Well sump interval: 1244.6 to 1276.4 ft.

Figure 7.2-1. As-built configuration diagram, characterization well R-16

Annular fill was placed using a steel tremie pipe to deliver the materials at the depth intervals specified in the well design (Figure 7.2-1). The bottom of the borehole was measured with a tag line at 1237.7 ft bgs before fill material was introduced into the annulus, indicating 49.3 ft of slough remained in the borehole. Dynatec installed the annular fill material from September 4 through 11, 2002. Filter packs across screened intervals consisted of silica sand materials mixed with municipal water and placed in the annulus. Bentonite materials were placed between screened intervals to seal the annular space and prevent interaction between water-bearing zones. Portland® cement also was used for wellhead protection in the annular space in the upper 75 ft of the borehole. Approximately 13,600 gal. of municipal water were used during annular fill material placement.

During annular fill operations between screens 2 and 1, the 11.75 in. drill casing could not be retracted. Removal efforts were unsuccessful, leaving the casing stuck in place from ground surface to 729 ft bgs. The filter pack sequence for screen 1 was placed as planned, although the stuck casing left screen 1 nonfunctional. Since R-16 is a multiscreen completion well, cement or grout could not be placed opposite screen 1 as it would have adversely impacted the entire well. Bentonite seals were placed above and below screen 1 to isolate it from the other screens. The annulus of the 11.75-in. casing was cemented in place from 130 ft bgs to the surface.

Table 7.2-1 lists the annular fill materials installed. The final configuration of the annular materials placed in R-16 is also illustrated in Figure 7.2-1.

Table 7.2-1
Annular Fill Materials, Characterization Well R-16

Material	Use/Function	Amount	Unit*
20/40 sand (medium-grained)	To pack screen intervals	82	bag
30/70 sand (fine-grained)	To separate filter packs from bentonite seals	25	bag
Benseal® (bentonite)	As a high-solids, multipurpose grout	2	bag
Pelplug® bentonite (0.25-in. by 0.375-in. refined elliptical pellets)	To provide a borehole annular seal below the water table	790	bucket
Portland® cement (mixed with municipal water at a ratio of 5 gal. water to 1 bag)	To provide annular support and surface seal on the upper 100 ft of the borehole	70	bag

*Sand bag = 45 lb ea, bentonite bag/bucket = 50 lb ea, cement bag = 94 lb ea.

8.0 WELL DEVELOPMENT AND HYDROGEOLOGIC TESTING

Well development and hydrologic testing activities at R-16 were conducted from September 14 to December 4, 2002 (Figure 3.0-2). Well development procedures included preliminary bailing, wire brushing, surging and bailing, chemically treating the well screens, and pumping to develop the well. Development activities were followed by hydrologic slug tests conducted by Hydrogeologic Services, Inc., for screens 2, 3, and 4.

8.1 Well Development

Well development at R-16 consisted of wire-brushing the well interior, swabbing and surging the screen intervals to draw fine sediment from the constructed filter pack, and bailing to remove solid materials from the well. Chemical treatment procedures were applied to individual well screens to break up and disperse borehole-wall filter cake and particulate build-up in the screen and formation, which were consequences

of mud-rotary drilling. To pump each screen level, a submersible pump was lowered to screens 2, 3, and 4, and each isolated water-bearing zone was pumped to remove remaining fines from the filter packs and adjacent formation.

Well-development criteria were based on water-quality parameters (turbidity, specific conductance, pH, and temperature) measured in groundwater samples. To monitor progress during development, groundwater samples were collected periodically and parameter measurements were recorded. One objective of well development was to remove suspended sediment from the water until turbidity, measured in nephelometric turbidity units (NTU), decreased to a value of less than 5 NTU for three consecutive samples. Similarly, other measured parameters needed to stabilize before the well was successfully developed. The well was declared sufficiently developed when the above criteria were met or could not be improved with continued pumping. Table 8.1-1 presents pumping and water-quality parameter data measured at the beginning and end of each development method.

Table 8.1-1
Development of Characterization Well R-16

Method	Water Produced (gal.)	Range of Parameters[a]			
		pH	Temperature (°C)	Specific Conductance (µS/cm)[b]	Turbidity (NTU)
Preliminary bailing	610	9.2–8.6	23.4–24.1	NM[c]–329	>1000–>1000
Pumping/jetting	2040	8.4	16.8	NM	>1000
Surging/bailing	1660	8.5–8.0	22.7–24.2	NM–138	249–52.1
Chemical treatment; swabbing 200 gal. In each screen (2, 3, 4)	+600	—[d]	—	—	—
Surging/bailing	1185	2.0–6.2	NM–22.1	NM–188	NM–108
Chemical treatment; added 600 gal. PFD to well	+600	—	—	—	—
Surging/bailing	1300	7.8–7.8	22.8–22.4	141–221	1.4–364
Pumping at screen 4 without packer	54,720	7.2–7.3	18.4–23.2	265–311	141–1.0
Pumping at screen 4 with packer	5675	7.6–8.1	19.5–21.9	215–182	3.76–1.9
Pumping at screen 3 with packer	3270	8.1–7.8	23.4–24.6	178–194	3.16–0.87
Pumping at screen 2 with packer	7590	7.9–8.0	24.7–24.3	173–170	2.7–1.34
TOTAL	76,850				

[a] Parameters presented as value at beginning followed by value at end of development method.

[b] Specific conductance reported in microsiemens per centimeter (µS/cm).

[c] NM = Not measured.

[d] — = No samples collected.

Preliminary bailing using a 9-gal. steel bailer was performed from the R-16 well sump on September 14, 2002, to remove debris and sediment. The casing and screens were cleaned using a wire-brush system

to remove any materials that may have been introduced into the well interior during construction. Surging techniques were then employed across screens 2, 3, and 4 using a wire-line-controlled surge block for rapid upward strokes. The well screens were surged repeatedly; periods of bailing followed from September 17 to 23, 2002. Approximately 610 gal. were removed, and the bailed water consisted primarily of drilling fluid.

Additionally, jetting procedures were performed at screen 4 (September 18, 2002) in an attempt to break up particulate matter in the filter pack and the surrounding formation. Water turbidity exceeded 1000 NTU during this phase; a total of 2040 gal. of water were removed. Following jetting, another 1660 gal. of water were removed by surging and bailing; turbidity decreased from 249 NTU at the beginning of surging to 52.1 NTU at the end of bailing. (Table 8.1-1).

On October 2, 2002, chemical treatment was applied to screens 2, 3, and 4 to assist in breaking down and removing the drilling wall cake. An acidic solution containing 30 lb. of AQUA-CLEAR™-MGA and 3 gal. of AQUA-CLEAR™-AE was mixed per 100 gal. of municipal water. Then 200 gal. of the mixture were injected into the full screen interval for each screen. Surging/bailing procedures resumed briefly at each screen. To enhance wall-cake breakdown and removal, a dispersant mixture containing 1.5 qt of AQUA-CLEAR™-PFD per 100 gal. of municipal water was injected at each screen. The screens were surged, and bailing resumed after the well was allowed to sit for two days. An additional 2485 gal. were bailed from the well (Table 8.1-1) during the chemical-treatment phase.

R-16 pump development began on October 11, 2002. A 10-horsepower (hp) submersible pump was lowered to within the top 2 ft of screen 4. On/off cyclic pumping was conducted with nominal 30-min periods of nonpumping to allow water levels in the well to recover. Water samples were collected at approximately 1-hr intervals to monitor parameters. Initial pumping was done at screen 4 without the assistance of packers. Subsequently, inflatable packers were positioned above and below the screen to isolate the water-bearing zone and pumping resumed. An estimated 60,395 gal. were purged, and turbidity measurements decreased from an initial value of 141 to 1.9 NTU (Table 8.1-1) when pumping stopped.

Pump development using inflatable packers, as described above, were used at screens 2 and 3 on November 20 and 21, 2002. As indicated in Table 8.1-1, field parameters for both screens were consistently within acceptable ranges throughout the process.

8.2 Hydrologic Testing

On November 25, 26, and 27, 2002, the Laboratory conducted straddle-packer/injection tests of saturated materials behind screens 2, 3, and 4 in well R-16. An injection assembly, consisting of two inflatable packers separated by a perforated pipe, was positioned around each screen, in turn. For a given screen, the water-level response to injecting municipal water at different rates for different periods of time was monitored with a pressure transducer. Specifically, three tests were conducted at screens 2 and 3 and two tests were conducted at screen 4. Following the testing, approximately 22,800 gal. of water were purged from the well. This amount represents more than five times the volume of water introduced during the tests. Results of these tests, as well as details of their design, implementation, and analysis, will be presented in a separate Laboratory report.

8.3 Installation of Westbay™ Monitoring System

A Westbay™ sampling system was installed inside the stainless steel well casing after development and testing procedures in well R-16 were completed. The base of the multiport casing was set at 847.5 ft bgs.

The system was set in place using a series of 10 packers inflated with de-ionized water and positioned to target each well screen with a set of valved ports. The R-16 system contains seven measurement ports used to verify packer integrity. Screen 1 is isolated by drill casing, but the zone does contain one measurement port for monitoring zone isolation. Screens 2, 3, and 4 are each accessed by two measurement ports and one pumping port. Quarterly sampling of Westbay™-equipped wells is accomplished using a Laboratory-owned sampling trailer equipped with the MOSDAX® sampling system (controller, sampler probe, and sample bottle train) and a motorized winch and boom system. The Westbay™ summary MP casing log provides details of the installed system (Appendix F).

9.0 WELLHEAD COMPLETION AND SITE RESTORATION

When operational tests were completed on the installed sampling system, the protective casing height was adjusted to accommodate a locking cap over the Westbay™ installation. Finish work commenced on the wellhead area, well components were surveyed, and the site underwent final clean up and restoration.

9.1 Wellhead Completion

Surface completion for well R-16 involved constructing a reinforced (5000 psi) concrete pad, 5 ft by 10 ft by 12-in.-thick, around the well casing to ensure the long-term structural integrity of the well components (Figure 9.1-1). The concrete pad was poured on November 5, 2002. A 10.75-in. steel casing with locking lid protects the well riser. Steel bollards, 4 in. in diameter, were placed at each side of the pad boundary. The bollard on the west side of the well pad is removable to allow access to the well for sampling and maintenance activities. A brass survey pin was installed in the northwest corner of the concrete pad.

9.2 Geodetic Survey of Completed Well

Southwest Mountain Surveys, Inc. (NMPLS #6998) conducted a geodetic survey of well R-16 on December 19, 2002, using a global positioning satellite (GPS) system. The GPS system utilizes National Geodetic Vertical Datum (NGS) of 99/96 for vertical computations and the datum for the horizontal control network is North American Datum 1983 (NAD 83). The survey located the brass cap monument in the northwest corner of the concrete pad and measured location and elevation at the top of the steel protective casing, the top of the Westbay™ cap, and the top of the Westbay™ plate (Table 9.2-1). The coordinates shown are in New Mexico State Plane coordinates, Central Zone (NAD 83) expressed in feet. To be consistent with current Laboratory standards, elevations are expressed in feet above mean sea level and referenced to the National Geodetic Vertical Datum of 1929 (NVGD29).

9.3 Site Restoration

Site restoration activities at R-16 were conducted by K. R. Swerdfeger Construction, Inc., from February 16 to February 20, 2003 (Figure 3.0-2). Prior to and concurrent with restoration, waste-management activities were also performed. Waste materials were removed from the site as specified in the WCSF. Drilling media included drilling fluids, cuttings, and development water. These media were sampled for contaminant analysis; results are provided in Appendix G. The waste data were reviewed by the Laboratory and the NMED.

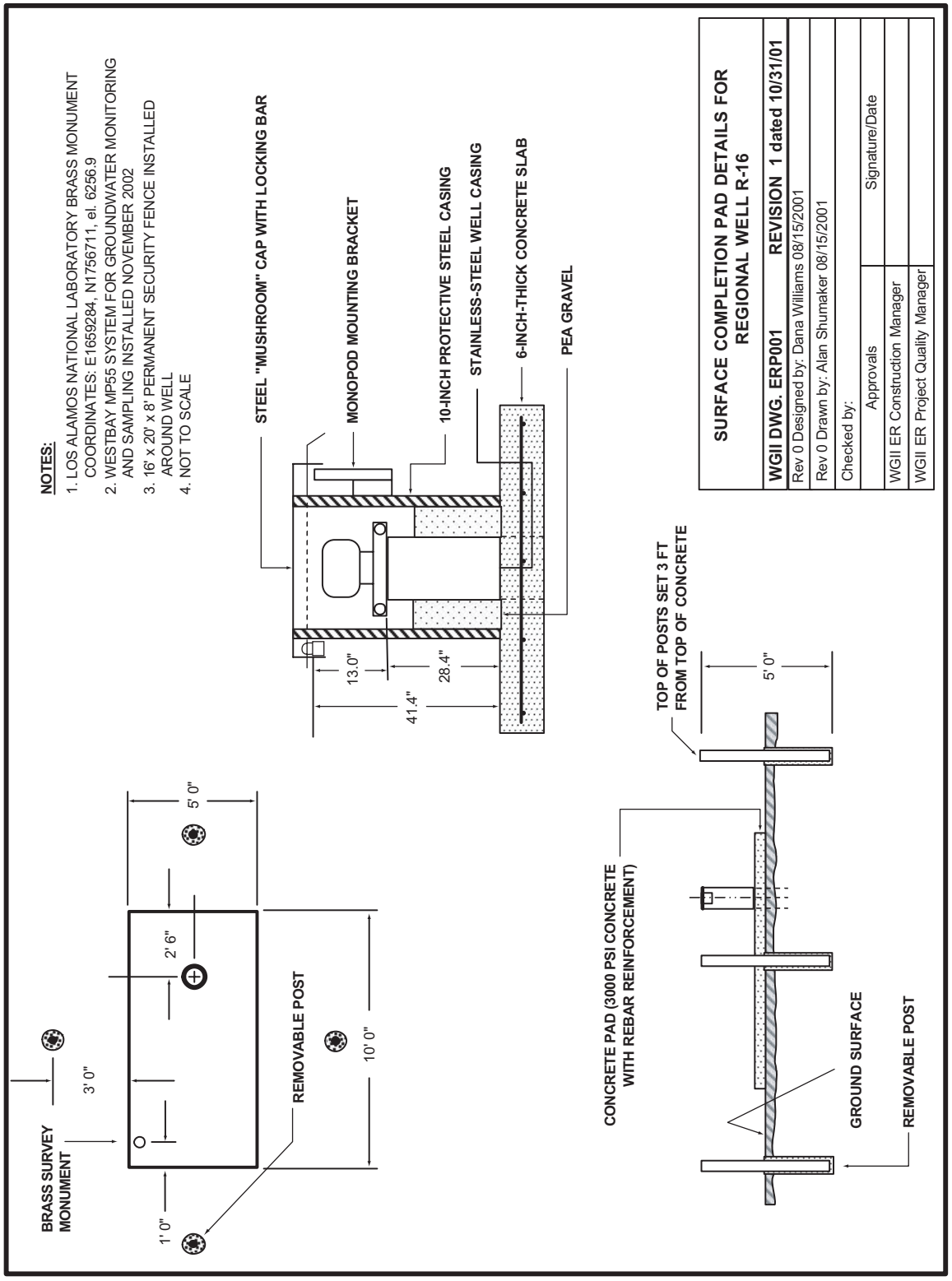


Figure 9.1-1. Surface completion configuration diagram, characterization well R-16

Table 9.2-1
Geodetic Data, Characterization Well R-16

Description	East	North	Elevation
Top of steel protective well casing	1659285.20	1756709.36	6260.40
Top of Westbay™ cap	1659284.75	1756709.34	6260.00
Top of Westbay™ plate	1659284.59	1756709.38	6259.41
Brass cap in R-16 pad	1659283.61	1756710.97	6256.87

The drill cuttings were used to backfill the containment area. The drilling fluids were approved for road application at selected Laboratory locations. Development water was discharged to the White Rock waste-water treatment plant pond. Waste streams from minor spill cleanup included petroleum-contaminated soils and absorbent materials used to clean up all spills. Before the site was regraded, the cuttings-containment area was excavated and the plastic lining was removed. The containment area then was backfilled with drill cuttings and dirt that had been bermed during pad construction. Base-course gravel was regraded and compacted across the site to form a smaller pad. The temporary chainlink fence that had been erected during site pad construction was dismantled and removed. The site was re-seeded with a blend of native grasses mixed with fertilizer and mulch to facilitate regrowth of ground cover. A permanent 16-ft by 20-ft by 8-ft-high fence was installed around the well for long-term security.

10.0 DEVIATIONS FROM THE R-16 SAP

Appendix A compares the actual characterization activities performed at R-16 with the planned activities delineated in the hydrogeologic work plan and the R-16 SAP (LANL 1998, 59599; LANL 2002, 73390). Significant deviations are discussed below.

- *Number of water samples collected for contaminant analysis.* No perched water was detected during drilling. Also, because of the type of drilling performed, water samples could not be collected from the regional aquifer. During final pumping/packer development, a representative sample was collected from screens 2, 3, and 4.
- *Number of core/cuttings samples collected for contaminant analysis.* The SAP called for the collection of up to five cuttings samples for geochemical and contaminant characterization within water-bearing zones encountered during drilling. No perched zones were encountered. The lack of any contaminants of concern in screening-water samples collected from the regional aquifer precluded the usefulness of submitting cuttings samples for analysis.
- *Field hydraulic property testing.* Field hydraulic property testing in the SAP called for performing straddle-packer/injection tests in all screens completed below the regional water table. Screen 1 straddled the water table; therefore, testing was inappropriate.

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Appendix A

Activities Planned for R-16 Compared with Work Performed

Activity	Hydrogeologic Work Plan	R-16 Sampling and Analysis Plan	R-16 Actual Work
Planned depth	100 to 500 ft bgs into the regional aquifer	Estimated depth of 1283 ft below ground surface (bgs)	Total drill depth 1287 ft bgs
Drilling method	Methods may include, but are not limited to hollow stem auger (HSA), air-rotary/Odex/Stratex, air-rotary/Barber rig, and mud-rotary drilling	Foam air rotary, air rotary, mud rotary flooded-reverse circulation, and fluid-assist air rotary with casing advance	Conventional mud rotary and fluid-assist air rotary with casing advance
Amount of core	10% of the borehole	No core collection	No core collected
Lithologic log	Log to be prepared from core, cuttings and drilling performance data.	Log to be prepared from cuttings, geophysical logs and drilling performance	Log prepared from cuttings, geophysical logs, and drilling performance
Number of water samples collected for contaminant analysis	A water sample may be collected from each saturated zone, five zones assumed. The number of sampling events after well completion is not specified	If perched water is encountered, within the unsaturated zone, one groundwater-screening sample will be collected within up to three perched zones. Groundwater-screening samples will be collected within the regional aquifer at the regional water table and at the total depth (TD) of the borehole.	No water samples collected during drilling. Three samples were collected from the three operable screens after well development.
Water sample analysis	Initial sampling: Radiochemistry I, II, and III, tritium, general inorganics, stable isotopes, VOCs, and metals. Saturated zones: radionuclides (tritium, ^{90}Sr, ^{137}Cs, ^{241}Am), plutonium isotopes, uranium isotopes, gamma spectrometry, and gross alpha, beta, and gamma), stable isotopes (hydrogen, oxygen, and in special cases nitrogen), major ions (cations and anions), trace metals, and trace elements.	Metals (dissolved), anions (dissolved), VOCs, ^{99}Tc, gamma spec, ^{241}AM, ^{137}Cs, ^{238}, ^{239},^{240}Pu, ^{234}, ^{235}, ^{238}U, ^{90}Sr, stable isotopes (^{18}O/^{16}O, D/H, ^{15}N/^{14}N), tritium, tritium (low level or direct counting), RV gross-alpha, beta, gamma	Following well completion and development, groundwater samples (from screens 2, 3, and 4 were analyzed for Metals (dissolved), Anions (dissolved), gamma spectrometry, ^{241}Am, ^{238}, ^{239},^{240}Pu, ^{234}, ^{235}, ^{238}U, ^{90}Sr, stable isotopes (^{18}O/^{16}O, D/H, ^{15}N/^{14}N), tritium, tritium (low level or direct counting), U-total, perchlorate, alkalinity, and total Kjeldahl nitrogen (TKN). RV gross-alpha, beta, gamma
Water sample field measurements	Alkalinity, pH, specific conductance, temperature, turbidity	Alkalinity, pH, specific conductance, temperature, turbidity	pH, specific conductance, temperature, turbidity
Number of core/cuttings samples collected for contaminant analysis	Twenty samples of core or cuttings to be analyzed for potential contaminant identification in each borehole.	Up to five cuttings samples will be collected for geochemical and contaminant characterization within water-bearing zones encountered during drilling.	No cuttings samples submitted for analysis

Activity	Hydrogeologic Work Plan	R-16 Sampling and Analysis Plan	R-16 Actual Work
Core/cuttings sample analytes	Uppermost core or cuttings sample to be analyzed for a full range of compounds: deeper samples will be analyzed for the presence of radiochemistry I, II, and III analytes, tritium (low and high detection levels), and metals. Four samples to be analyzed for VOCs.	Analytical suite for cuttings samples includes anions, stable isotopes, VOCs, tritium profiles, perchlorate, ^{241}Am, ^{238}, ^{239},^{240}Pu, ^{234}, ^{235}, ^{238}U, ^{90}Sr, gamma spectroscopy, radiological screening (gross alpha, beta, and gamma), radionuclides, and metals.	No analyses were performed
Laboratory hydraulic-property tests	Physical properties analyses will be conducted on 5 core samples and will typically include moisture content, porosity, particle density, bulk density, saturated hydraulic conductivity, and water retention characteristics.	No core will be collected for hydraulic property analyses.	No core collected
Geology	Ten samples of core or cuttings will be collected for petrographic, x-ray fluorescence (XRF) and x-ray diffraction (XRD) analyses.	Analytical testing of samples may include mineralogy by XRD, petrography by modal analysis of thin sections, by electron microprobe, and/or by scanning electron microscope, and geochemistry by XRF.	16 samples were characterized for mineralogy, petrography, and rock chemistry.
Geophysics	In general, open-hole geophysics includes caliper, electromagnetic induction, natural gamma, magnetic susceptibility, borehole color videotape (axial and side scan), fluid temperature (saturated), fluid resistivity (saturated), single-point resistivity (saturated), and spontaneous potential (saturated). In general, cased-hole geophysics includes gamma-gamma density, natural gamma, and thermal neutron.	The number and types of logs will vary as function of borehole condition, and the presence or absence of drill or well casing. In general, open-hole geophysics includes caliper, array induction, triple litho density, combinable magnetic resonance, natural gamma, natural gamma ray spectrometry, epithermal compensated neutron, mechanical sidewall coring tool, fullbore formation microimager, and borehole color videotape (axial and side scan). In general, cased-hole geophysics includes triplelitho density, natural gamma ray spectrometry, natural gamma, and epithermal compensated neutron.	LANL tools: 0–20 ft bgs (cased), 20–117 ft bgs (open hole) video, 0-729 ft bgs (cased), 729-1287 ft bgs (open hole): natural gamma; 0–1276.7 ft bgs (well): video, natural gamma Schlumberger geophysics: 0–729 ft bgs (cased), 729-1287 ft bgs (open hole): array induction, combinable magnetic resonance, fullbore formation microimager, sonic caliper, triple lithodensity, spectral gamma, natural gamma, elemental capture, and thermal-epithermal neutron
Water-level measurements	Procedures and methods not specified in hydrogeologic work plan.	Water levels will be determined for each saturated zone by water-level meter or by pressure transducer.	Water-level meter determined water levels for the regional water table.

Activity	Hydrogeologic Work Plan	R-16 Sampling and Analysis Plan	R-16 Actual Work
Field hydraulic-property tests	Tests to be conducted not specified in hydrogeologic work plan.	Straddle-packer/injection tests will be performed in all screens completed below the regional water table.	Constant rate injection tests were conducted on screens 2, 3, and 4.
Surface casing	Approximately 20-in. outer diameter (OD) extends from land surface to 10-ft depth in underlying competent layer and grouted in place.	Install 18- or 20-in. OD steel casing to approximately 60 ft.	18.625-in. OD steel casing set at 20 ft bgs, cemented in place
Conductor casing	Unless other technical methods are applied, a temporary steel casing, up to 14-in. OD, will be advanced to total depth of borehole.	Install 11.75-in. OD steel casing from 0 to ~700 to 800 ft bgs, or approximately 100 ft above anticipated regional water level, or set thin-wall casing over problem zone(s) and seal off casing using whatever is required by regulation.	11.75-in. OD drill casing from 0 to 729 ft bgs, cemented in place
Minimum well casing size	6.625-in. OD	5-in. OD	5-in. OD x 4.5-in. inner diameter (ID) stainless steel casing w/ external couplings.
Well screen	Machine-slotted (0.01-in.), stainless steel screens with flush-jointed threads; number and length of screens to be determined on a site-specific basis and proposed to NMED.	Well screen shall be constructed with multiple sections of 5.5-in. OD stainless steel pipe with wire wrap (0.010-in. slot opening).	Screened intervals constructed of 5.56-in. OD (4.5-in. ID) pipe based, stainless steel, wire- wrapped, 0.010-in. slotted screen
Filter material	>90% silica sand, properly sized for the 0.010-in. slot size of the well screen; extends 2 ft above and below each well screen.	Filter pack shall extend at least 5 ft and no more than 10 ft above and below each well screen. No differentiation made between primary and secondary filter packs.	Primary filter pack consisted of 20/40 silica sand placed from 25.3 ft above screen 4 to upper 0.7 ft of screen; slough below. Secondary filter pack consisted of 30-70 silica sand placed in a layer 8-ft-thick above primary filter pack at screen 4. Primary filter pack consisted of 20/40 silica sand placed 6.1 ft below and 8.1 ft above screen 3. Secondary filter pack consisted of 30/70 silica sand placed in a layer 1.7-ft-thick above primary filter pack. Primary filter pack consisted of 20/40 silica sand placed 6.6 ft below and 11.3 ft above screen 2.

Activity	Hydrogeologic Work Plan	R-16 Sampling and Analysis Plan	R-16 Actual Work
Filter material			Secondary filter pack of 30/70 silica sand placed in a layer 5-ft-thick below and 0.7-ft-thick above. Primary filter pack consisted of 20/40 silica sand placed 4.8 ft below and 6.5 ft above screen 1. Secondary filter pack of 30/70 silica sand placed in a layer 1.3-ft-thick below and 2.9-ft-thick above.
Backfill material (exclusive of filter materials)	Uncontaminated drill cuttings below sump and bentonite above sump.	Bentonite and cement in borehole or well annulus.	Slough in borehole and annulus below and around sump and bottom well screen from TD to 0.7 ft below top of screen 4. Bentonite seal above screen 4 filter pack and above and below screens 3, 2, and 1 filter packs. Cement-bentonite grout from surface to 75 ft bgs.
Sump	Stainless steel casing with an end cap	Not specified	5-in.-diameter stainless steel casing, 32.1-ft-long, with an end cap
Bottom seal	Bentonite	Bentonite	None

Appendix B

Drill-Additive Product Specifications
(CD attached to inside back cover)

Appendix C

Lithology Log

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Qal, alluvium	Unconsolidated sediments, clay (CH) with sand and gravel, light brown (5YR 6/4). +12F (i.e., plus No. 12 seize sieved sample fraction): clay-coated clasts of volcanic tuff, quartz and sanidine crystals, and dacite lithic fragments. Note: Cuttings were sampled and described in the interval from 0 to 1287 ft bgs)	0–5	6256.9–6251.9
Qbo, Otowi Member of the Bandelier Tuff	Rhyolite tuff, light brownish (5YR 6/4), lithic-rich. +12F: 15%–25% pumice fragments; 1%–3% basalt fragments; 75%–85% dacitic fragments that are strongly oxidized. WR sample (i.e., unsieved cuttings sample) is clay-rich.	5–10	6251.9–6246.9
	Rhyolite tuff, medium light gray (N6), poorly welded to nonwelded, lithic-rich. +12F: 1%–3% pumice fragments; 2%–3% quartz and sanidine crystals; 90%–95% abundant dacitic and lesser basalt fragments that are strongly oxidized.	10–14	6246.9–6242.9
	Rhyolite tuff, yellowish-gray (5YR 6/1), poorly welded to nonwelded. +12F: 60%–70% vitric pumice fragments; 25%–30% dacitic and basalt fragments in equal proportions. +40F (i.e., plus No. 40 size sieved sample fraction): contains 50% pumice, 40% quartz and sanidine crystals, and 10% volcanic lithics.	14–15	6242.9–6241.9
	Rhyolite tuff, medium light gray (N6), poorly welded to nonwelded, lithic-rich. +12F: 15%–20% oxidized pumice fragments; 75%–85% abundant basalt and lesser dacite volcanic lithics.	15–20	6241.9–6236.9
	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded, pumiceous. +12F: 80%–90% glassy fibrous pumice lapilli (up to 1 cm), light limonite-staining; 2%–4% quartz and sanidine crystals; 5%–15% volcanic lithics (basalt and lesser dacite). +40F: contains 60%–70% quartz and sanidine crystals.	20–28.5	6236.9–6228.4
	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded. +12F: 25%–30% white, unaltered, vitric pumice fragments (up to 1.5 cm); 20%–40% quartz and sanidine crystals; 20%–40% volcanic lithic fragments (dacite with lesser basalt).	28.5–43.5	6228.4–6213.4
	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded, lithic-rich. +12F: 20%–25% white vitric pumice fragments; 15%–20% quartz and sanidine crystals; 50%–60% volcanic lithic fragments (up to 0.7 cm) made up of dacite, basalt, rhyodacite, and latite.	43.5–48.2	6213.4–6208.7
	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded, pumice-rich. +12F: 70%–75% white vitric pumice fragments (up to 1.0 cm) that are partly limonite-stained; 5%–10% quartz and sanidine crystals; 10%–15% volcanic lithic fragments made up of pink and gray dacite with minor basalt.	48.2–63.2	6208.7–6193.7
	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded, pumice- and lithic-rich. +12F: 50% white vitric, fibrous pumice fragments (up to 0.6 cm); 5%–10% quartz and sanidine crystals; 35%–40% volcanic lithic fragments made up of intermediate to felsic lithologies. +40F: contains 97%–98% quartz and sanidine crystals.	63.2–68.2	6193.7–6188.7

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Qbo, Otowi Member of the Bandelier Tuff	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded, pumice-rich. +12F: 90%–95% white vitric, fibrous pumice fragments; 5%–10% quartz and sanidine crystals; 2%–3% volcanic lithic fragments made up of intermediate to felsic lithologies.	68.2–78.2	6188.7–6178.7
Qbo	Rhyolite tuff, grayish-orange pink (5YR 7/2), poorly welded to nonwelded, pumice-rich. +12F: 95%–97% white vitric, fibrous and limonite-stained pumice fragments (up to 1.0 cm); <1% quartz and sanidine crystals; 2%–3% dacitic lithic fragments. +40F: contains 75%–80% quartz and sanidine crystals.	83–88	6178.7–6173.7
Basaltic sediments	Basalt-rich sediments, gravel (GW) with sand, varicolored light tan (10 YR 6/2) to dark gray (N3), subangular to subrounded clasts (up to 0.5 cm). +12F: contains mixed volcanic lithologies including 30%–50% vesicular to massive basalt, 20%–30% dacite and silicified dacite, 5%–20% white to light tan clay nodules and fragments; and 1%–2% black vitrophyre. Basalt and dacite clasts have clay or iron-oxide/clay coatings. +40F: orange-colored limonite cementing clasts/chips; 40% clay particles/nodules. Note: stratigraphic top of this unit is estimated at 84 ft bgs; its base is estimated at 92 ft bgs.	88–103	6173.7–6164.7
Tpl, Puye lakebed sediments	Lakebed sediments, yellowish-gray (5Y 8/1), clay (CH) with broken gravel chips and subrounded pebble-size clasts. +12F: 10%–15% vesicular basalt chips and pebbles; 3%–5% dacite; 80%–85% whitish tan chips of soft clay containing microscopic tubules that appear siliceous, locally limonite-stained; Mn-oxides common.	92.2–102.2	6164.7–6154.7
	Lakebed sediments, yellowish-gray (5Y 8/1) to medium dark gray (N4), clayey gravel (GC), broken chips and subrounded pebble-size clasts (up to 1.0 cm). +12F: 7%–10% vesicular basalt clasts with strong clay and/or limonite coatings; 90%–93% whitish fragments of clay that are subrounded (milled), clays contains abundant silica tubules (diatomaceous clay); 1%–2% dacite chips.	102.2–107.2	6154.7–6149.7
	Lakebed sediments, yellowish-gray (5Y 8/1), clay (CH). WR: whole rock sample only collected. 100% clay of high plasticity.	107.2–127.2	6149.7–6129.7
	Lakebed sediments, very pale yellowish-orange (10YR 8/2), clay (CH) with gravel. WR: whole rock sample only collected. 10%–15% angular vesicular basalt fragments (up to 0.7 cm); 85%–95% clay of high plasticity.	127.2–142.2	6129.7–6114.7
	Transition Tpl/Tb interval, very pale orange (10YR 821), clay (CH) with gravel, broken chips (up to 0.5 cm) in clay matrix. +12F: 85%–90% vesicular, olivine-basalt chips; 10%–15% clay-cemented sandstone clasts; 1%–2% bright-orange, altered volcanic lithics (possible palagonite). Note: Basal contact of lakebed sediments with underlying Cerros del Rio basalt estimated at 147 ft bgs.	142.2–152.2	6114.7–6104.7

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tb4, Cerros del Rio basalt	Basalt with clay (CH), light gray (N6), sparsely porphyritic with aphanitic groundmass, massive to sparsely vesicular. +12F: chips finely ground and clay coated, textures obscured. Groundmass is unaltered or very weakly altered. Local clay nodules suggest amygdaloidal fillings.	152.2–162.2	6104.7–6094.7
	Basalt, medium gray (N5), porphyritic with aphanitic groundmass, sparsely vesicular. +12F: brownish-olivine phenocrysts (up to 1.0 mm) are oxidized, groundmass altered and bleached; 3%–5% clay nodules, partly limonite-stained and yellowish. WR sample moderately clay-rich.	162.2–172.2	6094.7–6084.7
	Basalt, light brownish-gray (5YR 6/1), porphyritic with aphanitic groundmass, sparsely vesicular. +12F: 85%–95% basalt chips that are partially alteredd, clay coatings obscure textures; 5%–15% whitish clay fragments and clay-cemented sandstone. WR sample clay-rich.	172.2–177.2	6084.7–6079.7
	Basalt, light brownish-gray (5YR 6/1), porphyritic with aphanitic groundmass, sparsely vesicular. +12F: olivine phenocrysts (up to 2 mm) are replaced by iddingsite, chips clay-coated obscuring textures, slight Fe-oxide/clay coating on some fractures. WR sample contains clay binding chips.	177.2–187.2	6079.7–6069.7
	Basalt, medium light gray (N5), slightly porphyritic with aphanitic groundmass, vesicular. +12F: olivine phenocrysts (1%–3% of volume, up to 3 mm) commonly rounded and wholly replaced by iddingsite; groundmass is bleached and partially altered; some vesicles contain yellowish clay.	187.2–197.2	6069.7–6059.7
	Basalt, medium light gray (N5), slightly porphyritic with aphanitic groundmass, vesicular. +12F: pale green olivine phenocrysts (2%–3% of volume, up to 2 mm) are unaltered; groundmass partially altered, bleached, trace light tan clay fragments.	197.2–212.2	6059.7–6044.7
	Transitional Tb4/lakebed sediments, light gray (N7) to grayish orange (10YR 7/4), slightly porphyritic with aphanitic groundmass, vesicular. +12F: olivine phenocrysts (1%–2% of volume, up to 2 mm) mostly replaced by iddingsite; groundmass strongly altered, strongly bleached; yellowish clay chips, angular, hard, locally limonite-stained. Note: Basal Tb4 contact estimated at 212 ft bgs.	212.2–222	6044.7–6034.9
Tpl, Puye Lakebed Sediments	Lakebed sediments, pale reddish-brown (10YR 5/4), basalt chips in clay matrix. +12F: 80%–85% angular altered basalt chips, mostly clay-coated; 10%–15% reddish-brown, fine-grained sandstone clasts; 2%–3% clay nodules locally containing sand grains. WR sample clay-rich. +40F: contains 40%–50% sandstone, 1% granitic grains.	222–227	6034.9–6029.9
Ta, Older Alluvium	Clastic sediments, gravel (GW) with sand and clay, pale reddish-brown (10R 5/4). +12F: 20%–25% angular basalt chips, clay-coated; 60%–70% clay-cemented, fine-grained sandstone fragments (up to 0.5 cm) composed of quartz, granite, and volcanic grains; 5%–10% angular granitic clasts. WR sample clay-rich.	227–232	6029.9–6024.9

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Ta, Older Alluvium	Clastic sediments, gravel (GW) with sand and clay, light brown (5YR 6/4). +12F: 15%–30% angular basalt chips, clay-coated; 20%–25% clay-cemented, fine-grained sandstone and clay; 50%–60% subrounded quartz, microcline, and granitic clasts (up to 0.5 cm).	232–242	6024.9–6014.9
	Clastic sediments, clayey gravel (GC) with sand, light brown (5YR 6/4). +12F: 15%–20% basalt and other volcanic lithics; 25%–30% whitish claystone and clay-cemented sandstone; 40%–50% broken to subrounded quartz, microcline, and granitic clasts (up to 0.5 cm). WR sample clay-rich.	242–252	6014.9–6004.9
	Clastic sediments, gravel (GW) with clay, light brown (5YR 6/4). +12F: 5%–7% angular basalt chips; 15%–20% quartzo-feldspathic sandstone fragments; 70%–75% coarse sand /granules composed of quartz, microcline, chert, Precambrian granite and quartzite. WR sample clay-rich.	252–262	6004.9–5994.9
	Clastic sediments, clayey gravel (GC) with sand, pale yellowish-brown (10YR 6/2), subangular to subrounded pebbles (up to 0.7 cm). +12F: 60%–70% clasts of various granitic rocks, 5%–10% quartzo-feldspathic sandstone fragments; 5%–10% quartzite; 5%–10% white clay nodules; rare basalt fragments. Clasts commonly clay-coated.	262–272	5994.9–5984.9
	Clastic sediments, clayey gravel (GC) with sand, pale yellowish-brown (10YR 6/2). +12F: 50%–80% clasts made up of quartz, pink microcline, metamorphic and granitic rocks, and quartzite; 20%–50% fine-grained sandstone; 1%–2% basalt.	272–287	5984.9–5969.9
	Clastic sediments, clayey sand (SC) with gravel, pale yellowish-brown (10YR 6/2). +12F: 50%–80% subangular to subrounded clasts (up to 0.7 cm) made up of pinkish pink microcline, quartz, and metamorphic and granitic rocks; 20%–50% micaceous sandstone and siltstone; 1%–2% basalt.	287–302	5969.9–5954.9
	Clastic sediments, clayey sand (SC) with gravel, pale yellowish-brown (10YR 6/2). +12F: 60%–70% clay-cemented tuffaceous sandstone and siltstone; 30%–40% coarse sand and granules (up to 0.5 cm) made up of pinkish pink microcline, quartz, and metamorphic and granitic rocks, minor basalt and dacite; clasts commonly clay-coated.	302–312	5954.9–5944.9
	Clastic sediments, clayey sand (SC) with gravel, pale yellowish-brown (10YR 6/2). +12F: 90%–95% clay-cemented, quartz-bearing tuffaceous sandstone and siltstone; 5%–10% granitic and minor volcanic fragments.	312–317	5944.9–5939.9
	Clastic sediments, clayey gravel (GC) with sand, pale yellowish-brown (10YR 6/2). +12F: 10%–30% clay-cemented, quartz-feldspar-mica-volcanic sandstone; 70%–80% subangular to subrounded clasts (up to 0.5 cm) made up of pinkish pink microcline, quartz, and granitic rocks; 3%–5% dacitic volcanic clasts.	317–322	5939.9–5934.9

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Ta, Older Alluvium	Clastic sediments, clayey sand (SC) with gravel, pale yellowish-brown (10YR 6/2). +12F: 30%–50% fine-grained, quartz-volcanic-sandstone and siltstone; 50%–60% subangular to subrounded clasts (up to 0.5 cm) made up of clay-coated pink microcline, quartz, and granitic rocks; 2%–3% light gray dacitic volcanic clasts. WR sample clay-rich.	322–332	5934.9–5924.9
	Clastic sediments, clayey sand (SC) with gravel, pale yellowish-brown (10YR 6/2), coarse sand to granules (up to 0.5 cm), subrounded to angular. +12F: 40%–50% indurated fragments of quartz-volcanic and hornblende-volcanic sandstone; 50%–60% subrounded clasts made up of pink microcline, white feldspar, quartz, and granitic rocks; 3%–5% light gray dacitic volcanic clasts. WR sample clay-rich.	332–342	5924.9–5914.9
	Basalt/clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1). +12F: 40%–60% angular chips of olivine-basalt; 30%–40% fine-grained, quartz-feldspar sandstone fragments; 10%–30% subrounded clasts made up of pink and white feldspar, quartz, and granitic rocks. WR sample clay-rich	342–352	5914.9–5904.9
	Basalt/clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1). +12F: 70%–80% angular chips of vesicular olivine-basalt, commonly clay-coated; 30%–40% subrounded coarse sand and granules (up to 0.9 cm) composed of quartz, feldspar, and granitic and metamorphic rocks; 10%–15% fragments of fine-grained sandstone and siltstone. WR sample clay-rich	352–367	5904.9–5889.9
	Basalt/clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1). +12F: 50%–60% angular/broken chips of olivine-basalt, commonly clay-coated; 40%–50% subrounded/broken clasts composed of quartz, feldspar, and granitic lithics; 10%–15% fragments of fine-grained sandstone and siltstone. WR sample clay-rich.	367–377	5889.9–5879.9
Tpt, Totavi Lentil	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1). +12F: 35%–45% angular/broken chips of clay-coated basalt, minor rounded hornblende dacite; 10%–20% light tan fragments of fine-grained, quartzo-feldspathic sandstone and siltstone; 50%–60% subrounded/broken clasts (up to 0.5 cm) pink and white feldspar, quartz, quartzite, and granitic lithics. WR sample clay-rich.	377–392	5879.9–5864.9
	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1). +12F: 30%–40% angular/broken chips basalt and subrounded hornblende-bearing dacite; 10%–20% light tan fragments of sandstone and siltstone; 50%–60% subrounded/broken clasts (up to 0.4 cm) pink and white feldspar, quartz, quartzite, and granitic lithics. WR sample clay-rich.	392–407	5864.9–5849.9
	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1). +12F: 35%–45% angular/broken chips basalt and broken/subrounded clasts of light gray dacite; 10%–15% fragments of quartzo-feldspathic sandstone; 50%–60% subrounded/broken clasts (up to 0.5 cm) pink microcline, plagioclase, quartz, quartzite, and meta-granitic lithics.	407–422	5849.9–5834.9

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tpt, Totavi Lentil	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1), medium to coarse sand with pebbles (up to 0.5 cm) +12F: 30%–40% angular/broken chips basalt and subangular/subrounded clasts dacite; 10%–15% fragments of fined-grained sandstone; 50%–60% subrounded/broken clasts pink and white feldspar, quartz, quartzite, and granitic lithics. WR sample clay-rich.	422–432	5834.9–5824.9
	Clastic sediments, clayey gravel (GC) with sand, grayish-orange pink (5YR 7/2), broken to rounded clasts, pebbles (up to 0.5 cm). +12F: 50%–60% volcanic lithics (dacite, basalt, and possible pumice); 30%–40% clasts pink microcline, quartz, and quartzite of Precambrian sources; 5%–10% siltstone fragments. WR sample clay-rich.	432–442	5824.9–5814.9
	Clastic sediments, clayey gravel (GC) with sand, grayish-orange pink (5YR 7/2), broken to rounded clasts, pebbles (up to 0.5 cm). +12F: 25%–35% mixed clay-coated dacite and basalt chips; 10%–15% whitish clay fragments; 60%–70% subrounded/broken clasts of pink microcline, quartz, granite, and quartzite of Precambrian sources. WR sample clay-rich.	442–457	5814.9–5799.9
	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1), medium to coarse sand with pebbles (up to 0.5 cm). +12F: 35%–45% clay-coated dacite and minor basalt chips; 15%–20% fine-grained sandstone and clay fragments; 40%–60% subrounded/broken clasts pink microcline, quartz, granite, and quartzite of Precambrian sources. WR sample clay-rich.	457–472	5799.9–5784.9
	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1), medium to coarse sand with pebbles (up to 0.5 cm). +12F: 25%–35% clay-coated dacite and minor basalt chips; 10%–15% fine-grained sandstone and claystone fragments; 50%–60% subrounded/broken clasts of pink microcline, quartz, chert, granite, and quartzite. WR sample clay-rich.	472–482	5784.9–5774.9
	Clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1), broken and subrounded clasts (up to 1.0 cm). +12F: 10%–20% rounded dacite and minor basalt chips; 15%–20% fine-grained quartzo-feldspathic sandstone fragments; 65%–75% subrounded to rounded clasts of quartzite, pink microcline, and granitic lithics. WR sample clay-rich.	482–492	5774.9–5764.9
	Clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1), broken and subrounded clasts (up to 1.0 cm). +12F: 10%–20% dacite clasts and minor basalt chips; 15%–25% fine-grained quartzo-feldspathic sandstone fragments; 60%–70% subrounded to rounded clasts (up to 1.0 cm) of quartzite, pink microcline, chert, granite, and meta-granite lithics. WR sample clay-rich.	492–507	5764.9–5749.9

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tpt, Totavi Lentil	Clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1), subrounded and broken clasts. +12F: 15%–25% volcanic lithic clasts, mostly dacite with minor basalt chips; 5%–7% indurated siltstone fragments; 70%–80% subangular to subrounded clasts (up to 1.5 cm) of quartzite, pink microcline, granite, and metamorphic lithics. WR sample clay-rich.	507–522	5749.9–5734.9
	Clastic sediments, clayey gravel (GC) with sand, light olive-gray (5Y 6/1), subrounded and broken clasts. +12F: 15%–25% volcanic lithic clasts, mostly dacite with minor basalt chips; 3%–5% indurated fine-grained sandstone; 75%–80% subangular to subrounded clasts (up to 0.7 cm) of quartzite, pink microcline, chert, granite, and metamorphic lithics.	522–537	5734.9–5719.9
	Clastic sediments, clayey gravel (GC) with sand, grayish-orange pink (5YR 7/2), subrounded and broken clasts. +12F: 15%–25% rounded to broken dacite clasts; 3%–5% indurated fine-grained, quartzo-feldspathic sandstone; 70%–80% subrounded and broken clasts (up to 0.7 cm) of quartzite, pink microcline, granite, and metamorphic lithics. WR sample clay-rich.	537–547	5719.9–5709.9
	Clastic sediments, clayey gravel (GC) with sand, grayish-orange pink (5YR 7/2), subrounded and broken clasts. +12F: 15%–25% dacite clasts; 10%–20% indurated fine-grained quartzo-feldspathic sandstone; 60%–70% clasts of quartzite, pink microcline, granite, and metamorphic lithics. WR sample clay-rich.	547–562	5709.9–5694.9
	Clastic sediments, gravel (GW) with sand, grayish-orange pink (5YR 7/2), subangular to subrounded clasts (up to 1.0 cm), clay-coated. +12F: 15%–20% dacite clasts; 5%–10% indurated fine-grained sandstone; 60%–70% clasts of quartzite, quartz, pink microcline, granite, and metamorphic lithics.	562–577	5694.9–5679.9
	Clastic sediments, clayey sand (SC), grayish-orange pink (5YR 7/2). +12F: 15%–25% dacite clasts; 85%–90% clasts of quartzite, pink microcline, granite, and metamorphic lithics. WR sample clay-rich.	577–602	5679.9–5654.9
	Clastic sediments, clay (CH) with sand, grayish-orange pink (5YR 7/2). +12F: clay-rich matrix binding chips and obscuring composition. +40F: 10%–20% dacite clasts; 80%–90% grains of quartzite, quartz, pink microcline, granite, and metamorphic lithics in clayey matrix. WR sample contains 40%–50% clay.	602–612	5654.9–5644.9
	Clastic sediments, clay (CH) with sand, grayish-orange pink (5YR 7/2). +12F: 60%–70% volcanic clasts with clay-rich matrix. +40F: 35%–45% grains of dacite lithics; 45%–55% grains of quartzite, quartz, pink microcline, granite, and metamorphic lithics in clayey matrix; 5%–10% fragments of white clay. WR sample contains more than 50% clay.	612–617	5644.9–5639.9

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tpt, Totavi Lentil	Clastic sediments, clay (CH) with sand, grayish-orange pink (5YR 7/2). +12F: unidentified volcanic clasts in clay-rich matrix. +40F: 30%–35% grains of dacite lithics; 60%–70% grains of quartzite, quartz, pink microcline, and granite lithics. WR sample contains 30%–50% clay matrix.	617–627	5639.9–5629.9
Tpf, Puye Formation	Clastic sediments, clayey sand (SC), yellowish-gray (5Y 8/1). +12F: 80%–95% subrounded to rounded granules/pebbles (4–7 mm) of pink and gray dacite lithics; 5%–7% clasts of quartzite and rare granitic and metamorphic lithics, 5%–15% sandstone clasts. WR sample contains 30%–35% clay matrix binding fine to very coarse sand.	627–642	5629.9–5614.9
	Clastic sediments, clayey sand (SC), yellowish-gray (5Y 8/1), fine to very coarse sand, 30%–35% clay/silt. +12F: 97%–98% subrounded to rounded granules/pebbles (up to 0.5 mm) of pink and gray dacite lithics; 2%–3% clasts of quartzite and rare granitic lithics.	642–647	5614.9–5609.9
	Clastic sediments, clayey gravel (GC) with sand, grayish-orange pink (5RY 7/2), fine to very coarse sand/granules, 20%–25% clay matrix, +12F: 60%–70% broken and subrounded to rounded clasts (up to 1.0 cm) of pink and gray dacite lithics; 15%–20% clasts of quartzite, granite, and chert lithics, 10%–15% fine-grained sandstone and siltstone fragments.	647–657	5609.9–5599.9
Tpt, Totavi Lentil	Clastic sediments, clayey gravel (GC), yellowish-gray (5Y 8/1). +12F: 45%–55% rounded to subrounded dacite granules; 30%–40% angular/broken chips of quartzite and granitic lithics, 5%–10% sandstone clasts. WR sample contains clayey matrix, white clay.	657–667	5599.9–5589.9
	Clastic sediments, clayey gravel (GC), yellowish-gray (5Y 8/1). +12F: 75%–85% well-rounded clasts and broken chips of pink and gray dacite; 10%–20% broken chips of quartzite, chert, and metamorphic lithics. WR sample contains clayey matrix.	667–677	5589.9–5579.9
Tpf, Puye Formation	Clastic sediments, clayey gravel (GC), yellowish-gray (5Y 8/1). +12F: 70%–85% subrounded granules (4–6 mm) gray dacite; 10%–15% broken chips/clasts of quartzite, pink microcline, and granitic lithics; 5%–7% sandstone fragments. WR sample contains 30%–40% clay matrix.	677–687	5579.9–5569.9
	Clastic sediments, clayey gravel (GC) with sand, grayish-orange pink (5YR 7/2). +12F: 50%–60% subrounded granules pink and light gray dacite; 5%–10% clasts of quartzite lithics; 25%–35% sandstone and white claystone fragments. WR sample contains 30%–40% clay matrix.	687–697	5569.9–5559.9
	Clastic sediments, clayey sand (SC), grayish-orange pink (5YR 7/2). +12F: 50%–60% rounded to subrounded pebbles (up to 1.0 cm) of dacite volcanics; 5%–20% clasts and broken chips of quartz, quartzite, white and pink feldspar, and metamorphic lithics; 10%–25% light tan siltstone fragments. WR sample contains 30%–40% clay matrix.	697–712	5559.9–5544.9

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tpf, Puye Formation	Clastic sediments, clay (CH) with sand, grayish-orange pink (5YR 7/2). +12F: 30%–40% subrounded to rounded clasts of pink and gray dacite; 20%–30% clasts of quartzite and granite lithics; 10%–25% pink to white claystone fragments. WR sample contains at least 50% clay matrix.	712–722	5544.9–5534.9
	Clastic sediments, clayey sand (SC) with gravel, grayish-orange pink (5YR 7/2), gravel clasts subrounded and broken (up to 1.0 cm). +12F: 15%–20% clasts of dacite and minor basalt; 50%–60% clasts of quartzite and granite lithics; 20%–25% fine-grained sandstone and pink to white claystone fragments. WR sample contains 30% clay matrix.	722–728	5534.9–5528.9
Tsf, Santa Fe Group Sediments	Clastic sediments, clayey sand (SC), grayish-orange pink (5YR 7/2). +12F: less than 1% of sample retained on No. 12 sieve; 80%–90% volcanic clasts; 10%–15% lithic clasts of Precambrian sources. +40F: mixed fine sand grains of volcanic rocks and quartz that are rounded and frosted. WR sample contains 20%–30% clay matrix.	728–747	5528.9–5509.9
	Clastic sediments, clayey sand (SC), grayish-orange pink (5YR 7/2). +12F: less than 10 per cent of sample retained on No. 12 sieve; 70%–80% light and dark gray dacite; 10%–20% grains of Precambrian quartzite; 5%–15% indurated fine-grained sandstone. WR sample contains fine- to medium-grained with 20%–30% clay matrix.	747–762	5509.9–5494.9
	Clastic sediments, clayey sand (SC) with gravel, grayish-orange pink (5YR 7/2). +12F: 70%–80% broken chips of pink and gray dacite, rhyodacite, trace basalt; 15%–20% clasts of quartzite; 3%–5% fine-grained carbonate-cemented sandstone. WR sample contains fine- to medium-grained with 20%–30% clay matrix.	762–772	5494.9–5484.9
	Clastic sediments, clayey sand (SC) with gravel, grayish-orange pink (5YR 7/2). +12F: 40%–45% volcanic rocks, predominantly gray dacite; 30%–40% clasts of quartzite, pink and white feldspar, and granitic lithics; 10%–15% fine-grained carbonate-cemented sandstone fragments. WR sample contains 20%–30% clay matrix.	772–782	5484.9–5474.9
	Clastic sediments, clayey sand (SC) with gravel, grayish-orange pink (5YR 7/2). +12F: 50%–65% volcanic rocks, mostly broken chips of dacite, minor rhyodacite, trace altered pumice; 15%–20% clasts of quartzite, pinkish feldspar, and granitic lithics; 20%–25% fine-grained, carbonate-cemented sandstone fragments. WR sample contains 20%–30% clay matrix.	782–787	5474.9–5469.9
	Clastic sediments, clayey sand (SC), grayish-orange pink (5YR 7/2). +12F: less than 5% of sample retained on No. 12 sieve; roughly equal parts grains of volcanic lithologies(with 1%–2% altered pumice), Precambrian quartzite, and sandstone fragments. WR sample contains 20%–30% clay matrix.	787–797	5469.9–5459.9

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tsf, Santa Fe Group Sediments	Clastic sediments, sand (SW) with clay, grayish-orange pink (5YR 7/2), subrounded and broken chips (up to 0.5 cm). +12F: 30%–35% volcanic rocks, dominantly gray dacite with minor pumice; 35%–45% clasts of quartzite, pink and white feldspar, and granitic lithics; 10%–25% fine-grained carbonate-cemented sandstone fragments. WR sample contains 20%–30% clay matrix.	797–812	5459.9–5444.9
	Clastic sediments, sand (SW) with clay, light brown (5YR 6/4), subrounded to subangular clasts (up to 0.5 cm). +12F: 30%–35% volcanic lithics, mostly gray dacite with minor basalt; 30%–35% clasts of quartzite, pink and white feldspar, and granitic lithics; 15%–20% indurated fine-grained sandstone fragments. WR sample contains 10%–15% clay matrix.	812–822	5444.9–5434.9
	Clastic sediments, sand (SW), light brown (5YR 6/4), subangular to broken (up to 0.5 cm). +12F: 25%–35% volcanic lithics, mostly gray dacite; 40%–45% clasts of quartzite, pink and white feldspar, and granitic lithics; 25%–35% indurated fine-grained sandstone fragments.	822–837	5434.9–5419.9
	Clastic sediments, clayey sand (SC), light brown (5YR 6/4), grains subangular. +12F: less than 1% of sample retained on No. 12 sieve in the interval 842 to 847 ft bgs; 20%–30% volcanic lithics, mostly gray dacite, minor basalt and pumice; 40%–50% broken chips of quartzite, pink and white feldspar, and granitic lithics; 15%–25% indurated fine-grained sandstone fragments. WR sample contains 25%–35% clay matrix.	837–852	5419.9–5404.9
	Clastic sediments, clayey sand (SC) with gravel, light brown (5YR 6/4), subrounded clasts (up to 1.5 cm). ; +12F: less than 10% of sample retained on No. 12 sieve, 20%–30% dacite lithics; 40%–50% broken chips of lithics from Precambrian sources; 25% indurated fine-grained sandstone fragments. WR sample contains 30%–35% clay matrix.	852–857	5404.9–5399.9
	No cuttings recovered in this interval.	857–862	5399.9–5394.9
	Clastic sediments, sand (SW) with clay, grayish-orange pink (5YR 7/2), subrounded pebbles (up to 0.5 cm). ; +12F: 10%–20% dacite lithics; 65%–75% broken chips of quartz, feldspar, and granitic lithics from Precambrian sources; 10%–15% indurated fine-grained, quartzo-feldspathic sandstone fragments.	862–867	5394.9–5389.9
	No cuttings recovered because of lost circulation of drilling fluids in this interval.	867–1047	5389.9–5209.9
	Clastic sediments, clayey sand (SC), light brown (5YR 6/4), fine to medium sand with 35% clay. +12F: dominantly Precambrian-source grains, lesser volcanic lithics, clayey matrix. +40F: 25%–35% grains of dacite, black vitrophyre, and rare rhyodacite; 65%–75% rounded, frosted grains of quartz and feldspar.	1047–1057	5209.9–5199.9

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tsf, Santa Fe Group sediments	Clastic sediments, sand (SW) with clay, light brown (5YR 6/4), fine to medium sand. +12F: sample clay-rich. +40F: 20%–30% grains of dacite, well rounded black vitrophyre, and rare rhyodacite; 75%–80% rounded, frosted grains of quartz and feldspar.	1057–1062	5199.9–5194.9
	Clastic sediments, clayey sand (SC) to clay (CH) with sand, light brown (5YR 6/4), fine to medium sand. +12F and +40F: samples very clay rich, 40%–50% grains of volcanic lithics; 40%–50% grains of quartz and feldspar.	1062–1072	5194.9–5184.9
	Clastic sediments, clayey sand (SC), light brown (5YR 6/4), fine to coarse sand with 30%–35% clay. +12F: sample clay-rich. +40F: 30%–40% grains light gray dacite, black vitrophyre; 65%–75% grains of quartz and feldspar.	1072–1082	5184.9–5174.9
	Clastic sediments, clayey gravel (GC) with sand, light brown (5YR 6/4), 25%–30% clay, 40%–45% pebble gravel. +12F: sample clay-rich, abundant well-rounded and frosted clasts, mixed volcanic and Precambrian lithics. +40F: 35%–45% grains dacite, basalt, and spherical black vitrophyre; 45%–50% well rounded grains of quartz with frosted surfaces, feldspar, granite, quartzite, chert; 10%–15% indurated fine-grained sandstone fragments.	1082–1097	5174.9–5159.9
	Clastic sediments, clayey sand (SC) with gravel, light brown (5YR 6/4), 25%–50% clay, 15%–20% pebble gravel. +12F: sample clay-rich, 50%–60%clay-cemented balls of fine-grained sandstone; 25%–35% volcanic lithics; dacite, minor basalt; 10%–20% clasts of quartz with frosted surfaces, feldspar, granite, and quartzite.	1097–1107	5159.9–5149.9
	Clastic sediments, clayey sand (SC), light brown (5YR 6/4), fine to medium sand, 30%–40% clay, 10% granules. +12F: 20%–30% clay-cemented fragments of fine-grained sandstone; 55%–65% volcanic lithics (pink and gray dacite, minor basalt); 10%–15% clasts of quartz and quartzo-feldspathic lithologies.	1107–1117	5149.9–5139.9
	Clastic sediments, clayey sand (SC) to clay (CH) with sand, light brown (5YR 6/4), fine to medium sand, 40%–50% clay, 10%–15% granules. +12F: 70%–85% clay-cemented fragments of fine-grained sandstone and clay clots; 15%–25% subrounded clasts (up to 0.5 cm) of volcanic lithics; pink and gray dacite, minor basalt; 5%–7% clasts of quartz, quartzite, feldspar, and granitic lithologies.	1117–1132	5139.9–5124.9
	Clastic sediments, clayey sand (SC), light brown (5YR 6/4), fine to medium sand, 30%–40% clay. +12F: 75%–90% light tan clay-cemented, fine-grained quartzo-feldspathic sandstone fragments and clay clots; 10%–25% clasts of volcanic lithics (dacite, basalt). +40F: 20%–30% grains of dacite, well rounded of black vitrophyre; 70%–80% grains of frosted quartz and feldspar.	1132–1147	5124.9–5109.9

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tsf, Santa Fe Group sediments	Clastic sediments, clayey sand (SC) with gravel, light brown (5YR 6/4), fine to coarse sand, 25%–35% clay, 10%–15% pebble gravel. +12F:15%–30% clay-cemented sandstone fragments; 30%–40% clasts of volcanic lithics; pink and gray dacite, basalt; 25%–30% subangular clasts (up to 0.5 cm) quartzite, quartz, feldspar and granite lithics.	1147–1157	5109.9–5099.9
	Clastic sediments, clayey sand (SC) with gravel, light olive-gray (5Y 6/1), fine to coarse sand, 15%–20% clay, 20%–25% pebble gravel. +12F: 20%–30% clay-cemented fine-grained sandstone fragments; 40%–50% subrounded clasts (up to 0.5 cm) of volcanic lithics; dacite, minor basalt; 20%–30% quartzo-feldspathic component.	1157–1172	5099.9–5084.9
	Clastic sediments, clayey sand (SC) with gravel, light brown (5YR 6/4), fine to coarse sand, 25%–35% clay matrix. +12F: 15%–25% clay-cemented fine-grained sandstone fragments; 55%–65% clasts of pink and gray dacite; 15%–20% quartz, feldspar, quartzite, and granite lithics. +40F: contains abundant well-rounded grains of frosted quartz.	1172–1182	5084.9–5074.9
	Clastic sediments, clayey sand (SC) with gravel, light brown (5YR 6/4), fine to medium sand, 20%–25% clay matrix. +12F: 70%–75% clay-cemented, fine-grained sandstone fragments; 15%–20% subrounded clasts (up to 0.4 cm) of dacite and minor basalt; 10%–15% quartz, feldspar, quartzite, and granite lithics. +40F: contains 75% quartzo-feldspathic and 25% volcanic grains.	1182–1192	5074.9–5064.9
	Clastic sediments, clayey sand (SC), light brown (5YR 6/4), 20%–25% clay matrix. +12F: 15%–30% clay-cemented, fine-grained sandstone fragments; 40%–50% clasts of pink and gray dacite, minor basalt; 20%–25% quartz, feldspar, quartzite, and granite lithics.	1192–1207	5064.9–5049.9
	Clastic sediments, clayey sand (SC), light brown (5YR 6/4), 30%–40% clay matrix. +12F: 25%–30% clay-cemented, fine-grained sandstone fragments; 40%–50% clasts of dacite, minor basalt; 15%–20% quartz, feldspar, and granite lithics.	1207–1222	5049.9–5034.9
	Clastic sediments, sand (SW) with clay and gravel, light brown (5YR 6/4). +12F: 15%–20% clots of indurated sandy clay; 60%–70% subrounded clasts of pink and gray dacite, latite, tuffaceous quartz crystals, and minor basalt; 10%–15% Precambrian (quartzite, granite) lithics.	1222–1232	5034.9–5024.9
	Clastic sediments, sand (SW) with clay and gravel, light brown (5YR 6/4). +12F: 20%–30% clots of clay-cemented fine-grained sandstone; 50%–60% rounded clasts of pink and gray dacite and white latite; 5%–10% Precambrian (quartzite, granite) lithics.	1232–1247	5024.9–5009.9
	Clastic sediments, clayey sand (SC), light brown (5YR 6/4). +12F: 3%–5% indurated, fine-grained sandstone fragments; 80%–90% volcanic clasts of pink and gray dacite (tuff, quartz porphyritic?) white biotite-bearing latite, and rare basalt; 5%–7% Precambrian (quartzite, granite) lithics.	1247–1262	5009.9–4994.9

Geologic Unit	Lithologic Description	Sample Interval (ft bgs)	Elevation Range (ft above msl)
Tsf, Santa Fe Group sediments	Clastic sediments, clayey sand (SC), light brown (5YR 6/4). +12F: 5%–7% indurated, fine-grained sandstone fragments; 70%–80% subrounded volcanic clasts of pink and gray dacite (tuff, quartz porphyritic?) white biotite-bearing latite and rare basalt; 5%–7% Precambrian (quartzite, granite) lithics.	1262–1277	4994.9–4979.9
	Clastic sediments, gravel (GW) with clay and sand, light brown (5YR 6/4). +12F: 5%–10% indurated, fine-grained sandstone fragments; 80%–90% volcanic clasts of pink and gray dacite (tuff, quartz porphyritic?) white biotite-bearing latite and rare basalt; 3%–5% quartzite clasts.	1277–1287	4979.9–4969.9
R-16 borehole total depth (TD) = 1287 ft bgs			

Notes:

1. American Society for Testing Materials (ASTM) standards (D 2488-90: Standard Practice and Identification of Soils [Visual-Manual Procedure]) were used to describe the texture of drill chip samples for sedimentary rocks such as alluvium and the Puye Formation. ASTM method D 2488-90 incorporates the Unified Soil Classification System (USCS) as a standard for field examination and description of soils. The following standard USCS symbols were used in the R-16 lithologic log:

   SW = Well-graded sand GM = Silty gravel SC = Sand/clay
   GW = Well-graded gravel GC = Clayey gravel CH = Clay, high plasticity
   GP = Poorly graded gravel SM = Silt

2. Cuttings at R-16 were collected at nominal 5-ft intervals and divided into three sample splits: (1) unsieved, or whole rock (WR) sample; (2) +12F sieved fraction (No. 12 sieve equivalent to 1.75 mm); and (3) +40F sieved fraction (No. 40 sieve equivalent to 0.425 mm).
3. The term *percent,* as used in the above descriptions, refers to percent by volume for a given sample component.
4. Color designations such as hue, value, and chroma (e.g., 5YR 5/2) are from the Geological Society of America's Rock Color Chart.

Appendix D

LANL Borehole Video Log
(CD attached to inside back cover)

Appendix E

Schlumberger Geophysical Report/Montage
(CD attached to inside back cover)

Appendix F

Westbay™ Multi-Level Sampling Diagram
(CD attached to inside back cover)

Appendix G

Waste Characterization Data

Los Alamos
NATIONAL LABORATORY

Risk Reduction & Environmental Stewardship Division
Water Quality & Hydrology Group (RRES-WQH)
PO Box 1663, MS K497
Los Alamos, New Mexico 87545
(505) 667-7969/Fax: (505) 665-9344

Date: October 31, 2002
Refer to: RRES-WQH: 02-403

Mr. John Young
Hazardous Materials Bureau
New Mexico Environment Department
P.O. Box 26110
Santa Fe, New Mexico 87502

Mr. Curt Frischkorn
Ground Water Quality Bureau
New Mexico Environment Department
P.O. Box 26110
Santa Fe, New Mexico 87502

SUBJECT: NOTICE OF INTENT TO DISCHARGE, HYDROGEOLOGIC WORKPLAN WELL R-16

Dear Mr. Young and Mr. Frischkorn:

On October 28, 2002, your agency concurred with Los Alamos National Laboratory's request to land apply approximately 75,000 gallons of ground water produced during the development of Hydrogeologic Workplan Well R-16 (personal communication, Mr. Bob Beers, Los Alamos National Laboratory, and Mr. Curt Frischkorn, New Mexico Environment Department). The Laboratory's proposal to discharge development water from Workplan Well R-16 was made in accordance with the requirements of the Hydrogeologic Workplan Notice of Intent (NOI) submitted to your agency on August 2, 2001, and subsequently revised on July 16, 2002. Under the Hydrogeologic Workplan NOI, when development water produced from a Hydrogeologic Workplan Well exceeds a New Mexico Water Quality Control Commission (NM WQCC) Regulation 3103 ground water standard or a RCRA regulatory limit the Laboratory will coordinate disposal with the NMED. Since the development water produced from Workplan Well R-16 exceed the NM WQCC Regulation 3103 ground water standards for manganese (Mn) and cobalt (Co), your agency's concurrence was requested.

The Laboratory has containerized approximately 75,000 gallons of ground water produced during the development of Workplan Well R-16. Workplan Well R-16 is located in White Rock in the vicinity of Los Alamos County's White Rock WWTP. Depth to ground water at the land application site is approximately 622 feet. In accordance with our proposal, all development water from Workplan Well R-16 will be land applied to the grounds of Los Alamos County's WWTP. Los Alamos County has granted the Laboratory permission for this activity. As required by the Workplan NOI, no ponding, pooling, or run-off of the discharged water will be permitted. Information regarding the quality of the development water is provided below.

Mr. Young and Mr. Frischkorn - 2 - October 31, 2002
RRES-WQH:02-403

Water Quality Data
Attachment 1.0 contains analytical reports (metals, general chemistry, perchlorate, nitrate, tritium, and high explosives) from the sampling of containerized development water from Workplan Well R-16. All samples were filtered prior to analysis. Sample results were compliant with all NM WQCC Regulation 3103 ground water standards with the exception of the following contaminants:

Contaminant	Screening Result (mg/L)	NM WQCC ground water standard (mg/L)
Mn	0.95	0.2
Co	0.054	0.05

No perchlorate, tritium, nitrate/nitrite, or high explosives were detected in the Workplan Well R-16 development water at concentrations greater than the analytical laboratory's Method Detection Limits (MDLs).

Please call me at (505) 667-6969 or Roy Bohn of the Laboratory's Environmental Restoration Project (RRES-R) at (505) 665-5138 if additional information is required.

Sincerely,

Bob Beers
Water Quality & Hydrology Group

BB/tml

Enclosures: a/s

Cy: M. Leavitt, NMED/GWQB, Santa Fe, NM, w/enc.
J. Davis, NMED/SWQB, Santa Fe, NM, w/enc.
J. Bearzi, NMED/HWB, Santa Fe, NM, w/enc.
J. Vozella, DOE/OLASO, w/enc., MS A316
G. Turner, DOE/OLASO, w/enc., MS A316
M. Johansen, DOE/OLASO, w/enc., MS A316
J. Holt, ADO, w/enc., MS A104
B. Ramsey, RRES-DO, w/o enc., MS J591
K. Hargis, RRES-DO, w/o enc., MS J591
D. Stavert, RRES-EP, w/enc., MS J978
S. Rae, RRES-WQH, w/o enc., MS K497
D. Rogers, RRES-WQH, w/o enc., MS K497
M. Saladen, RRES-WQH, w/o enc., MS K497
R. Bohn, RRES-R, w/o enc., MS M992
D. McInroy, RRES-R, w/o enc., MS M992
RRES-WQH File, w/enc., MS K497
IM-5, w/enc., MS A150

Los Alamos
NATIONAL LABORATORY

Risk Reduction & Environmental Stewardship Division
Water Quality & Hydrology Group (RRES-WQH)
PO Box 1663, MS K497
Los Alamos, New Mexico 87545
(505) 667-7969 / Fax: (505) 665-9344

Date: December 3, 2002
Refer to: RRES-WQH: 02-444

Mr. John Young
Hazardous Materials Bureau
New Mexico Environment Department
P.O. Box 26110
Santa Fe, New Mexico 87502

Mr. Curt Frischkorn
Ground Water Quality Bureau
New Mexico Environment Department
P.O. Box 26110
Santa Fe, New Mexico 87502

SUBJECT: NOTICE OF INTENT TO DISCHARGE, HYDROGEOLOGIC WORKPLAN WELL R-16, DRILLING WATER

Dear Mr. Young and Mr. Frischkorn:

On November 26-27, 2002, your agency concurred with Los Alamos National Laboratory's proposal to land apply water produced during the drilling of Hydrogeologic Workplan Well R-16 (November 26, 2002, personal communication, Mr. Curt Frischkorn, NMED, and Mr. Bob Beers, LANL; and November 27, 2002, voicemail, Mr. John Young, NMED, to Mr. David Broxton, LANL). The Laboratory's proposal to discharge drilling water from Workplan Well R-16 was made in accordance with the requirements of the Hydrogeologic Workplan Notice of Intent (NOI) submitted to your agency on August 2, 2001, and subsequently revised on July 16, 2002. Under the Hydrogeologic Workplan NOI, when drilling water produced from a Hydrogeologic Workplan Well exceeds a New Mexico Water Quality Control Commission (NM WQCC) Regulation 3103 ground water standard or a RCRA regulatory limit the Laboratory will coordinate disposal with the NMED. Since the drilling water produced from Workplan Well R-16 exceeds the NM WQCC Regulation 3103 ground water standard for manganese (Mn), your agency's concurrence was requested.

The Laboratory has containerized approximately 60,000 gallons of water produced during the drilling of Workplan Well R-16. Workplan Well R-16 is located in White Rock near Los Alamos County's White Rock WWTP. Candidate sites for the land application of R-16 drilling water are as follows:

- The road to Mortandad Canyon from TA-52. Depth to ground water: regional = 1260 ft.
- The road to the R-14 drill site: Depth to ground water: regional = 1180 ft.
- The roads at TA-49: Depth to ground water: regional = 1180 ft.

Because current weather conditions are not conducive to evaporation (lower temperatures, higher humidity) and recent precipitation has increased soil moisture, it is necessary for the Laboratory to utilize a variety of land application sites. The conditions at each site will be carefully evaluated before use. In accordance the Workplan NOI, no ponding, pooling, or run-off of the discharged water will be permitted. Information regarding the quality of the Workplan Well R-16 drilling water is provided below.

Water Quality Data

Attachment 1.0 contains analytical reports (metals, general chemistry, perchlorate, nitrate, total Hg, and tritium) from the sampling of containerized drilling water from Workplan Well R-16. All samples were filtered prior to analysis (with the exception of total Hg). Sample results were compliant with all NM WQCC Regulation 3103 ground water standards with the exception of the following contaminant:

Contaminant	Screening Result (mg/L)	NM WQCC ground water standard (mg/L)
Mn	0.61	0.2
Mn	1.29	0.2
Mn	0.18	0.2

No perchlorate or tritium were detected in the Workplan Well R-16 drilling water at concentrations greater than the analytical laboratory's Method Detection Limits (MDLs).

Please call me at (505) 667-6969 or Roy Bohn of the Laboratory's Environmental Restoration Project (RRES-R) at (505) 665-5138 if additional information is required.

Sincerely,

Bob Beers
Water Quality & Hydrology Group

BB/tml

Attachments: a/s

Cy: M. Leavitt, NMED/GWQB, Santa Fe, NM, w/att.
J. Davis, NMED/SWQB, Santa Fe, NM, w/att.
J. Bearzi, NMED/HWB, Santa Fe, NM, w/att.
J. Vozella, DOE/OLASO, w/o att., MS A316
G. Turner, DOE/OLASO, w/att., MS A316
M. Johansen, DOE/OLASO, w/att., MS A316
J. Holt, ADO, w/att., MS A104

Mr. Young and Mr. Frischkorn - 3 - December 3, 2002
RRES-WQH:02-444

Cy (continued):
B. Ramsey, RRES-DO, w/o att., MS J591
K. Hargis, RRES-DO, w/o att., MS J591
D. Stavert, RRES-EP, w/att., MS J591
C. Nylander, RRES-GP, w/o att., MS M992
S. Rae, RRES-WQH, w/att., MS K497
D. Rogers, RRES-WQH, w/o att., MS K497
M. Saladen, RRES-WQH, w/o att., MS K497
J. McCann, RRES-WQH, w/o att., MS M992
R. Bohn, RRES-R, w/att., MS M992
D. Volkman, FWO-UI, w/o att., MS K718
RRES-WQH File, w/att., MS K497
IM-5, w/att., MS A150

ATTACHMENT 1.0

HYDROGEOLOGIC WORKPLAN
WELL R-16

CONTAINERIZED DRILLING WATER

ANALYTICAL REPORTS:

- GENERAL CHEMISTRY
- METALS
- PERCHLORATE
- NITRATE/NITRITE
- TOTAL HG
- TRITIUM

SAMPLE DATES:

SEPTEMBER 9, 2002
SEPTEMBER 12, 2002
OCTOBER 1, 2002

Workplan Well R-16 Drilling Water
Screening Data

ER WATER SAMPLES

SAMPLE ID	DESCRIPTION	DATE MM/DD/YY	ER Req#	Ag ppm	Al ppm	Std.D. +/-	As ppm	Std.D. +/-	B ppm	Std.D. +/-	Ba ppm
GW16-02-49356	R-16 mud, analyzed after filtering	09/09/02	1188S	<0.0003	0.57	0.01	0.033	0.001	0.064	0.002	0.30
GW16-02-49357	R-16 mud, analyzed after filtering	09/09/02	1188S	<0.0003	0.84	0.01	0.021	0.001	0.077	0.001	0.70
GW16-02-49358	R-16 mud, analyzed after filtering	09/09/02	1188S	<0.0003	0.22	0.01	0.023	0.001	0.074	0.001	0.094

Workplan Well R-16 Drilling Water
Screening Data

SAMPLE ID	Std.D. +/-	Be ppm	Br ppm	Ca ppm	Std.D. +/-	Cd ppm	Cl ppm	ClO3 ppm	ClO4 ppm	Co ppm	Std.D. +/-	Cr ppm	Std.D. +/-	Cs ppm	Cu ppm
GW16-02-49356	0.01	<0.002	<0.1	103	1	<0.001	7.15	<0.1	<0.01	0.0018	0.0001	0.010	0.001	<0.003	0.010
GW16-02-49357	0.01	<0.002	0.08	144	4	<0.001	7.50	<0.1	<0.01	0.0022	0.0001	0.013	0.001	<0.003	0.0078
GW16-02-49358	0.001	<0.002	<0.1	20.3	0.6	<0.001	10.9	<0.1	<0.01	0.0013	0.0001	0.0093	0.0006	<0.003	0.0095

Page 2

Workplan Well R-16 Drilling Water
Screening Data

SAMPLE ID	Std.D. +/-	F ppm	Fe ppm	Std.D. +/-	Hardness CaCO3 ppm	Hg ppm	Std.D. +/-	K ppm	Std.D. +/-	Li ppm	Std.D. +/-	Mg ppm	Std.D. +/-	Mn ppm	Std.D. +/-
GW16-02-49356	0.001	0.28	0.28	0.01	305	0.0018	0.0002	7.87	0.03	0.14	0.01	11.7	0.1	0.61	0.01
GW16-02-49357	0.0002	0.41	0.73	0.01	439	0.0015	0.0001	10.7	0.1	0.13	0.01	19.3	0.2	1.29	0.08
GW16-02-49358	0.0002	0.40	0.24	0.01	62.5	0.0009	0.0001	4.27	0.05	0.12	0.01	2.86	0.03	0.18	0.01

Workplan Well R-16 Drilling Water
Screening Data

SAMPLE ID	Mo ppm	Std.D. +/-	Na ppm	Std.D. +/-	Ni ppm	Std.D. +/-	NO2 ppm	NO3 ppm	N total ppm	Oxalate ppm	Pb ppm	Std.D. +/-	PO4 ppm	Rb ppm	Std.D. +/-
GW16-02-49356	0.057	0.001	296	1	0.010	0.001	0.51	0.75	0.32	<0.1	0.0015	0.0001	1.29	0.011	0.001
GW16-02-49357	0.066	0.002	265	2	0.012	0.001	0.44	0.21	0.18	0.41	0.0015	0.0001	1.20	0.019	0.001
GW16-02-49358	0.068	0.003	237	2	0.0042	0.0001	0.27	3.52	0.88	0.49	0.0021	0.0001	1.56	0.006	0.001

Workplan Well R-16 Drilling Water
Screening Data

SAMPLE ID	Sb ppm	Std.D. +/-	Se ppm	Std.D. +/-	Si ppm	Std.D. +/-	SiO2 ppm calc	SO4 ppm	Sn ppm	Sr ppm	Std.D. +/-	Th ppm	Std.D. +/-	Ti ppm	Std.D. +/-
GW16-02-49356	0.0011	0.0001	0.004	0.001	21.5	0.1	46.0	177	<0.002	1.46	0.01	<0.001		0.004	0.001
GW16-02-49357	<0.001		0.004	0.001	24.3	0.3	52.0	224	<0.002	1.69	0.01	0.0016	0.0001	0.009	0.001
GW16-02-49358	<0.001		0.002	0.001	21.5	0.1	46.0	141	<0.002	0.44	0.01	<0.001		<0.001	

Workplan Well R-16 Drilling Water
Screening Data

SAMPLE ID	Tl ppm	U ppm	Std.D. +/-	V ppm	std.D. +/-	Zn ppm	Std.D. +/-	Acetate ppm	Formate ppm	comments
GW16-02-49356	<0.002	0.0082	0.0001	0.022	0.001	0.008	0.001	+	+	unknown peak before NO3
GW16-02-49357	<0.002	0.0092	0.0001	0.030	0.002	0.006	0.001	+	+	unknown peak before NO3
GW16-02-49358	<0.002	0.0066	0.0001	0.013	0.001	0.002	0.001	+	+	unknown peak before NO3

Certificate of Analysis

Company : Los Alamos National Lab
Address : PO Box 1663
TA-3, Bldg. 271, Drop Pt. 01U
Los Alamos, New Mexico 87545
Contact: Keith Greene
Project: Groundwater Project

Report Date: October 24, 2002
Page 1 of 1

Client Sample ID:	GW16-02-49614 05	Project:	LANL00401
Sample ID:	68194001	Client ID:	LANL004
Matrix:	Ground Water		
Collect Date:	01-OCT-02 00:00		
Receive Date:	03-OCT-02		
Collector:	Client		

Parameter	Qualifier	Result	DL	RL	Units	DF	AnalystDate	Time	Batch	Method
Mercury Analysis Federal										
7470 Cold Vapor Hg Liquid										
Mercury	U	ND	0.943	4.00	ug/L	20	NOR1 10/23/02	1818	210028	1

The following Prep Methods were performed

Method	Description	Analyst	Date	Time	Prep Batch
SW846 7470A Prep	EPA 7470A Mercury Prep Liquid	KHN	10/22/02	1500	210025

The following Analytical Methods were performed

Method	Description	Analyst Comments
1	SW846 7470A	

Notes:
The Qualifiers in this report are defined as follows :

< Actual result is less than amount reported
> Actual result is greater than amount reported
B Analyte found in the sample as well as the associated blank.
BD Flag for results below the MDC or a flag for low tracer recovery.
E Concentration exceeds instrument calibration range
H Holding time exceeded
J Indicates an estimated value. The result was greater than the detection limit, but less than the reporting limit.
P The response between the confirmation column and the primary column is >40%D
U Indicates the compound was analyzed for but not detected above the detection limit
UI Uncertain identification for gamma spectroscopy.
X Lab-specific qualifier - must be fully described in case narrative and data summary package
Y QC Samples were not spiked with this compound.

The above sample is reported on an "as received" basis.

Where the analytical method has been performed under NELAP certification, the analysis has met all of the requirements of the NELAC standard unless qualified on the Certificate of Analysis.

This data report has been prepared and reviewed in accordance with General Engineering Laboratories, Inc. standard operating procedures. Please direct any questions to your Project Manager, Stacy Griffin.

Reviewed by

Certificate of Analysis

Company : Los Alamos National Lab
Address : PO Box 1663
TA-3, Bldg. 271, Drop Pt. 01U
Los Alamos, New Mexico 87545
Contact: Keith Greene
Project: Groundwater Project

Report Date: October 24, 2002

Page 1 of 1

Client Sample ID:	GW16-02-49615 05	Project:	LANL00401
Sample ID:	68194002	Client ID:	LANL004
Matrix:	Ground Water		
Collect Date:	01-OCT-02 00:00		
Receive Date:	03-OCT-02		
Collector:	Client		

Parameter	Qualifier	Result	DL	RL	Units	DF	AnalystDate	Time	Batch	Method
Mercury Analysis Federal										
7470 Cold Vapor Hg Liquid										
Mercury	U	ND	0.943	4.00	ug/L	20	NOR1 10/23/02	1824	210028	1

The following Prep Methods were performed

Method	Description	Analyst	Date	Time	Prep Batch
SW846 7470A Prep	EPA 7470A Mercury Prep Liquid	KHN	10/22/02	1500	210025

The following Analytical Methods were performed

Method	Description	Analyst Comments
1	SW846 7470A	

Notes:
The Qualifiers in this report are defined as follows :

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H Holding time exceeded
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P The response between the confirmation column and the primary column is >40%D
U Indicates the compound was analyzed for but not detected above the detection limit
UI Uncertain identification for gamma spectroscopy.
X Lab-specific qualifier - must be fully described in case narrative and data summary package
Y QC Samples were not spiked with this compound.

The above sample is reported on an "as received" basis.

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This data report has been prepared and reviewed in accordance with General Engineering Laboratories, Inc. standard operating procedures. Please direct any questions to your Project Manager, Stacy Griffin.

_____
Reviewed by

Certificate of Analysis

Company : Los Alamos National Lab
Address : PO Box 1663
TA-3, Bldg. 271, Drop Pt. 01U
Los Alamos, New Mexico 87545
Contact: Keith Greene
Project: Groundwater Project

Report Date: October 24, 2002

Page 1 of 1

Client Sample ID:	GW16-02-49616 05	Project:	LANL00401
Sample ID:	68194003	Client ID:	LANL004
Matrix:	Ground Water		
Collect Date:	01-OCT-02 00:00		
Receive Date:	03-OCT-02		
Collector:	Client		

Parameter	Qualifier	Result	DL	RL	Units	DF	AnalystDate	Time	Batch	Method
Mercury Analysis Federal										
7470 Cold Vapor Hg Liquid										
Mercury	U	ND	0.0472	0.200	ug/L	1	NOR1 10/22/02	1212	207403	1

The following Prep Methods were performed

Method	Description	Analyst	Date	Time	Prep Batch
SW846 7470A Prep	EPA 7470A Mercury Prep Liquid	KHN	10/21/02	1630	207402

The following Analytical Methods were performed

Method	Description	Analyst Comments
1	SW846 7470A	

Notes:
The Qualifiers in this report are defined as follows :

< Actual result is less than amount reported
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B Analyte found in the sample as well as the associated blank.
BD Flag for results below the MDC or a flag for low tracer recovery.
E Concentration exceeds instrument calibration range
H Holding time exceeded
J Indicates an estimated value. The result was greater than the detection limit, but less than the reporting limit.
P The response between the confirmation column and the primary column is >40%D
U Indicates the compound was analyzed for but not detected above the detection limit
UI Uncertain identification for gamma spectroscopy.
X Lab-specific qualifier - must be fully described in case narrative and data summary package
Y QC Samples were not spiked with this compound.

The above sample is reported on an "as received" basis.

Where the analytical method has been performed under NELAP certification, the analysis has met all of the requirements of the NELAC standard unless qualified on the Certificate of Analysis.

This data report has been prepared and reviewed in accordance with General Engineering Laboratories, Inc. standard operating procedures. Please direct any questions to your Project Manager, Stacy Griffin.

Reviewed by

Certificate of Analysis

Company: Los Alamos National Lab
Address: PO Box 1663
TA-3, Bldg. 271, Drop Pt. 01U
Los Alamos, New Mexico 87545
Contact: Keith Greene
Project: Groundwater Project

Report Date: September 23, 2002

Page 1 of 1

Client Sample ID: GW16-02-49356 13/14
Sample ID: 67047001
Matrix: Misc Liquid
Collect Date: 12-SEP-02
Receive Date: 13-SEP-02
Collector: Client

Project: LANL00401
Client ID: LANL004

Parameter	Qualifier	Result	DL	TPU	RL	Units	DF	Analyst	Date	Time	Batch	Mtd.
Rad Liquid Scint												
LSC, Tritium Dist, Liquid												
Tritium		-55.3	252	68.0	250	pCi/L		CAF1	09/23/02	1102	202687	1

The following Analytical Methods were performed

Method	Description
1	EPA 906.0

Notes:
TPU is calculated at the 67% confidence level (1-sigma).
The Qualifiers in this report are defined as follows :

< Actual result is less than amount reported
> Actual result is greater than amount reported
B Analyte found in the sample as well as the associated blank.
E Concentration exceeds instrument calibration range
H Holding time exceeded
J Indicates an estimated value. The result was greater than the detection limit, but less than the reporting limit.
P The response between the confirmation column and the primary column is >40%D
U Indicates the compound was analyzed for but not detected above the detection limit
UI Uncertain identification for gamma spectroscopy.
X Lab-specific qualifier - must be fully described in case narrative and data summary package
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Reviewed by

Certificate of Analysis

Company: Los Alamos National Lab
Address: PO Box 1663
TA-3, Bldg. 271, Drop Pt. 01U
Los Alamos, New Mexico 87545
Contact: Keith Greene
Project: Groundwater Project

Report Date: September 23, 2002

Client Sample ID: GW16-02-49357 13/14
Sample ID: 67047002
Matrix: Misc Liquid
Collect Date: 09-SEP-02
Receive Date: 13-SEP-02
Collector: Client

Project: LANL00401
Client ID: LANL004

Parameter	Qualifier	Result	DL	TPU	RL	Units	DF	Analyst	Date	Time	Batch	Mtd.
Rad Liquid Scint												
LSC, Tritium Dist, Liquid												
Tritium		-27.3	170	50.7	250	pCi/L		CAF1	09/20/02	1157	202687	1

The following Analytical Methods were performed

Method	Description
1	EPA 906.0

Notes:
TPU is calculated at the 67% confidence level (1-sigma).
The Qualifiers in this report are defined as follows :

< Actual result is less than amount reported
> Actual result is greater than amount reported
B Analyte found in the sample as well as the associated blank.
E Concentration exceeds instrument calibration range
H Holding time exceeded
J Indicates an estimated value. The result was greater than the detection limit, but less than the reporting limit.
P The response between the confirmation column and the primary column is >40%D
U Indicates the compound was analyzed for but not detected above the detection limit
UI Uncertain identification for gamma spectroscopy.
X Lab-specific qualifier - must be fully described in case narrative and data summary package
The above sample is reported on an "as received" basis.

This data report has been prepared and reviewed in accordance with General Engineering Laboratories, Inc. standard operating procedures. Please direct any questions to your Project Manager, Stacy Griffin.

Reviewed by

Certificate of Analysis

Company: Los Alamos National Lab
Address: PO Box 1663
TA-3, Bldg. 271, Drop Pt. 01U
Los Alamos, New Mexico 87545
Contact: Keith Greene
Project: Groundwater Project

Report Date: September 23, 2002

Page 1 of 1

Client Sample ID: GW16-02-49358 13/14
Sample ID: 67047003
Matrix: Misc Liquid
Collect Date: 09-SEP-02
Receive Date: 13-SEP-02
Collector: Client

Project: LANL00401
Client ID: LANL004

Parameter	Qualifier	Result	DL	TPU	RL	Units	DF	Analyst	Date	Time	Batch	Mtd.
Rad Liquid Scint												
LSC, Tritium Dist, Liquid												
Tritium		-53.1	165	48.5	250	pCi/L		CAFI	09/20/02	1327	202687	1

The following Analytical Methods were performed

Method	Description
1	EPA 906.0

Notes:
TPU is calculated at the 67% confidence level (1-sigma).
The Qualifiers in this report are defined as follows :

< Actual result is less than amount reported
> Actual result is greater than amount reported
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X Lab-specific qualifier - must be fully described in case narrative and data summary package
The above sample is reported on an "as received" basis.

This data report has been prepared and reviewed in accordance with General Engineering Laboratories, Inc. standard operating procedures. Please direct any questions to your Project Manager, Stacy Griffin.

Reviewed by