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Workplan for R-Well Rehabilitation and Replacement

Los Alamos
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Prepared by
Environmental Stewardship Division–
Environmental Remediation and Surveillance Program

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EXECUTIVE SUMMARY

As part of the 1998 to 2005 characterization program outlined by the Los Alamos National Laboratory's (LANL's or the Laboratory's) "Hydrogeologic Workplan" (HWP), 33 wells (called R-wells) were drilled within the Laboratory's boundary and the surrounding area. It was anticipated that eventually these characterization wells might become part of a groundwater monitoring network. During the later years of the HWP, concerns were raised that some R-wells might not be suitable for monitoring because fluids and additives used in the drilling and well construction appeared to have been incompletely removed during the development of some of the wells. These fluids could impact the ability of the wells to provide representative groundwater data and compromise the ability to detect reactive contaminants. As a result of these concerns, the Laboratory conducted an extensive analysis of the 33 R-wells (documented in the Laboratory's "Well Screen Analysis Report" [WSAR]), on a screen-by-screen basis, to determine which screens appeared to be impacted and to what degree.

The WSAR results indicated that for 64 screens analyzed, 16 of the wells had screens that were in Fair or Poor condition and could not be relied upon to provide representative data or to detect contaminants in groundwater. These results prompted the New Mexico Environment Department in its reply to the Laboratory's "Interim Facility-wide Groundwater Monitoring Plan" to request a well rehabilitation plan. This document responds to that request by providing the basis for rehabilitating or replacing impacted characterization wells at LANL to render them capable for inclusion in a monitoring network.

To arrive at potential courses of action for each of the impacted wells, conditions known to exist at individual screens were evaluated. Of the 16 out of 33 wells with screens that scored Fair to Poor in the WSAR, two—R-16 and R-20—have been selected for a pilot well rehabilitation study to be conducted in the summer of 2006. The present well rehabilitation workplan is informed by the pilot study.

The highest-priority wells are those needed for monitoring Mesita del Buey and Technical Area (TA) 54, including R-16, R-20, R-32, and R-22. Another high-priority well is R-12 because of its importance in chromium source monitoring. The next highest priority is monitoring TA-16's 260 outfall. Here it was decided to focus on R-25 in fiscal year 2007 (FY07). Also a high priority is well R-26, which is upgradient of the Laboratory and is needed to establish background chemistry. Finally, R-14 is of a rather high priority because of its location in Ten Site Canyon. Wells R-12, R-14, R-16, R-20, R-22, R-25, R-26, and R-32 are slated for corrective action in FY06 and FY07, and the remaining wells will be decided upon in FY08 when insights have been gained from the FY06 and FY07 activities. The results of a decision analysis for the groundwater monitoring network to be completed later in FY06 will be used to reevaluate this prioritization and to decide on a path forward for the remaining wells that would undergo corrective action in FY08.

This well rehabilitation workplan explains the selection of wells for rehabilitation, the rehabilitation methods, and the measures to evaluate the degree of success of rehabilitation. The Laboratory will interpret and analyze these results and will report them in an annual update to this well rehabilitation workplan. Water-quality data collected as part of the well rehabilitation will be compared with results compiled in the WSAR. Success will be defined as a rating of Good or Very Good, according to the geochemical criteria developed for the WSAR. In addition, changes in, and improvements to, hydrologic parameters will be noted. The collective results of rehabilitation efforts in FY07, along with insights gained from the FY06 pilot study, will be used to guide decisions made for wells in FY08 and to refine the methods used in their rehabilitation.

In addition to reporting the results of the redevelopment process in the annual update to this well rehabilitation workplan, results also will be discussed and interpreted in a 2008 update of the WSAR. The updated WSAR will provide a more comprehensive discussion of well conditions and the degree of success of the rehabilitation efforts.

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LIST OF ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
Consent Order	Compliance Order on Consent (March 1, 2005)
DO	division office
DOE	Department of Energy (U.S.)
DP	Defense Program
ECR	Environmental Characterization and Remediation (an ENV group)
ENV	Environmental Stewardship (a LANL division)
EPA	Environmental Protection Agency (U.S.)
ER	environmental restoration
ERS	Environmental Remediation and Surveillance (an ENV program)
FY	fiscal year
GDAP	Groundwater Data Adequacy Project
HWP	Hydrogeologic Workplan
LANL	Los Alamos National Laboratory
MDA	material disposal area
NMED	New Mexico Environment Department
ORP	oxidation-reduction potential
P&A	plug and abandon
QA	quality assurance
QP	quality procedure
RDX	1,3,5-trinitro-1,3,5-triazacyclohexane
RPF	Records Processing Facility (an ENV archive)
SOP	standard operating procedure
TA	technical area
TKN	total Kjehldahl nitrogen
TOC	total organic carbon
WQH	Water Quality and Hydrology (an ENV group)
WSAR	Well Screen Analysis Report
XRD	x-ray diffraction

1.0 INTRODUCTION

The Los Alamos National Laboratory's (LANL's or the Laboratory's) "Hydrogeologic Workplan" (HWP) (LANL 1998, 59599) outlined a program that was conducted from 1998 to 2005 to characterize the hydrogeology, geochemistry, and flow pathways beneath the Laboratory. It was understood that results of the HWP would be used, along with other information and knowledge, to design a groundwater monitoring network for the Laboratory.

As part of the HWP, 33 wells were drilled within the Laboratory boundary and surrounding area, and they continued to be drilled following completion of the HWP (Figure 1-1). The 33 wells are collectively referred to as "R-wells" even though a few of them have different prefixes, such as CdV and MCOBT. Data-quality objectives were developed for each individual well to address questions about the hydrogeologic and geochemical framework beneath the Laboratory, groundwater flow directions in the regional aquifer and perched intermediate zone, aquifer characteristics, ranges in hydraulic properties of different lithologic units, and other aspects of characterization. The Laboratory, the U.S. Department of Energy (DOE), the New Mexico Environment Department (NMED), and an external advisory group all agreed to the purpose and objectives for the wells. It was anticipated and assumed by all that eventually these wells might become part of a groundwater monitoring network even though they were constructed for characterization purposes.

During the later years of the HWP, and culminating in 2005, numerous parties, both internal and external to the Laboratory, raised concerns that some of the multiple-screen R-wells might not be suitable for monitoring because fluids and additives used in drilling and well construction appeared to have been incompletely removed during the development of some of the wells. These fluids impact the ability of those wells to provide representative groundwater data and hence compromise the ability to detect reactive contaminants. As a result of these collective concerns, the Laboratory conducted an extensive analysis of all 33 R-wells on a screen-by-screen basis (64 screens) to determine which screens appeared to be impacted by well construction methods and to what degree ("Well Screen Analysis Report" [WSAR], LANL 2005, 91121).

The WSAR results indicated that 17 of the 33 R-wells had screens that were in Very Good to Good condition and that the remaining 16 wells had screens that were in Fair or Poor condition (the rating scheme is explained in the WSAR) and could not be relied upon to provide representative data or to detect all potential contaminants in groundwater. The screen ratings for the most recent sample taken as of November 2005 are shown in Figure 1-2. The outcome of the WSAR prompted NMED in its reply (NMED 2005, 91828) to the Laboratory's "Interim Facility-wide Groundwater Monitoring Plan" (LANL 2005, 88789) to state

> *"The Permitees must also develop a plan for rehabilitation of all wells where fluids were utilized and where construction problems (e.g., misplaced screens/grout or excessive filter pack lengths) are documented. This plan must be submitted completed [(sic]) prior to and reported in the annual update (2006) of the Monitoring Plan. If the wells cannot be rehabilitated to provide representative, quality groundwater monitoring data, the Permitees may be required by NMED to plug and abandon and complete a new well in an adjacent or more appropriate location."*

This well rehabilitation workplan provides the basis for rehabilitating or replacing impacted characterization wells at LANL so they can function, if needed, in a monitoring network.

This report is organized in the following way: Section 2 provides background for this workplan in the context of the Groundwater Data Adequacy Project (GDAP). Section 3 reviews site conditions and conditions known to exist at the impacted wells that influence potential courses of action. Section 4 provides the scope of activities included in the plan, which follow from criteria established for selecting particular wells for rehabilitation or replacement, and the methods used to establish these criteria. Section 5 describes the investigation methods chosen for potentially successful well rehabilitation. Section 6 provides a framework for implementation, including quality assurance (QA) and organizational responsibilities. Section 7 defines how data will be collected and results analyzed to determine whether rehabilitation has been successful. Section 8 summarizes the plan and provides a time frame for activities.

2.0 BACKGROUND

This well rehabilitation workplan is part of the GDAP and is informed by the pilot well rehabilitation study to be conducted in the summer of 2006 (LANL 2006, 92471). The pilot study will provide a test of rehabilitation methods for two multiple-screen wells, R-16 and R-20. Results of the pilot study will then be used to aid the rehabilitation of the remaining wells, which are prioritized in this well rehabilitation workplan (section 4.3). This workplan will be revised annually; some aspects of the workplan may be revised based on the pilot study's final results.

The GDAP was established to improve the defensibility of groundwater sampling data over the period from fiscal year 2006 (FY06) through FY08. The objective of the GDAP is to ensure that groundwater data meet data-quality criteria. The GDAP consists of eight components, including (1) a pilot well rehabilitation project to be completed in FY06 (LANL 2006, 92471), (2) an expanded well rehabilitation and replacement project (for which this document serves as the plan), (3) documentation of the regulatory guidelines used to establish groundwater data adequacy, (4) performance of QA checks on certain data-collection methods, (5) specific additional laboratory and field tests on groundwater and aquifer materials, (6) chemical speciation and transport modeling, (7) historical and current data qualification, and (8) a plan to communicate the GDAP to stakeholders and the public. GDAP activities that were initiated in May 2006 include #3, 4, 6, 7, and 8 of the above components. Field and laboratory tests (#5) will begin in FY07. Laboratory testing and modeling are intended to demonstrate the types and degrees of impact to particular screens and their future ability to produce representative groundwater samples. The results of testing and modeling will be used to inform subsequent revisions of this well rehabilitation workplan.

As a follow-up to the WSAR, correlations between various physical characteristics and screen conditions were evaluated (e.g., screen performance versus hydraulic conductivity of formation). It was hoped that these correlations would help identify some problems that occurred in more than one screen and would provide insights into each screen's potential for rehabilitation. Unfortunately, the only strong performance indicator shown in Figure 2-1 is the distinction between single-screen and multiple-screen wells, with single-screen wells performing much better than multiple-screen wells.

As an initial step in making planning decisions for each well, the original data-quality objectives for the HWP wells were revisited, along with, to some extent, objectives for monitoring. This assessment included tabulated information drawn from well completion reports and other sources (see Appendix A), the correlations mentioned above, and a decision peer review. The assessment included examinations of drilling methods and fluids appropriate for the depths required and lithologies encountered, of well design (having a multiple-screen well versus clustered well monitoring points), and of groundwater sampling systems appropriate for multiple-screen or single-screen wells completed at great depths. The decision peer review resulted in a preliminary prioritized list of wells for corrective action, as discussed in section 4.

3.0 SITE CONDITIONS

As indicated in section 1, the R-wells drilled for the HWP were constructed to obtain hydrologic and geochemical parameters in order to characterize flow and transport in groundwater beneath the Laboratory. For the wells to reach the regional aquifer in some wells (e.g., in the Santa Fe Group), fluids and additives were used during drilling and well installation to enable the advancement of the drill casing or drill bit and to prevent the collapse of open-borehole intervals during the collection of borehole geophysical data. The hydrogeologic complexity and varying degrees of competence of the stratigraphic units beneath the Laboratory also dictated the use of fluids for penetration. Bentonite drilling muds were used at nine screens in four of the wells that are shown in this workplan as requiring rehabilitation or replacement. Organic fluids, such as EZ-MUD and QUIKFOAM, were used in all of the wells. If not completely removed by subsequent development, bentonite can serve as both a source of ions to groundwater as well as a sink for sorbing cations and organic species. Similarly, residual organic drilling fluids left in situ provide nutrients for microorganisms, a situation that leads to reducing conditions that can dissolve naturally occurring metal oxides and hydroxides, including those of iron and manganese, thereby releasing any coprecipitated or sorbed metals. At the same time, organic fluids reduce anions such as nitrate to nitrogen gas and sulfate to sulfide. Reducing conditions also may enhance the degradation rate of some organic species in the vicinity of the screen. The combined effects of these chemical reactions create conditions leading to unrepresentative groundwater quality and the inability to determine the presence or absence of contaminants in the groundwater with confidence. For a more detailed explanation of these reactions, see the WSAR (LANL 2005, 91121).

To arrive at potential courses of action for each of the impacted wells, conditions known to exist at individual screens were evaluated. This information is tabulated in Appendix A and depicted in the well diagrams in Appendix B. The specific conditions relevant to wells that are of the highest priority for rehabilitation in FY07 are discussed in section 4.4.

4.0 SCOPE OF ACTIVITIES

Section 4 provides the scope of activities included in the workplan, focusing primarily on activities that will be accomplished in FY06 and FY07. Leading up to a decision about the scope of work to be performed, an initial tabulation of physical conditions was made for every well that was a candidate for corrective action (rehabilitation, replacement, or other action) (section 4.1). This information is found in Appendix A and was used in conjunction with well diagrams from Appendix B to help guide a decision peer review (section 4.2). Section 4.3 discusses specific actions to be taken in FY07 for each of the wells ranked high for corrective action by the Decision Peer Review Team.

4.1 Pre-Decision Peer Review Assessment

DOE and the Laboratory established that of the 16 out of 33 wells with screens that scored Fair to Poor in the WSAR, R-16 and R-20 should be included in the pilot study. These wells were chosen because they had a number of screens showing various degrees of impact from drilling fluids, because they were easily accessible, and because of their locations relative to monitoring. (See LANL 2006 [92471] for a more detailed discussion of the selection criteria for these wells.) Based on information tabulated in Appendix A, eight of the remaining wells are candidates for rehabilitation, two will likely remain in use without redevelopment (R-5 and R-33, discussed in section 4.3), and the rest will undergo a combination of partial replacement, partial rehabilitation, and partial abandonment. Table 4.1 shows the current plan of action for these wells.

4.2 Decision Peer Review

The objective of the decision peer review was to prioritize the impacted wells for partial or full rehabilitation, replacement, or other corrective action. This was done within the guidelines identified as necessary for the monitoring or characterization of the screens.

4.2.1 Assumptions Made by the Decision Peer Review Team

- Not all screens will be needed for monitoring or additional characterization. Some screens have achieved their characterization purposes, while others may still be needed for the collection of hydrologic properties to further refine conceptual flow models in the regional aquifer.
- This well rehabilitation workplan will not address screens rated as Good or Very Good. The scope of this workplan will include only actions to be taken at the 16 wells that are most impacted by fluids.
- Currently, no acceptable sampling system exists as an alternative to Westbay for situations where more than two screens per well are needed for the monitoring system.
- The Laboratory will opt for as many single- or dual-screen wells as possible, taking into consideration technical needs for monitoring and characterization. This option will allow purging the well before sampling. This concept includes conversion of wells with three or more screens to single- or dual-screen completions by plugging and abandoning some of the deeper screens.
- Wells having productive screens exclusively in perched zones will be kept and rehabilitated (among the wells included in this workplan as requiring rehabilitation or replacement, only R-9i meets this condition).
- If there are perched intermediate zones in multiple-screened wells, either rehabilitation will be attempted at all screens, in which case the well will retain the Westbay sampling system, or, if the perched zone screen is needed for monitoring, the regional screen(s) will be retained for monitoring in the existing well and a new perched intermediate zone well will be drilled nearby.
- If a well location is needed for monitoring, but there is a low probability of successful rehabilitation, then the well will be replaced with a single-screen completion well to the top of the regional aquifer.
- If only one or two screens are needed (in wells converted to single- or dual-screen completion), alternative sampling systems to Westbay will be considered.
- If more than two screens are needed in a well for monitoring, then the well will remain a Westbay well, and it will be rehabilitated by methods tested in the pilot study (see section 5).
- Screens not required for monitoring will be plugged and abandoned (if the lowest screen) or isolated (if the screen is situated above or between other needed screens).

4.2.2 Decision Peer Review Team Discussion

Before arriving at priorization criteria for the wells to be rehabilitated, the Decision Peer Review Team considered many factors, including the following (not ranked by importance):

- Suitability of the well location for monitoring background
- Location of the well within the Laboratory footprint
- Location of the screen at the top of the regional aquifer

- Whether the screen shows the presence of contamination
- Whether the screen shows the presence of conservative Laboratory contaminants, indicating “modern” water (e.g., tritium; nitrate; perchlorate; 1,3,5-trinitro-1,3,5-triazacyclohexane [RDX])
- For deeper screens, whether the screen shows evidence of a downward vertical pressure gradient
- Whether the screen is needed to support corrective action decisions under the Compliance Order on Consent (Consent Order) signed by NMED, DOE, and the Regents of the University of California on March 1, 2005 (e.g., Technical Area [TA] 54 material disposal areas [MDAs], TA-16 260 outfall)
- Whether the well and screen are needed to help resolve a highly visible issue (e.g., chromium sources and migration)
- The current status of screen condition and trends, including long-term prognosis for the screen’s recovery to predrilling conditions
- Whether the screen interval is located in a formation that is too tight to ever be adequately developed or to allow adequate purging
- The cost of the applicable rehabilitation method (e.g., retrofitting a well to allow purging before collecting a sample is probably not as costly as screen rehabilitation)

Reasons to assign a low priority to screen rehabilitation or to plug and abandon an interval include inadequate hydraulic conductivity in the screen interval; problems during borehole drilling and well construction (e.g., bentonite emplaced next to a screen); or lost circulation resulting in a large volume of drilling fluids being introduced into the interval.

4.3 Results of the Decision Peer Review

The highest-priority wells are those needed for monitoring Mesita del Buey and TA-54. This includes R-16 and R-20 (both of which are being addressed in the pilot study), R-32 and R-22 (proposed for rehabilitation in FY07), and R-21 and R-23 (for which no action is planned because these single-screen wells are in Very Good to Good condition). R-12 is a high-priority well because of its importance in chromium source monitoring. The next highest priority is monitoring the TA-16 260 outfall, which includes wells R-25, CdV-R-15-3, and CdV-R-37-2. The plan focuses on R-25 in FY07 and defers the others to FY08. Well R-26, which is upgradient of the Laboratory and is needed to establish background chemistry, is also a high-priority well. Finally, R-14 is included in the high-priority list for FY07 because of its location in Ten Site Canyon. Having established these wells for corrective action in FY07, the Decision Peer Review Team decided that the remaining wells would be acted on in FY08 after insights will have been gained by FY06 and FY07 activities.

Two exceptions are wells R-5 and R-33, where rehabilitation is unnecessary. R-5 has two screens rated Very Good, one in the vadose zone (Screen 2), and one at the water table (Screen 3; see Appendix B, Figure B-3). Screen 1 in the vadose zone is dry and is not needed for monitoring; Screen 4 (rated Fair) at about 860 ft depth in the Santa Fe Group is also not needed for monitoring. Well R-33 has two screens in the regional aquifer, a Fair-rated screen right at the water table and a Very Good screen 80 ft below (Figure B-17). The same water is sampled at both screens and the Very Good screen meets monitoring requirements.

The final ranking of the wells to be redeveloped in FY07 is as follows: (1) R-12 (which may be accelerated to FY06), (2) R-32, (3) R-14, (4) R-26, (5) R-22, and (6) R-25. R-12 and R-32 received very high ranks for monitoring chromium and contaminant sources at TA-54. R-14 and R-26 took middle places in the ranking because their rehabilitation is likely to be less difficult than R-22 or R-25. Note that R-22 is geologically very complex at depth, which has a bearing on its rank in the prioritization. The redevelopment results of the earlier wells will be evaluated to identify appropriate action at R-22. R-25 took last place on the list because it is the most complex well with nine screens and because of the incomplete nature of the most recent water-quality data for these screens.

Results of the decision analysis for the groundwater monitoring network, to be completed later in FY06, will be used to reevaluate this prioritization and to decide on a path forward for the remaining wells slated for corrective action in FY08 (see Table 4.1).

4.4 Specific Actions at Wells Prioritized for FY07

The well diagrams in Appendix B help visualize the well conditions (see Figure 4-1 for a visualization of the water table with respect to the well locations).

4.4.1 R-12

The R-12 well has three screens (Figure B-7). Rehabilitation will be attempted at Screen 1 (rated Poor in the vadose zone) and Screen 3 (rated Fair at the water table). Screen 2 will be isolated and the Westbay sampling system will be reinstalled (alternative sampling systems to Westbay only work when the pump is fully submerged and both screens are in the regional aquifer). If the rehabilitation of both screens fails, R-12 will be converted to a single-screen well at the water table, and a new well will be drilled to monitor the intermediate perched zone.

4.4.2 R-32

The R-32 well has three screens, all in the regional aquifer (Figure B-16). Screen 1 at the water table is rated Very Good and thus requires no action. Screen 2 is a pressure port which will be maintained. Screen 3 will be rehabilitated. Because R-32 will then essentially become a dual-screen well, it is a candidate for conversion to a non-Westbay sampling system.

4.4.3 R-14

This well has two screens, both in the regional aquifer (Figure B-8). The top screen at the water table is rated Very Good and requires no action. The bottom screen is rated Poor. Since the screens are separated by only 54 ft and probably sample the same water, the lower screen will be plugged and abandoned.

4.4.4 R-26

This well has two screens (Figure B-14). The upper screen is located in a thick perched zone, and the lower screen is located in what is believed to be the regional aquifer. The top screen at the water table is rated Good and thus requires no action. The bottom screen at 1422 ft below ground surface (bgs) is nearly 800 ft below the top screen. The Puye Formation at the bottom screen is so tight that even if the screen could be rehabilitated, it would probably not yield water. No crossflow of water has been demonstrated at this screen. R-26 will become a single-screen well.

4.4.5 R-22

This well has five screens (Figure B-12). The top screen straddles the water table and the other four screens are within the regional aquifer. The top screen, rated Poor, will be packed off and isolated. Screen 2 is rated Very Good. Since there are only approximately 33 ft between Screens 1 and 2, they probably sample the same water, and Screen 2 will become the water table screen. Screen 3 is rated Good and thus requires no action. Screens 4 and 5 are rated Poor; they will be plugged and abandoned. After rehabilitation, R-22 will become a dual-screen well and a candidate for conversion to an alternative sampling system.

4.4.6 R-25

This well has nine screens (Figure B-13). Of the 33 wells constructed under the HWP, R-25 is the most complicated and the most problematic and has been the subject of an investigation workplan (LANL 2005, 89397). However, based on the evolution of events and thinking during the past year, this well rehabilitation workplan replaces the R-25 investigation workplan. Action proposed for R-25 will depend on the rehabilitation results at the first five wells. It may be possible to salvage the four screens in the perched intermediate zone at R-25. Screens 1 and 2 are rated Fair, Screen 3 is unusable except as a pressure port and was not rated, and Screen 4 is Very Good.

There are also five screens in the regional aquifer. Screen 5, just below the water table, is rated Fair. Screens 6 and 7 are Very Good, Screen 8 is Good, and Screen 9 (at approximately 1900 ft bgs) is unusable. An attempt could be made to rehabilitate Screen 5, or a new single-screen well could be drilled to the water table.

5.0 INVESTIGATION METHODS

Unless the pilot study’s early results indicate that certain steps performed during that study are ineffective, unnecessary, or require more or less time, the same methods will be used and the same duration of tasks is estimated for each well described in this workplan. In some cases, additional methods beyond those used in the pilot study may be required; these will be determined as the pilot study progresses. In addition, pretest calculations estimate the effect of drilling fluids on hydraulic conductivity at certain wells and predict the amount of additional development needed to mitigate the chemical effects of fluids at prioritized wells.

Pressure data from well screens will be used along the way to estimate hydrologic properties and the degree of connectivity/communication with adjacent screens and with the atmosphere. This information may be useful in predicting the likely effectiveness of the proposed rehabilitation (i.e., it may not be worthwhile to try to rehabilitate tight intervals). Compiled pressure data will be examined for the well screens under consideration, along with the extent to which individual screens (e.g., in R-22) respond to pumping.

In addition to pressure responses, parameters to be measured during the redevelopment include turbidity, pH, conductivity, oxidation-reduction potential (ORP), alkalinity, sulfide, total organic carbon (TOC), and any specific test criteria that were failed by that particular screen. (Parameter measurement is covered in more detail in section 7.)

The steps defined in the rehabilitation of wells in the pilot study are as follows. Additional detail can be found in the pilot study (LANL 2006, 92471).

1. Collect baseline water-quality data, including major cations and anions, trace elements, TOC, volatile and semivolatile compounds, total Kjehldahl nitrogen (TKN), stable isotopes (particularly nitrogen and carbon), radionuclides, and hexavalent chromium. The data also will include field-measured parameters such as pH, temperature, dissolved oxygen, sulfide, specific conductance, ORP, and turbidity. Collect solids (including fine-grained material) by filtration and acid-digest for major and trace element analyses.
2. Remove the Westbay sampling system from the well and install rehabilitation tools. A down-hole video of the well will be made after the Westbay system has been removed.
3. Test the specific capacity at each screen.
4. Perform air lifting, pumping, and jetting at the screens. This involves forcing water through the screen openings, which agitates and rearranges the materials in areas immediately surrounding the screens. This activity should help remove some of the residual fluids and redevelop the area around the screen. Water is introduced into the screen openings at the jets and reenters the well above the jets, bringing fine particles into the well, which are then removed by air lifting and pumping.
5. Use the Hydropuls generator within each well screen to agitate the material and filter pack at the screen by high water-pressure pulsations. The screen will then be pumped using an isolation swabbing tool.
6. Pump the well using a dual-packer isolation system.
7. Repeat the specific-capacity test at each well screen.
8. As a last resort, chemical techniques will be evaluated for enhanced well development if all of the above mechanical techniques are unsuccessful. The chemicals may include dispersing agents (e.g., phosphate-free detergent and sodium hypochlorite [bleach], which is used in industry for cleaning up water-supply wells).
9. Remove tools from the well.
10. The Westbay system may be reinstalled, depending on the rehabilitation approach.
11. All pumped water will be containerized and managed in accordance with regulatory requirements.

Methods may be revised after the pilot study’s final results have been analyzed.

6.0 IMPLEMENTATION

Section 6 provides a framework for the plan’s implementation, including QA and organizational responsibilities.

6.1 Quality Assurance

Activities described in this workplan will be performed in accordance with the applicable QA requirements addressed in the Environmental Stewardship (ENV) Division–Environmental Characterization and Remediation (ECR) Quality Management Plan; quality procedures (QPs); standard operating procedures (SOPs); and Laboratory requirement documents (e.g., Laboratory implementation requirements and Laboratory performance requirements); or equivalent subcontractor documents (e.g., statements of work or field implementation plans).

The ENV Division procedures that will be used in this workplan are listed in Table 6.1. The ENV-ECR procedures are available online at http://erproject.lanl.gov/documents/procedures/sops.html and http://erproject.lanl.gov/documents/procedures/qps.html.

6.2 Organizational Responsibilities

Beginning in FY07, the Laboratory will administer a contract to conduct well redevelopment methods with a company that has yet to be determined. The Laboratory will provide planning, technical oversight, and logistical support to the activities, as well as sample collection and archiving, data interpretation, assessment, and reporting.

7.0 MONITORING AND SAMPLING PROGRAM

Section 7 outlines how data will be collected and results analyzed to determine whether the rehabilitation has been successful.

7.1 Sample Collection and Analysis

Groundwater samples will be collected and analyzed as needed through the various steps of the well development process: (1) before pulling the Westbay system; (2) during initial specific-capacity testing; (3) after steps 4, 5, and 6; (4) during final specific-capacity testing; and (5) after the reinstallation of the Westbay system. The results will indicate the extent to which various development methods contribute to the screen cleaning. However, the analytical results may not be available before initiating the next step of development.

Groundwater parameters from pumping will be collected with a flow-through cell that has data logging capabilities. Parameters to be collected with the data logger will consist of pH, temperature, conductivity, ORP, and dissolved oxygen. Turbidity data will be collected at specified time intervals.

Samples will be filtered, while solids will be collected and analyzed chemically (method to be determined) and mineralogically (by x-ray diffraction [XRD]). The results of the combined chemical and mineralogical analysis should indicate which chemical constituents are being pulled out of the aquifer during the intensified well development and which are associated with residual well construction materials or drilling fluids.

7.2 Evaluation of the Well Redevelopment Process

A summary report will document field activities and field parameters measured at each well or well screen. The report will document all field activities, including variations from the workplan. The Laboratory will then interpret and analyze these results and will report them in an annual update to this well rehabilitation workplan. Water-quality data collected as part of well rehabilitation will be compared with results compiled in the WSAR. Improved collection methods will be implemented based on recommendations made by U.S. Environmental Protection Agency (EPA) contractors (Ford et al. 2005, 90545). Success will be defined as a rating of Good or Very Good according to the geochemical criteria developed for the WSAR. In addition, changes in, and improvements to, hydrologic parameters will be noted. Pre- and postrehabilitation specific-capacity test results will be compared. There should be no doubt as to the success of the methods used and the screen condition after the redevelopment. However, postrehabilitation monitoring will be an important means of measuring the effectiveness of the well redevelopment. If screens do not show improvement, additional speciation modeling may be performed and predictions made as to whether the screen might ever be expected to improve. In consultation with NMED, a final decision will be made whether to plug and abandon the screen, attempt additional rehabilitation at the screen, or drill a new well to the depth needed.

8.0 REPORTING AND DOCUMENTATION

The collective results of the rehabilitation efforts in FY07, along with the results from the FY06 pilot study, will guide decisions made for wells in FY08 and refine methods to be used in their rehabilitation.

A specific workplan for each individual well will identify the quality objectives for the well, along with specific methods to be used and requirements to be met. After the work has been completed, a summary report will document the field activities and field parameters measured at each well or well screen.
The report will document all field activities, including variations from the workplan, redevelopment and sampling procedures, and recommendations, if any, for consideration in follow-up rehabilitation activities at other wells.

The Laboratory will report results of the redevelopment process in an annual update to this well rehabilitation workplan. Such an update will allow feedback on lessons learned from the pilot study, the incorporation of any refinements to quality objectives, and adjustment of priorities and actions in response to changing water-quality conditions and trends. In 2008, an update of the WSAR will also discuss and interpret the results. The well rehabilitation workplan updates in FY07 and FY08 will include an assessment of the then-current geochemical status of all the wells, including those drilled after publication of the initial WSAR in November 2005. The updated FY08 WSAR will provide a more comprehensive discussion of well conditions and of the degree of success of the rehabilitation efforts.

9.0 REFERENCES

The following list includes all documents cited in this work plan. 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 ENV Division-Environmental Remediation and Surveillance (ERS) Program's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the ENV-ERS Program master reference set.

Copies of the master reference set are maintained at NMED's Hazardous Waste Bureau; DOE-Los Alamos Site Office; EPA, Region 6; and the ENV-ERS Program. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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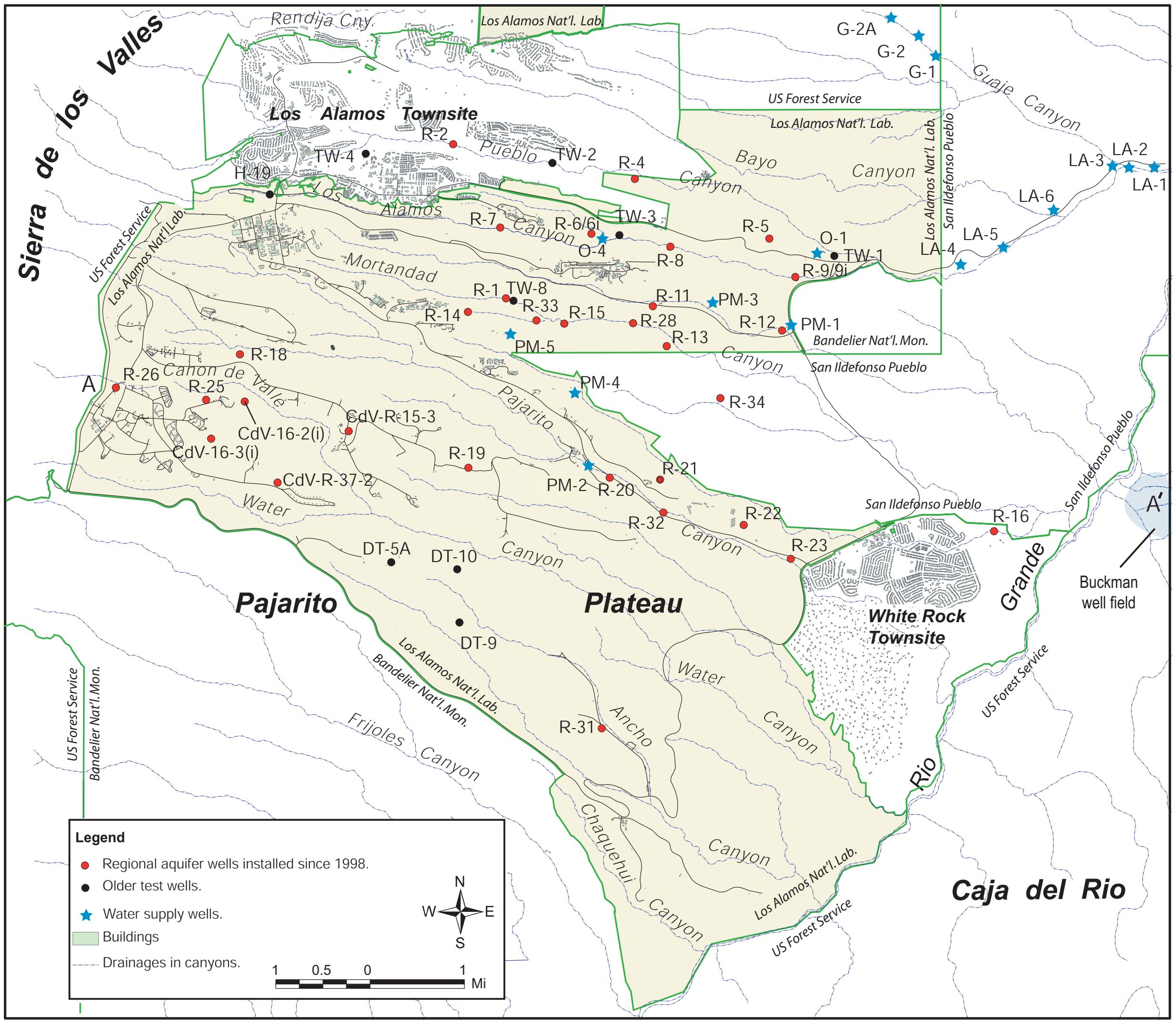

Figure 1-1. Map showing location of wells constructed under the Hydrogeologic Workplan

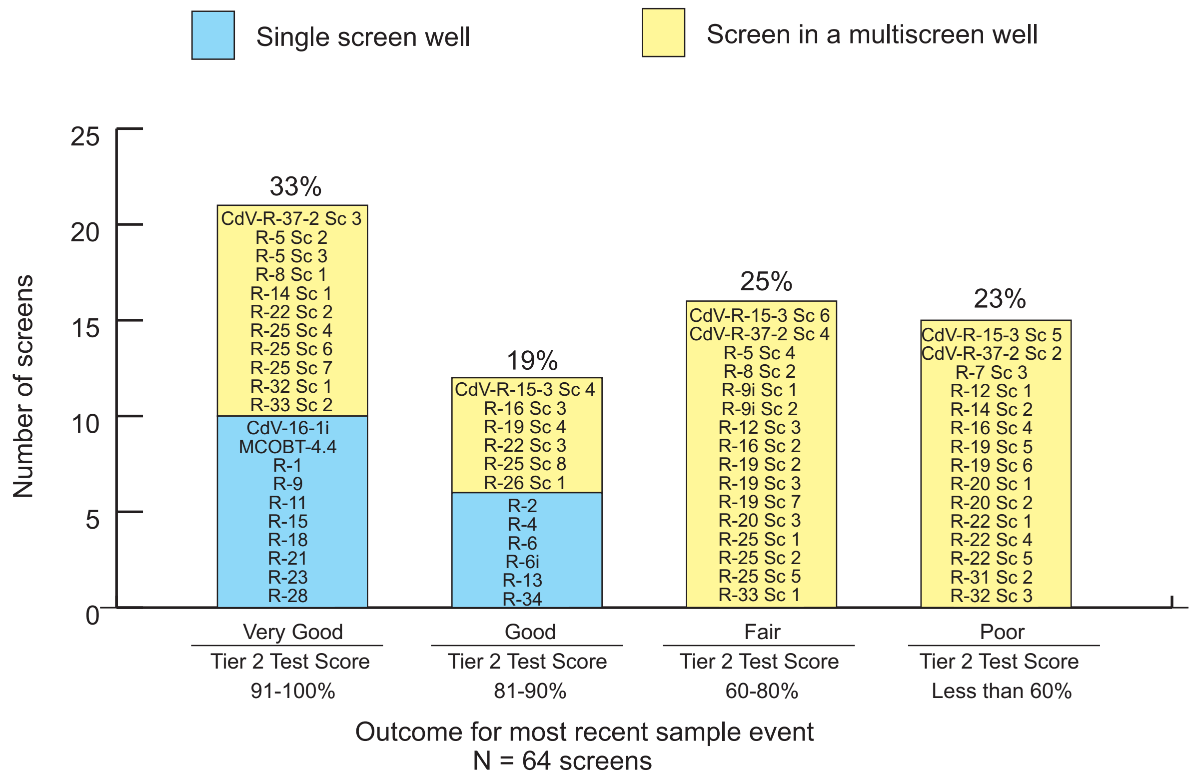

Figure 1-2. **Overall condition of screens for producing reliable and representative water-quality samples as of November 2005**

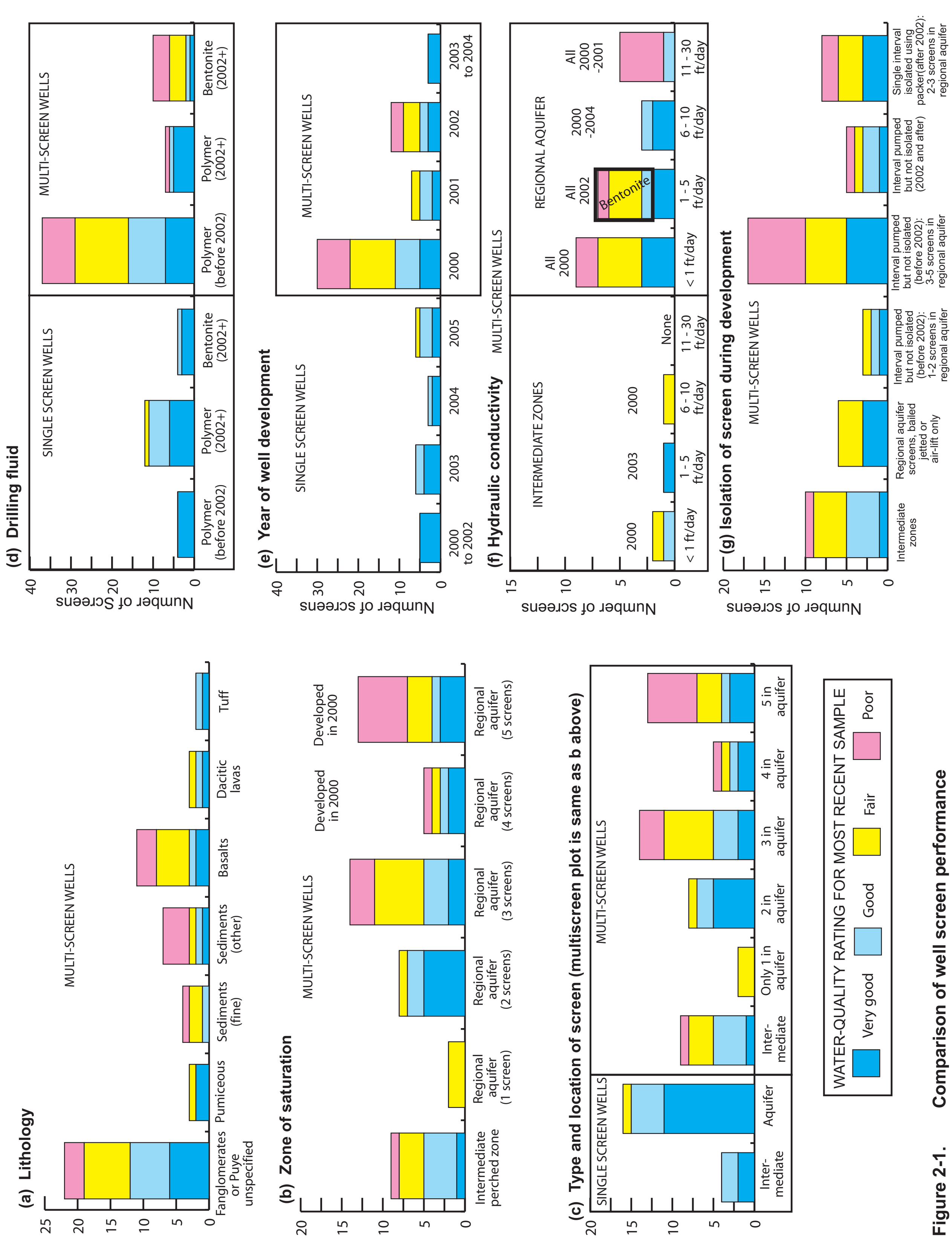

Figure 2-1. Comparison of well screen performance

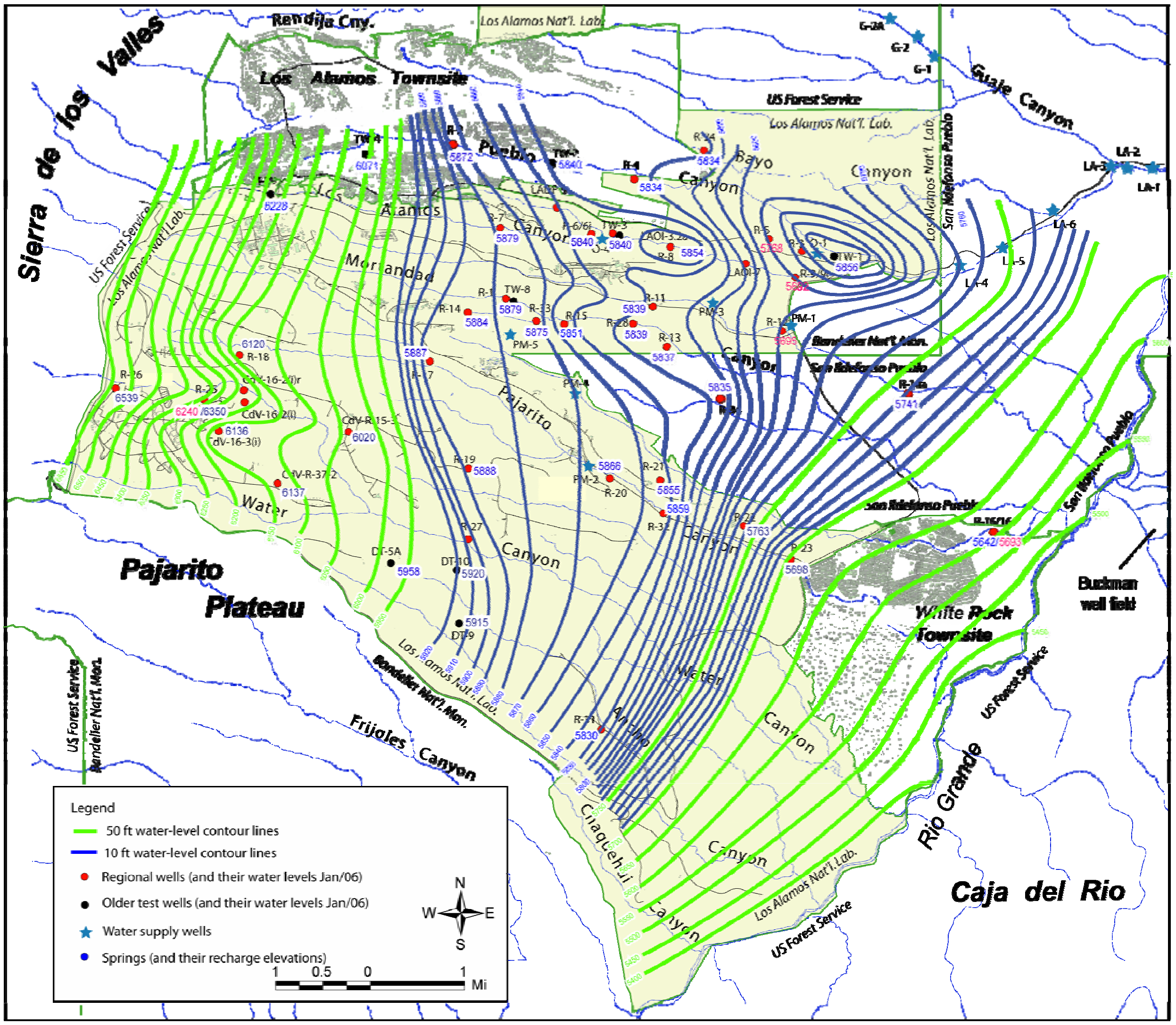

Figure 4-1. Water table elevation and location of Hydrogeologic Workplan wells

Table 4.1
Plan of Action for Hydrogeologic Workplan Wells

Note: This revision reflects actions taken as a result of the decision peer review on the Well Rehabilitation Plan held on April 27, 2006 and is consistent with BCP-005.

Well	OK As Is Rated Very Good/Good	Rehabilitate	Redrill	P&A*	Notes
CdV-16-1	X				
CdV-R15-3		X partial – in FY08		Partial in FY08	May replace Westbay in upper screen(s) with different sampling system – defer action to FY08
CdV-R37-2		X defer to FY08			
MCOBT-4.4	X				May need different sampling system
R-1	X				
R-2	X				
R-4	X				
R-5					No action – Screen 1 dry, 2 Very Good, 3 just a port, 4 Fair but not needed
R-6	X				
R-6i	X				
R-7		X defer to FY08			
R-8				Partial in FY08	P&A lower screen, replace Westbay with pump – defer to FY08
R-9	X				
R-9i		X defer to FY08			
R-11	X				
R-12		X in part-in FY07	Possibly in FY08		Rehab perched screens, drill supplemental regional well
R-13	X				
R-14		X in FY07			
R-15	X				
R-16		Pilot 06			
R-18	X				
R-19		X in FY08			
R-20		Pilot 06			
R-21	X				
R-22		X in FY07			
R-23	X				
R-25		Part in FY07	In FY07 or FY08-partial		Leave current well in place and continue to monitor
R-26		X in FY07			
R-28	X				
R-31		X in part		In FY07	May replace Westbay with alternative sampling system
R-32		X in FY07			
R-33	In part				No action - Screen 1 (Fair) and improving; Screen 2 Very Good
R-34	X				

*P&A = plug and abandon.

Table 6.1
Procedures Governing the Collection, Analysis, and Review of Water Data

ENV-DO-203	Field Water Quality Analyses
ENV-DO-206	Sample Containers and Preservation
ENV-DO-207	Handling, Packaging, and Transporting Field Samples
ENV-ECR-QP-4.4	Record Transmittal to the Records Processing Facility
ENV-ECR SOP-05.02	Well Development
ENV-ECR SOP-06.01	Purging and Sampling Methods for Single Completion Wells
ENV-ECR SOP-06.03	Sampling for Volatile Organic Compounds in Groundwater
ENV-ECR SOP-06.32	Multi-Level Groundwater Sampling of Monitoring Wells—Westbay MP System
ENV-ECR SOP-15.01	Routine Validation of Volatile Organic Data
ENV-ECR SOP-15.02	Routine Validation of Semivolatile Organic Data
ENV-ECR SOP-15.03	Routine Validation of Organochlorine Pesticides and Polychlorinated Biphenyls Data
ENV-ECR SOP-15.04	Routine Validation of High Explosives Data
ENV-ECR SOP-15.05	Routine Validation of Inorganic Data
ENV-ECR SOP-15.06	Routine Validation of Gamma Spectroscopy Data
ENV-ECR SOP-15.07	Routine Validation of Chemical Separation Alpha Spectrometry, Gas Proportional Counting, and Liquid Scintillation Data
ENV-ECR SOP-15.09	Chain of Custody for Analytical Data Packages
ENV-WQH-QP-029	Creating and Maintaining Chain of Custody
ENV-WQH-SOP-048	Groundwater Sampling Using Bladder Pumps
ENV-WQH-SOP-049	Groundwater Sampling Using Submersible Pumps
ENV-WQH-SOP-050	Groundwater Sampling Using Westbay System

Appendix A

Well Screen Parameters and Characteristics

A.1 WELL CONSTRUCTION AND DEVELOPMENT INFORMATION

CdV-R-15-3, Data Quality Objectives

This well was installed east of Cañon de Valle, within TA-15.

- Constructed primarily to investigate the extent of contamination in deep perched and regional groundwater systems associated with high explosives (HE) presumably derived from potential release site 16-021(c)-99, the Building 260 outfall.
- In addition, objectives included determining how fast any contamination detected is moving downgradient toward the Pajarito well field or other exposure points.
- Investigating the directions of groundwater flow and the hydrologic gradients within the regional aquifer and deep perched saturated zones in and around TA-16.
- Screens 1, 2, and 3 were set opposite suspected perched water zones.
- Screen 4 spans the surface of the regional aquifer.
- Screens 5 and 6 are set in middle and deep parts of the regional aquifer in the Puye Formation.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed[b]	Time Screens/Zones in Communication[c]
Screen 1 (604–626)	Water, QUIKFOAM, EZ-MUD 0–1722:open hole, air rotary, dual-wall reverse circulation.	None	Not listed in completion report but probably water for filter pack and water plus EZ-MUD for bentonite pellet and slurry seals.	Wire brushing	46 days (Aug. 6 – Sept 19, 2000)
Screen 2 (785–806)				Wire brushing	
Screen 3 (944–975)				Wire brushing	
Screen 4 (1212–1287)				Wire brushing, bailing, pumping; 9126 gal. removed by bailing and pumping.	
Screen 5 (1321–1349)				Wire brushing, bailing, pumping; 7966 gal. removed by bailing and pumping.	
Screen 6 (1604–1649)				Wire brushing, bailing, pumping; 23,466 gal. removed by pumping.	

Note: The data shown in this table were taken from LANL 2002 (73179). Also see LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; it does not include transitional sand pack adjacent to sealing materials.

[b] Includes an additional 7040 gal. pumped from the sump during development to equal the total amount removed as listed in the completion report.

[c] From completion of well development to completion of Westbay installation.

LCM = lost circulation material(s)

CdV-R-37-2, Data Quality Objectives

This well was installed within TA-37 and lies approximately 200 ft north of K-Site Road at the western boundary of TA-37, on the southern rim of Cañon de Valle.

- The well was constructed as part of the Corrective Measures Study for Potential Release Site 16-021(c)-99.
- The primary objective is to help determine if the high explosives (HE) contamination detected in the perched and regional aquifers at Well R-25 (in TA-16) extends to the southeast.
- Determining how fast water and contamination, if present, have been moving downgradient toward the Pajarito well field or toward other potential exposure points.
- Investigating the direction of groundwater flow and the hydraulic gradients within the regional and perched aquifers in the western portion of the Laboratory.
- To meet the design and construction requirements for a regional-aquifer characterization well as described in the Hydrogeologic Workplan and possibly to be incorporated into the Laboratory-wide groundwater monitoring program.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screens/Zones in Communication[b]
Screen 1 (904.2–943.8) Dry	Water, EZ-MUD, QUIKFOAM 0–794: open hole, air rotary. 794–825: casing advance. 825–1208: open hole, air rotary. 1208–1404: open hole, DHH. 1404–1664: open hole, air rotary.	None	Water for filter pack and water plus EZ-MUD for bentonite pellet and slurry seals. Approx. 15,000 gal. of municipal water used.	Wire brushing (Screen dry)	17 days (Sept. 21 to Oct. 8, 2001)
Screen 2 (1179.6–1221)				Wire brushing, bailing, surging (Screen not productive enough to pump)	
Screen 3 (1343–1382)				Wire brushing, bailing, surging, pumping; 17,530 gal. removed by bailing and pumping.	
Screen 4 (1539.7–1560.7)				Wire brushing, bailing, surging, bailing, pumping; 9910 gal. removed by bailing and pumping.	

Note: The data shown in this table were taken from LANL 2003 (88803). Also see LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

DHH = downhole hammer, LCM = lost circulation material(s)

R-5, Data Quality Objectives

This well was installed on the southern side of lower Pueblo Canyon, about 3000 ft west-northwest of supply well Otowi-1 and about 4700 ft southeast of the Bayo Canyon Sewage Treatment Plant.

- The primary purpose of the well is to provide water-quality, geochemical, hydrologic, and geologic information that would contribute to understanding the hydrogeologic setting beneath the Laboratory.
- The well was also designed to help determine whether Laboratory releases and sewage treatment plant effluents may be present in the regional aquifer beneath lower Pueblo Canyon, and, if so, the extent to which contaminants may have affected groundwater quality.
- Other goals include implementing a Laboratory-wide groundwater monitoring network and monitoring a possible perched saturation zone in the Puye Formation identified from geophysics (Screen 1), a possible saturation zone in the Puye Formation (Screen 2), the top of the regional zone of saturation in Santa Fe Group sediments (Screen 3), and a deeper part of the regional zone of saturation in Santa Fe Group basalts (Screen 4).

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., Solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screens/Zones in Communication[b]
Screen 1 (316.5–338.0) (dry)	"Air rotary drilling was assisted at times with municipal water mixed with polymer additives such as EZ-MUD and QUIKFOAM. 0–130: casing advance, DHH. 130–547: open hole, DHH. 130–547: casing advance. 547–570: casing advance, DHH. 570–828: open hole, DHH. 570–825: casing advance, DHH. 870–902: open hole, air rotary, fluid assisted.	None mentioned	Water for filter pack, water for chip seals, water plus EZ-MUD for pellet seals below water table.	Wire brushing, swabbing/surging, bailing; 755 gal. removed by bailing.	28 days (June 21 to July 19, 2001)
Screen 2 (364.5–399.5) (not productive)				Wire brushing, swabbing/surging, bailing; 755 gal. removed by bailing.	
Screen 3 (666.5–727.0)				Wire brushing, swabbing/surging, bailing, pumping; 10,980 gal. removed by bailing and pumping.	
Screen 4 (851.0–902.0) (not productive)				Wire brushing, swabbing/surging, bailing, pumping; 1740 gal. removed by bailing and pumping.	

Note: The data shown in this table were taken from LANL 2003 (80925). Also see LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

DHH = Downhole hammer, LCM = lost circulation material(s)

R-7, Data Quality Objectives

This well was installed in upper Los Alamos Canyon, approximately 1 mile upstream of its confluence with DP Canyon to

- provide a well east of TA-2 and south of TA-21 where contaminated effluent has been released,
- characterize the occurrence and quality of water in the intermediate perched zones (Screens 1 and 2),
- permit sampling at the top of the regional zone of saturation (Screen 3), and
- possibly incorporate the well into the Laboratory-wide groundwater-monitoring program.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (dry) (355.6–383.6)	Water, EZ-MUD, QUIKFOAM 11–26: open hole, DHH. 26–290: casing advance with DHH. 290–342: open hole, air rotary –casing set to 290. 287–382: open hole, air rotary. 382–1084: open hole, air rotary. 1084–1097: open hole, air rotary.	None mentioned	Water for filter pack, water for chip seal.	Not attempted. Production too low for development.	17 days (Feb. 8 to Feb. 25, 2001)
Screen 2 (dry) (725–754)			Water for filter pack, water plus EZ-MUD for pellet seal	Not attempted. Production too low for development.	
Screen 3 (880–946.8)			Water for filter pack, water plus EZ-MUD for pellet seal	Wire brushing and bailing (screens not isolated). Pumping not possible because of low productivity. 3000 gal. removed	

Note: The data shown in this table were taken from LANL 2002 (72717). Also see LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

DHH = downhole hammer, LCM = lost circulation material(s), DP = Delta Prime

R-8, Data Quality Objectives

(The well completed in a second borehole, BH2 [located hydraulically upgradient when the first borehole, BH1] had to be abandoned.)

This well is located in Los Alamos Canyon, approximately 3300 ft downstream of the confluence with DP Canyon, in the northeastern portion of the Laboratory. The well was designed to

- provide hydrogeologic and water-quality data on the regional groundwater and to assess the impact of Laboratory activities on the Los Alamos Canyon watershed,
- gather geologic, hydrologic, geochemical, and water-quality information to contribute to further understanding of the Laboratory's subsurface hydrogeologic setting including the locations of possible intermediate perched water zones and the distribution of any contaminants downgradient of TA-21,
- sample the top of the regional zone of saturation (Screen 1), and
- monitor a deeper, more productive zone within the regional aquifer (Screen 2).

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (687.4–796.8)	Water, QUIKFOAM, EZ-MUD 0–90: casing advance, DHH. 90–684: casing advance, DHH. 684–862: open hole, air rotary. 706–880: open hole, air rotary. 750–809: casing advance, DHH.	None	Water for filter packs and bentonite chip and pellet seals.	Wire brushing, bailing, swabbing and injecting, surging/bailing. No mention in WSAR of amount injected. 3500 gal. removed by bailing.	10 days (Feb. 14 to Feb. 24, 2002)
Screen 2 (812.3–832.4)				Wire brushing, bailing, swabbing and injecting, surging/bailing, pumping. No mention of amount injected. 16,240 gal. removed by bailing and pumping.	

Note: The data shown in this table were taken from LANL 2003 (79594).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

DHH = downhole hammer, LCM = lost circulation material(s)

R-9i, Data Quality Objectives

This well is located near the eastern boundary of the Laboratory in Los Alamos Canyon. The well is designed to

- characterize temporal variations in water quality and water levels for the two uppermost intermediate-depth perched groundwater zones at this location,
- satisfy requirements of the workplan for Los Alamos and Pueblo Canyons and the Laboratory's Hydrogeologic Workplan,
- monitor the uppermost intermediate-depth perched groundwater in the Cerros del Rio basalt that could be connected upgradient with surface water and alluvial groundwater in Los Alamos Canyon (Screen 1), and
- monitor a small perched zone at the base of the Cerros del Rio basalt that contains elevated uranium concentrations (Screen 2).

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (185.5–200.7)	No fluids specifically mentioned but probably included water and QUIKFOAM 0–332: open hole, air rotary.	None	Water for filter packs and bentonite chip and pellet seals.	Bailing/surging and pumping; 250 gal. removed by bailing/surging. 2850 gal. removed by pumping. Screens probably not isolated.	8 days (Apr. 7 to Apr. 15, 2000)
Screen 2 (266.4–282.1)				Bailing/surging and pumping; 300 gal. removed by bailing/surging. 1615 gal. removed by pumping. Screens probably not isolated.	

Note: The data shown in this table were taken from LANL 2001 (71251). Also see LANL 2003 (76003) and LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

LCM = lost circulation material(s)

R-12, Data Quality Objectives

This well was installed in Sandia Canyon near the eastern boundary of the Laboratory as part of the Hydrogeologic Workplan to

- provide information about the quality of groundwater at the eastern boundary of the Laboratory;
- provide early warning of contaminants reaching the upper part of the regional aquifer near water-supply well PM-1;
- gather water-quality and water-level data for the potential intermediate-depth perched zones and from the regional aquifer downgradient of numerous contaminant source areas in upper Los Alamos, Sandia, and Mortandad Canyons (Aggregates 1 and 7 in the Hydrogeologic Workplan);
- support a completion strategy for BH R-9;
- possibly be incorporated into the Laboratory-wide groundwater-monitoring program;
- monitor the upper part of the perched groundwater zone within the Cerros del Rio basalt (Screen 1);
- monitor the lower part of the perched groundwater zone within the old alluvium sediments (Screen 2); and
- monitor the top of the regional zone of saturation (Screen 3).

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids[b]	Well Development Methods and Volumes Added/Removed[c]	Time Screen/Zones in Communication[d]
Screen 1 453–481	Mainly casing advancement, some open-BH RC or DHH drilling in basalt Water and EZ-MUD, some foam	None mentioned	NL	Jetting, pumping (screens not isolated). 666 gal. of water added during jetting. 538 gal. removed by pumping.	41 days (Feb. 6 to Mar. 19, 2000)
Screen 2 495–522	Casing advancement Water and EZ-MUD, some foam	None mentioned	NL	Jetting, pumping (screens not isolated). 666 gal. of water added during jetting. 538 gal. removed by pumping.	
Screen 3 793–856	Casing advancement Water and EZ-MUD, some foam	None mentioned	NL	Jetting, pumping (screens not isolated). 666 gal. of water added during jetting. 538 gal. removed by pumping.	

Note: The data shown in this table were taken from LANL 2001 (71252). Also see LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] Not listed in well completion report (LANL 2001, 71252).

[c] Assumes the amounts added/removed are equal for each screened interval.

[d] From completion of well development to completion of Westbay installation.

BH = borehole, DHH = downhole hammer, LCM = lost circulation material(s), NL = not listed

R-14, Data Quality Objectives

This well was installed in Ten Site Canyon, a tributary to Mortandad Canyon in the east-central portion of the Laboratory. R-14 is downgradient of the active RLW treatment facility at TA-50 and the former RLW and septic facilities at TA-35. The well was designed to

- determine if releases and effluents may be present in and around the Mortandad Canyon watershed, and, if so, the extent to which contaminants affect groundwater quality,
- monitor near the top of the regional zone of saturation (Screen 1),
- monitor a deeper productive zone within the regional aquifer (Screen 2),
- collect data for evaluating the hydrogeologic setting of Mortandad Canyon, and
- contribute to implementing a Laboratory-wide groundwater-monitoring network.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (1196.8–1240.2)	From 848–1315 ft bgs: Water, QUIKFOAM, Liqui-Trol 12.2–306: open hole, air rotary fluid assisted. 306–1068: open hole, air rotary fluid assisted (ream). 1068–1225: open hole, air rotary fluid assisted. 1225–1285: open hole, mud rotary (set casing). 1285–1327: casing advance, DHH.	Soda ash, Pac-L, N-Seal, magma fiber	Water for filter packs, water and EZ-MUD for bentonite pellet seals. Approximately 13,631 gal. of water used to place annular fill.	Wire brushing, surging/bailing, pumping with screen isolated, surging/bailing, chemical treatment, surging/bailing, pumping. 510 gal. of chemical solutions added[c] 11,385 gal. removed. By bailing and pumping.	7 days (Nov. 18 to Nov 25, 2002)
Screen 2 (1281.0–1299.0)				Wire brushing, surging/bailing, pumping with screen isolated, surging/bailing, chemical treatment, surging/bailing, pumping. 290 gal. of chemical solutions added[a], 188,735 gal. removed by bailing and pumping.	

Note: The data shown in this table were taken from LANL 2003 (76062). Also see LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

[c] Modified granular acid (MGA), acid enhancer (AE), and phosphate-free dispersant (PFD) were added to each screen interval followed by surging/bailing; when the pH stabilized, pump development started.

DHH = downhole hammer, LCM = lost circulation material(s), RLW = radioactive liquid waste

R-16, Data Quality Objectives

This well was installed in Cañada del Buey as part of the Hydrogeologic Workplan to

- determine the water table and vertical gradient for the regional aquifer near the Rio Grande;
- act as a monitoring point between TA-54 and the Rio Grande;
- determine the relationship between the regional water table and springs in White Rock Canyon; and
- contribute to understanding flow paths between Mortandad Canyon and springs in White Rock Canyon.

The screen intervals were selected to monitor the top of regional aquifer (Screen 1) and deeper more productive zones within the regional aquifer (Screens 2–4).

Effective Screen Interval[a] (ft)	Drilling Method(s) Used	Drilling Fluids and Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 634.5–653.4	Interval isolated behind abandoned drive casing.	NA	NA	NA	NA
Screen 2 852.1–877.5	Mud rotary for this interval.	Water, Quick-Gel, EZ-MUD, Liqui-Trol, magma fiber, Pac-L, N-Seal, soda ash	Water for filter pack. Water plus EZ-MUD for pellet seals.	Wire brushing, swabbing and surging, bailing (screens not isolated). Acid and dispersant added. Pumping with packer isolation. 4301 gal. removed.	6 days (Dec. 4 to Dec. 10, 2002)
Screen 3 1006.7–1028.5	Mud rotary for this interval.	Water, Quick-Gel, EZ-MUD, Liqui-Trol, magma fiber, Pac-L, N-Seal, soda ash	Water for filter pack. Water plus EZ-MUD for pellet seals.	Wire brushing, swabbing and surging, bailing (screens not isolated). Acid and dispersant added. Pumping with packer isolation. 8621 gal. removed.	
Screen 4 1211.7–1287	Mud rotary for this interval.	Water, Quick-Gel, EZ-MUD, Liqui-Trol, magma fiber, Pac-L, N-Seal, soda ash	Water for filter pack. Water plus EZ-MUD for pellet seals.	Wire brushing, swabbing and surging, bailing (screens not isolated) and jetting. Acid and dispersant added. Pumping with/without packer isolation. 65,126 gal. removed.	

Note: The data shown in this table were taken from LANL 2003 (76061). Also see LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

LCM = lost circulation material(s), NA = not applicable

R-19, Data Quality Objectives

This well was installed atop the mesa separating Threemile and Potrillo Canyons, east of firing site IJ.

- primarily designed to provide water-quality and water-level data for potential intermediate-depth perched zones and for the regional aquifer downgradient of HE contaminant release sites at TA-16. Also designed to
- sample possible perched groundwater (Screens 1, 2) that could be connected upgradient with HE-contaminated perched water at R-25;
- sample the top of the regional zone of saturation (Screen 3);
- sample high-permeability zones that might act as fast pathways for contaminants in the regional system (Screens 5, 6, 7);
- provide spatial coverage for sampling the thick sequences of less permeable rocks in the upper part of the regional zone of saturation (Screen 4);
- help evaluate the nature and extent of HE contamination originating at TA-16; and
- increase the understanding of the hydrogeology of a little-studied part of the Laboratory and to update the sitewide conceptual hydrogeologic model.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (802.2–858.6)	EZ-MUD, QUIKFOAM slurries 16–143: casing advance (dry). 143–227: casing advance , fluid assisted. 225–1902.5: open hole, air rotary fluid assisted.	None mentioned	Not listed but probably water for filter pack and water plus EZ-MUD for bentonite pellet and slurry seals.	Washing, air jetting, and airlifting. 1143 gal. added during jetting. 1143 gal. removed by airlifting.	54 days Jul. 19 to Sept. 11, 2000 (estimated development completion date)
Screen 2 (868.3–926.0)				Washing, air jetting, and airlifting. 1143 gal. added during jetting. 1143 gal. removed by airlifting.	
Screen 3 (1149.8–1240.5)				Washing, air jetting, airlifting, and pumping. 1143 gal. added during jetting. 13,834 gal. removed by airlifting and pumping[c].	
Screen 4 (1380.0–1445.5)				Washing, air jetting, airlifting, and pumping. Screens not isolated 1143 gal. added during jetting. 14,918 gal. removed by airlifting and pumping[c].	
Screen 5 (1557.9–1606.8)				Washing, air jetting, airlifting, and pumping. Screens not isolated 1143 gal. added during jetting. 17,243 gal. removed by airlifting and pumping[c].	
Screen 6 (1675.9–1779.8)				Washing, air jetting, airlifting, and pumping. Screens not isolated 1143 gal. added during jetting. 16,143 gal. removed by airlifting and pumping[c].	
Screen 7 1828.2–1848.4)				Washing, air jetting, airlifting, and pumping. Screens not isolated. 1143 gal. added during jetting. 18,793 gal. removed by airlifting and pumping[c].	

Note: The data shown in this table were taken from LANL 2001 (71254). Also see LANL 2003 (76003) and LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

[c] The well completion report (LANL 2001, 71254) states that 63,000 gal. of fluids was generated during drilling. The assumption is that most of the water was derived from Screens 3 through 7.

HE = high explosive(s), LCM = lost circulation material(s)

R-20, Data Quality Objectives

This well was installed east of TA-18, on the south side of Pajarito Road in Pajarito Canyon to

- provide hydrogeologic and water-quality data for regional groundwater near potential contaminant release sites at TA-54,
- function primarily as a monitoring well between MDA L at TA-54 and supply well PM-2,
- provide data for the Laboratory hydrologic and geologic conceptual models, and
- contribute to implementing a Laboratory-wide groundwater monitoring system.

Screen 1 was designed to monitor near the top of the regional aquifer in cinder beds of the Cerros del Rio lavas. Screen 2 was designed to monitor within the regional aquifer in pumiceous Puye Formation fanglomerate. Screen 3 was designed to monitor within the regional aquifer in the Santa Fe Group sediments.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed[b]	Time Screen/Zones in Communication[c]
Screen 1 (895.2–926.5)	(Below 780 ft bgs) Mud rotary Water, Quick-Gel, Liqui-Trol	Pac-L, N-Seal, magma fiber	Water for filter pack, water and EZ-MUD for bentonite (Benseal, Pelplug) seals. Approx. 41,400 gal. of municipal water used for installation.	Brushing/swabbing/surging/bailing, PFD added, surging/bailing, acid treatment, surging/bailing, pumping, brushing/bailing, pumping, pumping with packer isolation. 616 gal. of PFD and MGA+AE solutions added. 24,018 gal. removed.	27 days (Dec. 22 to Jan. 18, 2003)
Screen 2 (1132.5–1165.5)				Brushing/swabbing/surging/bailing, PFD added, surging/bailing, acid treatment, surging/bailing, pumping, brushing/bailing, pumping, pumping with packer isolation. 616 gal. of PFD and MGA+AE solutions added. 29,160 gal. removed.	
Screen 3 (1320.6–1344.5)				Brushing/swabbing/surging/bailing, PFD added, surging/bailing, acid treatment, surging/bailing, pumping, brushing/bailing, pumping, pumping with packer isolation. 616 gal. of PFD and MGA+AE solutions added. 35,680 gal. removed.	

Note: The data shown in this table were taken from LANL 2003 (79600). Also see LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] Chemical treatments involved PFD, MGA, and AE solutions.

[c] From completion of well development to completion of Westbay installation.

AE = acid enhancer, LCM = lost circulation material(s), MDA = material disposal area, MGA = modified granular acid, PFD = phosphate-free dispersant

R-22, Data Quality Objectives

This well was installed atop the mesa separating Cañada del Buey and Pajarito Canyon as part of the Hydrogeologic Workplan to

- provide water-quality and water-level data for potential intermediate-depth perched zones and for the regional aquifer downgradient of the waste disposal facility at TA-54;
- collect geologic, hydrologic, and geochemical data that contribute to the understanding of the vadose zone and regional aquifer in this part of the Laboratory;
- sample the top of the region zone of saturation (Screens 1 and 2); two intervals were necessary since two distinct static water levels were observed;
- sample within the upper Puye Formation fanglomerate (Screen 3);
- sample within the older basalt (Screen 4); and
- sample within the lower fanglomerate tentatively assigned to the Puye Formation (Screen 5).

The well was designed to also meet the requirements of a monitoring well as defined in the Hazardous Waste Facility Permit. Incorporation into a Laboratory-wide monitoring network was to be evaluated later.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (862.0–922.0)	Open-hole, DHH Water, QUIKFOAM, EZ-MUD.	None mentioned	Water for filter pack. Water plus EZ-MUD for pellet seals.	Wire brushing, bailing with screens not isolated. A total of 4115 gal. removed. Not pump developed	19 days (Nov. 19 to Dec. 8, 2000)
Screen 2 (937.5–1007.0)	Open-hole, DHH Water, QUIKFOAM, EZ-MUD.			Wire brushing, bailing with screens not isolated. A total of 4115 gal. removed. Not pumped developed.	
Screen 3 (1243.5–1284)	Casing advance, DHH, water, QUIKFOAM, EZ-MUD.			Wire brushing, bailing with screens not isolated. A total of 4115 gal. removed. Pump developed with and without packer isolation. A total of 7365 gal. removed.	
Screen 4 (1368.5–1387.0)	Open-hole, DHH Water, QUIKFOAM, EZ-MUD.			Wire brushing, bailing with screens not isolated. A total of 4115 gal. removed. Pump developed without isolation. A total of 15,785 gal. removed.	
Screen 5 (1437–1478.0)	Open-hole, DHH Water, QUIKFOAM, EZ-MUD.			Wire brushing, bailing with screens not isolated. A total of 4115 gal. removed. Pump developed without isolation. A total of 3526 gal. removed. Sump also pumped and 8086 gal. removed.	

Note: The data shown in this table were taken from LANL 2002 (71471). Also see LANL 2003 (76003) and LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

DHH = downhole hammer, LCM = lost circulation material(s)

R-25, Data Quality Objectives

This well was installed in on the south rim of Cañon de Valle, within TA-16, near the southwestern boundary of the Laboratory to

- provide water-quality and water-level data for intermediate-depth perched groundwater and the regional aquifer in a previously poorly characterized area of the Laboratory;
- provide geologic and hydrologic information that will contribute to the understanding of the hydrogeologic setting beneath the Laboratory;
- establish the distribution of HE contaminants in the upper zone of saturation and to determine vertical head data for this zone (Screens 1, 2, 3);
- determine whether the alternating wet and dry zone from 1132–1286 ft is hydraulically connected to the upper saturated zone or the regional aquifer (Screen 4);
- determine the water-quality and water-level at the top of the regional zone of saturation (Screen 5), and
- determine the vertical extent of contamination and establish vertical head data for the regional zone of saturation (Screens 6, 7, 8, and 9).

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Repair and Development Methods	Well Development Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (732–762)	0-588: Casing advance air rotary (drilled without fluids) 588-1427: casing advance air rotary fluid assisted Water, Tork-Ease, bentonite products[d].	Fibrous materials: cellophane, mag fiber, nylon	Water for filter pack? 610–1026: bentonite placed with plain water. Above 610: Bentonite placed in annulus dry.	Prior to screen repairs Screens 1, 2, 4, 5, 6, 7, and 8 were pressure-washed with water and SAPP. Some purging of the well below Screen 3 was performed. Screens 2 and 8 were partially developed by airlifting. Purging introduced 900 gal. of water and the removal of 1200 gal. Development included airlifting 39,000 gal. for the interval between Screens 8 and 9 and airlifting 500 gal. from a depth corresponding to Screen 2. Following repairs: Screens 1 and 2 were wire brushed, then all screens except 3 and 9 were jetted. Then the well was purged with a pump set at 1760. Two months later, Screens 1 and 2 were wire brushed again. The well was airlifted from just above replacement Screen 9 and the screens pumped starting at 4 and working downward. Screens 4 to 6 were scrubbed and the intervals pumped. Development was interrupted by the Cerro Grande fire for 5 months and the screens were pump developed again. A total of 192,000 gal. removed following screen repairs.	28,875 gal. removed by airlifting and pumping.	425 days (March 10, 1999, to Sept. 29, 2000)
Screen 2 (878–897)					29,375 gal. removed by airlifting and pumping.	
Screen 3[c] (1046–1070)			Water for filter pack? 1026–1942: Bentonite placed with transport fluid of bentonite, water, and "Catalyst™" retardant.		NA	
Screen 4 (1180–1191)					150 gal. added. 29,075 gal. removed by airlifting and pumping.	
Screen 5 (1290–1307)					150 gal. added. 29,075 gal. removed by airlifting and pumping.	
Screen 6 (1398–1415)					150 gal. added. 29,075 gal. removed by airlifting and pumping.	
Screen 7 (1600–1618)	1427-1942: casing advance, air rotary water, QUIKFOAM, EZ-MUD, bentonite products[c], cellophane, MF-1[e].	Cellophane, MF-1[e]			150 gal. added. 29,075 gal. removed by airlifting and pumping.	
Screen 8 (1786–1805)					150 gal. added. 29,075 gal. removed by airlifting and pumping.	
Screen 9[c] (1862.2–1930)					150 gal. added. 29,075 gal. removed by airlifting and pumping.	

Note: The data shown in this table were taken from LANL 2002 (72640). Also see LANL 2005 (89397) and LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] Estimated from completion of well installation to completion of Westbay installation; 67 days of actual well development completed.

[c] Screens 3 and 9 damaged during installation. Replacement Screen 9 installed at 1871.5–1875 ft in well with packer just above screen, sealing off zone from well. Screen 3 sealed off with Portland cement/micro matrix plug and interval redrilled.

[d] Bentonite products include Ben-Seal, Bentonite Gel, Aqua-Guard Bentonite, and Pel-Plug.

[e] MF-1 is a flocculent.

HE= high explosive(s), LCM = lost circulation material(s), NA = not applicable, SAPP = sodium acid pyrophosphate

R-26, Data Quality Objectives

R-26 is located in Cañon de Valle, just east of State Highway 4 and upgradient of TA-16.

- well was installed as part of the Hydrogeologic Workplan. Characterization and sampling activities were conducted in accordance with the SAP for drilling and testing characterization wells R-2, R-4, R-11, and R-26.
- to provide background water chemistry for perched and regional groundwater upgradient of LANL activities in the TA-16 vicinity.

R-26

- monitored the intermediate perched zone in the Cerro Toledo interval of the Bandelier Tuff penetrated by existing wells R-25 and SHB-3 (Screen 1);
- monitored the regional zone of saturation in the Puye Formation upgradient of LANL activities in the TA-16 vicinity (Screen 2).

This well is located on the downthrown block of the Pajarito fault system. Data will be used to evaluate the influence of the Pajarito fault system on the regional aquifer piezometric surface and provide information on the role of faults in recharge.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (620–672)	Water, QUIKFOAM, EZ-MUD, drilling mud[c] 0–77: casing advance, air rotary. 77–140: open hole, air rotary. 140–147: open hole air rotary (air only). 147–205: open hole, DHH (water only). 205–1000: open hole air rotary, fluid assisted.	Aqua-Gel, N-seal, Pac-L, soda ash	Water for filter packs and bentonite chip seals	Airlifting to remove drilling mud. 3872 gal. removed. October–November 2003: Bailing, swabbing, bailing /surging pumping. 8948 gal. removed. July 2004: Pumping prior to Westbay installation (screens not isolated). 41,818 gal. removed.	239 days (Nov. 16, 2003, to July 17, 2004)
Screen 2 (1411–1450)	At 1000 ft bgs, lost circulation problems, drill casing set to 1005 ft bgs. 1000–1490.5: mud rotary.			October –November 2003: Bailing, swabbing, bailing /surging pumping. 29,259 gal. removed. July 2004: Pumping prior to Westbay Installation (Screens not isolated). 3733 gal. removed.	

Note: The data shown in this table were taken from Kleinfelder 2005 (92033). Also see LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

[c] Drilling mud is a mixture of water, bentonite, soda ash, and Pac-L.

DHH = downhole hammer, ft bgs = feet below ground surface, LCM = lost circulation material(s), SAP = sampling and analysis plan

R-31, Data Quality Objectives

This well installed in the north fork of Ancho Canyon, within TA-39, as part of the Hydrogeologic Workplan.

R-31

- provides hydrogeologic, water-quality, and water-level data for potential intermediate-depth perched zones and for the regional aquifer downgradient of the disposal and explosives testing sites at TA-39.
- Screen 1 was designed to monitor a possible perched horizon in the Cerros del Rio lavas.
- Screen 2 was designed to span the top of the regional aquifer.
- Screen 3 was designed to monitor a fractured and possibly transmissible interval within the Cerros del Rio lavas.
- Screens 4 and 5 were designed to monitor transmissive gravels below the lavas.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screen/Zones in Communication[b]
Screen 1 (432.8–460.6)	0–285: casing advance (dry) 285–345: open hole, air rotary (dry) 345–787: open hole, air rotary fluid assisted.	None mentioned	Water for filter pack. Water plus EZ-MUD for pellet seals.	NA (dry)	10 days (Mar. 27 to Apr. 6, 2000)
Screen 2 (496.3–551.3)	345–787: open hole, air rotary fluid assisted.			Washing/jetting, surging, airlifting, pumping 3400 gal. removed[c].	
Screen 3 (659.0–677.0)	345–787: open hole, air rotary fluid assisted. 787–1103: casing advance, fluid assisted.			Washing/jetting, surging, airlifting, pumping 5430 gal. removed[c].	
Screen 4 (780.5–842.0)	787–1103 : casing advance, fluid assisted.			Washing/jetting, surging, airlifting, pumping 3220 gal. removed[c].	
Screen 5 (873.7–1072.6)				Washing/jetting, surging, airlifting, pumping 2880 gal. removed[c].	

Note: The data shown in this table were taken from LANL 2002 (72615). Also see LANL 2003 (76003) and LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] From completion of well development to completion of Westbay installation.

[c] Minimum amount, no volumes listed for amounts added or removed during washing/jetting or airlifting.

LCM = lost circulation material(s), NA = not applicable

R-32, Data Quality Objectives

This well was installed in Pajarito Canyon, within TA-36, on the northern side of Pajarito Road and southwest of MDA G in TA-54 to

- provide hydrogeologic and water-quality data for regional groundwater near potential contaminant release sites at TA-54,
- provide data for the Laboratory hydrogeologic and geologic conceptual models and contribute to implementing a Laboratory-wide groundwater monitoring system,
- monitor the regional aquifer in river gravels present above the Cerros del Rio basalt (Screen 1),
- monitor the uppermost part of the Puye Formation in the regional aquifer (Screen 2), and
- monitor the regional aquifer in deepest part of the Puye Formation penetrated by the borehole (Screen 3).

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed[b]	Time Screen/Zones in Communication[c]
Screen 1 (862.5–879.2)	0–792: open hole, fluid assist: water, quick-gel, Liqui-Trol, QUIKFOAM. Casing installed to 797. 808–908: open hole, fluid assist. 908–1008: Mud rotary, open hole water, quick-gel, EZ–MUD. Liqui-Trol, QUIKFOAM.	0–792: Soda ash	Water for filter pack, Water plus EZ-MUD for pellet seals. 12,200 gal. of water used to place annular fill materials.	Wire brushing, surging/bailing, pumping, chemical treatments, surging/bailing, pumping 233 gal. of PFD and MGA+AE solutions added. 31,626 gal. removed.	7 days (Nov. 1 to Nov. 10, 2002)
Screen 2 (925.2–938.7)		908–1008 Pac-L, N-Seal, Magma-Fiber		Wire brushing, surging/bailing, pumping, chemical treatments, surging/bailing, pumping 233 gal. of PFD and MGA+AE solutions added. 30,191 gal. removed.	
Screen 3 (961.7–978.2)				Wire brushing, surging/bailing, pumping, chemical treatments, surging/bailing, pumping 233 gal. of PFD and MGA+AE solutions added. 51,986 gal. removed.	

Note: The data shown in this table were taken from LANL 2003 (79602). Also see LANL 2004 (89552) and LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] Chemical treatments involved phosphate-free dispersant (PFD), modified granular acid (MGA) and acid enhancer (AE) solutions.

[c] From completion of well development to completion of Westbay installation.

AE = acid enhancer, LCM = lost circulation material(s), MGA = modified granular acid, PFD = phosphate-free dispersant

R-33, Data Quality Objectives

This well was installed within Ten Site Canyon, upgradient from the confluence with Mortandad Canyon.

- well is intended to serve as a monitoring point for municipal water supply well PM-5 and lower Ten Site Canyon.
- data will be used to evaluate the nature and extent of potential contamination in the regional aquifer in Ten Site and Mortandad Canyons relative to former release sites in TA-48, TA-35, and TA-50.
- the two screens were designed to monitor potential contaminants and groundwater chemistry in the two uppermost productive zones of the regional aquifer and to determine if vertical hydraulic gradients are present in this part of the Laboratory.

Effective Screen Interval[a] (ft)	Drilling Fluids and Method(s) Used	Additives (i.e., solids, LCM)	Well Installation Fluids	Well Development Methods and Volumes Added/Removed	Time Screens/Zones in Communication[b]
Screen 1 (991–1027)	Water, QUIKFOZM, EZ-MUD, defoaming agent. 56.4–285: open hole, air rotary (water only). 285–530: open hole, air rotary fluid assisted. 530–1030: open hole, DHH. 1030–1140: open hole, air rotary fluid assisted.	None	Water for filter pack and bentonite chip seals.	Bailing/swabbing, pumping (aquifer testing) 19,167 gal. removed by bailing and pumping.	2 days (Oct. 5 2004 to Feb. 3, 2005)
Screen 2 (1107–1126)				Bailing/swabbing, pumping (aquifer testing), pumping 103,013 gal. removed by bailing and pumping.	

Note: The data shown in this table were taken from Kleinfelder 2005 (92385). Also see LANL 2005 (91121).

[a] Effective screen interval is sand pack installed across the well screen; does not include transitional sand pack adjacent to sealing materials.

[b] Packer installed after well development to isolate screens; packer removed immediately prior to Barcad installation.

LCM = lost circulation material(s), DHH = downhole hammer

A.2 GEOLOGY AND GEOPHYSICS OF SCREENED INTERVAL

CdV-R-15-3, Geology and Geophysics of Screened Interval

CdV-R-15-3 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (604–626)	Otowi Member, Bandelier Tuff Nonwelded vitric tuff with abundant feldspar and quartz phenocrysts.	Neutron logging (CMR and APS readings) and LDT formation porosity readings were used to identify six potentially productive regions. The six screens were placed adjacent to, or at the bottom of, these regions. The HNGS and total GR probe provided geochemical information throughout the borehole. The GR tool helped define subdivisions of the Bandelier and identify the Cerro Toledo interval. In the Puye Formation and the deep pumiceous unit, the HNGS could identify gamma potassium-uranium-thorium subdivisions not seen on any other tool. The Pleistocene Cerro Toledo was determined to be much thicker (200 ft) than the thickness predicted by the 3-D geologic model. The borehole video provided a record of clast sizes through the interval. Neither video nor geophysical logs showed evidence for any saturation in the Cerro Toledo. Borehole caliper logging indicated significant washout from about 120 ft to 154 ft; the APS measurements suggested numerous washouts from 1496 ft to 1680 ft.	Possible perched water at 598–611, unconfirmed on borehole video. CMR log indicated higher moisture at 610–620 ft. Water samples at 602 ft and 662 ft gave positive result on field HE detection kit (later confirmed as an artifact)
Screen 2 (785–806)	Contact of Guaje Pumice Bed and Puye Formation Vitric pumice fall, pumice fragmented in cuttings. Puye Formation – sand and gravel.		Borehole video indicates that coarse cobbles exceeding the 30-cm borehole diameter are present. CMR log indicated highest vadose zone water content at 790-800 ft, in lower Guaje Pumice bed.
Screen 3 (944–945)	Cerros del Rio dacite (963–980) and basalt (980–1012). (Puye Formation 800–963: sand and gravel. Borehole video indicates that coarse cobbles exceeding the 30-cm borehole diameter are present.)		Borehole video indicates flow-top rubble from 963-966 and massive from 966 to 987 and perched water at 960-990. Approx 10% free-fluid porosity 968–984.
Screen 4 (1212–1287)	Puye Formation (Tpf) Fanglomerate 1207–1232: Medium to fine sand. 1232–1262: Gravel and coarse sand. 1262–1272: Medium to fine sand. 1272–1282: Gravel and coarse sand. 1282–1317: Medium to fine sand.		Borehole video indicates coarsest cobbles are approx 10 cm in diameter. Borehole video indicates washouts and possible perched water at 1242–1249. High-K zone at 1260–1266.
Screen 5 (1321–1349)	Puye Formation (Tpf) Fanglomerate 1317–1367: Gravel and coarse sand.		Borehole caliper logs indicate numerous washouts from 1496 to 1680. Borehole video indicates washouts. High-K zone at 1337–1347.
Screen 6 (1604–1649)	Pumiceous unit (Tpp) 1562–1612: Gravel. 1612–1622: Gravel with coarse sand and pumice. 1622–1647: Gravel and coarse sand with vitric pumice.		Higher porosity below 1518 corresponding to gravel zones within the Puye. Numerous washouts from 1496–1680.

Note: The data shown in this table were taken from LANL 2002 (73179). Also see LANL 2005 (91121).

APS = accelerator porosity probe, CMR = combinable magnetic resonance, GPIT = general purpose inclinometer tool, GR = gross gamma-ray tool, HE = high explosive(s), HNGS = hostile environment gamma-ray sonde, K = hydraulic conductivity, TD = total depth, 3-D = 3 dimensional

CdV-R-37-2, Geology and Geophysics of Screened Interval			
CdV-R-37-2 Screen (Sand Interval ft bgs)	Lithology at Screen Interval	General Geophysical Interpretation (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (904.2–943.8) Dry	Puye Formation (Tpf) 902-922: Gravel (GW) broken to subrounded clasts. 922-942: Gravel (GW) mainly angular clasts. 942-947: Gravel with sand (GW) .	The following important results can be seen from the processed geophysical logs: 1. The depth of the regional aquifer water table appears to coincide with the water level in the well at the time of logging (1195 ft), based on the integrated log analysis results. In CdV-R-37-2, the processed geophysical log results display a distinct boundary at 1195 ft between mostly saturated and unsaturated conditions, as detected by the combination of the logs. 2. The formation in the bottom section of the well (1365–1665 ft) has high total and effective porosity, averaging 35%–40%, indicating very high groundwater flow capacity. The formation appears to be highly heterogeneous: very fractured and fragmented, with sharp vertical changes in mineralogy and porosity. The inferred mineralogy is rich in plagioclase and quartz, with significant amounts of heavy mafic minerals, likely of volcanic origin (e.g., a dacitic flow deposit). 3. The interval of 1075–1365 ft has lower porosity, in general (as low as 5%), than the bottom zone, although it is also highly heterogeneous and has zones with porosity greater than 40%. The inferred mineralogy is similar to the zone below but contains a consistently higher amount of heavy mafic minerals. 4. The interval of 895–1075 ft appears to be clay-rich, containing zones with as much as 50% clay volume fraction. Total and water-filled porosity average about 20% and 10%, respectively. Inferred mineralogy is similar to the zone below, other than the presence of montmorillonite and possibly silica glass, which replaces much of the quartz. 5. The start (in the upward direction) of the volcanic tuff/pumice sequence is clearly distinguished on the logs at 895 ft, including a marked increase in thorium, potassium, and uranium. As seen in most of the Los Alamos characterization and monitoring wells drilled to date, the tuff/pumice sequence is directly underlain by a thin clay layer. 6. Bed boundaries between 1195 ft and 1655 ft have a wide range of dip azimuths (direction beds are dipping to), but a predominant amount are in the sector 40–180 degrees (the mean is 111 degrees). Fractures from this interval have a similar range of dip azimuths, but the majority dip between 130 and 210 degrees (the mean is 176 degrees), with lesser numbers in the sectors 90–100 degrees and 30–70 degrees. Both bed boundaries and fractures dip quite steeply, with mean dip angles of 15 and 33 degrees, respectively, but both have a large spread of dip angles. Throughout this interval, the electrical resistivity image shows highly fragmented beds, with large chunks of broken rock visible, and zones with extensive fracturing.	875–1075: Appears to be relatively clay-rich, containing zones with as much as 50% modeled clay volume fraction. Volume of clay 20%–40% in 940–947 and 913–922 ft bgs intervals. 900-1074: Total porosity drops to 10–20% average. Water content rises to 15%–20% coincident with high clay content intervals.
Screen 2 (1179.6–1221)	Tschicoma Formation (Tt) 1162–1192: Dacite with local hydrothermal alterations. 1192–1207: Dacite 1207–1214: Dacite/Clastic sediments; broken to subrounded clasts of tuffaceous siltstone. 1214–1229: Dacite plus fragments of tuffaceous siltstone.		Depth of regional aquifer coincides with the water level at time of logging (1196.7 ft bgs). 1075–1365: Has lower porosity than the bottom zone, although it is also highly heterogeneous and contains some zones whose porosity is >40%. 1074–1278: Total and water-filled porosity increase swiftly to 28% at 1195. Above 1195, water-filled porosity drops to 10%–15%, total porosity stays at 25%–35%.
Screen 3 (1343–1382)	Tschicoma Formation (Tt) 1324–1364: Dacite, possibly fractured or brecciated. 1364–1379: Dacite, broken fragments and subrounded clasts. 1379–1389: Dacite/Clastic sediments, broken to subrounded clasts 5%–10% waxy clay.		1278-1330: Total and water-filled porosity decrease to <10% at 1220 but reach >35% in short intervals.
Screen 4 (1539.7–1560.7)	Tschicoma Formation (Tt) 1529–1564: Dacite, groundmass locally bleached, sericitized, or pitted corroded.		1365–1665: Has high total and effective porosity, averaging 35%–40%, indicating very high groundwater flow capacity. Total and water-filled porosities average 35%–40% but vary between 10%–60%.

Note: The data shown in this table were taken from LANL 2003 (88803). Also see LANL 2005 (91121).

R-5, Geology and Geophysics of Screened Interval

R-5 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (316.5-338.0) (Dry)	Lower Puye 312-317: Gravel (GW) with sand. 317-327: Gravel (GW) with sand. 327-332: Silty gravel (GM) with sand. First appearance of Precambrian (PreC) lithologies denotes stratigraphic top of axial river gravels of Puye Formation. 332-342: Silty gravel.(GM) with sand.	Open portion of the borehole at time of Schlumberger logging 850–898 ft bgs Above 534 ft the estimated water saturation is consistently below 50%, indicating that there are no significant perched water zones above this depth and the regional aquifer groundwater level lies below. The water level in the borehole, both inside and outside the free-standing casing, was 711 ft at the time the geophysical logs were acquired. The estimated water saturation is 100% or quite high through much of the section below this depth. However, there are also zones showing full saturation above 711 ft and below 534 ft. These results, interpreted independent of other data sources, suggest that the regional aquifer groundwater level may lie at 711 ft or that there could be saturated conditions as high as 534 ft. The highest water-filled porosities are near the bottom of the log interval from 711 to 850 ft, varying from about 25%–45%, with the highest values at the top and bottom of the zone. The lowest water-filled porosities (5%–10%) are at the top of the log interval (39–120 ft) and in the zone 560–670 ft. The total and air-filled porosity is high in the top zone and low in the bottom zone. Significant geologic contacts appear to be present at 73 ft, 152 ft, 338 ft, 534 ft, 612 ft, 723 ft, 790 ft, 849 ft, and 860 ft—marked by changes in the lithology/mineralogy of the optimized mineral-fluid model that is estimated from the integrated log analysis. There are zones in the R-5 log interval where the bulk density and total porosity (derived from bulk density) are unreasonably low and high, respectively, for natural geologic formations—indicating the likelihood of problematic standoff. Because of the limited geophysical logging suite acquired in R-5, a quantitative analysis of clay volume could not be performed.	Above 534 ft the estimated water saturation is consistently below 50%, indicating that there are no significant perched water zones above this depth. Extremely high total porosity (100%) and low water content (0%) anomalies in the zones 330–338 ft and 473–482 ft, probably corresponding to large air-filled voids behind the casing.
Screen 2 (364.5–401.0) (Not Productive)	Lower Puye 362–372: Clastic sediments, silty gravel with sand. 372–377: Silty gravel (GM) with sand. 10–15% PreC rounded granite and quartzite clasts. 377–382: Silty gravel with sand, much lower % of PreC clasts than interval above. 382–387: Clayey gravel (GC) with sand. 387–397: Silty gravel with sand. 397–402: Silty gravel (GM) with sand.		Generally constant water content (20%) from 340 to 532 ft.
Screen 3 (666.5–727.0)	Lower Puye 670–675: Clayey sand (SC) F- VC sand 675–680: Clayey sand (SC) mainly CG sand. 680–685: Sand (SW) with clay and gravel. 685–690: Sand (SW) with clay. 690–695: Clayey sand with gravel. 695–700: Clayey sand (SC). 700–705: Sand (SW) with gravel. 705–715: Gravel (GW) with sand. 715–720: Clayey sand (SC) with gravel. 720–735: Basaltporphyritic, slightly vesicular.		The regional aquifer groundwater level may lie at 711 ft or there could be saturated conditions as high as 534 ft The highest water-filled porosities are near the bottom of the log interval from 711 to 850 ft, varying from about 25% to 45%, with the highest values at the top and bottom of the zone. Low water-filled porosity (5%–10%) in the zone 560–670 ft. 711–726 ft, apparent water content of 30% or greater, the top 8 ft of which likely correspond with a large water-filled void behind the casing. Generally low water content (10%–15%) from 532–672 ft. Constant water content of 20% from 672–711 ft. Decreasing water content from 90% at 711 ft to 12% at 749 ft likely corresponding to voids behind casing.

R-5, Geology and Geophysics of Screened Interval (continued)

R-5 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 4 (851.0–902.0) (Not Productive)	Santa Fe Group Basalt. 850–892: Basalt. 892–897: Gravel (GW) with sand. 897–902: Clayey sand (SC) with gravel.		The highest water-filled porosities are near the bottom of the log interval from 711 ft–850 ft, varying from about 25% to 45% with the highest values at the top and bottom of the zone. Much lower water content (15–20%) at the bottom of the log interval (849–866 ft) A quantitative analysis of clay volume could not be performed.

Note: The data shown in this table were taken from LANL 2003 (80925). Also see LANL 2005 (91121).

ft bgs = feet below ground surface

R-7, Geology and Geophysics of Screened Interval

R-7 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (Dry) (355.6–383.6)	Puye: Pumice-poor fanglomerate. 352–367 Silty to clayey gravel (GM/GC). 367–382: Similar to above (lower % fines?). 382–397: Silty to sandy gravel (GM).	Well water level varied considerably over the course of the geophysical logging, between 865 ft and 899 ft. The depth of the regional aquifer water table is not clear from the logging results due to high moisture content and possible perched water zones, in the vadose zone. As a best guess, the water table was somewhat arbitrarily chosen as 894 ft, based on the integrated log analysis performed and on density log response. Relatively high moisture content above the presumed regional aquifer water table, especially below 734 ft, where total and effective water-filled porosity averages about 20% and between 5% and 10%, respectively. Above 734 ft, total water-filled porosity averages between 7%–20%, but effective water-filled porosity averages much less than 5%. Estimated water saturation averages about 50% below 675 ft, 30% from 530 to 675 ft, 10% from 420 to 530 ft, and 30 to 50% from 275 to 420 ft. Indication of the presence of clay throughout the logged section (275–1050 ft), with high clay volume fractions (10%–60%) from 318 to 525 ft, moderate clay volumes (5%–30%) in the intervals 525–680 and 940–1050 ft, and low clay volumes (less than 10%) from 680 to 940 ft. Notable spectral natural gamma ray characteristics at 875–915 ft (large uranium peak), 285–325 ft (large thorium and uranium peak), 865 ft and 875 ft (step increase in thorium and potassium, respectively, in the up hole direction), and 730 ft (step increase in thorium/potassium ratio in the up hole direction). Bed boundaries between 865 ft and 1054 ft have predominant dip directions between south and north, with most beds dipping between 230–310 degrees (west). More than 90% of these interpreted bed boundaries have dip angles less than 10 degrees. The electrical resistivity image shows thinly laminated beds of alternating clays and sands through this interval.	The summary porosity logs indicate high moisture content above the apparent regional groundwater table (in the vicinity of 900 ft) – remaining, on average, 10% or higher from 260 to 734 ft. Water-filled porosity increases from a low (less than 10% between 450 and 530 ft) to 20% at the top of the logged section at 260 ft. There is low effective water-filled porosity (less than 5%) above 697 ft. The hydraulic conductivity is estimated to be greater than 10–5 cm/s in the intervals 360–362, 344–347, and 336–338 ft. The estimated water saturation of close to, or greater than 50% (above the picked regional groundwater table of 894 ft) in the intervals 356–358 ft, and 331–337 ft (the high saturation at the top of the logged section is an artifact of the ELAN processing, not considered valid).
Screen 2 (Dry) (725–754)	Puye: Pumice-poor fanglomerate 717–737: Sandy gravel (GW). 737–742: Silty sandy gravel (GM). 742–767: Sandy gravel (GW).		The summary porosity logs indicate high moisture content above the apparent regional groundwater table (in the vicinity of 900 ft) – remaining, on average, near 20% from 900 ft to 734 ft and 10% or higher from 734 to 260 ft. The highest water-filled porosity is at the bottom of the borehole (30%–40%), and decreases slowly going up the borehole to the lowest values in the interval 450 to 530 ft (less than 10%). Above 890 ft the effective water-filled porosity is close to or greater than 10% in the intervals 735–740 ft, and 697–699 ft. Hydraulic conductivity is estimated to be greater than 10–5 cm/s in the intervals 747–816 ft and 734–740 ft. The estimated water saturation is close to, or greater than, 50% (above the picked regional groundwater table of 894 ft) in the intervals 746–825 ft and 722–731 ft.
Screen 3 (880–946)	Puye: Pumiceous Fanglomerate 862–887: Sand (SW) 887–892: Sand (SP) 892–912: Sandy gravel (GW) 912–927: Sandy gravel (GW) 927–937: Sandy gravel (GW) 937–952: Sandy gravel (GW)		The depth of the regional groundwater table is very difficult to determine with the log results alone. The depth of the water table was chosen somewhat arbitrarily as 894 ft in the ELAN log processing, based on performing the ELAN analysis with water only (no air) and seeing at what depth there start to be major departures between the modeled and measured log responses (especially density). The summary porosity logs indicate high moisture content above the apparent regional groundwater table (in the vicinity of 900 ft) – remaining, on average, near 20% from 900 ft to 734 ft and 10% or higher from 734 ft to 260 ft. The highest water-filled porosity is at the bottom of the borehole (30%–40%) and decreases slowly going up the borehole to the lowest values in the interval 450 ft to 530 ft (less than 10%). The highest effective water-filled porosity is below 890 ft (10%–20% or higher). The hydraulic conductivity is estimated to be greater than 10–5 cm/s in the intervals 1017–1040, 998–1008, 948–992, 930–940, 904–913, 900–902, 892–894, and 860–879 ft. The estimated water saturation is close to, or greater than, 50% (above the picked regional groundwater table of 894 ft) in the interval 833–900 ft.

Note: The data shown in this table were taken from LANL 2002 (72717). Also see LANL 2005 (91121).

ELAN = elemental log analysis program, ft bgs = feet below ground surface

R-8, Geology and Geophysics of Screened Intervals

R-8 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (687.4–796.8)	Lower Puye (Tpf) 682–762: Alternating sequences of clayey gravels (GC), clayey sands (SC), gravels (GW), gravels with sand and clay. Expansive clay at 706.	Schlumberger logs run in (abandoned) BH1 to a depth of about 764 ft bgs. 1. A significant shift in water content at 642 ft (decreasing from 25–30% below to 10%–15% above) and a corresponding significant decrease in water saturation from near-full saturation below to well-below-full saturation above. These results, interpreted independently of other data sources, suggest that this depth may correspond to the regional aquifer groundwater level or the top of a thick perched zone, although the results could be an artifact of borehole conditions behind the casing. 2. The highest water-filled porosities are at the bottom and top of the well, averaging 25%–30% from 642 to 750 and 30 to 96 ft. The bottom interval could be in the regional aquifer or a thick perched zone (see above point) and the top interval is likely within a volcanic tuff/pumice sequence. The processed logs indicate the top interval is not even close to full water saturation as a result of very high total porosity—characteristic of the Los Alamos tuffs. 3. The lowest water-filled porosities are in the zone 100–175 ft, averaging 5%–10%. This zone also has very high air-filled porosity, possibly elevated due to a large air-filled annulus behind the casing. Directly above is a large thorium peak and high water content (see point 2 above)—possibly indicative of a clay-rich layer that corresponds to a permeability barrier (note that clay does not show in the integrated log analysis results at this depth due to required model constraints). 4. A significant geologic contact exists at 92 ft, marked by a significant increase (in the upward direction) in thorium, uranium, thorium/potassium ratio, and water content. The inferred mineralogy changes from the section below by a reduction in heavy mafic minerals, augite, and plagioclase feldspar, and a large increase in hornblende. This interval likely corresponds to the presence of volcanic tuff or pumice deposits, based on similar log response in other wells. 5. A distinct geologic/lithologic zone exists from 186 to 367 ft, marked by a decrease in potassium and silicon and an increase in iron and titanium. The inferred mineralogy contains a relatively large amount of heavy iron-bearing mafic minerals and augite and minimal amounts of hypersthene—likely corresponding to a massive basalt flow.	Schlumberger logs run in (abandoned) BH1 to a depth of about 764 ft bgs. There are zones in the R-8 log interval where the bulk density and total porosity (derived from bulk density) are unreasonably low and high, respectively, for natural geologic formations—indicating the likelihood of problematic standoff. Intervals where density porosity is above 60% and/or bulk density is below 1.5 g/cc include (from bottom to top): 740–746, 632–640, 597–607, 496–512, 210–287, and 63–173 ft In these intervals the bulk density measurement may not be representative of true formation bulk density and, consequently, the total porosity estimate may not be valid due to fluid- or air-filled annulus behind casing. The processed log results do indicate a significant shift in water content at 642 ft from 10–15% above to 25–30% below, and a corresponding significant increase in water saturation from well-below-full saturation above to near-full saturation below. These results, interpreted by themselves, suggest that this depth may correspond to the regional aquifer groundwater level or the top of a thick perched zone, although the results could be an artifact of borehole conditions behind the casing. R-8 porosity summary log shows zones with apparent water content of 30% or greater by volume at 42–86 ft and 362–366 ft. The R-8 porosity log shows an extremely high total porosity (95%) and low water content (0%) anomaly in the zone 740–746 ft, probably corresponding to a large air-filled void behind the casing and a similar, less severe high total porosity (70%) and low water content (10%) anomaly in the zone 632–640 ft, probably corresponding to a large void behind the casing. The spectral gamma ray log shows a large U peak (maximum 7.1 ppm) in the 630–644 ft interval. Th and K increase slightly from 628–634 ft. The interval coincides with a very large porosity spike (ELAN total porosity reaching greater than 70%), likely a large washout behind the casing, and it is possible U-rich bentonite drilling mud is present in the washout.
Screen 2 (821.3–832.4)	Lower Puye (Tpf) 807–827: Sand (SW) with silt and gravel. 827–832: Sand (SW) with gravel and silt.		

Note: The data shown in this table were taken from LANL 2003 (79594). Also see LANL 2005 (91121).

BH = borehole, ELAN = elemental log analysis program.

R-9i, Geology and Geophysics of Screened Interval

R-9i Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (185.5–200.7)	Cerros del Rio basalt; upper alkalic basalt 180–206: Scoriaceous olivine basalt, approximately 20% vesicles range from 5 mm to 3 cm, some have clay coatings or infillings.	No logging performed.	No logging peformed.
Screen 2 (266.4–282.1)	Cerros del Rio basalt; lower alkalic basalt 245–274; Very fine-grained olivine basalt, microfractured to the size of coarse sand rare clay. 274–282: Vesicular olivine basalt, clay aggregates >1 cm with rounded basaltic fragments several cm in diameter. This zone appears to mark a flow base.		

Note: The data shown in this table were taken from LANL 2001 (71251). Also see LANL 2003 (76003) and LANL 2005 (91121).

ft bgs = feet below ground surface.

R-12, Geology and Geophysics of Screened Interval

R-12 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 453–481	Lower alkalic basalt of the Cerros del Rio Volcanic Field 450–488.2: Saturated, massive basalt. Slightly vesicular near base, with some calcite infilling. Fractured, based on drilling performance. Water encountered at 443, static at 424. Probably in hydraulic communication with groundwater in underlying perched zone.	Note: This well was logged using a color video camera, natural gamma radiation (NGR) and caliper tools. The Cerros del Rio basalt has a significantly lower NGR than the overlying Otowi Member (102–112 ft). The NGR for the basalt from 136 to 280 ft was uniform at 15 cps. The NGR remains low and uniform throughout the thickness of the basalt. Below the basalt, the NGR count rate gradually increases from 15 cps in the old alluvium (at 492 ft) to values of 74 cps at depths of 600–670 ft in the Puye Formation. Caliper measurements were made on the inside of the drill casing to inspect for the presence of clay-rich cutting buildup, which might cause anomalous NGR readings. The caliper shows that a buildup only occurred at a depth greater than 645 ft and any impact on the NGR was limited to 645–660 ft.	Only video, natural gamma, and caliper measurements made.
Screen 2 495–522	Older alluvium 495–509: Sandy gravel. 509–519.1: Fine- to medium sand; silt and clay rich. 519.1–535.5: Micaceous claystone. Dry below 520 ft. Some zones contain fine sand. 519: Claystone subunit of old alluvium forms perching layer. Probably in hydraulic communication with groundwater in overlying basalts.		Only video, natural gamma, and caliper measurements made.
Screen 3 793–856	Santa Fe Group basalt 784–803: Slightly scoriaceous, coarse-grained basalt with very irregular vesicles to 1 mm. Saturated zone encountered at 804 ft. 830–866: Slightly vesicular, coarse-grained basalt with round to slightly elongate vesicles to 6 mm, some with white clay coatings.		Only video, natural gamma, and caliper measurements made.

Note: The data shown in this table were taken from LANL 2001 (71252). Also see LANL 2005 (91121).

ft bgs = feet below ground surface, NGR = natural gamma radiation.

R-14, Geology and Geophysics of Screened Interval

R-14 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (1196.8–1240.2)	Puye Formation (Tpf) lower section 1185–1210: Volcaniclastic sediments: Silty sands (SW) and silty sand (SM). Pumiceous Fanglomerates. 1210–1245: Clastic sediments: Silty sand (SM), sand (SW) with clay, clayey sand (SC).	Schlumberger logs only run from 12.2 ft to approximately 1070 ft. Only LANL video and natural gamma tools run to TD (1327 ft). The inferred water saturation remains below 75% through most of the logged section, with no significant fully saturated intervals. These results, interpreted independently of other data sources, suggest that the regional aquifer groundwater level lies somewhere below the bottom of the log interval (1063 ft) and that there are no significant perched water zones within the logged section. Water-filled porosity is less than 20% through most of the logged section, ranging from a low of 3% to a high of 31%. The highest water-filled porosities (greater than 20%) occur in the zones 524–534 ft, 975–1000 ft, 1024–1030 ft, and 1062–1066 ft, which also have high total (air plus water) porosity. Effective water-filled porosity (moveable water) is less than 3% through most of the logged section (averaging less than 1%), ranging from a low of 0% to a high of 26%. Correspondingly, the inferred hydraulic conductivity is generally very low. The highest effective water-filled porosities (greater than 2%) occur in the zones 212–240, 520–534, 584–588, 597–602, 607–620, and 771–783 ft; the top two intervals are likely within the Bandelier Tuff sequence (the second likely corresponding to the Guaje Pumice Bed) and, from the integrated log analysis, appear to be directly underlain by clays, which possibly act as inhibitors to downward flow. As would be expected, inferred hydraulic conductivity is highest in these zones, although it is also high (relative to other intervals) in the zones 975–1000 ft and 1062–1066 ft, which have high total water-filled porosity. The integrated log analysis shows a dense, low total porosity (less than 10%) and mafic-mineral rich zone from 623 to 767 ft that likely corresponds to a massive basalt and is surrounded by zones with similar mineral content, but higher porosity, that are likely composed of fractured basalt. Toward the bottom of the log interval the amount of heavy mafic minerals decreases, replaced by small amounts of hornblende, but otherwise the inferred mineral composition remains relatively constant. A volcanic tuff sequence (likely the Bandelier Tuff) in the upper half of the logged interval (10–534 ft) is clearly distinguished by the logs. The borehole was largely washed out throughout the log interval, the diameter ranging from 17 to 22 in. compared with a 16-in. bit size. However, the washouts were no worse than most other Los Alamos wells and the borehole rugosity was less.	NA, this section of well not logged.
Screen 2 (1281.0–1299.0)	Puye Formation (Tpf) Lower section 1265–1290: Lost circulation, no cuttings. 1290–1300: Sand (SW) with silt. Pumiceous.		NA, this section of well not logged.

Note: The data shown in this table were taken from LANL 2003 (76062). Also see LANL 2005 (91121).

ft bgs = feet below ground surface, NA = not applicable, TD = total depth

R-16, Geology and Geophysics of Screened Interval

R-16 Well Screens (Sand interval ft bgs)	Lithology at Screen Interval	General Geophysical Interpretation (depths in ft bgs)	Geophysical Indication of Screened Intervals (depths in ft bgs)
Screen 1 (634.5–653.4)	NA	The estimated water saturation (fraction of pore space filled with water) remains high through most of the logged section, never dropping below 50% of total pore volume. These processed log results, interpreted by themselves, suggest that the entire interval from 311 to 1285 ft may lie within the regional aquifer, below the water table, although the results could be an artifact of borehole conditions behind the casing within the cased hole section. No information about the water content or the water table above the well water level can be inferred from the geophysical logs; it is possible the well water level at the time of the logging (311 ft) corresponds to the water table. In the open-hole log interval (731–1285 ft) water content and total porosity averages around 32% of total volume, varying between 20% and 70%; the highest water content and total porosity occurring just below the bottom of the casing from 731 to 788 ft bgs, ranging predominantly 40%–70%, but the measured porosity could be elevated due to significant washouts in this interval. In the cased hole log interval (146–731 ft) there are many zones with unrealistically high estimated water content and total porosity (greater than 50%), likely due to washouts behind casing. The integrated log analysis indicates highly heterogeneous mineralogy across the open-hole log interval (731–1285 ft), but an overall high silica content (quartz and silica glass) as high as 70% dry weight fraction. The inferred mineralogy includes significant, highly variable amounts of montmorillonite clay (0%–70% by volume) throughout this interval. The processed logs indicate the geologic formation across this interval consists of a thinly bedded sequence of silica-clastic sediments with highly variably grain size (alternating clay to sand/gravel beds). In the cased hole log interval an accurate estimate of the mineralogy from the processed logs is not possible due to the limited number of valid log measurements. Interpreted bed boundaries across the imaged interval 768–1290 ft have dip azimuths (direction beds are dipping to) predominantly in the sector 230–330 degrees, with the highest concentration falling in the 10 degree range 290–300 degrees. The mean dip azimuth across this interval is 278 degrees. The interpreted bed boundaries have a wide range of dip angles (degrees of dip) from zero to 60 degrees, although more than 80% have dip angles less than 20 degrees and the average dip angle is 6 degrees. No fractures were discernible across this interval. Throughout this interval the electrical resistivity image shows a well-bedded, thinly bedded alternating sand-silt-clay stratigraphy. The borehole was enlarged and/or washed out in the top half of the open-hole log interval (731–975 ft), but it appears only the severe washouts (as large as 19-in. borehole diameter) just below the casing (731–804 ft) caused any possible impact on geophysical log quality. However, washouts were likely present in a number of zones within the cased hole log interval (145–731 ft), causing the log measurements to be heavily influenced by the annular space between the casing and formation. Borehole deviation is measured with the GPIT, run as part of the FMI across the interval 790–1290 ft. The maximum deviation of the borehole across the log interval it was measured (790–1290 ft) is only 2.5 degrees; the azimuth of deviation is to the southeast.	NA. Screen 1 isolated behind drive casing.
Screen 2 (852.1–877.5)	Santa Fe Group (Tsf) 852–857: Clayey sand (SC) with gravel. 857–862: No recovery. 862–867: Sand (SW) with clay. 867–1047: No recovery, lost circulation.		Below the bottom of the free-standing casing (731 ft) the processed log results clearly indicate fully saturated conditions throughout most of the open-hole interval. In the open-hole log interval (731–1285 ft) water content and total porosity averages around 32%, varying between 20% and 70%. The processed logs indicate the geologic formation across this interval consists of a thinly bedded sequence of silica-clastic sediments with highly variably grain size (clay to sand/gravel beds) and bed dip magnitudes.
Screen 3 (1006.7–1028.5)	Santa Fe Group (Tsf) 867–1047: No recovery, lost circulation.		
Screen 4 (1211.7–1287)	Santa Fe Group (Tsf) 1207–1287: Clastic sediments, sand (SW) with clay and gravel, clayey sands (SC), gravel (GW) with clay and sand near TD.		

Note: The data shown in this table were taken from LANL 2003 (76061). Also see LANL 2005 (91121).

ft bgs = feet below ground surface, GPIT = general purpose inclinometry tool, NA = not applicable, TD = total depth

R-19, Geology and Geophysics of Screened Interval

R-19 Well Screen (Sand Interval ft bgs)	Lithology at Screen Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (802.2–858.6)	Otowi Member of the Bandelier Tuff 603–830. Puye Formation, upper fanglomerate 840–925.	In general, the formation containing the greatest amount of porosity as shown by the density porosity is the Guaje Pumice Bed from 808 ft to 840 ft. The formation containing the least porosity is the massive Cerros del Rio basalt unit from 925 ft to 1000 ft. Formations containing the highest amount of permeability are the Guaje Pumice Bed (808–840 ft) and the lower Puye Formation (1178–1902 ft). Notable porosity zones are: <u>830- to 840-ft interval</u> This interval from about 830 ft to 840 ft within the Guaje Pumice Bed exhibits a lower formation density than the overlying Otowi Member and an elevated density porosity up to 20%. The CMR log data indicate total porosity up to 40% in this interval, a free fluid porosity of up to 28%, and a calculated permeability up to 1000 millidarcies (md). However, flowing water was not encountered in this zone and the increased moisture content may be unsaturated moisture contained within the formation, which may have been introduced during drilling. The deep resistivity curves show higher resistivity and separation from the shallow curves from 834 to 838 ft, which indicates some near-borehole formational changes possibly caused by drilling. <u>896- to 912-ft interval</u> A 16-ft interval from 896 ft to 912 ft in the upper Puye Formation above the Cerros del Rio basalt also exhibits higher porosity values. The density porosity ranges from 30% to 60%. The relative neutron moisture content increases by a factor of about 3 compared with the adjacent zones within the Puye Formation. The open-hole video log shows an increase in moisture on the walls of the borehole between 900 ft and 910 ft. The total CMR porosity increases from an average in the formation of 6% to 20%, with a high of about 35%. The calculated permeability from 906 ft to 910 ft is from 1 to 10 md. Below 912 ft the porosity curves return to 4% to 6% with no detectable calculated permeability. The CMR pore water data show that the majority of the water in this interval is bound to fine-grained sediments, small-pore, micro-pore, and clay-bound. <u>998- to 1030-ft interval</u> A 32–ft interval corresponds to the zone of volcaniclastic sediments between two massive basalt flows in the Cerros del Rio basalt. The red scoria zone from 1018 ft to 1030 ft is differentiated from the breccia zone above by a higher gamma value of 140 API units compared with about 100 API units in the breccia zone. The lower part of the breccia zone from 1006 ft to 1018 ft contains density porosity of 50% to 60% and corresponding CMR total porosity of 17% to 25%. The scoria zone contains density porosity of 20% to 30% and CMR total porosity of 10% to 20%. However, the CMR free-fluid porosity in the breccia zone is about 5%, which increases up to 15% in the scoria zone. The neutron log indicates some level of elevated moisture content in the breccia zone, which decreases downward in the scoria zone. The CMR log shows limited permeability in the breccia zone but permeability ranging from 1 to 10 md in the scoria zone. The CMR bound water data indicate that moisture in this zone is primarily bound up in clay-sized pores.	830–840: Elevated density porosity up to 20%. The CMR log indicates total porosity up to 40%, a free-fluid porosity of up to 28% and a K of up to 1000 md. Driller noticed water returning with cuttings at 837 ft.
Screen 2 (868.3–926.0)	Puye Formation, upper fanglomerate 840–925.		896–912: Density porosity ranges from 30% to 60%. The video log shows increased moisture on walls between 900 and 910 ft bgs. The CMR porosity increases from an average of 6 up to 205 with a high of 35%. Calculated K for 906–910 ft ranges from 1 to 10 md. The gamma log indicates a change to finer-grained materials. CMR pore water data indicates majority of water in this interval is bound to fine-grained sediments.
Screen 3 (1149.8–1240.5)	Puye Formation, lower fanglomerate facies 1080–1530. Washout zone: 1194–1197.		1178–1550: Upper part of regional aquifer exhibits 24%–30% porosity on the neutron log and 30–40% on density log. The CMR log indicates porosity of about 20% with 2–8% free-fluid porosity. However, porosity is generally from smaller pore sizes. The calculated K varies from 1 to 10 md CMR log indicates a high unbound water content zone at 1216–1220 ft.
Screen 4 (1380.0–1445.5)	Puye Formation, lower fanglomerate facies 1080–1530.		Total porosity = 21.7%, calculated K = 1.01 md
Screen 5 (1557.9–1606.8)	Pumiceous sedimentary deposits, unassigned 1530–1902.5.		1530–1900: The neutron log shows average porosities of 35–40%. The CMR log shows 24–40% total porosity with an average of 4–20% free fluid porosity. The calculated K varies generally from 0.1 to 177.8 md, with the highest porosity and permeability zones at 1634–1638 and 1733–1736 ft bgs. Total porosity = 31.6%, calculated K = 178.77 md. The CMR log indicates a modest rise in porosity at 1581–1595 ft.

R-19, Geology and Geophysics of Screened Interval

R-19 Well Screen (Sand Interval ft bgs)	Lithology at Screen Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 6 (1675.9–1779.8)	Pumiceous sedimentary deposits, unassigned 1530–1902.5 Washout zone: 1774–1778.	<u>1064- to 1072-ft interval</u> This 8-ft interval is present directly beneath the lower massive basalt flow and may represent a basalt breccia zone similar to the breccia zone from 998 to 1018 ft. This zone exhibits increased moisture content on the neutron log, density porosity of 35% to 40%, CMR total porosity of 16% to 20%. However, the CMR log does not indicate the presence of significant free-fluid porosity, nor does the CMR log indicate the presence of significant calculated permeability. There is some separation in the resistivity curve, indicating that the formation contains low permeability. <u>Regional aquifer</u> The water level of the regional aquifer was encountered at 1178 ft at the time of the Schlumberger logging. The neutron moisture and CMR data indicate less than 1 ft of capillary fringe above the water level. The permeability, as interpreted from the geophysical logs, at the top of the water table, is very low (1 to 10 md). <u>1178- to 1530-ft interval</u> The upper part of the regional saturation from 1178 to about 1550 ft exhibits 24% to 30% porosity on the neutron log and 30% to 40% porosity on the density log with the highest porosity zone at 1242 ft to 1246 ft. The total porosity shown on the CMR averages about 20%, with 2% to 8% free-fluid porosity. The porosity through this zone is generally from smaller pore sizes from clay to micro-pore size. Calculated permeability shown on the CMR log varies generally from 1 to 10 md. The resistivity curves track very closely showing the saturated nature of the formation; the only separation is in the deep resistivity in zones of less porosity, where some higher resistivity values are present at deeper distances from the borehole. <u>1530- to 1900-ft interval</u> The deeper part of the regional saturation from 1530 to 1900 ft exhibits higher porosity values than the zone described above. The neutron log shows average porosity values of approximately 35% to 40% and the density log shows 40% to 50% average porosity. The CMR log shows 24% to 40% total porosity, with an average of 4% to 20% free-fluid porosity. Average calculated permeability shown on the CMR log varies generally from 0.1 to 177.8 md, with the highest porosity and permeability zones at 1634 ft to 1638 ft and 1733 ft to 1736 ft. The resistivity curves track very close to showing the saturated nature of the formation; the only separation is in the deep resistivity in zones of less porosity, where some higher resistivity values are present. This lower zone appears to be a more transmissive part of the regional aquifer in R-19.	Total porosity = 34.9%, calculated K = 131.79 md. The CMR log indicates a significant rise in pore-held water from 1730 to 1740 ft.
Screen 7 1828.2–1848.2)	Pumiceous sedimentary deposits, unassigned 1530–1902.5.		Total porosity = 34.3%, calculated K = 92.68 md. CMR log indicates a moderately high pore-water content in a broad zone from 1815 to 1845 ft.

Note: The data shown in this table were taken from LANL 2001 (71254). Also see LANL 2003 (76003) and LANL 2005 (91121).

CMR = combinable magnetic resonance, ft bgs = feet below ground surface, K = hydraulic conductivity, md = millidarcies

R-20, Geology and Geophysics of Screened Interval

R-20 Screen (Sand interval ft bgs)	Lithology at Screen Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (895.2–926.5)	Cerros del Rio Basalt (Tb4) Scoria/sediments, scoria (altered and bleached). 915–920: No recovery.	A significant shift in water saturation occurs at 755 ft; the location of the borehole fluid level at the time of the logging. However, another large shift in the water content occurs at 827 ft, decreasing from 15 to 50% below to 5%–15% above, with a corresponding equivalent decrease in total porosity associated with a significant lithology change. The low porosity formation above 827 ft has low hydraulic conductivity and, thus, is not an aquifer. These processed geophysical log results, interpreted by themselves, suggest that the top of the regional groundwater aquifer likely is 827 ft, with the tight bed above acting as a confining layer. It is possible the confining layer is saturated up to the depth of 755 ft. The measured near wellbore water-filled porosity is greater than 20% of total formation volume through most of the interval 828–1365 ft and is less than 20% and predominantly below 10% through most of the interval 46–828 ft. In the upper interval there are two major zones where the water content is elevated compared with surrounding zones: 132–286 and 398–546 ft, reaching 20% and 30% total rock volume fraction (matrix plus pore space), respectively. The highest water-filled porosities (greater than 30%) occur in the major zones 858–877 ft, 1086–1089 ft, and 1136–1244 ft. Effective water-filled porosity (moveable water) is generally 5% or less through most of the logged section, ranging from a low of 0% to a high of 26%. Correspondingly, the estimated hydraulic conductivity is generally low. The highest effective water-filled porosities (greater than 10%) occur in the zones 1086–1090 and 1127–1240 ft, with a peak of 26% of total volume at 1194 ft. The integrated log analysis shows a mafic-mineral-rich and quartz/silica-glass deficient interval from 393 to 924 ft that likely corresponds to a basalt lava flow sequence. The interval 397–630 ft has very high matrix grain density (2.8–3.1 g/cc) and significant heavy mafic mineral content (10–22% dry weight fraction), but widely varying total (air and water-filled) porosity ranging from 11% to 55% volume fraction. The high-porosity zones must be highly fractured and broken up (e.g., volcanic breccias), highly vesicular, or of .aa-texture. The remaining sections of the logged section contain a significant amount of quartz/silica glass. A volcanic tuff sequence (likely the Bandelier Tuff) in the upper half of the logged interval (54–390 ft) is clearly distinguished by the logs and is characterized by • very high total porosity (60%) in the bottom 15 ft (275–390 ft), which likely corresponds to the Guaje Pumice Bed; • lower, but still high, porosity (50%–55%) in the uphole direction from 172–275 ft; • a distinct drop in the gross gamma log and bulk density across the zone 158–172 ft, for which the integrated log analysis shows decreased total porosity (average 35%) and increased amounts of clay, likely corresponding to a formation/lithology change; and • very high total porosity (48%–60%) across the interval 54–158 ft.	These processed geophysical log results suggest that the top of the regional groundwater aquifer intersected by R-20 likely is 827 ft, with the tight bed above acting as a confining layer. It is possible the confining layer is saturated up to the depth of 755 ft or that 755 ft is the potentiometric head of the regional aquifer (the static water level in the well). Zones with apparent water content of 30% or greater by volume occur at 884–886 ft and 983–987 ft. The measured near-wellbore water-filled porosity is greater than 20% of total formation volume through most of the interval 828–1365 ft. The highest water-filled porosities (greater than 30%) occur in the major zones 858–877 ft, 1086–1089 ft, and 1136–1244 ft. Effective water-filled porosity (moveable water) is generally 5% or less through most of the logged section, ranging from a low of 0% to a high of 26%. Correspondingly, the estimated hydraulic conductivity is generally low. Pe is consistently above 3 from 392 to 924 ft and mostly above 4 (often 5 or above) from 400 to 830 ft. The dense upper section 397–630 ft is probably basalt lava flow material. The lower interval, 630–924 ft, is also likely comprised of basaltic rock, although with a lower heavy mafic mineral content. The ELAN analysis predicts variable amounts of clay/montmorillonite throughout most of the logged section. Above 975 ft there are a few zones with clay content above 20%, but most of the logged interval contains 15% or less, with many zones containing no clay.

R-20, Geology and Geophysics of Screened Interval

R-20 Screen (Sand interval ft bgs)	Lithology at Screen Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 2 (1132.5–1165.5)	Top of pumiceous Puye Formation (Tpp). Fanglomerate. volcaniclastic sediments, mainly clayey sand (SC) with gravel and clayey sand (SC).	The integrated log analysis predicts significant, but highly variable, amounts of clay/montmorillonite below 975 ft, on average mostly above 10% dry rock matrix volume, frequently above 20%, and with a peak value of 62%. Above 975 ft there are a few zones with clay content above 20%, but most of the logged interval contains 15% or less, with many zones containing no clay. Interpreted bed boundaries across the imaged interval 777–1370 ft have dip azimuths (direction beds are dipping to) predominantly in the sector 180–260 degrees, with the highest concentration falling in the 10-degree range 210–220 degrees. The mean dip azimuth across this interval is 226 degrees. The interpreted bed boundaries have a wide range of dip angles (degrees of dip) from zero to 60 degrees, although more than 90% have dip angles less than 20 degrees and the mean dip angle is 6 degrees. A number of fractures were discernible across this interval, having dip azimuths mostly in the sector 170–220 degrees and a mean dip azimuth of 192 degrees. The fracture dip angles ranged 20–90 degrees, with a mean of 47 degrees. Across much of the imaged interval (928–1370 ft) the electrical resistivity image shows a well-bedded, thinly bedded alternating gravel-sand-silt-clay stratigraphy. Above this, the image exhibits much more massive bedding, likely corresponding to basalt lavas. A significant portion of the borehole was washed out in the top half of the log interval (46–775 ft), the diameter ranging from 17 in. (the bit size) to 25 in. The bottom half of the logged interval (775–1370 ft) contains only one interval of significant washouts (826–876 ft). Some of the washouts are abrupt, possibly cavities. The shallow-reading log measurements, predominantly the porosity reading ones, were adversely affected in a relatively few zones that contained abrupt washouts and/or high hole rugosity. The maximum deviation of the borehole across the log interval measured (777–1370 ft) is 3.5 degrees; the azimuth of deviation is to the north-northeast.	The measured near wellbore water-filled porosity is greater than 20% of total formation volume through most of the interval 828–1365 ft. The highest effective (moveable) water-filled porosities (greater than 10%) occur in the zones 1086–1090 and 1127–1240 ft, with a peak of 26% of total volume at 1194 ft. The ELAN log analysis predicts significant, but highly variable, amounts of clay/montmorillonite below 975 ft, on average mostly above 10% dry rock matrix volume, frequently above 20%, and with a peak value of 62%.
Screen 3 (1320.6–1344.5)	Santa Fe Group (Tsf) Volcaniclastic sediments, sand (SW) with clay.		The measured near-wellbore water-filled porosity is greater than 20% of total formation volume through most of the interval 828–1365 ft. The ELAN log analysis predicts significant, but highly variable, amounts of clay/montmorillonite below 975 ft, on average mostly above 10% dry rock matrix volume, frequently above 20%, and with a peak value of 62%.

Note: The data shown in this table were taken from LANL 2003 (79600). Also see LANL 2005 (91121).

ELAN = elemental log analysis program, ft bgs = feet below ground surface, Pe = photoelectric effect (a measure of porosity)

R-22, Geology and Geophysics of Screened Interval

R-22 Well Screen (Sand Interval ft bgs)	Lithology at Screen Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (862.0–922.0)	Cerros del Rio basalt (Tb) 780–893 dark gray, massive, minor vesicles to 1 mm, some red-yellow oxidation. 893–903: No recovery. 903–908: Porphyritic with aphanitic groundmass, massive, rare small vesicles. 908–928: Local fractures with Fe/Mn coatings.	The well had a water level of 955 ft and a probable regional groundwater level of 886 ft at the time of logging (October 2000). Increased vadose zone moisture content in the intervals 50–180 ft (on average 5%) and 350–715 ft (on average 10% or greater). Increased saturated zone porosity (greater than 40%) in the interval 1405–1478 ft (log total depth), corresponding to the Lower Puye Formation. Clearly defined stratigraphic/lithologic boundaries from the spectral gamma and geochemical logs. The analysis predicts clay (montmorillonite) only below the bottom of the Cerros del Rio Formation (1164 ft), primarily within the Upper and Lower Puye Formation. The clay volume (and weight %) within these intervals is generally less than 20%, although there are a few isolated peaks above 40% dry clay volume. The average clay weight % is 5% in the Lower Puye and 2% in the Upper Puye. The high clay volume/weight % at the bottom of the borehole is an unreal artifact and should be disregarded. Large intervals where density porosity is above 60% and/or bulk density is below 1.5 g/cc include (from bottom to top): 1263–1285, 1093–1158, 1026–1059, 877–887, 667–867, 523–595, 255–357, and 189–208 ft. Thus, it is apparent that in large sections of the cased hole section of R-22 the bulk density measurement is not representative of formation bulk density and, consequently, the total porosity estimate is not valid due to water- or air-filled annulus.	Very low volumetric moisture content (less than 5%) in the intervals 745–864 ft, and 876–886 ft. Relatively high water saturated porosities (greater than 35%) in the interval 887–901 ft. Elevated total porosity (greater than 60%) in the intervals 716–864 ft, 876–886 ft, probably due to the presence of water- and/or air-filled annulus between the drill string casing and the formation.
Screen 2 (937.5–1007.0)	Cerros del Rio basalt (Tb) As above with Fe/Mn coatings on fractures at 958–963. 970–973: Local fracture surfaces show oxidation ± silica coating.		Relatively high water-saturated porosities (greater than 35%) in the interval 956–962 ft.
Screen 3 (1243.5–1284)	Puye Formation (Tpf) Volcaniclastic sediments: Sand, sands with gravel, and silty sand with gravel.		Relatively high water saturated porosities (greater than 35%) in the interval 1264–1290 ft. The average clay weight % is 5% in the Lower Puye and 2% in the Upper Puye.
Screen 4 (1368.5–1387.0)	Santa Fe Group basalt Porphyritic, nonvesicular 1382–1392: With 10% clay.		Relatively lower-saturated porosity (averaging about 30%) and elevated chlorinity (averaging about 2 parts-per-thousand) across the “Older Basalt” unit (1337–1406 ft).
Screen 5 (1437–1478.0)	Puye Formation (Tpf) Clastic sediments: Sandy gravel, pebble gravel, sands.		Relatively high water-saturated porosities (greater than 35%) in the interval 1405–1478 ft. The average clay weight % is 5% in the Lower Puye and 2% in the Upper Puye.

Note: The data shown in this table were taken from LANL 2002 (71471). Also see LANL 2003 (76003) and LANL 2005 (91121).
ft bgs = feet below ground surface

R-25, Geology and Geophysics of Screened Interval

R-25 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (732–762)	Otowi Member of Bandelier Tuff Nonwelded ash-flow tuff. Video log shows subvertical open fractures with maximum apertures of 0.5 in.	Gamma activity is highly variable through the Cerro Toledo interval (384–509 ft). This probably reflects varying proportions of tuff and dacite detritus that make up individual beds in this deposit. The Otowi Member undergoes several distinct step-wise increases in gamma activity as a function of depth. Increases occur at the top of the unit (about 600 ft), at 650 ft, and at 725 ft. A significant decrease occurs at 790 ft and is coincident with faint horizontal layer observed in the video log and may represent a depositional break within the Otowi Member. The Guaje pumice bed exhibits a low gamma spike just above the abrupt gamma decrease associated with the geologic contact with the top of the Puye Formation. The borehole video shows the spike is coincident with lithic-rich beds from 844 to 846 ft. The natural gamma activity in the upper part of the Puye Formation varies little down to a depth of 1180 ft. Gamma activities decrease systematically from 1180 to 1450 ft and then remain constant to about 1655 ft. At 1655 ft, gamma activity increases correspond to the top of the Rendija Canyon fan deposits. Another increase at about 1870 ft may mark the top of the older fan deposits. Neutron logging identified zones of high water content that may indicate bridging in the annual fill (1250–1256, 1398–1404, 1444–1446, 1668–1672 ft). Westbay pressure readings confirmed the isolation of the screens. Logging was unable to delineate bentonite seals due to low potassium content of bentonite product used. Logging indicated an upper groundwater system from 711 to 1132 ft. Alternating wet-dry zones were encountered from 1132 to 1286 ft. Regional aquifer was encountered at 1286 ft.	Borehole video shows an abrupt increase in moisture on the borehole wall at 718 ft. Water first recognized at 747 ft. Video also shows subvertical open fractures, with maximum apertures of 0.5 in. Neutron logging identified zones of high water content that may indicate bridging in the annual fill (1250–1256, 1398–1404, 1444–1446, 1668–1672 ft bgs). Westbay pressure readings indicate confirmed isolation of the screens. Unable to delineate bentonite seals due to low potassium content of bentonite. Saturated 747–1132 ft bgs (Screens 1–3).
Screen 2 (878–897)	Puye Formation fanglomerate Cobbles and boulders derived mainly from the upper dacite of Pajarito Mountain. Minor amounts of sand, some clay present at depth intervals 851–853, 901–903, 997–1002, 1012–1016 and 1022–1026.		
Screen 3 (1046–1070)			
Screen 4 (1180–1191)			Alternating wet and dry zones 1132–1286 ft bgs.
Screen 5 (1290–1307)			Saturated below 1286 ft bgs. (Screens 5–9)
Screen 6 (1398–1415)			
Screen 7 (1600–1618)			
Screen 8 (1786–1805)			
Screen 9 (1862.2–1930)			

Note: The data shown in this table were taken from LANL 2002 (72640). Also see LANL 2005 (89397) and LANL 2005 (91121).
ft bgs = feet below ground surface

R-26, Geology and Geophysics of Screened Interval

R-26 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (620–672)	Cerro Toledo Interval (Qct) Volcaniclastic sediments: 615–645: Well-graded fine to very coarse grained sand (SW) with gravel. 645–655: Silty sand (SM) with gravel. 655–660: No returns. 660–680: Well-graded fine to very coarse grained sand (SW) with gravel.	1. The Puye Formation fanglomerate at the bottom of the well (953–1490.5 ft) is likely fully saturated with water throughout. The porosity across this interval is mostly in the range of 20%–30% of the total rock volume, although there are a number of zones with higher porosity. The most porous zones (in which logs are not affected by hole conditions) appear to be 1075–1108 ft and 1186–1200 ft, with porosity mostly ranging 30%–40% and a peak of over 50% at 1102 ft. Both these zones have high moveable water content (effective porosity) of 15%–20% of total rock volume. 2. The high porosity glass/tuff pumice beds and volcaniclastic sediments of the Cerro Toledo interval and Otowi member (472–955 ft) lying above the Puye Formation are likely not fully saturated with water through most of the section, although they have very high water content (30–50% of total rock volume) from 570–955 ft. The general trend is an increase in water content with depth – culminating at 52% of total rock volume at the bottom of the Guaje Pumice bed at 955 ft. The moveable water content is relatively high as well (5–25% of total rock volume, except 40% at the bottom of the Guaje Pumice Bed). Although much of the glass tuff/pumice interval may not be fully saturated with water, the total and moveable water content suggests that, in general, the water is quite mobile. Likely, water in this interval is connected (in a broad sense) to the saturated Puye Formation below. 3. Three heterogeneous fanglomerate-type beds within the Cerro Toledo interval are clearly delineated by the logs at 505–524, 530–544, and 779–828 ft. These beds have significantly lower porosity (mostly 20%–30% of the total rock volume) than the surrounding sediments (mostly 40%–50% of total rock volume). The processed logs indicate that some zones within these beds may be fully saturated with water – particularly the interval 780–827 ft – but the moveable water content is highly variable and mostly less that 5% of total rock volume. 4. The crystalline tuff beds (60–472 ft) generally have very low porosity (10–20%) of total rock volume) and water content (5–10%). Some zones within this interval appear to be fully saturate with water, but the low movable water content (5% of total rock volume) likely limits the slow of water. The total porosity above 134 ft appears to be much higher (35–45%). 5. Fractures were identified from the electrical image log (acquired across the interval 390–1390 ft) at 412, 681, 687, 690, 700, 701, 710, 870, 880, 882, 883, 947.5, 950, 952, and 1363.5 ft. All are in the volcanic tuff sequence, except the deepest one is in the Puye Formation. 6. Clay-rich beds occur in the zones 1023–1026, 1051–1053, 1080–1114 ft, 1135–1143 ft, 1171–1177 ft, and 1187–1200 ft.	The processed logs indicate high water-filled porosity within the porous, volcaniclastic sediments and glass tuff/pumice sections of R-26 from 575 to 955 ft – ranging from 30% to 52% of the total rock volume. However, the processed logs indicate quite strongly that most of this interval is no fully saturated with water. The total porosity (estimated from ELAN integrated log analysis) ranges from 40% to over 50% of the total rock volume-resulting in saturations of generally 50–80%. The highest estimated water saturation across this interval of water-rich sediments and glass tuff/pumice occurs in the following zones: 620–640: Water saturation ranges from 85–90%, due to a decrease in total porosity to 30% to 40%, with water-filled porosity averaging 30%. 642–662: Water saturation reaches over 90% as a result of increased water-filled porosity as high as 42%, due to a decrease in total porosity to 30% to 40%. With water-filled porosity averaging 30%. The estimated moveable water content is generally quite high across this water-rich sediments and glass tuff/pumice interval – ranging from 5% to 25% of total rock volume. Although much of the 575–955-ft interval may not be fully saturated with water, the high total and moveable water content suggests that, in general, the water table is quite mobile. Likely, water in this interval is connected (in a broad sense) to the saturated Puye Formation below.
Screen 2 (1411–1450)	Puye Formation (Tpf) fanglomerates. Volcaniclastic sediments. 1405–1420: Poorly graded very fine-fine grained sand (SP). 1420–1430: Poorly graded very fine-fine sand with silt (SP-SM). 1430—1440 No returns. 1440–1445: Poorly graded very fine-fine sand with silt (SP-SM). 1445–1455: Well graded very fine to medium sand (SW).		The estimated pore volume water saturation computed from ELAN analysis is very high (mostly over 85%) from 954 to the bottom for the log interval (1484 ft). Water-filled and total porosity mostly ranges from 20% to 30% across the interval, although there are a number of zones with elevated porosity. 1422–1452: Elevated porosity of 30%–35% possibly associated with a slight change in lithology (indicated by a drop in potassium content). There is a thin "tight" streak at 1490 ft. Estimated water-filled effective porosity (moveable water) generally varies from 7% to 15% of the total rock volume across this interval. The hydraulic conductivity estimated from ELAN integrated log analysis (largely based on the CMR moveable water measurement) generally ranges from 0.1–1 gal./d/ft^2 in a few zones – most notably 1100–1108 ft and 1186–1200 ft.

Note: The data shown in this table were taken from Kleinfelder 2005 (92033). Also see LANL 2005 (91121).
CMR = combinable magnetic resonance, ELAN = elemental log analysis program, ft bgs = feet below ground surface.

R-31, Geology and Geophysics of Screened Interval

R-31 Well Screen (Sand Interval ft bgs)	Lithology at Screen Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (432.8–460.6)	Cerros del Rio lavas Clay-rich sediment bed.	R-31 was logged with geophysical tools twice. A precompletion (February 2000) geophysical logging was conducted to provide an in-situ evaluation of formation properties (hydrogeology and geology) intersected by the well. The primary objective of the postcompletion logging (March 2000) was to evaluate the integrity of the well completion – condition of casing and screens and the placement of bentonite and sand fill behind the casing, as well as the location, behind the inner casing, of a dropped section of drill casing and a lost sounding rod. The precompletion logging (February 2000), which were run through drill casing, appear to be severely influenced by water between the casing and the borehole wall below the well water level – resulting in highly elevated water-filled porosity measurements in many intervals within the saturated portion of the borehole. However, the moisture measurements above the water level and the spectral gammaray measurements throughout the well are generally unaffected by these annular voids. The precompletion log results indicate the following: • A regional groundwater level at 530 ft depth at the time of logging • Increased moisture content around 110 ft and 225 ft • Low moisture content (on average 10% or less) extending from 285 to 530 ft • Increased moisture content and low concentrations of K and Th from 590 to 626 ft, roughly corresponding with the entire “alluvial scoria” stratigraphic interval • Decreased moisture content from 626 to 695 ft, corresponding with most of the lower Cerros del Rio lavas (Tcb-A) The postcompletion logging (March 2000) results indicate the following: • A dropped section of drill casing outside the inner 5¼-in. casing resides at a depth of 882–952 ft, and a dropped copper sounding rod is suspected to reside at a depth of 382.5–391 ft • A number of zones where there are air/water-filled voids behind the casing; • Most of the screened intervals appear to contain sand fill and are surrounded above and below by clay-rich fill • The casing and screens are geometrically intact, with possible slight ovalization in the joints above screens 3 and 5. The ELAN analysis estimates significant volumes of clay throughout the well – consistently above 20%–30%. It is believed that the high clay volume is largely due to the presence of minerals and glasses of volcanic origin – not included in the ELAN model – that have elevated thorium concentrations and neutron capture cross-sections similar to those of the clay minerals that are included in the ELAN model. Thus, the model is “forced” to increase clay volumes to match the measured response and estimates of clay volume cannot be used in a quantitative manner, only in a qualitative manner (e.g., looking at relative changes.)	Clay-rich sediment occurring at 444 to 450 ft represents a hiatus in volcanic activity. The borehole video indicated accumulation of water above the sediment and flow along the borehole wall.
Screen 2 (496.3–551.3)	Cerros del Rio lavas Basalt: Flow breccia in interval, monitored zone across clay-altered zone contact with flow sequence C and B.		This represents the contact between alkalic-basalt flow sequence C and the basaltic andesites of flow sequence B.
Screen 3 (659.0–677.0)	Cerros del Rio lavas Basalt: Columnar jointed in monitored zone.		Borehole video images show continuous columnar jointing, without evidence of clay infilling. The hydraulic conductivity of approximately 7 ft/day measured in this zone is attributed to fracture connection.
Screen 4 (780.5–842.0)	Puye Formation Totavi river gravels plus fanglomerates.		Neutron-based analyses of water-filled porosity have values of only 30%. Interval is within the river gravels of the Puye Formation.
Screen 5 (873.7–1072.6)	Puye Formation Totavi river gravels plus fanglomerates.		Neutron-based analyses of water-filled porosity have values of approximately 50% for this screened interval. Interval crosses a more variable section of the riverine gravel deposits of the Puye Formation.

Note: The data shown in this table were taken from LANL 2002 (72615). Also see LANL 2003 (76003) and LANL 2005 (91121).

ELAN = elemental log analysis program, ft bgs = feet below ground surface, Th = thorium

R-32, Geology and Geophysics of Screened Interval

R-32 Well Screen (Sand Interval ft bgsl)	Lithology at Screen Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (862.5–879.2)	Cerros del Rio basalts (Tb4) Basalts, interbedded river gravels and clastic sediments. River gravels interpreted for 863–870.	Note: This well was logged to a depth of about 800 ft. The estimated water saturation (only fraction of pore space filled with water) remains below 75% through most of the logged section with no significant fully saturated intervals. These results, interpreted independently of other data sources, suggest that the regional aquifer groundwater level lies somewhere below the bottom of the log interval (800 ft) and that there are no significant perched water zones within the logged section. The measured near-wellbore water-filled porosity is less than 20% of total formation volume through most of the logged section, ranging from a low of 3% to a high of 40%. The highest water-filled porosities (greater than 20%) occur in the zones 145–149, 276–286, 403–415, 449–480, 646–654, 660–664, and 722–800 ft. The bottom moist zone, which corresponds with the water-filled section of the borehole at the time of the logging, has the highest estimated water saturation of these zones (averaging about 75%). Effective water-filled porosity (moveable water) is less than 3% through most of the logged section, ranging from a low of 0% to a high of 30%. Correspondingly, the estimated hydraulic conductivity is generally very low. The highest effective water-filled porosities (greater than 10%) occur in the zones 145–149, 276–286, and 722–800 ft. The top two zones are likely within the Bandelier Tuff sequence (the second likely corresponding to the Guaje Pumice Bed) and, from the integrated log analysis, appear to be directly underlain by clays that likely inhibit downward flow and cause the accumulation of moisture above. The bottom zone coincides with the water-filled section of the borehole that also contains significant washouts; it is likely that the measured moveable water content is unrepresentative of true formation conditions (reading too high) due to the measuring of water-filled washouts. As would be expected, estimated hydraulic conductivity is highest in these zones, especially in the interval 726–748 ft. The integrated log analysis shows a mafic-mineral rich and quartz/silica glass deficient zone from 290 to 800 ft that likely corresponds to a basalt lava flow sequence. The zone from 290 to 654 ft is very dense (matrix grain density of 2.8–3.0 g/cc) and heavy-mafic-mineral rich with intervals of low total porosity interspersed with a number of fractured and altered zones. The zone from 654 to 800 ft is less dense, contains significant amounts of clay, and has higher porosity—likely highly fractured and altered basalt. The washed out, high-porosity zones in both intervals likely correspond to fractured, broken-up altered zones, possibly "rubble" zones. A volcanic tuff sequence (likely the Bandelier Tuff) in the upper half of the logged interval (55–286 ft) is clearly distinguished by the logs. The borehole was largely washed out throughout the log interval, the diameter ranging from 16 in. (the bit size) to greater than 20 in. Many of the washouts are abrupt, possibly cavities. The shallow-reading log measurements, predominantly the bulk density, were adversely affected in zones with high rugosity.	Note: This well was logged only to a depth of approximately 800 ft. No specifics available for the screened intervals.
Screen 2 (925.2–938.7)	Puye Formation (Tpf) No cuttings returned. Contact of basalt with sediments interpreted at 923 ft.		
Screen 3 (961.7–978.2)	Puye Formation (Tpf) No cuttings returned.		

Note: The data shown in this table were taken from LANL 2003 (79602). Also see LANL 2004 (89552) and LANL 2005 (91121).

CMR = combinable magnetic resonance, ft bgs = feet below ground surface, P_e = photoelectric effect (a measure of porosity)

R-33, Geology and Geophysics of Screened Interval

R-33 Screen (Sand Interval ft bgs)	Lithology of Interval	Geophysical Logging Summary (depths in ft bgs)	Geophysical Indication of Screened Interval (depths in ft bgs)
Screen 1 (991–1027)	Pumiceous Unit, Unassigned, Tpp (964–1122) Volcaniclastic sediments: Silty sands, sands, gravels.	1. The well water level was stable throughout the logging acquisition, remaining between 983 ft bgs and 985 ft during all four logging runs. 2. The processed logs indicate that the intersected geologic section from 984 ft to the bottom of the log interval (1131 ft) is fully saturated with water throughout, possibly representing the top of the regional aquifer. The porosity across this interval is mostly in the range of 35% to 55% of the total rock volume, although it is higher in borehole washouts, which are especially prevalent in the interval 984 ft to 1028 ft. Most of the saturated log interval appears to be porous and, likely, productive. The most porous, potentially productive zone delineated by the logs is 984 to 1028 ft, an inferred pumice-rich zone with over 50% porosity (even after accounting for washouts). Other likely productive (albeit less prolific) zones are 1028 to 1050, 1056 to 1078, 1100 to 1104, and 1106 to 1108 ft. A low-porosity, tight zone appears to exist at 1122 to 1126 ft, although porosity seems to increase again at the bottom of the log interval. 3. The processed logs do not indicate any significant fully water-saturated (perched) zones above 984 ft. Estimated water saturation is mostly below 60%, except in very low porosity basalt zones, where the overall water content is very low anyway. 4. Above the log-inferred groundwater level (984 ft), the processed logs identify a thick section of heterogeneous alluvium/fanglomerate with low estimated water saturation (mostly less than 50% of pore space containing water) – overlain at 730 ft by a basalt lava flow sequence.	The estimated pore-volume water saturation (fraction of the total pore volume containing water) computed from the ELAN analysis is very high (mostly above 90%) from 984 ft to the bottom of the log interval (1131 ft), compared with 40% to 60% in the interval directly above 984 ft. 984–1028 ft: Significantly washed-out zone characterized by very high total and water-filled porosity (50% to greater than 60%), as well as effective porosity (30% to greater than 60%). Total and water-filled porosity generally overlap in this zone and all zones below (indicating 100% water saturation). Unrealistically high log-measured/derived porosity peaks are associated with borehole washouts (984 to 986 ft bgs, 989 to 994, 997 to 1001, 1010 to 1017, and 1022 to 1024 ft). The ELAN integrated log analysis model results indicate that the interval does not contain much clay and other fine-grained material, as does the FMI image (overall very high resistivity in the scaled image) – also suggestive of very productive aquifer material. The very high total and effective porosity across this zone are indicative of pumice-rich material.
Screen 2 (1107–1126)	Stream Gravels (1122–1140) Volcaniclastic sediments: Silty sands with trace of gravel.	5. The basalt lava flow sequence intersected by the well (530 ft to 730 ft, as delineated from the logs) primarily consists of dense, low-porosity zones (average about 12% total porosity) but also contains some higher-porosity zones (20 to 30% total porosity) containing slightly higher water content (maximum 12% of total rock volume). The most significant higher-porosity basalt zones are at 530 to 573 and 643 to 665 ft. 6. The geophysical log response in the zone 466 ft to 473 ft is characteristic of the Guaje Pumice Bed, with extremely high total porosity (60%), relatively high water-filled porosity (20%) that decreases in the upward direction, and the presence of moveable water (17%). The pumice bed is overlain by slightly less-porous volcanic tuff (total porosity ranging 40 % to 52%). 7. A section of heterogeneous alluvium/fanglomerate beds is clearly delineated from the processed logs between the bottom of the Guaje Pumice Bed and the top of the basalt lava flow sequence (484 ft to 530 ft), as delineated from the logs). 8. Interpreted bed boundaries across the electrically imaged interval from 984 to 1127 ft have dip azimuths (direction to which beds are dipping) predominantly to the southwest, and have dip angles (angle from horizontal) mostly less than 15 degrees. One fracture was identified in this interval – an apparently open fracture (estimated aperture of 0.04 in.) at 994 ft (within pumiceous fanglomerate) that dips 40 degrees to the east.	1106–1108 ft: The processed logs indicate a peak in total and effective porosity at this depth (43% and 24%, respectively). 1108–1122 ft: This zone is characterized by relatively lower total and effective porosity, ranging 37% to 41% and 17% to 21%, respectively. The FMI and ELAN results indicate presence of clay and other fine-grained material, especially in the intervals 1108 ft to 1113 ft, and 1116 ft to 1120 ft. 1122–1126 ft: This zone is characterized by a significant decrease in total porosity to about 20% – indicative of a tight zone. 1126–1131 ft (bottom of log interval): Porosity appears to increase at the bottom of the log interval, reaching 40%. No direct information about effective porosity is available from the log measurements since this interval is below the bottom of the CMR log. The FMI and ELAN results (FMI log bottom is about 1128 ft) indicate the interval does not contain much clay and other fine-grained material – suggestive of productive aquifer material.

Note: The data shown in this table were taken from Kleinfelder 2005 (92385). Also see LANL 2005 (91121).
CMR = combinable magnetic resonance, ELAN = elemental log analysis program, ft bgs = feet below ground surface

A.3 WELL SCREEN EVALUATION

CdV-R-15-3, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Not tested (dry)	Yes	NL	NL	NL
Screen 2	Not tested (dry)	Yes	NL	NL	NL
Screen 3	Not tested (dry)	Yes	NL	NL	NL
Screen 4	Not tested, straddles regional aquifer	Yes	Good	High	Stable
Screen 5	Straddle-packer/injection test K = 0.25 ft/day (Theis analysis)	Yes	Poor	Moderate	Improving
Screen 6	Straddle-packer/injection test K = 0.10 ft/day (Bouwer and Rice analysis)	Yes	Fair	High	Variable

Note: The data shown in this table were taken from LANL 2002 (73179).
DQO = data quality objective, K = hydraulic conductivity, NA = not applicable, NL = not listed,
WSAR = Well Screen Analysis Report (LANL 2005, 91121).

CdV-R-37-2, Well Screen Evaluation

Screen	Aquifer Parameters[a]	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Not tested (dry)	Yes	NL	NL	NL
Screen 2	Not tested, straddles regional aquifer	Yes	Poor	High	Stable
Screen 3	Straddle-packer tests K = 7.0 ft/day	Yes	Very Good	High	Stable
Screen 4	Straddle-packer tests K =11.4 ft/day	Yes	Fair	High	Stable

Note: The data shown in this table were taken from LANL 2003 (88803).
[a] Hydraulic conductivity results are for Bouwer-Rice analysis.
DQO = data quality objective, K = hydraulic conductivity, NA = not applicable, NL = not listed.

R-5, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Screen dry	No	NL	NL	NL
Screen 2	Screen not productive enough for testing	Yes	Very Good	High	Stable
Screen 3	Screen straddles regional water table	Yes	Very Good	High	Stable
Screen 4	Screen not productive enough for testing	No?	Fair	Moderate	Variable

DQO = data quality objective, NL = not listed.

R-7, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	NA	1, 2 –Yes. Water sample was collected from the zones during well drilling	NA	NA	NA
Screen 2	NA	1 – Yes. 2 – No. No water sample collected from this zone during drilling	NA	NA	NA
Screen 3	No hydraulic testing performed	1, 2 , 3 – Yes	Poor	High	Stable

Note: The data shown in this table were taken from LANL 2002 (72717).

DQO = data quality objective, K = hydraulic conductivity, NA = not applicable, NL = not listed

R-8, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Not tested	Yes	Very Good	High	Stable
Screen 2	Three injection tests performed. Preliminary results indicate this zone has a production capacity exceeding 23.8 gpm.	Yes	Fair	Moderate	Indeterminate

Note: The data shown in this table were taken from LANL 2003 (79594).

DQO = data quality objective.

R-9i, Well Screen Evaluation

Screen	Aquifer Parameters[a]	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	(Screen tested twice) K = 4.87, 3.88 K = 3.71, 3.07 K = 4.57, 3.46 T = 49.4 T = 315.3 T = 13.2	Yes	Fair	Moderate	Improving
Screen 2	K = 0.11 K = 0.18 K = 0.12	Yes	Fair	High	Improving

Note: The data shown in this table were taken from LANL 2001 (71251). Also see LANL 2003 (76003).

[a] Hydraulic conductivity results (ft/day) are for Bouwer-Rice, Cooper-Bredehoeft-Papadopolous, and Hvorslev analysis, respectively. ransmissivity values (ft^2/day) are for Theis, Neuman (early), and Neuman (late) analysis, respectively.

DQO = data quality objective, K = hydraulic conductivity, T = transmissivity.

R-12, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Not tested	1, 2, 3, 4 –Yes. Four water samples were collected from the zones during well drilling. 5 – Probably met	Poor	Moderate	Improving
Screen 2	Not tested		Not listed (Dry)	Not listed	NA
Screen 3	Not tested		Fair	Moderate	Variable

Note: The data shown in this table were taken from LANL 2001 (71252).

DQO = data quality objective, NA = not applicable.

R-14, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Not tested	Yes	Very Good	Moderate	Improving
Screen 2	K (minimum) = 0.9 ft/day (Theis RR) K (minimum) = 1.1 ft/day (specific-capacity method) T (minimum) = 142.5 ft2/day (Theis RR) T (minimum) =-177.2 ft^2/day (specific-capacity method)	No	Poor	High	Worsening

Note: The data shown in this table were taken from LANL 2003 (76062).
DQO = data quality objective, K = hydraulic conductivity (Theis RR analysis), T = transmissivity, Theis RR = Theis residual recovery analysis

R-16, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	NA	5 – No. Screen isolated behind abandoned drive casing.	NA	NA	NA
Screen 2	3 slug tests: Results to be presented in separate laboratory report	1, 2 – Yes 3, 4 – Yes 5 - No	Fair	High	Stable
Screen 3	3 slug tests: Results to be presented in separate laboratory report	1, 2 – Yes 3, 4 – Yes 5 – Yes	Good	High	Improving
Screen 4	2 slug tests: Results to be presented in separate laboratory report	1, 2 – Yes 3, 4 – Yes 5 – No	Poor	High	Stable

Note: The data shown in this table were taken from LANL 2003 (76061).
DQO = data quality objective, NA = not applicable.

R-19, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Screen Dry	Yes	NL	NL	NL
Screen 2	NL	Yes	Fair	High	Stable
Screen 3	NL	Yes	Fair	Low	Worsening
Screen 4	NL	Yes	Good	High	Stable
Screen 5	NL	Yes	Poor	Moderate	Stable
Screen 6	From straddle-packer injection tests: K = 17.5 ft/day[a]	Yes	Poor	Moderate	Improving
Screen 7	From straddle-packer injection tests: K = 19.6 ft/day[a]	Yes	Fair	Moderate	Variable

Note: The data shown in this table were taken from LANL 2001 (71254). Also see LANL 2003 (76003).

[a]Cooper-Jacob method analysis.

DQO = data quality objective, K = hydraulic conductivity, NL = not listed.

R-20, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen	Confidence in Screen Rating from WSAR	Prognosis of Screen
Screen 1	3 straddle packer/injection test: Results to be presented in separate laboratory report	Yes	Poor	High	Variable
Screen 2	3 straddle packer/injection test: Results to be presented in separate laboratory report	Yes	Poor	High	Variable
Screen 3	3 straddle packer/injection test: Results to be presented in separate laboratory report	Yes	Fair	Moderate	Stable

Note: The data shown in this table were taken from LANL 2003 (79600).

DQO = data quality objective.

R-22, Well Screen Evaluation

Screen	Aquifer Parameters[a]	DQOs Met?	Condition of Screen	Confidence in Screen Rating from WSAR	Prognosis of Screen
Screen 1	Not tested	Yes	Poor	High	Stable
Screen 2	Straddle-packer/injection test K = 0.04 (ft/day) K = 0.06 K = 0.05	Yes	Very Good	High	Stable
Screen 3	Straddle-packer/injection test K = 0.21 (ft/day) K = 0.53 K = 0.25	Yes	Good	Moderate	Variable
Screen 4	Straddle-packer/injection tests (two) K = 0.54; 0.72 (ft/day) K = 0.66; 0.66 K = 0.61, 0.76	Yes	Poor	High	Variable
Screen 5	Straddle-packer/injection test K = 0.27 (ft/day) K = 0.64 K = 0.39	Yes	Poor	High	Variable

Note: The data shown in this table were taken from LANL 2002 (71471). Also see LANL 2003 (76003).

[a]Hydraulic conductivity results are listed vertically for Bouwer-Rice, Cooper-Bredehoeft-Papadopolous (C-B-P), and Hvorslev analyses, respectively.

DQO = data quality objective, K = hydraulic conductivity.

R-25, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Slug-injection testing failed	Yes	Fair	High	Improving
Screen 2	Slug-injection testing failed	Yes	Fair	High	Variable
Screen 3	NA	Maybe	NL	NL	NA
Screen 4	Slug-injection testing failed	Yes	Very Good	Moderate	Variable
Screen 5	Slug-injection testing failed	Yes	Fair	Moderate	Improving
Screen 6	Slug-injection testing failed	Yes	Very Good	Moderate	Stable
Screen 7	Slug-injection testing failed	Yes	Very Good	Moderate	Stable
Screen 8	Slug-injection testing failed	Yes	Good	High	Improving
Screen 9	NA	NA	NL	NL	NA

Note: The data shown in this table were taken from LANL 2002 (72640). Also see LANL 2005 (89397).
DQO = data quality objective, NA = not applicable, NL = not listed.

R-26, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Adjacent to borehole K (ave) = 1.7 ft/day Further from borehole K = 2.4–3.7 ft/day Upper range values considered most reliable. Aquifer limited in areal extent and not well connected to lower regional aquifer	Yes	Good	Moderate	Stable
Screen 2	K = 0.0022 ft/day with a lower bound of 0.003 ft/day.	No	NL	NL	NL

Note: The data shown in this table were taken from Kleinfelder 2005 (92033).
DQO = data quality objective, K = hydraulic conductivity, NL = not listed.

R-31, Well Screen Evaluation

Screen	Aquifer Parameters[a]	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	Not tested	NA Screen Dry	NA	NA	NA
Screen 2	Not tested	Yes	Poor	Moderate	Variable
Screen 3	Straddle-packer/injection tests[b] K = 0.41 (ft/day) K = 0.48 K = 0.53 T(i) = 5.50 (ft^2/d) T(r) = 5.90 (ft^2/d)	No	NA	NA	NA
Screen 4	Straddle-packer/injection tests[b] K = 1.23 (ft/day) K = 1.40 K = 1.48	No	NA	NA	NA
Screen 5	Straddle-packer/injection test[b] Conducted after only initial (incomplete) development K = 0.75 (ft/day) K = 1.35 K = 0.88	No	NA	NA	NA

Note: The data shown in this table were taken from LANL 2002 (72615). Also see LANL 2003 (76003).

[a] Hydraulic conductivity results are for Bouwer-Rice, Cooper-Bredehoeft-Papadopoulos, and Hvorslev, respectively.

DQO = data quality objective, K = hydraulic conductivity, NA = not applicable, T(i) = transmissivity based on injection water-level data, T(r) = transmissivity based on recovery water-level data.

R-32, Well Screen Evaluation

Screen	Aquifer Parameters[a]	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	T (R) = 29.0 ft^2/day T (RR) =29.5 ft^2/day Spec. capacity = 29.5 K (R) = 4.1 ft/day K (RR) = 4.2 ft/day Spec. capacity =4.2	Yes	Very Good	High	Stable
Screen 2	Not tested	Unknown	NL	NL	NL
Screen 3	T (RR) = 105.2 ft^2/day Spec. capacity = >104 K (RR) = >1.2ft/day Spec. capacity = >1.2	Yes	Poor	High	Stable

Note: The data shown in this table were taken from LANL 2003 (79602). Also see LANL 2004 (89552).

[a] K and T values are for Theis analysis of results. T and K values listed are those recommended in the hydraulic test report for this well (LANL 2004, 89552).

DQO = data quality objective, K = hydraulic conductivity, K (R) = from recovery data, K (RR) = from residual recovery data, NL = not listed, T = transmissivity, T(R) = from recovery data, T(RR) = from residual recovery data.

R-33, Well Screen Evaluation

Screen	Aquifer Parameters	DQOs Met?	Condition of Screen from WSAR	Confidence in Screen Rating from WSAR	Prognosis of Screen from WSAR
Screen 1	The piezometric level of the upper zone was 7.4 ft higher than the composite water level. Strong downward gradient indicated by the difference in piezometric levels with an intervening aquitard between the two screens. Constant-rate pumping tests. K = 4.5–7.0 ft/day	Yes	Fair	Low	Indeterminate
Screen 2	The piezometric water level for lower zone is 18.9 ft lower than the composite water level. Constant-rate pumping tests K = 1.3–2.4 ft/day	Yes	Very Good	Low	Indeterminate

Note: The data shown in this table were taken from Kleinfelder 2005 (92385).

DQO = data quality objective, K = hydraulic conductivity.

Appendix B

Depth and Condition of Well Screens

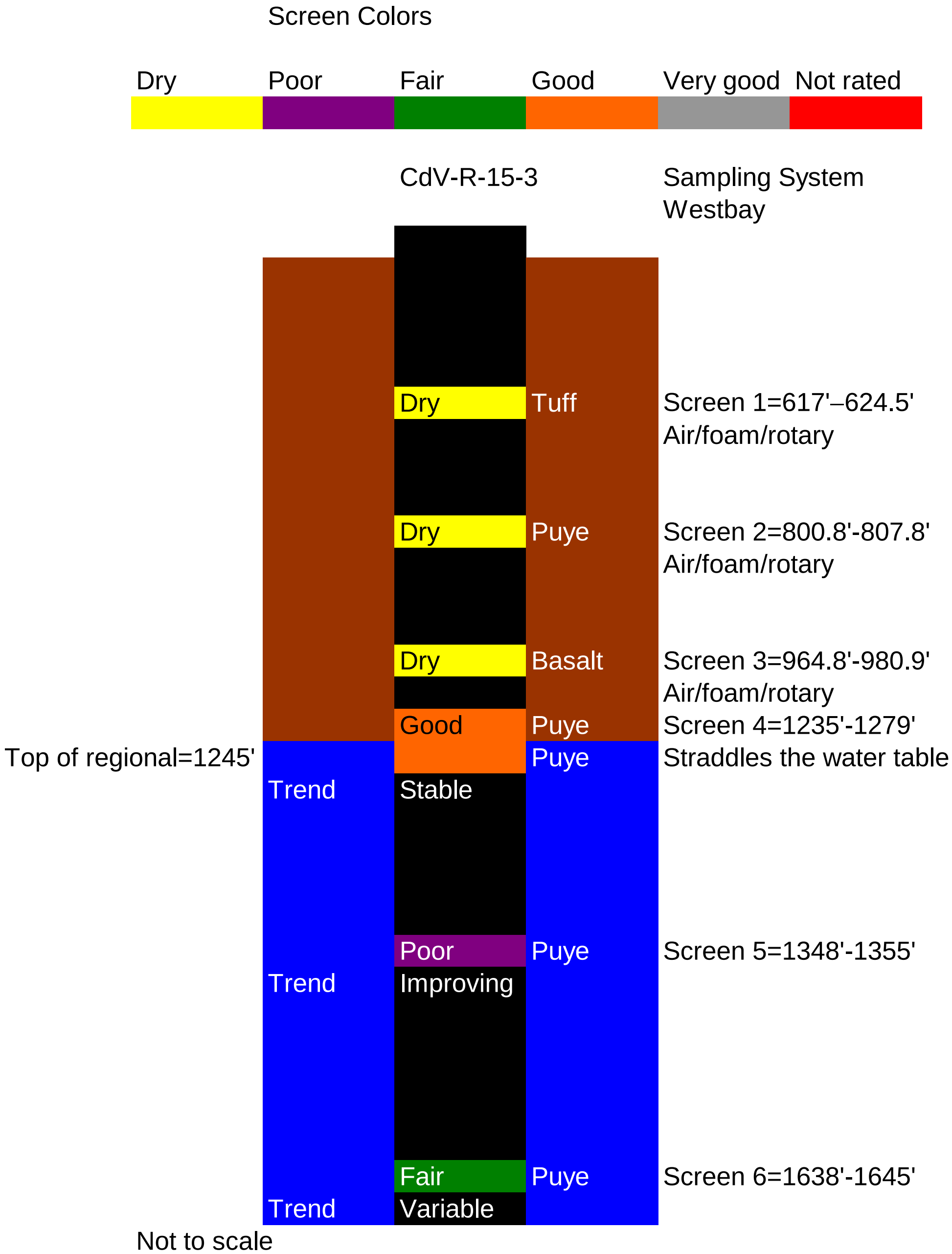

Figure B-1. Position and condition of well screens in CdV-R-15-3

Note: This figure shows the depth of well screens, their rating in the WSAR as of November 2005 (color-coded), thickness of unsaturated zone (brown), top of the regional aquifer, regional aquifer (blue), geochemical trend (variable, improving, etc.), sampling system, drilling methods, and other notes.

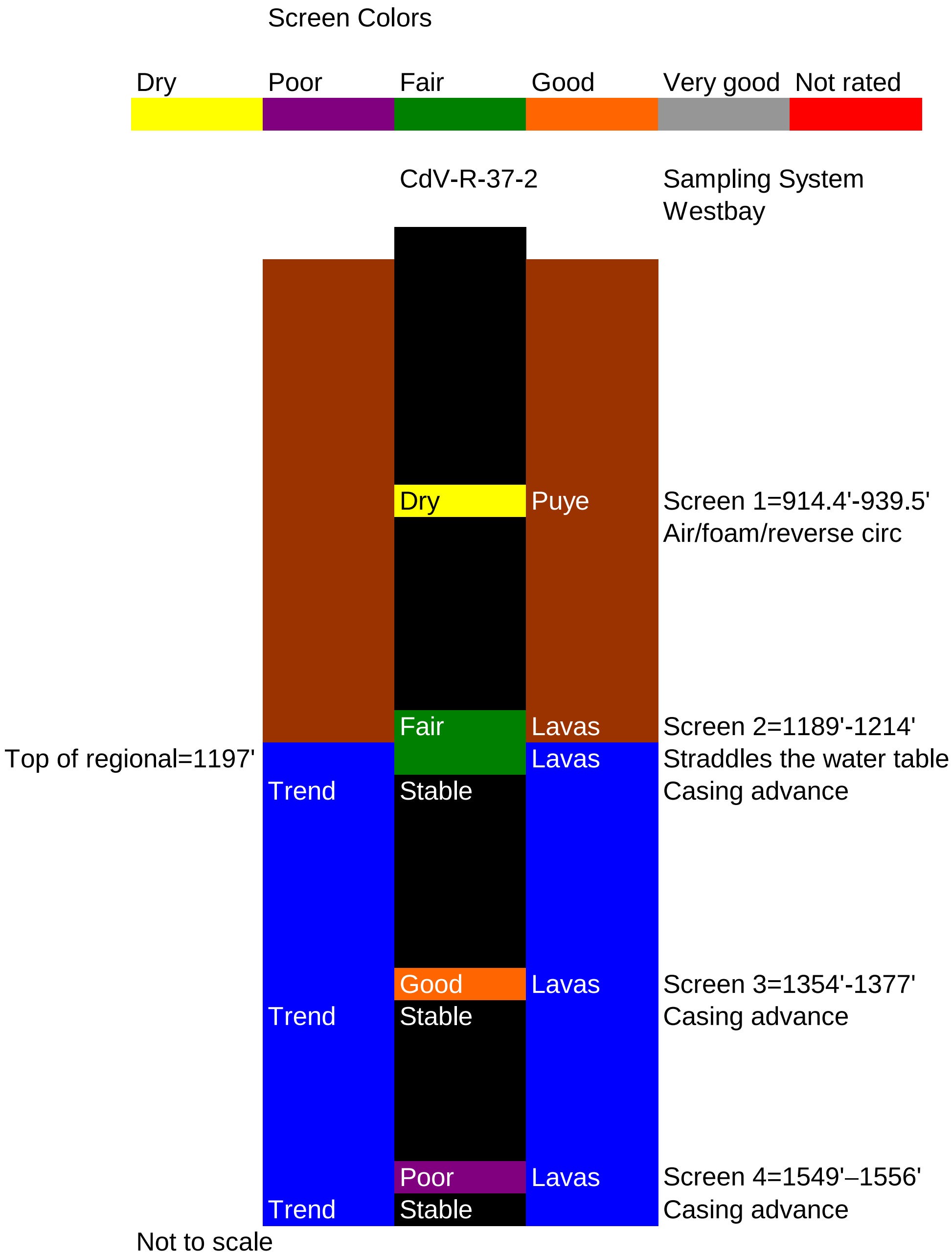

Figure B-2. Position and condition of well screens in CdV-R-37-2 (see note on Figure B-1)

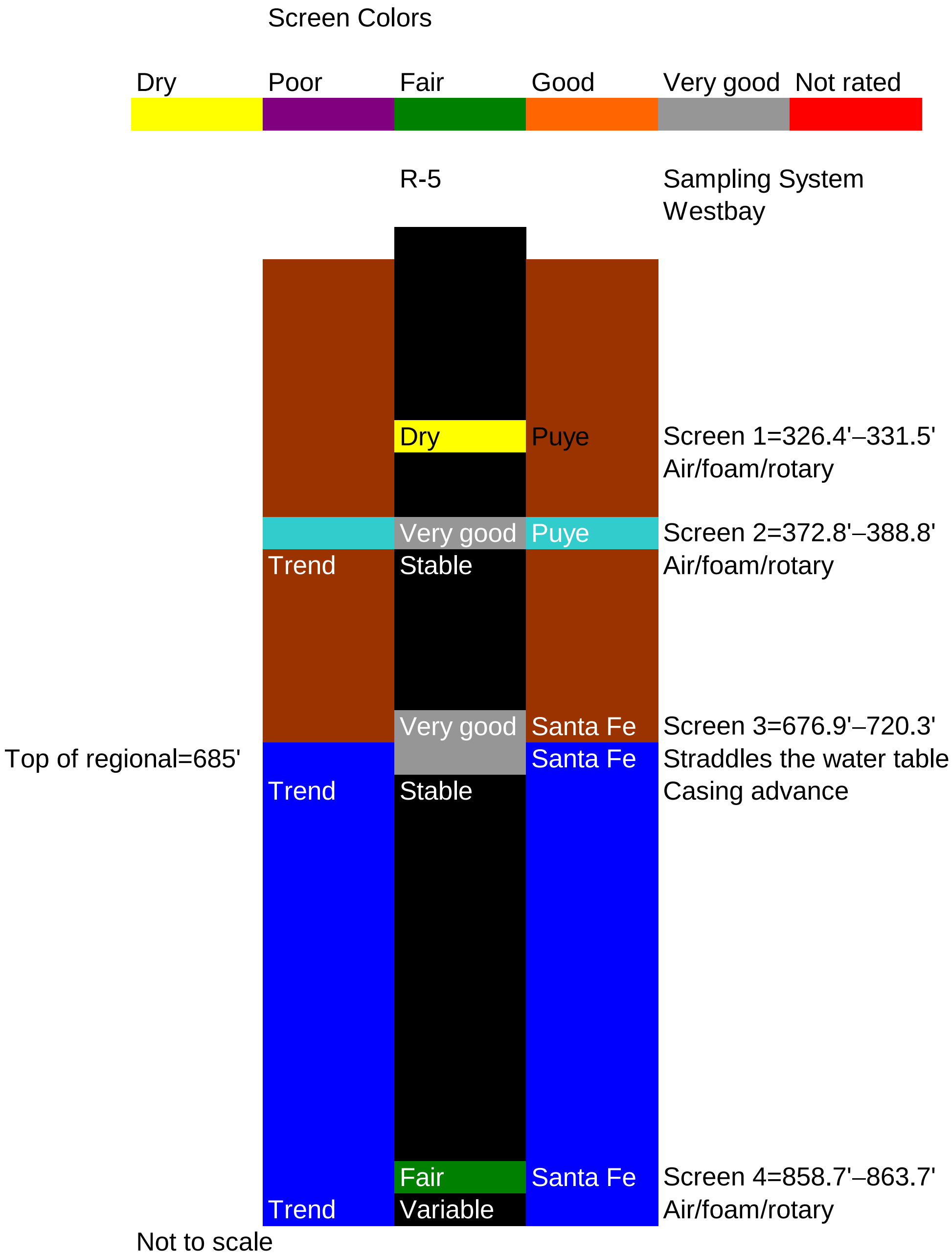

Figure B-3. Position and condition of well screens in R-5 (see note on Figure B-1)

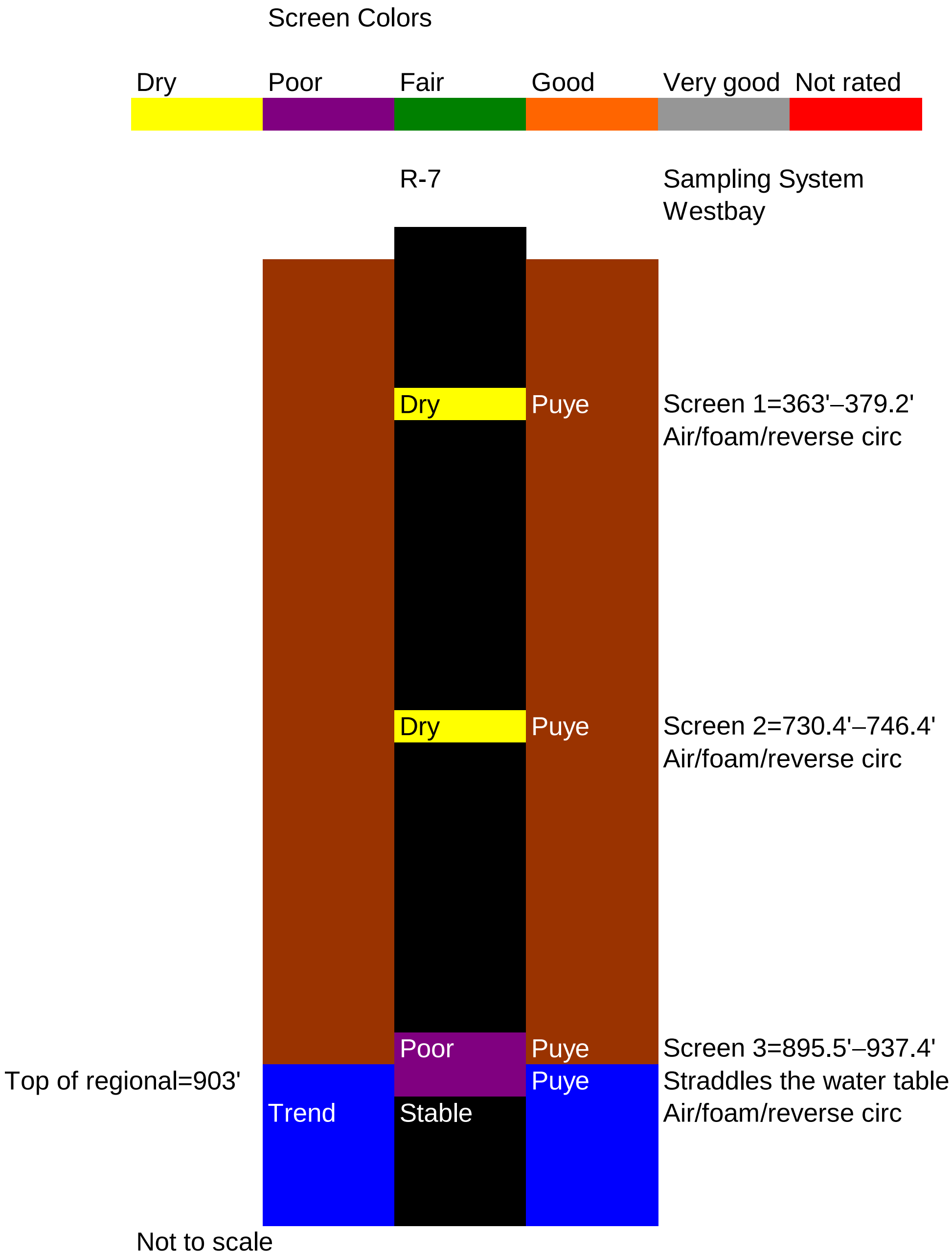

Figure B-4. Position and condition of well screens in R-7 (see note on Figure B-1)

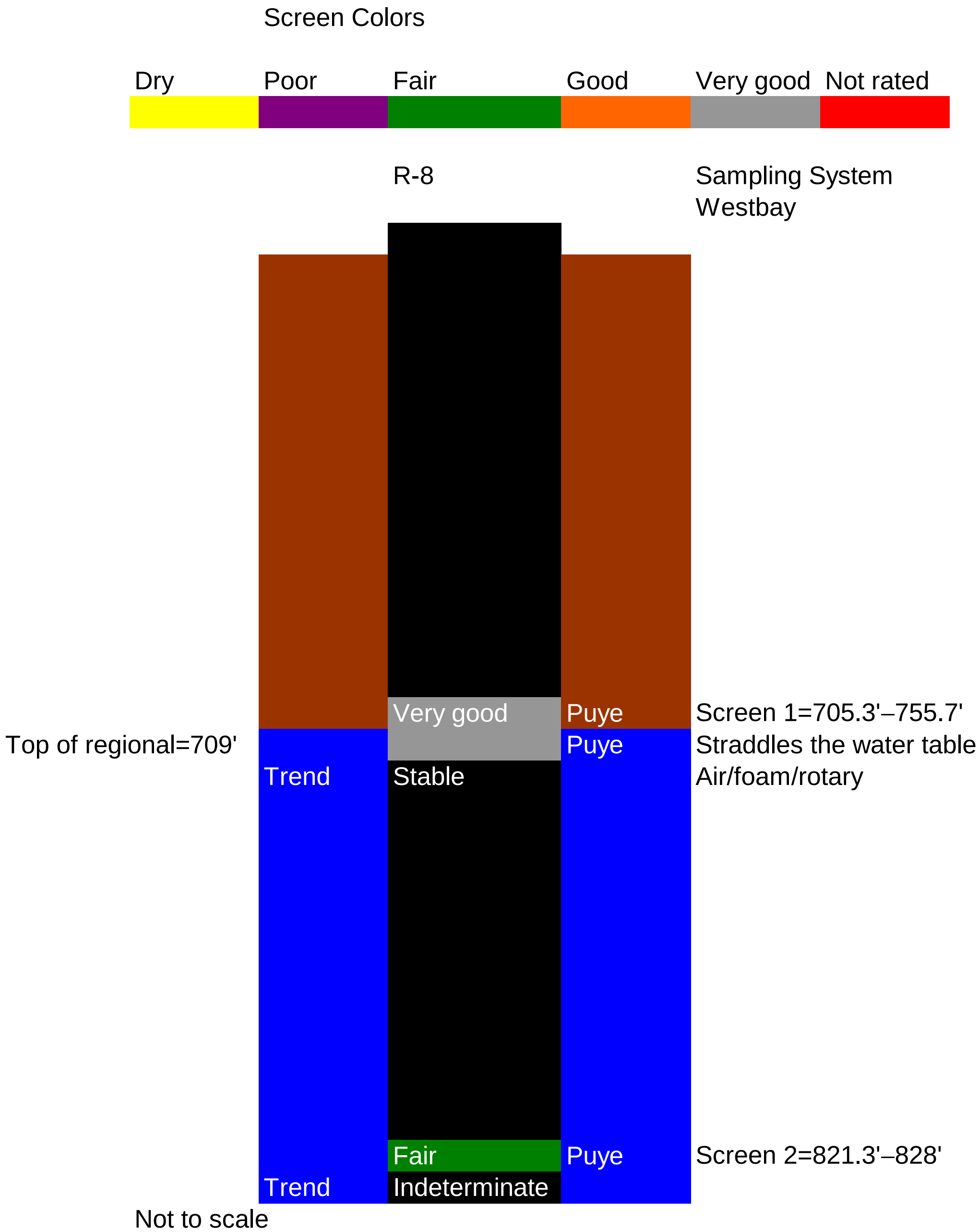

Figure B-5. Position and condition of well screens in R-8 (see note on Figure B-1)

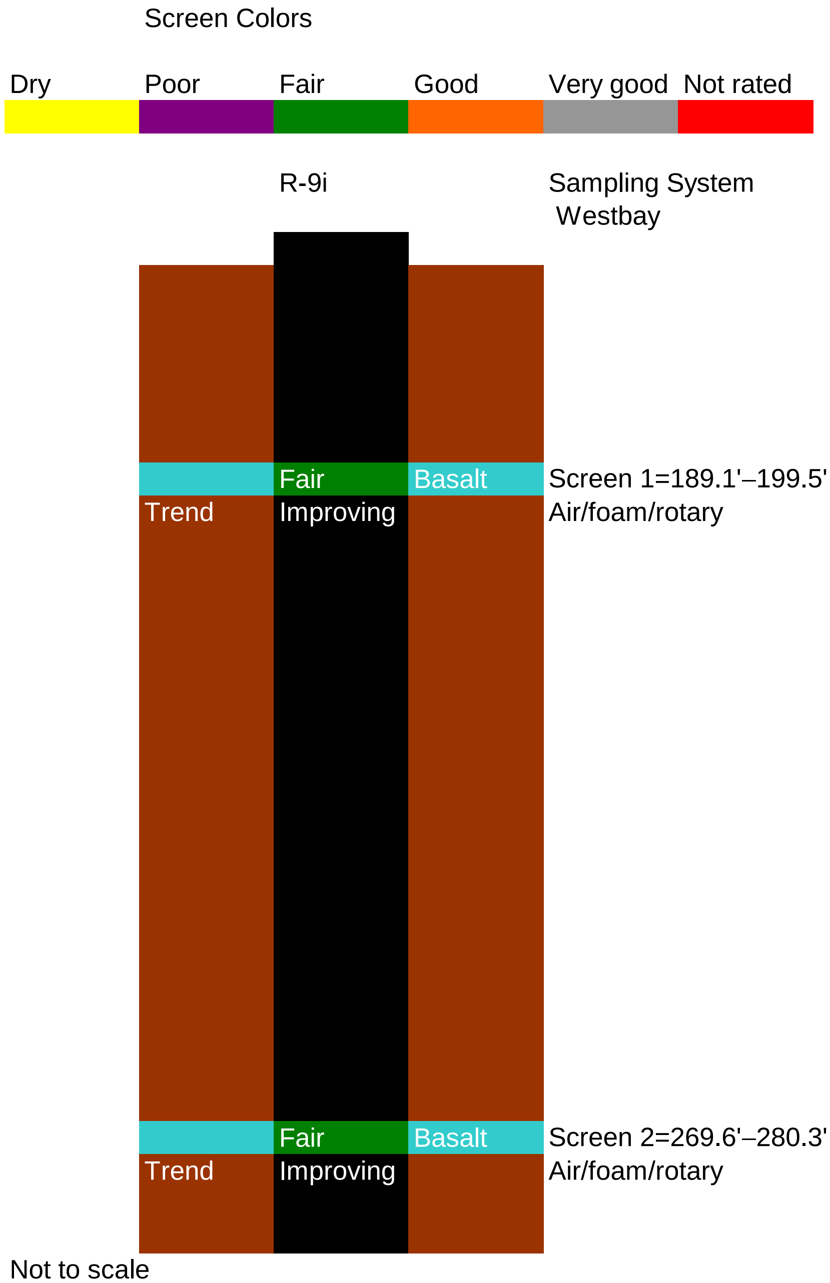

Figure B-6. Position and condition of well screens in R-9i (see note on Figure B-1)

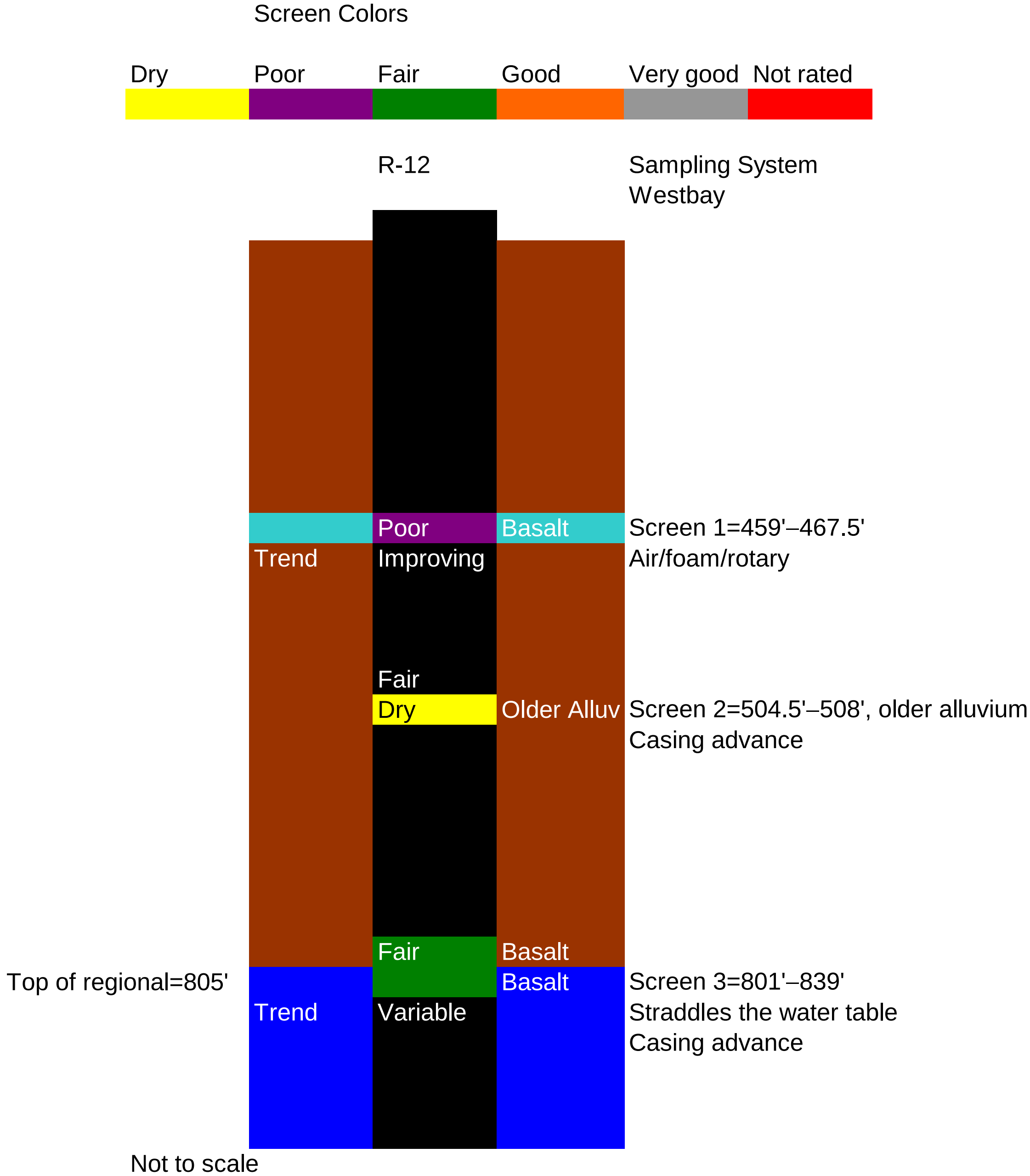

Figure B-7. Position and condition of well screens in R-12 (see note on Figure B-1)

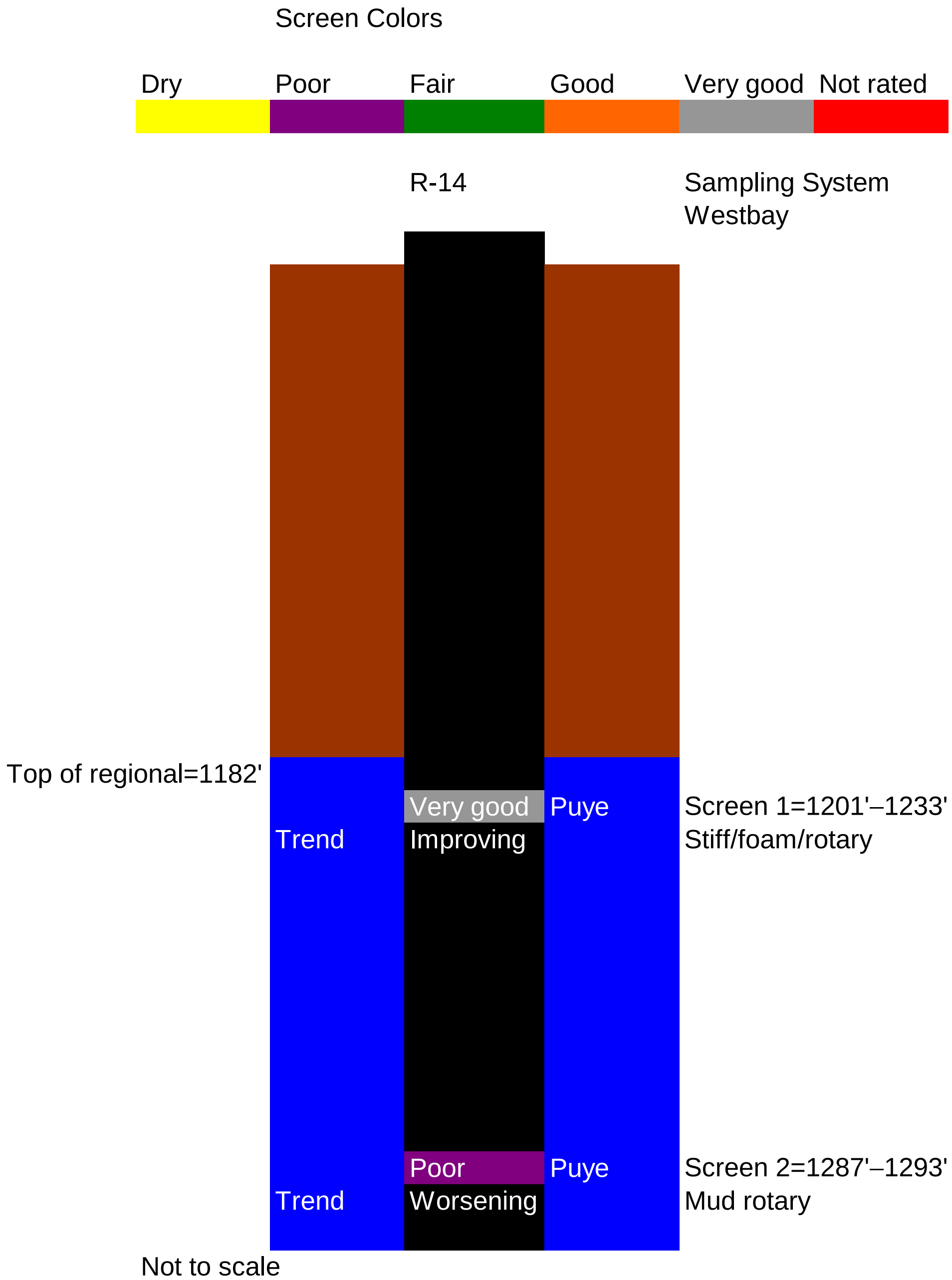

Figure B-8. Position and condition of well screens in R-14 (see note on Figure B-1)

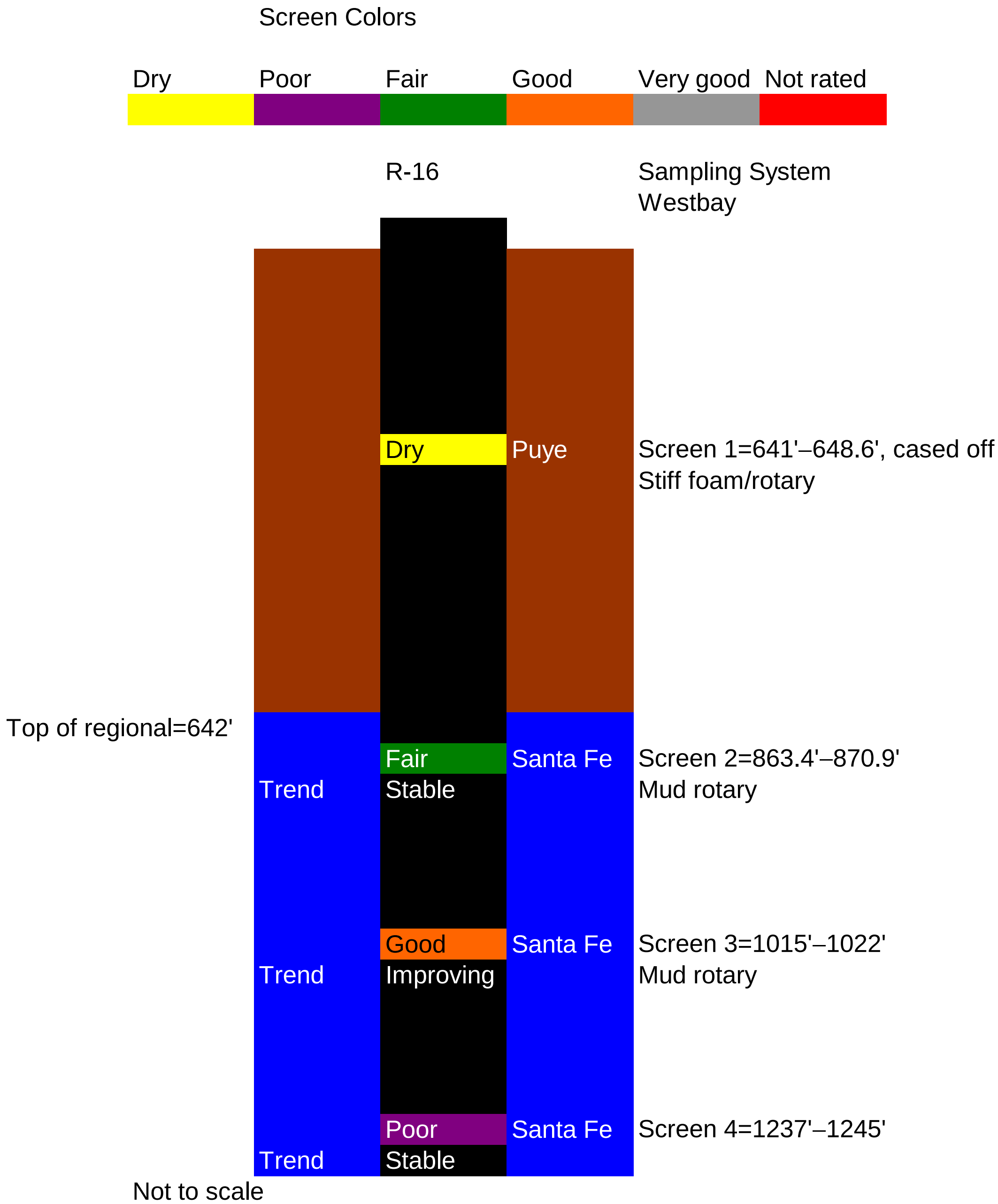

Figure B-9. Position and condition of well screens in R-16 (see note on Figure B-1)

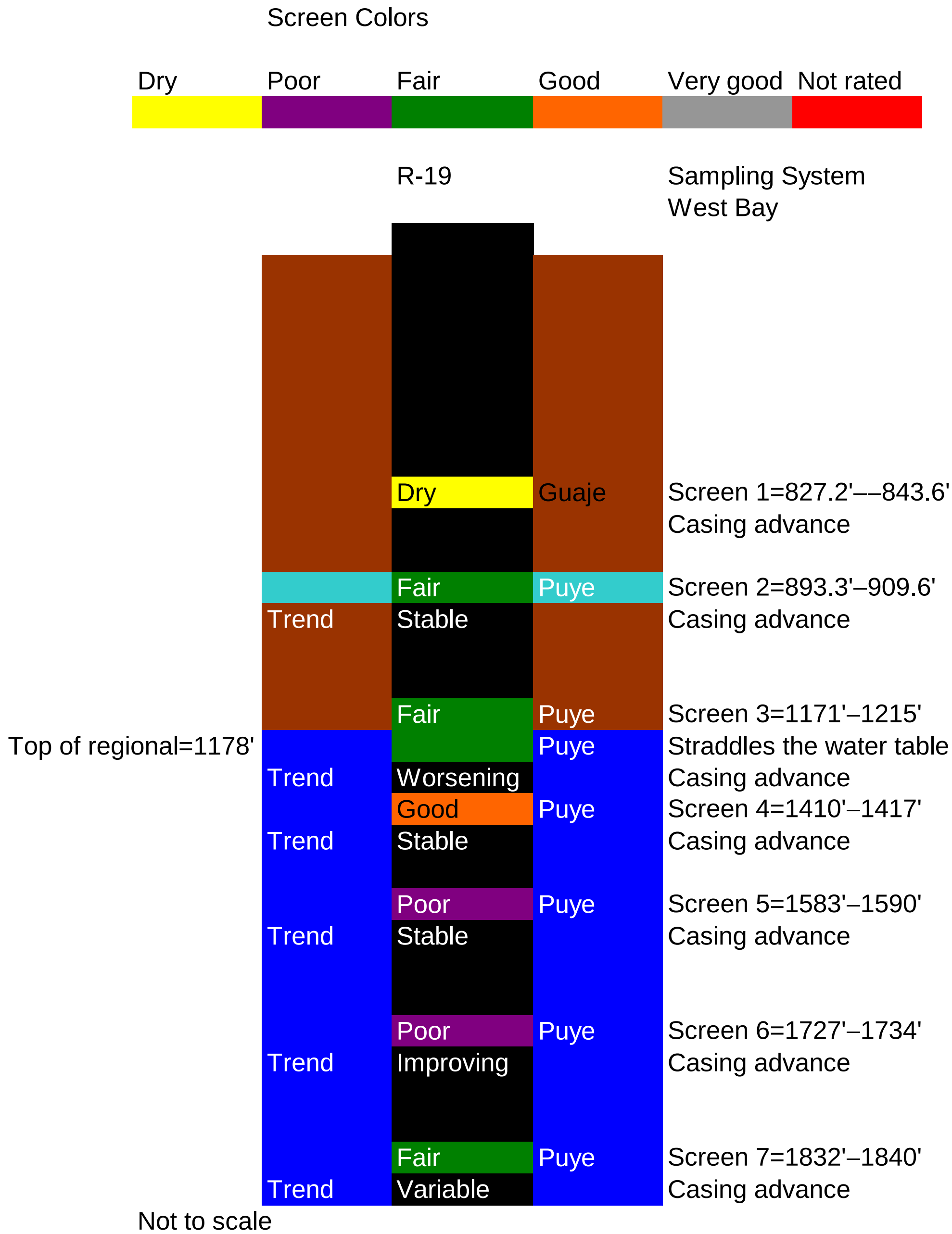

Figure B-10. Position and condition of well screens in R-19 (see note on Figure B-1)

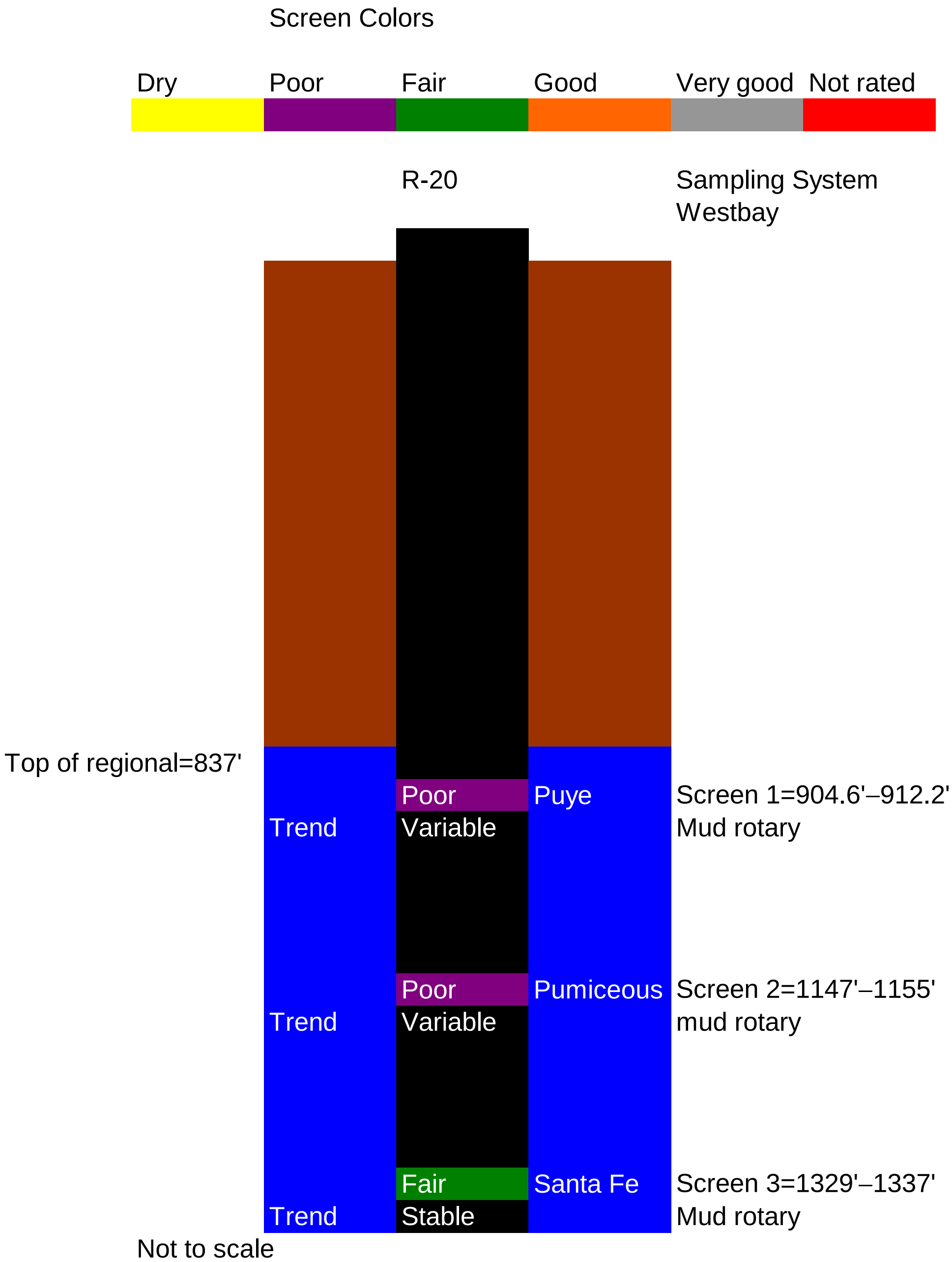

Figure B-11. Position and condition of well screens in R-20 (see note on Figure B-1)

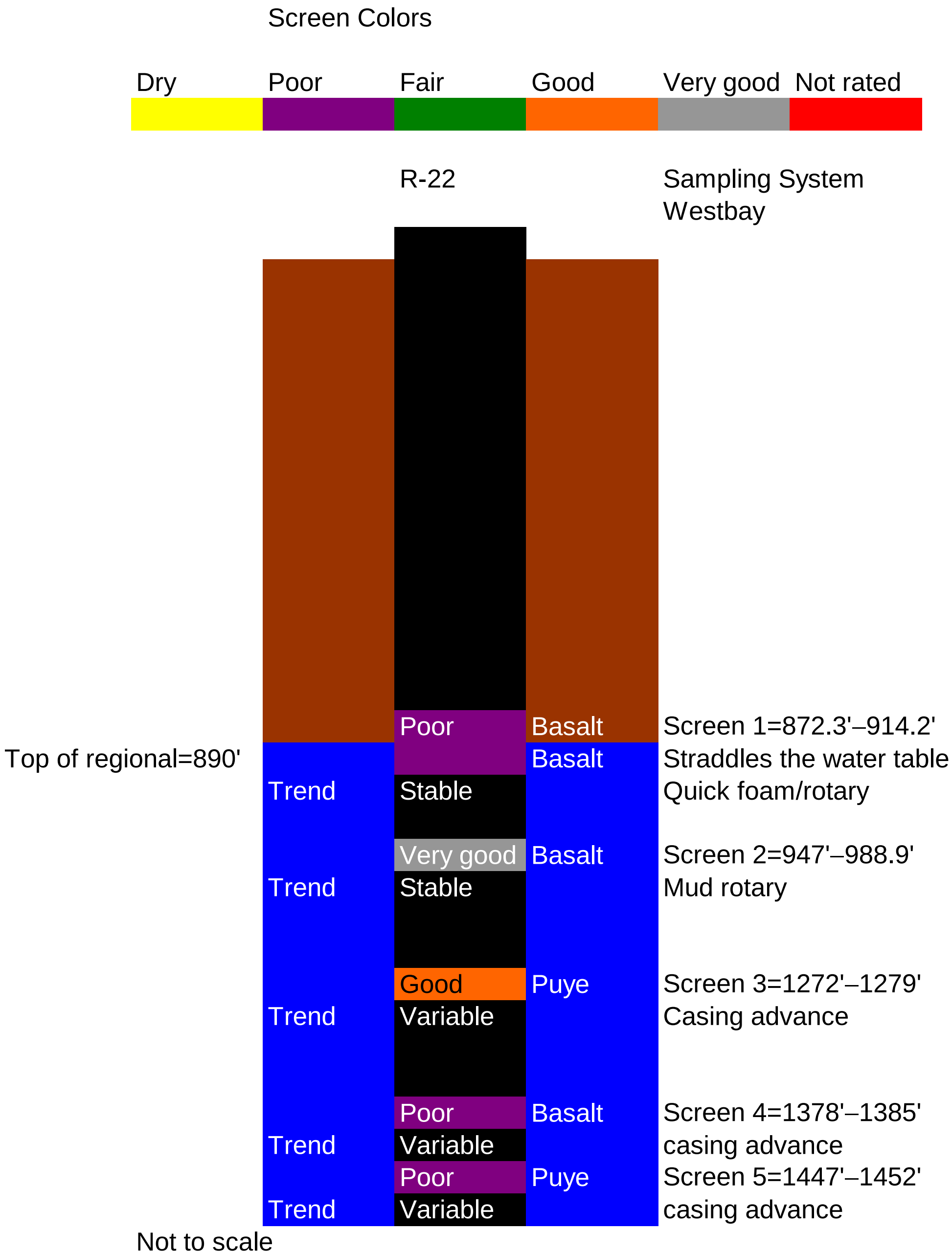

Figure B-12. Position and condition of well screens in R-22 (see note on Figure B-1)

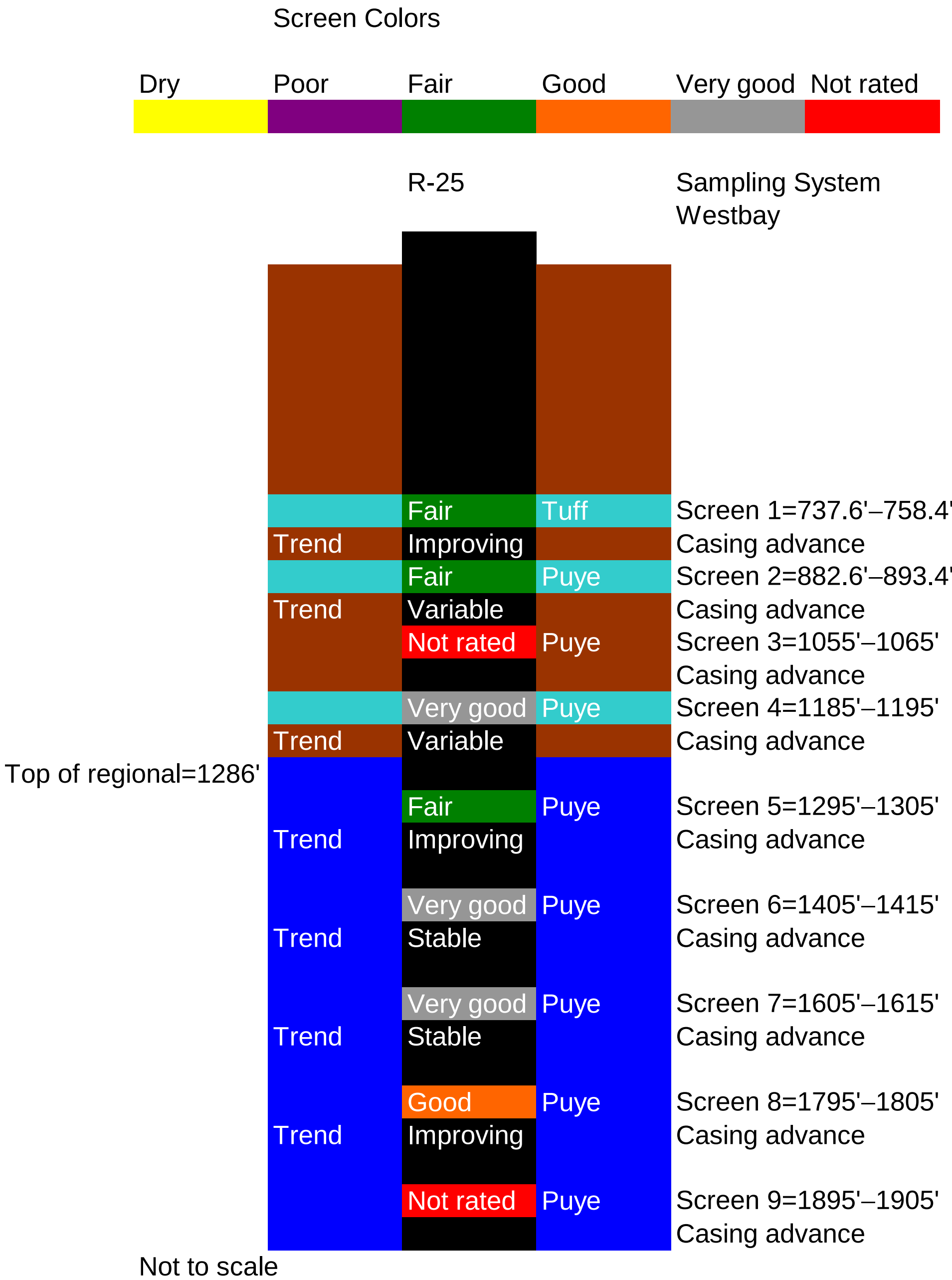

Figure B-13. Position and condition of well screens in R-25 (see note on Figure B-1)

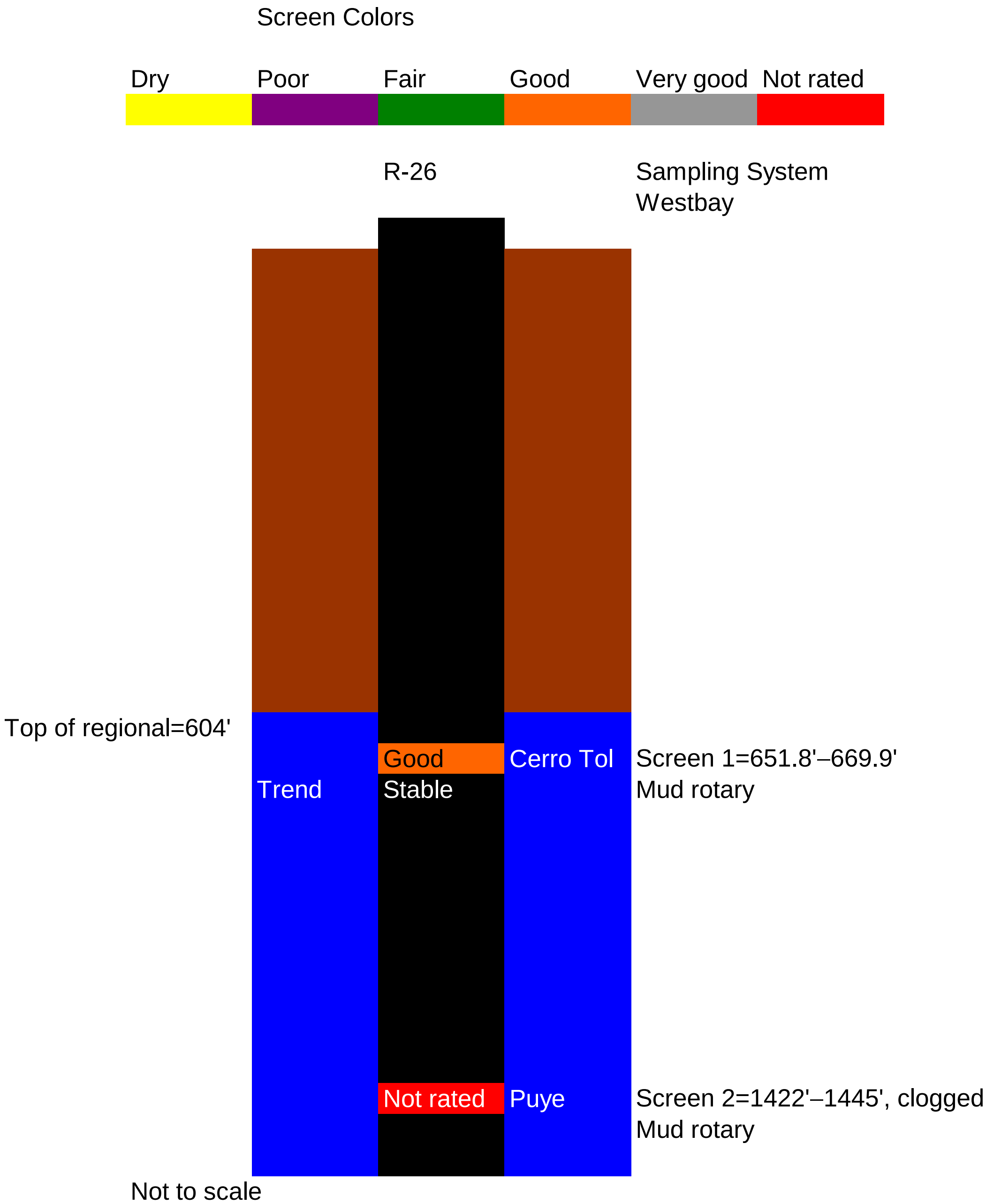

Figure B-14. Position and condition of well screens in R-26 (see note on Figure B-1)

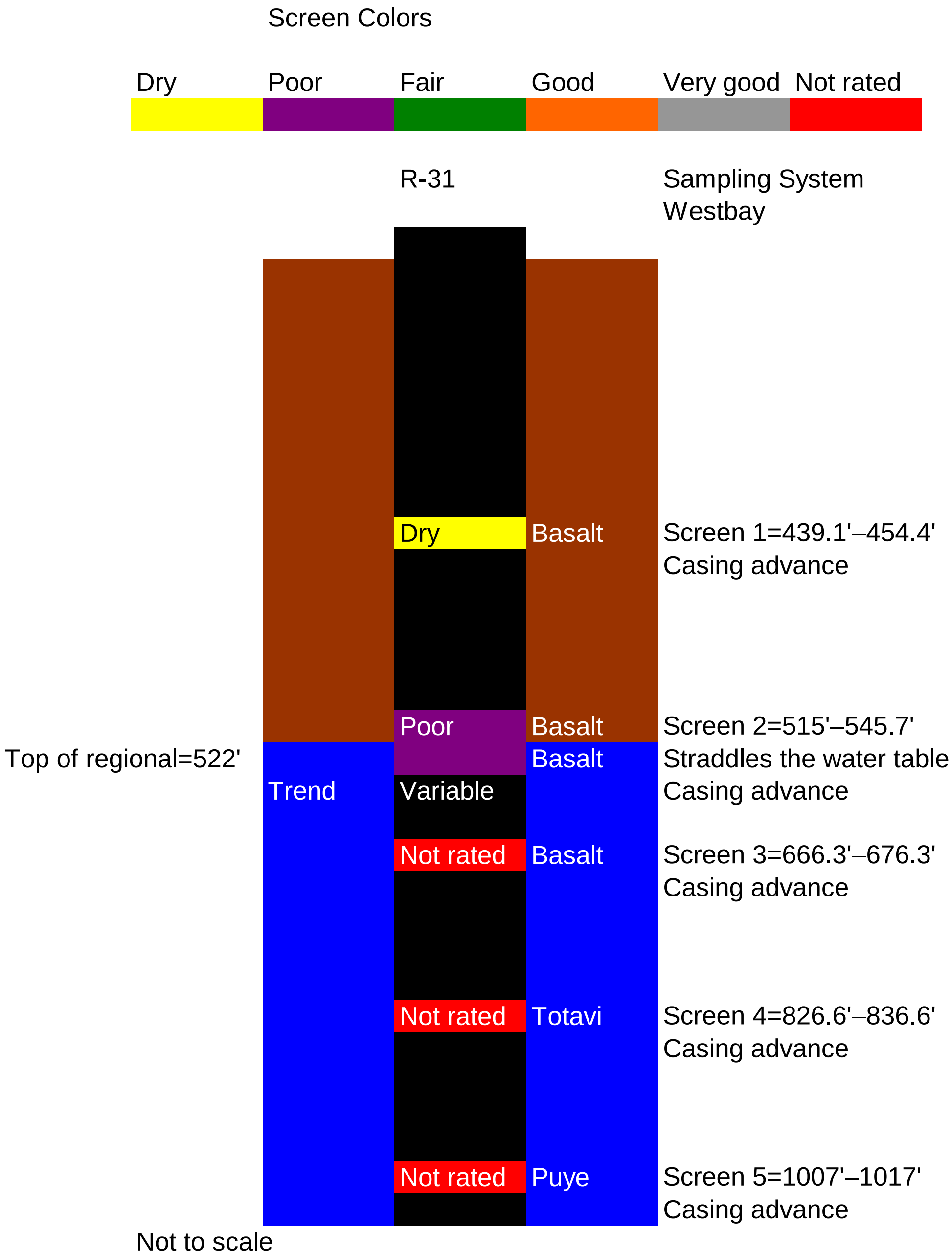

Figure B-15. Position and condition of well screens in R-31 (see note on Figure B-1)

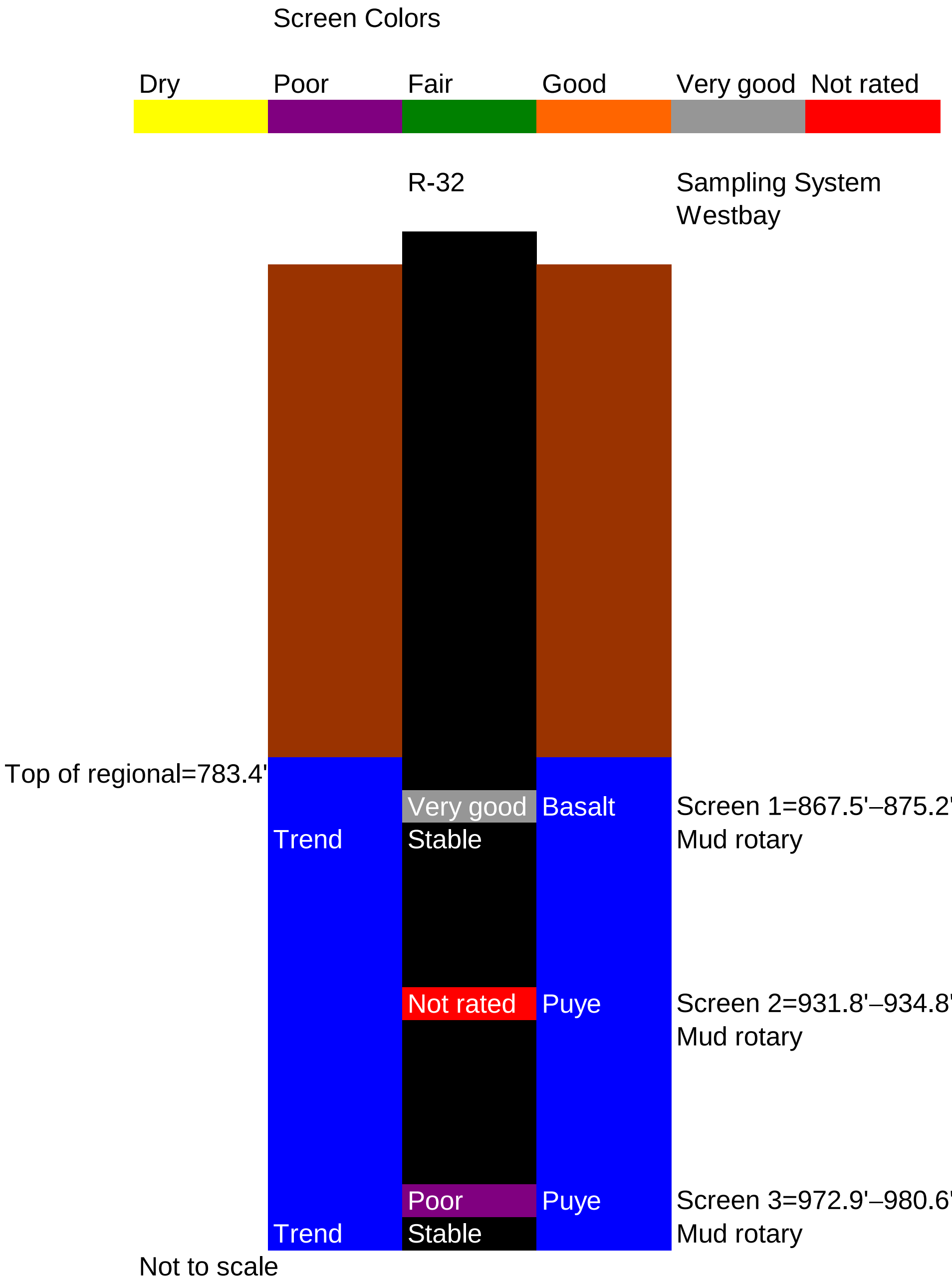

Figure B-16. Position and condition of well screens in R-32 (see note on Figure B-1)

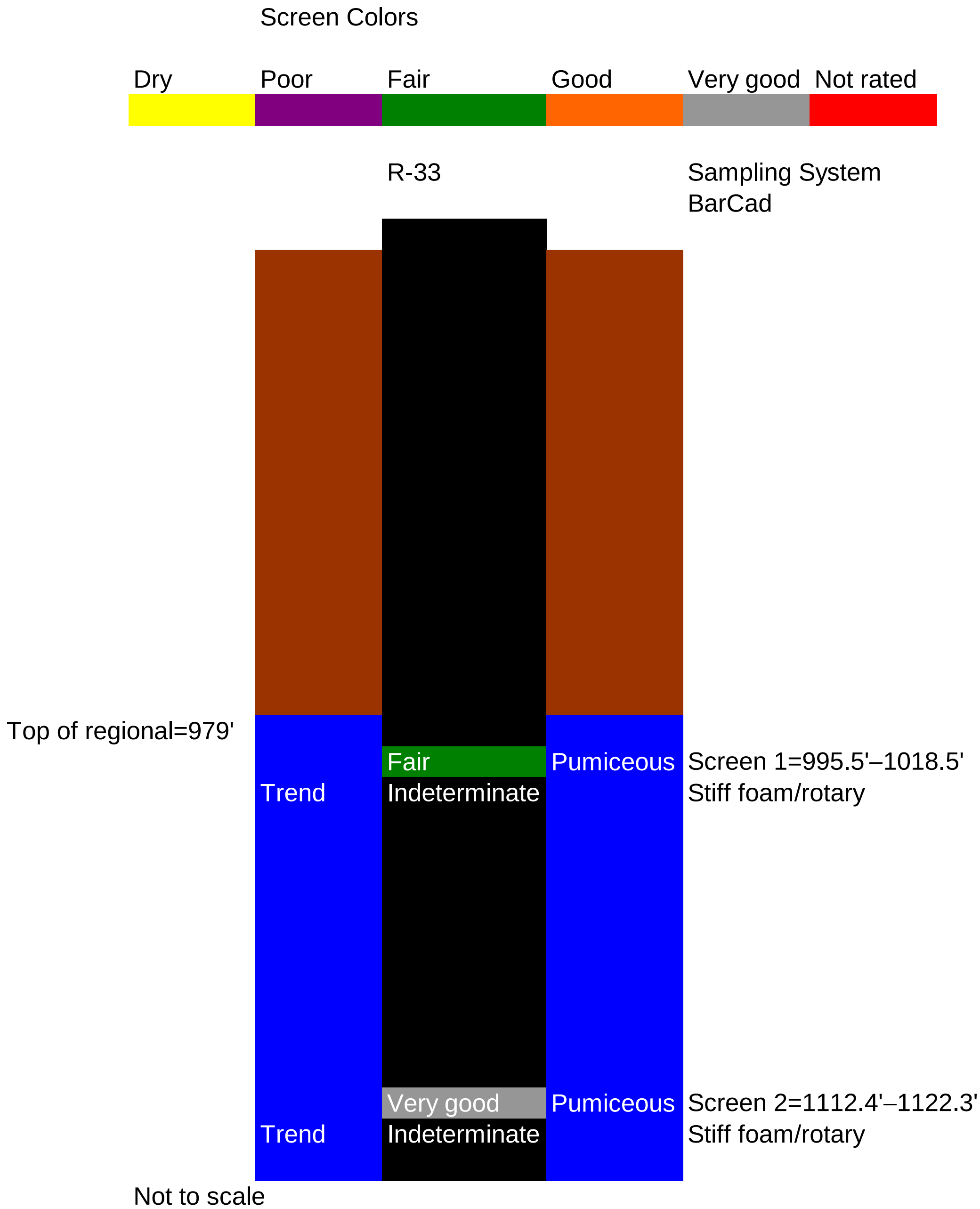

Figure B-17. Position and condition of well screens in R-33 (see note on Figure B-1)