LA-UR-09-0311
January 2009
EP2009-0014

Fieldwork Plan for R-22 Well Rehabilitation and Conversion

Los Alamos
NATIONAL LABORATORY
EST. 1943

Prepared by the Environmental Programs Directorate

LA-UR-09-0311
EP2009-0014

Fieldwork Plan for R-22 Well Rehabilitation and Conversion

January 2009

Responsible program manager:

Ardyth Simmons	[signature]	Project Leader	Environmental Programs	1-28-09
Printed Name	Signature	Title	Organization	Date

Responsible LANS representative:

Michael J. Graham	[signature]	Associate Director	Environmental Programs	1/29/09
Printed Name	Signature	Title	Organization	Date

Responsible DOE representative:

David R. Gregory	[signature] for	Project Director	DOE-LASO	1/30/09
Printed Name	Signature	Title	Organization	Date

CONTENTS

Figures

Attachments

1.0 SUMMARY

This work plan provides technical guidance for field activities associated with R-22 well rehabilitation and conversion to a dual-screen well. Plans for R-22 conversion were presented in the "Work Plan for R-Well Rehabilitation and Replacement, Revision 2" (LANL 2007, 098119) that was approved by the New Mexico Environment Department (NMED) on August 20, 2007 (NMED 2007, 098182). The R-22 borehole was drilled to a total depth of 1489 ft using fluid-assisted air-rotary and conventional mud-rotary techniques and was completed with five screened intervals in the regional aquifer: screen 1 from 872.3 to 914.2 ft, screen 2 from 947.0 to 988.9 ft, screen 3 from 1272.2 to 1278.9 ft, screen 4 from 1378.2 to 1384.9 ft, and screen 5 from 1447.3 to 1452.3 ft. A dedicated Westbay sampling system was installed in the well after completion.

The results of the well screen analysis for R-22 indicated that screen 1 passed 38% of the assessment tests, screen 2 passed 100% of the assessment tests, screen 3 passed 75% of the assessment tests, and both screens 4 and 5 passed 52% of the assessment tests (LANL 2007, 096330). Screens 4 and 5 will be abandoned as part of the rehabilitation and conversion program. Screen 1 will not be abandoned in the sense of being sealed-off from the rest of the R-22 well due to uncertainties in available methods and products for abandoning an upper well screen. Instead, screen 1 will be isolated from the sampled intervals below by an inflatable packer. A Baski dual-port system utilizing a single submersible pump will be installed for long-term sampling of screens 2 and 3 at R-22.

The activities to be performed as part of the R-22 rehabilitation include Westbay sample system removal, video logging, sampling of screen 5, initial aquifer testing at screens 2 and 3, sampling of screen 1, selective redevelopment at screens 2 and 3, abandonment of screens 4 and 5, final aquifer testing at screens 2 and 3, and dedicated sample system installation in accordance with the work plan approved by NMED.

2.0 REHABILITATION ACTIVITIES

Following are brief descriptions of the rehabilitation activities.

2.1 Westbay Removal

Westbay Instruments Inc., personnel will be mobilized to the site to remove the Westbay sampling system from the well. This task will be supported by TerranearPMC and Boart Longyear, Inc. The polyvinyl chloride (PVC) casing and ports will be decontaminated by high-pressure washing, air-dried, and sleeved in plastic lay-flat tubing for storage at a designated Los Alamos National Laboratory (LANL or the Laboratory) location. The decontamination water will be containerized and stored on site for waste characterization.

2.2 Video Logging

Upon removal of the dedicated Westbay system, a downhole video camera will be used to document well screen and casing conditions and to confirm the composite water level in the well. The Laboratory-owned downhole camera will be used for video logging and will be operated by a Laboratory technician.

2.3 Sampling and Initial Specific Capacity Testing

Several sampling and initial testing objectives will be performed at R-22 before redevelopment and abandonment activities.

To evaluate the presence of tritium previously detected in screen 5, a purging and sampling event will be conducted. A submersible pump with inflatable packers above and below the pump will be installed in the well, and the packers will be inflated in order to isolate screen 5. Pumping duration and sampling protocols will be defined before beginning purging and will be modified as required, based on the observed pumping response of screen 5. The pumping duration will be sufficient to remove a volume of water greater than the amount that flows into screen 5 from the other screens during Westbay equipment removal and pump installation. The details of the sampling to be conducted are presented in Attachment A.

Upon completing the purging and sampling exercise at screen 5, the same submersible pump and packer assembly will be used to establish initial specific capacity values for screens 2 and 3. The pump will be raised above the top of each screen and the packers will be inflated. After a minimum of 1 h of equilibration, a specific capacity test will be conducted for a minimum of 3 h, followed by a minimum of 3 h of recovery time at both screens 2 and 3. After the initial specific capacity testing has been completed at screens 2 and 3, the pump and packer assembly will be removed from the well.

To evaluate sulfate-reducing conditions enhanced by the oxidation and breakdown of drilling fluids originally used to complete the borehole, another sampling exercise will be conducted at screen 1. A submersible pump and a jetting tool will be installed in the well to accomplish the screen 1 sampling objectives. Screen 1 will be jetted and simultaneously pumped to generate solids from within the filter pack and adjacent borehole face for analysis. Assuming that the zones may be so low yielding that flow to the surface cannot be produced in a reasonable time, the sediment sample will have to be caught from the lower sections of drop pipe when they are unscrewed and removed from the well. (Note that even if production is steady, after about the first 40 gal. the water produced will include some screen 2 contribution.) The details of the sampling to be conducted are presented in Attachment A.

2.4 Redevelopment of Screens 2 and 3

Screens 2 and 3 will be redeveloped before abandoning screens 4 and 5. Development will be performed using two methods: (1) swabbing and (2) high-velocity jetting with simultaneous pumping. Performing redevelopment before screen abandonment is determined to be beneficial; the reverse order could place materials from redevelopment on top of cement abandonment materials, leaving a dirtier well.

Swabbing will be performed first by running a swabbing tool through the entire intervals at screens 2 and 3. The swabbing tool will be constructed on a rigid piece of pipe with nylon (or similar) discs mounted to the pipe. Surging of the well screen will be performed by rapidly moving the swab up and down the screened interval. Sediment loosened by the swabbing tool will be carried downward to the bottom of the well by the ambient downward flow within the borehole.

Jetting will be performed using a 10-hp submersible pump. A jetting tool just above the pump discharge will direct a portion of the pump output through the screen openings to deliver energy to the filter pack and formation. The remainder of the pump output will be discharged to the surface to effect net removal of water and sediment from the well during the jetting process. Both screens are of uncertain yield, and care (e.g., through water-level monitoring, water-flow measurements) must be taken to avoid running the pump dry by diverting too much flow to the surface while jetting. The design of the jetting tools used in the development process will be based on the measured specific capacities of each of the screen zones.

Care must also be taken to minimize cross-communication between screens throughout the duration of the field activities. Calculations showing the expected communication are presented in Attachment B. Every effort will be made to limit the actual cross-communication to volumes estimated in the calculations.

2.5 Selective Screen Abandonment

The lowermost screens (screens 4 and 5) will be abandoned by placement of sand and sealing materials at selected depths (see Figure 2.5-1). To keep sealing materials, such as cement, contained within the well casing, 10/20 filter grade sand will be emplaced throughout the screen intervals at a minimum level of 10 ft above the screen slot sections. A 5-ft interval of fine 20/40 filter grade sand will be installed above the 10/20 sand. Bridge plugs that are 4.5 in. in diameter will be set above the 20/40 sand intervals. An approximate 13-ft interval of neat cement will be installed above the fine 20/40 transition sand. An interval of 10/20 filter sand will be installed above the cement column. This column of 10/20 sand will extend within 20 to 30 ft of screen 3. All sand material will be placed through a tremie pipe and will be washed into place by running a small volume of potable water along with the sand.

Cement will be placed by use of a wireline dump bailer that will spot a volume of 1.5 ft^3 of cement on top of the 4.5-in. bridge plugs. This volume of cement will fill up to 13.5 ft of the 4.5-in. inner diameter well casing. Bridge plugs will be installed in the well to facilitate the use of the dump bailer. The bridge plugs will be encased in cement. Following a curing period of 12 h, a 3-in. tremie pipe will be installed through screens 1, 2, and 3 to near the depth of the cement plug. A bailer will be used inside the 3-in. pipe to remove any potential cement residue and affected water within the casing. Once relatively clean water is obtained by bailing (as measured by pH and turbidity), the 3-in. pipe will serve as the tremie pipe for placing the final 10/20 backfill material.

A viton and stainless-steel K packer will be installed above the abandonment materials. The packer will isolate the abandonment materials below from the sampled water column above. The packer will be constructed of stainless steel with viton-sealing gaskets.

2.6 Aquifer Testing

Aquifer testing of screens 2 and 3 will be performed following the plugging and abandonment of screens 4 and 5. Testing will be accomplished by running a shrouded submersible pump with inflatable packers above and below the pump and a dedicated downhole pressure transducer beneath the pump and shroud. Once the equipment has been placed, final well cleanup will be performed before testing. This step is intended to remove any turbid water resulting from emplacement of backfill materials. Pumping will be performed initially with the pump placed within the well casing between screens 2 and 3 and with the packers deflated. Then the pump will be placed within the sump space beneath screen 3, and purging will be performed to remove dirty water that has collected in the sump. Once cleanup is complete, the pump will be raised above the top of each screen and the packers will be inflated. After a minimum of 1 h of equilibration, a specific capacity test will be conducted for a minimum of 3 h, followed by a minimum of 3 h of recovery time at both screens 2 and 3.

3.0 SAMPLING ACTIVITIES

The subcontractor field team leader will monitor discharge from the pump using a flow-through cell and multiparameter meter in data-logging mode. Alternatively, if site conditions present difficulty for containerizing the discharge from a flow-through cell, samples will be collected directly from the pump discharge as grab samples and parameters will be documented in a logbook. The discharge from the screened intervals will be monitored for pH, temperature, conductivity, oxidation-reduction potential, and dissolved oxygen using a YSI 556 MPS multiparameter meter or equivalent unit. Turbidity samples will be collected at periodic intervals using a Hach 2100P turbidimeter or equivalent.

The Laboratory will collect all samples for laboratory analysis. The Laboratory will be responsible for obtaining sample paperwork and bottles, collecting, filtering, and preserving samples, and laboratory analyses. Analytical results of all samples collected will be included in the "R-22 Rehabilitation and Conversion Summary Report."

4.0 DEDICATED SAMPLE SYSTEM INSTALLATION

R-22 will be outfitted with a Baski-designed sampling system utilizing a single submersible pump for screens 2 and 3. The Baski system will utilize pneumatically actuated access port valves (APVs). The APVs are actuated using compressed gas from ground surface. The submersible pump will be an environmentally retrofitted 4-in. Grundfos pump that will be specified based on the results of the aquifer testing. Inflatable packers will be installed between the two sampling intervals (screens 2 and 3) and between screens 1 and 2. The 1-in. drop pipe will consist of threaded schedule 40 Type 304 nonannealed pipe meeting the requirements of the American Society for Testing and Materials Standard A 554 for welded stainless-steel mechanical tubing. The thread design will be American Petroleum Institute 10 Round Non-Upset Casing Threads. Two dedicated 1-in. PVC transducer tubes will be installed with and banded to the pump column. The transducer tube that will monitor screen 2 will terminate above the pump but will have a flexible tube, which will pass through the pump shroud and packer to monitor water levels below the packer.

If the permanent Baski-designed sampling system does not arrive by the time rehabilitation and conversion activities are completed, temporary packers will be used to isolate screens 2 and 3 until the permanent system arrives.

5.0 WASTE MANAGEMENT

All investigation-derived waste (IDW) generated during well R-22 rehabilitation and conversion activities will be managed in accordance with applicable standard operating procedures (SOPs). These SOPs incorporate the requirements of all applicable U.S. Environmental Protection Agency and New Mexico Environment Department (NMED) regulations, U.S. Department of Energy orders, and Laboratory requirements. The SOP applicable to the characterization and management of IDW is

- EP-ERSS-SOP-5022, Characterization and Management of Environmental Restoration (ER) Project Waste (http://www.lanl.gov/environment/all/qa/adep.shtml).

A waste characterization strategy form (WCSF) has been prepared and approved per requirements of EP-ERSS-SOP-5022. The WCSF provides detailed information on IDW characterization methods, management, containerization, and potential volumes.

Fluids (i.e., rehabilitation and decontamination waters) and contact waste (e.g., gloves, paper towels, plastic, and/or glass sample bottles) are the primary waste streams anticipated to be generated during R-22 rehabilitation and testing activities. The fluids produced will be sampled and analyzed for the suite of constituents listed in the WCSF.

Fluids produced during rehabilitation activities will be containerized, sampled, and evaluated for compliance with the New Mexico Water Quality Control Commission Regulation 3103 groundwater standards and applicable Resource Conservation and Recovery Act regulatory limits before any release of water occurs. Decisions regarding the release of rehabilitation water will be made in accordance with the 2006 notice of intent decision tree for drilling, development, rehabilitation, and sampling purge water. The decontamination water, contact waste, and any other IDW will be managed in accordance with the approved WCSF.

6.0 REPORTING

A summary report will be prepared to document the field activities and field parameters measured during redevelopment activities. The report will document all field activities, including deviations from the work plan, redevelopment, sampling procedures, and recommendations, if any, for consideration in follow-up activities. The report will include analytical laboratory results of all water samples collected, as well as solids from screen 1. Tritium analyses from screen 5 water samples will be reported when received from the off-site analytical laboratory. The report will provide as-built figures for abandonment materials and sampling component installation details.

7.0 REFERENCES

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

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

Bouwer, H., and R.C. Rice, June 1976. "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells," *Water Resources Research,* Vol. 12, No. 3, pp. 423-428. (Bouwer and Rice 1976, 064056)

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

LANL (Los Alamos National Laboratory), July 2007. "Work Plan for R-Well Rehabilitation and Replacement, Revision 2," Los Alamos National Laboratory document LA-UR-07-5087, Los Alamos, New Mexico. (LANL 2007, 098119)

NMED (New Mexico Environment Department), August 20, 2007. "Approval of the Workplan for R-Well Rehabilitation and Replacement, Revision 2," New Mexico Environment Department letter to D. Gregory (DOE-LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2007, 098182)

Stone, W.J., and S.G. McLin, March 2003. "Hydrologic Tests at Characterization Wells R-9i, R-13, R-19, R-22, and R-31," Los Alamos National Laboratory report LA-13987-MS, Los Alamos, New Mexico. (Stone and McLin 2003, 076003)

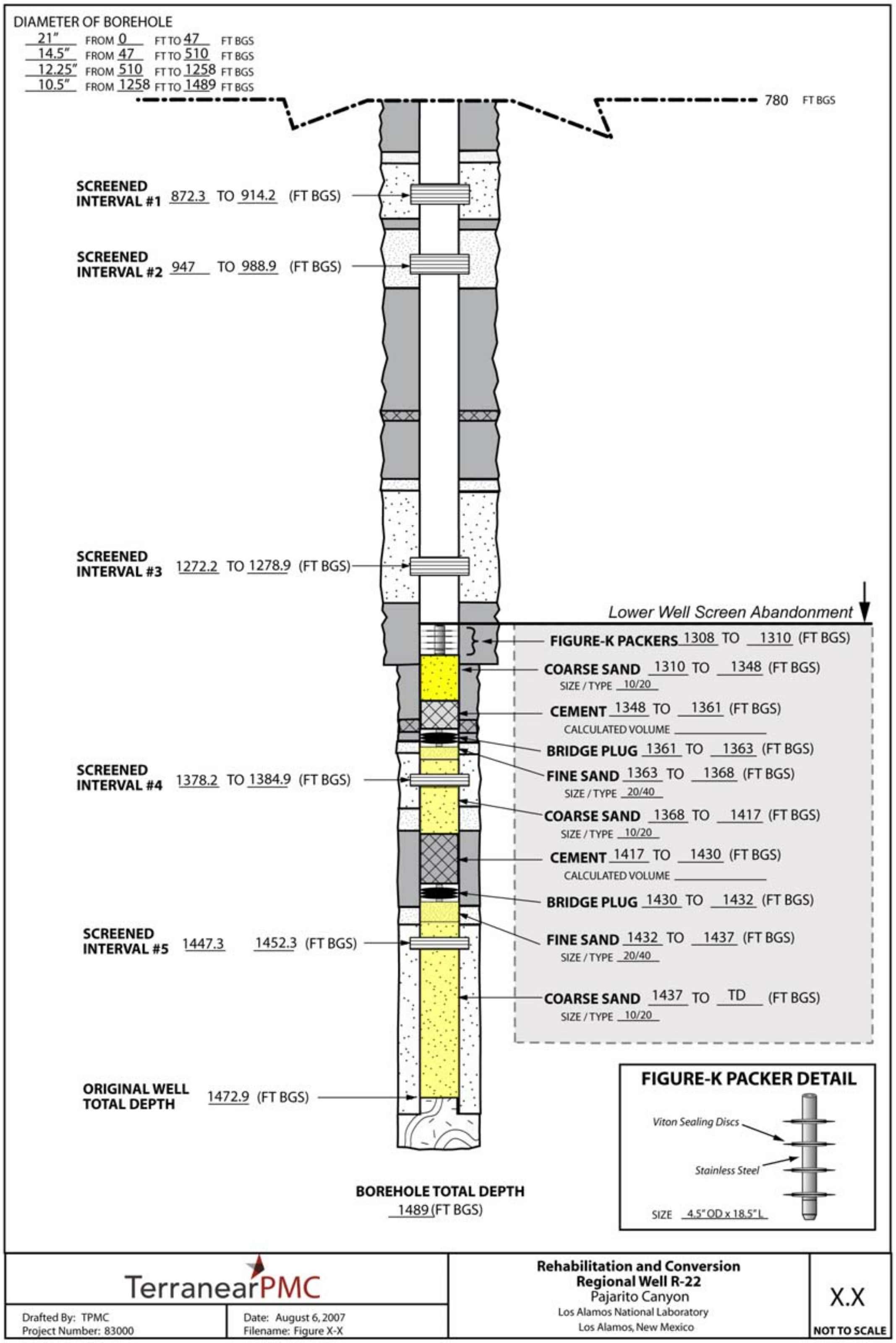

Figure 2.5-1 Well R-22 proposed rehabilitation and configuration

Attachment A

R-22 Well Rehabilitation Sampling at Screens 1 and 5

Organic polymer-based drilling fluids (EZ-MUD and QUIK-FOAM) were used during the drilling of R-22. Organic fluids have remained in screens 1, 4, and 5 after well development that potentially stimulate local microbial growth because of the added nutrient sources (e.g., elevated organic carbon, organic nitrogen, ammonia, oxalate, and phosphate) that are left behind. These microbes utilize oxygen while metabolizing these nutrient sources so a reducing environment is created. R-22 screen 1 is the most impacted zone characterized by sulfate-reducing conditions enhanced by the oxidation and breakdown of EZ-MUD and QUIK-FOAM. This reducing environment can influence the mobility of key indicators of background and contaminant chemistry in groundwater. Reductive dissolution of hydrous ferric oxide and manganese dioxide has taken place, resulting in elevated above-background concentrations of these two metals and other trace elements within screens 1, 4, and 5. New reactive minerals may have precipitated from groundwater in response to the reducing conditions resulting from oxidation of residual drilling fluids. These newly precipitated minerals potentially influence water chemistry through reduction-oxidation processes. Screens 1 and 5 are of primary importance during R-22 well rehabilitation for mineralogy/water chemistry (screen 1) and for evaluating the presence of tritium (screen 5).

A time series of the results of key indicator field parameters and laboratory analytical results will help determine the severity of the reducing environment in the formation surrounding the R-22 well screens 1 and 5. The concept behind the well rehabilitation and pumping test is that a long, continuous sample test will pull water from a distance surrounding the well screen that is greater than that potentially invaded by organic fluids during drilling. Changes in both analyte concentrations and key indicator parameters over time during the test would potentially indicate a residual drilling fluid effect. Nonfiltered water samples will be collected during the pumping test to evaluate the nature and composition of suspended solids potentially produced from drilling fluid effects. Selected water samples will be analyzed for inorganic chemicals at the Hydrology, Geology, and Geology (EES-14) department and low-level tritium at a Laboratory external laboratory (screen 5 only).

Continous Pumping at R-22 Screen 5

Before sampling and pumping of R-22 screen 5, a packer will be installed to eliminate mixing water (screens 1 through 4) with the lowermost screen. This is essential to evaluate the long-term presence of tritium in screen 5 without dilution taking place. R-22 screen 5 will be pumped continuously to purge a minimum of three well casing volumes, in addition to purging the volume of water introduced by removing the Westbay system and to obtain stable field parameters. An in-line flowmeter will be used to measure purge rate and volumes.

Sample Collection

As stated in section 3.0, field parameters will be measured using a flow-through chamber. Water samples will be collected for laboratory analyses according to the following sample collection schedule. Nonfiltered samples will be collected at the beginning and every 15 min for the first hour, every 30 min for the next hour, and every hour for the duration of the pumping tests for screens 1 and 5. Samples will be filtered through both 0.02-µm and 0.45-µm filters. Sampling methods will follow procedures described in the "Interim Facility-Wide Groundwater Monitoring Plan," using appropriate standard operating procedures.

Analytical Suite

EES-14 will analyze major ions, trace elements, and total organic carbon for nonfiltered and filtered samples (0.45-µm and 0.02-µm membranes). Low-level tritium analyses for groundwater pumped from screen 5 will be performed at Advanced Radiation Services or the University of Miami.

Solids Characterization at Screen 1

Water-suspended sediment samples will be collected in individual 30-gal. high-density polyethylene bottles with caps during pumping of R-22 screen 1 at the frequencies mentioned in section 2.3. Solids will be allowed to settle for several days, and groundwater will be decanted and separated from the solids before mineral characterization. Visual observation along with turbidity measurements will be used to select specific samples for solids characterization. Quantitative x-ray diffraction will identify reactive minerals produced from drilling fluid effects and natural aquifer material (silicates and carbonates).

Attachment B

Interflow Estimates for R-22 Screens 1 through 5

This report summarizes an analysis of the flow potential from one screen to another within R-22 that would occur when the Westbay isolation packers are removed for rehabilitation work. This information has been prepared to evaluate the impacts of opening the well for a period of time to purge screen 5 and perform the work needed to convert R-22 to a two-screen well, salvaging screens 2 and 3, while abandoning screens 1, 4, and 5. Work would include removing the Westbay equipment, conducting extended pumping of screen 5, abandoning screens 4 and 5, and developing and testing screens 2 and 3. Following this work, temporary packers would be installed in the well to isolate the remaining screens while permanent sampling equipment is manufactured. Once the permanent sampling equipment is obtained, the well would be opened a second time to remove the temporary packers and install the permanent sampling pump.

Flow estimates were calculated by estimating the specific capacity of each production zone using the hydraulic conductivity values presented in the revised version of the hydraulic analysis report prepared by Stone and McLin (2003, 076003). These hydraulic conductivity values were derived by applying slug test analysis methods to injection data. Once the specific capacity of each zone was determined, the flow rate into or out of that zone was computed by multiplying the specific capacity by the drawdown that would be applied to that zone. (No hydraulic test has been performed on screen 1. The hydraulic conductivity computed for screen 2 was assigned to screen 1 for the purposes of this analysis.)

The drawdown for a given zone was computed as the difference between its static water level and the composite water level that will occur when the well is opened. An exception to this was made for any zone where the composite water level dropped beneath the well screen. If this occurred, the drawdown value used in the flow-rate calculations was limited to the difference between the static water level and the midpoint of the initially saturated portion of the well screen. Even though drawdown actually would be applied to the bottom of the screen, limiting the value used in the computations in this way provided a mathematical correction for loss of capacity associated with dewatering of the screen.

The Stone and McLin (2003, 076003) report presented hydraulic conductivity values computed using multiple slug test methods. The values selected for this analysis were those obtained using the Bouwer and Rice procedure (1976, 064056). This was because the Bouwer and Rice method is based on relatively short pumping times, consistent with the duration of typical slug tests. To compute specific capacity, however, an equation was used that is based on extended pumping time. It was believed that the prediction based on late time would be consistent with the extended time that R-22 would be open to conduct the necessary work on the well.

One form of this equation, in mixed units, is as follows:

$$\frac{Q}{s} = \frac{KL}{70.55 \log \frac{L}{r_w}}$$ **Equation 1**

Where, Q = discharge rate, in gallons per minute,

s = drawdown, in feet,

K = hydraulic conductivity, in feet per day,

L = screen length, in feet, and

r_w = borehole radius, in feet (0.51 ft).

To perform the computations, an iterative approach was used in which the composite water level was adjusted until the net discharge was zero, that is, until the total flow into the well from the upper well screens equaled the total flow exiting the well through the bottom screens. Table B-1 summarizes the results of the calculations for the case in which the entire well would be open, exposing all five screens at the same time.

The tops and bottoms of the screens shown in Table B-1 were obtained from construction drawings of the well. The static water level elevations were provided by Rich Koch and represent recent observations. The hydraulic conductivity values are those from Stone and McLin (2003, 076003), while the specific capacity values were computed using the formula presented above. The discharge values (Q) shown in the table are positive for water entering the well and negative for water exiting the well.

As shown in Table B-1, to balance incoming and outgoing flow, it was necessary to adjust the composite water level in the well to an elevation of 5703.29 ft. With this level inside the well, screens 1 and 2 would yield 0.16 gpm and 0.64 gpm, respectively. Simultaneously, screens 3, 4, and 5 would receive 0.07 gpm, 0.56 gpm, and 0.18 gpm, respectively.

As a check on the results, the predicted composite water level was compared with a measured value obtained in December 2000 when the well was open. The December 2000 open-hole water level was 5703.2 ft, in agreement with the predicted value of 5703.29. It is likely that R-22 water levels have declined over the past 7 yr and that the open-hole level currently would fall below 5703.2 ft. Thus, the apparent agreement between the observed and predicted values may be overstated somewhat.

During well rehabilitation and conversion activities, not all five screens will be open for flow at all times. Periodically, packers will be set in various intervals, restricting and altering the flow patterns. At other times, zones will be purged or tested, causing net removal of water from the well. Also, as screens 4 and 5 are abandoned, they will cease accepting water from overlying zones. Thus, at various times, there will be several different combinations of screens in hydraulic communication with one another.

To account for interflow that would occur during the various rehabilitation procedures considered for R-22, interflow calculations were performed for the combinations of screens that are expected to be in hydraulic communication during the work. Tables B-2 through B-7 show anticipated water levels and interflow rates applicable to those anticipated combinations of open screen zones. The information in Tables B-1 through B-7 was used to prepare a description of water volume movement throughout R-22 during the rehabilitation effort.

Obtaining accurate estimates of the interflow volumes required an analysis identifying the individual tasks that would be performed on R-22, the time that each task would take and which screens would be in hydraulic communications during each procedure. Table B-8 shows the results of this analysis, presenting a summary of the operations considered for R-22, estimates of their execution times, and the screen zones involved.

All execution times shown in Table B-8 were rounded to the nearest whole number of days. Actual times will involve fractions of days in many instances. However, the execution times are considered only approximate. Actual work performance rates will be affected by extraneous factors, including weather, equipment down time, availability of personnel, weekends and holidays, postdevelopment cleanup time, and other factors. The time estimates shown in Table B-8 are simply nominal predictions that are considered reasonable based on experience with similar activities in other wells on the plateau.

The tasks shown in Table B-8 were consolidated by combining adjacent tasks for which the same set of screens were in hydraulic communication. For the consolidated chronology, the relevant time durations and individual screen interflow rates were used to compute the total volume of water that would flow into or out of each screen. Table B-9 shows the results of these calculations, with positive numbers indicating water contributed to the well and negative numbers indicating water received by a given zone.

It is apparent that screen 1 always contributes water to the well, while screen 2 nearly always does so. Conversely, screen 4 almost exclusively receives water from the overlying screen zones. Screen 5 receives water except for the substantial purging event, with an estimated total of 289 gal. of water flowing into the zone following purging.

Screen 3 is unique in that it receives and contributes somewhat similar volumes of water alternately throughout the rehabilitation/conversion process, with a net acceptance of more than 2400 gal. by the end of the project. Because the last flux occurrences for screen 3 correspond to injection of 5760 gal. of water, including more than 5000 gal. during installation of the permanent sampling system, it would be prudent to purge this interval extensively following installation of the sampling equipment.

In most cases, the volume of water received by a particular zone can be assumed to consist of a blend of water from the overlying contributing zones that is roughly in proportion to each zone's contribution to the well. As an example, during task 4, screen 1 contributes 230 gal. of water and screen 2 contributes 922 gal. Therefore, the relative proportions of contribution are 20% and 80% for screens 1 and 2, respectively. This means, for example, when examining the 806 gal. of water received by screen 4, as a first approximation, it can be assumed to consist of 20% screen 1 water (161 gal.) and 80% screen 2 water (645 gal.). The actual blend proportions will sometimes be slightly different than this because the antecedent water volume stored in the blank casing above the receiving zone before each task may have different contribution percentages than those for the active task. Nevertheless, this discrepancy is expected to be insignificant in most cases.

Note that Table B-9 may appear to include redundant steps. For example, it includes a line item for task 12 (identified previously in Table B-8 as "purge well") plus a subsequent line item entitled "Purge Well." The two sets of entries are included to represent the interflow that occurs during prepurging preparation activities (the task 12 entry) as well as removal of water during the purging itself (the "Purge Well" entry).

It is important to point out that the projected water removal volumes shown in Table B-9 corresponding to jetting, purging, and testing are merely estimates. The pumping rates that will be applied and the duration of the episodes are not known with certainty. Therefore, it is likely that the actual volumes removed during these activities will be different than the estimates shown in the table. Because much of the pumping will occur after thorough development procedures are applied to screens 2 and 3, it is possible that pumping performance will be better than current projections and removal volumes will exceed the estimates in Table B-9.

It is important to note also that the basis for the interflow calculations was data obtained from injection tests. These tests are not as accurate as pumping tests for determining yield characteristics of sediments. Clogging of the injection zone with entrained air can restrict flow, causing an underestimate of well and formation properties. Conversely, leakage past the packers that were used during testing can allow flow intended for a specific zone to move into another zone, causing an overestimate of hydraulic parameters. In addition to these limitations, as stated above, there was no hydraulic information available for screen 1. Nevertheless, the results of the interflow calculations provide insight into the patterns of water exchange among the screen zones that can be expected to occur during rehabilitation and conversion of R-22.

Table B-1
Theoretical Open-Hole Interflow for R-22 Screens 1 through 5
Los Alamos National Laboratory, Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (ft amsl*)	Screen Length (ft)	K (ft/d)	Static Water Level (ft)	Pumping Water Level (ft)	Q (gpm)
1	0.0124	5778.2 5736.3	41.9	0.04	5762.22	5749.26	0.16
2	0.0124	5703.5 5661.6	41.9	0.04	5755.25	5703.29	0.64
3	0.0178	5378.3 5371.6	6.7	0.21	5699.60	5703.29	–0.07
4	0.0611	5272.3 5265.6	6.7	0.72	5694.10	5703.29	–0.56
5	0.0193	5203.2 5198.2	5.0	0.27	5694.05	5703.29	–0.18

*amsl = Above mean sea level.

Table B-2
Theoretical Open-Hole Interflow for R-22 Screens 1 and 2
Los Alamos National Laboratory, Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (ft amsl)	Screen Length (ft)	K (ft/d)	Static Water Level (ft)	Pumping Water Level (ft)	Q (gpm)
1	0.0124	5778.2 5736.3	41.9	0.04	5762.22	5758.73	0.04
2	0.0124	5703.5 5661.6	41.9	0.04	5755.25	5758.73	–0.04

Table B-3
Theoretical Open-Hole Interflow for R-22 Screens 1 through 3
Los Alamos National Laboratory, Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (ft amsl)	Screen Length (ft)	K (ft/d)	Static Water Level (ft)	Pumping Water Level (ft)	Q (gpm)
1	0.0124	5778.2 5736.3	41.9	0.04	5762.22	5749.26	0.16
2	0.0124	5703.5 5661.6	41.9	0.04	5755.25	5727.75	0.34
3	0.0178	5378.3 5371.6	6.7	0.21	5699.60	5727.75	–0.50

Table B-4
Theoretical Open-Hole Interflow for R-22 Screens 1 through 4
Los Alamos National Laboratory, Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (ft amsl)	Screen Length (ft)	K (ft/d)	Static Water Level (ft)	Pumping Water Level (ft)	Q (gpm)
1	0.0124	5778.2 5736.3	41.9	0.04	5762.22	5749.26	0.16
2	0.0124	5703.5 5661.6	41.9	0.04	5755.25	5705.24	0.62
3	0.0178	5378.3 5371.6	6.7	0.21	5699.60	5705.24	–0.10
4	0.0611	5272.3 5265.6	6.7	0.72	5694.10	5705.24	–0.68

Table B-5
Theoretical Open-Hole Interflow for R-22 Screens 2 through 4
Los Alamos National Laboratory, Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (ft amsl)	Screen Length (ft)	K (ft/d)	Static Water Level (ft)	Pumping Water Level (ft)	Q (gpm)
2	0.0124	5703.5 5661.6	41.9	0.04	5755.25	5703.48	0.64
3	0.0178	5378.3 5371.6	6.7	0.21	5699.60	5703.48	–0.07
4	0.0611	5272.3 5265.6	6.7	0.72	5694.10	5703.48	–0.57

Table B-6
Theoretical Open-Hole Interflow for R-22 Screens 3 through 5
Los Alamos National Laboratory, Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (ft amsl)	Screen Length (ft)	K (ft/d)	Static Water Level (ft)	Pumping Water Level (ft)	Q (gpm)
3	0.0178	5378.3 5371.6	6.7	0.21	5699.60	5695.09	0.08
4	0.0611	5272.3 5265.6	6.7	0.72	5694.10	5695.09	–0.06
5	0.0193	5203.2 5198.2	5.0	0.27	5694.05	5695.09	–0.02

Table B-7
Theoretical Open-Hole Interflow for R-22 Screens 4 and 5
Los Alamos National Laboratory, Los Alamos, New Mexico

Screen	Specific Capacity (gpm/ft)	Screen Top and Bottom (ft amsl)	Screen Length (ft)	K (ft/d)	Static Water Level (ft)	Pumping Water Level (ft)	Q (gpm)
4	0.0611	5272.3 5265.6	6.7	0.72	5694.10	5694.09	0.001
5	0.0193	5203.2 5198.2	5.0	0.27	5694.05	5694.09	–0.001

Table B-8
R-22 Rehabilitation and Conversion Procedures
Los Alamos National Laboratory, Los Alamos, New Mexico

Task	Task Description	Duration (d)	Open Screens
1	Remove Westbay	3	1,2,3,4,5
2	Assemble and trip double packers	1	1,2,3,4,5
3*	Purge screen 5, assess chemistry	7	2,3,4
4	Round trip pump and packers for testing	1	1,2,3,4,5
5	Test screen 3	1	1,2, 4,5
6	Test screen 2	1	3,4,5
7	Pull pump, run tremie, plug screen 5	1	1,2,3,4
8	Plug screen 4	1	1,2,3
9	Bail clean, tremie sand, swab, prepare to jet	2	1,2,3
10	Jet screen 3	1	1,2,3
11	Jet screen 2	1	1,2,3
12	Purge well	1	1,2,3
13	Round trip pump and packers for testing	1	1,2,3
14	Test screen 3	1	1,2
15	Test screen 2	1	None
16	Pull pump, run temporary packers	1	1,2,3
17	Pull temporary packers, install pumping system	7	1,2,3

*Assumes that screen 1 would be packed off.

Table B-9
Individual Screen Flow Volumes
Los Alamos National Laboratory, Los Alamos, New Mexico

Tasks/Operations	Duration (d)	Open Screens	Water Volume Transfer (gal.)				
			Screen 1	Screen 2	Screen 3	Screen 4	Screen 5
1 and 2	4	1,2,3,4,5	922	3686	–403	–3226	–1037
3*	7	2,3,4	0	6451	–706	–5746	18000
4	1	1,2,3,4,5	230	922	–101	–806	–259
5	1	1,2 and 4,5	58	-58	2400	1	–1
6	1	3,4,5	0	600	115	–86	–29
7	1	1,2,3,4	230	893	–144	–979	0
8, 9 and 10	4	1,2,3	922	1958	–2880	0	0
Jet screen 3	1	1,2,3	60	300	1200	0	0
11	1	1,2,3	230	490	–720	0	0
Jet screen 2	**1**	1,2,3	60	300	1200	0	0
12	1	1,2,3	230	490	–720	0	0
Purge well	1	1,2,3	120	600	2400	0	0
13	1	1,2,3	230	490	–720	0	0
14	1	1,2	58	-58	2400	0	0
15	1	None*	0	600	0	0	0
16 and 17	8	1,2,3	1843	3917	–5760	0	0
		Net Total Volume	5193	21581	–2439	–10842	16674

*Assumes five 12-h d of pumping.