LA-UR-07-6436
October 2007
EP2007-0591

Technical Area 54 Well Evaluation and Network Recommendations, Revision 1

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Environmental Programs Directorate

LA-UR-07-6436
EP2007-0591

Technical Area 54 Well Evaluation and Network Recommendations, Revision 1

October 2007

Responsible project leader:

Danny Katzman		Project Leader	Environmental Programs	10.4.07
Printed Name	Signature	Title	Organization	Date

Responsible LANS representative:

Susan G. Stiger		Associate Director	Environmental Programs	10/4/07
Printed Name	Signature	Title	Organization	Date

Responsible DOE representative:

for David R. Gregory		Project Director	DOE-LASO	10/5/07
Printed Name	Signature	Title	Organization	Date

CONTENTS

1.0 INTRODUCTION

This monitoring well network evaluation for Technical Area (TA) 54 (see Figure 1.0-1) is being conducted pursuant to a requirement set forth by the New Mexico Environment Department's (NMED's) letter on "Well Evaluations for Intermediate and Regional Wells," dated April 5, 2007 (NMED 2007, 095999). In addition, this evaluation is directed by requirements set forth by the NMED's "Approval with Direction, Technical Area 54 Well Evaluation and Network Recommendations" (NMED 2007, 098283).

This evaluation of the adequacy of the groundwater-monitoring network around TA-54 is being conducted to support ongoing investigations and pending corrective measures implemented under the Compliance Order on Consent and to support ongoing operations at TA-54 currently under Resource Conservation and Recovery Act (RCRA) interim status. The draft RCRA Part B operating permit is expected to be issued late in 2007, and the groundwater-monitoring well network will be a key aspect of Los Alamos National Laboratory's (LANL's, or the Laboratory's) demonstration of compliance with the anticipated permit requirements.

The corrective measures evaluations (CMEs) for solid waste management units (SWMUs) at Material Disposal Areas (MDAs) H, L, and G benefit from a demonstration of adequate knowledge of the groundwater environment beneath the sites. This evaluation and the associated recommendations and actions are intended to provide the basis for making that demonstration. The network recommendations that derive from this evaluation are intended to capture the monitoring requirements to support selection and implementation of the corrective measures and monitoring for compliance with anticipated permit requirements. Additional monitoring needs, including vadose-zone monitoring, will be presented as part of the CME reports and will also be a component of the integrated monitoring network that will incorporate anticipated permit requirements.

The group of intermediate and regional groundwater-monitoring wells evaluated in this report was predominantly installed during implementation of the "Hydrogeologic Workplan" (LANL 1998, 059599). Although the Hydrogeologic Workplan wells were installed primarily as characterization wells, the Laboratory had a "next-phase" objective to evaluate the utility of each well in the context of area-specific objectives, such as MDA remedy selection and implementation of regulatory monitoring requirements. This evaluation is intended to accomplish that goal.

The approach used to evaluate the monitoring network involves examination of well and network performance in three main categories—physical, hydrologic, and geochemical—and these categories are considered in the context of the monitoring objectives and conceptual models of contaminant pathways as they relate to groundwater systems. The physical and hydrologic criteria include the effectiveness of sampling systems to provide representative groundwater data; well construction; isolation of sampling zones; and a review of factors such as well locations, screen positions, and screen lengths evaluated in the context of the conceptual model and monitoring objectives. Geochemical criteria include an assessment of whether conditions are present in the aquifer resulting from drilling that prevent sample data from meeting monitoring objectives. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to NMED in accordance with U.S. Department of Energy policy.

2.0 CONCEPTUAL MODEL FOR MDAs H, L, AND G AT TA-54

This section is an overview of the Laboratory's current conceptual model for the fate and transport of contaminants in the subsurface from MDAs H, L, and G at TA-54. The conceptual model is based on a large amount of field data and analyses that have been collected and performed over more than two decades. These results, combined with the basic tenets of chemical transport through porous and fractured rock, are then used as the basis for a description of how contaminants, including volatile organic compounds (VOCs), and tritium, are likely to move through the subsurface at TA-54. MDAs H, L, and G are mesa-top disposal facilities located atop Mesita del Buey at TA-54. Wastes are buried at these areas in underground pits, shafts, and/or trenches and include radioactive materials, metals, high-explosive compounds, and VOCs.

The three MDAs are located within thick, unsaturated units of the Bandelier Tuff, and present-day aqueous-phase transport is generally observed to be minimal. Because of the low observed infiltration rates, travel times for nonadsorbing aqueous-phase contaminants from the disposal units to the regional aquifer are expected to be greater than several hundred years and significantly longer for sorbing constituents (Newman 1996, 059118; Birdsell et al. 2005, 092048). However, pore-gas monitoring shows that vapor-phase transport of contaminants does occur in the upper portion of the unsaturated zone. The primary contaminants that have transported in the vapor phase at TA-54 are 1,1,1-trichloroethane (1,1,1,-TCA), trichloroethene (TCE), Freon-113, and tritium (LANL 2005, 090513; LANL 2005, 092591; LANL 2007, 096409). In terms of transport rates from these MDAs at TA-54, vapor-phase VOCs migrate the most rapidly, tritium moving as water vapor moves somewhat slower, aqueous-phase nonsorbing contaminants migrate slower still, and aqueous-phase adsorbing contaminants transport the slowest. The transport mechanisms leading to this behavior are described in the text that follows.

Stratigraphy is an important control over liquid-phase contaminant transport beneath TA-54. Numerical simulations performed for the MDA G PA (Stauffer et al. 2005, 097432) show that liquid-phase travel times to the regional aquifer are proportional to the thickness of the Bandelier Tuff beneath a given disposal area. Stratigraphic data show that the Bandelier Tuff is substantially thicker on the western side of MDA G than on the eastern side, and resultant travel times are approximately 50% greater for the western side (Stauffer et al. 2005, 097432). The Bandelier Tuff is thicker at MDAs H and L than at MDA G.

The Cerros del Rio basalt, which lies beneath the Bandelier Tuff, also exerts strong controls over travel times and direction for liquid transport. Data from a tracer test through the Cerros del Rio basalt beneath the low-head weir site in Los Alamos Canyon indicate that high rates of gravity-driven flow and liquid-phase transport can occur through the basalt in low porosity fracture networks under wet (ponded) conditions (Stauffer and Stone 2005, 090037). The model of rapid fracture flow of liquid in the Cerros del Rio basalt has been used as a conservative assumption for transport predictions at TA-54. Areas with a relatively thicker sequence of basalt and a relatively thinner sequence of overlying Bandelier Tuff are expected to have more rapid liquid-phase travel times beneath the MDAs. However, ponding on top of the basalts is not expected to occur beneath the dry mesa at TA-54, and data collected from depth beneath Mesita del Buey to date support this assumption. The Guaje Pumice Bed, which is often present atop the Cerros del Rio basalt at TA-54, has higher (but not saturated) moisture contents than overlying tuff units because its pore structure causes high suction (i.e., the pores tend to trap water). No perched intermediate groundwater was found directly beneath MDA G to 700 ft, beneath MDA L to 660 ft, or in R-22 to 883 ft (Ball et al. 2002, 071471). Also, no seeps or springs are known to occur along the mesa sides. Therefore, although unsaturated flow in the basalts may occur through fractures, flow is not expected to be saturated, and transport rates will be dictated by the limited amount of water that percolates through the mesa (Birdsell et al. 2005, 092048). Data and analyses from wet canyons such as

Los Alamos and Mortandad Canyons show that perched alluvial aquifers in the bottom of wet canyons lead to more rapid vertical transport toward the regional aquifer than from mesa sites (Birdsell et al. 2005, 092048). Therefore, some component of liquid-phase transport from MDA G may be affected by enhanced infiltration beneath Pajarito Canyon if there is a lateral component of unsaturated flow in the vadose zone that could potentially divert pore water (and contaminants) to beneath the canyon.

Stratigraphy is a less important control for vapor-phase transport. Extensive analyses of the VOC contamination beneath MDA L have shown that vapor migration of VOCs in the subsurface can be fully explained by diffusive behavior that is unaffected by preferential air flow or barometric pumping within the mesa (Stauffer et al. 2005, 090537). With low vapor concentrations occurring at the top and sides of the mesas, the steepest concentration gradients are toward the surface, which preferentially leads to vapor transport toward these external boundaries rather than downward toward the regional aquifer. In addition, rapid transport via advective vapor flow is not a likely transport mechanism within the fractured Cerros del Rio basalt because vapor-phase densities are low enough that gravity-driven downward flow in fractures does not occur. Additionally, if vapor-phase transport of VOCs were to reach the regional aquifer by diffusing through the fractured Cerros del Rio basalt, the Henry's Law partitioning would result in extremely low groundwater concentrations based on current observed vapor concentrations (LANL 2005, 092591; LANL 2007, 096409). The diffusive nature of VOC transport should result in any migration to the regional aquifer that may occur to be centered directly below a given site rather than stratigraphically controlled.

Tritium is transported in the subsurface at TA-54 through a multiphase-coupled process. Primarily, it is transported by the diffusion of water vapor. However, as tritiated water vapor diffuses away from a source area, it readily equilibrates with tritium-free pore water. The relatively rapid process of vapor-phase diffusion (in the case of tritium, the vapor is water vapor) is effectively slowed down by the presence of porewater, which acts as a reservoir that removes some tritium from the vapor. This interaction with porewater results in a lower effective water-vapor diffusion coefficient than would be observed if no liquid pore water were present. This conceptual model is based on observations of tritium in the subsurface at both MDA G and TA-53 (Vold 1996, 070155; Stauffer 2003, 080930). Data and modeling results indicate that the effective vapor-phase diffusion coefficient for tritium is 25-times lower than for the more volatile vapor-phase VOCs at TA-54, primarily because those VOCs do not partition as readily into pore water. Diffusion of significant amounts of tritium toward the regional aquifer is unlikely unless the source concentration is large. In addition, radioactive decay of tritium (half-life of 12.3 yr) decreases tritium mass as it migrates through the unsaturated zone. If some tritium does reach the water table by water-vapor diffusion, it should be centered directly below the disposal site because this is the shortest diffusive pathway, and the tritium would then significantly partition into the groundwater. The likelihood of tritium reaching that water table is greatest at MDA G where the source is greatest.

Perched intermediate groundwater is present in the Cerros del Rio basalt beneath Pajarito Canyon at well R-23i. The source of the perched water is expected to be from infiltration in the canyon because Pajarito Canyon is a large relatively wet canyon that heads in the mountains (Birdsell et al. 2005, 092048). Several contaminants are present in this well, including nitrate, uranium, sulfate, and tritium. Several regional groundwater-monitoring wells also show evidence of potential contamination, although characterization is still underway to confirm these findings. The wells and potential contaminants include R-20 (toluene), R-23 (nitrate), and R-22 (tritium). The source of these contaminants is not known at this time but could be from locations at TA-54.

2.1 MDA H

MDA H is a small classified waste disposal facility comprising nine 60-ft deep shafts. The predominant inventory at MDA H is uranium and plutonium in both metallic and oxide forms. The site also contains a limited inventory of the more mobile high explosives hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and 2,4,6-trinitrotoluene (TNT) (LANL 2001, 070158; LANL 2003, 076039; LANL 2005, 089332). Some tritium and very low concentrations of VOC have been detected beneath the shafts.

Based on the data and conceptual model described above, the likelihood for impacts to groundwater from MDA H is the lowest of the MDAs at TA-54. The site has the thickest section of Bandelier Tuff, and subsequently, travel times for liquid transport to the regional aquifer should be the longest for a given infiltration rate. Furthermore, there was no known liquid waste input to the shafts. With little potential for water to infiltrate the waste, the rate at which the inventory can move will be limited. In the absence of significant liquid phase transport, the two remaining chemical types of potential concern—tritium and VOCs—both may continue to move through vapor diffusion. However, because of the very low concentrations observed at the site, and preferential transport of vapors toward the surface, the expected rate of downward movement is quite low.

2.2 MDA L

MDA L was a nonradioactive liquid-waste disposal facility that has a large inventory of VOCs buried in 34 shafts to depths of 60 ft. Additionally, a pit and three impoundments were used to dispose of batch-treated salt solutions, lithium hydride, and metal-contaminated waste. Data from core holes and vadose-zone monitoring in the subsurface beneath MDA L do not show signs of increased infiltration of water or high residual pore water from previous disposals. The Bandelier Tuff is relatively thick across the site; thus, vadose zone travel for liquidborne species is expected to be minimal. VOCs have been detected in pore gas at depths greater than 300 ft. Tritium has also been measured in the subsurface beneath MDA L, while detections of metals below the impoundments are limited to a few meters depth (LANL 2005, 092591; LANL 2007, 096409).

VOC migration beneath MDA L is of concern because of the large inventory and historic liquid disposal practices. An unknown mass of VOCs is currently slowly leaking, resulting in a VOC plume that behaves diffusively and can be well fit by numerical modeling (Stauffer et al. 2005, 090537). The mass of VOC contamination by volume is primarily composed of 1,1,1 TCA (70%), TCE (12%), and Freon-113 (11%). A 2006 pilot study of soil-vapor extraction showed that this technology was effective in removing VOCs from the vadose zone (LANL 2006, 094152). Simulations of catastrophic drum failure suggest that VOCs could reach the regional aquifer in less than 100 yr, albeit at low concentrations due to the diffusive dilution of the plume as it migrates through the large volume of the subsurface. The diffusive footprint at the regional water table from such an event is predicted to be centered on the source regions at the surface. Additionally, diffusion is not preferentially downward and would tend to spread the vapor constituents laterally as well as vertically. VOCs transported by vapor diffusion at concentrations at or less than 10 ppmv in the vapor phase would result in very low water concentrations at the top of the regional aquifer because VOCs preferentially fractionate into the vapor phase. The migration of tritium toward the regional aquifer is expected to be slow.

2.3 MDA G

MDA G is the largest of the MDAs at TA-54. It contains low-level radioactive waste and hazardous waste. It consists of 38 large pits and 4 trenches that were filled with Laboratory waste beginning in the 1950s, with low-level radioactive waste emplacement continuing into the present (Hollis et al. 1997, 063131; LANL 2005, 090513). Additionally, there are dozens of shafts at the site, some of which received large inventories of tritium, and high-activity tritium waste accounts for more than 90% of the total radionuclide inventory projected for the facility. Other radionuclides present in large quantities include isotopes of americium, plutonium, and uranium.

Currently, the only significant subsurface transport at MDA G has been of VOCs and tritium, both of which travel in the vapor phase. The VOC inventory at MDA G is much lower than at MDA L, and the maximum VOC concentrations in the subsurface are also approximately an order of magnitude lower than at MDA L. Transport of VOCs at MDA G should be quite similar to that at MDA L. With a thinner vadose zone to diffuse through, the VOC could potentially reach the regional aquifer more quickly than simulations at MDA L predict. However, concentrations would be lower because of the lower source-term concentrations. The footprint at the regional aquifer would be similarly localized beneath MDA G, following the shortest diffusive pathway. Also, concentrations measured in the regional aquifer would be expected to be quite low because of minimal fractionation from the vapor phase into liquid water at the water table.

Tritium at MDA G is the primary contaminant of concern because of its relatively high mobility in the vapor phase (water vapor) as well as the large inventory (>2 million Ci) disposed of at this site. The vapor-phase transport mechanisms are expected to be the same as described at MDAs H and L, but because of the thinner vadose zone, diffusive travel time to depth could be shorter at MDA G. Also, a water vapor tritium plume will equilibrate with clean porewater that it encounters. For example, if tritium in water vapor encounters elevated saturations in the Guaje Pumice Bed at the top of the Cerros del Rio basalt, exchange with the porewater could result in lateral transport of tritiated water along that steeper topographic gradient, leading to a more complicated footprint of tritium at the water table from MDA G than at the other sites. Tritiated porewater flowing south along the gradient of the basalt topography may then encounter recharge infiltration occurring beneath Pajarito Canyon, leading to enhanced downward migration to the regional aquifer to the south of MDA G than would be expected for transport through the mesa itself.

Liquid-phase migration is the dominant transport method for nonvolatile contaminants at MDA G. It is expected to be quite slow because of very dry conditions that limit migration. However, because of thinning Bandelier Tuff units, the fastest liquid-phase travel times are expected to occur at the eastern end of MDA G, which has the greatest inventory.

3.0 MONITORING OBJECTIVES

The monitoring objectives for TA-54 are based on both the regulatory status described in Section 1.0 and the conceptual model described in Section 2.0. They are described below. The recommendations provided in Section 5.0 are made in the context of these objectives.

1. Evaluate whether the existing groundwater-monitoring well network provides an understanding of nature and extent of contamination sufficient to support remedy selection for SWMUs and anticipated permit requirements for TA-54.

This objective is focused on an evaluation of the network from the perspective of whether there is some unknown aspect of nature and extent related to the physical, geochemical, or hydrologic status of wells that is sufficient to change or affect the remedy selection for MDAs H, L, and G. This objective is based in large part on the conceptual model and the nature of known releases from each of the MDAs.

2. Establish a groundwater-monitoring network that meets the requirements for “detection monitoring” and subsequent “compliance monitoring” at permitted units at TA-54.

   The following requirements from 40 CFR 264.90-.99, Subpart F apply to permitted units or regulated units that received waste after July 26, 1982. The regulations apply throughout the active life of the units and the closure and post-closure period if the units are not “clean-closed” under RCRA. The groundwater-monitoring network and facility process must be able to detect, evaluate, and respond to releases of hazardous waste or hazardous waste constituents into the uppermost aquifer. Detection monitoring is required to establish that a release has occurred. It is assumed that because of the significant depth to groundwater beneath TA-54, vadose-zone monitoring will be a key component of the overall monitoring program in support of both CMEs and the RCRA Part B permit.

   An integrated groundwater-monitoring system must consist of a sufficient number of near-field wells and downgradient monitoring wells installed at appropriate locations and depths to obtain representative groundwater samples from the uppermost aquifer. These samples must represent both the quality of background water not affected by the regulated unit and the quality of groundwater passing beneath the regulated unit to allow for detection of contamination in the uppermost aquifer.

3. Evaluate the configuration of the monitoring network to confidently protect water-supply wells and detect contaminants that may migrate off-site.

   This objective integrates water-supply protection with the above objectives to ensure that contaminants, if present, can be detected before reaching water-supply wells or the Laboratory boundary. The objective is met using sampling data and a groundwater-transport model that traces the path of hypothetical mobile contaminants from locations where contaminants might break through to the regional groundwater system. The model is used to assess the ability of the current well network to detect at least 95% of potential contaminants from TA-54 that might migrate toward a production well or pass beneath the Laboratory boundary. The current network configuration was found to be inadequate to detect for potential offsite releases. Therefore, this evaluation includes newly proposed well locations that are discussed below.

4.0 MONITORING NETWORK ASSESSMENT

The following table summarizes the evaluation of the physical and geochemical performance of the group of wells considered for TA-54 in the context of the monitoring objectives described in Section 3.0. The physical criteria include the effectiveness of sampling systems to provide representative groundwater data, well construction, and isolation of sampling zones. Also included are reviews of factors such as screen positions and screen length evaluated in the context of the conceptual model and monitoring objectives. Geochemical criteria include the consideration of conditions within the aquifer related to drilling operations that may result in sample data that do not meet monitoring objectives.

The Well Screen Analysis Report (LANL 2007, 096330) provided geochemical criteria to evaluate water-quality data obtained from wells R-20, R-21, R-22, R-23, R-23i, and R-32 to determine if these wells are providing reliable and representative analytical results. Because certain screens in wells R-20, R-22, and R-32 are not providing reliable and representative data, they will be abandoned pursuant to requirements made by NMED in a letter dated April 5, 2007 (NMED 2007, 095999). The Laboratory agreed to the requirements as discussed in the "Work Plan for R-Well Rehabilitation and Replacement, Rev. 1" for wells R-20, R-22, and R-32 (LANL 2007, 097419).

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
R-20 Screen 1	Meets objectives. The well screen is 76 ft beneath the top of the regional zone of saturation within a thick section of cinder deposits. Because of vertical dispersion within the cinder deposits, the screened interval serves as a useful monitoring point, especially given the distances downgradient of potential contaminant source areas at MDAs H and L and at TA-18. Dispersion may also be facilitated by downward hydraulic gradients at this location.	Conditionally meets objectives. Well rehabilitation activities were conducted at R-20 from June 29, 2006, to October 17, 2006, but only one post-rehabilitation water-quality sample is available at this time. Redox indicators are still equilibrating. These conditions may improve after installation of a sampling system that can be purged. Good prognosis for fully meeting objectives.
R-20 Screen 2	Meets objectives	Conditionally meets objectives. Well rehabilitation activities were conducted at R-20 from June 29, 2006, to October 17, 2006, but only one post-rehabilitation water-quality sample is available at this time. Redox indicators are still equilibrating, but this condition may improve after installation of a sampling system that can be purged.
R-20 Screen 3	Meets objectives	Conditionally meets objectives. Well rehabilitation activities were conducted at R-20 from June 29, 2006, to October 17, 2006, but only one post-rehabilitation water-quality sample is available at this time. Overall geochemical conditions remain unfavorable because of reducing conditions and residual bentonite.
R-21	Meets objectives	Meets objectives
R-22 Screen 1	Meets objectives	Does not meet objectives. Persistent sulfate-reducing conditions and other drilling-related geochemical conditions indicate poor prognosis for meeting objectives within useful time frame.
R-22 Screen 2	Meets objectives	Meets objectives
R-22 Screen 3	Meets objectives	Conditionally meets objectives. Still shows evidence of residual constituents leached from bentonite in the annular seal. Otherwise, geochemical conditions are favorable.

Well Name	Physical and Hydrologic Evaluation (Appendix A)	Geochemical Evaluation (Appendix B)
R-22 Screen 4	Meets objectives	Does not meet objectives. Iron-reducing conditions, residual organic drilling fluids, and other drilling-related geochemical conditions indicate poor prognosis for meeting objectives within useful time frame.
R-22 Screen 5	Meets objectives	Does not meet objectives. Iron-reducing conditions indicate poor prognosis for meeting objectives within useful time frame.
R-23	Meets objectives	Meets objectives
R-32 Screen 1	Meets objectives. Screen 1 at R-32 is 89.5 ft below the water table, within highly productive river gravel deposits intercalated within the Cerros del Rio basalt. The screened interval serves as a useful monitoring point for potential contaminant source areas at MDAs H and L and at TA-18.	Meets objectives
R-32 Screen 2	Screen 2 is used to monitor water levels.	Not applicable because water-quality samples are not collected.
R-32 Screen 3	Meets objectives	Does not meet objectives. Iron-reducing conditions, residual organic drilling fluids, and other drilling-related geochemical conditions indicate poor prognosis for meeting objectives within useful time frame.
R-23i Screen 1	Meets objectives. Screen 1 was mostly covered by slough during well construction, but this natural filter pack does not seem to adversely impact the ability of the well to develop properly and produce reliable and representative water samples.	Meets objectives conditionally. Overall geochemical trends are favorable. Limited sample data are available for well; need to confirm screen geochemical performance with ongoing sampling.
R-23i Screen 2	Meets objectives	Meets objectives conditionally. Overall geochemical trends are favorable. Limited sample data are available for well; need to confirm screen geochemical performance with additional sampling.
R-23i Piezometer	Meets objectives	Not applicable for geochemistry

Appendix C presents an assessment of the overall monitoring well network to determine the efficiency of the existing and proposed regional well locations for intercepting potential plumes before their arrival at production wells or the Laboratory boundary. The results are presented in detail in Appendix C, and the implications for recommendations are discussed in Section 5.0

5.0 RECOMMENDATIONS

The recommendations presented herein are intended to provide an integrated groundwater-monitoring network that incorporates anticipated vadose-zone monitoring, RCRA detection monitoring for the MDAs, and additional downgradient monitoring wells. The resultant network will address the different regulatory drivers described in the Section 2.0 objectives. The following recommendations also incorporate comments from NMED about the locations for additional regional and perched intermediate monitoring wells (NMED 2007, 098283).

The table below presents the recommended actions and rationale for each of the existing wells evaluated as part of the TA-54 groundwater-monitoring well network evaluation. These recommendations are based on the physical, geochemical, and hydrologic factors considered in the context of the monitoring objectives. Following this, recommendations for installation of new wells are made to address gaps in the capability of the existing wells to fulfill the objectives of the monitoring network.

Well Name	Recommended Action	Rationale
R-20 Screen 1	Replace the Westbay sampling system with a purgeable Baski sampling system Continue to monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665) and evaluate the efficacy of well rehabilitation	The Baski sampling system allows two well screens to be isolated from one another and for each screen to be individually purged before sampling. This will allow groundwater to be drawn into the well screen from the formation away from any near-field geochemical conditions attributable to residual drilling fluids. With the Baski system, screen 1 is expected to be fully capable of producing water that is sufficiently representative of groundwater conditions to meet monitoring network objectives. The trends toward representative water quality are favorable and can be improved with the installation of a purgeable sampling system. This is consistent with NMED direction to install a purgeable sampling system for screens 1 and 2.
R-20 Screen 2	Replace the Westbay sampling system with a purgeable Baski sampling system Continue to monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665) and evaluate the efficacy of well rehabilitation	The Baski sampling system allows two well screens to be isolated from one another and for each screen to be individually purged before sampling. This will allow groundwater to be drawn into the well screen from the formation away from any near-field geochemical conditions attributable to residual drilling fluids. With the Baski system, screen 2 is expected to be fully capable of producing water that is sufficiently representative of groundwater conditions to meet monitoring network objectives. The trends toward representative water quality are favorable and can be improved with the installation of a purgeable sampling system. This is consistent with NMED's direction to install a purgeable sampling system for screens 1 and 2.

Well Name	Recommended Action	Rationale
R-20 Screen 3	Abandon screen	The overall geochemical conditions in this screen are unfavorable. The Baski sampling system does not allow for sampling across more than two screens, so this screen is being abandoned. This is consistent with NMED's direction to abandon screen 3.
R-21	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
R-22 Screen 1	Abandon screen	The overall geochemical conditions in this screen are unfavorable. The Baski sampling system does not allow for sampling across more than two screens, so this screen is being abandoned. This is consistent with NMED's direction to abandon screen 1.
R-22 Screen 2	Replace the Westbay sampling system with a purgeable Baski sampling system Continue to monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665) and evaluate the efficacy of well rehabilitation	The screen meets objectives for providing representative water-quality samples. The Baski sampling system installed for screens 2 and 3 will provide isolation between screens and allow each screen to be individually purged before sampling. This will allow groundwater to be drawn into the well screen from the formation away from any near-field geochemical conditions attributable to residual drilling fluids. With the Baski system, screen 2 is expected to be fully capable of producing water that is sufficiently representative of groundwater conditions to meet monitoring network objectives. This is consistent with NMED's recommendation to monitor screens 2 and 3 and abandon screens 1, 4, and 5.
R-22 Screen 3	Replace the Westbay sampling system with a purgeable Baski sampling system Continue to monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665) and evaluate the efficacy of well rehabilitation	The screen does not meet objectives for providing representative water-quality samples. The Baski sampling system installed for screens 2 and 3 will provide isolation between screens and allow each screen to be individually purged before sampling. This is consistent with NMED's recommendation to monitor screens 2 and 3 and abandon screens 1, 4, and 5.
R-22 Screen 4	Abandon screen	The overall geochemical conditions in this screen are unfavorable. The Baski sampling system does not allow for sampling across more than two screens, so this screen is being abandoned. This is consistent with NMED's direction to abandon screen 4.

Well Name	Recommended Action	Rationale
R-22 Screen 5	Abandon screen	The overall geochemical conditions in this screen are unfavorable. The Baski sampling system does not allow for sampling across more than two screens, so this screen is being abandoned. This is consistent with NMED's direction to abandon screen 5.
R-23	Monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
R-32 Screen 1	Replace the Westbay sampling system with a single-screen submersible pump sampling system Continue to monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665) and evaluate the efficacy of well rehabilitation	Screen 1 meets objectives for providing representative water-quality samples. Screen 2 is used only for water-level data, and screen 3 does not provide representative water-quality data and does not show favorable trends towards improvement. Therefore, screen 1 will be maintained as the only monitored screen in R-32. This is consistent with NMED's direction to convert R-32 to a single screen well.
R-32 Screen 2	Abandon screen	Screen 2 is used only for water-level data and will be abandoned as part of the conversion of R-32 to a single-screen well as described above.
R-32 Screen 3	Abandon screen	Screen 3 will be abandoned as part of the conversion of R-32 to a single-screen well as described above.
R-23i Screen 1	Continue to monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
R-23i Screen 2	Continue to monitor in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Well meets monitoring network objectives.
R-23i piezometer	Continue to collect water level data in accordance with the "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2007, 096665)	Piezometer meets monitoring network objectives.

The configuration of wells in the existing network that meet the physical and geochemical criteria was considered insufficient to meet the monitoring objectives described in Section 3.0. The following discussion and table contain recommendations to augment the existing network to meet monitoring objectives.

Although the existing wells generally provide for adequate detection monitoring for the production wells, an additional well (R-40) is proposed to detect potential contaminants that might travel toward PM-2 from MDA H (Figure 5.0-1). Two additional wells (R-39 and R-41) are proposed to provide detection monitoring in the uppermost aquifer downgradient from MDA G. These new wells will enhance the ability of the groundwater-monitoring well network to detect contaminant migration and will work in conjunction with the anticipated vadose-zone monitoring to allow for the earliest possible detection.

The general direction of groundwater flow beneath MDAs H and L potentially has a northeasterly component toward the Laboratory boundary. Modeling indicates that there is currently insufficient monitoring coverage between MDAs H and L and the Laboratory boundary. Therefore, this network evaluation proposes installation of two additional monitoring wells. Each of these wells would be placed between the facility (R-37 downgradient of MDA H and R-38 downgradient of MDA L) and the Laboratory property boundary in the most likely direction of groundwater flow and contaminant transport.

The network analysis in this report does not evaluate the need for perched intermediate monitoring wells. However, contaminants are present in perched intermediate monitoring well R-23i, and the source is uncertain. Therefore, two new perched intermediate monitoring wells are proposed to investigate the potential source(s) of contamination.

Well Name	Recommended Action	Rationale
R-37	Install new single-screen regional groundwater-monitoring well downgradient of MDA H. A conceptual location for this well is shown in Figure 5.0-1. A specific location will be presented in a well-specific work plan.	This well is proposed to monitor for potential contaminants from MDA H. The existing regional groundwater-monitoring network is not sufficient to detect off-site migration from MDA H. Placement of this well will increase the monitoring network detection efficiency to greater than 95% with respect to potential off-site transport from MDA H. The water-level and geochemical data from this well will be used to refine the conceptual model for regional groundwater flow paths and hydrostratigraphy in this area. Along with R-40, this will be the one of the first new regional wells installed at TA-54 because it will help to constrain understanding of the water table for the area and will better define the lateral transition from fanglomerate to basalt at the water table for the west end of TA-54. The proposed locations of other new wells, described below are considered provisional and may be adjusted as necessary and in consultation with NMED if new data from R-37 and R-40 results in significant changes to the hydrogeologic conceptual model.

Well Name	Recommended Action	Rationale
R-38	Install new single-screen regional groundwater-monitoring well downgradient of MDA L outside the area of the vadose-zone vapor plume. A conceptual location for this well is shown in Figure 5.0-1. A specific location will be presented in a well-specific work plan.	The existing regional groundwater-monitoring network is not sufficient to detect off-site migration from MDA L. Placement of this well will increase the monitoring-network detection efficiency to greater than 95% with respect to potential off-site releases from MDA L. The location of R-38 may be refined after geology and water-level data from R-37 and R-40 become available.
R-39	Install new single-screen regional groundwater-monitoring well adjacent to MDA G. A conceptual location for this well is shown in Figure 5.0-1. A specific location will be presented in a well-specific work plan.	Installation of a new well adjacent to the MDA G aggregate will serve as a detection monitoring well for potential releases from the facility. This well will serve as part of the overall network (including vadose-zone monitoring) to ensure that adequate monitoring is in place for the MDA G CME and for the RCRA permit.
R-40	Install a new single-screen regional groundwater-monitoring well between MDA H and PM-2. A conceptual location for this well is shown in Figure 5.0-1. A specific location will be presented in the well-specific work plan.	Installation of a new well south-southeast of MDA H will serve as a sentry well for potential contaminants that may travel toward supply well PM-2. This will be the first new regional well installed at TA-54 because it will help to constrain understanding of the water table for the area and will better define the lateral transition from fanglomerate to basalt at the water table for the west end of TA-54. The proposed locations of other new wells are considered provisional and may be adjusted as necessary and in consultation with NMED if new data from R-40 and R-37 result in significant changes to the hydrogeologic conceptual model.
R-41	Install a new single-screen regional groundwater-monitoring well adjacent to MDA G. A conceptual location for this well is shown in Figure 5.0-1. A specific location will be presented in a well-specific work plan.	Installation of a new well adjacent to the MDA G aggregate will serve as a detection monitoring well for potential releases from the facility. This well will serve as part of the overall network (including vadose-zone monitoring) to ensure that adequate monitoring is in place for the MDA G CME and for the RCRA permit. The location of R-41 may be refined after water-level data from R-37 and R-38 become available.

Well Name	Recommended Action	Rationale
PCI-1	Install a new single-screen perched intermediate well on LANL property in Pajarito Canyon A conceptual location for this well is shown in Figure 5.0-1. A specific location will be presented in a well-specific work plan.	This well is proposed to monitor for potential sources of contamination from MDA G. It addresses the conceptual model element that describes potential south or southwestward vadose zone or perched intermediate flow paths driven by dipping surfaces on and within the Cerros del Rio basalts beneath MDA G. Potential contaminant transport within the vadose zone to the south of MDA G may be enhanced by infiltration beneath Pajarito Canyon. PCI-1 will be the first of two new perched intermediate wells drilled in Pajarito Canyon. If PCI-1 does not encounter perched groundwater, the need to install PCI-2 will be reevaluated in consultation with NMED.
PCI-2	Install a new single-screen perched intermediate well on LANL property in Pajarito Canyon. A conceptual location for this well is shown in Figure 5.0-1. A specific location will be presented in a well-specific work plan.	The location of this well will provide baseline information about contaminants in perched intermediate groundwater upgradient of MDA G, thus providing information to distinguish between potential sources at TA-18 and MDA G. The need for and location of PCI-2 will be reevaluated in consultation with NMED based on the presence or absence of perched intermediate groundwater and contaminants at PCI-1.

Implementation of the recommendations in the table above will result in an integrated groundwater-monitoring network that fulfills detection monitoring requirements for the RCRA permit as well as the objectives for the CMEs for MDAs H, L, and G. The monitoring frequency and analyte suites will be specified in annual updates to the Interim Facility-wide Groundwater Monitoring Plan. This network is expected to be supplemented with vadose-zone monitoring, as appropriate.

6.0 SCHEDULE

Upon NMED’s approval of the recommendations contained in this report, the Laboratory will submit work plan(s) for implementation of the actions. Each work plan will contain specifics for each of the actions and propose a schedule for implementation.

7.0 REFERENCES

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

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

Ball, T., M. Everett, P. Longmire, D. Vaniman, W. Stone, D. Larssen, K. Greene, N. Clayton, and S. McLin, February 2002. “Characterization Well R-22 Completion Report,” Los Alamos National Laboratory report LA-13893-MS, Los Alamos, New Mexico. (Ball et al. 2002, 071471)

Birdsell, K.H., B.D. Newman, D.E. Broxton, and B.A. Robinson, 2005. “Conceptual Models of Vadose Zone Flow and Transport beneath the Pajarito Plateau, Los Alamos, New Mexico,” *Vadose Zone Journal,* Vol. 4, pp. 620-636. (Birdsell et al. 2005, 092048)

Hollis, D., E. Vold, R. Shuman, K.H. Birdsell, K. Bower, W.R. Hansen, D. Krier, P.A. Longmire, B. Newman, D.B. Rogers, and E.P. Springer, March 27, 1997. “Performance Assessment and Composite Analysis for Los Alamos National Laboratory Material Disposal Area G,” Rev. 2.1, Los Alamos National Laboratory document LA-UR-97-85, Los Alamos, New Mexico. (Hollis et al. 1997, 063131)

LANL (Los Alamos National Laboratory), May 22, 1998. “Hydrogeologic Workplan,” Los Alamos National Laboratory document LA-UR-01-6511, Los Alamos, New Mexico. (LANL 1998, 059599)

LANL (Los Alamos National Laboratory), May 2001. “RFI Report for Material Disposal Area H at Technical Area 54,” Los Alamos National Laboratory document LA-UR-01-1208, Los Alamos, New Mexico. (LANL 2001, 070158)

LANL (Los Alamos National Laboratory), May 2003. “Corrective Measures Study Report for Material Disposal Area H, Solid Waste Management Unit 54-004, at Technical Area 54,” Los Alamos National Laboratory document LA-UR-03-3354, Los Alamos, New Mexico. (LANL 2003, 076039)

LANL (Los Alamos National Laboratory), June 2005. “Corrective Measures Study Report for Material Disposal Area H, Solid Waste Management Unit 54-004, at Technical Area 54, Revision 1,” Los Alamos National Laboratory document LA-UR-05-0203, Los Alamos, New Mexico. (LANL 2005, 089332)

LANL (Los Alamos National Laboratory), September 2005. “Investigation Report for Material Disposal Area G, Consolidated Unit 54-013(b)-99, at Technical Area 54,” Los Alamos National Laboratory document LA-UR-05-6398, Los Alamos, New Mexico. (LANL 2005, 090513)

LANL (Los Alamos National Laboratory), September 2005. “Investigation Report for Material Disposal Area L, Solid Waste Management Unit 54-006, at Technical Area 54,” Los Alamos National Laboratory document LA-UR-05-5777, Los Alamos, New Mexico. (LANL 2005, 092591)

LANL (Los Alamos National Laboratory), November 2006. “Summary Report: 2006 In Situ Soil Vapor Extraction Pilot Study at Material Disposal Area L, Technical Area 54, Los Alamos National Laboratory,” Los Alamos National Laboratory document LA-UR-06-7900, Los Alamos, New Mexico. (LANL 2006, 094152)

LANL (Los Alamos National Laboratory), May 2007. “Addendum to the Investigation Report for Material Disposal Area L, Solid Waste Management Unit 54-006, at Technical Area 54,” Los Alamos National Laboratory document LA-UR-07-3214, Los Alamos, New Mexico. (LANL 2007, 096409)

LANL (Los Alamos National Laboratory), May 2007. “Well Screen Analysis Report, Revision 2,” Los Alamos National Laboratory document LA-UR-07-2852, Los Alamos, New Mexico. (LANL 2007, 096330)

LANL (Los Alamos National Laboratory), May 2007. “2007 Interim Facility-Wide Groundwater Monitoring Plan,” Los Alamos National Laboratory document LA-UR-07-3271, Los Alamos, New Mexico. (LANL 2007, 096665)

LANL (Los Alamos National Laboratory), June 2007. “Work Plan for R-Well Rehabilitation and Replacement, Revision 1,” Los Alamos National Laboratory document LA-UR-07-3370, Los Alamos, New Mexico. (LANL 2007, 097419)

Newman, B.D., December 9, 1996. “Vadose Zone Water Movement at Area G, Los Alamos National Laboratory, TA-54: Interpretations Based on Chloride and Stable Isotope Profiles,” Los Alamos National Laboratory document LA-UR-96-4682, Environmental Science Group, EES-15, Los Alamos, New Mexico. (Newman 1996, 059118)

NMED (New Mexico Environment Department), April 5, 2007. “Well Evaluations for Intermediate and Regional Wells,” New Mexico Environment Department letter to D. Gregory (DOE LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED HWB), Santa Fe, New Mexico. (NMED 2007, 095999)

NMED (New Mexico Environment Department), August 31, 2007. “Approval with Direction, Technical Area 54 Well Evaluation and Network Recommendations,” New Mexico Environment Department letter to D. Gregory (DOE LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED HWB), Santa Fe, New Mexico. (NMED 2007, 098283)

Stauffer, P.H., October 2003. “Summary of TA53 Borehole Tritium Analysis,” Los Alamos National Laboratory document LA-UR-07-5084, Los Alamos, New Mexico. (Stauffer 2003, 080930)

Stauffer, P.H., K.H. Birdsell, M.S. Witkowski, and J.K. Hopkins, 2005. “Vadose Zone Transport of 1,1,1-Trichloroethane: Conceptual Model Validation through Numerical Simulation,” *Vadose Zone Journal,* Vol. 4, pp. 760-773. (Stauffer et al. 2005, 090537)

Stauffer, P.H., and W.J. Stone, 2005. “Surface Water–Groundwater Connection at the Los Alamos Canyon Weir Site: Part 2. Modeling of Tracer Test Results,” *Vadose Zone Journal,* Vol. 4, pp. 718–728. (Stauffer and Stone 2005, 090037)

Stauffer, P.H., H.S. Viswanathan, B.A. Robinson, C.W. Gable, G.L. Cole, D.E. Broxton, E.P. Springer, and T.G. Schofield, 2005. “Groundwater Pathway Model for the Los Alamos National Laboratory Technical Area 54, Material Disposal Area G,” Los Alamos National Laboratory document LA-UR-05-7393, Los Alamos, New Mexico. (Stauffer et al. 2005, 097432)

Vold, E., July 16, 1996. “Errata #1 to 'LA-UR-96-973, An Analysis of Vapor Phase Transport in the Unsaturated Zone with Application to a Mesa Top Disposal Facility, Part I, draft 1, March 14, 1996' and to 'LA-UR-96-1848, Draft I - 052296, Determination of an In-Situ Vadose Zone Vapor Phase Diffusion Coefficient at a Mesa Top Waste Disposal Facility',” Los Alamos National Laboratory document, Los Alamos, New Mexico. (Vold 1996, 070155)

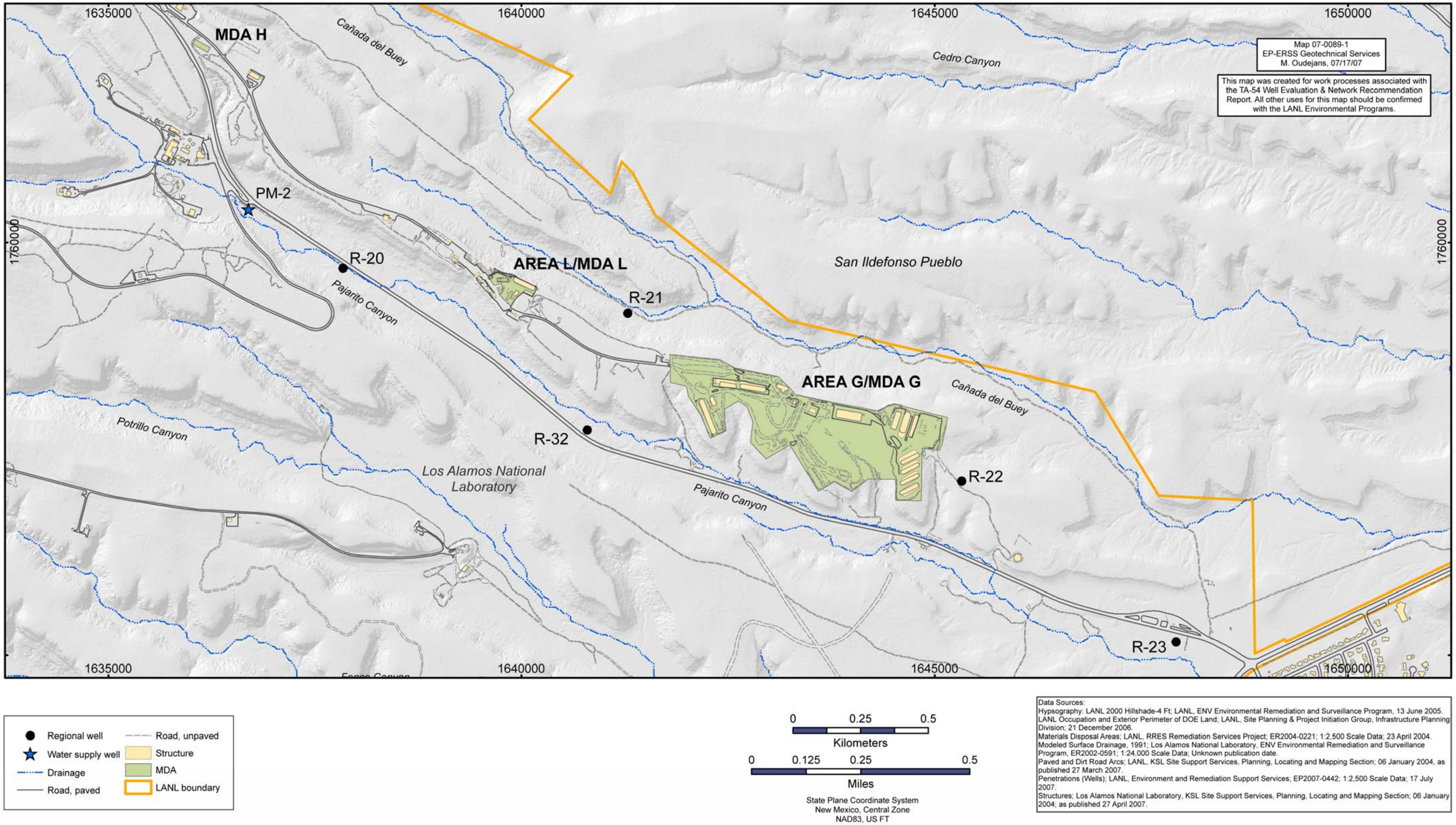


Figure 1.0-1 Location of TA-54: MDAs H, L, and G including the existing water-supply wells and regional wells considered in this evaluation

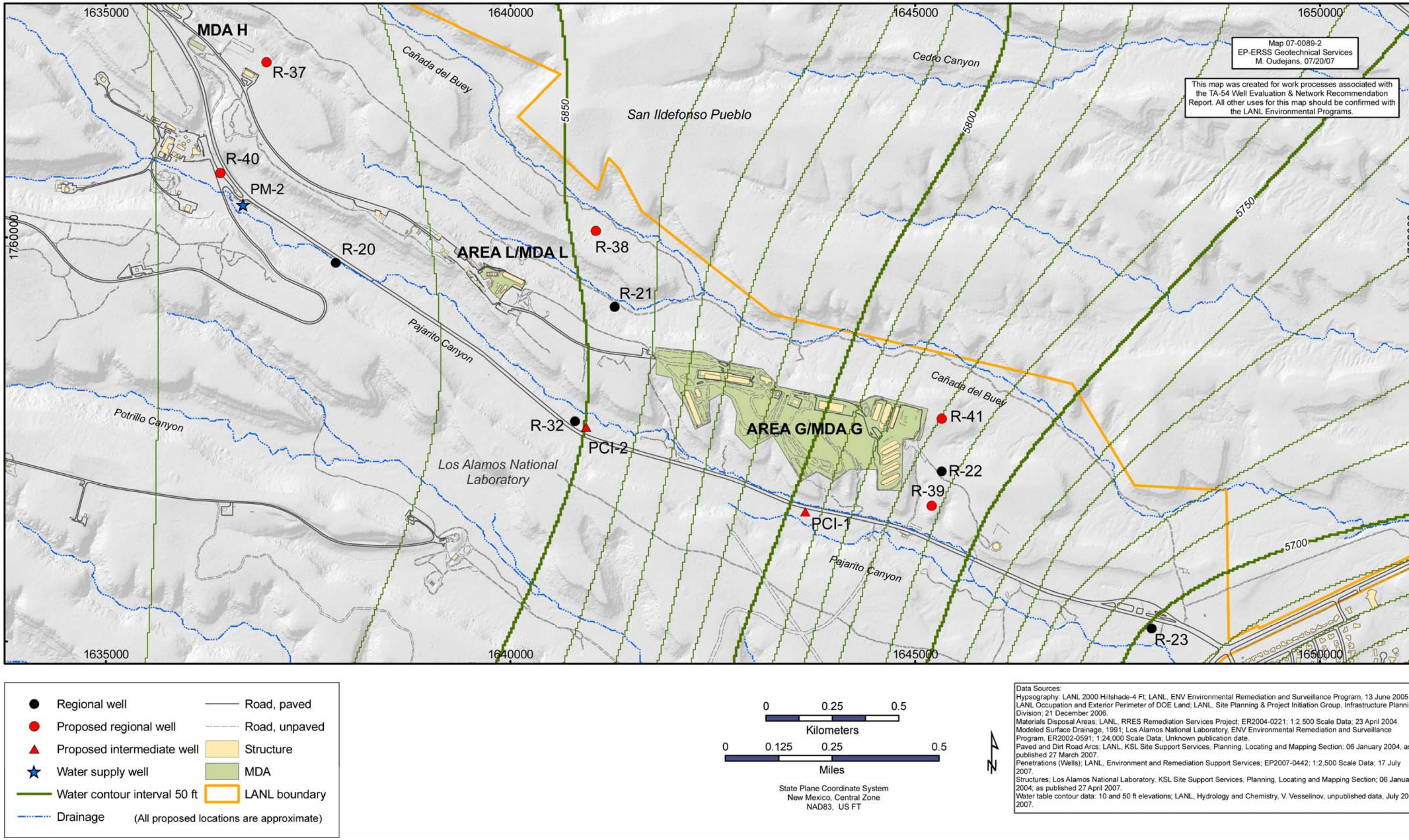


Figure 5.0-1 Location of TA-54: MDAs H, L, and G including the existing water-supply wells and regional wells; proposed locations for new wells and water-table contours

Appendix A

Physical and Hydrologic Attributes of Network Wells

The acronyms and abbreviations defined below are used throughout this appendix.

AE	acid enhancer
AIT	Array Induction Tool
bgs	below ground surface
CMR	Combinable Magnetic Resonance
CNT	compensated neutron tool
DTW	depth to water
ECS	elemental capture spectroscopy
ELAN	Elemental Log Analysis
FMI	Formation MicroImager
HNGS	hostile-environment natural gamma-ray sonde
I.O.	inside diameter
LANL	Los Alamos National Laboratory
MDA	material disposal area
MGA	modified granular acid
MP	Multiple Port
n/a	not applicable
NGS	natural gamma spectrometry
NTU	nephelometric turbity unit
O.D.	outside diameter
PFD	phosphate-free dispersant
TA	technical area
TD	total depth
TLD	triple lithodensity

R-20 Well

R-20 Well		
	Description	Evaluation
Drilling Method	R-20 was drilled by mud-rotary drilling.	R-20 was drilled using conventional-circulation mud-rotary drilling in an open hole. Loss of drilling fluid circulation was a significant problem while drilling through the Cerros del Rio basalt, and no cuttings were returned to the surface between a depth of 490 and 785 ft. At 785-ft depth, 13.375-in. thin-wall casing was installed to a depth of 780 ft and sealed in place with cement and bentonite because of the persistent circulation problems. Before installation of the 11.75-in. casing, Schlumberger, Inc., collected a suite of geophysical logs in the open borehole from 0 to 785 ft. Following geophysical logging, an open borehole was advanced from 785 to 1365 ft (TD) using conventional-circulation mud-rotary drilling. When drilling was completed, Schlumberger, Inc., returned to the site and collected geophysical logs in the open borehole from 780 to 1365 ft. The combination of drilling fluid loss and use of mud-rotary drilling in the well screen intervals are significant issues for the ability of R-20 well screens to produce representative and reliable water-quality data. Drilling additives can adversely affect the ability to collect representative water samples if they are not removed from the well during development. At R-20, open borehole mud-rotary drilling exposed the borehole wall to a variety of drilling additives including QUIK-GEL, QUIK-FOAM, N-SEAL, PAC-L, EZ-MUD, LIQUI-TROL, Magma Fiber, and soda ash. Well development was particularly aggressive at R-20 to remove residual drilling fluids. Well development to remove drilling fluids consisted of wire brushing the well interior, surging to draw fine sediment from the constructed filter packs, and bailing to remove unwanted solid materials from the well. In addition, the well was pumped to remove any remaining fines from the filter pack and adjacent formation. As part of development, chemical treatments were applied to the well screens to break up borehole wall mud filter cake and to disperse particulate matter that resulted from adding drilling fluids during conventional mud-rotary drilling. Chemical treatment included surging mixtures of 2.5 gal. of AQUA-CLEAR-PFD and 950 gal. of municipal water into the three well screens. Following surging and bailing, a solution containing 270 lb of AQUA-CLEAR-MGA and 27 gal. of AQUA-CLEAR-AE mixed with 900 gal. of municipal water was pumped into the well and surged into all three screens. Following chemical treatment, the well was initially pumped by lowering a submersible pump next to each well screen without the use of packers. Packers were then positioned above and below each well screen, and additional development pumping was conducted. About 87,008 gal. of water was removed from the well during development.
General Well Characteristics	R-20 is a three-screen well constructed of 4.5-in.-I.D. and 5.0-in.-O.D.-type A304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.

R-20 Well (continued)		
	Description	Evaluation
Well Screen Construction	The pipe-based screens are constructed of 4.5-in.-I.D./5.563-in.-O.D. 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might otherwise be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screens were used at R-20 after two rod-based well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack, and formation during development may be less effective at developing the well in those areas that are not adjacent to holes in the well casing. Also, the wire wrap on the R-20 well screens contains 0.010-in. slots. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in. slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the wells.
Screen Length and Placement	Screen 1 extends from 904.6 to 912.2 ft (length of 7.6 ft). The current water level in screen 1 is about 828 ft bgs. Screen 2 extends from 1147.1 to 1154.7 ft (length of 7.6 ft). The current water level in screen 2 is about 834 ft bgs. Screen 3 extends from 1328.8 to 1336.5 ft (length of 7.7 ft). The water level in screen 3 is currently 864 ft.	R-20 well screen lengths and placements were selected with the following goals in mind: • Investigate the nature and extent of impacts to regional groundwater that resulted from LANL activities in the Pajarito Canyon watershed • Detect contaminants being drawn toward municipal supply well PM-2 from MDA L • Screen across hydrostratigraphic units that might be expected to be along contaminant flow paths • Determine the magnitude and direction of vertical pressure gradients in the vicinity of TA-54 • Monitor water levels at multiple depths to determine pressure responses to municipal well pumping in the Pajarito well field The upper part of the regional aquifer at R-20 occurs within basal basaltic lavas and layered cinder deposits at the base of the Pliocene Cerros del Rio basalt. The Cerros del Rio basalt is underlain by bedded coarse sands, gravels, and cobbles of the Puye Formation in the depth interval between 932 and 1127 ft. The Puye Formation is underlain by highly stratified Miocene volcaniclastic sands with rare intercalated gravels of the informal pumiceous unit in the interval between 1127 and 1242 ft. The pumiceous unit is underlain by well-bedded Miocene sands and gravels from 1242 to 1365 ft (TD).

R-20 Well (continued)		
	Description	Evaluation
Screen Length and Placement (continued)		Screen 1 is located within highly porous (35% to 45% total porosity) basaltic cinder deposits near the top of the regional zone of saturation and is the shallow measurement point for vertical hydraulic gradients. This location was fixed relative to a water level of 873 ft bgs inferred from field observations during drilling. The original goal was for the top of the sand pack to be placed 20 ft below the water table so the screen would be completely submerged for proper well development. However, water levels cannot be measured directly while drilling using mud-rotary methods and were inferred by driller's observations of water production. Subsequent water-level measurements in the completed well indicate the water level in screen 1 is actually 76.6 ft below the water table. Ideally, screen 1 would have been positioned closer to the regional water table for monitoring shallow contamination. Given the highly porous nature of the cinder deposits, the downward hydraulic gradient in this area and the distance to MDA L (1850 ft), screen 1 is probably adequately positioned for monitoring groundwater quality near the water table. The need for shallow monitoring at R-20 will be better understood after proposed monitoring wells are installed at MDAs L and H. These proposed wells will target the top of the regional zone of saturation, and discovery of contaminants at either of these sites could lead to a reassessment of the monitoring network. Finally, because R-20 is located approximately 2150 ft of TA-18, the combination of screen 1 and screen 2 serves as useful downgradient monitoring points for that facility and other release sites in the Pajarito Canyon watershed. Screen 2 was located at a depth approximately midway between screens 1 and 3 for vertical gradient information. Schlumberger geophysical logs were used to select an interval near the top of a zone with relatively high-effective porosity within Miocene pumiceous sedimentary deposits so that the screen could also provide an opportunity to determine if water chemistry in this area is vertically stratified. Screen 2 was placed across an interval of high-effective porosity (up to 45%) centered on a depth of 1149 ft. Screen 3 is located as deep as possible in the completed borehole for vertical gradient information. Schlumberger geophysical logs were used to select an interval that was at the higher end of the range of generally low-effective porosities (10%–20%) found in the Miocene sedimentary deposits that make up the lower part of the borehole. The vertical distribution of well screens in R-20 has proven effective for determining vertical hydraulic gradients in this area. In addition, responses during pump tests provided important information about vertical aquifer responses to pumping from municipal wells PM-2 and PM-4. Maintaining the distribution of well screens at R-20 should be considered for future planned pump tests (e.g., PM-1 and PM-3).

R-20 Well (continued)		
	Description	Evaluation
Filter Pack Materials and Placement	The filter packs and their placements are discussed for the three well screens in the column to the right.	The primary filter pack for screen 1 is made up of 20/40 sand from 895.2 to 926.5 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 893.1 to 895.2 ft and 926.5 to 930 ft, respectively. The primary filter pack extends 9.4 ft above and 14.3 ft below the well screen. These filter pack dimensions allow groundwater to be drawn from a larger volume of the basalt cinder deposits from a relatively short screen. The primary filter pack for screen 2 is made up of 20/40 sand from 1132.5 to 1165.5 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 1130.3 to 1132.5 ft and 1165.5 to 1167.6 ft, respectively. The primary filter pack extends 14.6 ft above and 10.8 ft below the well screen. The combination of this filter pack with a relatively short well screen is appropriate for monitoring for contaminants in highly stratified sedimentary deposits deep within the aquifer where contaminant flow pathways cannot be reliably predicted. The primary filter pack for screen 3 is made up of 20/40 sand from 1320.6 to 1344.5 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 1318.3 to 1320.6 ft and 1344.5 to 1346.5 ft, respectively. The primary filter pack extends 8.2 ft above and 8 ft below the well screen. The combination of this filter pack with a relatively short well screen is appropriate for monitoring contaminants in highly stratified sedimentary deposits deep within the aquifer where contaminant flow pathways cannot be reliably predicted.
Sampling System	Westbay Multiple Port sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids are critical before installation of Westbay wells because groundwater is collected in proximity to the well screen due to low-flow sampling and the inability to purge the well screen before sampling. Samples collected from Westbay wells are particularly prone to water-quality problems that develop if residual drilling fluids are present and hydraulically connected to the screen interval.

R-20 Well (continued)		
	Description	Evaluation
Other Issues That Could Affect the Performance of the Well	Redevelopment	All three screens in R-20 showed varying impacts from residual drilling fluids as documented in the Well Screen Analysis Report. Because of these impacts, the Westbay sampling system was removed from R-20, and the well was redeveloped in summer and autumn 2006. Specific capacity tests were performed on each screen by utilizing a submersible pump with single- and dual-packer systems with transducer. After the specific capacity tests, all three screens were swabbed and bailed. It was originally planned to deploy Hydropuls, a well development tool that uses compressed nitrogen emitted in short bursts, to dislodge fine-grained material from the well screen and filter pack. Because of the problems encountered during the two Hydropuls runs, its use was discontinued, and efforts concentrated more on conventional redevelopment techniques. Screens were then swabbed, bailed, and subjected to pumping without isolation by packers. A second specific capacity test was conducted on screen 3. Attempts to conduct second specific capacity tests on screens 1 and 2 failed when neither zone could sustain a minimum flow rate to conduct a test. Further bailing, injection, and isolation pumping with packers occurred in various combinations in the three screens, and flow in screens 1 and 2 was reestablished but at diminished capacity. Jetting and isolation pumping with packers were conducted in screen 3. Isolation packers were installed after redevelopment was completed. The Westbay sampling system has not been reinstalled at this time, pending final decisions about the disposition of the well.
Additives Used		**Interval 0–780 ft:** Air Municipal water—48,300 gal. QUIK-FOAM—483 gal. LIQUI-TROL—135 gal. QUIK-GEL—26,565 lb Soda ash—536 lb **Interval 780–1365 ft:** Municipal water—37,100 gal. QUIK-GEL—7000 lb LIQUI-TROL—87 gal. PAC-L—200 lb N-SEAL—100 lb Magma Fiber—620 lb EZ-MUD added for bentonite placement—Quantity not specified Fluids recovered during development—87,008 gal.

R-20 Well (continued)		
	Description	Evaluation
Annular Fill Other Than Filter and Transition Sands		QUIK-GROUT high-solids bentonite—0.375-in. unrefined chips (125 50-lb bags) Benseal—Granular (8 mesh) bentonite for seals (5.5 50-lb bags) Pelplug bentonite—0.25 in. by 0.375-in. refined elliptical pellets (354 50-lb buckets) Surface seal of Portland cement slurry (48 94-lb bags)

Location: East of TA-18 on the south side of Pajarito Rd., east of the stream channel.

Survey coordinates (brass marker in NW corner of R-20 cement pad): x: 1637835 E y: 1759695 N (NAD 83) z: 6694.3 ft asl (NGVD 29)

Drilling: Conventional mud drilling, casing advance; air rotary core w/ wireline retrival.
R-20 Start date: 08/15/02, end date: 09/06/02.
Coring start date: 10/16/02, end date: 10/19/02

Borehole R-20 drilled to 1365 ft. bgs. (T.D.).

Data collection:
- Hydrologic properties: Field hydraulic test: Constant Rate Injection Test on screen #1, screen #2, and screen #3
- Cores/cuttings submitted for geochemical and contaminant characterization: (0)
- Groundwater samples submitted for geochemical and contaminant characterization: (3)
- Geologic properties: (12) Mineralogy, petrography, and chemistry
- Borehole logs from R-20:
  - Lithologic: 0-490 ft. and 785 ft.-1365 ft.
  - Borehole Video (LANL tool): 82-785 ft. (open hole).
  - Natural gamma + Induction (LANL tool): 0-80.2 ft. (cased), 80.2 ft.-785 ft. (cased).
  - Schlumberger Logs: 0-80.2 ft. (cased), 80.2-785 ft. (open hole): Array Induction, Litho Density, Natural Gamma, Thermal/Epithermal Neutron,Caliper, Combinable Magnetic Resonance, and Elemental Capture Sonde.
  - Natural Gamma (LANL tool): 0-780 ft. (cased), 780-1365 ft. (open hole).
  - Schlumberger Logs: 0-780 ft. (cased), 780-1365 ft. (open hole): Thermal/Epithermal Neutron, Litho Density, Micro Imager, Array Induction, and Natural Gamma.

Contaminants Detected in R-20 Water Samples: none

Well construction:
- Drilling Completed: 09/06/02
- Contract Geophysics: 08/26/02; 09/06/02
- Well Constructed : 09/07/02-09/15/02
- Well Developed : 09/15/02-12/22/02
- Westbay Installed : 01/08/03-01/18/03

Casing: 4.5-in I.D. stainless steel with external couplings.

Number of Screens: 3
4.5-in I.D. pipe based, s.s. wire-wrapped with 0.010-in slots.

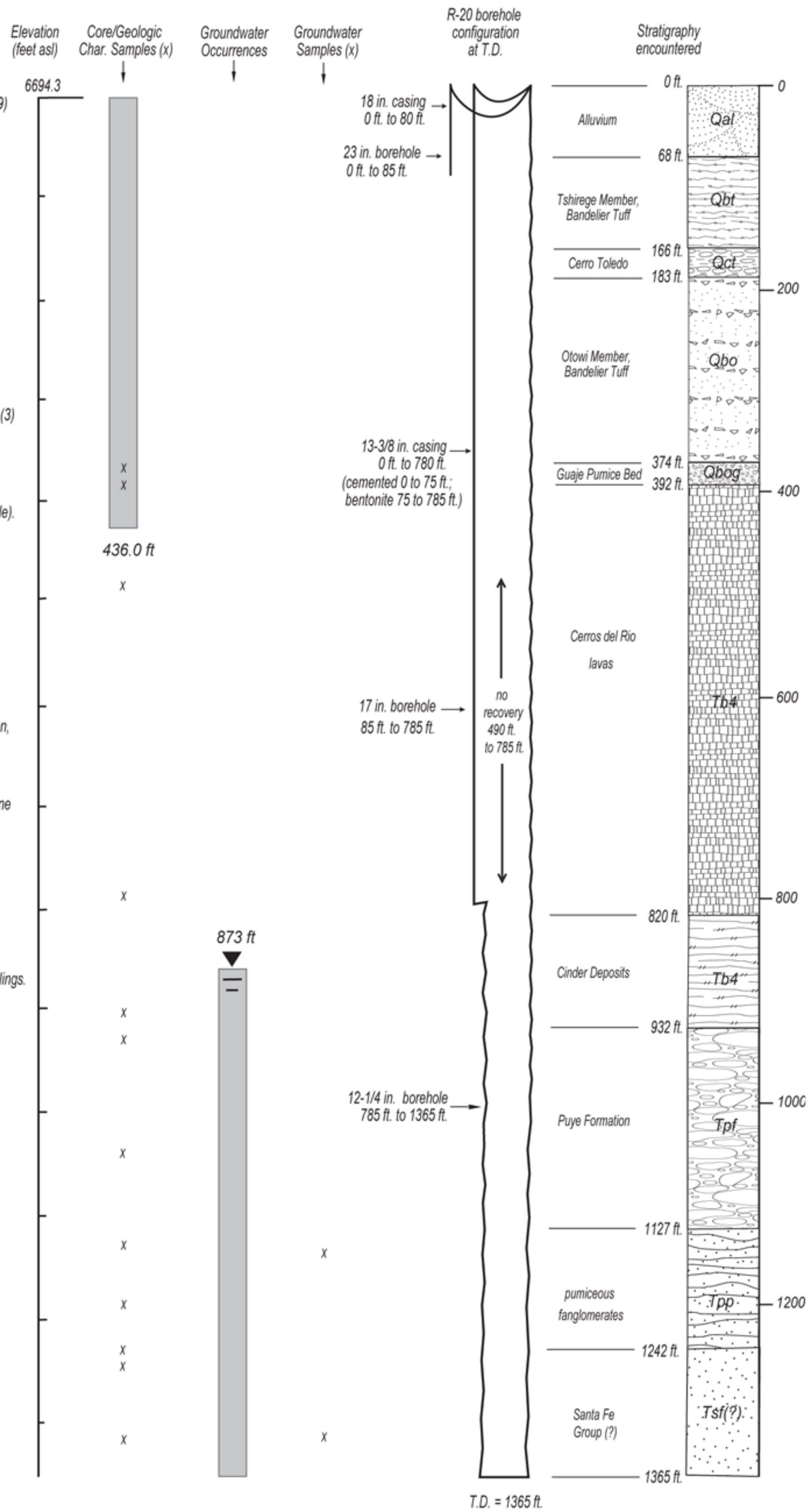
Screen (perforated pipe interval):
- Screen #1 - 904.6 - 912.2 ft. bgs.
- Screen #2 - 1147.1 - 1154.7 ft. bgs.
- Screen #3 - 1328.8 - 1336.5 ft. bgs.

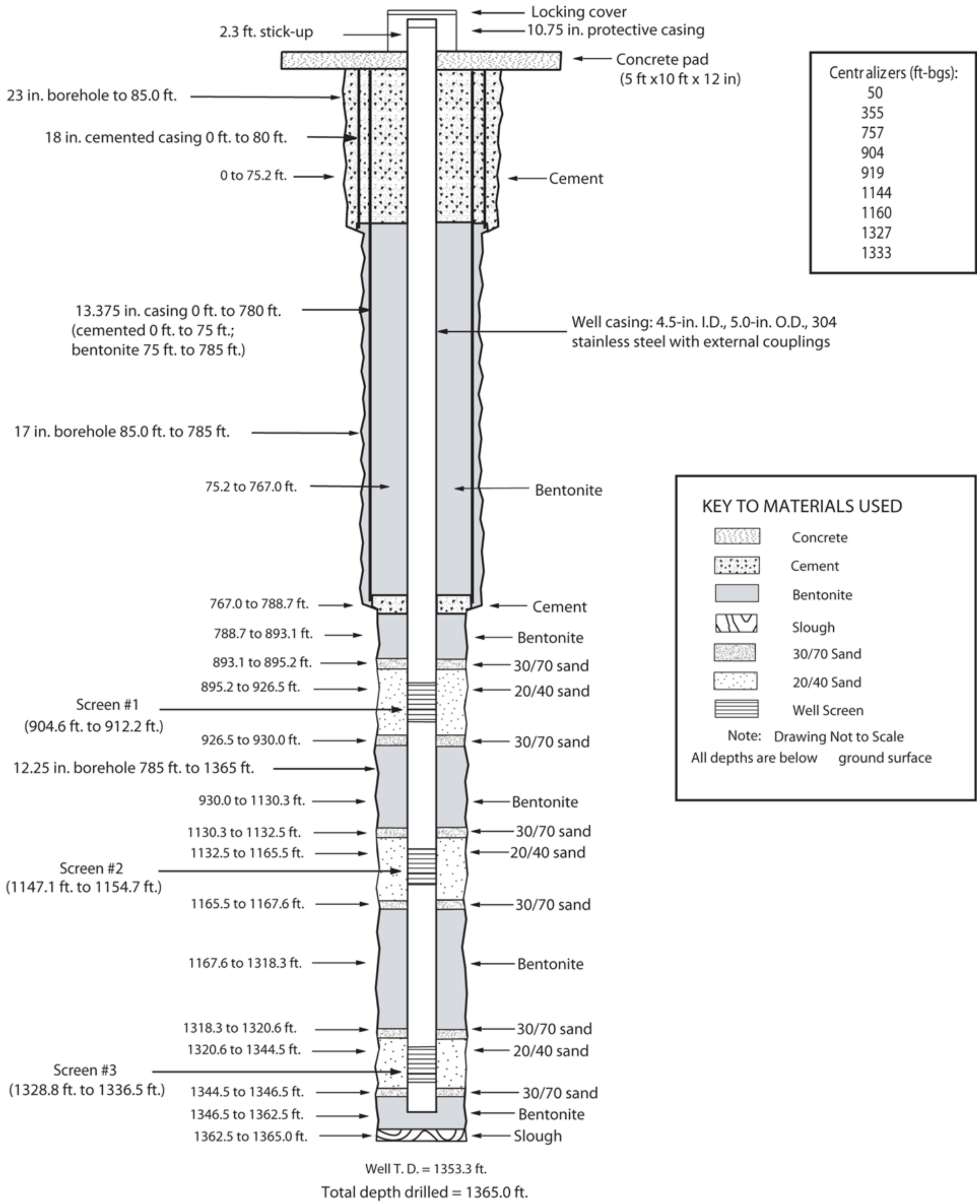
Well development consisted of wire brushing, bailing, chemical treatment, surging, and pumping.

Groundwater occurrence was determined for R-20 by recognition of first water produced while drilling, by borehole geophysics, and by borehole video. Static water levels were determined after the R-20 borehole was rested.

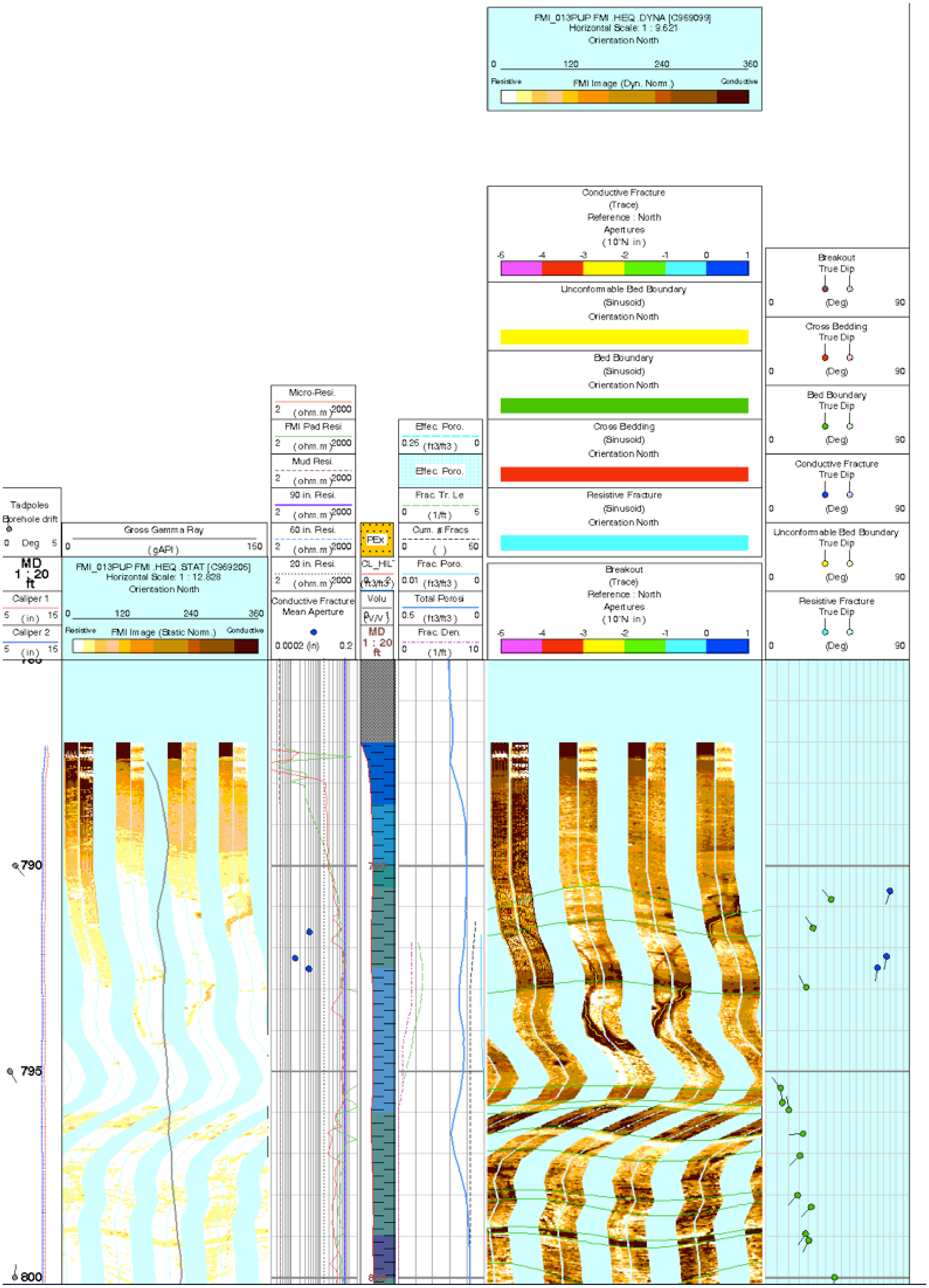
Groundwater samples collected from packed off screen intervals after well development.

Geologic contacts for R-20 were determined by examination of cuttings and interpretation of geophysical logs. Contacts may be refined by petrographic, geochemical, or mineralogic analysis of geologic samples.

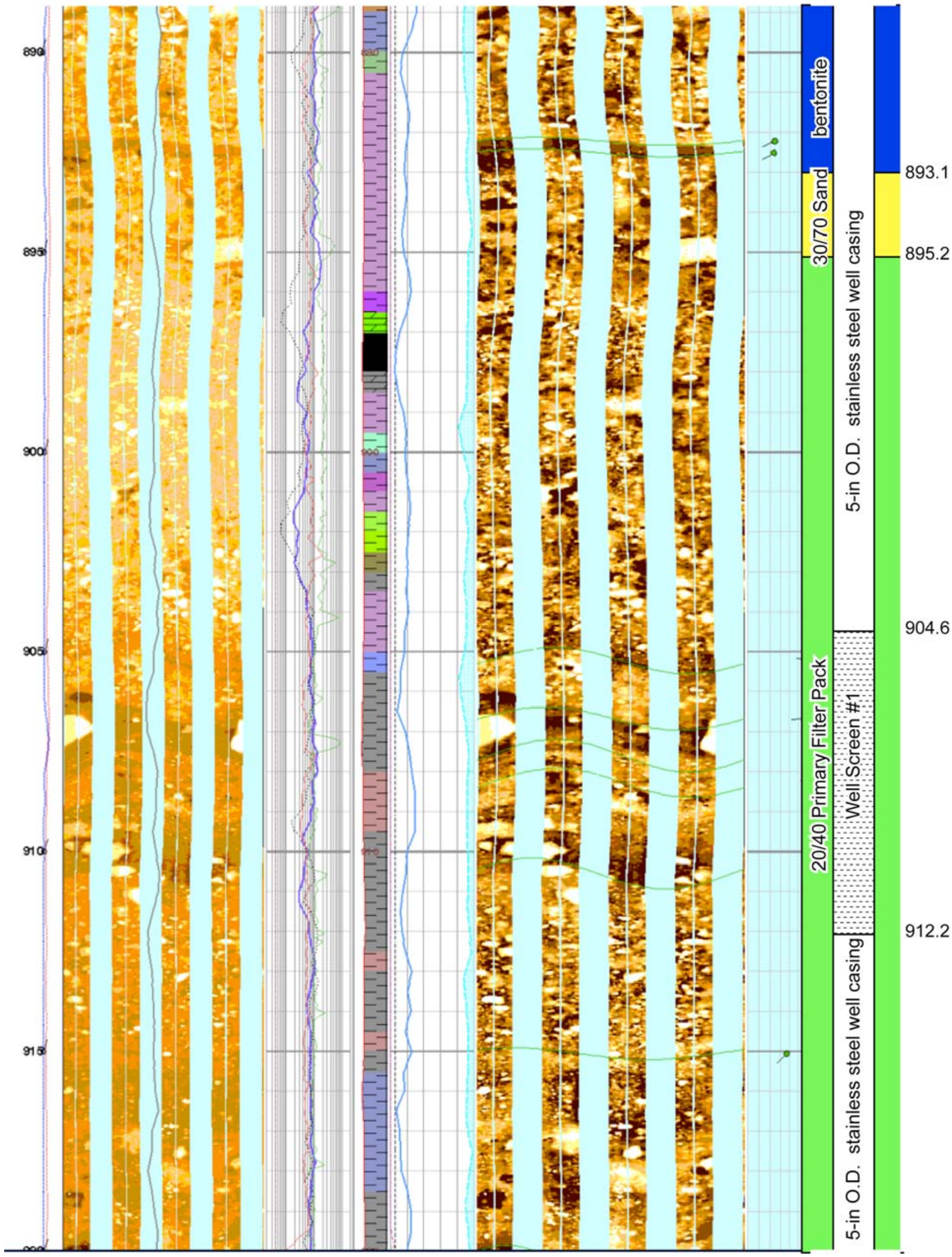




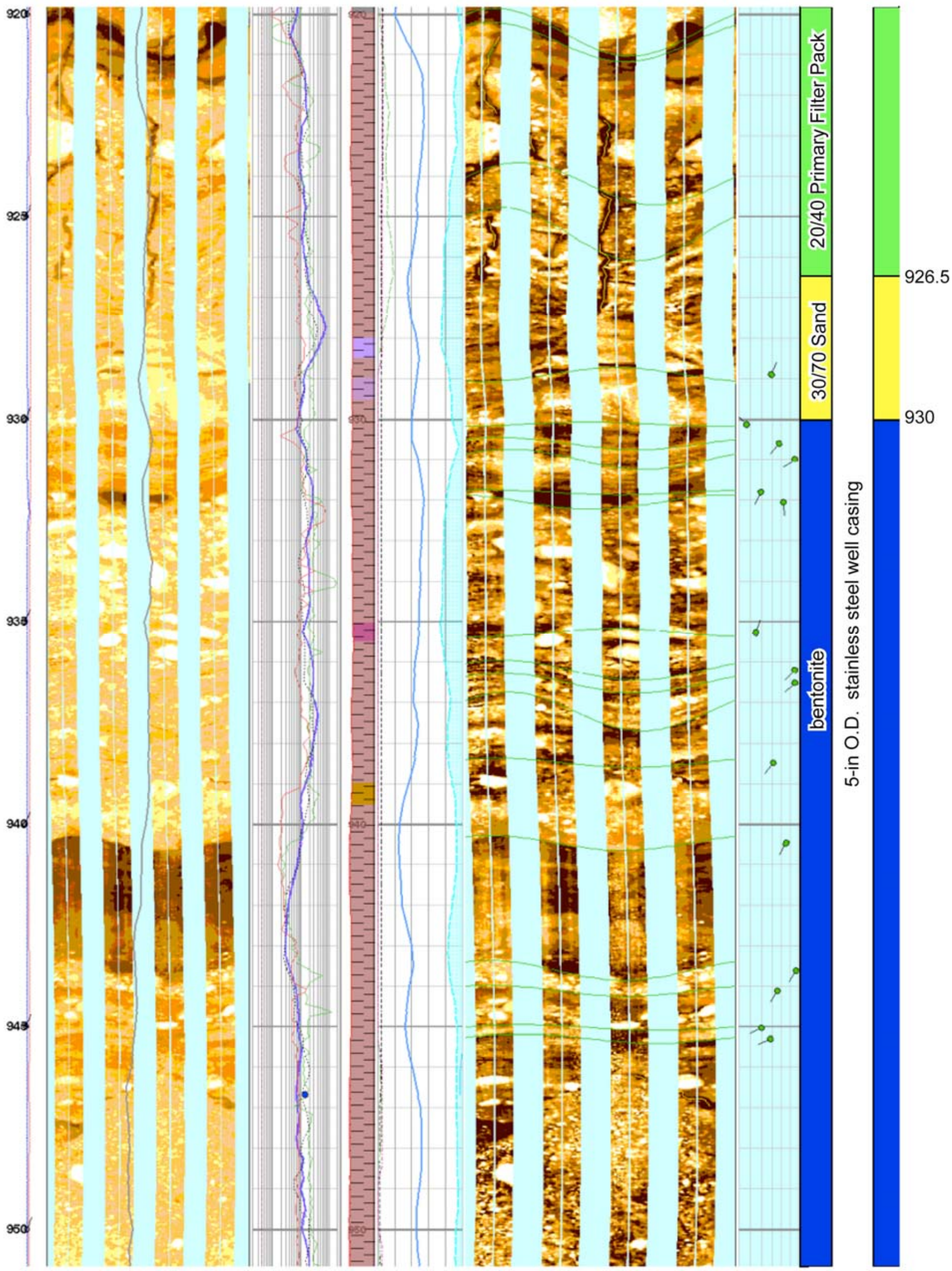
Note: 1. Each screen interval lists the footage of the pipe perforations, not the top and bottom of screen joints.
2. The interval of slough consists of sands and gravel provisionally attributed to the Santa Fe Group.
3. Westbay multiport sampling system (MP-55) casing not shown.
4. Pipe-based screen: 4.5-in. I.D., 5.563-in. O.D., 304 stainless steel with s.s. wire wrap; 0.010-in slot.
5. Well sump interval: 1336.5 to 1353.3 ft.



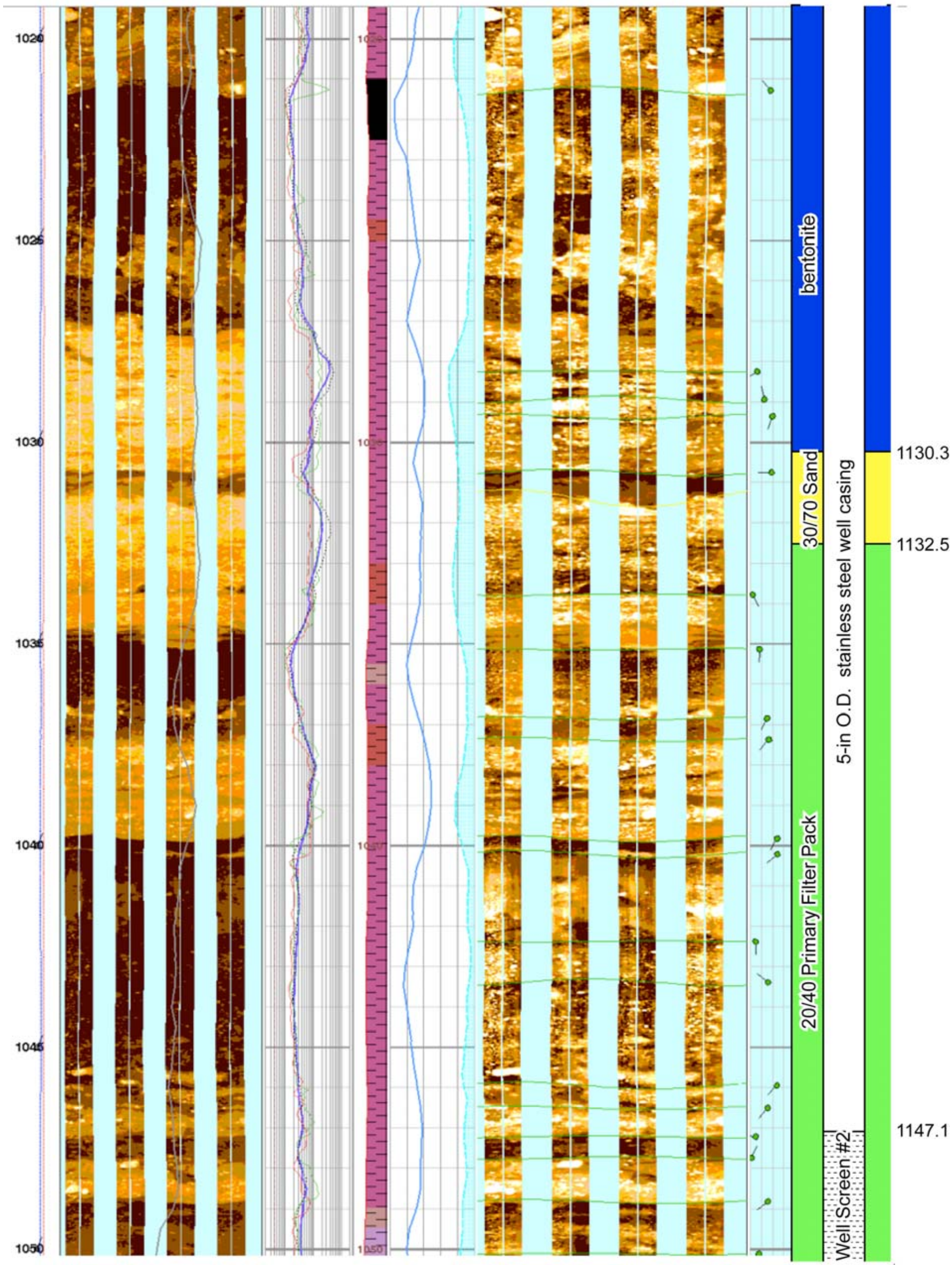
Legend for FMI images on following pages



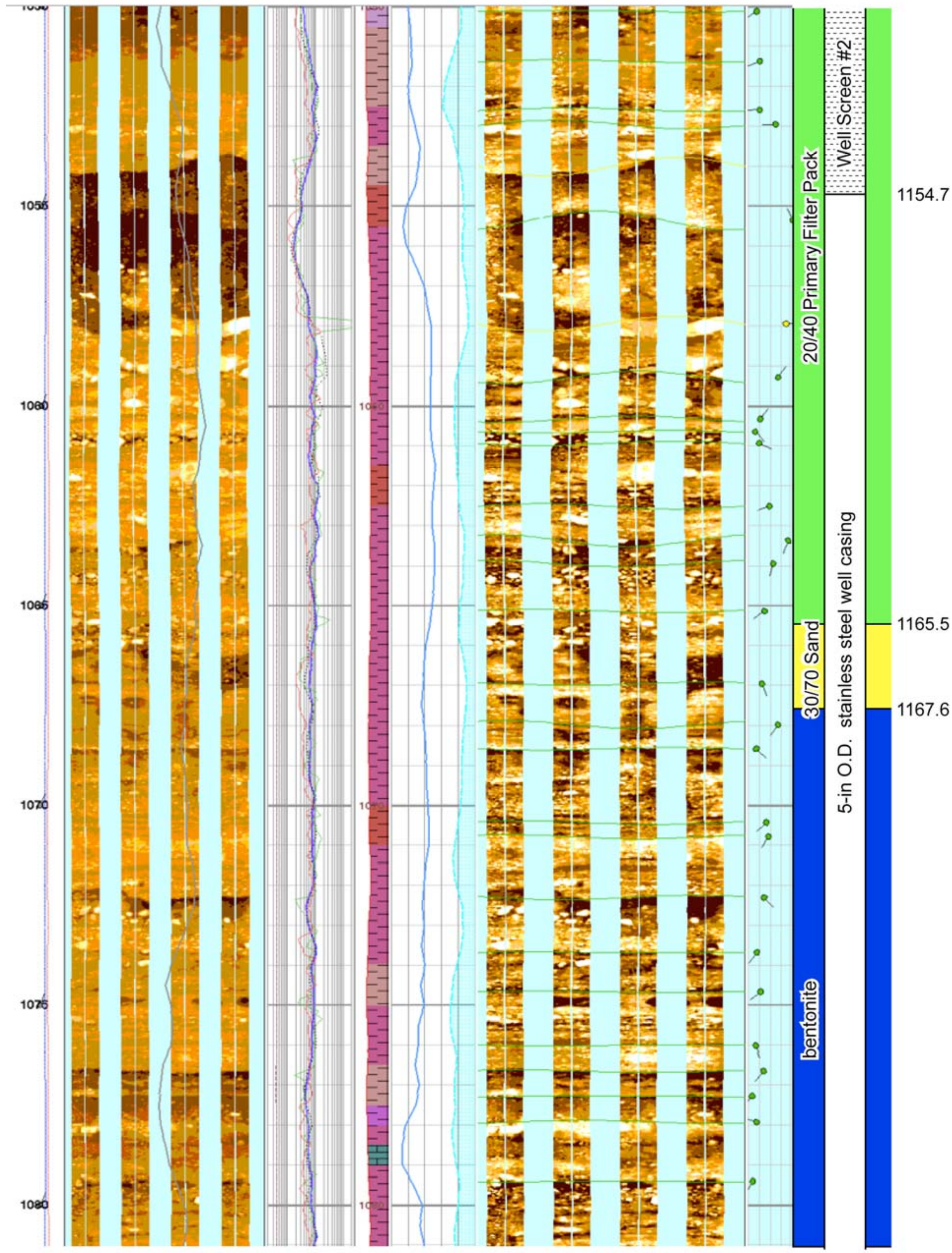
Screen #1 setting



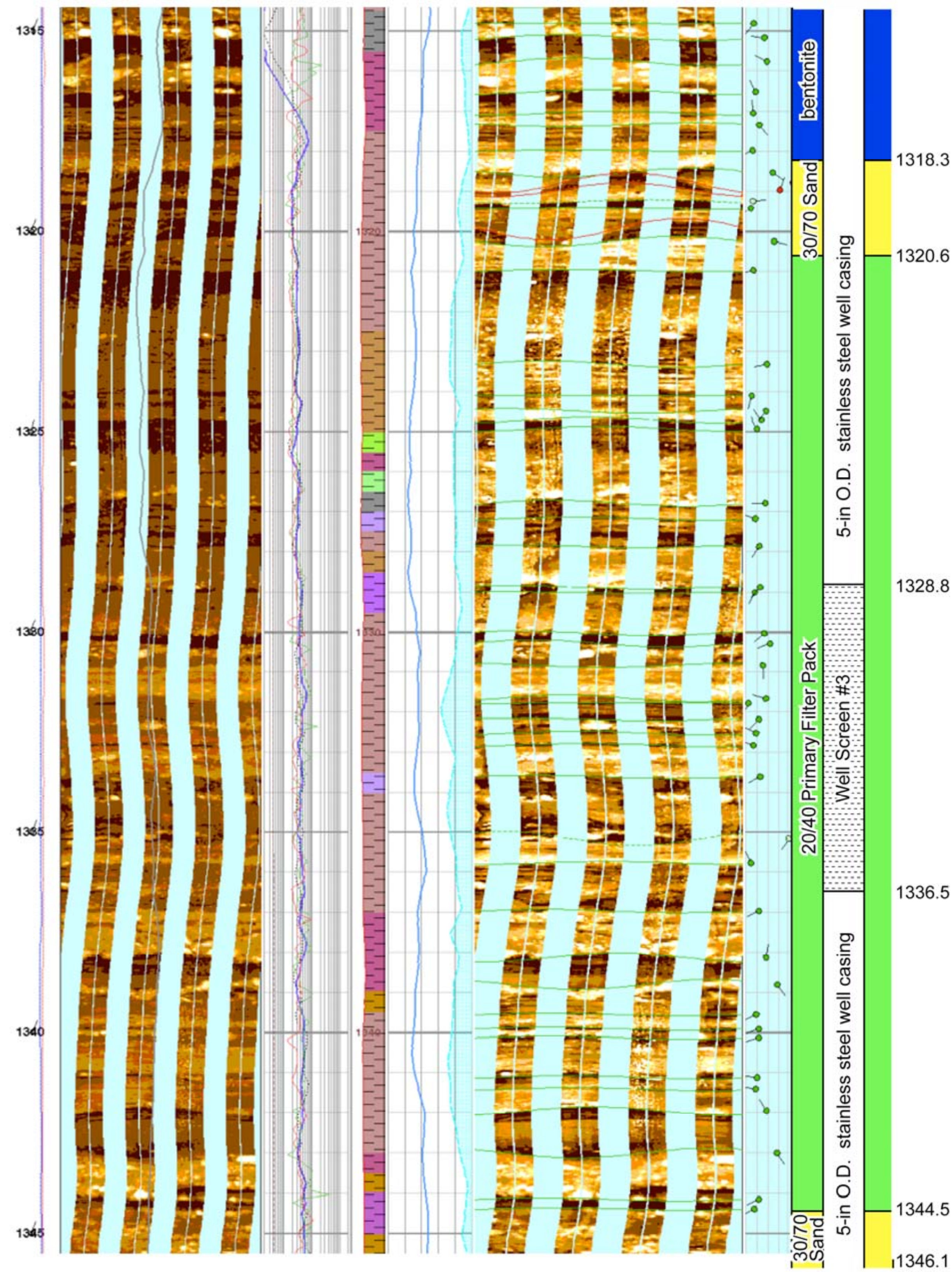
Screen 1 setting continued



Screen 2 Setting



Screen 2b setting continued



Screen 3 setting

R-21 Well

R-21 Well		
	Description	Evaluation
Drilling Method	R-21 was drilled using fluid-assisted air-rotary casing advance methods.	R-21 was drilled using conventional-circulation air-rotary drilling in an open hole to 237 ft followed by conventional-circulation fluid-assisted air-rotary drilling in an open hole to TD at 995 ft. Circulation of cuttings was primarily accomplished using air and municipal water mixed with QUIK-FOAM. The loss of drilling fluid circulation was a significant problem while drilling through the Cerros del Rio basalt. Initial attempts at controlling circulation loss involved the use of a small amount (15 gal.) of EZ-MUD to condition the borehole wall in the interval from 545 to 563 ft. In addition, approximately 10 ft^3 of bentonite chips was added to the borehole at 545 ft and 30 ft^3 of bentonite chips, and N-Seal was added to the borehole at 563 ft to seal off a lost-circulation zone in the basalt. Despite these measures, circulation problems persisted for the remainder of the borehole, and cuttings were retrieved for only 21.4% of the footage drilled below a depth of 545 ft. Drilling additives can adversely affect the ability to collect representative water samples, but this effect is minimized in R-21 because it is a single-completion well. Single-completion wells are intrinsically easier to develop than multiscreen wells, and they can be purged before sampling. Also, the drilling additives used in the vicinity of the well screen at R-21 consisted of air, municipal water, and QUIK-FOAM; these fluids are easy to remove during development in comparison to other types of drilling fluids. Use of bentonite and EZ-MUD in the vadose zone should not impact the well screen in the regional aquifer.
General Well Characteristics	R-21 is a single-screen well constructed of 6-in.-I.D./6.625-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The well screen is constructed of 6-in.-I.D./6.625-in.-O.D. 304 stainless-steel wire wrap with 0.020-in. slots.	The R-21 well screen construction (0.020-in. wire-wrapped screen) is considered an optimum design that balances the need to prevent fine-grained material from entering the well with the need to promote the free flow of water during well development and sampling.
Screen Length and Placement	The well screen extends from 888.8 to 906.8 ft and has a length of 18 ft. The top of the screen is currently 87 ft below the water table.	This screen length and its placement were selected with the following goals in mind: • Provide a monitoring point in the regional aquifer downgradient of MDA L • Place a screen as close to the top of the regional aquifer as feasible because of the well's proximity to MDA L • Screen across a stratigraphic interval expected to be a contaminant flow path • Submerge the screen fully to facilitate well development

R-21 Well (continued)		
	Description	Evaluation
Screen Length and Placement (continued)		The upper part of the regional aquifer at R-21 occurs near the base of a thick stack of lavas, interflow breccias, cinder deposits, and interflow sediments that make up the Pliocene Cerros del Rio basalt. Recognition of regional saturation was hampered by the lack of circulation to the surface of cuttings and produced water throughout the lower part of the borehole. The first indication of possible regional groundwater during drilling occurred at a depth of 890 ft where the driller noted the firing speed of the down-the-hole hammer decreased and the sound of the hammer changed; these changes are frequently associated with the presence of saturated conditions. Drilling was halted at a depth of 905 ft (30 ft deeper than the predicted water table), and water levels monitored over 4.25 ft stabilized at a depth of 803.6 ft. Drilling resumed and the borehole was advanced to determine the depth of the contact between the Cerros del Rio basalt and the Puye Formation. The borehole was terminated at a depth of 995 ft, and a broad suite of Schlumberger geophysical logs was run in the open borehole. In the absence of drill cuttings, the geophysical logs provided important information about the nature of the rocks in the lower part of the borehole and provided the basis for designing the well. Water-level observations during drilling, Schlumberger logs, and water-level observations in the completed well provide a consistent picture of the potentiometric surface in R-21 occurring at a depth of 802–803 ft. The water table occurs within a massive interflow sedimentary deposit that extends from a depth of 784 to 820 ft. These deposits consist of angular basaltic detritus made up of matrix-supported boulders, cobbles, and gravels. Geophysical logs indicate that above 814 ft, these deposits are partially saturated and have relatively low effective porosity (2%–10%). From 814 to 820 ft, these deposits are fully saturated with high effective porosity (20%–45%). These coarse sedimentary deposits overlie a massive basalt from 820 to 890 ft. This basalt contains relatively few fractures, and geophysical logs indicate total porosity is less than 10% and effective porosity is less than 1%. The Puye Formation occurs from 890 ft to a TD of 995 ft. The borehole in the upper part of the Puye Formation from 890 to 909 ft is characterized by severe washouts that are reflected by unreasonably high effective porosity values (35%–70%). Nonetheless, because water was first detected in the borehole at a depth of 890 ft during drilling, this zone became the primary target for the well screen. Deeper zones within the Puye Formation where washouts are less severe have effective porosities between 20% and 30%; these more reliable measurements of effective porosity are probably typical of the well screen interval.

R-21 Well (continued)		
	Description	Evaluation
Screen Length and Placement (continued)		A major issue in determining the well screen interval at R-21 was whether the top of the regional saturation is confined beneath the lowermost Cerros del Rio basalt at a depth of 890 ft or if it occurs under water-table conditions at 803 ft within the interflow sedimentary deposits atop the basalt. As noted above, the driller first detected water in the borehole at a depth of 890 ft, and after a short period of time, the water level stabilized at 803-ft depth. Geophysical logs confirmed the water level of 803 ft but found that the rocks above 814 ft were only partially saturated. These observations raise the possibility that groundwater is confined below the basalt and that the elevated water content in the overlying sedimentary deposits is caused by the invasion of water into the formation by water rising in the open borehole. Because of uncertainty about confinement of the regional aquifer, the decision was made to place the screen at the top of the Puye Formation where water was first detected. R-21 is 1130 ft downgradient of the MDA L footprint. The placement of the well screen across the 888.8- to 906.8-ft-depth interval meets the goals for a monitoring well at this location. The well screen is located within the uppermost permeable horizon that could be clearly delineated in the regional groundwater system. Consideration was given to the placing the screen in the interval from 803 to 820 ft, but this was rejected because there was considerable risk this interval might be dry once it was isolated from groundwater below the basalt.
Filter Pack-Materials and Placement	The primary filter pack extends from 878 to 914 ft and is made up of 10/20 sand. Secondary filter packs of 20/40 sand were placed above and below the primary filter pack at 876–878 ft and 914–916 ft, respectively.	The primary filter pack extends 10.8 ft above and 7.2 ft below the well screen. The filter pack above the well screen is slightly longer than optimum but has relatively little effect on samples collected because the most productive water-bearing zones are located toward the bottom of the screen interval.
Sampling System	Submersible Pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. Conventional purging and sampling allow water to be drawn more deeply from within formation materials surrounding the well screen in comparison to low-flow systems, and there is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.

R-21 Well (continued)		
	Description	Evaluation
Other Issues That Could Affect the Performance of the Well	Dropped tremie pipe	During well construction, 500 ft of tremie pipe used to place annular materials between the well casing and the borehole wall became detached from the hoisting bail while being lowered, and it fell into the borehole annulus. The top of the bentonite seal above the filter pack was at a depth of 865 ft at that time. Video logs and lowering a bailer showed that the well casing and screen were undamaged from the dropped tremie pipe. The top of the dropped tremie pipe was located using a down-hole video camera in the borehole annulus. Thirteen joints of tremie pipe 260 ft long were recovered. Additional camera runs indicate that the remainder of the dropped tremie pipe apparently broke into three pieces, with tops at depths of approximately 691 ft, 770 ft, and at an unknown depth above 759 ft. There were several unsuccessful attempts to retrieve the remaining dropped tremie pipe with a recovery tool. Based on down-hole observations, it was calculated that the deepest that the tremie could have reached was 850 ft. This is 26 ft above the filter pack and 38.8 ft above the screen. After efforts to retrieve the remaining tremie pipe failed, the decision was made to backfill around the dropped tremie pipe with bentonite and continue with well construction. Water-quality data collected after development and during subsequent groundwater monitoring are characterized by turbidity values of less than 5 NTU and show no indicators for bentonite contamination. Based on these data, it is concluded that the filter pack around the well screen was not compromised by the dropped tremie pipe.
Additives Used		Air Municipal water—18,950 gal. QUIK-FOAM—196.7 gal. EZ-MUD—15 gal. (all between 545 and 563 ft) Bentonite and N-SEAL—40 ft^3 (all between 545 and 563 ft) Fluids recovered during development—3205 gal. (an additional 13,337 gal. of water was pumped from the well during the step test following development)
Annular Fill Other Than Filter and Transition Sands		Holeplug bentonite—0.375-in. unrefined chips (513 bags) Aquagel Gold Seal bentonite (8 bags added to cement) Pelplug bentonite—0.25 in. by 0.375-in. refined elliptical pellets (19 50-lb buckets) Surface seal of Portland cement slurry (78 bags) Municipal water—1000 gal.

Location: North of TA-54 in
Canada del Buey

Survey Coordinates:
(Brass marker in NW corner of R-21 well pad)

Northing: 1759143 05
Easting: 1641284 17
Elevation: 6656 24
(New Mexico State Plane Coordinates NAD83.
Elevation is NAVD88)

Drilling: 12.25" Mill tooth Tricone, 57'-237'
12.25" Button Bit 237'-244'
12.25" Down hole hammer w/foam 244'-545'
12.25" Button Bit' w/foam 545'-563
12.25" Down hole hammer w/foam 563'-995'

Data Collection:
Hydrogeologic Properties:
Stepped pumping test (5. 10. and 15 gallons per minute)

Cores/cuttings submitted for geochemical and contaminant characterization: 11 Samples

Geologic Properties:
Mineralogy, petrography, and chemistry: 10 Samples

Borehole:
Lithologic: 0'-995'
Video (LANL tool): 57'- 578' bgs (open hole)
Schlumberger logs: All open hole
Compensated Neutron log: 57'-982'
Triple lithodensity: 57'-982'
Array induction imager: 57'-976'
Elemental Capture Sonde: 57'-930'
Natural GR spectroscopy: 57'-976'
Combinable Magnetic Resonance: 100'-910'
Fullbore formation micro imager: 800'-930'

Core drilling completed: 11-4-02 to 11-9-02
Rotary drilling completed: 11-14-02 to 11-17-02
Contract geophysics: 11-18-02 to 11-19-02
Well constructed: 11-19-02 to 11-26-02
Well developed: 12-4-02 to 12-5-02

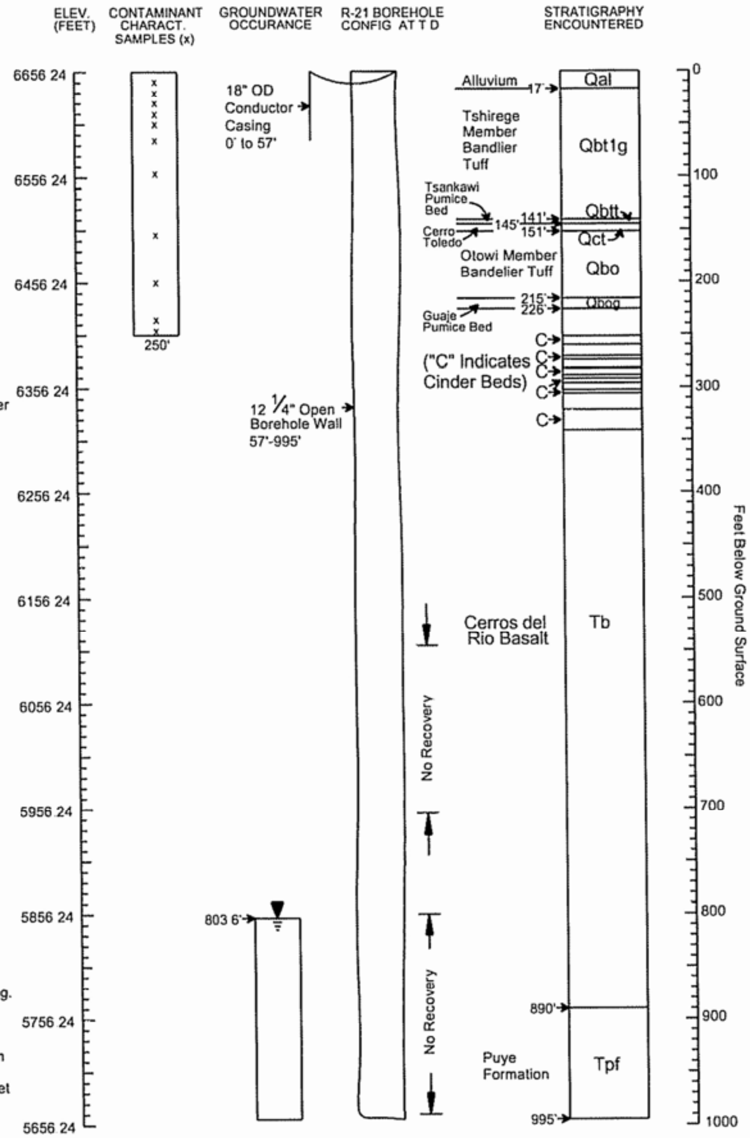
Casing: 6" I.D /6-5/8" O D. SCH 40
A304 stainless with external couplings.

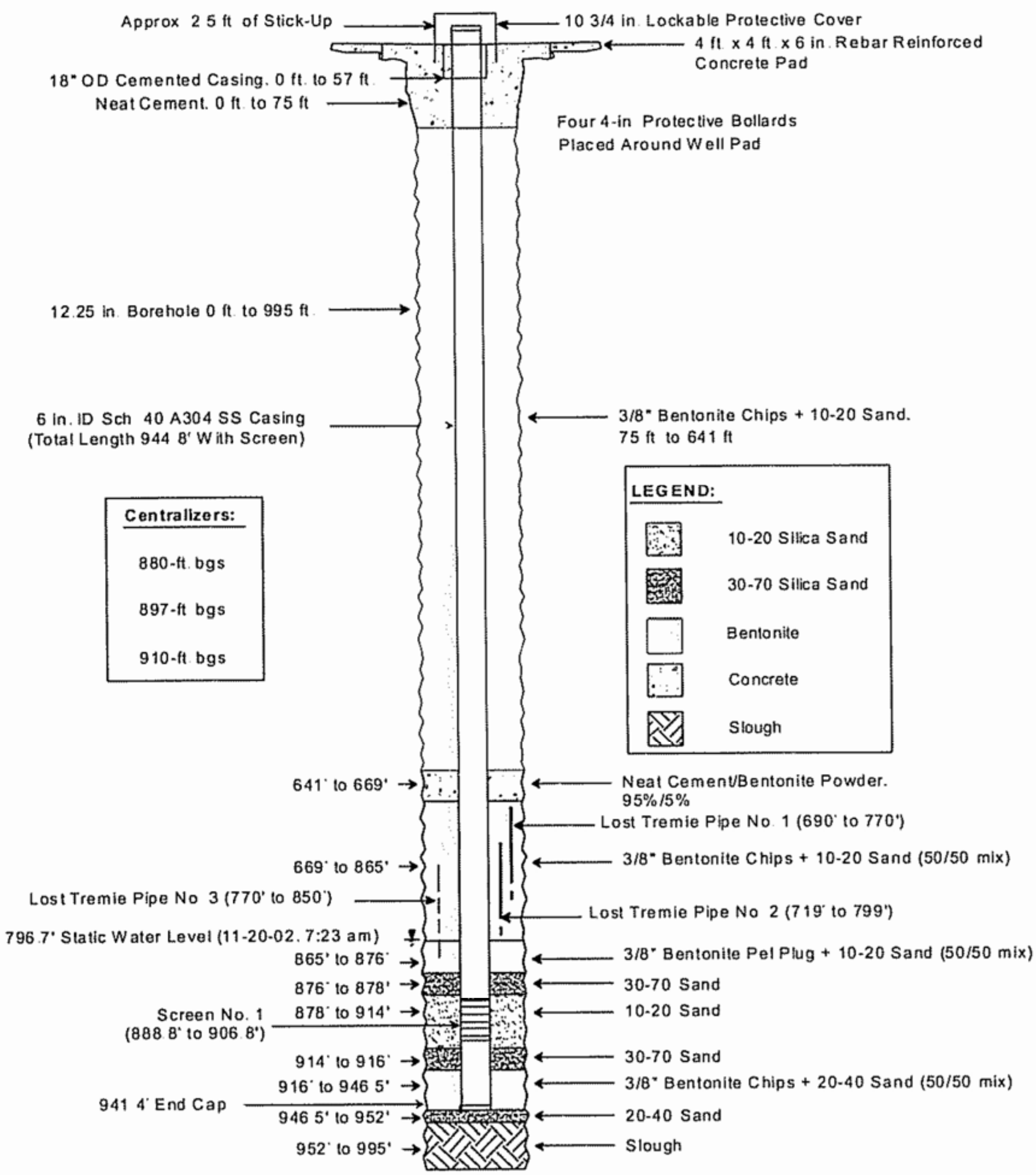
Number of screens:
One 6" I D /6-5/8" O D wire-wrapped 0 020 slot stainless w/ external couplings

Screen interval: 888 8'-906 8'

Well development performed by swabbing, bailing. and pumping Approximately 3,205 gallons of water removed during development

Geologic contacts for R-21 were determined from core samples, cuttings. borehole video and geophysical logs. Core samples collected in offset boring located 72' northwest of boring drilled for Characterization Well R-21

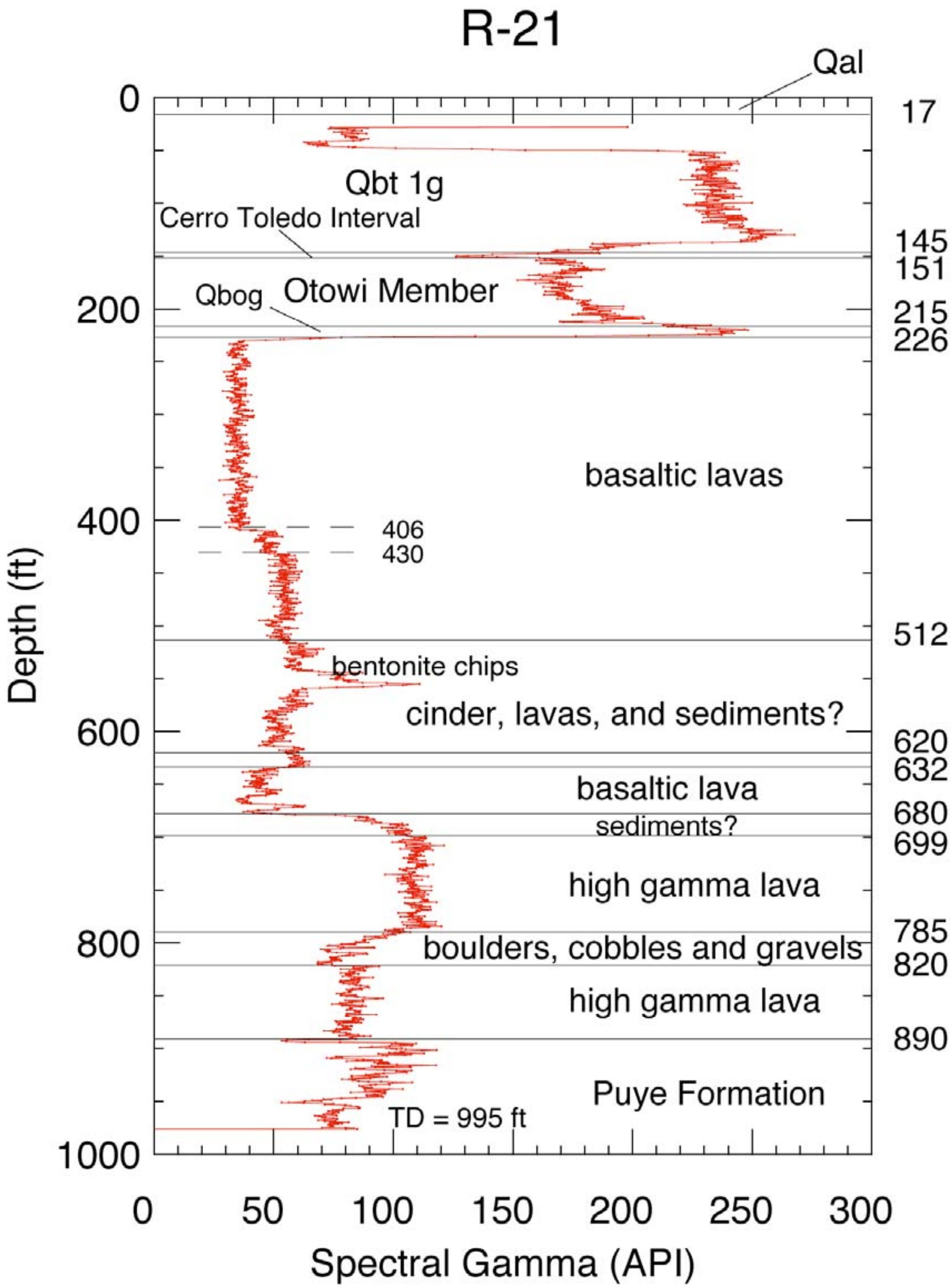


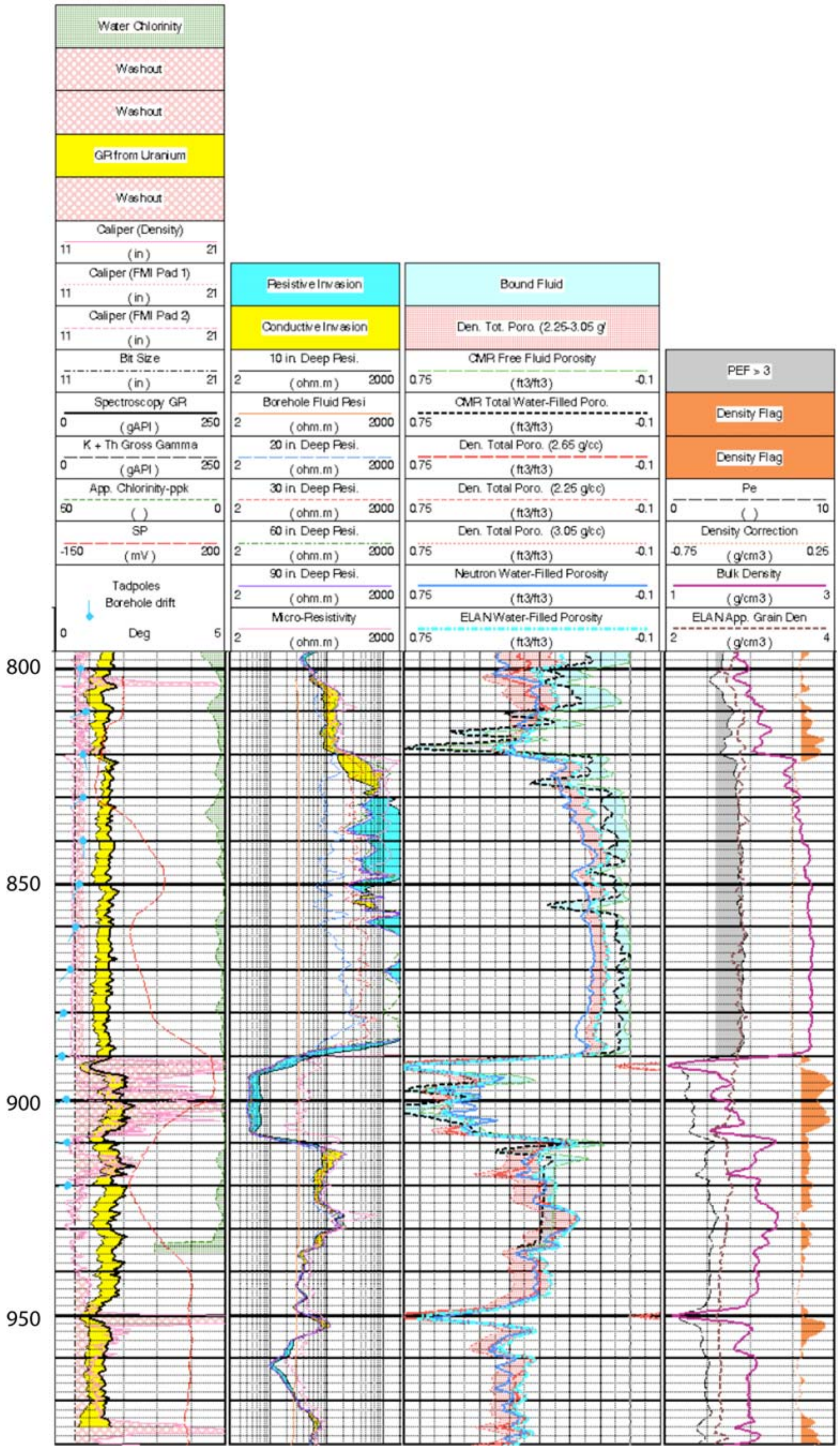


NOTES:

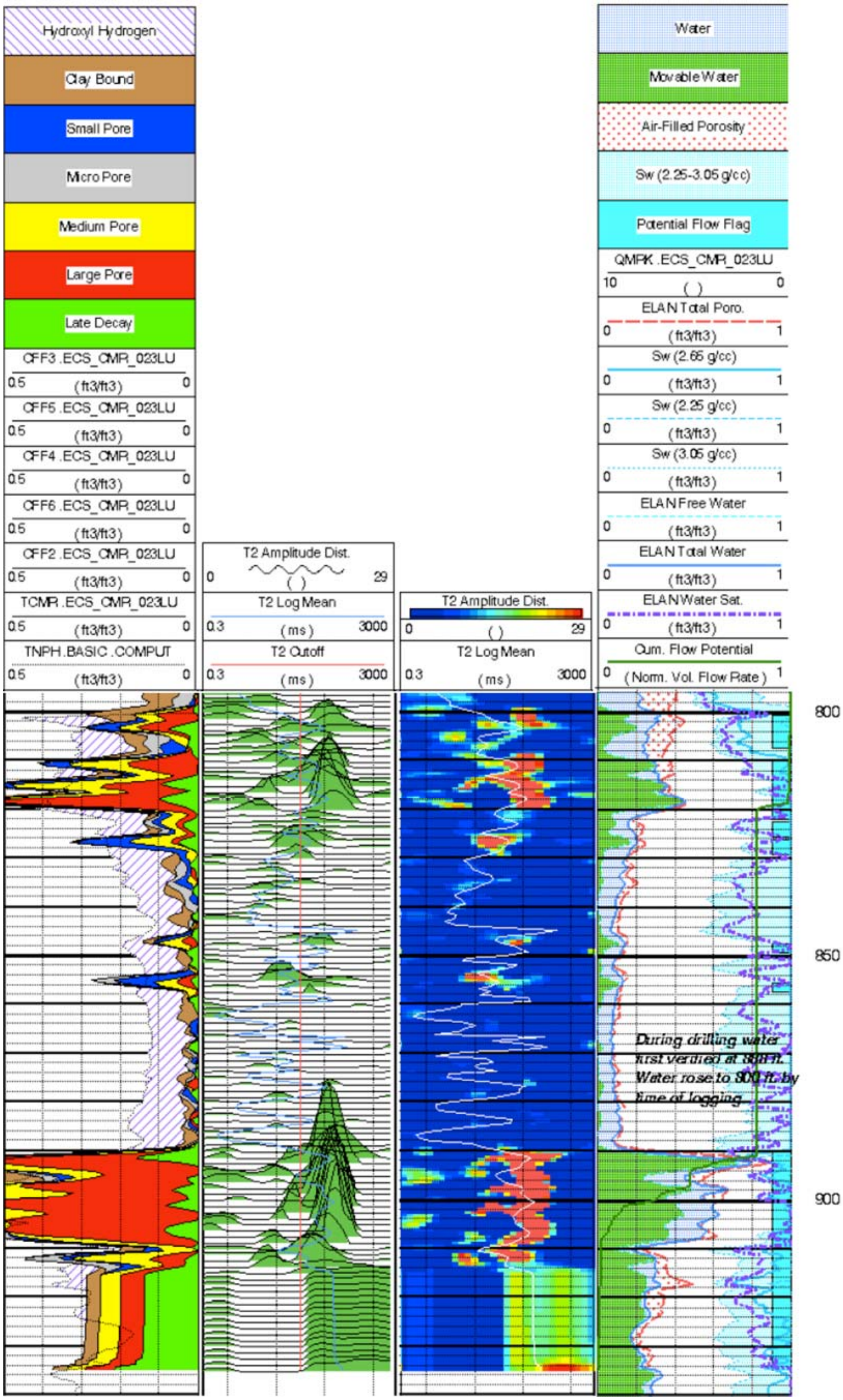
Well T D 941 4 ft
Boring T D 995 ft

1. The screen interval lists the footage of pipe perforations and not the top and bottom of screen joints
2. Well screen is 6 in inside diameter (ID), 6 5/8 in outside diameter (OD). 0 020-inch (in) wire wrapped A304 stainless steel
3. Well blank is 6 in ID. 6 5/8 in OD. A304 stainless steel with stainless steel couplings
4. Stainless steel sump is located at 906 8-feet (ft) below ground surface (bgs) to 941 4-ft bgs
5. All depths are below ground surface
6. Sample pump consists of 4-in OD, Grundfos Model 5S20-39DS. 2-Horsepower. single phase. 230-Volt
7. Pump intake located at 864 ft below top of casing
8. Pump discharge connection consists of 1-in stainless steel female pipe thread fitting
9. Drawing is not to scale.
10. Lost tremie pipe lengths and locations are interpreted based on video log and field observations Lengths are dashed where inferred

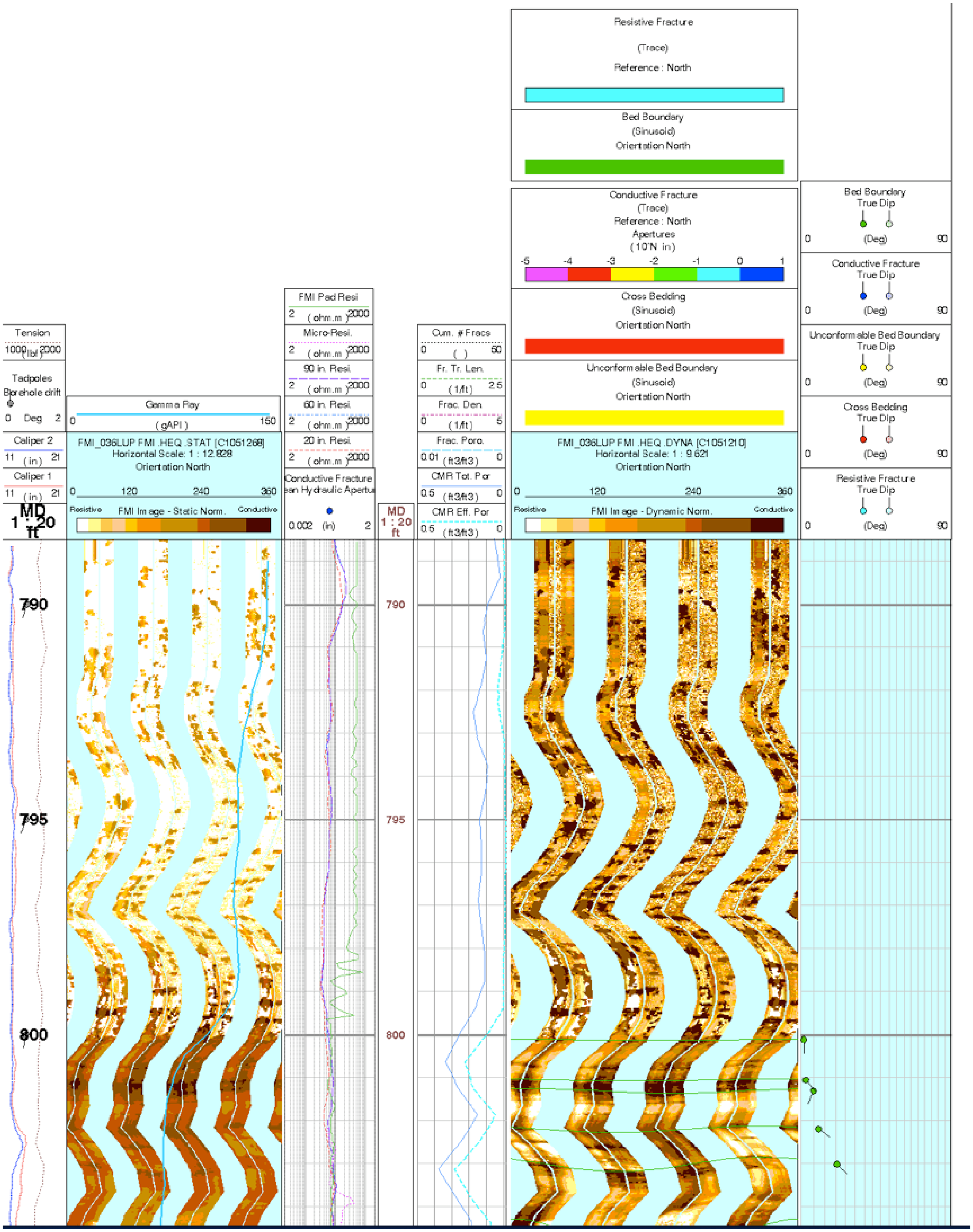

R-21
Qal
17
Qbt 1g
Cerro Toledo Interval
145
151
Qbog
Otowi Member
215
226
basaltic lavas
406
430
512
bentonite chips
cinder, lavas, and sediments?
620
632
basaltic lava
680
sediments?
699
high gamma lava
785
boulders, cobbles and gravels
820
high gamma lava
890
Puye Formation
TD = 995 ft
Depth (ft)
0
200
400
600
800
1000
0
50
100
150
200
250
300
Spectral Gamma (API)

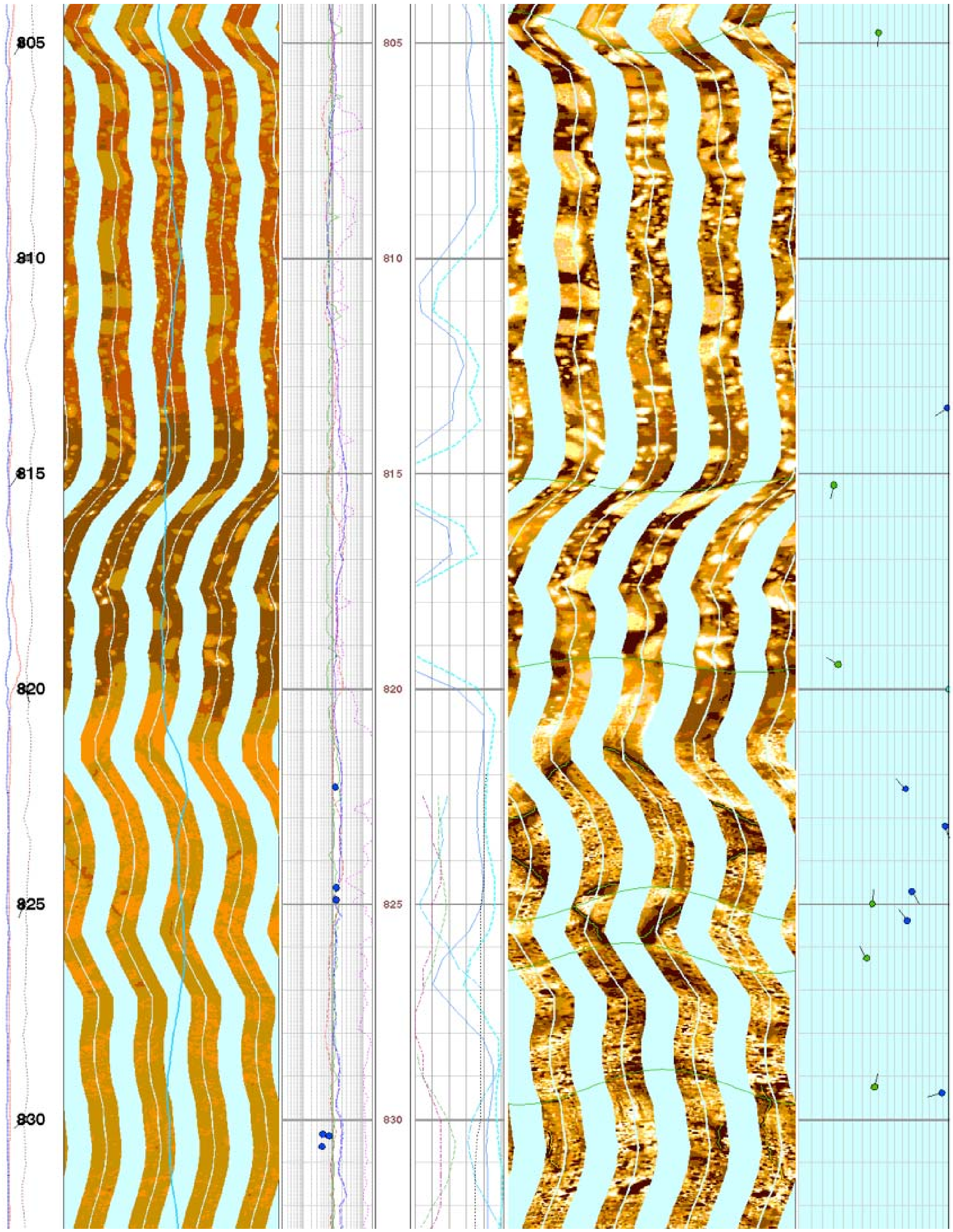


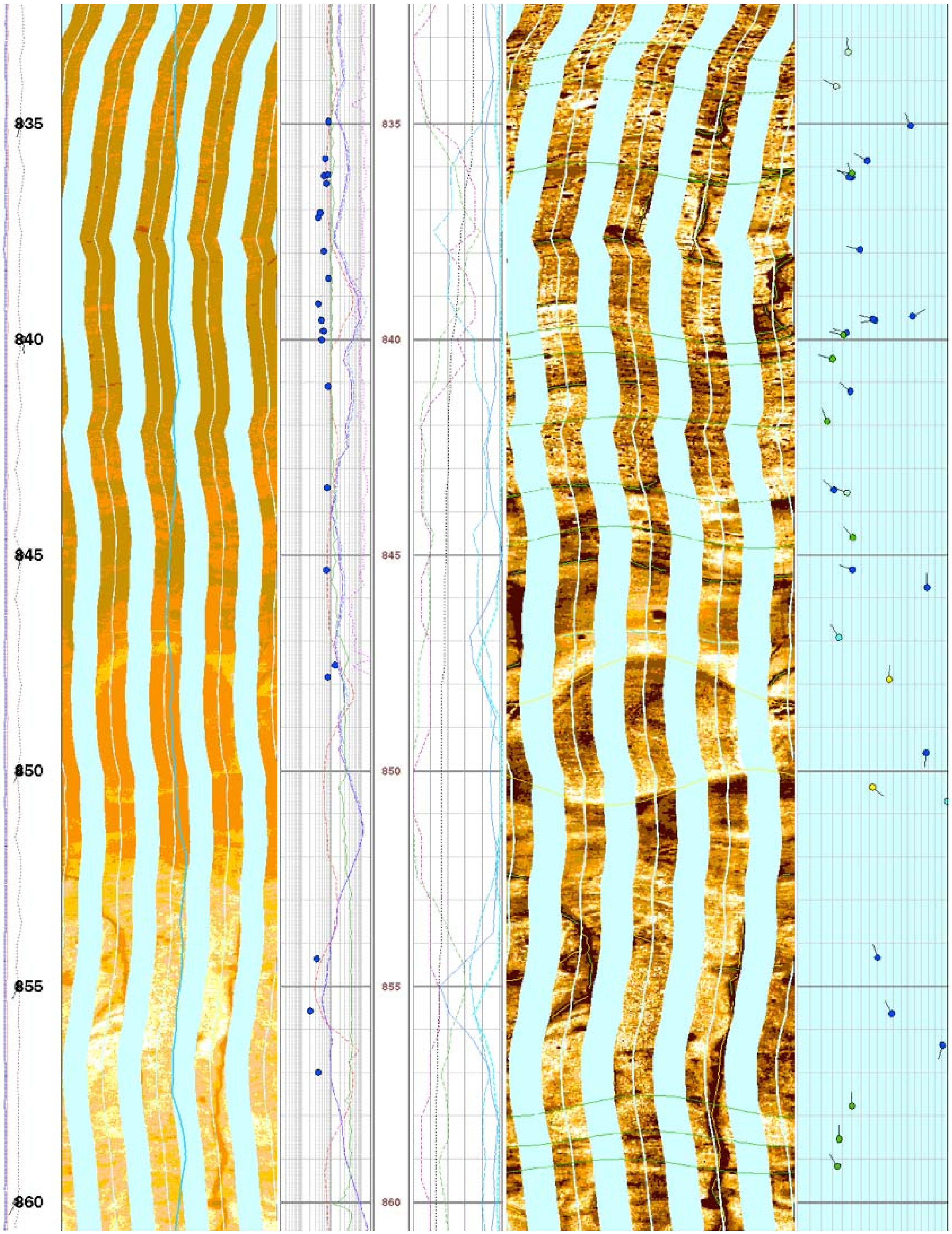
Water Chlorinity
Washout
Washout
GR from Uranium
Washout
Caliper (Density)
11 (in) 21
Caliper (FMI Pad 1)
11 (in) 21
Caliper (FMI Pad 2)
11 (in) 21
Bit Size
11 (in) 21
Spectroscopy GR
0 (gAPI) 250
K + Th Gross Gamma
0 (gAPI) 250
App. Chlorinity-ppk
50 ( ) 0
SP
-150 (mV) 200
Tadpoles
Borehole drift
0 Deg 5
Resistive Invasion
Conductive Invasion
10 in. Deep Resi.
2 (ohm.m) 2000
Borehole Fluid Resi
2 (ohm.m) 2000
20 in. Deep Resi.
2 (ohm.m) 2000
30 in. Deep Resi.
2 (ohm.m) 2000
60 in. Deep Resi.
2 (ohm.m) 2000
90 in. Deep Resi.
2 (ohm.m) 2000
Micro-Resistivity
2 (ohm.m) 2000
Bound Fluid
Den. Tot. Poro. (2.25-3.05 g/
CMR Free Fluid Porosity
0.75 (ft3/ft3) -0.1
CMR Total Water-Filled Poro.
0.75 (ft3/ft3) -0.1
Den. Total Poro. (2.65 g/cc)
0.75 (ft3/ft3) -0.1
Den. Total Poro. (2.25 g/cc)
0.75 (ft3/ft3) -0.1
Den. Total Poro. (3.05 g/cc)
0.75 (ft3/ft3) -0.1
Neutron Water-Filled Porosity
0.75 (ft3/ft3) -0.1
ELAN Water-Filled Porosity
0.75 (ft3/ft3) -0.1
PEF > 3
Density Flag
Density Flag
Pe
0 ( ) 10
Density Correction
-0.75 (g/cm3) 0.25
Bulk Density
1 (g/cm3) 3
ELAN App. Grain Den
2 (g/cm3) 4
800
850
900
950

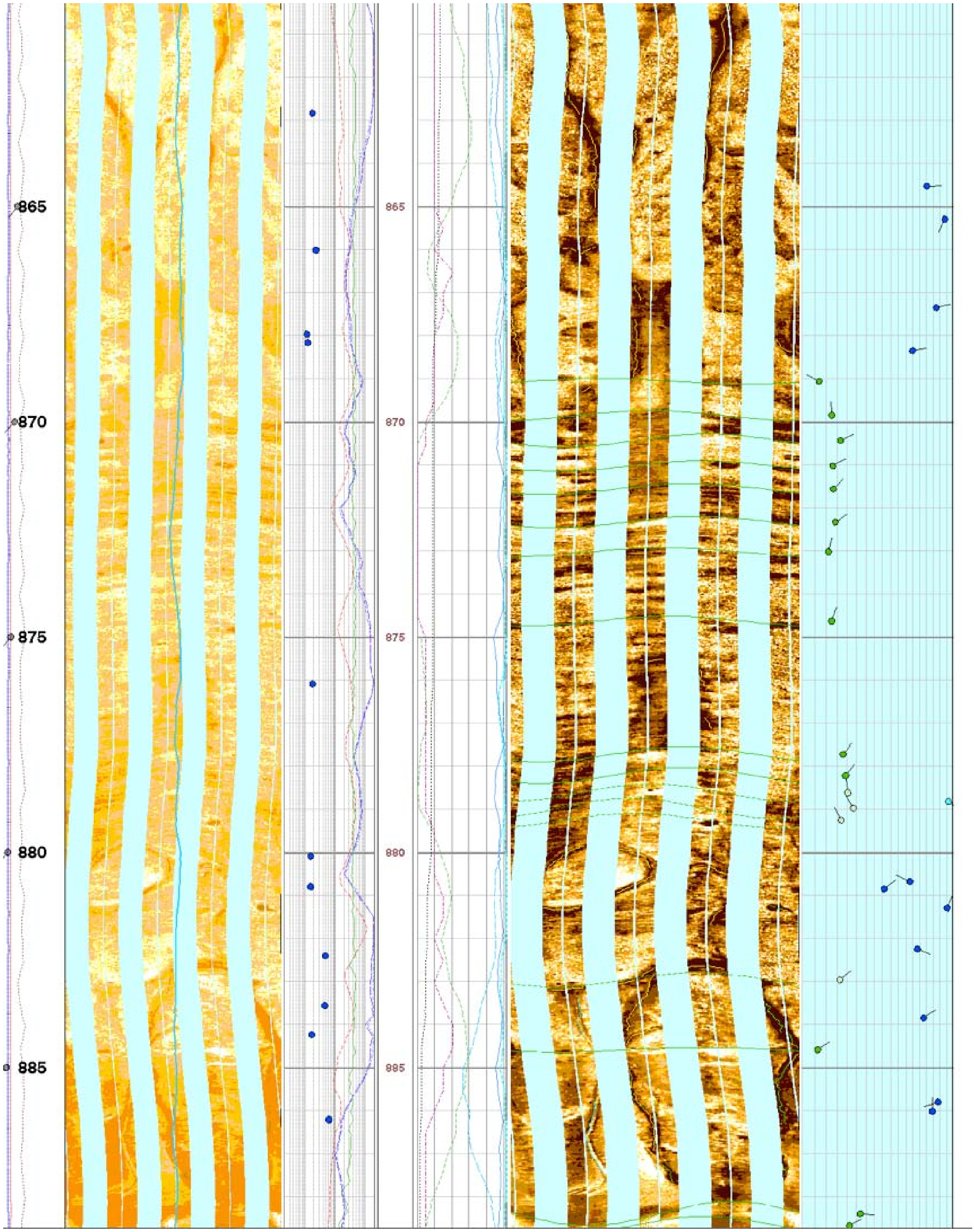


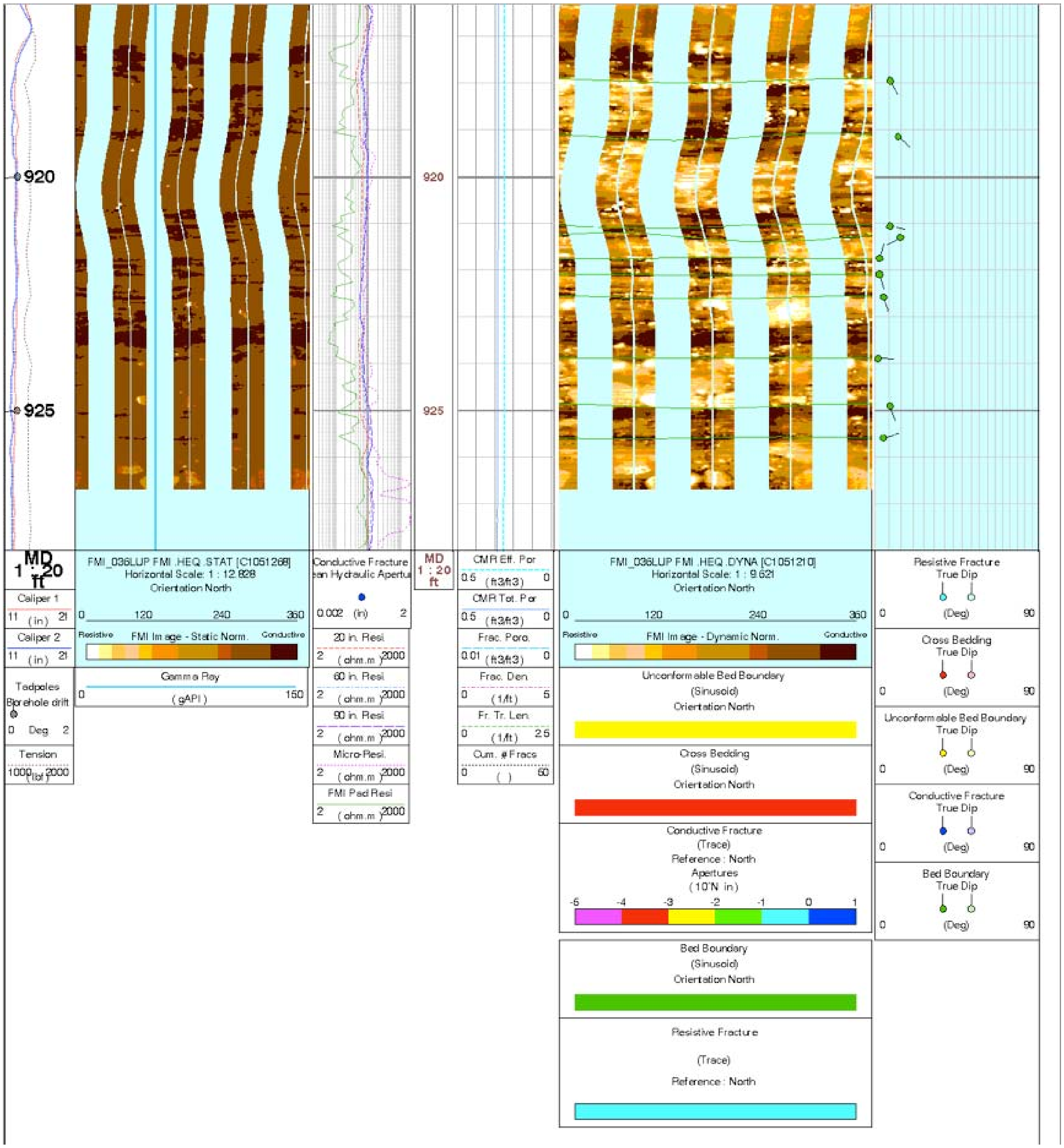
Hydroxyl Hydrogen
Clay Bound
Small Pore
Micro Pore
Medium Pore
Large Pore
Late Decay
CFF3.ECS_CMR_023LU
0.5 (ft3/ft3) 0
CFF5.ECS_CMR_023LU
0.5 (ft3/ft3) 0
CFF4.ECS_CMR_023LU
0.5 (ft3/ft3) 0
CFF6.ECS_CMR_023LU
0.5 (ft3/ft3) 0
CFF2.ECS_CMR_023LU
0.5 (ft3/ft3) 0
TCMR.ECS_CMR_023LU
0.5 (ft3/ft3) 0
TNPH.BASIC.COMPUT
0.5 (ft3/ft3) 0
T2 Amplitude Dist.
0 ( ) 29
T2 Log Mean
0.3 (ms) 3000
T2 Cutoff
0.3 (ms) 3000
T2 Amplitude Dist.
0 ( ) 29
T2 Log Mean
0.3 (ms) 3000
Water
Movable Water
Air-Filled Porosity
Sw (2.25-3.05 g/cc)
Potential Flow Flag
QMRK.ECS_CMR_023LU
10 ( ) 0
ELAN Total Poro.
0 (ft3/ft3) 1
Sw (2.65 g/cc)
0 (ft3/ft3) 1
Sw (2.25 g/cc)
0 (ft3/ft3) 1
Sw (3.05 g/cc)
0 (ft3/ft3) 1
ELAN Free Water
0 (ft3/ft3) 1
ELAN Total Water
0 (ft3/ft3) 1
ELAN Water Sat.
0 (ft3/ft3) 1
Cum. Flow Potential
0 (Norm. Vol. Flow Rate) 1
800
850
900
During drilling water first verified at 890 ft. Water rose to 800 ft. by time of logging


Resistive Fracture
(Trace)
Reference : North
Bed Boundary
(Sinusoid)
Orientation North
Conductive Fracture
(Trace)
Reference : North
Apertures
(10^N in)
-5 -4 -3 -2 -1 0 1
Cross Bedding
(Sinusoid)
Orientation North
Unconformable Bed Boundary
(Sinusoid)
Orientation North
Bed Boundary True Dip
Conductive Fracture True Dip
Unconformable Bed Boundary True Dip
Cross Bedding True Dip
Resistive Fracture True Dip
0 (Deg) 90
FMI Pad Resi
Micro Resi.
90 in. Resi
60 in. Resi
20 in. Resi
2 (ohm.m) 2000
Conductive Fracture
ean Hydraulic Apertu
0.002 (in) 2
Tension
1000 (lbf) 2000
Tadpoles
Borehole drift
0 Deg 2
Caliper 2
11 (in) 21
Caliper 1
11 (in) 21
MD
1 : 20
ft
Gamma Ray
0 (gAPI) 150
FMI_036LUP FMI_HEQ_STAT [C1051268]
Horizontal Scale: 1 : 12.828
Orientation North
0 120 240 360
Resistive FMI Image - Static Norm. Conductive
Cum. # Fracs
0 ( ) 50
Fr. Tr. Len.
0 (1/ft) 2.5
Frac. Den
0 (1/ft) 5
Frac. Poro.
0.01 (ft3/ft3) 0
CMR Tot. Por
0.5 (ft3/ft3) 0
CMR Eff. Por
0.5 (ft3/ft3) 0
FMI_036LUP FMI_HEQ_DYNA [C1051210]
Horizontal Scale: 1 : 9.621
Orientation North
0 120 240 360
Resistive FMI Image - Dynamic Norm. Conductive
790
795
800


805
810
815
820
825
830
805
810
815
820
825
830


835
840
845
850
855
860


865
870
875
880
885
865
870
875
880
885


920
925
MD 1 : 20 ft
Caliper 1
11 (in) 21
Caliper 2
11 (in) 21
Tadpoles
Borehole drift
0 Deg 2
Tension
1000 (lbf) 2000
FMI_036LUP FMI .HEQ .STAT [C1051268]
Horizontal Scale: 1 : 12.828
Orientation North
0 120 240 360
Resistive FMI Image - Static Norm. Conductive
Gamma Ray
0 (gAPI) 150
Conductive Fracture
Mean Hydraulic Aperture
0.002 (in) 2
20 in. Resi
2 (ohm.m) 2000
60 in. Resi
2 (ohm.m) 2000
90 in. Resi
2 (ohm.m) 2000
Micro-Resi.
2 (ohm.m) 2000
FMI Pad Resi
2 (ohm.m) 2000
CMR Eff. Por
0.5 (ft3/ft3) 0
CMR Tot. Por
0.5 (ft3/ft3) 0
Frac. Poro.
0.01 (ft3/ft3) 0
Frac. Den.
0 (1/ft) 5
Fr. Tr. Len.
0 (1/ft) 25
Cum. # Fracs
0 ( ) 60
FMI_036LUP FMI .HEQ .DYNA [C1051210]
Horizontal Scale: 1 : 9.621
Orientation North
0 120 240 360
Resistive FMI Image - Dynamic Norm. Conductive
Unconformable Bed Boundary
(Sinusoid)
Orientation North
Cross Bedding
(Sinusoid)
Orientation North
Conductive Fracture
(Trace)
Reference : North
Apertures
(10^N in)
-5 -4 -3 -2 -1 0 1
Bed Boundary
(Sinusoid)
Orientation North
Resistive Fracture
(Trace)
Reference : North
Resistive Fracture
True Dip
0 (Deg) 90
Cross Bedding
True Dip
0 (Deg) 90
Unconformable Bed Boundary
True Dip
0 (Deg) 90
Conductive Fracture
True Dip
0 (Deg) 90
Bed Boundary
True Dip
0 (Deg) 90

R-22 Well

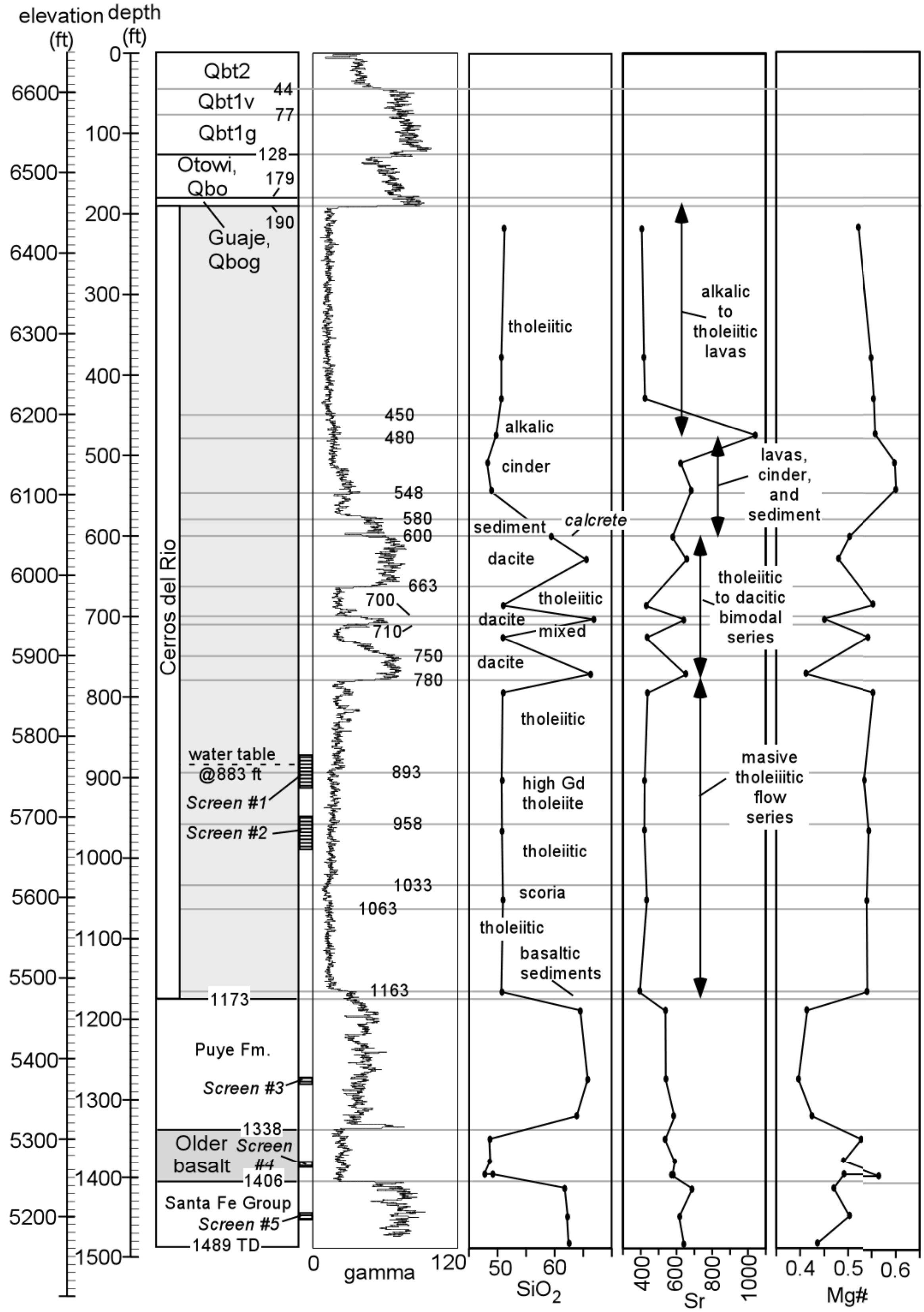
R-22 Well		
	Description	Evaluation
Drilling Method	R-22 was drilled using fluid-assisted air-rotary methods with dual-wall reverse circulation, in both casing advance and open-hole operation.	R-22 was drilled using fluid-assisted (water mixed with QUIK-FOAM and EZ-MUD) air-rotary methods with dual-wall reverse circulation and a 16-in. tricone bit to a depth of 194 ft (4 ft into the top of the Cerros del Rio lavas). At that point, the bit was switched to a 16-in. down-hole hammer, and drilling progressed to 212 ft where 210 ft of 13 ⅝-in. casing was inserted to stabilize the hole. From that point, a 12 ¼-in. hammer was used to advance to 252 ft where caving and lost circulation required a change in drilling method to casing advance. During casing advance, drilling mud was used behind the casing for lubrication. TORKEASE polymer, QUIK-FOAM, and EZ-MUD bentonite slurries mixed with community water were also used. The hole was reamed with a 14½-in. bit from 194 to 252 ft to allow insertion of 13 5/8-in. casing. The 13 5/8-in. casing was then advanced to 510 ft where it was reamed into a cinder-and-lava sequence of the Cerros del Rio in the belief that the bottom of the Cerros del Rio was very close. (Existing geologic model at the time of drilling suggested that the base of the lavas should have been at about 487 ft depth.) The hole was then advanced open-hole to 1258 ft using a 12 ¼-in. hammer. At this point, the hole had passed through the bottom of the Cerros del Rio at 1173 ft, and the decision was made to switch to a 12 ¼-in. tricone to prevent the borehole from expanding in the softer Puye sediments. On tripping in, it was found that the borehole had caved in up to 1160 ft into the basaltic tephra and sediment at the base of the Cerros del Rio lavas. The tricone bit was removed, and the 13 ⅝-in. casing was retracted to 510 ft to allow use of a 14 ½-in. under-reaming bit to set the casing in more solid rock (likely a thin lava flow) at 514 ft. From this point, drilling was by casing advance using a 10 ½-in. hammer and 9 ⅝-in. casing to 1345 ft, 7 ft into the top of a Miocene lava sequence. From here, the 10-½ in. hammer was advanced open-hole to TD at 1489 ft. The well installed at R-22 has five screens. Well development at R-22 consisted of wire brushing of the well interior, bailing, bailer-surging, and zone-specific pumping of the lower three screens to draw fine sediment from the filter packs, followed by bailing to remove muddy fluid and solid materials from the well sump. Zone-specific pumping produced significant amounts of fluid only at the three deepest screens (screens 3, 4, and 5). However, screens 1 and 2 are within dense lava and do not produce sufficient water for pump development. The inability to produce sufficient pump volume in the two uppermost screens is an issue concerning whether these screens can produce acceptable water-quality data. However, this issue is moderated by the relatively small amounts of additives used in drilling. More aggressive development was possible in the deeper screens. The efficacy of well development and the impact of residual drilling fluids must be evaluated by examining the quality of groundwater data collected from the completed well.

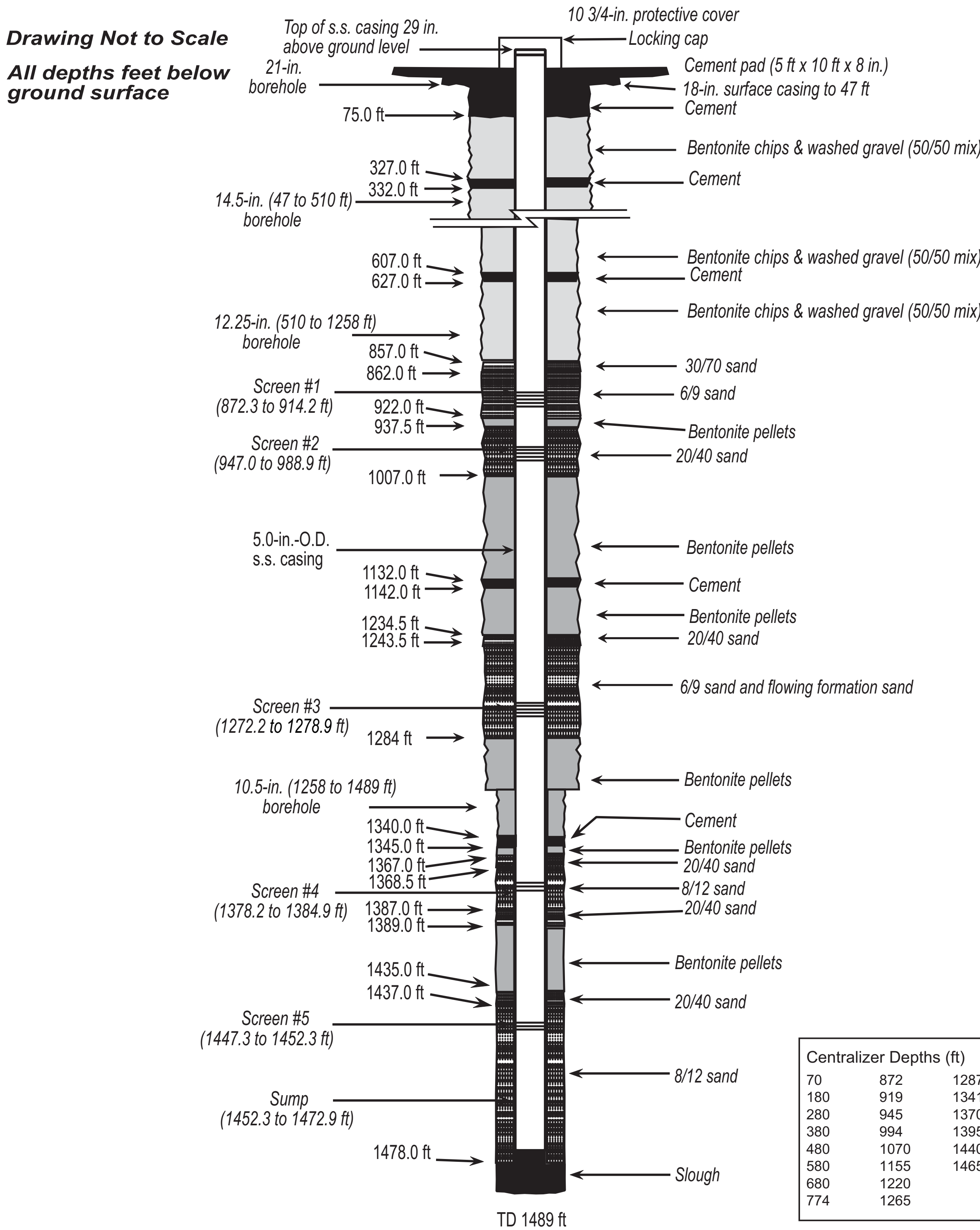
R-22 Well (Continued)		
	Description	Evaluation
General Well Characteristics	R-22 is a five-screen well constructed of 4.5-in.-I.D. and 5.0-in.-O.D. Type 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The pipe-based screens are constructed of 4.5-in.-I.D./5.56-in.-O.D. Type 304 stainless-steel casing perforated with 0.375-in. holes and wrapped with stainless-steel wire wrap with 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might otherwise be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screens were used at R-22 after two rod-based well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack and formation during development may be less effective at developing the well in those areas that are not adjacent to holes in the well casing. Also, the wire wrap on the R-22 well screens contains 0.010-in. slots. More recent wells in coarse deposits such as those at R-22 contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in. slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the specific well.
Screen Length and Placement	Screen 1 extends from 872.3 to 914.2 ft (length of 41.9 ft). The current water level in screen 1 is about 888 ft bgs. Screen 2 extends from 947.0 to 988.9 ft (length of 41.9 ft). The current water level in screen 2 is about 894.5 ft bgs. Screen 3 extends from 1272.2 to 1278.9 ft (length of 6.7 ft). The water level in screen 3 is currently 950.5 ft bgs. Screen 4 extends from 1378.2 to 1384.9 ft (length of 6.7 ft). The water level in screen 4 is currently 956.5 ft bgs.	R-22 well screen lengths and placements were selected with the following goals in mind: • Sample the top of the regional aquifer at a spot immediately downgradient of Area G at TA-54 • Screen across hydrostratigraphic units that might be expected to be along contaminant flow paths • Determine the magnitude and direction of vertical pressure gradients in the vicinity of TA-54 • Monitor water levels at multiple depths to determine pressure responses to municipal well pumping in the Pajarito well field • Provide new hydrogeologic data for poorly known units The upper part of the regional aquifer at R-22 occurs in dense tholeiitic lavas of the Pliocene Cerros del Rio basalt. Accurate determination of the water level was problematic during drilling as well as in interpretation of logs that were collected through 9 ⅝-in. casing that extended down to 1330 ft during logging with open borehole below. The tools used were limited because of the extensive length of casing but included CNT, HNGS, ECS, TLD, and gross gamma. Limitations on interpretation because of the presence of casing led to ambiguity in defining the top of regional saturation. Depth to water in the casing at time of logging was 955 ft, but the log interpretation suggested that the top of the regional aquifer was actually at a depth of 886 ft.

R-22 Well (Continued)		
	Description	Evaluation
Screen Length and Placement (continued)	Screen 5 extends from 1447.3 to 1452.3 ft (length of 5.0 ft). The water level in screen 5 is currently 956.5 ft bgs.	To be sure that a screen was emplaced across the top of saturation at this key location close to Area G, two long screens (screens 1 and 2, both 41.9 ft long) were placed to capture both of the two estimated depths to the top of regional saturation. Screen 1 (872.3 to 914.2 ft) targets the interpreted top of regional saturation at 886 ft. Screen 2 (947.0 to 988.9 ft) targets the observed depth to water (955 ft) during logging. Both screens are long because of the need to ensure that whichever screen spanned the top of regional saturation would be capable of providing water samples from the top of regional saturation despite potential drawdown over the life span of the well (~50 yr). Screen 3 (1272.2 to 1278.9 ft) is short and is placed in the volcaniclastic sediments below the Cerros del Rio lavas and above the Miocene lavas. The log response was relatively uniform across the sediments in this interval, but screen 3 targets a zone of apparent low density and high porosity (although this could be a washout zone behind the casing). The screen location was selected to sample a representative interval below a zone from 1191 to 1237 ft where circulation was lost and no cuttings were returned. Because the sedimentary lithologies above and below the zone of no returns were similar and the log data indicate no presence of a different lithology between them, it was decided to put the screen in a zone where returns were well established rather than placing the screen blindly. This satisfied one of the goals at this well, which was to provide hydrogeologic data for representative deep units that were poorly characterized. Screen 4 (1378.2 to 1384.9 ft) is also short and was placed in the Miocene basalt. The geophysical log data for the Miocene basalt are rather featureless, but the cuttings suggested that the top and bottom are somewhat more clay-altered and therefore could be somewhat less transmissive. Screen 4 is located in relatively unaltered basalt and above a horizon that was exceptionally clay-altered. This screen also satisfies the goal of providing representative hydrogeologic data for deep units that are poorly characterized, in this case, the Miocene basalt that also hosts the regional aquifer screens at R-9 and R-12. Screen 5 (1447.3 to 1452.3 ft) is in the somewhat finer-grained but still predominantly volcaniclastic sediments beneath the Miocene lava. The Schlumberger logs in this interval (1405–1478 ft) suggest relatively high porosity. The screen is within this interval and provides hydrogeologic data on the very poorly known sediments that underlie the Miocene lavas that extend beneath the Laboratory.
Filter Pack Materials and Placement	The filter packs and their placements are discussed for the five well screens in the column to the right.	The primary filter pack for screen 1 is made up of 6/9 sand from 862.0 to 922.0 ft. A secondary filter pack of 30/70 sand was placed above the primary filter pack from 857.0 to 862.0 ft. The primary filter pack extends 10.3 ft above and 5.8 ft below the well screen. These filter pack dimensions allow groundwater to be drawn from a larger volume of this very dense, thick, and homogeneous tholeiitic lava where the distribution of water-producing fractures is likely sparse (see attached stratigraphic figure with screen locations).

R-22 Well (Continued)		
	Description	Evaluation
Filter Pack Materials and Placement (continued)		The primary filter pack for screen 2 is made up of 20/40 sand from 937.5 to 1007.0 ft. There is no secondary filter pack at screen 2. The primary filter pack extends 9.5 ft above and 18.1 ft below the well screen. As with screen 1, these filter pack dimensions allow groundwater to be drawn from a larger volume of the very dense tholeiitic lava where water-producing fractures are likely sparse. The primary filter pack for screen 3 is made up of 6/9 sand plus flowing formation sands (flowing sands coincide with the lost circulation that was common in the upper part of this section). This mixture of introduced 6/9 sand and formation materials extends from 1243.5 to 1284.0 ft. A secondary filter pack of 20/40 sand was placed above this interval from 1234.5 to 1243.5 ft. The primary filter pack of 6/9 sand plus formation materials extends 28.7 ft above and 5.1 ft below the well screen. These dimensions include much unstable sediment and are likely to draw water from a broad interval that includes the zone of lost circulation and no cuttings returns, which extended down to 1237 ft. The primary filter pack for screen 4 is made up of 8/12 sand from 1368.5 to 1387.0 ft. Secondary filter packs of 20/40 sand were placed above the primary filter pack from 1367.0 to 1368.5 ft and below the primary filter pack at 1387.0 to 1389.0 ft. The primary filter pack extends 9.7 ft above and 2.1 ft below the well screen. These filter pack dimensions allow groundwater to be drawn from a larger volume of the Miocene lava where water-producing fractures are likely sparse but do not cross through the lava section at 1382 to 1392 ft where more abundant clay was noted in the drill cuttings. The primary filter pack for screen 5 is made up of 8/12 sand from 1437.0 to 1478.0 ft. A secondary filter pack of 20/40 sand was placed above the primary filter pack from 1435.0 to 1437.0 ft. The primary filter pack extends 10.3 ft above and 20.6 ft below the well screen. This extensive pack of coarse sand covers much of the high-porosity interval (1405–1478 ft) noted in the Schlumberger geophysical logs.
Sampling System	Westbay Multiple Port sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single-well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well, which was one of the goals at R-22. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids are critical before installation of Westbay wells because groundwater is collected in proximity to the well due to low-flow sampling and the inability to purge the well before sampling. Samples collected from Westbay wells are particularly prone to water-quality problems that develop if residual drilling fluids are hydraulically connected to the screen interval.

R-22 Well (Continued)		
	Description	Evaluation
Other Issues That Could Affect the Performance of the Well		• During drilling, acetone was detected at the regional water table. Analysis and testing suggested that isopropyl alcohol was introduced with injection water and misidentified as acetone. Nevertheless, future sampling should be alert to potential acetone or alcohol detections. • Screens 1 and 2 did not produce sufficient water for pump development. • Cement-tainted fluids were detected at screen 3 during development, possibly introduced during placement of the primary filter pack at screen 3 that included considerable amounts of formation materials plus possible introduced material from higher in the hole.
Additives Used		Both QUIK-FOAM and EZ-MUD were mixed with injection water during drilling. QUIK-FOAM, EZ-MUD, and TORKEASE polymer were used behind the casing during casing advance. EZ-MUD was also used in the emplacement of annular fill bentonites. The quantities used are not listed in the well completion report. Fluids recovered during development—34,762 gal. principally from screen 3 (7365 gal.), screen 4 (15,785 gal.), screen 5 (3526 gal.), and the sump (8086 gal.). Very little water was removed through screens 1 and 2.
Annular Fill Other Than Filter and Transition Sands		Holeplug ⅜ in. bentonite chips (1000 50-lb bags = 50,000 lb) Pelplug bentonite—0.25 in. by 0.375-in. refined elliptical pellets (238 5-gal. buckets = 1190 gal.) Portland cement (190 94-lb bags = 17,860 lb) (mostly near surface but also above screens 1 and 2, between screens 2 and 3, and between screens 3 and 4)

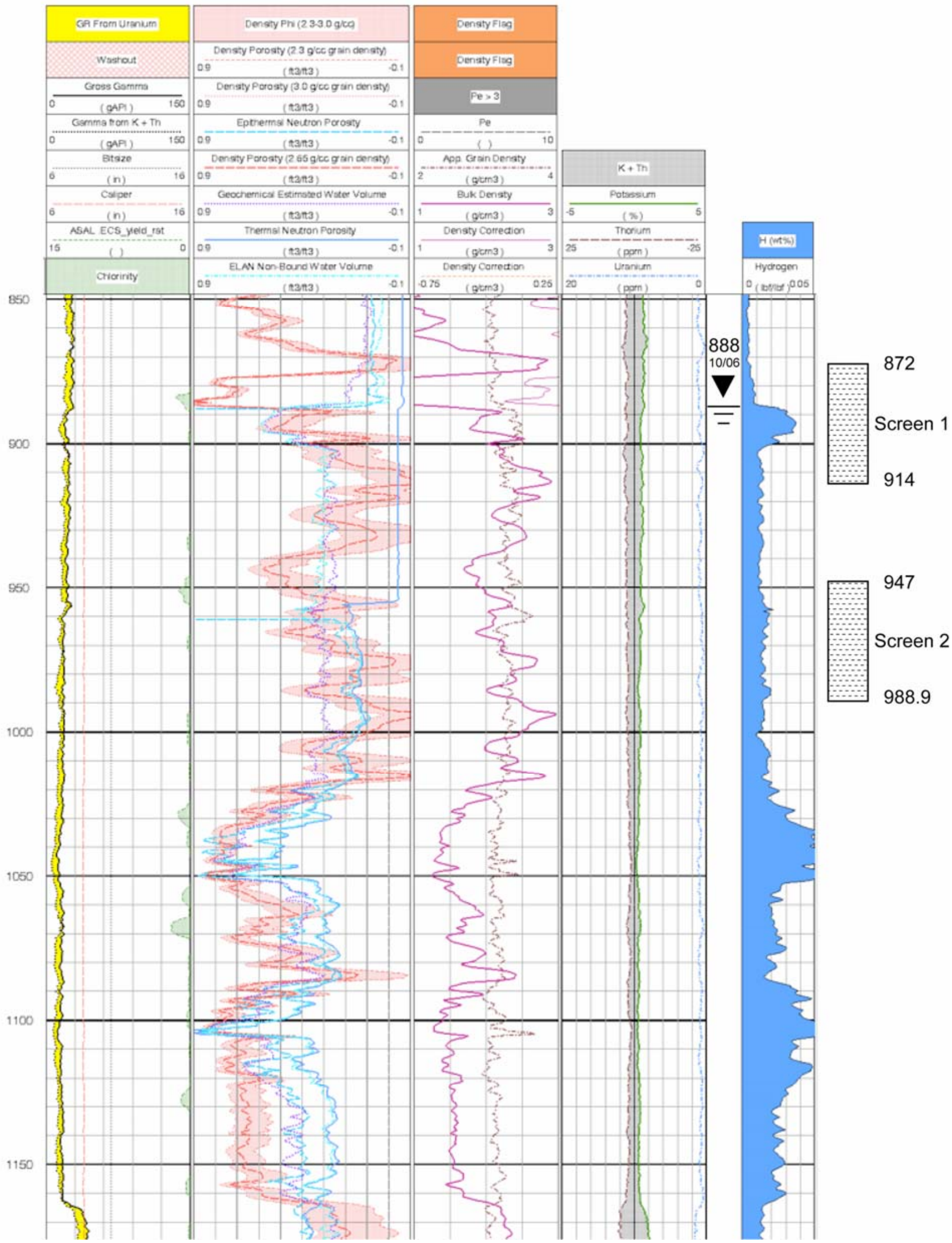

elevation (ft)
depth (ft)
Qbt2
Qbt1v
Qbt1g
Otowi, Qbo
Guaje, Qbog
Cerros del Rio
water table @883 ft
Screen #1
Screen #2
Puye Fm.
Screen #3
Older basalt
Screen #4
Santa Fe Group
Screen #5
1489 TD
gamma
SiO2
Sr
Mg#
tholeiitic
alkalic
cinder
sediment
calcrete
dacite
mixed
high Gd tholeiite
scoria
basaltic sediments
alkalic to tholeiitic lavas
lavas, cinder, and sediment
tholeiitic to dacitic bimodal series
masive tholeiiitic flow series

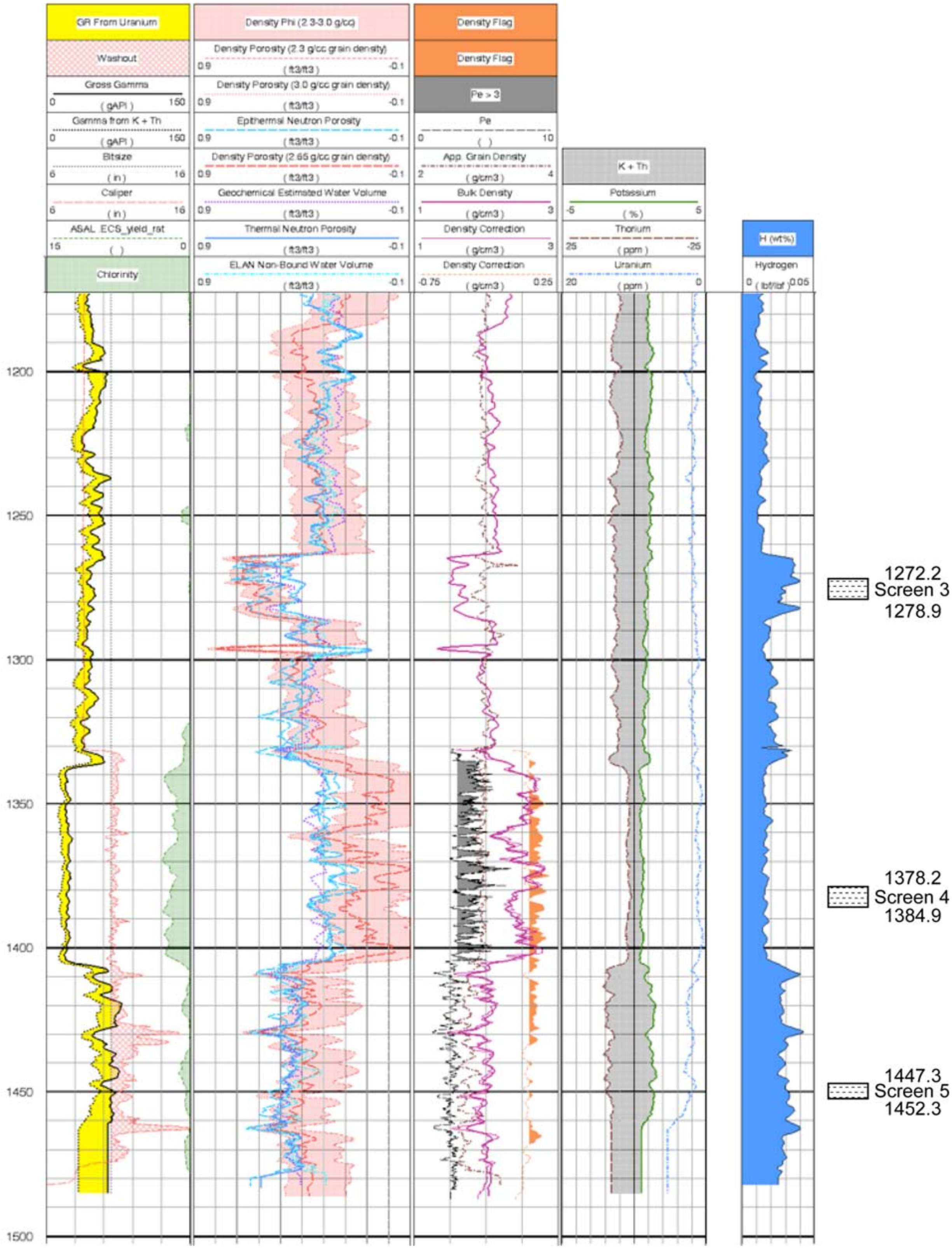


Centralizer Depths (ft)

70	872	1287
180	919	1341
280	945	1370
380	994	1395
480	1070	1440
580	1155	1465
680	1220	
774	1265	

Note: The screen intervals list the footages of the pipe perforations, not the tops and bottoms of screen joints.


GR From Uranium
Washout
Gross Gamma
Gamma from K + Th
Bitsize
Caliper
ASAL_ECS_yield_rst
Chlorinity
Density Phi (2.3-3.0 g/cc)
Density Porosity (2.3 g/cc grain density)
Density Porosity (3.0 g/cc grain density)
Epithermal Neutron Porosity
Density Porosity (2.65 g/cc grain density)
Geochemical Estimated Water Volume
Thermal Neutron Porosity
ELAN Non-Bound Water Volume
Density Flag
Pe > 3
Pe
App. Grain Density
Bulk Density
Density Correction
K + Th
Potassium
Thorium
Uranium
H (wt%)
Hydrogen
850
900
950
1000
1050
1100
1150
888
10/06
872
Screen 1
914
947
Screen 2
988.9


GR From Uranium
Washout
Gross Gamma
Gamma from K + Th
Bitsize
Caliper
ASAL.ECS_yield_rst
Chlorinity
Density Phi (2.3-3.0 g/cc)
Density Porosity (2.3 g/cc grain density)
Density Porosity (3.0 g/cc grain density)
Epithermal Neutron Porosity
Density Porosity (2.65 g/cc grain density)
Geochemical Estimated Water Volume
Thermal Neutron Porosity
ELAN Non-Bound Water Volume
Density Flag
Pe > 3
Pe
App. Grain Density
Bulk Density
Density Correction
K + Th
Potassium
Thorium
Uranium
H (wt%)
Hydrogen
1200
1250
1300
1350
1400
1450
1500
1272.2
Screen 3
1278.9
1378.2
Screen 4
1384.9
1447.3
Screen 5
1452.3

R-23 Well

R-23 Well		
	Description	Evaluation
Drilling Method	R-23 was drilled using fluid-assisted open-hole and casing advance methods to TD at 935-ft depth.	No core was collected at R-23. Drilling was by air-rotary methods with a combination of 16-in. tricone bit to 92-ft depth, where the bit became stuck. The tricone bit was removed and followed by a 12.25 in. under-reaming hammer from 92 to 170 ft, 10.625-in. under-reaming hammer from 170 to 238 ft, and 10.65-in. tricone bit from 238- to 287-ft depth through an interflow zone where lost circulation problems became significant. At that point, casing advance was used to remedy borehole instability and lost circulation problems. A 12.25-in. under-reaming hammer was used to widen the hole from 170 to 280 ft, followed by emplacement of 11.75-in. casing to 270 ft. From that point drilling was open-hole with a 10.625-in. tricone bit to a depth of 926 ft. The hole was then twice redrilled because of bridging up to a sand and clay zone at 540-ft depth, followed by emplacement of 9.625-in. casing into solid lava at 599-ft depth and redrilling through the base of the Cerros del Rio lavas and into Santa Fe Group sediments to a depth 935 ft with a 7.5-in. mill-tooth bit. Slough up to flow-base basaltic sediments at 812-ft depth required further redrilling with the 7.5-in. mill-tooth bit. Slough again up to the same sediments at 820-ft depth required use of a 10.75-in. under-reaming hammer to advance additional 9.-in. casing to 887 ft to allow emplacement of the well. R-23 was designed as a single-screen well.
General Well Characteristics	R-23 is a single-screen well constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction (816.0-873.2)	The pipe-based screen is constructed of 4.5-in.-I.D./5.56-in.-O.D. pipe drilled with 0.5-in. holes covered by wire screen having 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screen was introduced after two well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack and formation during development is less effective in those areas that are not adjacent to holes in the well casing. Also the wire wrap on the R-23 well screen contains 0.010-in. slots. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in. slot wire-wrapped rod-based screens to develop properly must be judged on the quality of groundwater data collected from the well. The screen at R-23 was developed successfully using brushing, surging, bailing, and pumping.

R-23 Well (continued)		
	Description	Evaluation
Screen Length and Placement	The screen is 57.2 ft long, placed from 816.0 to 873.2 ft depth. The top of the screen is 13 ft above the water table (829-ft depth after well development).	***Relevant stratigraphy:*** Cerros del Rio lavas (Tb 4) with intercalated sediments from 36 to 795-ft depth with a porous flow-base and scoria unit from 760 to 795 ft; sediments with basaltic detritus from 795- to 821-ft depth; Santa Fe Group sediments (Tsf) from 821 ft depth to TD (935 ft). ***Relevant geophysical log results:*** Most of the Schlumberger logging tools were run from 0- to 828-ft depth with casing extending to 599-ft depth and open hole below. Exceptions are the AIT and CMR tools, which were run only in the open section (599–828 ft). The tools used were CMR, CNT, TLD, AIT, NGS, and ECS. An ELAN was performed by Schlumberger using the log results. Results are somewhat limited because obstruction in the borehole allowed these logs to be collected only to within 1 ft of the top of regional saturation. The Schlumberger analysis indicated possible perched saturation at ~420–560-ft depth, above a very dense lava sequence at ~584–622-ft depth. A well dedicated to this perched zone was put off to a later date (see separate discussion of R-23i). The LANL video and natural gamma tools were run twice: from surface to 840-ft depth before well emplacement and within the completed well to 886-ft depth. ***Screen placement:*** The screen was located to straddle the top of regional saturation. The screen is within flow-base sediments below the Cerros del Rio lavas and upper deposits of the upper Santa Fe Group. Screen length and placement were selected to provide a monitoring point at the very top of the regional aquifer downgradient of contaminant sources in TA-54. Depth of the screen was limited by poor borehole stability beneath the water table.
Filter Pack Materials and Placement (Primary sand 789.0–883.0 ft; upper collar of secondary sand 782.5–789.0 ft; no lower secondary sand)	The primary filter pack is made up of 20/40 sand with an upper collar of secondary 30/70 sand.	Primary filter pack extends 27 ft above the screen openings and 9.8 ft below. The long upper filter pack allows access to Cerros del Rio flow-base sediments (760–795 ft) that indicated high CMR porosity in the Schlumberger logs, allowing for uncertainty in the true top of regional saturation because of groundwater perturbation that followed multiple redrilling of the section below the Cerros del Rio lavas.

R-23 Well (continued)		
	Description	Evaluation
Sampling System	Submersible pump	Submersible pumps installed in single completion wells allow groundwater to be purged from the well casing, well-filter pack, and to some degree, near-well formation materials. Water can pumped at a rate of 10–12 gal./min, greatly facilitating effective purging and efficient sampling. The pump installed at R-23 is a 4-in.-diameter 5 hp Grundfos capable of producing groundwater at 10 gal./min. There are some limitations on development by pumping when the screened interval straddles the water table, as at R-23. Conventional purging and sampling allow water to be drawn more deeply from within formation materials surrounding the well screen in comparison to low-flow systems. There is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. Water levels can be measured manually or by dedicated pressure transducers.
Other Issues That Could Affect the Performance of the Well	No seal between the filter pack and mobilized slough at the bottom of the well	The first attempt at emplacing the well was unsuccessful because of slough in the borehole to 830-ft depth. In order to bring the well down to target depth, EZ-MUD and air pressure were first used unsuccessfully. The well string was removed, and the 9.625-in. casing was advanced to 887 ft. The well was then reinserted and lowered from 882.8 to 886.3 ft using EZ-MUD solution to wash slough out of the bottom of the casing. Use of EZ-MUD to mobilize slough and wash the well into place could affect performance.
Additives Used		The drilling report provides the following information on additive use: Municipal water—55,000 gal. QUIK-GEL bentonite—28,250 lb LIQUI-TROL—46 gal. QUIK-FOAM—550 gal. Soda ash—41 lb Pac-L—700 lb N-seal—1830 lb Magma Fiber—2160 lb Additional additive use to wash out slough during well emplacement: EZ-MUD— (unspecified amount)
Annular Fill Other Than Filter and Transition Sands		Benseal granular bentonite——6250 lb (125 50-lb bags) Holeplug 0.375 in. bentonite chips—17,800 lb (356 50-lb bags) Pelplug bentonite pellets—17,850 lb (357 50-lb buckets) Cement grout surface seal—5358 lb (57 94-lb bags)
Water Produced On Development And Testing		3800 gal. was removed from the screen by bailing, brushing, and surging; 22,100 gal. was removed by pumping; and 5970 gal. was removed during hydrologic testing (total of 31,870 gal.).

Location: In Pajarito Canyon, just west of the N.M. 4 and Pajarito Road intersection; on the south side of Pajarito Road.

Survey coordinates (brass marker in NW corner of R-23 cement pad):
x: 1647914 E y: 1755165 N (NAD 83)
z: 6527.8 ft asl (NGVD 29)

Drilling: air rotary drilling, casing advance.
R-23 Start date: 8/17/02
R-23 End date: 9/27/02

Borehole R-23 drilled to 935.0 ft. bgs. (T.D.).

Data collection:
Hydrologic properties: Field hydraulic test: Pump test
Cores/cuttings submitted for geochemical and contaminant characterization: (0)
Groundwater samples submitted for geochem and contaminant characterization: (1)
Geologic properties: (14)
Mineralogy, petrography, and chemistry
Borehole logs from R-23:
Lithologic: 0-935.0 ft.
Video (LANL tool): 0-599 ft. (cased) and 599-826.6 ft. (open hole).
Natural gamma (LANL tool): 0-599 ft. (cased) and 599-840 ft. (open hole).
Schlumberger Logs: 0-599 ft. (cased) and 599-828 ft. (open hole): Litho density, Thermal/Epithermal Neutron, Array Induction, Natural Gamma, Elemental Capture, and Combinable Magnetic Resonance.

Contaminants Detected in R-23 Water Sample: none

Well construction:
Drilling Completed: 09/27/02.
Contract Geophysics: 09/23-24/02.
Well Constructed : 09/27/02-10/02/02.
Well Developed : 10/08/02-02/20/03
Dedicated Pump: 01/06/03-01/08/03

Casing: 4.5-in. I.D. stainless steel with external couplings.

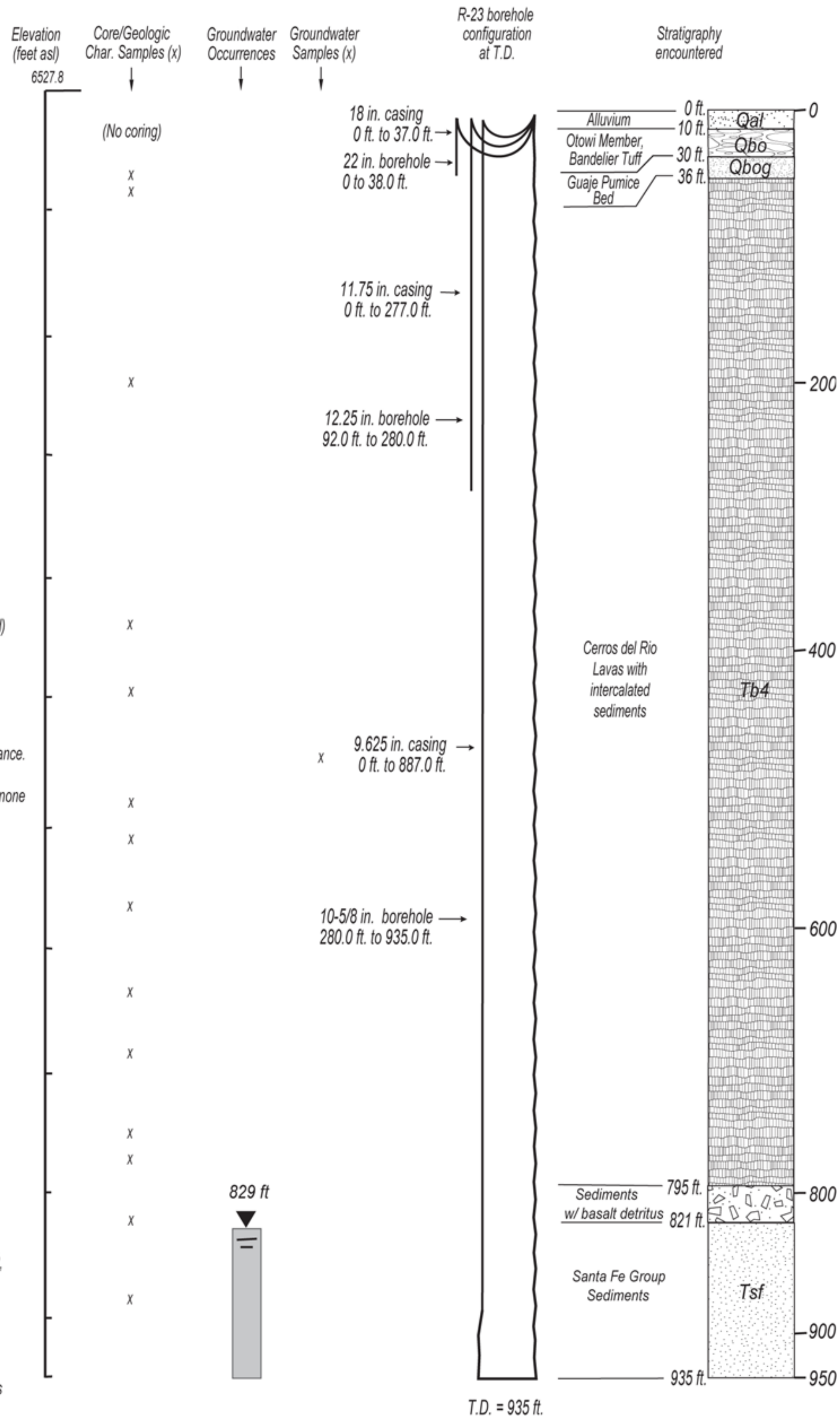
Number of Screens: 1
4.5-in. I.D. pipe based, s.s. wire-wrapped with 0.010-in slots.

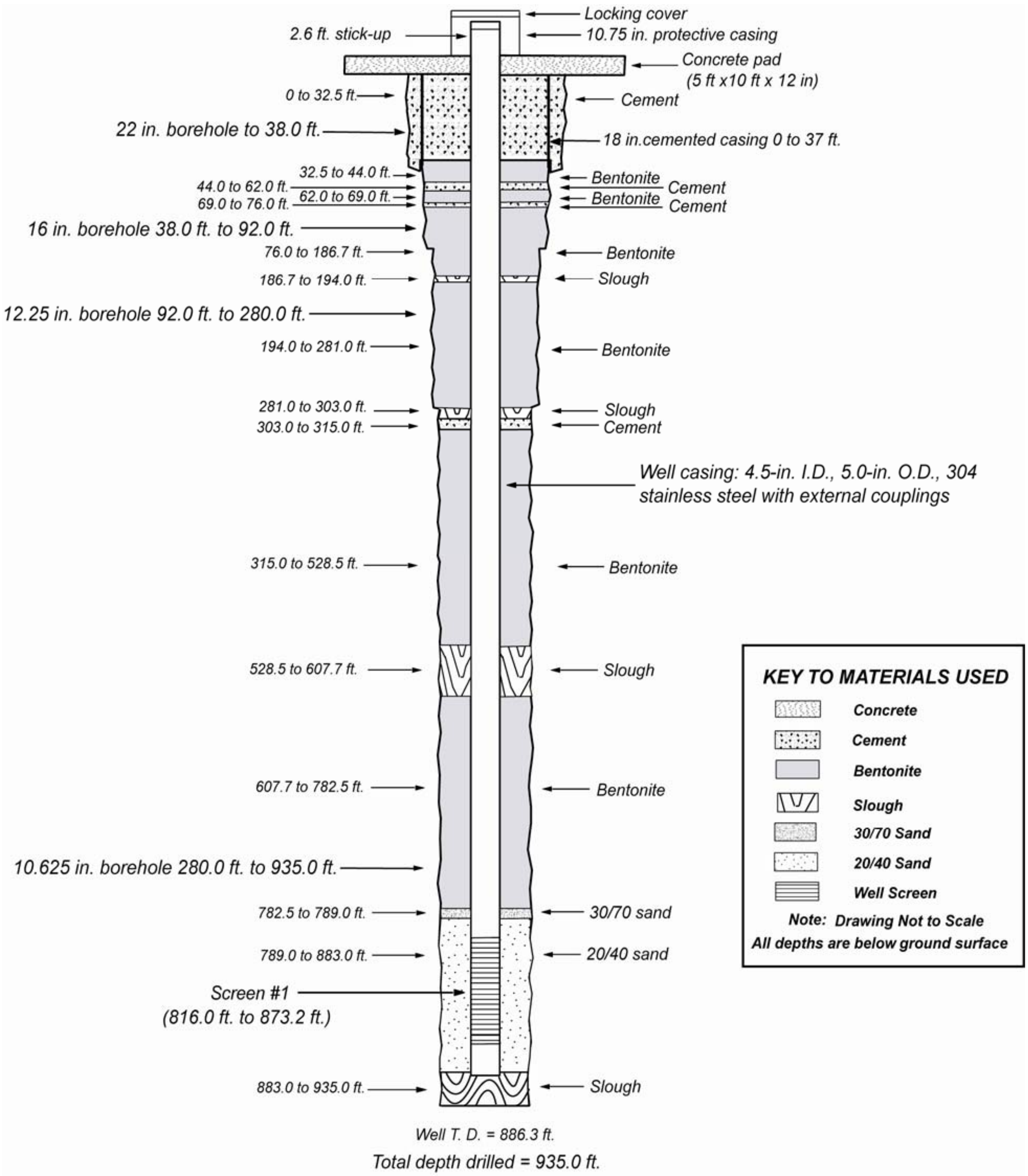
Screen (perforated pipe interval):
Screen #1 - 816.0 - 873.2 ft. bgs.

Well development consisted of wire brushing, bailing, surging, and pumping.

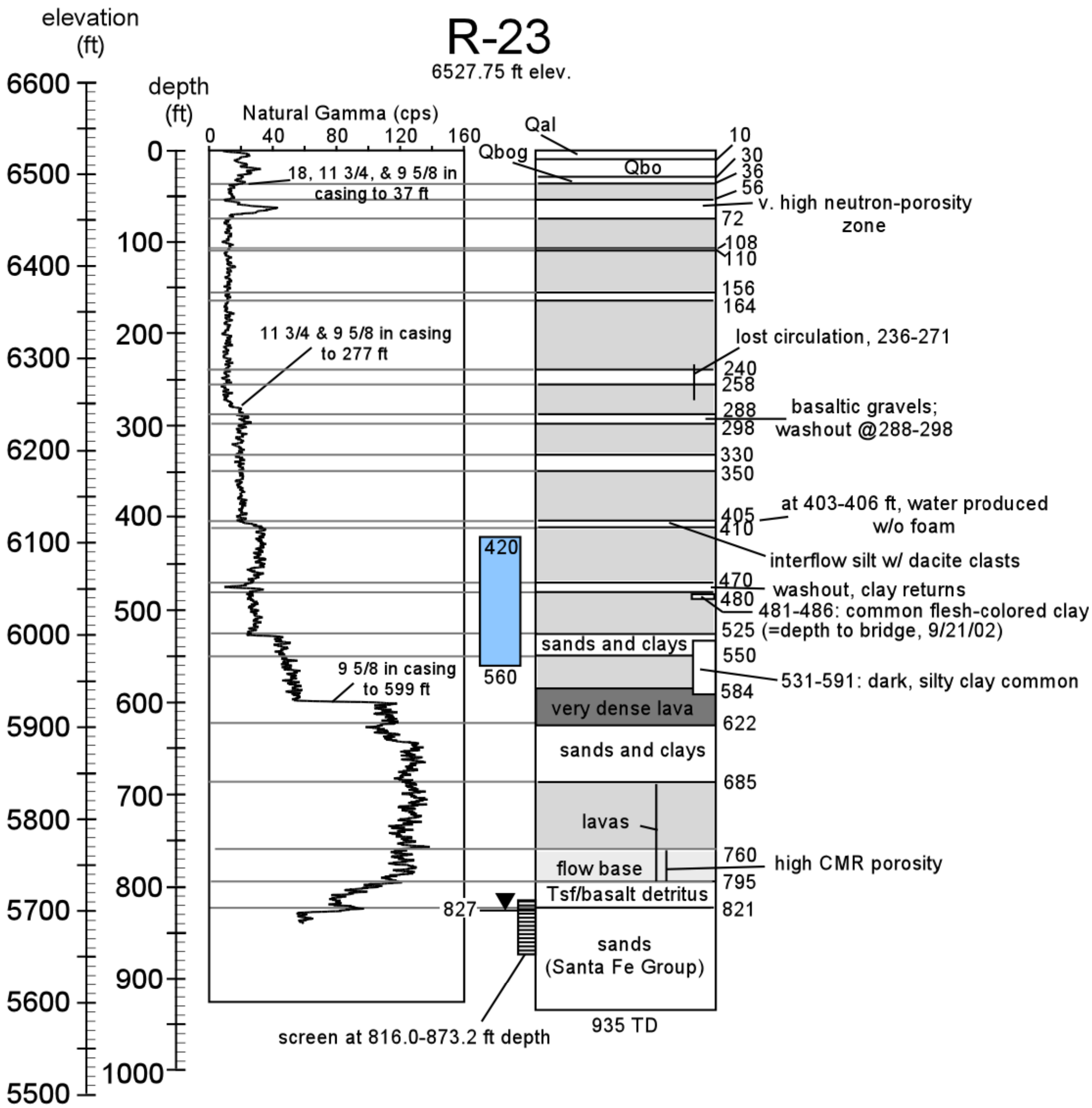
Static water level measured on October 8, 2002, in completed and developed well.

Geologic contacts for R-23 were determined by examination of cuttings and interpretation of geophysical logs. Contacts may be refined by petrologic, geochemical, or mineralogic analysis of geologic samples.





Note: 1. The screen interval lists the footage of the pipe perforations, not the top and bottom of screen joints.
2. Pipe-based screen: 4.5-in. I.D., 5.563-in. O.D., 304 stainless steel with s.s. wire wrap; 0.010-in slot.
3. The upper intervals of slough consist of basaltic gravels; slough at the base of the borehole consists of Santa Fe Group sands.
4. Centralizers not placed due to use of 9-5/8" casing for borehole stability.
5. Dedicated pump location not shown.
6. Well sump interval: 873.2 to 886.3 ft.



R-23
6527.75 ft elev.
elevation (ft)
depth (ft)
Natural Gamma (cps)
0 40 80 120 160
6600 6500 6400 6300 6200 6100 6000 5900 5800 5700 5600 5500
0 100 200 300 400 500 600 700 800 900 1000
18, 11 3/4, & 9 5/8 in casing to 37 ft
11 3/4 & 9 5/8 in casing to 277 ft
9 5/8 in casing to 599 ft
420
560
827
screen at 816.0-873.2 ft depth
Qal
Qbog
Qbo
10 30 36 56
v. high neutron-porosity zone
72 108 110 156 164
lost circulation, 236-271
240 258
basaltic gravels; washout @288-298
288 298 330 350
at 403-406 ft, water produced w/o foam
405 410
interflow silt w/ dacite clasts
470
washout, clay returns
480
481-486: common flesh-colored clay
525 (=depth to bridge, 9/21/02)
sands and clays
550
531-591: dark, silty clay common
584
very dense lava
622
sands and clays
685
lavas
760
high CMR porosity
flow base
795
Tsf/basalt detritus
821
sands (Santa Fe Group)
935 TD

R-23i Well and Piezometer

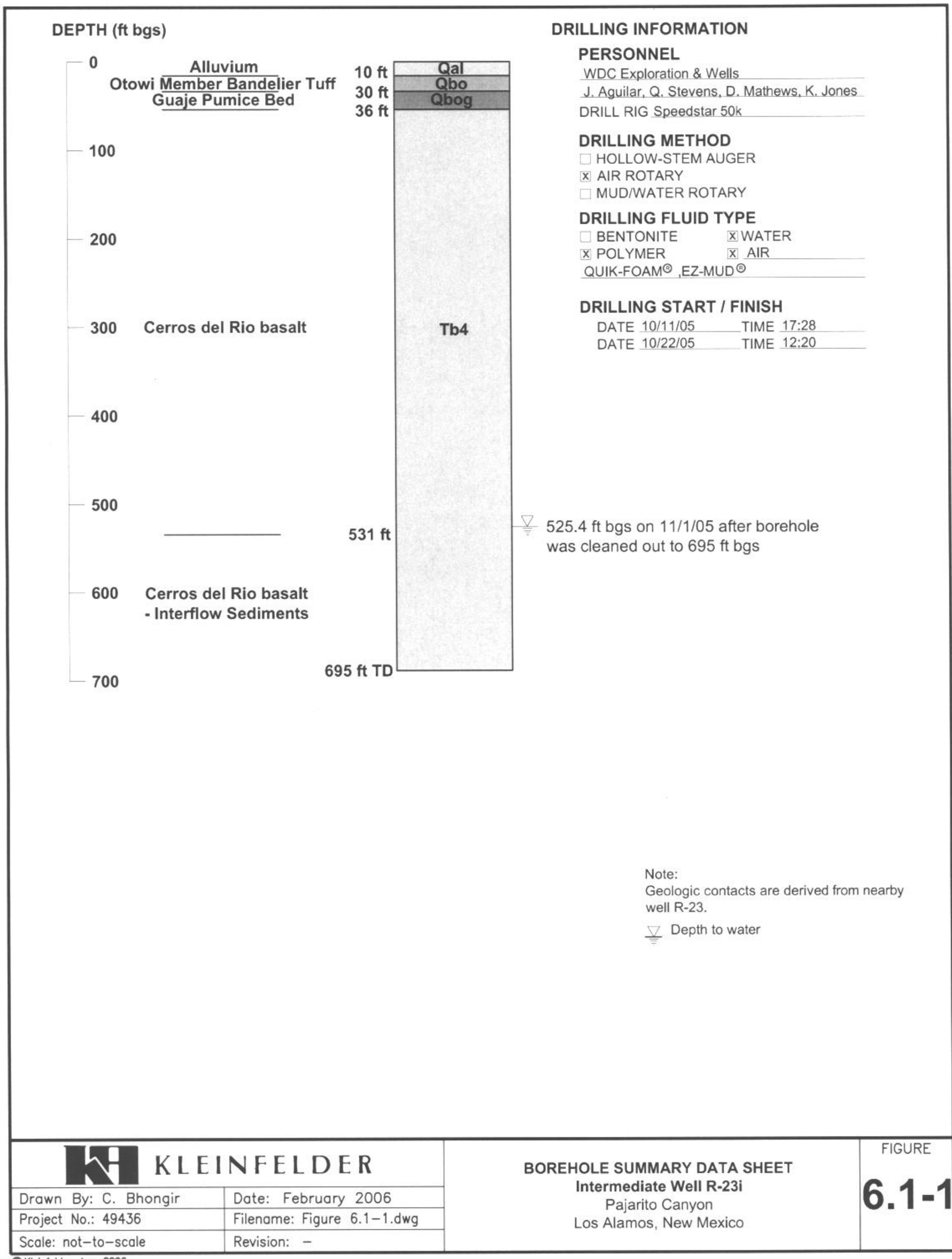
R-23i Well and Piezometer		
	Description	Evaluation
Drilling Method	R-23i was drilled to 695-ft depth using air-rotary and fluid-assisted air-rotary methods. Both a tricone bit and a down-the-hole-hammer were used.	No core was collected at R-23i. A 12.25-in. tricone bit was used to drill to 100-ft depth. Because of lost circulation, the interval from 41 to 94 ft was cemented and drilled through with a 12.25-in. hammer bit. This bit was then used to drill open-hole to a depth of 695 ft. After drilling open hole, 9 ⅝-in. casing was advanced in stages to 656-ft depth in order to test intervals where water was suspected of entering the borehole. R-23i was designed as a two-screen well. A shallower piezometer was also installed in the annulus adjacent to the primary well. All screens are in intervals above the zone of regional saturation (see well R-23 for description of regional aquifer well emplacement at this site).
General Well Characteristics	The well at R-23i is two-screen and is constructed of 4.5-in.-I.D./5-in.-O.D. 304 stainless-steel casing. The piezometer at R-23i is single-screen and is constructed of 2.1-in.-I.D./2.4-in.-O.D. stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well and Piezometer Screen Construction ***Well:*** (470.2-480.1 and 524.0–547.0) ***Piezometer:*** (400.3–405.9)	**Well:** The rod-based wire-wrapped screens are constructed of 4.5-in. I.D./5.3-in.-O.D. stainless-steel casing wrapped with stainless-steel wire wrap with 0.020-in. slots. **Piezometer:** The rod-based wire-wrapped screens are constructed of 2.1-in.-I.D./2.4-in.-O.D. stainless-steel casing wrapped with stainless-steel wire wrap with 0.020-in. slots.	Rod-based screen provides extensive, uniformly distributed openings for access to the filter pack during development. Also, the 0.020-in. slots in the R-23i screens allow greater water movement during development than 0.010-in. screen openings. The ability of 0.020-in. slot wire-wrapped rod-based screens to develop properly must be judged on the quality of groundwater data collected from the well. The upper screen in the well at R-23i was developed to a point where NTUs were consistently <5, but the lower screen remained turbid (NTUs off-scale). The screen in the piezometer produced very little water and could not be aggressively developed; NTUs in the piezometer were also off-scale.

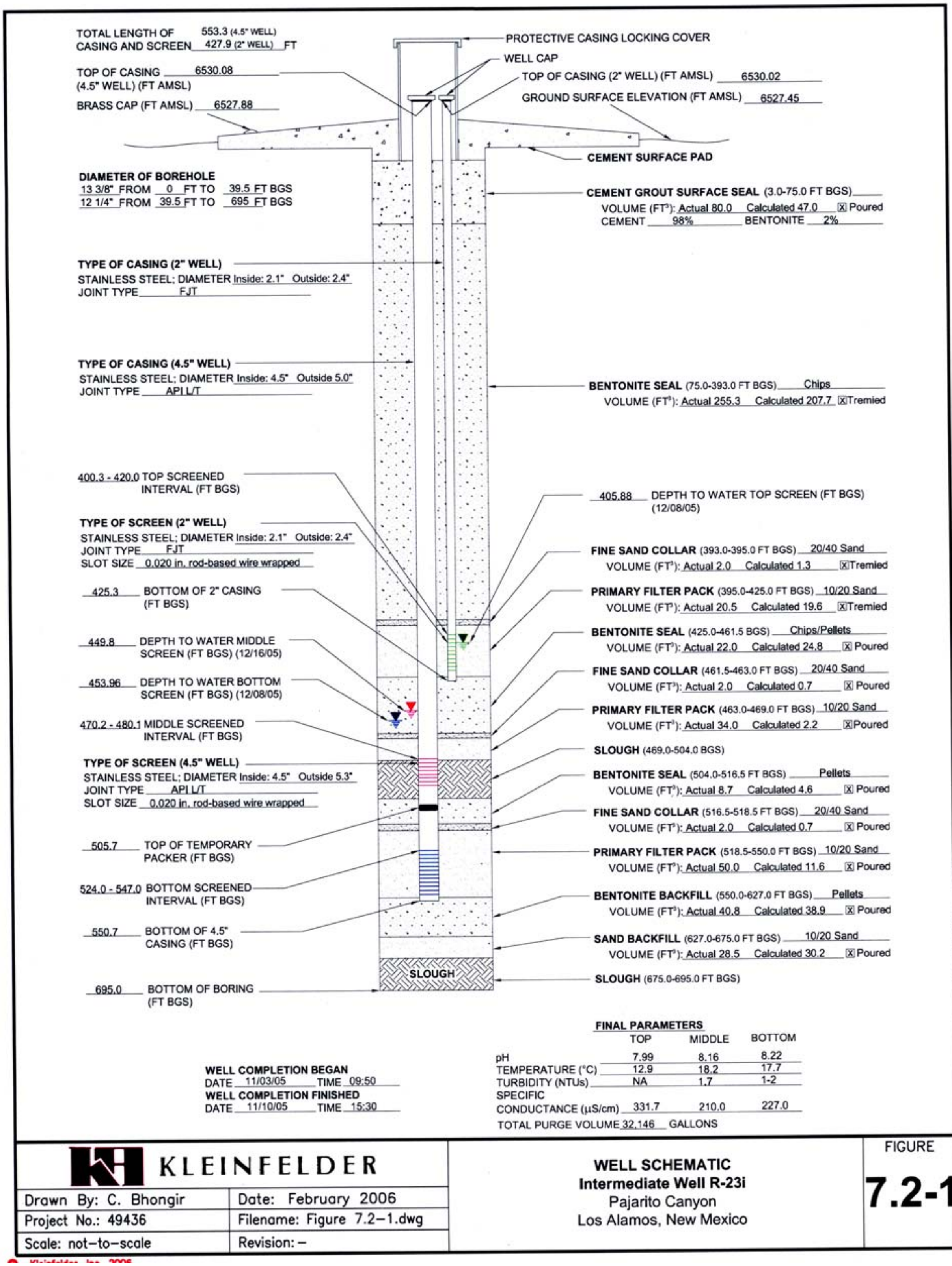
R-23i Well and Piezometer (continued)		
	Description	Evaluation
Screen Lengths and Placement	**Well:** The upper screen in the well at R-23i is 9.9 ft long, placed from 470.2- to 480.1-ft depth. The top of this screen is 20.4 ft below the top of perched saturation as measured at this screen (449.8-ft depth on 12/16/05, following well development). The lower screen in the well at R-23i is 23 ft long, placed from 524.0- to 547.0-ft depth. The top of this screen is 20.4 ft below the top of perched saturation as measured at this screen (454.0-ft depth on 12/8/05, following well development). **Piezometer:** The piezometer at R-23i is 19.7 ft long, placed from 400.3- to 420.0-ft depth. Depth to water in the piezometer was measured at 5.6 ft below the top of the screen (DTW of 405.9 ft on 12/8/05, after installation but before development).	***Relevant stratigraphy:*** (Based on R-23) Quaternary alluvium (Qal) to 10-ft depth; ash flows of the Otowi Member (Qbo) from 10- to 30-ft depth; Guaje Pumice Bed from 30- to 36-ft depth; Cerros del Rio lavas (Tb 4) and intercalated sediments from 36 ft to TD at 695 ft. ***Relevant geophysical and video log results:*** Four video logs were run by Kleinfelder and one by LANL at R-23. In addition, one gamma log and three induction logs were run by Kleinfelder. Results of these logs indicated the following: 10/20/05: With drilled depth at 560 ft, water was seeping into the borehole at 403.5-ft depth; standing water was at 455 ft depth. After blowing water out of the hole, it was nevertheless again found standing at 455-ft depth on a second video log. 10/21/05: After TD at 695 ft, an induction tool hit a bridge at 470-ft depth. 10/22/05: Video log found bridge at 476-ft depth; depth to bridge tagged at 468.5 ft after video. 10/23/05: Water was seeping into borehole at 403-ft depth and standing water was at 464-ft depth. Induction tool hit a bridge at 473–475-ft depth. 11/1/05: Induction tool hit a bridge at 483-ft depth. 11/7/05: Video of annulus outside well casing noted no standing water to 423.5-ft depth. Schlumberger logging tools were not used at R-23i. However, Schlumberger logs were run at nearby R-23 (25 ft distant). At R-23 most of the Schlumberger logging tools were run from 0- to 828-ft depth, with casing extending to 599-depth and open hole below. Exceptions are the AIT and CMR tools, which were run only in the open section (599–828 ft). The tools used were CMR, CNT, TLD, AIT, NGS, and ECS. An ELAN analysis was performed by Schlumberger using the log results. Results are of somewhat limited use at R-23 because an obstruction in the borehole allowed the logs to be collected only within 1 ft of the top of regional saturation, but the logs span the perched interval at R-23i and have relevance for this drill hole. The Schlumberger logs indicate very high-density lava from 584- to 624-ft depth, providing a likely perching horizon. Interflow or flow-rubble intervals of higher porosity are evident at 472–478-ft depth and spread broadly across the zone from 525- to 545-ft depth.

R-23i Well and Piezometer (continued)		
	Description	Evaluation
Screen Lengths and Placement (continued)		***Placement of R-23i well screens:*** The two screens in the R-23i well are located to capture the two most porous zones indicated in the Schlumberger logs that were collected at R-23 (porosity estimated for these zones at R-23 is likely to be exaggerated because of washout). The upper screen (470.2–480.1 ft) spans the porous zone at 472–478-ft depth. The lower screen (524.0–547.0 ft) spans the porous zone at 525–545-ft depth while staying above the top of the dense lava (584-ft depth) that may provide a perching horizon. ***Piezometer screen placement:*** The piezometer at R-23i (400.3–420.0 ft) is located to capture the highest indication of seepage into the borehole noted in video logs (403–403.5-ft depth) as well as wet intervals along the borehole wall below that point.
Filter Pack Materials and Placement ***Well upper screen:*** (primary 463.0–469.0 ft; upper secondary sand 461.5–463.0 ft; slough covers most of the screen) ***Well lower screen:*** (primary 518.5–550.0 ft; upper secondary sand 516.5–518.5 ft) ***Piezometer screen:*** (primary 395.0–425.0 ft; upper secondary sand 393.0–395.0 ft)	The primary filter packs are made up of 10/20 sand. Upper collars of 20/40 secondary sand were emplaced.	***Well upper screen:*** Primary filter pack extends 7.2 ft above the screen openings and extends downward into only 1.2 ft of the upper part of the screen; slough covers the remaining 8.7 ft (88%) of the screen length. ***Well lower screen:*** Primary filter pack extends 5.5 ft above the screen openings and 3.0 ft below. ***Piezometer screen:*** Primary filter pack extends 5.3 ft above the screen openings and 5.0 ft below.

R-23i Well and Piezometer (continued)		
	Description	Evaluation
Sampling system	Baski packer with dual-pump system	A Baski packer with dual-pump system was installed in the deep R-23i monitoring well. This system uses a packer to isolate the two screen intervals and a dedicated pump within each interval to provide discrete groundwater samples; no valves or associated control lines are used in the dual-pump system. This sampling system is a relatively high-flow system capable of pumping rates adequate for conventional purging and sampling. Pumping rates at R-23i are 1.6 and 1.9 gal./min which were designed for the specific capacity of the formation; higher flow rates may be obtained with this system in other wells. Purging and sampling with the Baski system allow water to be drawn more deeply from within formation materials surrounding the well screen in comparison to low-flow systems. There is a greater likelihood of obtaining water from zones beyond potential near-well drilling effects. Storage and disposal of purged water require additional resources relative to low-flow sampling systems. The Baski packer system incorporates separate gage tubes that provide access to each screen zone using conventional transducer equipment and manual measurement methods
Other Issues That Could Affect the Performance of the Well	Slough covering most of the upper screen	In hydrologic testing, it was noted that in combined pumping of the two screens in the well, the calculated storage equaled the annulus volume. This suggests that there may be an open void outside the well casing at ~465-ft depth. This result could have been a coincidence or could indicate the presence of a void between the borehole and the well casing at the elevation where the water level was changing—about 465 ft bgs. During well construction, the volume of annular fill material required between 463 and 550 ft was 5 times the calculated amount (95 vs. 19 ft^3) because of bridging and cleanout attempts that occurred after TD was reached. During construction, slough filled the annulus between 504 and 469 ft bgs, with the latter depth being the approximate depth of the bridge that had developed in the open borehole. It is possible that a void formed in this interval, although the screened interval was swabbed to settle the native formation across the middle screened interval. Also, if present, the void probably represents a local feature; water-level measurements indicate screens 2 and 3 are hydraulically isolated.
Additives Used		Air-rotary drilling was assisted by municipal water mixed with limited amounts of QUIK-FOAM and EZ-MUD, followed by defoamer to accommodate the downhole video log. The drilling report provides the following information on additive use: Municipal water—4,679 gal. QUIK-FOAM—82 gal. EZ-MUD—15 gal. Defoamer—less than 1 gal.
Annular Fill Other Than Filter and Transition Sands		Bentonite chips/pellets—326.8 ft^3 Cement slurry surface seal with 2% bentonite—80 ft^3

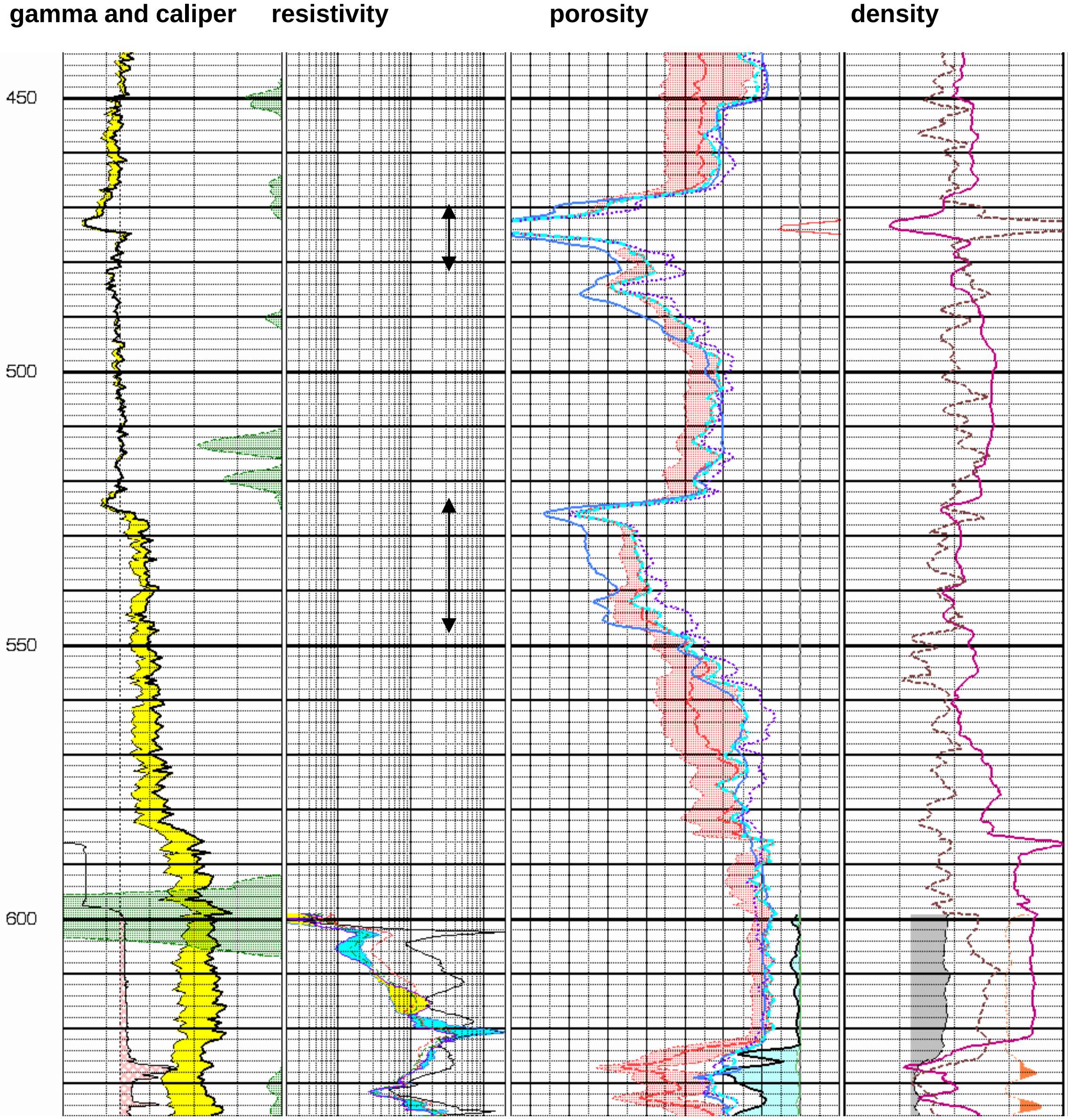
R-23i Well and Piezometer (continued)		
	Description	Evaluation
Water Produced On Development And Testing		**R-23i well:** For both screens without packer emplaced, 350 gal. bailed and swabbed and1649 gal. pumped. With packer emplaced, an additional 25,796 gal. was pumped from the lower screen and 4264 gal. from the upper screen. Aquifer testing of the lower screen removed an additional 1189 gal. from that screen. **R-23i piezometer:** 88 gal. bailed; no pumping.


DEPTH (ft bgs)
0
100
200
300
400
500
600
700
Alluvium
Otowi Member Bandelier Tuff
Guaje Pumice Bed
10 ft
30 ft
36 ft
Qal
Qbo
Qbog
Cerros del Rio basalt
Tb4
531 ft
Cerros del Rio basalt - Interflow Sediments
695 ft TD
525.4 ft bgs on 11/1/05 after borehole was cleaned out to 695 ft bgs
DRILLING INFORMATION
PERSONNEL
WDC Exploration & Wells
J. Aguilar, Q. Stevens, D. Mathews, K. Jones
DRILL RIG Speedstar 50k
DRILLING METHOD
HOLLOW-STEM AUGER
X AIR ROTARY
MUD/WATER ROTARY
DRILLING FLUID TYPE
BENTONITE
X WATER
X POLYMER
X AIR
QUIK-FOAM®, EZ-MUD®
DRILLING START / FINISH
DATE 10/11/05 TIME 17:28
DATE 10/22/05 TIME 12:20
Note:
Geologic contacts are derived from nearby well R-23.
Depth to water
KLEINFELDER
Drawn By: C. Bhongir
Date: February 2006
Project No.: 49436
Filename: Figure 6.1-1.dwg
Scale: not-to-scale
Revision: –
BOREHOLE SUMMARY DATA SHEET
Intermediate Well R-23i
Pajarito Canyon
Los Alamos, New Mexico
FIGURE
6.1-1



TOTAL LENGTH OF CASING AND SCREEN 553.3 (4.5" WELL) 427.9 (2" WELL) FT
TOP OF CASING (4.5" WELL) (FT AMSL) 6530.08
BRASS CAP (FT AMSL) 6527.88
PROTECTIVE CASING LOCKING COVER
WELL CAP
TOP OF CASING (2" WELL) (FT AMSL) 6530.02
GROUND SURFACE ELEVATION (FT AMSL) 6527.45
CEMENT SURFACE PAD
DIAMETER OF BOREHOLE
13 3/8" FROM 0 FT TO 39.5 FT BGS
12 1/4" FROM 39.5 FT TO 695 FT BGS
CEMENT GROUT SURFACE SEAL (3.0-75.0 FT BGS)
VOLUME (FT³): Actual 80.0 Calculated 47.0 [X] Poured
CEMENT 98% BENTONITE 2%
TYPE OF CASING (2" WELL)
STAINLESS STEEL; DIAMETER Inside: 2.1" Outside: 2.4"
JOINT TYPE FJT
TYPE OF CASING (4.5" WELL)
STAINLESS STEEL; DIAMETER Inside: 4.5" Outside 5.0"
JOINT TYPE API L/T
BENTONITE SEAL (75.0-393.0 FT BGS) Chips
VOLUME (FT³): Actual 255.3 Calculated 207.7 [X]Tremied
400.3 - 420.0 TOP SCREENED INTERVAL (FT BGS)
405.88 DEPTH TO WATER TOP SCREEN (FT BGS) (12/08/05)
TYPE OF SCREEN (2" WELL)
STAINLESS STEEL; DIAMETER Inside: 2.1" Outside: 2.4"
JOINT TYPE FJT
SLOT SIZE 0.020 in. rod-based wire wrapped
FINE SAND COLLAR (393.0-395.0 FT BGS) 20/40 Sand
VOLUME (FT³): Actual 2.0 Calculated 1.3 [X]Tremied
425.3 BOTTOM OF 2" CASING (FT BGS)
PRIMARY FILTER PACK (395.0-425.0 FT BGS) 10/20 Sand
VOLUME (FT³): Actual 20.5 Calculated 19.6 [X]Tremied
BENTONITE SEAL (425.0-461.5 BGS) Chips/Pellets
VOLUME (FT³): Actual 22.0 Calculated 24.8 [X] Poured
449.8 DEPTH TO WATER MIDDLE SCREEN (FT BGS) (12/16/05)
FINE SAND COLLAR (461.5-463.0 FT BGS) 20/40 Sand
VOLUME (FT³): Actual 2.0 Calculated 0.7 [X] Poured
453.96 DEPTH TO WATER BOTTOM SCREEN (FT BGS) (12/08/05)
PRIMARY FILTER PACK (463.0-469.0 FT BGS) 10/20 Sand
VOLUME (FT³): Actual 34.0 Calculated 2.2 [X]Poured
470.2 - 480.1 MIDDLE SCREENED INTERVAL (FT BGS)
SLOUGH (469.0-504.0 BGS)
TYPE OF SCREEN (4.5" WELL)
STAINLESS STEEL; DIAMETER Inside: 4.5" Outside 5.3"
JOINT TYPE API L/T
SLOT SIZE 0.020 in. rod-based wire wrapped
BENTONITE SEAL (504.0-516.5 FT BGS) Pellets
VOLUME (FT³): Actual 8.7 Calculated 4.6 [X] Poured
FINE SAND COLLAR (516.5-518.5 FT BGS) 20/40 Sand
VOLUME (FT³): Actual 2.0 Calculated 0.7 [X] Poured
505.7 TOP OF TEMPORARY PACKER (FT BGS)
PRIMARY FILTER PACK (518.5-550.0 FT BGS) 10/20 Sand
VOLUME (FT³): Actual 50.0 Calculated 11.6 [X] Poured
524.0 - 547.0 BOTTOM SCREENED INTERVAL (FT BGS)
BENTONITE BACKFILL (550.0-627.0 FT BGS) Pellets
VOLUME (FT³): Actual 40.8 Calculated 38.9 [X] Poured
550.7 BOTTOM OF 4.5" CASING (FT BGS)
SAND BACKFILL (627.0-675.0 FT BGS) 10/20 Sand
VOLUME (FT³): Actual 28.5 Calculated 30.2 [X] Poured
SLOUGH
SLOUGH (675.0-695.0 FT BGS)
695.0 BOTTOM OF BORING (FT BGS)
FINAL PARAMETERS
TOP MIDDLE BOTTOM
pH 7.99 8.16 8.22
TEMPERATURE (°C) 12.9 18.2 17.7
TURBIDITY (NTUs) NA 1.7 1-2
SPECIFIC CONDUCTANCE (µS/cm) 331.7 210.0 227.0
TOTAL PURGE VOLUME 32,146 GALLONS
WELL COMPLETION BEGAN
DATE 11/03/05 TIME 09:50
WELL COMPLETION FINISHED
DATE 11/10/05 TIME 15:30
KLEINFELDER
Drawn By: C. Bhongir
Date: February 2006
Project No.: 49436
Filename: Figure 7.2-1.dwg
Scale: not-to-scale
Revision: –
WELL SCHEMATIC
Intermediate Well R-23i
Pajarito Canyon
Los Alamos, New Mexico
FIGURE
7.2-1

Schlumberger log section (from nearby borehole R-23)



Arrows indicate locations of upper and lower screens in the well at R-23i.

Gamma, caliper and resistivity (only below casing at 599 ft), resistivity, and density increase to the right; porosity increases to the left (full scale for porosity is 0.75).

R-32 Well

R-32 Well		
	Description	Evaluation
Drilling Method	R-32 was drilled using a combination of fluid-assisted air-rotary methods, casing advance, and mud-rotary drilling.	R-32 was drilled using reverse-circulation air-rotary methods in an open hole to a depth of 808 ft. Loss of drilling fluid circulation was a significant problem while drilling through the Cerros del Rio basalt. Because of these circulation problems, 11.75-in. thin-wall casing was installed to a depth of 797.3 ft and sealed in place with cement and bentonite so that the borehole could be advanced to the target depth (1356 ft). Before installation of the 11.75-in. casing, Schlumberger, Inc., collected a suite of geophysical logs in the open borehole. Following geophysical logging, an open borehole was advanced to a depth of 908 ft depth using reverse-circulation fluid-assisted air-rotary drilling. Because of persistent circulation problems, the borehole was completed using a conventional-circulation mud-rotary system in the interval from 908 to 1008 ft (TD). The borehole was terminated at 1008 ft because circulation of drilling mud was lost and could not be reestablished. The combination of drilling fluid loss and use of mud-rotary drilling in the well screen intervals are significant issues for the ability of R-32 well screens to produce representative and reliable water-quality data. Drilling additives can adversely affect the ability to collect representative water samples if they are not removed from the well during development. At R-32, air and municipal water mixed with QUIK-FOAM, LIQUI-TROL, QUIK-GEL, and soda ash were used to drill an open borehole in the interval from 0 to 808 ft. The 11.75-in. casing was then installed to a depth of 797.3 ft. Open borehole drilling below 797.3 ft exposed the borehole wall to mud-drilling additives including N-SEAL, PAC-L, EZ-MUD, LIQUI-TROL, and Magma Fiber. Well development was particularly aggressive at R-32 to remove residual drilling fluids. At R-32, well development consisted of wire brushing the well interior, surging to draw fine sediment from the constructed filter packs, and bailing to remove unwanted solid materials from the well. In addition, the well was pumped to remove any remaining fines from the filter pack and adjacent formation. As part of development, chemical treatments were applied to the well screens to break up borehole wall mud filter cake and disperse particulate matter that resulted from adding drilling fluids during conventional mud-rotary drilling. Chemical treatment included surging mixtures of 1 gal. of AQUA-CLEAR-PFD and 400 gal. of municipal water into the three well screens. Following surging and bailing, a solution containing 90 lb of AQUA-CLEAR-MGA, 9 gal. of AQUA-CLEAR-AE, and 330 gal. of municipal water mixed was pumped into the well and surged into all three screens. Following chemical treatment, the well was initially pumped by lowering a submersible pump next to each well screen without the use of packers. Packers were then positioned above and below each well screen, and additional development pumping was conducted. About 144,970 gal. of water was removed from the well during development.

R-32 Well (continued)		
	Description	Evaluation
Drilling Method (continued)		The combination of drilling fluid loss and use of mud-rotary drilling in the well screen intervals are significant issues for the ability of R-32 well screens to produce representative and reliable water-quality data. Residual drilling fluids can interact with some contaminants and mask their detection. To address these issues, well development was particularly aggressive at R-32. The efficacy of well development and the impact of residual drilling fluids must be evaluated by examining the quality of groundwater data collected from the completed well.
General Well Characteristics	R-32 is a three-screen well constructed of 4.5-in.-I.D. and 5.0-in.-O.D.-type A304 stainless-steel casing.	The stainless-steel well materials are designed to prevent corrosion.
Well Screen Construction	The pipe-based screens are constructed of 4.5-in.-I.D./5.563-in.-O.D. 304 perforated stainless-steel casing wrapped with stainless-steel wire wrap with 0.010-in. slots.	Pipe-based screen provides structural stability to well screens that might otherwise be damaged during well installation or by shifting geologic materials after well installation. Pipe-based screens were used at R-32 after two rod-based well screens were damaged during installation of well R-25. A drawback to pipe-based screens is that water surged into the filter pack and formation during development may be less effective at developing the well in those areas that are not adjacent to holes in the well casing. Also, the wire wrap on the R-32 well screens contains 0.010-in. slots. More recent wells contain 0.020-in. slots that facilitate the movement of water through the well screen when surging and pumping the well during development. The ability of 0.010-in. slot wire-wrapped pipe-based screen to develop properly must be judged on the quality of groundwater data collected from the wells.
Screen Length and Placement	Screen 1 extends from 867.5 to 875.2 ft (length of 7.7 ft). The current water level in screen 1 is about 778 ft bgs. Screen 2 extends from 931.8 to 934.9 ft (length of 3.1 ft). The current water level in screen 2 is about 788 ft bgs. Screen 3 extends from 972.9 to 980.6 ft (length of 7.7 ft). The water level in screen 3 is currently 788.6 ft bgs.	R-32 well screen lengths and placements were selected with the following goals in mind: • Investigate the nature and extent of impacts to regional groundwater that resulted from LANL activities in the Pajarito Canyon watershed • Screen across hydrostratigraphic units that might be expected to be along contaminant flow paths • Determine the magnitude and direction of vertical pressure gradients in the vicinity of TA-54 • Monitor water levels at multiple depths to determine pressure responses to municipal well pumping in the Pajarito well field

R-32 Well (continued)		
	Description	Evaluation
Screen Length and Placement (continued)		The upper part of the regional aquifer at R-32 occurs in the lower part of a thick stack of lavas, interflow breccias, cinder deposits, and interflow sediments that make up the Pliocene Cerros del Rio basalt. The water level was stable at a depth of 722 ft when geophysical logs were collected in the open borehole by Schlumberger. At the time, it was not clear whether this water level represented the top of the regional aquifer or if it was drilling fluid that accumulated in the open borehole. The Schlumberger log interpretation suggested that the logged interval (0–800 ft) did not contain rocks that were fully saturated. However, this interpretation is not supported by water-level measurements that range between depths of 778 to 788.6 ft in the three screens of the completed well. Thus, it is possible that the water table lies between 722 ft, the depth measured during geophysical logging by Schlumberger, and 778 ft, the current water measured in screen 1. Schlumberger geophysical logs provide good detail about the geologic units encountered from 722- to 800-ft depth and demonstrate the variable lithologic nature of the Cerros del Rio basalt. Based on Schlumberger density logs, massive low-porosity lavas occur at depths of 724 to 732 ft, 744 to 748 ft, 752 to 754 ft, 763 to 772 ft, and 790 to 800 ft. These lavas are separated by highly porous interflow breccias or zones of highly fractured basalt. The highest effective porosity is 40% to 55% within an interflow breccia centered between 736 and 742 ft; in part, these high porosities reflect washouts associated with this zone. Information about geologic units from 800 to 915.5 ft is provided by drill cuttings. Below 915.5 ft, there were no cuttings returned to the surface, and geologic units below that depth are inferred from changes in drilling behavior and from gamma and induction logs collected by LANL. Cerros del Rio basalt is inferred to extend to a depth of 923 ft where there is a sharp increase in borehole conductivity, which is presumed to represent the transition from dense resistive lavas to water-filled pores in sedimentary deposits of the underlying Puye Formation. Screen 1 (867.5 to 875.2 ft) includes interbedded river gravels and underlying lava flows in the lowermost part of the Cerros del Rio basalt. The river gravels were expected to be permeable and provide samples from the upper part of the aquifer. Water samples and water-level data are collected from screen 1. Screen 2 (931.8 to 934.9 ft) was placed just below the inferred contact between the Cerros del Rio basalt and the Puye Formation. Screen 2 has a short screen interval and is designed to collect water-level data only. The borehole induction log indicates that the rocks targeted by screen 2 are conductive relative to intervals above and below. Screen 3 (972.9 to 980.6 ft) targets inferred sedimentary rocks of the Puye Formation in the lowermost part of the borehole. The borehole induction log indicates that the rocks targeted by screen 3 fall within the mid-range of conductivity values for the sedimentary deposits in the lower part of the borehole. Lack of Schlumberger geophysical logs below 800 ft was a serious impediment for siting the well screens at R-32. This was compounded for screens 2 and 3 because no drill hole cuttings were circulated to the surface below 915.5 ft.

R-32 Well (continued)		
	Description	Evaluation
Filter Pack Materials and Placement	The filter packs and their placements are discussed for the three well screens in the column to the right.	The primary filter pack for screen 1 is made up of 20/40 sand from 862.5 to 879.2 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 859.3 to 862.5 ft and 879.2 to 882.4 ft, respectively. The primary filter pack extends 5 ft above and 4 ft below the well screen. These filter pack dimensions allow groundwater to be drawn from a larger volume of the basalt where the distribution of water-producing fractures is poorly known. The primary filter pack for screen 2 is made up of 20/40 sand from 925.2 to 938.7 ft. A secondary filter pack of 30/70 sand was placed above and below the primary filter pack from 923.6 to 925.2 ft and 938.7 to 942 ft, respectively. The primary filter pack extends 6.6 ft above and 3.8 ft below the well screen. The combination of this filter pack with a relatively short well screen is appropriate for the water-level measurements that are the primary purpose of this well screen. The primary filter pack for screen 3 is made up of 20/40 sand from 961.7 to 978.2 ft. A secondary filter pack of 30/70 sand was placed above the primary filter pack from 960 to 961.7 ft. The primary filter pack extends 11.2 ft above the well screen. Because of unstable borehole conditions during well construction, the lower 2.4 ft of the well screen is covered by a mixture of slough and 30/70 sand. These filter pack dimensions are appropriate for the intended use of collecting water samples.
Sampling System	Westbay Multiple Port sampling system	Westbay is a low-flow sampling system that allows groundwater sampling of multiple well screens within a single well installation. Well screens are isolated by packers and sampled individually. Westbay is the only sampling system capable of sampling three or more screens in a multiscreen well. It is particularly effective for monitoring water levels at multiple depths within a well. Flow-through cells for measuring field parameters cannot be used at multiscreen wells containing the Westbay sampling system. Effective development and removal of residual drilling fluids are critical before installation of Westbay wells because groundwater is collected in proximity to the well due to low-flow sampling and the inability to purge the well before sampling. Samples collected from Westbay wells are particularly prone to water-quality problems that develop if residual drilling fluids are hydraulically connected to the screen interval.
Other Issues That Could Affect the Performance of the Well	None	n/a

R-32 Well (continued)		
	Description	Evaluation
Additives used		**Interval 0–792 ft:** Air Municipal water—53,000 gal. QUIK-FOAM—550 gal. LIQUI-TROL—175 gal. QUIK-GEL—20,000 lb Soda ash—400 lb **Interval 792–1008 ft:** Municipal water—45,000 gal. QUIK-GEL—25,000 lb EZ-MUD—25.5 gal. LIQUI-TROL—5 gal. PAC-L—50 lb N-SEAL—800 lb Magma Fiber—800 lb Fluids recovered during development—114,970 gal. (An additional 29,910 gal. of water was removed during hydrologic testing.)
Annular fill other than filter and transition sands		QUIK-GROUT high-solids bentonite—0.375-in. unrefined chips (47 bags) Pelplug bentonite—0.25 in. by 0.375-in. refined elliptical pellets (95 buckets) Surface seal of Portland cement slurry (44 bags)

Location: In Pajarito Canyon, south of TA-54, along the north side of Pajarito Rd.

Survey coordinates (brass marker in NW corner of R-32 cement pad):
x: 1640798 E y: 1757730 N (NAD 83)
z: 6637.6 ft asl (NGVD 29)

Drilling: air rotary core w/ wireline retrieval, conventional mud drilling.
R-32 Start date: 07/13/02.
R-32 End date: 08/7/02.

Borehole R-32 drilled to 1008 ft. bgs. (T.D.).

Data collection:
Hydrologic properties: Field hydraulic test: Constant Rate Injection Test on screen #1 and screen #3
Cores/cuttings submitted for geochemical and contaminant characterization: (13)
Groundwater samples submitted for geochem and contaminant characterization: (3)
Geologic properties: (7)
Mineralogy, petrography, and chemistry.
Borehole logs from R-32:
Lithologic: 0-915.5 ft.
Caliper (LANL): 0-1008 ft.
Video (LANL tool): 0-720 ft.
Natural gamma + Induction (LANL tool): 0-808 ft. and 0-1008 ft.
Schlumberger Logs: 0-54.5 ft. (cased), 54.5-808 ft. (open hole): Epithermal Neutron, Litho density, Induction, Combinable Magnetic Resonance, Elemental Capture, Spectral Gamma.

Contaminants Detected in R-32 Water Samples: none

Well construction:
Drilling Completed: 08/07/02
Contract Geophysics: 07/31/02
Well Constructed: 08/09/02 - 08/12/02
Well Developed: 8/18/02 - 11/10/02
Westbay Installed: 11/11/02 - 11/17/02 2

Casing: 4.5-in I.D. stainless steel with external couplings.

Number of Screens: 3
4.5-in I.D. pipe based, s.s. wire-wrapped with 0.010-in slots.

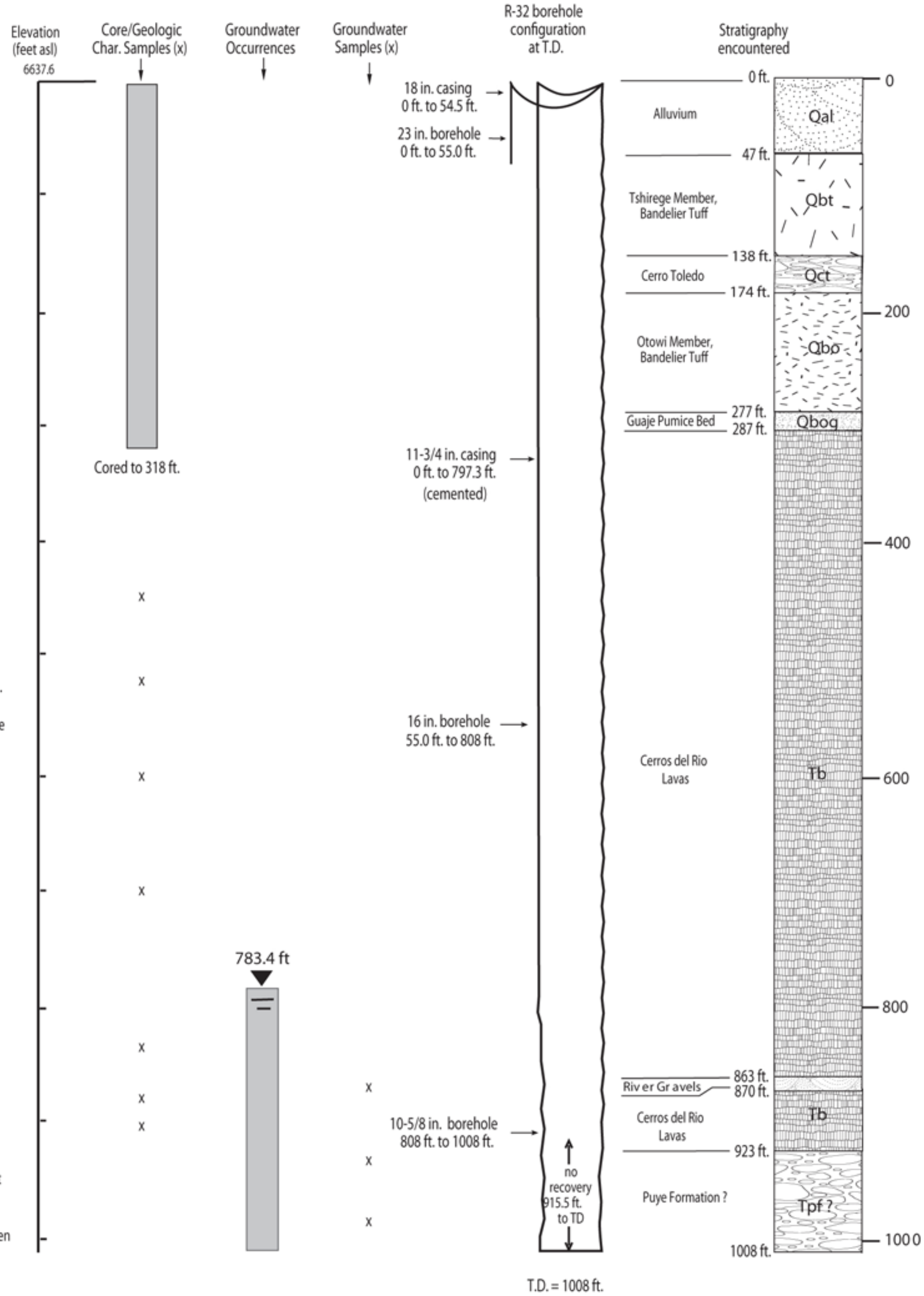
Screen (perforated pipe interval):
Screen #1 - 867.5 - 875.2 ft. bgs.
Screen #2 - 931.8 - 934.9 ft. bgs.
Screen #3 - 972.9 - 980.6 ft. bgs.

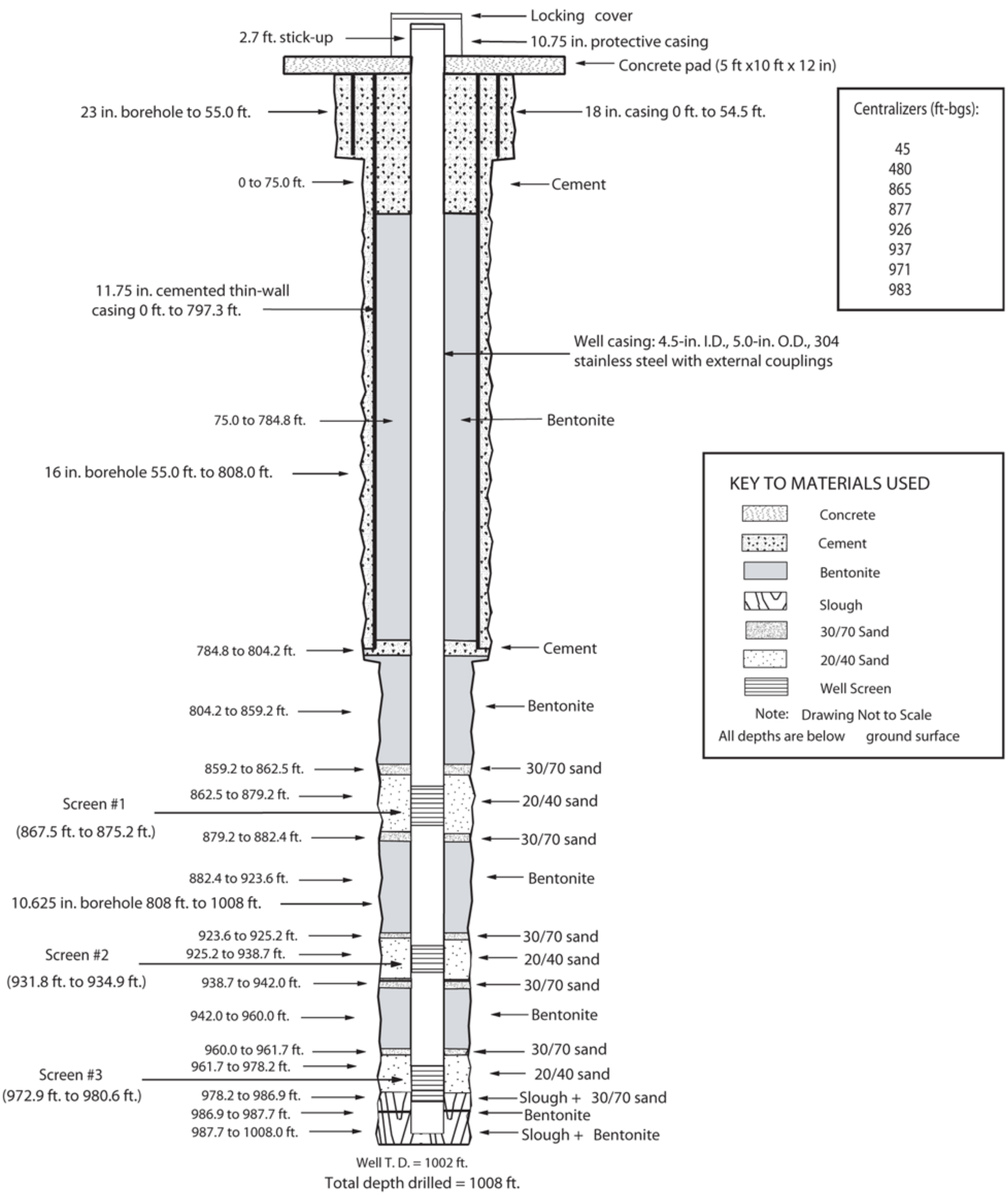
Well development consisted of wire brushing, bailing, chemical treatments, surging, and pumping.

Static water level measured on November 11, 2002, at 783.4 ft in completed and developed well.

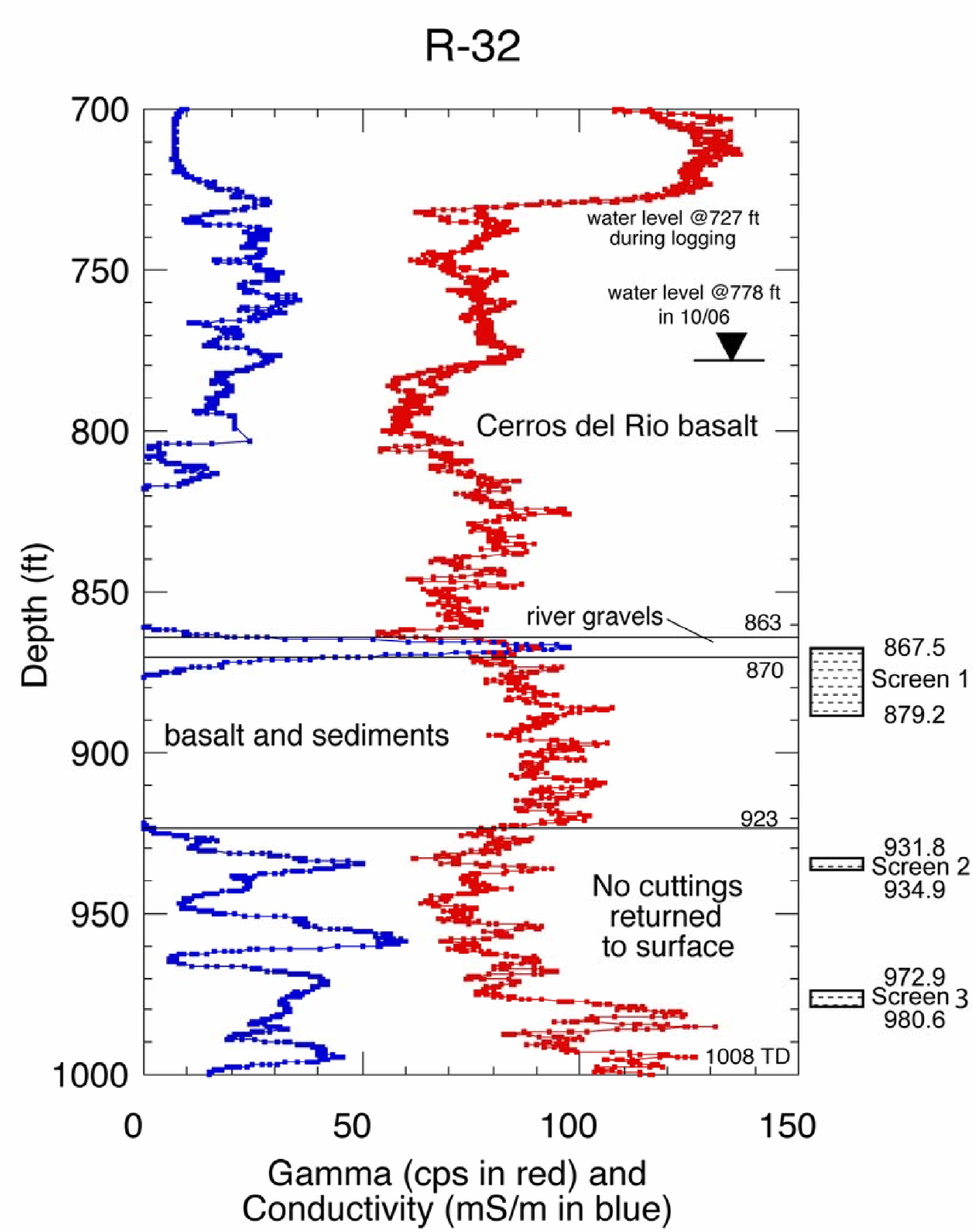
Groundwater samples collected from packed off screen intervals after well development.

Geologic contacts for R-32 were determined by examination of cuttings and interpretation of geophysical logs. Contacts may be refined by petrographic, geochemical, or mineralogic analysis of geologic samples.





Note: 1. Each screen interval lists the footage of the pipe perforations, not the top and bottom of screen joints.
2. The interval of slough probably consist of sands and gravel of the Puye Formation.
3. Westbay multiport sampling system (MP-55) casing not shown.
4. Pipe-based screen: 4.5-in. I.D., 5.563-in. O.D., 304 stainless steel with s.s. wire wrap; 0.010-in. slot.
5. Well sump interval: 980.6 to 1002 ft.



Due to calibration errors, conductivity values are shifted to low values, data are useful for showing relative conductivity.

Appendix B

Geochemical Performance of Network Wells

B-1.0 PURPOSE

This appendix presents results obtained in the evaluation of the reliability and representativeness (R&R) of sample data collected from six candidate wells for the Technical Area (TA) 54 monitoring network. These six wells contain 14 screened intervals that provide water samples for chemical and radiochemical analyses. The objective of the evaluation is to determine whether these intervals are capable of providing data that are R&R of predrilling conditions for chemicals of potential concern (COPCs), such that the screens can be shown to meet objectives for the TA-54 monitoring network.

The evaluation is conducted following the approach described in the "Well Screen Analysis Report, Revision 2" (hereafter, WSAR Rev. 2) (LANL 2007, 096330). After summarizing the outcome of the evaluation in Section B-2.0 and Table B-1, the rest of the appendix outlines the steps of the process applied and documents the data used to derive the evaluation results.

B-2.0 Results of Geochemical Performance Evaluation

The capability of each screen to meet geochemical-monitoring objectives is expressed by assignment of the screen to one of three categories.

- Meets geochemical-monitoring objectives unconditionally—provides R&R samples for all COPCs.
- Meets geochemical-monitoring objectives conditionally—currently provides R&R samples for some COPCs. Classified as conditional for at least one of two reasons.
    - ❖ The post-development or post-rehabilitation data record spans less than a year; in which case the screen is classified as conditionally meeting monitoring objectives, subject to the results of future data.
    - ❖ Data may have the potential to be biased high for some constituents and biased low for others at the present time, but this limitation is expected to be resolved within a reasonable time frame as the screen continues to improve.
- Does not meet geochemical-monitoring objectives—cannot provide R&R samples for most COPCs, and conditions do not show clear signs of improving within a reasonable time frame.

Evaluation results are summarized below in terms of the present-day status of each screen interval with respect to its recovery from residual effects of drilling. The capability of each screen to provide water samples that are R&R for specific COPCs and other key analytes is tabulated in Table B-1. COPCs were selected to include those that would be useful for early detection of any contaminant plume originating from a potential source upgradient of these wells, as well as those COPCs which could serve as a diagnostic indicator for a specific source:

Tritium	Waste constituent in Material Disposal Areas (MDAs) G, H, and L
Uranium, plutonium	Waste constituents in MDAs G and H
Strontium-90	Waste constituent in MDA G
1,1,1-Trichloroethane (1,1,1-TCA)	Waste constituent in MDAs G and L
Trichloroethylene (TCE)	Waste constituent in MDAs G and L
Trichlorotrifluoroethane (Freon-113)	Waste constituent in MDAs G and L
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); 2,4,6-trinitrotoluene (TNT)	Waste constituents in MDA H
Chromium	Waste constituent in MDA L
Chloride, nitrate, sulfate, perchlorate	Geochemical indicators present in background groundwater and impacted by residual drilling effects; also commonly present in laboratory waste streams

R-20 screen 1 meets geochemical-monitoring objectives conditionally.

- Well rehabilitation activities were conducted at R-20 from June 29, 2006, to October 17, 2006.
- Drilling-related conditions in the screen interval show a significant improvement relative to those before rehabilitation activities at this location. The first post-rehabilitation sample (January 22, 2007) indicates successful removal of residual inorganic and organic drilling constituents, as well as restoration of background pH, alkalinity, and calcium concentrations. Sample turbidity was very high in this first post-rehabilitation sample.
- Water near the screen is slightly manganese-reducing, which is an improvement over the persistent sulfate-reducing conditions that prevailed before rehabilitation. The capability of the screen to detect nitrate and perchlorate in the most recent sample indicates a good prognosis for complete recovery in the near future.
- An important consideration is that only one post-rehabilitation water-quality sample is available at this time. A single sample provides an inadequate basis for determining with confidence the current capability of the screen to provide R&R samples for all COPCs.
- Of the selected COPCs listed in Table B-1, R-20 screen 1 is considered capable of providing R&R data for tritium, chloride, uranium, 1,1,1-TCA, and strontium-90. The screen is capable of detecting perchlorate, chromium, nitrate, and RDX, but these data may be biased low because of manganese-reducing conditions. It can probably provide R&R data for plutonium and TNT, but this evaluation is uncertain because of the lack of indicators for enhanced adsorption of these chemicals onto residual bentonite that could conceivably be present in the interval. It may not be able to provide R&R data for nondetects of TCE or Freon-113.

R-20 screen 2 meets geochemical-monitoring objectives conditionally.

- Well rehabilitation activities were conducted at R-20 from June 29, 2006, to October 17, 2006.
- Drilling-related conditions in the screen interval show a significant improvement relative to those that dominated before rehabilitation activities at this location. The first post-rehabilitation sample (January 22, 2007) indicates successful removal of residual inorganic and organic drilling constituents as well as restoration of background pH, alkalinity, and alkaline-earth (Ca, Ba, Sr) concentrations.
- Sample turbidity was slightly elevated in this first post-rehabilitation sample. Although total chromium concentration and total-to-dissolved iron and chromium ratios are elevated, it does not seem likely in this case that these indicate metal corrosion products. This condition will be reevaluated when additional data become available from future samples.

- Water near the screen is slightly iron-reducing, which is a significant improvement over the persistent sulfate-reducing conditions before rehabilitation. The detection of nitrate and perchlorate in the most recent sample indicates a fair prognosis for complete recovery in the near future, subject to the installation of a sampling system capable of adequate purging of an adequate volume of water before sample collection.
- An important consideration is that only one post-rehabilitation water-quality sample is available at this time. A single sample provides an inadequate basis for determining with confidence the current capability of the screen to provide R&R samples for all COPCs.
- Of the selected COPCs listed in Table B-1, R-20 screen 2 is considered capable of providing R&R data for tritium, chloride, 1,1,1-TCA, and strontium-90. It can probably provide R&R data for plutonium and TNT, but this evaluation is uncertain because of the lack of indicators for enhanced adsorption of these chemicals onto residual bentonite that could conceivably be present in the interval. The screen is capable of detecting perchlorate, chromium, nitrate, uranium, and RDX, but these data may be biased low. Because of iron-reducing conditions, it may not be able to provide R&R data for nondetects of TCE or Freon-113.

R-20 screen 3 meets geochemical-monitoring objectives conditionally.

- Well rehabilitation activities were conducted at R-20 from June 29, 2006, to October 17, 2006.
- Drilling-related conditions in the screen interval show a moderate improvement relative to those before rehabilitation activities at this location. The first post-rehabilitation sample (January 19, 2007) indicates successful removal of residual inorganic and organic drilling constituents.
- Water near the screen is slightly iron-reducing, which is a significant improvement over the persistent sulfate-reducing conditions that prevailed before rehabilitation. The prognosis for complete recovery from drilling effects looks good based on the trends shown by key redox indicators and by the absence of residual organic drilling fluids. Although nitrate and perchlorate could not be detected in the most recent sample, this condition could be resolved in future samples if the screen interval continues to improve.
- An important consideration is that only one post-rehabilitation water-quality sample is available at this time. A single sample provides an inadequate basis for determining with confidence the current capability of the screen to provide R&R samples for all COPCs.
- Of the selected COPCs listed in Table B-1, R-20 screen 3 is considered capable of providing R&R data for tritium, chloride, 1,1,1-TCA, and strontium-90. It can probably provide R&R data for plutonium and TNT, but this evaluation is uncertain because of the lack of indicators for enhanced adsorption of these chemicals onto residual bentonite that could conceivably be present in the interval. The screen is capable of detecting perchlorate, chromium, and RDX, but these data may be biased low. Because of reducing conditions, it cannot provide R&R data for nitrate, uranium, TCE, or Freon-113.

R-21 meets geochemical-monitoring objectives unconditionally.

R-22 screen 1 does not meet geochemical-monitoring objectives.

- Highly elevated total carbonate alkalinity, persistent sulfate-reducing conditions, and inferred changes to iron and manganese-bearing and carbonate minerals are present in this interval. Recovery to predrilling conditions is highly unlikely within the next few years in the absence of rehabilitation efforts.

- Of the selected COPCs listed in Table B-1, R-22 screen 1 is considered capable of providing R&R data for tritium, chloride, and strontium-90. Because of sulfate-reducing conditions, it cannot provide R&R data for perchlorate, chromium, nitrate, uranium, 1,1,1-TCA, TCE, Freon-113, plutonium, RDX, or TNT.

R-22 screen 2 meets geochemical-monitoring objectives unconditionally.

R-22 screen 3 meets geochemical-monitoring objectives conditionally.

- Residual inorganic and organic drilling constituents and carbonate-mineral disequilibria appear to be present in this interval, potentially affecting the R&R status of some COPCs. Initially, screen 3 contained residual bentonite most likely released from the bentonite seal adjacent to the filter pack (Longmire 2002, 073676). Groundwater samples collected from screen 3 are characterized by elevated concentrations of sodium, sulfate, and uranium, which are all characteristic indicators for solutes leached from bentonite products. Screen 3 has partially cleaned up, based on decreasing concentrations of these three solutes.
- Of the selected COPCs listed in Table B-1, R-22 screen 3 is considered capable of providing R&R data for tritium, perchlorate, chromium, 1,1,1-TCA, Freon-113, strontium-90, RDX, and TNT. Chloride and uranium concentrations are detected, but their concentrations are above background levels due to residual inorganic drilling products; uranium may also be biased high because of complexing with bicarbonate and carbonate concentrations. Because of the potential for residual bentonite near the screen, it cannot provide R&R data for plutonium. Persistently elevated total organic carbon concentrations suggest the presence of residual organic constituents, in which case it may not be able to provide R&R data for nondetects of TCE.

R-22 screen 4 does not meet geochemical-monitoring objectives.

- Residual organic constituents, iron-reducing conditions, and carbonate-mineral disequilibria persist in this interval, rendering it incapable of providing R&R data for a majority of the COPCs. Although conditions show slow but steady improvement, complete recovery to predrilling conditions is highly unlikely within the next few years in the absence of rehabilitation efforts.
- Of the selected COPCs listed in Table B-1, R-22 screen 4 is considered capable of providing R&R data only for tritium, 1,1,1-TCA, and strontium-90.

R-22 screen 5 does not meet geochemical-monitoring objectives.

- Iron-reducing conditions persist in this screen interval, rendering it incapable of providing R&R data for a majority of the COPCs. Although conditions show slow but steady improvement, complete recovery to predrilling conditions is highly unlikely within the next few years in the absence of rehabilitation efforts.
- Of the selected COPCs listed in Table B-1, R-22 screen 5 is considered capable of providing R&R data only for tritium, 1,1,1-TCA, and strontium-90.

R-23 meets geochemical-monitoring objectives unconditionally.

R-23i screen 1 meets geochemical-monitoring objectives conditionally.

- Post-development data reported in WSAR Rev. 2 (LANL 2007, 096330) span less than a year. The evaluation in this report incorporates data from more recent samples collected in February and April 2007.

- This screen is known to show the presence of local contaminants, which affects the applicability of some of the geochemical evaluation criteria, as documented in Table B-2.
- Oxic conditions may be present in this interval, but there is uncertainty associated with this evaluation because several redox indicators appear inconsistent.
  - ❖ At face value, slowly increasing dissolved iron concentrations and low total dissolved chromium and perchlorate concentrations suggest iron-reducing conditions. However, these may be natural conditions for groundwater in the Cerros del Rio basalt, in which this screen is completed. Under this hypothesis, the presence of iron colloids (ferric oxyhydroxide) in filtered samples could account for the elevated dissolved iron concentrations because colloids would not be retained by the filter, and the low total dissolved chromium could reflect that relatively insoluble chromium(III) is the stable oxidation state of this metal at R-23i within the basalt.
  - ❖ Conversely, negligibly low manganese concentrations, consistently measurable nitrate and uranium concentrations, and dissolved oxygen above 2 mg/L indicate the presence of overall oxic conditions.
  - ❖ In Table B-2 redox conditions in the screen interval are assumed to be oxidizing based on measurable nitrate, uranium, sulfate, and dissolved oxygen.
- Residual inorganic or organic drilling constituents appear to be absent from this interval.
- The slightly elevated total organic carbon (TOC) concentration (1.3 mg/L as carbon) may be an indicator of contamination in this screen interval and may not be caused by residual organic drilling product.
- Calcium, sodium, and fluoride concentrations are slightly elevated above the background values reported for these elements in perched intermediate groundwater. The stability of the elevated calcium and fluoride concentrations suggests that they may be representative of the groundwater at this location. Sodium concentrations appear to track those of sulfate and so may be one of the contaminants present at this location.
- This evaluation is preliminary. Indicators of contamination (chloride, sulfate, nitrate, tritium, and uranium) are present at this location (Table B-2).
- R-23i screen 1 is considered capable of providing R&R data for all COPCs. The conditions summarized above and the capability of the screen to provide R&R data for COPCs will continue to be evaluated as additional data become available from future samples.

R-23i screen 2 meets geochemical-monitoring objectives conditionally.

- Post-development data reported in WSAR Rev. 2 (LANL 2007, 096330) span less than a year. The evaluation in this report incorporates data from more recent samples collected in February and April 2007.
- This screen is known to show the presence of local contaminants, which affects the applicability of some of the geochemical evaluation criteria, as documented in Table B-2.
- Oxic conditions prevail in this interval, and residual inorganic or organic drilling constituents appear to be absent.
- The slightly elevated TOC concentration (1.7 mg/L as carbon) may be an indicator of contamination in this screen interval and may not be caused by residual organic drilling product.

- As for R-23i screen 1, calcium and fluoride concentrations are slightly elevated above the background value for these elements in the perched-intermediate aquifer. The stability of the concentrations suggests that they may be representative of the noncontaminated groundwater at this location.
- This evaluation is preliminary. Potential contaminants (chloride, sulfate, nitrate, tritium, and uranium) may be present at this location (Table B.2).
- R-23i screen 2 is considered capable of providing R&R data for all COPCs. The conditions summarized above and the capability of the screen to provide R&R data for COPCs will continue to be evaluated as additional data become available from future samples.

<u>R-32 screen 1</u> meets geochemical-monitoring objectives unconditionally.

- Magnesium concentrations are slightly elevated above the background value for this solute in the regional aquifer but are considerably below its limit for the perched-intermediate aquifer. The stability of the elevated concentration suggests that it is representative of the groundwater at this location.

<u>R-32 screen 3</u> does not meet geochemical-monitoring objectives.

- The continuing presence of residual inorganic and organic drilling constituents is indicated by elevated concentrations of phosphate (1.4 mg/L as P) and ammonium (0.085 mg/L as N), respectively.
    - ❖ The most likely source of the elevated phosphate is the drilling additive PAC-L. PAC-L is a cellulosic polymer (fiber) commonly added to bentonite drilling slurries and was used during drilling of the interval below 792 ft. The water-leachable phosphate content of the raw product is 10,600 ppm as phosphate (PO_4), corresponding to 3460 mg/kg as P (LANL 2007, 096330, Tables 4-6 and A-10). Product literature recommends the addition of 1 lb PAC-L per 100 gal. of water, which would correspond to an initial concentration of 4.1 mg/L as P (LANL 2007, 096330, Table 4-7). The observation that the elevated phosphate is not accompanied by similarly elevated concentrations of other soluble PAC-L constituents (e.g., sodium and chloride) suggests that some proportion of the phosphate may have been precipitated in the formation as a salt.
    - ❖ Candidate sources for the elevated ammonium include QUIK-FOAM and EZ-MUD added to the bentonite drilling slurry, and AQUA-CLEAR-MGA was used during well development (LANL 2007, 096330, Table A-10).
- Iron-reducing conditions are persistent but improving.
- Barium concentrations are considerably elevated above the background value for this element. The cause is unknown, but the stability of the elevated concentration suggests that it is representative of the groundwater at this location.
- Of the selected COPCs listed in Table B-1, R-32 screen 3 is considered capable of providing R&R data for tritium, chloride, 1,1,1-TCA, and strontium-90. Nitrate and uranium are detected in the most recent sample but are biased low because of reducing conditions. It cannot detect perchlorate or chromium and cannot provide R&R data for TCE, Freon-113, plutonium, RDX, or TNT.

B-3.0 APPROACH

The evaluation summarized above was conducted following the approach described in Section 4 of WSAR Rev. 2 (LANL 2007, 096330). Analytical data are compared against background values for about 30 geochemical indicator species, which serve as test criteria for identifying the presence of residual drilling effects. The background values are defined based on levels measured in samples assumed to be representative of water quality in perched-intermediate water or in the regional aquifer, as reported in the "Groundwater Background Investigation Report, Rev. 2" (LANL 2007, 094856). The test criteria are used to identify samples that appear to be unreliable and/or are not representative of predrilling groundwater chemistry because of residual effects of drilling fluids. Site groundwater contamination for each well is also considered in this process. The residual effects are classified into six categories (LANL 2007, 096330).

- Category A—Residual inorganic constituents from drilling, construction, and development products
- Category B—Residual organic components from drilling products
- Category C—Modification of in situ redox conditions
- Category D—Modification of surface-active mineral surfaces with the effect of enhancing adsorption, such as onto drilling clays
- Category E—Carbonate-mineral disequilibria
- Category F—Corrosion of stainless-steel well components
- A seventh category includes general water-quality indicators—pH, alkalinity, and turbidity. Anomalous values for these constituents commonly accompany other indicators of residual drilling effects, but these excursions generally cannot be attributed with confidence to any single cause.

The results of each step of the geochemical performance evaluation are summarized in three tables for which supporting details are documented in WSAR Rev. 2 (LANL 2007, 096330).

- Table B-2 identifies test indicators that are not applicable for the R&R evaluation in specific sampling intervals because they are present as contaminants in that interval, which can bias the test outcome. Of the 14 screens covered by this report, contaminants are known to be present only in screened intervals of R-22 (tritium), R-23, and R-23i.
- Table B-2 summarizes the current status of each sampling interval for any residual effects of drilling, accounting for trends over time and focusing on the results for the most recent samples. Where appropriate, the status is taken directly from WSAR Rev. 2 (LANL 2007, 096330, Table 6-1).
- The result of the evaluation process was presented earlier as Table B-1, which summarizes the capability of each interval for producing R&R samples for representative COPCs. This table is constructed by combining the test outcomes (Table B-3) with COPC characteristics tabulated in WSAR Rev. 2 (LANL 2007, 096330; LANL 2007, 094856, Appendix A). Characteristics of some COPCs are updated for reasons described below.

B-4.0 ANALYSIS OF RESIDUAL EFFECTS OF DRILLING

Four chemicals in Table B-1 are not among those included in WSAR Rev. 2 (LANL 2007, 096330, Table 6-4). The residual effects of drilling that can impact the capability of a screen to provide R&R data for each of these chemicals are based on WSAR Rev. 2 (LANL 2007, 096330,Tables A-2 and A-8) and other references as noted here:

- Uranium concentrations may be elevated as the result of residual leaching products from bentonite (Category A) or from carbonate-mineral disequilibria (Category E), due to formation of carbonate complexes. Uranium concentrations can decrease to nondetectable levels if iron- or sulfate-reducing conditions are present (Category C) (LANL 2007, 096330, Table A-2).
- 1,1,1-TCA biodegradation can be enhanced under methanogenic conditions as well as in the presence of iron sulfide minerals (i.e., sulfate-reducing conditions, Category C) (Gander et al. 2002, 097384; National Library of Medicine 2005, 090524; Syracuse Research Corporation 2005, 090573). This information updates the impact category to which this chemical was assigned in WSAR Rev. 2 (LANL 2007, 096330, Table A-8), for which the default assumption was that biodegradation of this volatile organic compound would be enhanced under any reducing conditions.
- TCE can biodegrade under aerobic conditions only in the presence of another compound that can support microbial growth in a process called cometabolism (National Library of Medicine 2005, 090524). On this basis, TCE is considered potentially affected by the persistent presence of residual organic drilling products (Category B). This compound also can biodegrade under iron-reducing, sulfate-reducing, or methanogenic conditions (National Library of Medicine 2005, 090524; Syracuse Research Corporation 2005, 090573). Conservatively, nondetects of this compound are assumed not to be reliable under any reducing condition (Category C) (LANL 2007, 096330, Table A-8).
- Freon-113 was not among the chemicals included in WSAR Rev. 2 (LANL 2007, 096330, Appendix A). This compound is highly soluble, is not expected to adsorb onto clays or minerals, and can biodegrade under anaerobic conditions (National Library of Medicine 2007, 097385). Conservatively, nondetections are assumed not to be reliable for this compound under any reducing conditions (Category C).

B-5.0 REFERENCES

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

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

Gander, J.W., G.F. Parkin, and M.M. Scherer, 2002. "Kinetics of 1,1,1-Trichloroethane Transformation by Iron Sulfide and a Methanogenic Consortium," *Environmental Science & Technology,* Vol. 36, pp. 4540-4546. (Gander et al. 2002, 097384)

LANL (Los Alamos National Laboratory), February 2007. "Groundwater Background Investigation Report, Revision 2," Los Alamos National Laboratory document LA-UR-07-0755, Los Alamos, New Mexico. (LANL 2007, 094856)

LANL (Los Alamos National Laboratory), May 2007. "Well Screen Analysis Report, Revision 2," Los Alamos National Laboratory document LA-UR-07-2852, Los Alamos, New Mexico. (LANL 2007, 096330)

Longmire, P., October 2002. "Characterization Well R-22 Geochemistry Report," Los Alamos National Laboratory report LA-13986-MS, Los Alamos, New Mexico. (Longmire 2002, 073676)

Longmire, P., M. Dale, D. Counce, A. Manning, T. Larson, K. Granzow, R. Gray, and B. Newman, July 2007. "Radiogenic and Stable Isotope and Hydrogeochemical Investigation of Groundwater, Pajarito Plateau and Surrounding Areas, New Mexico," Los Alamos National Laboratory report LA-14333, Los Alamos, New Mexico. (Longmire et al. 2007, 096660)

National Library of Medicine, November 7, 2005. "Hazardous Substances Data Bank," on TOXNET (Toxicology Data Network), http://toxnet.nlm.nih.gov/. (National Library of Medicine 2005, 090524)

National Library of Medicine, July 19, 2007. "1,1,2-Trichloro-1,2,2-trifluoroethane," online search results from the Hazardous Substances Data Bank (HSDB) on TOXNET (Toxicology Data Network), http://toxnet.nlm.nih.gov/. (National Library of Medicine 2007, 097385)

Syracuse Research Corporation, November 7, 2005. CHEMFATE database search results, http://www.syrres.com/esc/chemfate.htm. (Syracuse Research Corporation 2005, 090573)

Table B-1
Capability of Screen to Provide Reliable and Representative Samples For Selected Chemicals of Potential Concern

Well	Port depth (ft)	Scr	^3H	Cl	ClO_4	Cr	NO_3	U[a]	1,1,1-TCA*	TCE*	Freon-113[a]	Pu	Sr-90	RDX	TNT
R-20	907	1	■[b]	■	■–[c]	■–	■–	■	■	—[d]	—	■?[e]	■	■–	■?
R-20	1150	2	■	■	■–	■–	■–	■–	■	—	—	■?	■	■–	■?
R-20	1330	3	■	■	■–	■–	—	—	■	—	—	■?	■	■–	■?
R-21	889	1	■	■	■	■	■	■	■	■	■	■	■	■	■
R-22	907	1	■	■	—	—	—	—	—	—	—	—	■	—	—
R-22	963	2	■	■	■	■	■	■	■	■	■	■	■	■	■
R-22	1273	3	■	—	■	■?	■	—	■	—	■	—?[f]	■	■	■
R-22	1378	4	■	—	—	—	—	—	■	—	—	—	■	—	—
R-22	1448	5	■	—	—	—	—	—	■	—	—	—	■	—	—
R-23	816	1	■	■	■	■	■	■	■	■	■	■	■	■	■
R-23i	470	2	■	■	■	■	■	■	■	■	■	■	■	■	■
R-23i	524	3	■	■	■	■	■	■	■	■	■	■	■	■	■
R-32	871	1	■	■	■	■	■	■	■	■	■	■	■	■	■
R-32	976	3	■	■	—	—	—	—	■	—	—	—	■	—	—

Sources: Capabilities shown in unshaded table cells are taken from WSAR Rev. 2 (LANL 2007, 096330, Table 6-4). Capabilities shown in shaded cells have been updated based on (a) data from more recent samples, as documented in Section B-2.0 and Table B-2.0-2or (b) additional information about conditions affecting specific COPCs, as documented in Section B-4.0.

1,1,1-TCA = 1,1,1-Trichloroethane; TCE = trichloroethylene; Freon-113 = 1,1,2-trichloro-1,2,2-trifluoroethane (sometimes shortened to trichlorotrifluoroethane).

[a] Four chemicals in this table were not among those included in WSAR Rev. 2 (LANL 2007, 096330, Table 6-4). The residual effects of drilling that can impact the capability of a screen to provide R&R data for each of these chemicals are described in Section B-4, based on WSAR Rev. 2 (LANL 2007, 096330, Table 6-4) and other references as noted.

[b] ■ = Screen can provide reliable and representative sample for this COPC.

[c] ■– = Screen has provided one or more recent samples in which this analyte was detected, but measured concentrations may be biased low because of residual effects of drilling. Note: Analytes to which this flag may be applied are limited to the redox-sensitive species in the above table: nitrate, perchlorate, chromium, and uranium.

[d] — = Screen cannot provide reliable and representative sample for this COPC.

[e] ■? = Screen probably can provide reliable and representative sample for this COPC, but there is uncertainty associated with this judgment.

[f] —? = Screen probably cannot provide reliable and representative sample for this COPC, but there is uncertainty associated with this judgment.

Table B-2
Indicators That May Not Be Applicable Due to Presence As a Contaminant

Well	Port Depth (ft)	Scr #	Watershed	Local Contamination[a]	Contaminants Present in Screened Intervals[b]								
					^3H	Alkalinity	Cl	ClO_4	F	Cr	NO_3	SO_4	U
R-20	907	1	Pajarito	None[a]	—[b]	—	—	—	—	—	—	—	—
R-20	1150	2	Pajarito	None	—	—	—	—	—	—	—	—	—
R-20	1330	3	Pajarito	None	—	—	—	—	—	—	—	—	—
R-21	889	1	Caňada del Buey	None	—	—	—	—	—	—	—	—	—
R-22	907	1	Pajarito	None	Yes[c]	—	—	—	—	—	—	—	—
R-22	963	2	Pajarito	None	—	—	—	—	—	—	—	—	—
R-22	1273	3	Pajarito	None	—	—	—	—	—	—	—	—	—
R-22	1378	4	Pajarito	None	—	—	—	—	—	—	—	—	—
R-22	1448	5	Pajarito	None	Yes	—	—	—	—	—	—	—	—
R-23	816	1	Pajarito	Present[d]	—	—	—	—	—	—	■[e]	—	—
R-23i	470	2	Pajarito	Present	Yes	—	■	—	—	—	■	■	■
R-23i	524	3	Pajarito	Present	Yes	—	■	—	—	—	■	■	■
R-32	871	1	Pajarito	None	—	—	—	—	—	—	—	—	—
R-32	976	3	Pajarito	None	—	—	—	—	—	—	—	—	—

Sources: Identification of contaminants in unshaded table cells is taken from WSAR Rev. 2 (LANL 2007, 096330, Table 2-1). Identification of contaminants in shaded table cells is discussed in Section B-2.

a None= No contaminant is known with certainty to be present in this screen interval.

b — = Constituent is either not present as a contaminant, or else its presence as a contaminant is indeterminate with the information available at this time. In the case of tritium (^3H) this symbol means that it is not present above the background values described below under footnote c.

c Yes = Tritium (^3H) is present as a potential contaminant. Background values of 17 pCi/L for perched groundwater and 1 pCi/L for regional groundwater are based on Longmire et al. (2007, 096660).

d Present = One or more contaminants are recognized as being present in this screen interval.

e ■ = Constituent is recognized as being present as a contaminant in the screened interval.

Table B-3
Summary of Evaluation Outcomes for Most Recent Sample

Well Screen			Conditions Present in Screen Interval										
Well	Port depth (ft)	Scr #	Modern Water	Contaminant	Outside pH-Alk Range	Resid Inorg	Resid Org	Redox Stage	Enhanced Adsorption	Fe Mineral	CO_3 Mineral	Steel Corrosion
R-20	907	1	—[a]	—	—	—	—	Mn	—	—	—	—
R-20	1150	2	—	—	—	—	—	Fe	—	—	—	—
R-20	1330	3	—	—	—	—	—	Fe	—	—	—	—
R-21	889	1	—	—	—	—	—	Oxic	—	—	—	—
R-22	907	1	■[b]	—	■	—?[c]	■?[d]	SO4	—	■	■	—
R-22	963	2	—	—	—	—	—	Oxic	—	—	—	—
R-22	1273	3	—	—	■	■	■	Oxic	—	—	■	—
R-22	1378	4	—	—	■	■	■	Fe	—	■	■	—
R-22	1448	5	■	■	■	■	■	Fe	—	■	■	—
R-23	816	1	—	■	—	—	—	Oxic	—	—	—	—
R-23i	470	2	■	■	■	—?	—?	Oxic	—	—	—?	—
R-23i	524	3	■	■	■	—?	—?	Oxic	—	—	—?	—
R-32	871	1	—	—	—	—	—	Oxic	—	—	—	—
R-32	976	3	—	—	—	■	■	Fe	—	—	—?	—

Source: Test outcomes for unshaded rows are taken from WSAR Rev. 2 (LANL 2007, 096330, Table 6-1). Test outcomes for shaded cells in otherwise unshaded rows have been modified from that presented in WSAR Rev. 2 for reasons described in Section B-2.0 of this report. Test outcomes for shaded rows on results for more recent samples are described in Section B-2.0 of this report.

[a] — = This residual effect of drilling does not appear to be present in the screen interval.

[b] ■ = This residual effect of drilling is inferred as likely to be present in the screen interval. The criteria for designating a condition as being present are summarized in WSAR Rev. 2 (LANL 2007, 096330, Table 6-1 footnotes).

[c] —? = This residual effect of drilling is probably not present in the screen interval, but there is more uncertainty than usual with this interpretation for reasons described in Section B-2.0 of this report.

[d] ■ ? = This residual effect of drilling is probably present in the screen interval, but there is more uncertainty than usual with this interpretation for reasons described in Section B-2.0 of this report.

Appendix C

Evaluation of Existing and Proposed Monitoring Well Locations for the Purpose of Detecting Contaminants from Material Disposal Areas H, L, and G at Technical Area 54

C-1.0 INTRODUCTION

This appendix describes an assessment of the regional monitoring well network's ability to detect contaminant plumes from Material Disposal Areas (MDAs) H, L, and G. The network consists of the existing and herein proposed monitoring wells. The current network configuration was found to be inadequate to detect for potential offsite releases. Therefore, this evaluation includes newly proposed well locations. Contaminant transport through the vadose zone is not explicitly considered in the applied numerical models. Instead, potential contaminants are assumed to migrate vertically from the disposal pits and shafts to the regional water table below the disposal units. The time required for transport through the vadose zone is not taken into account; thus modeling of contaminant transport begins at the regional water table.

C-2.0 MONITORING WELL NETWORK EVALUATION

A major objective of the numerical simulations is to analyze flow and contaminant transport directions near potential sources in the regional aquifer. Uncertainties in the flow directions are estimated as well. Through this analysis, monitoring wells important for detecting plume migration in the regional aquifer are identified.

For each MDA evaluation, contaminant transport in the regional aquifer is modeled from one or more anticipated breakthrough locations. For MDAs H and L, the breakthrough locations are defined as approximate projections of the disposal areas vertically downward onto the regional water table. For MDA G, three breakthrough locations are used: one at the eastern end of the disposal facility, one in the center and one at the western end. The three locations span the length of MDA G and provide better spatial resolution of simulation results than obtained using one larger footprint for the facility. This also allows for a more detailed and less conservative (in terms of network detection efficiency) approach for analysis of monitoring network efficiencies. The area at the eastern end of MDA G is anticipated to have the earliest breakthrough because waste was placed their first (starting in the early 1950s) and stratigraphic controls may yield more rapid transport there, as discussed in the site conceptual model (Section 2.3). The five breakthrough locations are presented in Figure C-1. The simulated plumes migrate in the regional aquifer from these breakthrough locations until they intercept a production well or the Los Alamos National Laboratory (LANL or the Laboratory) boundary.

The site-scale model domain used for these analyses is shown in Figure C-2. Laterally, the grid extends from the flanks of the Sierra de los Valles on the west to the Rio Grande on the east. The entire Laboratory lies within the boundaries of this domain, as do all of the Los Alamos County water-supply wells. The top of the grid is defined by the shape of the regional water table (Figure C-3). The computational grid is uniform (structured) with horizontal grid spacing of 25 m × 25 m (82 ft × 82 ft).

The explicit simulation of the phreatic zone in the numerical model generally requires a complex representation of both the saturated and unsaturated zones in a single three-dimensional numerical model. However, because the water table elevations do not exhibit pronounced transients and the flow directions in the phreatic zone are almost at a steady state (LANL 2006, 094161), the development of such a complex model is not necessary in this case. A simpler approach is used to simulate contaminant transport in the shallow phreatic zone. It is assumed that the water-table gradients are known and defined by the map of the water table in Figure C-3. It also is assumed that limited vertical mixing of contaminants occurs below the phreatic zone, and therefore, the model is reduced to a relatively thin zone along the water table. As a result, the two-dimensional model becomes pseudo-three-dimensional, with a uniform thickness of 100 m (328 ft).

Flow directions and magnitudes that control contaminant transport in the aquifer are generally dictated by the shape of the regional water table (Freeze and Cherry 1979, 088742, Chapter 5; Vesselinov 2005, 090040). Transport velocities are a function of the hydraulic gradients and the permeability and porosity of the hydrostratigraphic units. Permeability and porosity values of the hydrostratigraphic units are uncertain and represented as random variables, as defined in Table C-1; theoretical probability distribution functions are presented in Figures C-4 and C-5. The permeability ranges are based on site-specific field hydraulic tests reported in McLin (2006, 093670) and literature data (Freeze and Cherry 1979, 088742). The ranges of porosity values for the regional aquifer units are defined based on data from the literature (Freeze and Cherry 1979, 088742). The only site-specific data available are for the Cerros del Rio basalt (Tb 4) and Puye Fanglomerate (Tpf), and these data are considered in developing the distributions for those two units (Keating et al. 2001, 095399). The parameter ranges include high-permeability values and low-porosity values that are expected to occur in the case of fracture flow.

To represent the dispersion of the contaminant plumes, an axisymmetric form of the dispersion tensor is used (cf., Lichtner et al. 2002, 095397); the longitudinal and transverse dispersivities are defined to characterize the tensor. It is assumed that longitudinal and transverse dispersivities are random variables with statistical parameters presented in Table C-2. Site-specific data supporting these values are not available. Based on data from literature, the selected range of values is reasonable for the spatial scale of simulated contaminant transport (approximately 0.5 km [0.31 mi], (Neuman 1990, 090184) and the properties of the flow medium.

To estimate uncertainty in the model predictions, a Monte Carlo analysis is performed. A set of 1000 uncorrelated, equally probable random realizations are generated using a Latin Hypercube sampling technique with the software Crystal Ball. Each realization includes 26 random variables representing various model parameters that include the permeability and the porosity of the hydrostratigraphic units and the longitudinal and transverse dispersivities. It should be noted that the units are assumed to be uniform, and the dispersivities are the same for all of the hydrostratigraphic units. Because the parameter range includes high-permeability values and low-porosity values characteristic of fracture flow, a fraction (about one-tenth) of the realizations simulate fast preferential flow paths. Therefore, the probability that contaminant plumes might be affected by fracture flow is accounted for.

The numerical simulation of contaminant transport in the regional aquifer is performed using random-walk particle-tracking techniques (Lichtner et al. 2002, 095397). For each realization, a series of particles are released within areas at the top of the regional aquifer within the five potential source areas, as shown in Figures C-1. The results consist of 1000 possible contaminant plume distributions in the regional aquifer for each of the three MDAs. The results are used to evaluate the monitoring efficiency for locations of the existing and proposed new regional wells in and near Technical Area (TA) 54. The number of particles is selected to be large enough for sufficient characterization of contaminant dispersion in the numerical model. The particles' movement is tracked through the model domain to estimate potential spatial migration of contaminants. The numerical simulations are performed using particle-tracking capabilities of FEHM (Zyvoloski et al. 1996, 054421) and specially developed codes for numerical convolution (PlumeConvolute and PlumeStat). The saturated-zone analyses are computationally very intensive and produce a huge amount of output data. The analyses are achieved efficiently through parallelization using the Laboratory's supercomputers. The code MPRUN, which efficiently executes a series of Monte Carlo runs in a parallel environment, is used. Because of the independent nature of the individual Monte Carlo runs, the parallelization efficiency scales well with the number of applied processors.

It is important to note that the numerical convolution of a given source to compute the breakthrough curves at the wells requires uniform time steps. In these analyses, breakthrough concentrations are computed at the wells using 0.25-yr time steps.

The hydraulic gradients in the model are constrained based on the water table map (Figure C-3). As a result, it is possible that the permeability variation in the 1000 stochastic runs might produce groundwater flow (Darcy) velocities that exceed ranges expected based on previous information about the total amount of water flowing through the regional aquifer. Groundwater velocity is equal to hydraulic gradient times permeability, but the velocity can also be computed by dividing the total groundwater flow rate by the flow area (Freeze and Cherry 1979, 088742, Chapter 5). However, the transport velocities simulated in the model are considered to be characteristic only of the fraction of the groundwater flow medium where a dominant portion of contaminant transport occurs. As a result, the total amount of groundwater flowing through the aquifer will be consistent with existing hydrogeological information. Therefore, the simulations target estimation of potential uncertainties associated with contaminant transport velocities rather than groundwater flow velocities.

The shape of the water table presented in Figure C-3 is not expected to be affected by water-supply pumping at depth. However, the potential effects of pumping on contaminant transport are simulated by mimicking a cone of depression around each pumping well. In the simulations, the node that represents a particular pumping well is assigned a low pressure head consistent with water levels measured during pumping, and it is assigned a much higher permeability than the surrounding medium. This yields a gradient toward the pumping well, and the extent of the gradient varies in size depending on the permeability of the surrounding medium for a given realization. The pumping-well node is also defined as a sink that removes particles from the simulation domain and counts them as arriving at the water-supply well. Thus, while the hydraulic effects of pumping are not explicitly stated in this model, the potential for pumping wells to capture nearby plumes is included.

There are uncertainties in the shape of the water table that could locally impact the flow direction in the regional aquifer beneath the MDAs at TA-54. This is especially true for the area beneath MDA H. The existing water-level data in the vicinity (R-20, R-21, R-13, R-34; Figure C-3) suggest that there is a potential for flow in a northeastern direction. However, there are uncertainties, in particular, related to the impact of aquifer medium properties in the shape of the water table. It is possible that due to the spatial distribution of hydrostratigraphic units (especially the contact location between the Puye Formation and Cerros del Rio basalts in this area) and medium heterogeneity (for example, but not limited to, stratification of the Puye and the fracturing of the basalts), the shape of the water table might have less of a northeastern component than indicated by current data. The uncertainty of the water-table location will be potentially addressed by the water-level data acquired at the new proposed wells near TA-54. Some of the proposed well locations near MDA H (located in Cañada del Buey) might refine the shape of the water table and the hydrostratigraphy.

In the numerical simulations, the properties of various hydrostratigraphic units are assumed to be spatially uniform. In reality, the aquifer is expected to be highly heterogeneous. This heterogeneity is a major constraint regarding the generality of the simulation results. Real contaminant plumes are expected to be more spatially heterogeneous than currently represented in the model. Therefore, spatial heterogeneity might affect the ability of any monitoring network to detect potential contaminant plumes.

Simulated plumes are based on a unit concentration released at each of the two source areas. Therefore, the model produces concentrations relative to the original source concentration at monitoring and production wells. The movement of a nonsorbing conservative tracer is simulated. No analytical detection limit or regulatory limits are used in this analysis because the predicted concentrations are relative, not absolute concentrations. Therefore, the modeling results do not indicate whether any of the plumes are associated with concentrations that exceed regulatory standards or detection limits. However, the simulations yield information about flow directions and about relative magnitudes of concentrations at pumping and monitoring wells that can be used to define the efficiency of the network.

C-3.0 MONITORING METRICS

An efficient monitoring location must intercept a contaminant plume before arrival at production wells or before crossing the Laboratory boundary. There are a number of possible scenarios for each simulation (or plume).

- *Nondetects* are plumes that reach either a production well or the Laboratory boundary without being detected by any monitoring well.
- *Successful detections* are plumes that are first detected at a monitoring well and after that reach a production well or the Laboratory boundary.
- *Failed detections* are plumes that first reach a production well or the Laboratory boundary and then later arrive at a monitoring well.
- *False positives* are plumes that are detected by the monitoring wells but never reach either a production well or the Laboratory boundary.
- *Detected plumes* are plumes that arrive at the monitoring wells. They include successful detections and failed detections.
- *Plumes of concern* are plumes that reach either a production well or the Laboratory boundary.

Finally, detection efficiency is computed as the number of detected plumes divided by the number of simulated plumes (1000 plumes). Protection efficiency is computed as the number of successful detections (before the plumes reach the production wells or the Laboratory boundary) divided by the number of plumes of concern (in general, the number of plumes of concern can be different for each source).

To estimate successful detection, the model-predicted contaminant travel times from the source area to the monitoring wells are compared with travel times to the water-supply wells and the Laboratory boundary. If the contaminant arrives first at a monitoring well, the detection is considered to be successful. As described above, particle tracking is used to simulate contaminant transport. Arrival of the first particle in such simulations is sporadic and often not statistically significant. Therefore, the test computes and then compares the arrival times for the first 10% of the peak contaminant concentration arriving at the locations of interest rather than relying on the arrival time for the first particle. The arrival time of 10% of the contaminant peak concentration is an approximation of the average travel time of the first 10% of the released particles that reach each well. This approach allows for better definition of the rising limb of a breakthrough curve at a given location and proved to be a successful test for this assessment. However, the results presented below using this metric seem to be conservative..

C-4.0 RESULTS

The efficiencies (%) of the regional monitoring network to detect potential plumes and protect against plumes reaching production wells in the vicinity of TA-54 MDAs and the Laboratory boundary are shown in Table C-3. The network includes five new regional wells as shown in Figure C-1. The augmented monitoring network has almost perfect detection efficiency (greater than 99%) for each of the analyzed source areas. In addition, all of the analyzed production wells are protected by the monitoring network with probability greater than 95%. Therefore, the dominant portions of the potential plumes (>95%) will be detected before they reach the production wells. For any of the source areas within MDA G, the analyses demonstrate that at least 99% of the simulated plumes would be detected before arriving at the Laboratory boundary.

However, the modeling results indicate that potential plumes associated with MDAs H and L could leave the Laboratory boundary without being first detected at the monitoring wells (protection efficiency less than 95% Table C-3). As discussed in Section C-3.0, the currently applied approach to identify successful detection is overly conservative. It appears that it is not suitable in cases like this when there are substantial uncertainties in the flow direction, and the monitoring wells are located relatively close to the Laboratory boundary. There are other possible methods to compare breakthrough concentration curves and contaminant travel times at the monitoring wells and points of protection. For example, initial analyses based on an alternative statistical comparison of the results produced more realistic protection efficiencies. However, additional analyses are needed to evaluate the adequacy of the assumptions related to these new statistical tests. This subject should be further evaluated by Laboratory personnel, and the efficiencies tests should be further discussed with NMED personnel.

To better identify the best location of R-37 near MDA H, five alternative locations presented in Figure C-1 are explored. Because of the alternative locations of R-37, some of the protection efficiencies associated with MDAH vary and the estimated range is presented in Table C-3. Since a phased approach for drilling the wells is proposed in Section 5, the optimal locations of R-38 and R-41 will be based on the hydrogeologic information collected at R-37. To do this, an approach that optimizes well location similar to the one applied for R-37 here will be employed.

Tables C-4, C-5, C-6, C-7, C-8, and C-9 list details about the efficiency of individual existing and proposed regional-aquifer monitoring wells for detecting plumes from the source areas. For wells having more than one screen, the results in this table represent the upper screen because the numerical model is a two-dimensional representation near the top of the regional aquifer. Note that wells with low efficiencies may still be useful for purposes such as water-level monitoring, background sampling, or monitoring other watersheds/sources and may also have served as characterization wells.

Table C-5 presents information important to optimize the potential location of R-37. All the locations have almost perfect detection efficiency. However, the geology at the water table near MDA H is uncertain and may consist of basalt or fanglomerate. These rock types have contrasting heterogeneity structure that can substantially influence the potential plume dispersal and travel times. The current geologic framework model shows that MDA H is potentially underlain by the Puye Formation. However, the spatial extent of Puye Formation downgradient of MDA H at the water table is poorly constrained, and it is possible that basalt underlies this area. Because of this, it is recommended that R-37 be placed relatively close to MDA H, at location R-37d in Figure C-1. This location has the advantage of having the shortest predicted travel time (Table C-5). However, R-37d location has the disadvantage that potential plumes are close to the source and may not have sufficient time to disperse in the regional aquifer (NMED 2007, 098283). Another disadvantage is that a location farther to the east of R-37d may provide useful information to better constrain water levels, flow direction, and the geologic framework model. Based on these considerations, the R-37d location was chosen for the proposed monitoring well. A key aspect of this decision is the likelihood that this position will be in the same hydrostratigraphic unit at the water table as beneath MDA H.

C-5.0 REFERENCES

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

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

Freeze, R.A., and J.A. Cherry, January 1979. *Groundwater*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey. (Freeze and Cherry 1979, 088742)

Keating, E.H., V.V. Vesselinov, Z. Lu, and E. Kwicklis, 2001. "Annual Report on Regional Aquifer Modeling and Data Analysis," Los Alamos National Laboratory document LA-UR-04-1420, Los Alamos, New Mexico. (Keating et al. 2001, 095399)

LANL (Los Alamos National Laboratory), October 2006. "Mortandad Canyon Investigation Report," Los Alamos National Laboratory document LA-UR-06-6752, Los Alamos, New Mexico. (LANL 2006, 094161)

Lichtner, P.C., S. Kelkar, and B. Robinson, August 17, 2002. "New Form of Dispersion Tensor for Axisymmetric Porous Media with Implementation in Particle Tracking," *Water Resources Research,* Vol. 38, No. 8, pp. 21-1–21-16. (Lichtner et al. 2002, 095397)

McLin, S.G., May 2006. "A Catalog of Historical Aquifer Tests on Pajarito Plateau," Los Alamos National Laboratory document LA-UR-06-3789, Los Alamos, New Mexico. (McLin 2006, 093670)

Neuman, S.P., August 1990. "Universal Scaling of Hydraulic Conductivities and Dispersivities in Geologic Media," *Water Resources Research,* Vol. 26, No. 8, pp. 1749-1758. (Neuman 1990, 090184)

NMED (New Mexico Environment Department), August 31, 2007. "Approval with Direction, Technical Area 54 Well Evaluation and Network Recommendations," New Mexico Environment Department letter to D. Gregory (DOE LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED HWB), Santa Fe, New Mexico. (NMED 2007, 098283)

Vesselinov, V.V., 2005. "An Alternative Conceptual Model of Groundwater Flow and Transport in Saturated Zone Beneath the Pajarito Plateau," Los Alamos National Laboratory document LA-UR-05-6741, Los Alamos, New Mexico. (Vesselinov 2005, 090040)

Zyvoloski, G.A., B.A. Robinson, Z.V. Dash, and L.L. Trease, May 20, 1996. "Users Manual for the FEHMN Application," Rev. 1, Los Alamos National Laboratory document LA-UR-94-3788, Los Alamos, New Mexico. (Zyvoloski et al. 1996, 054421)

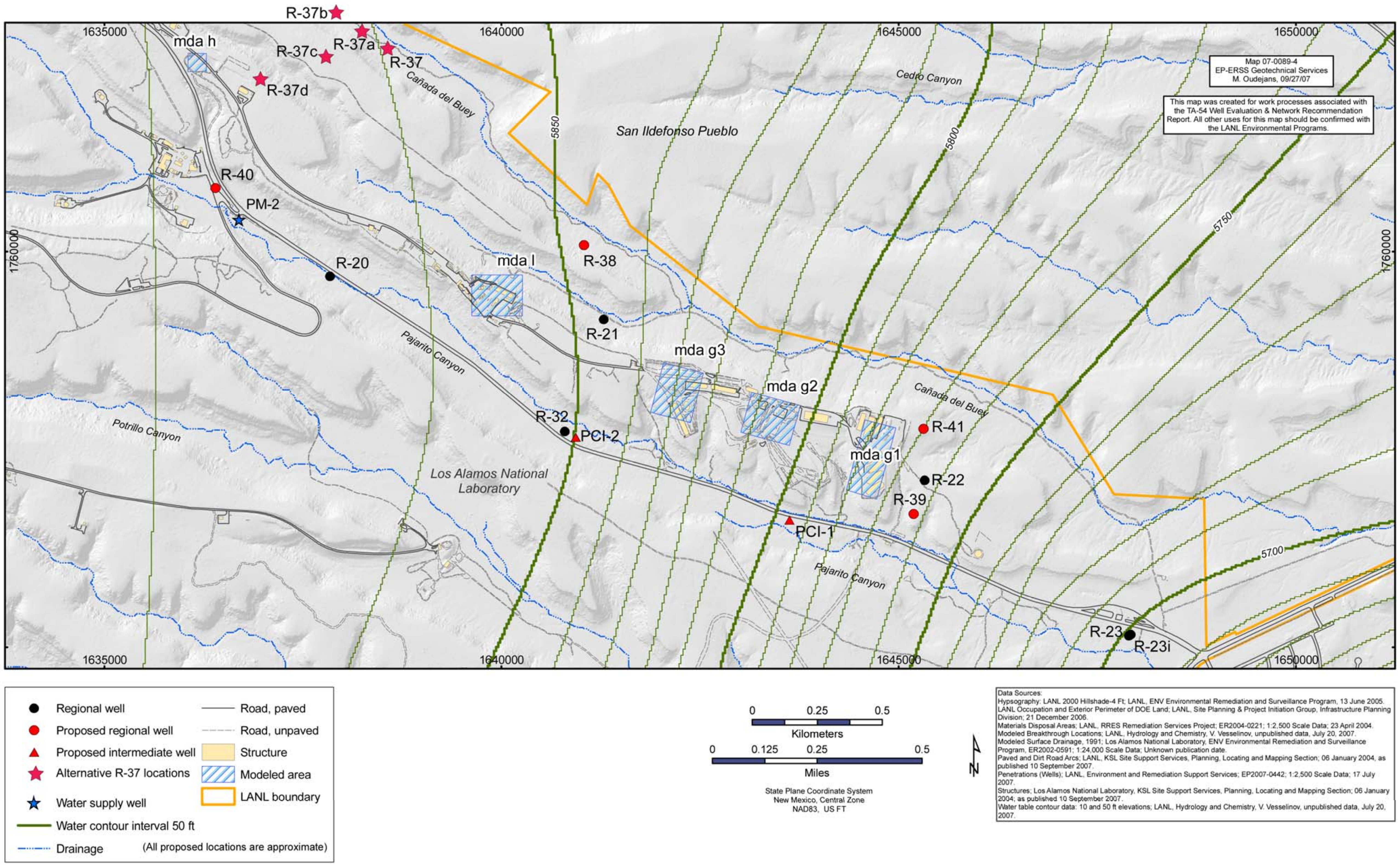


Figure C-1 Location of TA-54: MDAs H, L, and G including the existing regional wells, new proposed wells, water-table contours, water-supply wells, and the approximate breakthrough locations of mobile contaminants that have migrated through the unsaturated zone to the regional water table

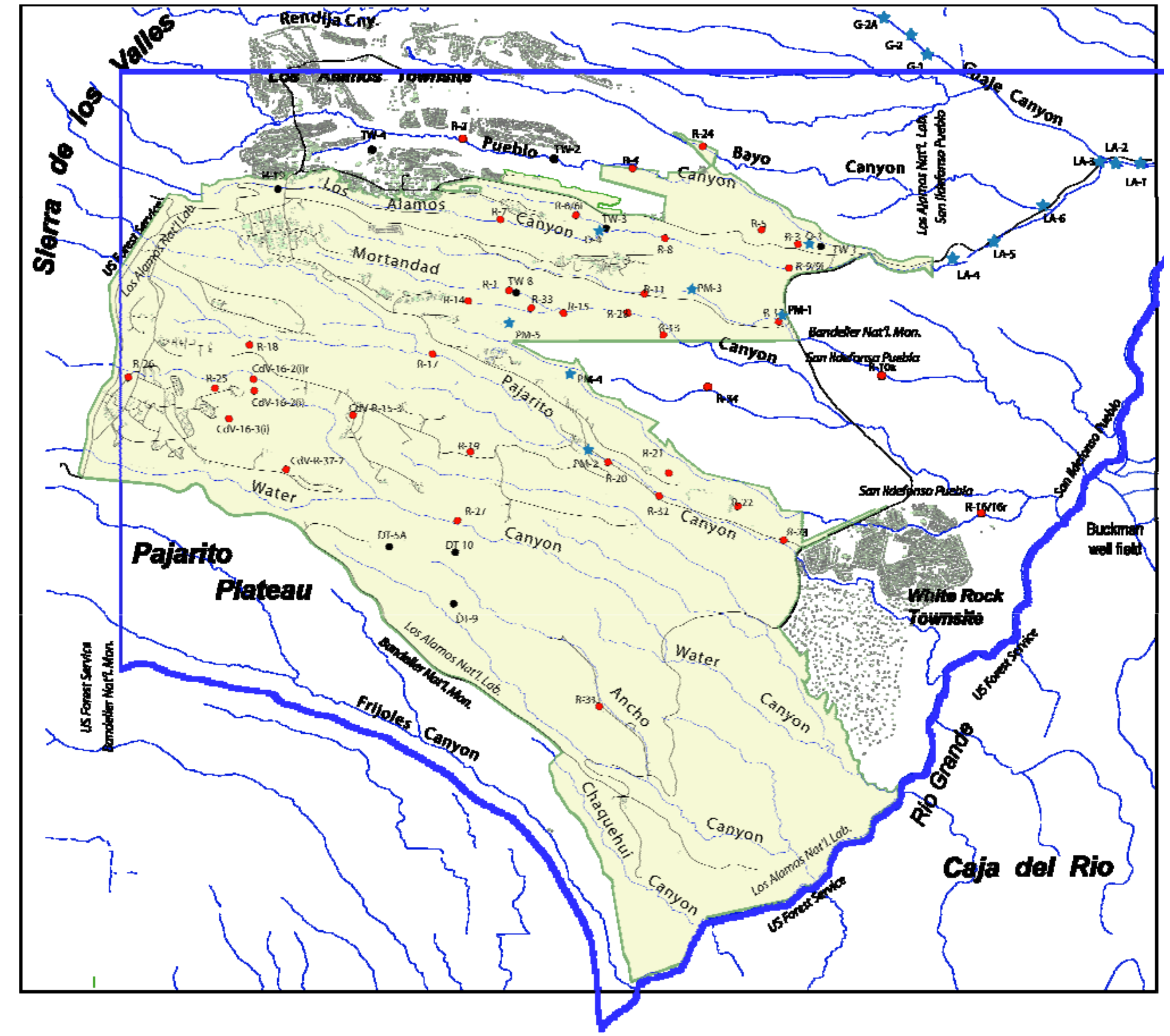


Figure C-2 Domain of the regional-aquifer numerical model used for the wells assessments

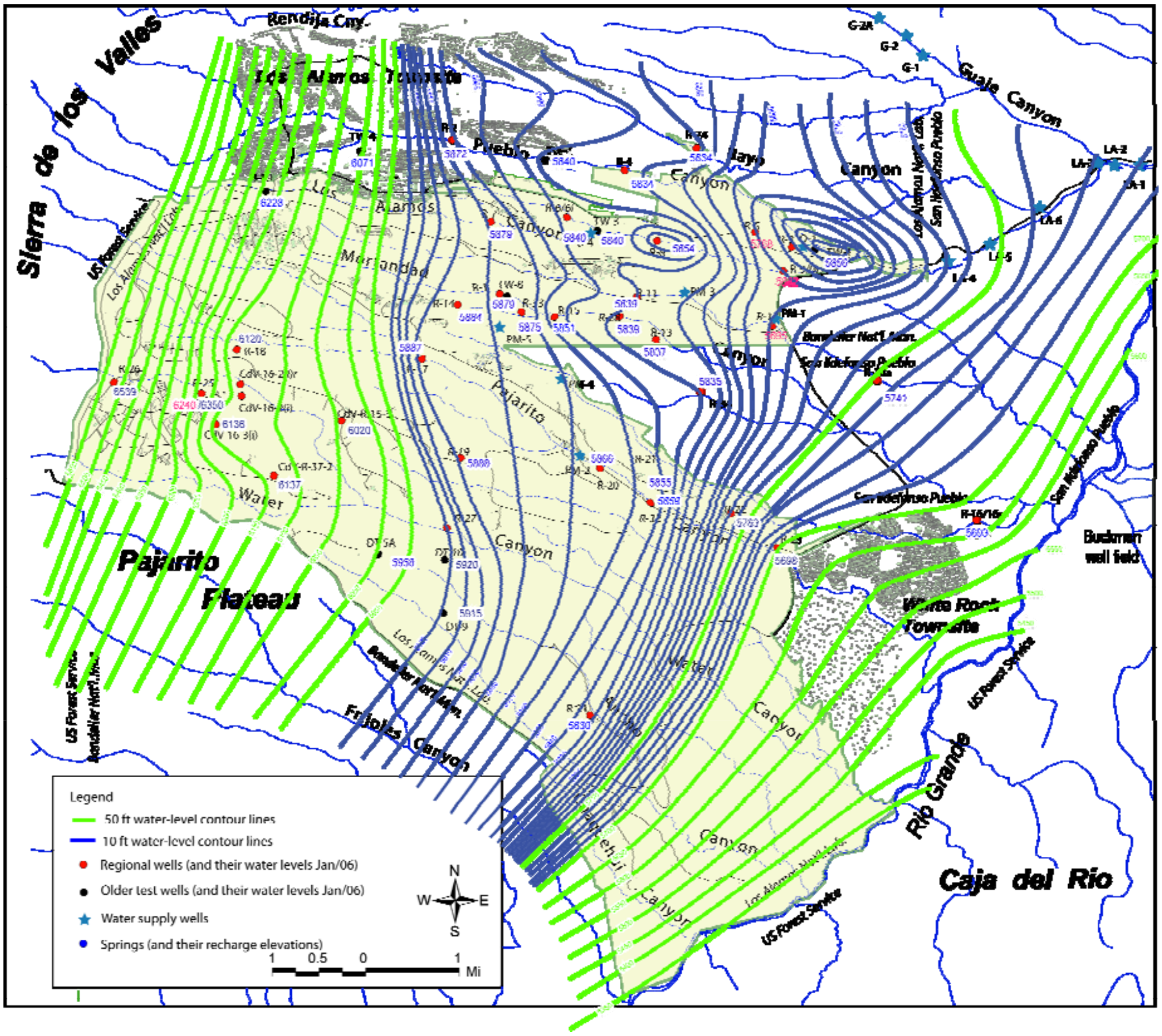
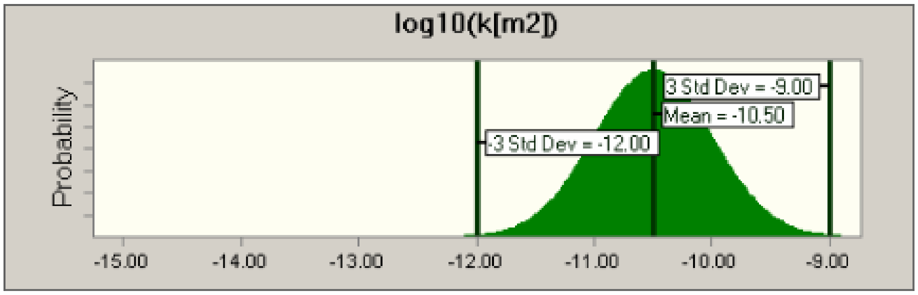
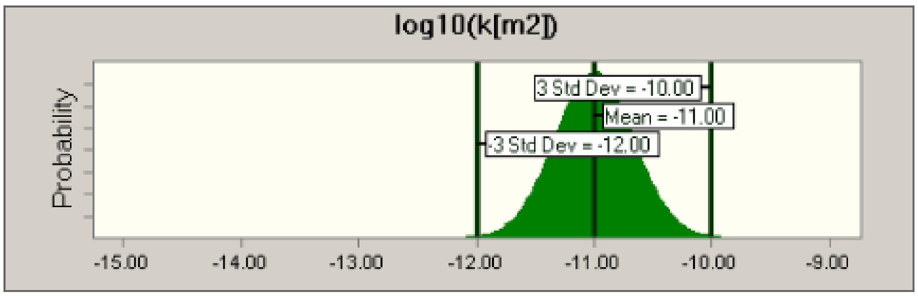


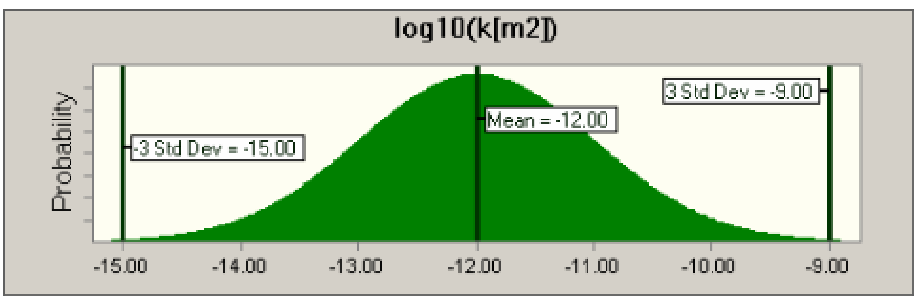
Figure C-3 Water-table map characterizing the flow direction in the phreatic zone of the regional aquifer



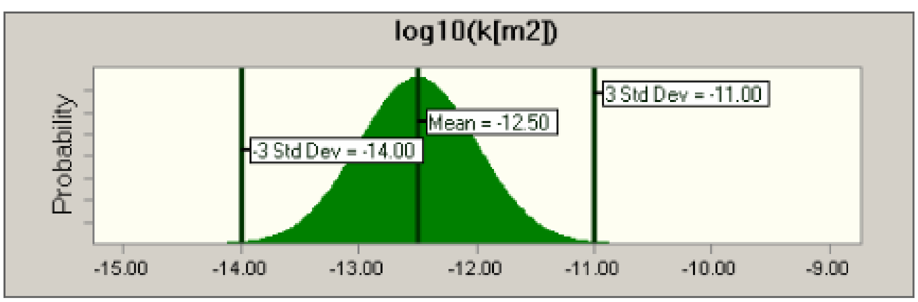
(a)



(b)

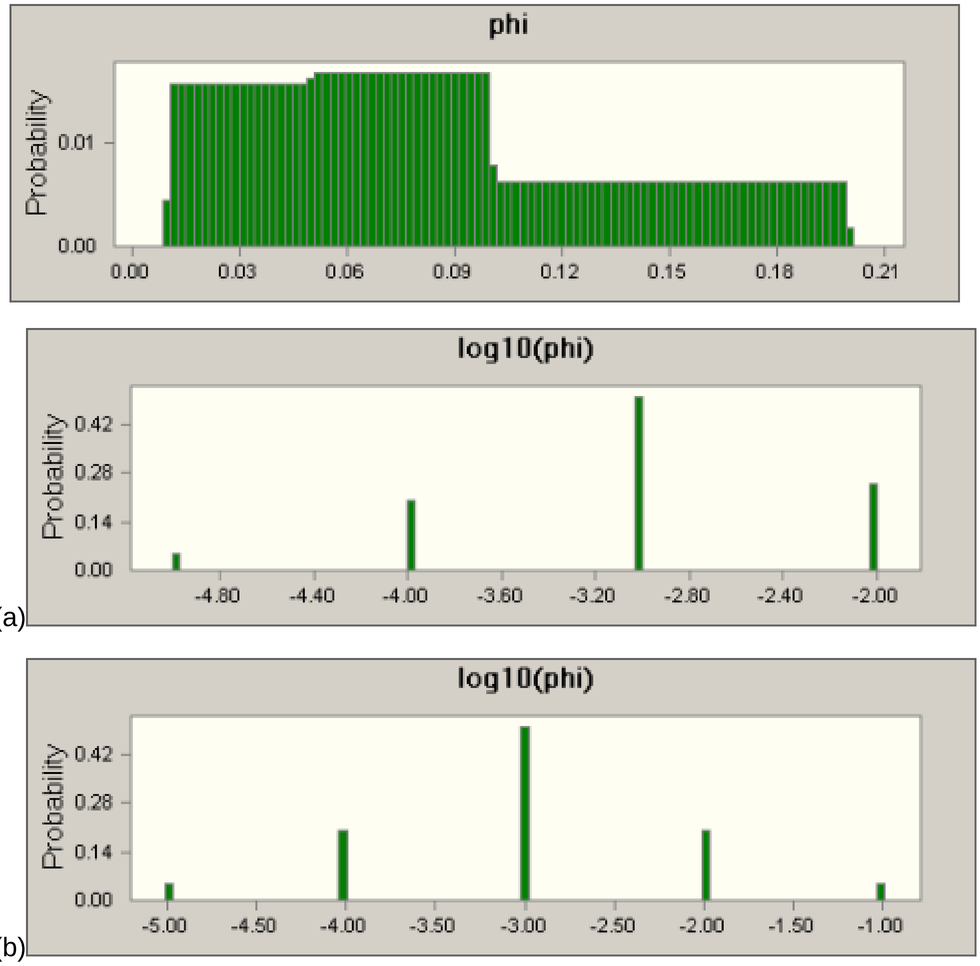


(c)



(d)

Figure C-4 Probability distributions of permeability for different hydrostratigraphic units: (a) Tschicoma, Keres group; (b) Totavi Lentil; (c) Cerros del Rio basalt, Bayo Canyon basalt; (d) pumiceous puye, puye fanglomerate, Santa Fe fanglomerate, Santa Fe silt and sands. The distributions are based on site-specific (field hydraulic tests; (McLin 2006, 093670) and literature data (Freeze and Cherry 1979, 088742).



(a)

(b)

(c)

Figure C-5 **Probability distributions of effective porosity for different hydrostratigraphic units: (a) Totavi Lentil, Pumiceous Puye, Puye Fanglomerate, Santa Fe Fanglomerate, Santa Fe Silt and Sands; (b) Tschicoma, Keres Group; and (c) Cerros del Rio Basalt, Bayo Canyon Basalt. The distributions are defined predominantly based on data from the literature (Freeze and Cherry 1979, 088742); the only site-specific data that are available are for the Cerros del Rio Basalt (Tb4) and Puye Fanglomerate (Tpf), and these data were considered in developing the distributions for those two units (Keating et al. 2001, 095399).**

Table C-1
Characteristics of Hydrostratigraphic Units Represented in the Model

				Permeability			Porosity		
Unit	Name	Number of Nodes	Percentage in the Model	Distribution Type	Mean	Standard Deviation	Distribution Type	Min	Max
Tschicoma	Tt	73049	10.5%	Log normal	-10.5	0.50	Discrete	1.E-05	1.E-02
Keres Group	Tk	2865	0.4%	Log normal	-10.5	0.50	Discrete	1.E-05	1.E-02
Cerros del Rio Basalt	Tb4	97099	14.0%	Log normal	-12.0	1.00	Discrete	1.E-05	1.E-01
Bayo Canyon Basalt	Tb2	24007	3.5%	Log normal	-12.0	1.00	Discrete	1.E-05	1.E-01
Totavi Lentil	Tpt	22543	3.2%	Log normal	-11.0	0.33	Discrete	1.E-02	2.E-01
Pumiceous Puye	Tpp	29116	4.2%	Log normal	-12.5	0.50	Discrete	1.E-02	2.E-01
Puye Fanglomerate	Tpf	152808	22.0%	Log normal	-12.5	0.50	Discrete	1.E-02	2.E-01
Santa Fe Fanglomerate	Tf	78269	11.3%	Log normal	-12.5	0.50	Discrete	1.E-02	2.E-01
Santa Fe Silt and Sands	Ts	214192	30.9%	Log normal	-12.5	0.50	Discrete	1.E-02	2.E-01

Table C-2
Statistical Properties of Dispersivities

	Distribution Type	Min	Max
Longitudinal dispersivity	uniform	50	100
Transverse dispersivity	uniform	5	10

Table C-3
Efficiency for the Regional Monitoring Network to Detect Potential Plumes and Protect against Undetected Migration toward the Production Wells and the Laboratory Boundary

Infiltration Window	Detection Efficiency	Protection Efficieny				
		PM-1	PM-2	PM-3	PM-4	Off-Site
MDA H	99.5-100%#	100%	100%	98.4-100%#	96.1-99.9%#	55.7-91.4%#
MDA L	100%	100%	100%	100%	100%	87%
MDA G3	99%	n/a*	n/a	n/a	n/a	99%
MDA G2	99%	n/a	n/a	n/a	n/a	100%
MDA G1	100%	n/a	n/a	n/a	n/a	100%

Note: Probabilities less than 95% are marked in red.

*n/a = Indicates that none of the 1000 simulated plumes reach this particular water supply well from this MDA, and thus, the monitoring network efficiency analysis is not applicable for this source/well combination.

 # = The efficiency varies depending on the location of R-37.

Table C-4
Details of Efficiency Calculations for MDA H for 1000 Simulated Plume Distributions

Monitoring Well	Total Detections	Detection Efficiency	Successful Detections	Failed Detections	False Positives	Protection Efficiency
R-20	88	8.8%	0	88	0	0.0%
R-21	59	5.9%	0	59	0	0.0%
R-22	192	19.2%	1	191	0	0.1%
R-23	657	65.7%	0	657	0	0.0%
R-32	23	2.3%	0	23	0	0.0%
R-34	962	96.2%	0	962	0	0.0%
R-37	995	99.5%	553	442	0	55.3%
R-37a	998	99.8%	796	202	0	79.6%
R-37b	1000	100.0%	555	445	0	55.5%
R-37c	999	99.9%	838	161	0	83.8%
R-37d	1000	100.0%	909	91	0	90.9%
R-38	133	13.3%	0	133	0	0.0%
R-39	149	14.9%	1	148	0	0.1%
R-40	208	20.8%	8	200	0	0.8%
R-41	263	26.3%	5	258	0	0.5%

Note: The total number of plumes of concern is 1000.

Table C-5
Comparison between Alternative Locations for R-37 Related to the Potential MDA H Source

Well	Average Travel Time in the Regional Aquifer [Years]	Detection Efficiency [%]	Protection Efficiency [%]
R-37	33	99.5%	55.3%
R-37a	31	99.8%	79.6%
R-37b	32	100.0%	55.5%
R-37c	27	99.9%	83.8%
R-37d	17.8	100.0%	90.9%

Table C-6
Details of Efficiency Calculations for MDA L for 1000 Simulated Plume Distributions

Monitoring Well	Total Detections	Detection Efficiency	Successful Detections	Failed Detections	False Positives	Protection Efficiency
R-20	182	18.2%	47	135	0	4.7%
R-21	1000	100.0%	428	572	0	42.8%
R-22	984	98.4%	19	965	0	1.9%
R-23	998	99.8%	0	998	0	0.0%
R-32	328	32.8%	29	299	0	2.9%
R-37	2	0.2%	2	0	0	0.2%
R-38	1000	100.0%	863	137	0	86.3%
R-39	802	80.2%	4	798	0	0.4%
R-40	1	0.1%	0	1	0	0.0%
R-41	998	99.8%	50	948	0	5.0%

Note: The total number of plumes of concern is 1000.

Table C-7
Details of Efficiency Calculations for MDA G3 for 1000 Simulated Plume Distributions

Monitoring Well	Total Detections	Detection Efficiency	Successful Detections	Failed Detections	False Positives	Protection Efficiency
R-20	0	0.0%	n/a*	n/a	n/a	0.0%
R-21	531	53.1%	282	249	0	28.2%
R-22	999	99.9%	934	65	0	93.4%
R-23	999	99.9%	247	752	0	24.7%
R-32	554	55.4%	315	239	0	31.5%
R-37	2	0.2%	2	0	0	0.2%
R-38	132	13.2%	49	83	0	4.9%
R-39	999	99.9%	924	75	0	92.4%
R-40	1	0.1%	0	1	0	0.0%
R-41	999	99.9%	919	80	0	91.9%

Note: The total number of plumes of concern is 1000.

*n/a = Indicates that the metric is not applicable because the contaminants do not migrate toward this monitoring location.

Table C-8
Details of Efficiency Calculations for MDA G2 for 1000 Simulated Plume Distributions

Monitoring Well	Total Detections	Detection Efficiency	Successful Detections	Failed Detections	False Positives	Protection Efficiency
R-20	0	0.0%	n/a*	n/a	n/a	0.0%
R-21	531	53.1%	282	249	0	28.2%
R-22	999	99.9%	934	65	0	93.4%
R-23	999	99.9%	247	752	0	24.7%
R-32	554	55.4%	315	239	0	31.5%
R-37	2	0.2%	2	0	0	0.2%
R-38	132	13.2%	49	83	0	4.9%
R-39	999	99.9%	924	75	0	92.4%
R-40	1	0.1%	0	1	0	0.0%
R-41	999	99.9%	919	80	0	91.9%

Note: The number of plumes of concern is 1000.

*n/a = Indicates that the metric is not applicable because the contaminants do not migrate toward this monitoring location.

Table C-9
Details of Efficiency Calculations for MDA G1 for 1000 Simulated Plume Distributions

Monitoring Well	Total Detections	Detection Efficiency	Successful Detections	Failed Detections	False Positives	Protection Efficiency
R-20	0	0.0%	n/a*	n/a	n/a	0.0%
R-21	15	1.5%	4	11	0	0.4%
R-22	1000	100.0%	1000	0	0	100.0%
R-23	1000	100.0%	454	546	0	45.4%
R-32	17	1.7%	6	11	0	0.6%
R-37	1	0.1%	0	1	0	0.0%
R-38	1	0.1%	0	1	0	0.0%
R-39	1000	100.0%	1000	0	0	100.0%
R-40	0	0.0%	0	0	0	0.0%
R-41	1000	100.0%	1000	0	0	100.0%

Note: The number of plumes of concern is 1000.

*n/a = Indicates that the metric is not applicable because the contaminants do not migrate toward this monitoring location.