Tracer Test Results

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ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
DFBA	Difluorobenzoate
ft	feet
FBA	Fluorobenzoate
gpm	gallons per minute
gpd	gallons per day
hrs	hours
NaBr	Sodium Bromide
NaI	Sodium Iodide
NC-EWDP	Nye County Early Warning Drilling Program
OD	outside diameter
PFBA	Pentafluorobenzoate
ppm	parts per million
ppt	parts per trillion
psi	pounds per square inch
psia	pounds per square inch absolute
PVC	Polyvinyl Chloride
QA	Quality Assurance
SSFM	Site-Scale Saturated Zone Flow Model
TFBA	Trifluorobenzoate
TeFBA	Tetrafluorobenzoate
UIC	Underground Injection Control

1.0 INTRODUCTION

This report presents analyses and interpretations of data for tracer testing performed at the Nye County Early Warning Drilling Program (NC-EWDP) Site 22, from November 2004 through October 2005. The tracer testing was conducted as part of the Nye County Nuclear Waste Repository Project Office (NWRPO) Independent Scientific Investigations Program (ISIP), which is funded by a cooperative agreement with the U.S. Department of Energy (DOE). The purpose of the tracer testing was to better understand the transport properties of the saturated alluvium and upper Tertiary sediments along a potential flow path between Yucca Mountain and populated areas of the Town of Amargosa Valley, Nevada.

The tracer testing consisted of both single-well injection/pumpback (i.e., push/pull) tests and multiple well cross-hole tracer tests, all conducted at NC-EWDP Site 22. Site 22 is located in Fortymile Wash, approximately 6 miles north of Lathrop Wells.

The site consists of one larger-diameter well and three smaller-diameter piezometers:

- NC-EWDP-22S is a four-screen well that served as the pumping well.
- NC-EWDP-22PA, -22PB, and -22PC are nested, dual-completion piezometers that served as pressure monitoring wells and tracer injection points.

The well and piezometers were drilled as part of the NC-EWDP and will be referred to as 22S, 22PA, 22PB, and 22PC herein. With the exception of 22PC, each was drilled and completed in late 2001 and early 2002 as part of Phase III of the NC-EWDP. Sonic methods were used to core 22PC, which was completed in late 2004 as part of Phase V of the NC-EWDP. Figure 2 shows the surface layout of Site 22.

Detailed descriptions of drilling, completion, and development procedures for 22S, 22PA, and 22PB that may impact tracer test results can be found in *Nye County Drilling, Geologic Sampling and Testing, Logging, and Well Completion Report for the Early Warning Drilling Program Phase III Boreholes* (NWRPO, 2003). A similar technical report for 22PC had not been produced at the time this tracer report was published. However, a report describing Phase IV NC-EWDP drilling and well construction activities (NWRPO, 2005) provides detailed coring and completion information for sonic corehole NC-EWDP-19PB, which is nearly identical to sonic corehole 22PC. Corehole 19PB is located at Site 19 approximately 3 miles south (downgradient) of 22PC in lower Fortymile Wash.

The Nye County NWRPO Quality Assurance (QA) Work Plan WP-9, *Work Plan for Tracer Testing* (NWRPO, 2003a) provides details of the technical rationale for selecting Site 22 over other sites in Fortymile Wash, identifying the hydrostratigraphic layer or zone to be tested in the upper alluvial aquifer, and determining the major types of tracers to be used. In addition, this plan provides a brief overview of the single-well and cross-hole testing planned for Site 22 and lists the environmental compliance and permitting requirements.

Also, this work plan describes the purpose and specific objectives of the tracer testing. Specific objectives included characterizing effective porosity, longitudinal hydrodynamic dispersion, stagnant water zones (if any), and communication between selected hydrostratigraphic layers in the alluvium.

The remaining sections of this report are organized as follows. Section 2 summarizes pertinent Site 22 background information including well and piezometer completion, textural layering in the upper alluvial aquifer, preliminary aquifer tests conducted in 2002, and isolated zone aquifer tests conducted in 2003. Section 3 describes methods used to conduct single-well and multiple-well tracer tests at Site 22. Section 4 presents data, analyses, and interpretations of these tracer tests. Section 5 summarizes important tracer test findings and conclusions.

Finally, Nye County acknowledges funding support from DOE and technical support from a number of DOE contractors who technically reviewed Nye County tracer test plans and procedures and supplied valuable technical input. These contractors included Los Alamos National Laboratory (LANL), U.S. Geological Survey (USGS), University of Nevada Las Vegas – Harry Reid Center (UNLV-HRC), and Bechtel SAIC Corporation (BSC). In addition, UNLV-HRC provided tracer preparation and chemical analysis support, and LANL and BSC provided field tracer sample collection and shipping support.

2.0 PERTINENT BACKGROUND INFORMATION

2.1 Well and Piezometer Completions

Well 22S was drilled to a depth of 1,196.5 feet (ft) below ground surface (bgs) and completed as shown in Figure 3. The upper three screens in 22S are completed in alluvium, and the lower screen is in a Tertiary volcanic conglomerate. The screened intervals are labeled Screen 1 through Screen 4, with Screen 1 referring to the uppermost interval. The well was completed with 6.625-inch outside diameter (OD) steel casing to permit the installation of packers to isolate well screens and to facilitate pumping during aquifer and tracer tests.

Piezometer 22PA was drilled to a total depth of 779.8 ft bgs, and 22PB was drilled to 1,199.7 ft bgs. Each piezometer was completed with two screens (2-inch Schedule 80 polyvinyl chloride [PVC]), as shown in Figure 4 and Figure 5. The screens in 22PA are at depths corresponding to the upper two screens in 22S; the screens in 22PB correspond to the lower two screens in 22S.

Piezometer 22PC was continuously cored from 460 ft to a depth of 760 ft bgs and completed with two screens (2-inch Schedule 80 PVC), as shown in Figure 6. Like the screens in 22PA, the screened depth intervals in 22PC correspond to the upper two screens in well 22S.

Screen depth intervals and associated sand packs for each of the Site 22 wells/piezometers are summarized in Table 1. Sand pack intervals will be referred to as zones in this report, and corresponding zones in the pumping well and piezometers have been assigned the same zone number.

2.2 Textural Layering

Particle size distribution data from field geologic logs and laboratory testing of the sonic core from 22PC provide accurate descriptions of textural layering in the upper 290 ft of saturated alluvium (approximately 470 to 763 ft bgs) at Site 22. Laboratory testing data from 22PC are found in Appendices A and B. These data are also available at the NWRPO Quality Assurance Records Center (QARC).

Prior to coring 22PC in 2004, the textural layering of alluvium in the Site 22 wells was based on data from an exploratory borehole, well 22SA, which was drilled using reverse circulation air-rotary drilling methods in the summer of 2001. The locations of the screens for 22S and subsequent wells at Site 22 were based on drilling observations, field textural measurements and estimates, and geophysical logging data.

Based on 22PC particle size distribution data and 22SA (the pilot borehole for 22S) particle size distribution data that have been adjusted to account for the drilling-related disturbance, the predominant textural layers encountered at Site 22 are clayey gravel with sand (GC) and clayey sand with gravel (SC). Zone 1 is located mainly in silty sand with gravel (SM) and clayey sand with gravel (SC) with greater than 12 percent (%) silt and clay; Zone 2 is in predominantly clayey sand with gravel (SC) and clayey gravel with sand (GC) with greater than 15% silt and clay; and data from Zone 3 suggests similar textural layering. The normalized gamma ray logs for 22PA, 22S, and 22PC show no evidence of obvious clay-rich confining layers between zones, nor obvious bed level correlations. Drill cuttings collected from the depth interval corresponding to Zone 3 exhibited a strong hydrochloric acid (HCl) reaction, suggesting that the formation sediments in this screened interval are cemented with calcium carbonate. In contrast, drill cuttings from depth intervals corresponding to Zones 1 and 2 exhibited little HCl reaction, suggesting that little cementation related to calcium carbonate is present.

2.3 Preliminary 2002 Aquifer Tests and Modifications to 22S

Preliminary aquifer tests were conducted at Site 22 in March 2002 and included aquifer pump-spinner and 48-hour pump tests (NWRPO, 2003b). The pump-spinner tests involved running spinner logs in 22S while simultaneously pumping all four zones in 22S. The 48-hour constant rate test again involved simultaneous pumping of all four zones in 22S while monitoring pressure responses in both 22S and observation piezometers 22PA and 22PB.

These tests indicated a transmissivity of 14,750 square feet per day (ft^2/day), corresponding to an average permeability of 14.1 darcies over the 368-ft productive thickness. In addition, no significant vertical gradient was present, and all intervals contributed to production. Hydraulic communication was demonstrated between the screens in 22S and each of the matching piezometer completions. However, the calculated well efficiency of 22S was only 19%. The majority of the head loss experienced was attributed to multilayer and non-darcy flow effects as flow converged to the well.

In April 2002, a Westbay® MP55™ casing and packer system was installed to isolate the various zones and allow individual zones to be monitored, sampled, or pumped during additional aquifer tests and planned tracer tests. In March 2003, the upper 515 ft of the 4-inch Schedule 80 PVC casing was replaced with 5-inch Schedule 80 PVC pipe to permit using larger pumps for future hydraulic and tracer test studies.

2.4 Isolated Zone Aquifer Tests in 2003

A second set of aquifer pump tests was conducted in each of the four isolated zones in 22S in August/September 2003 (NWRPO, 2004). The four tests, lasting approximately 11 hours (hrs) each, were conducted with only one 22S zone open to the wellbore for pumping, while simultaneously monitoring pressures in all 22S zones as well as the corresponding zones in 22PA and 22PB. Pumping rates for these tests ranged from approximately 20 to 44 gallons per minute (gpm). Subsequent to testing, recovery in each zone was monitored.

Head changes in the observation wells during pumping of isolated individual screens in 22S (the pumping well) demonstrated the existence of hydraulic connections in these aquifer units. No significant vertical head gradient was present. Total transmissivity at pumping well 22S was determined to be 10,700 ft^2/day, corresponding to an average permeability of 10 darcies over the 368-ft productive thickness. All intervals contributed to production and displayed permeabilities ranging from 4.5 to 14 darcies. These data are summarized in Table 2, which compares the results of the isolated zone aquifer pump tests to the results of the preliminary tests in which all the zones were pumped simultaneously.

Table 2 further shows that higher transmissivities, permeabilities, and storage coefficients were observed in the preliminary tests than in isolated zone tests. This was in part due to less leakance between layers during the preliminary pump-spinner tests because each zone produced water. The preliminary tests were also complicated by changing production rates from each zone over time due to ongoing development occurring during the test. The analysis of the preliminary test data was also limited because of the low frequency for recording pressure data during logging. This caused important pressure response data to be missed. For this reason, the isolated zone aquifer test data in Table 2 are considered more representative of aquifer properties at Site 22 than data from the preliminary aquifer test.

Finally, head changes in 22S during drawdown and recovery in the isolated zone tests were matched to determine the skin factor and the related well efficiency. The term "skin factor," used in the petroleum industry to account for near-wellbore pressure drops, is related to the concept of well efficiency in groundwater studies. The calculated well efficiency varied by zone in 22S, with a range of 15 to 30% (Table 3). The majority of head loss experienced in the individual zone tests is likely attributable to friction in the MP55™ casing system.

2.5 Selection of Zone 2 for Tracer Testing

Zone 2 was selected for the Nye County alluvial tracer test based on its high transmissivity and confined aquifer characteristics. These characteristics outweigh the disadvantage of its thickness (114.7 ft), which required larger quantities of tracers than Zones 1 and 3. More details regarding the selection of Zone 2 are presented in WP-9 (NWRPO, 2003a).

3.0 METHODS

3.1 Overview of Tracer Test Methods

Table 4 summarizes tracer and chase water injection as well as groundwater/tracer pumpback data for two single-well push/pull and five cross-hole tracer tests at Site 22. An overview of these tests is given in the following two sections, and details are presented in subsequent sections. Four of the five cross-hole tests were initiated in mid-January 2005, and the fifth test in late August of the same year. The first four cross-hole tests are referred to as Phase I tests; the fifth is referred to as the Phase II test.

3.1.1 Single-Well Tests

Two single-well push/pull tracer tests were conducted in 22S (Figure 12 and Figure 15) between mid-December 2004 and mid-March 2005. Both tests involved injecting approximately 1,000 gallons of tracer solution into Zone 2 of 22S, pushing these tracers into the formation by “chasing” them with approximately 20,000 gallons of previously collected formation water, allowing the tracers to “drift” slightly down-gradient with the natural movement of formation water, and then pulling them back to 22S by pumping 22S at approximately 48 gpm.

The two push/pull tests differed primarily by the period of time the tracers were allowed to drift. The drift periods for first and second tests were approximately 70 and 700 hours, respectively. In both tests, pumped groundwater samples from 22S were collected and analyzed for tracer concentrations, which in turn were plotted versus time (i.e., as tracer response curves). The two tracers used in each test had different diffusion coefficients, and the response curves provided information on the importance of diffusion into stagnant zones (i.e., “dead-end” pore space) in the formation. The tracer response curves also provided information about effective porosity, the natural gradient, and hydrodynamic dispersion.

3.1.2 Cross-Hole Tests

Five cross-hole tests were conducted at Site 22 primarily in Zone 2 beginning in mid-January 2005 and ending in October 2005. Four of the five tests were initiated in mid-January 2005 (Phase I tests), and the fifth test (Phase II test) in late August 2005. These tests involved injecting approximately 250 to 275 gallons of different tracers into piezometer strings 22PA Deep, 22PA Shallow, and 22PC Deep and then monitoring the tracer response (i.e., concentrations) in pumping well 22S, located approximately 60 ft from the injection piezometers. Approximately 100 gallons of previously collected formation water was then injected into the same piezometer strings to help chase the tracer solutions out of the piezometer screen and into the sand pack and formation. The tracers were then pulled toward and into 22S by pumping at approximately 48 gpm over a time period of approximately four months. Groundwater samples were collected from pumping well 22S and analyzed for tracer concentrations throughout the term of the cross-hole tests.

These cross-hole tracer tests used the following conservative tracers: iodide, bromide, and several fluorobenzoates; microsphere colloids; and an oxidation/reduction (redox) sensitive anion (perrhenate), which mimics the behavior of a radioactive contaminant (pertechnetate) that could potentially be released from waste stored at Yucca Mountain. Perrhenate acts as a conservative tracer under oxidizing conditions and a nonconservative reactive tracer under reducing conditions.

The use of perrhenate as a tracer required a major modification to Nye County's Underground Injection Control (UIC) permit, since perrhenate was not approved as a tracer in the original permit. During the time required to obtain this modification (from March 18 to August 25, 2005), pumping of cross-hole Phase I tracers into 22S was suspended in order to minimize the amount of water produced and to limit overall testing costs.

The tracer response curves from the cross-hole tests provided a larger-scale estimate than a single-well push/pull test of effective flow porosity, longitudinal dispersion, and stagnant zones. In addition, a cross-hole test between Zone 1 in 22PA Shallow and Zone 2 in 22S provided qualitative information regarding communication between hydrostratigraphic layers or zones. Finally, these tracer response data provided information regarding preferential flow paths present between injection piezometers and the pumping well, the importance of colloid transport in the alluvium, and the effect of redox conditions in the alluvium of Fortymile Wash on a redox-sensitive tracer.

Note that pumping 22S from mid-January to mid-March 2005 served to move the majority of tracers into 22S, both from the first four cross-hole tests and the second single-well push/pull test. Pumping of 22S then resumed in late August 2005, continued into October 2005, and served to complete the recovery of tracers from the above mentioned tests as well as the recovery of most of the tracers injected as part of the fifth cross-hole test.

3.2 Details of Tracer Test Methods

The tracer tests described in this report were conducted in accordance with detailed procedures included in the following NWRPO QA test plans (TPNs):

- TPN-9.2, *Single-Well Push/Pull Tracer Test at Well NC-EWDP-22S*.
- TPN-9.3, *Cross-Hole, Multiple-Well Tracer Test at Site 22*.
- TPN-9.4, *Site 22 Cross-Hole Tracer Test Using Perrhenate and Iodide*.

Each of these plans describes pertinent pumping well and piezometer completion information, equipment and instrument installation, plumbing and procedures for tracer injection/chasing and pumpback, and procedures for groundwater/tracer sample collection and analysis. Table 4 summarizes tracer injection, chase water, and pumping well information presented in these plans as well as data related to injection, chasing, and pumping collected during each of the tracer tests. The following sections will briefly describe the tracer testing method (presented in detail in the above TPNs) and the data presented in Table 4.

3.3 Common Preparation Steps and Assumptions for Tracer Tests

Several preparatory steps were the same for both the single-well and the first four cross-hole tracer tests at Site 22. Prior to the injection of tracers, Westbay® pressure/temperature measuring probes were placed in each zone in pumping well 22S (Figure 3) and the shallow and deep strings in each of the piezometers: 22PA, 22PB, and 22PC (Figure 4, Figure 5, and Figure 6, respectively). In addition, a probe was attached to the tubing string above the pump in 22S to measure the pressure in the pumping zone. These probes remained in place throughout the tests and were only removed from selected piezometer strings for short-term temperature and electrical conductivity logging (YSI probe measurements), groundwater sampling, and, in several cases, because of Westbay® probe failure.

These Westbay® probes were attached to one of three surface Westbay® MOSDAX™ data loggers, which recorded downhole pressure and temperature information, barometric pressure, and ambient temperature. Shallow and deep piezometers in 22PA, 22PB, and 22PC were instrumented with 30-pounds per square inch absolute (psia) sensors. In isolated Zones 1, 3, and 4 in 22S, 250-, 500-, and 1,000-psia sensors were placed, respectively. A 250-psia sensor was placed above the pump in Zone 2 of 22S.

Prior to injection of the tracers, 44,539 gallons of water were produced from Screen 2 of 22S and stored onsite in two 21,000-gallon tanks coated internally with epoxy along with two 1,500-gallon cone-bottom plastic water tanks, two 1,550-gallon flat-bottom plastic tanks, and one 305-gallon flat-bottom plastic tank. A schematic diagram showing these tanks at Site 22, and the piping/plumbing used to fill them, is shown in Figure 10. The produced water was used for tracer dilution and displacement during the subsequent tests.

For the purposes of this report, it was assumed that the downhole distance between the wells was the same as the surface distance, and that this distance does not materially affect the results of the analyses described in the following sections. Deviation surveys in the wells show little or no deviation from vertical. Additionally, except where explicitly noted, all tracer injection and production is into or out of Zone 2.

3.4 Single-Well Push/Pull Tracer Test Procedures

3.4.1 First Push/Pull Test

The first of two single-well push/pull tracer tests was begun on December 2, 2004, at 14:51 hrs with the injection of 1,054 gallons of a mixture of sodium iodide (NaI) and pentafluorobenzoate (PFBA). Table 5 shows the tracer concentrate and diluted mixture concentrations along with the calculated and measured masses injected. Prior to injection, concentrated tracer solutions were delivered to the location by UNLV–HRC and diluted onsite through circulation of the cone-bottom injectant tank with a small centrifugal pump, as shown in Figure 11. The diluted tracer solution was gravity fed from the cone-bottom tank into 22S through a 1.25-inch OD braided PVC hose and displaced away from the 22S wellbore with 19,842 gallons of produced water, which was also gravity fed into Screen 2. The tracer solution was injected into 22S at an average rate of 17.3 gpm for 61 minutes. The chase water was injected into 22S immediately following the injection of tracer solution and continued at an average rate of 17.9 gpm for 18.5 hrs. Injection times and volumes for the first single-well push/pull tracer test are shown in Table 4.

No effort was made to match the injected fluid temperature to the aquifer temperature. Since injection occurred during the winter months, the injectant was colder than the formation temperature. Figure 12 displays the temperature and pressure observed in 22S during injection and the beginning of the pumpback along with the ambient temperatures during this time period.

After injection and displacement of the iodide and PFBA tracers into Screen 2 of 22S, the tracer solution was allowed to drift with the natural gradient for a period of 70.2 hrs prior to being pumped back.

A total of 295,060 gallons of produced water and tracer solution was pumped back, from December 6 to December 10, 2004, at an average rate of 47.3 gpm. This pumpage was discharged on the ground surface down-gradient of the 22 site and was allowed to infiltrate. A bypass loop was installed on the discharge pipe that carried a representative portion of the produced fluids through a "Mobile Mini" trailer on location (Figure 13). Inside the trailer, integrated fluid samples were obtained using an autosampler provided by LANL (Figure 14). Sample intervals were variable during the pumpback, as shown in Table 6, and were designed to provide good tracer recovery curves and to minimize the difference in tracer concentrations between samples collected by the autosampler integrated sampling technique and the single-point-in-time manual "grab" samples method. Lag time in the bypass loop was minimized through the use of "pinwheel" flow indicators, which were monitored to make sure the bypass loop had a continuously high fluid velocity and mass flow rate.

Manual grab samples were obtained ahead of the bypass loop for the duration of the pumpback period for redundancy, allowing a comparison of integrated versus grab sampling techniques. The grab sample schedule was also variable, as indicated in Table 7.

3.4.2 Second Push/Pull Test

The second of two single-well push/pull tracer tests was begun on December 13, 2004, at 14:42 hrs with the injection of 1,032 gallons of a mixture of sodium iodide (NaI) and 2,3,4,5-tetrafluorobenzoate (2,3,4,5-TeFBA). Table 8 shows the tracer concentrate and diluted mixture concentrations along with the calculated and measured masses injected. Again prior to injection, concentrated tracer solutions were delivered to location by

UNLV–HRC and diluted onsite through circulation of the cone-bottom injectant tank with a small centrifugal pump.

The diluted tracer solution was gravity fed from the cone-bottom tank into 22S through a 1.25-inch OD braided PVC hose and displaced away from the 22S wellbore with 19,534 gallons of produced water, which was also gravity fed into Screen 2. The tracer solution was injected into 22S at an average rate of 15.4 gpm for 67 minutes. The chase water was injected into 22S immediately following the injection of tracer solution and continued at an average rate of 16.3 gpm for 21 hrs. Injection times and volumes for the second single-well push/pull tracer test are displayed in Table 4.

As with all the Nye County tracer tests, no effort was made to match the injected fluid temperature to the aquifer temperature. Figure 15 displays the temperature and pressure observed in 22S during injection along with ambient temperatures and barometric pressures during the second push/pull test.

After injection and displacement of the iodide and 2,3,4,5-TeFBA tracers into Screen 2 of 22S, the tracer solution was allowed to drift with the natural gradient for a period of 716 hrs prior to being pumped back.

From January 13 through March 18, 2005, 4,407,138 gallons of produced water and tracer solution were pumped back at an average rate of 47.8 gpm using the same bypass loop and autosampler as in the first test. Sample intervals were variable during the pumpback, as shown in Table 9, and were designed to provide well-defined tracer recovery curves and to minimize the difference between samples collected using the autosampler integrated sampling technique and those collected using the manual grab sample method. Lag time in the bypass loop was minimized by maintaining high fluid velocity and mass flow rates.

As with all the Nye County tracer tests, manual grab samples were obtained ahead of the bypass loop for the duration of the pumpback period for the sake of redundancy. The grab sample schedule was also variable, as shown in Table 10.

3.5 Phase I Cross-Hole, Multiple-Well Tracer Test Procedures

3.5.1 Cross-Hole Test 1 - Injection into 22PA Deep

Stabilized flow was obtained in 22S prior to cross-hole tracer injection by starting up the pump in 22S on January 13, 2005, at 08:51 hrs (Figure 16). The first cross-hole tracer test in Zone 2 was begun on January 14, 2005 at 10:27 hrs with the gravity-feed injection of 256.7 gallons of a mixture of lithium bromide (LiBr), lithium chloride (LiCl), and 2,4,5-trifluorobenzoate (2,4,5-TFBA) into 22PA Deep (Screen 2). Table 11 shows the tracer concentrate and diluted mixture concentrations along with the calculated and measured masses injected. The tracer was displaced into the aquifer surrounding 22PA Deep with 95.5 gallons of produced water.

The tracer solution was injected into 22PA Deep at an average rate of 11.7 gpm for 22 minutes. Chase water was injected into 22PA immediately following the injection of tracer solution and continued at an average rate of 6.8 gpm for 14 minutes. Injection times and volumes for injection into 22PA Deep are shown in Table 4.

As with the single-well tracer tests, all cross-hole multiple-well tracer chemicals were delivered prior to injection as concentrated tracer solutions by UNLV–HRC and diluted onsite through circulation in the injectant tank with a small centrifugal pump. Again, all tracer solutions were gravity fed from their respective injectant tanks into the desired piezometer screen through a 1.25-inch OD braided PVC hose.

3.5.2 YSI Probe Monitoring in 22PA Deep in Cross-Hole Test 1

LANL personnel monitored (manually logged) temperature and electrical conductivity over a two-day period using a YSI multiprobe in the screened interval in injection piezometer string 22PA Deep during and after the injection of bromide and 2,4,5-TFBA. The purpose of this monitoring effort was to determine the uniformity of tracer concentrations in the well screen and the uniformity of movement of tracers out of the screen and into the sand pack and formation.

Readings were logged at 10-second intervals at depths (i.e., stations) located 5 ft apart beginning at the top of Screen 2 at approximately 660 ft bgs and ending 10 ft above the bottom of Screen 2 at approximately 750 ft bgs. The presence of sediment in the well screen below 750 ft prevented logging deeper. Readings were collected at each station (generally for slightly more than a minute) until stable values were obtained. The probe was located at station 16 during tracer and chase water injection and at station 19 when not logging (i.e., overnight).

Electrical conductivity logging data showed that tracer concentrations were remarkably uniform over the entire screen length, except for the very top of the screen (upper three stations), where the decline in tracer concentrations lagged behind the decline in underlying intervals. This suggests that the tracers entered the formation quite uniformly over the length of the interval, with only the top 10 feet having significantly lower permeability.

The rate of decline in tracer concentration continually slowed over time. LANL suggests that two processes may have been operative: first, constant radial flow induced by pumping 22S, and second, density-driven flow decreasing over time out the bottom of the borehole due to the initial higher density of the tracer solution and its colder temperature compared to the formation water (Sandia, 2007).

3.5.3 Cross-Hole Test 2 - Injection into 22PC Deep

The second cross-hole, multiple-well tracer test in Zone 2 was begun on January 14, 2005, at 11:10 hrs with the gravity-feed injection of 275.9 gallons of 2,6-difluorobenzoate (2,6-DFBA) into 22PC Deep (Screen 2). Table 11 shows the tracer concentrate and diluted mixture concentrations along with the calculated and measured masses injected. The tracer was displaced into the aquifer surrounding 22PC Deep with 98.6 gallons of produced water.

The tracer solution was injected into 22PC Deep at an average rate of 11.7 gpm for 22 minutes. Chase water was injected into 22PC Deep immediately following the injection of tracer solution and continued at an average rate of 6.8 gpm for 14 minutes. Injection times and volumes for injection into 22PC Deep are shown in Table 4. Figure 17 displays the temperature and pressure observed in 22PC Deep during injection and the beginning of the pumping along with the ambient temperatures during this time period.

3.5.4 Cross-Hole Test 3 - Injection into 22PA Shallow

A third qualitative cross-hole, multiple-well tracer test was begun on January 14, 2005, at 11:59 hrs with the gravity feed injection of 278.5 gallons of 2,5-difluorobenzoate (2,5-DFBA) into 22PA Shallow (Screen 1). Table 11 shows the tracer concentrate and diluted mixture concentrations along with the calculated and measured masses injected. The tracer was displaced into the aquifer surrounding 22PA Shallow with 32.8 gallons of produced water.

The tracer solution was injected into 22PA Shallow at an average rate of 9.0 gpm for 31 minutes. Chase water was injected into 22PA Shallow immediately following the injection of tracer solution and continued at an average rate of 4.7 gpm for 7 minutes. Injection times and volumes for injection into 22PA Shallow are shown in Table 4. Figure 18 displays the temperature and pressure in 22PA Shallow observed during injection and the beginning of the pumping along with the ambient temperatures during this time period.

3.5.5 Cross-Hole Test 4 - Microsphere Colloid Injection into 22PA Deep

After observing the initial results (i.e., tracer arrival or breakthrough at 22S) of the previous conservative tracers that were injected into 22PA Deep and 22PC Deep (see Sections 4.2.1 and 4.2.2), LANL determined that it was likely that microsphere colloid tracers would also move rapidly from 22PA Deep to 22S and would provide valuable data on colloid movement in the upper alluvial aquifer.

Microsphere injection was therefore initiated on January 24, 2005, at 13:12 hrs with the gravity-feed injection of 271.8 gallons of microspheres (Molecular Probe Microspheres, 4.65×10^{14} particles total) into 22PA Deep (Screen 2). The tracer was displaced into the aquifer surrounding 22PA Deep with 87.9 gallons of produced water.

The microsphere solution was injected into 22PA Deep at an average rate of 15.1 gpm for 17 minutes. Chase water was injected into 22PA Deep immediately following the injection of tracer solution and continued at an average rate of 12.6 gpm for 7 minutes. Injection times and volumes for microsphere injection into 22PA Deep are shown in Table 4. Figure 19 displays the temperature and pressure observed in this piezometer screen during injection and the beginning of the pumping period.

3.6 Phase II Cross-Hole Tracer Test 5 - Perrhenate Injection into 22PA Deep

After observing the initial rapid recovery of Phase I conservative tracers in 22S that were initially injected in 22PA, Nye County determined that it would be beneficial to conduct an additional cross-hole test using perrhenate and iodide as tracers. As mentioned previously, perrhenate was selected because it mimics the transport behavior of pertechnetate, a radioactive contaminant that could potentially be released from waste stored at the high-level nuclear waste repository at Yucca Mountain. Under oxidizing conditions, both perrhenate and pertechnetate act as conservative tracers; under reducing conditions, both act as nonconservative tracers.

As described in Section 3.1.2, the perrhenate/iodide test required a major modification to Nye County's UIC permits. As a result, pumping of Phase I tracers into 22S was suspended from March 18 to August 25, 2005, at which time pumping was resumed and the Phase II perrhenate/iodide test was begun.

The gravity-feed injection of 254.5 gallons of sodium perrhenate ($NaReO_4$) and NaI into 22PA Deep (Screen 2) was started at 12:06 hrs on August 25, 2005. Table 12 shows the tracer concentrate and diluted mixture concentrations along with the calculated and measured masses injected. The tracer was displaced into the aquifer surrounding 22PA Deep with 95.4 gallons of produced water.

The tracer solution was injected into 22PA Deep at an average rate of 11.2 gpm for 23 minutes. Chase water was injected into 22PA Deep immediately following the injection of tracer solution and continued at an average rate of 10.0 gpm for 10 minutes. Injection times and volumes for injection of Phase II tracers into 22PA Deep are listed in Table 4.

3.7 Produced Tracer Sampling for Cross-Hole Tests

From January 14 to March 18, 2005, 4,334,277 gallons of produced groundwater were pumped from 22S at an average rate of 48 gpm to partially recover Phase I dissolved tracers and colloids injected into 22PA and 22PC, as described in the preceding sections. From March 18 to August 25, 2005, pumping in 22S to recover Phase I tracers was suspended while a modification to the UIC permit was obtained for Phase II cross-hole testing. During this 159-day time period, Phase I tracers remaining in the aquifer were allowed to drift with the natural gradient.

Pumping of 22S resumed on August 25, 2005, at average rate of 49.3 gpm, and groundwater sampling and analysis of produced water for Phase I tracers continued until October 10, 2005. This second pumping episode produced an additional 3,567,936 gallons of groundwater. Pumping for recovery of Phase II tracers continued until October 13, 2005, and produced a total of 7,691,185 gallons of groundwater.

As with previous tracer tests, a representative portion of pumpage from 22S was diverted through the Mobile Mini trailer, and integrated fluid samples were obtained though the use of an autosampler provided by LANL. Sample intervals were variable during the pumping interval, as shown in Table 13, and were designed to provide well-defined tracer recovery curves and to minimize the difference between samples collected using the autosampler integrated sampling technique and those collected using the manual grab sample method. Lag time in the bypass loop was minimized by maintaining high fluid velocity and mass flow rates.

During all tests, manual grab samples were obtained ahead of the bypass loop for the duration of the pumping period for the sake of redundancy. This allowed for a comparison of integrated versus grab sampling techniques. The grab sample schedule was variable and is shown in Table 14.

4.0 RESULTS

Tracer test results are presented graphically in this report as plots of tracer concentration in discharge samples versus pumping volume from 22S, tracer concentration versus producing time in days, mass-normalized concentration versus producing time in days, and the percentage of the injected tracer mass recovered. Producing volume is the volume pumped between the time that chase water injection ended and the time the discharge water was sampled. Similarly, producing time is simply the time in days between the end of chase water injection and the sampling of the produced water. Mass-normalized concentration is calculated by dividing the measured tracer concentration in samples by the total mass injected. The total mass injected was first determined by weighing (measuring) the mass of tracer used to make up the tracer concentrate in the laboratory. It was initially believed that this was the most direct and accurate method of determining the mass injected assuming all of this mass stayed in solution, the purity of the samples was very high as reported, and all the mass was injected into the formation.

The second method of calculating the total mass was by multiplying the laboratory-measured tracer concentration in subsamples of the diluted tracer solution (collected immediately before injection) by the total volume of diluted tracer solution injected. In several tracer tests, this second method of determining total mass differed from the first method and at the same time resulted in mass-normalized curves that were more consistent with known tracer properties.

To differentiate between these two methods of determining mass and mass-normalized concentrations, different terms are used to describe mass and mass-normalized concentration values. For the first method, the terms "measured mass" or "measured mass-normalized values" are used; for the second method, the terms "calculated mass" or "calculated mass-normalized values" are employed. Unless otherwise stated, the "measured" method was used in this report.

Although just a subset of the tracers pumped was used for quantitative analysis (see Section 6), all tracer responses were analyzed qualitatively. For example, where two tracers of differing diffusion coefficients were simultaneously injected, their respective tracer response curves were reviewed for indications of stagnant water layers. Additionally, the tracer response curves for perrhenate and iodide were compared for signs of retardation of the perrhenate, which would imply a reducing environment. Also, observed nonconservative lithium tracer response was compared with the response of the conservative bromide tracer. Finally, observed temperature and pressure data during tracer injection, when available, were reviewed for potential insights. These qualitative analyses, based on tracer response and related data, will be described in Sections 4.1 and 4.2 as well as in subsequent sections, where appropriate.

4.1 Single-Well Push/Pull Tracer Test Results

4.1.1 Push/Pull Test 1

As described in Section 3.4.1, in the first of the single-well push/pull tracer tests, the tracer masses were displaced into Zone 2 of the aquifer and allowed to drift with the natural gradient for a period of 70.2 hrs, after which time they were pumped back into 22S. The measured tracer concentrations in parts per million (ppm) in the produced water versus cumulative gallons of water produced are shown in Figure 20. Cumulative tracer recovery as a percentage of measured injected tracer mass is shown in Figure 21.

The nearly identical measured mass-normalized tracer recovery curves are presented in Figure 22. The lack of differentiation between the tracer recovery curves indicates that mechanical dispersion was the dominant factor affecting the shape of the recovery curves and that diffusion into a stagnant layer was either nonexistent or limited. Mechanical dispersion coefficients for the two tracers should be identical in value, and they should therefore affect the shape of the recovery curve similarly. Also, these coefficients are typically several orders of magnitude larger than diffusion coefficients, at the minimum. The specific diffusion coefficients for the tracers used in this test differ by a factor of approximately two.

Prior to tracer testing, concerns were raised about potential differences in the observed tracer response curves obtained by integrated sampling methodology versus manual grab sampling methods. A comparison of tracer recovery curves generated by the higher-frequency integrated sampling versus grab sampling methods displays excellent agreement (Figure 23).

4.1.2 Push/Pull Test 2

During the second single-well push/pull tracer test, tracer masses were allowed to drift with the natural gradient for a period of 716 hrs, after which time they were pumped back into 22S. This resulted in a drift time 10 times longer than the drift time in Push/Pull Test 1, and allowed a greater chance for potential diffusion effects to be detected. The observed tracer responses in ppm in the pumped water are shown in Figure 24. Cumulative tracer recovery as a percentage of measured injected tracer mass is shown in Figure 25.

Figure 26 displays measured mass-normalized response curves of the injected tracers. These curves show that peak values are reached at approximately the same time; however, normalized measured mass recovered is higher for iodide than for 2,3,4,5-TeFBA. Since the diffusion coefficient for iodide is greater than for 2,3,4,5-TeFBA, it does not appear that this difference in recovery is the result of diffusion into a stagnant layer. Rather, this recovery difference suggests a mass balance problem that may be related to the amount of iodide and TeFBA mass actually injected. Initial tracer concentration measured versus calculated indicates that the calculated mass of iodide injected could be greater by 0.7%, while the calculated mass of TeFBA injected could be lower by 13.1%. Figure 27 displays the calculated mass-normalized response curves based on the mass injected as calculated from the initial tracer concentrations determined by UNLV-HRC. The two curves have nearly identical recoveries, as observed in Push/Pull Test 1 (Figure 22). Therefore, the differences between the curves shown in Figure 26 and Figure 27 are probably due to uncertainty in the amount of tracer mass actually injected and sample analysis and not the result of diffusion into a stagnant layer.

Figure 28 shows excellent agreement between tracer recovery curves based on the higher-frequency integrated sampling method and curves based on the grab sampling method, as observed in Push/Pull Test 1.

4.2 Cross-Hole Multiple-Well Tracer Test Results

4.2.1 Cross-Hole Test 1

The first of the cross-hole tracer tests introduced 2,4,5-TFBA and bromide tracers into the injection piezometer well 22PA Deep located approximately 59 ft due north of the pumping well 22S. Tracer responses in 22S, the down-gradient pumping well, are shown in Figure 29 in ppm produced versus the producing time in days. Producing time is obtained by subtracting the date of sampling from the date when the injection of tracer chase water was completed. The curves in Figure 29 show that both bromide and 2,4,5-TFBA tracers first arrived (i.e., broke through) in Zone 2 of 22S in 0.3 days. This indicates an average first-arrival velocity of 197 ft/day, which is very rapid.

Measured mass-normalized tracer response curves are displayed in Figure 30. The magnitudes of the peaks are once again different, as they were in the second single-well push/pull test, suggesting a possible mass balance problem that may be related to uncertainty in the laboratory measurements. Initial tracer concentrations measured versus calculated indicate that the mass of bromine injected could be lower by 12.5%, while the mass of 2,6-DFBA injected could be lower by 5.4%. Figure 31 displays the calculated mass-normalized response curves based on the mass injected, as calculated from the initial tracer concentrations determined by UNLV-HRC. The two curves have nearly identical recoveries and are within the expected laboratory analysis error.

Mechanical dispersion is many orders of magnitude larger than diffusion at the higher fluid velocities induced by long-term pumping in these cross-hole tests. Thus, mechanical dispersion effects on recovery curves should mask any effects of diffusion. Moreover, mechanical dispersion values should be similar for each tracer and should have a similar effect on the recovery curve. Thus, any differences between the curves are most likely due to uncertainty in the amount of tracer mass actually injected and the related laboratory measurements, and not to the result of diffusion into a stagnant layer.

As observed in the single-well push/pull tests, response curves generated by higher-frequency integrated sampling methods agreed closely with curves resulting from using grab sampling methods (Figure 32). In addition, tracer recovery as a percentage of injected tracer mass was very high in the single-well push/pull tests (Figure 33).

Although the focus of the Nye County tracer tests is on conservative (i.e., non-reactive) tracers, data were generated for the nonconservative tracer lithium, which was used for charge balance with halide ions. The tracer response of lithium is shown, together with bromide, in Figure 34 in ppm produced versus producing days. Note that lithium showed evidence of response in 22S at approximately the same time as the bromide, indicating that, for at least some of the lithium mass injected, no retardation took place. The slow, nearly flat, lithium decline observed after 10 days is most likely caused by retardation of the remaining lithium mass. Cation exchange reactions (lithium with other cations present on mineral surfaces) are likely responsible for much of the lithium retardation.

4.2.2 Cross-Hole Test 2

The second cross-hole tracer test introduced the 2,6-DFBA tracer into the aquifer via 22PC Deep, approximately 59 ft due east of 22S. Tracer response in 22S, shown in Figure 35 in ppm produced versus the producing days, shows that tracers injected in 22PC first arrived in Zone 2 of 22S in 5.1 days. This indicates an average first-arrival velocity of 11.5 ft/day. This calculated breakthrough velocity is significantly lower than the velocity calculated for the first cross-hole test between 22PA Deep and 22S. The time required to reach peak concentration was also significantly longer (approximately 20 days versus 5 or 6 days) than the time observed for the first cross-hole test. Similar trends were observed in the mass-normalized tracer response curve, as displayed in Figure 36.

Tracer recovery as a percentage of injected tracer mass is high, as shown in Figure 37. As in previous tests, the comparison between the higher-frequency integrated sample results and the grab sample results shows excellent agreement (Figure 38).

4.2.3 Cross-Hole Test 3

The third cross-hole, multiple-well tracer test introduced a low mass of 2,5-DBFA into the aquifer via 22PA Shallow (Zone 1), 59 ft due north of 22S . This tracer was not observed during the pumping of Zone 2 in 22S. It is possible, however, that the tracer was produced below the detectable limits. This lack of response indicates that Zones 1 and 2 are not directly connected and that there are likely some restrictive (i.e., lower-permeability) layers present between these zones, which is consistent with the textural layering discussed in Section 2.

4.2.4 Cross-Hole Tracer Test 4

Initial tracer test results, briefly described in Sections 4.2.1 through 4.2.3, indicated that the highest travel velocity of conservative tracer, from 22PA Deep to 22S in Zone 2 (i.e., Cross-Hole Test 1), was observed in the first three cross-hole tests. Based on these preliminary results, microsphere colloids were injected into 22PA Deep in order to maximize the potential microsphere tracer response in 22S during the limited pumping window remaining in the UIC permit.

Microsphere tracer results are displayed in Figure 39. In general, compared with Cross-Hole Test 1, the results show similarly rapid movement in Zone 2 between 22PA Deep and 22S.

4.2.5 Cross-Hole Tracer Test 5

Perrhenate and iodide were injected into 22PA Deep, which is located approximately 59 ft due north of pumping well 22S, for the same reason these wells were selected for the microsphere cross-hole test; that is, a rapid tracer response and recovery was expected in 22S based on previous cross-hole test results. Perrhenate and iodide tracer response, shown in Figure 40 in ppm produced versus the producing days, indicates rapid movement in Zone 2, similar to results observed for Cross-Hole Tests 1 and 4. The mass-normalized tracer response curves also show the same fast response for first arrival and peak, as shown in Figure 41. As expected, small differences between perrhenate and iodide responses fall within the expected laboratory analysis error. Given the similarity of perrhenate and iodide responses, oxidizing conditions appear to exist.

As in previous tests, the comparison between the higher-frequency integrated sample results and the grab sample results shows excellent agreement (Figure 42). Tracer recovery as a percentage of injected tracer mass is high, as shown in Figure 43.

5.0 TRACER TEST MODELING ANALYSIS METHODOLOGY

This section describes numerical modeling methods, including model development, inputs, and calibration, for cross-hole testing. Once a calibrated model was developed for cross-hole testing, it was used to simulate single-well push/pull tests. The goal of this modeling effort was to be able to simulate the observed results of tracer tests with a model that is geologically reasonable for the alluvial depositional environment of concern.

5.1 Software

Several analytical and numerical methods are available for analyzing tracer test data. These methodologies include individual well analysis of tracer response, well pair analysis of tracer response, and coupled response analysis using numerical simulation. Tools available for individual well or well pair analysis are described in WP-9 (NWRPO, 2003a) and will not be considered further in this report. This report will focus on coupled-response numerical simulation.

Since the observed tracer responses in Zone 2 of 22S from the two injection wells (22PA Deep and 22PC Deep) were so different (Sections 4.2.1 and 4.2.2), finite-difference numerical simulation was used to perform a coupled analysis. The simulation package used consisted of Visual MODFLOW® v. 3.1.0.86 from Waterloo Hydrogeologic, Inc., coupled with the Modular 3-D Transport model, Multi-Species (MT3DMS). MT3DMS was used to solve the tracer transport, while MODFLOW was used to solve the fluid flow.

5.2 Simulation Model Geometry and Initial Parameters

Simulation requires discretization of the 3-D hydrogeologic system and digital representations of the required hydraulic and transport parameters. Initial hydrogeologic parameters for Site 22 were obtained from *Analysis of Aquifer Pump Tests in Individual*

Well Zones at Site 22 near Yucca Mountain, Nevada (NWRPO, 2004). Calibration of the simulation to the observed data requires modification of the initial input values, both hydrogeologic and transport, until a reasonable match between the simulation and observed data is obtained. Care must be taken to ensure that the modifications made to obtain the calibration are reasonable for the system being modeled. Additionally, it must be noted that any simulation or analytical solution of this type of test is nonunique.

Model calibration can be obtained through multiple techniques, such as automated nonlinear parameter estimation packages, visual best fit technique, least squares method, or combinations of all of the above.

Automated nonlinear parameter estimation was used early in the calibration but was found to be too limiting since the calibration process for this model involved changing the position of the paleochannel. The most cost effective calibration methodology, in both time and parameter magnitude estimation, was determined to be visual best fit along with parameter sensitivity analysis. The sensitivity analysis confirmed the final calibration as being reasonable. Further attempts at calibrating the model did not yield significant improvement, given the time involved and budgetary constraints.

The model, as constructed, consisted of three layers. The upper and lower layers are buffers for Zone 2, the screened/sandpacked interval simulated. The initial hydrogeologic parameters and model dimensions are shown in Table 15. The model geometry in map view is displayed in Figure 44.

Lateral boundaries for the simulation consisted of constant head boundaries along north and south model edges and no flow boundaries along east and west model edges. The constant head boundaries imposed a north-to-south hydraulic gradient of 0.00014 ft/ft (BSC, 2003). The model contained no recharge boundaries, as the time frame of simulation precludes the effect of recharge.

Pumping stress intervals are shown in Table 16. Tracer injection rates, pumping rates, times, temperatures, and water pressure for the tests are described in Section 3.

5.3 Simulation Model Tracer Response Input Data

Since the simulation curve had less refinement in time than the observed tracer response data, the simulation was matched to a temporal subset of all observed conservative tracer responses. Tracer response data were imported into MODFLOW for use during model calibration.

The break in pumping of 159 days created an opportunity to observe and match transport behavior impacted by both forced and natural gradient effects. The perpendicular locations of the tracer injection points (22PA and 22PC) compared to the producing well (22S) also maximized the potential to observe both the azimuth and the magnitude of the natural gradient acting on the in situ tracer masses.

5.4 Simulation Model Calibration Strategy

As mentioned in Section 5.0, it was determined that model calibration could be accomplished efficiently and in a technically sound manner by first concentrating on calibrating the model against the cross-hole conservative tracer test results. Then, using the same calibrated model, its ability to match the single-well push/pull test conservative tracer results with few or no changes to the hydraulic parameters (e.g., effective porosity, hydraulic conductivity, and hydraulic gradient) while modifying transport parameters to obtain a good match, was evaluated.

Although multiple cross-hole tracers were injected in upgradient piezometers, only two unique conservative tracer responses were noted in 22S during the cross-hole testing. These unique responses in 22S were for bromide injection into 22PA Deep (Cross-Hole Test 1) and 2,6-DFBA injection at 22PC Deep (Cross-Hole Test 2). This allowed the model calibration of the cross-hole tests to be addressed through modeling only two conservative tracer responses.

Perrhenate injection at 22PA Deep (Cross-Hole Test 4) was not used in model calibrations because it did not contain a natural drift component in its response curve. The response of lithium, a reactive tracer, was not used in the calibration. It was modeled (see Section 6), but its observed response was determined early on to be too complicated to calibrate, given time and budgetary constraints.

The quantified calibration strategy for each unique response consisted of several steps. First, breakthrough timing and peak tracer response, which are both dominated by the effective porosity, were matched. Second, the impact of pumping suspension on the tracer tails (i.e., declining concentrations), and the small peaks observed when pumping resumed on August 25, 2005, which are both impacted by the magnitude and azimuth of the hydraulic gradient, were matched to the model. Finally, calibration of the hydraulic conductivity was finished based on the observed pressure head data obtained during testing. The quantified calibration results are presented and discussed in Section 6.

5.5 Development of a Consistent Geologic Model

The observed rapid breakthrough of tracer material from 22PA Deep to 22S suggests a low effective porosity pathway in Zone 2 between these two wells (Section 4.2.1). Prior to this tracer test, hydraulic testing (NWRPO, 2004) indicated a high permeability for Zone 2 between these wells. This combination of low effective porosity coupled with high permeability is typically associated with the fractured volcanic aquifer at Yucca Mountain (BSC, 2003), and not the alluvial valley fill geologic setting at Site 22.

The following describes additional hydraulic and transport data and analyses resulting from tracer tests, which provide insight into a more realistic geologic model for Zone 2 between 22PA and 22S. At the time of the NWRPO, 2004 study, the pumping and observation wells available for testing and analysis (i.e., 22S, 22PA, and 22PB) were located primarily in a north-south direction. After that study, 22PC was drilled and completed due east of 22S, which provided additional opportunities for hydraulic analysis orthogonal to the previously analyzed north-south direction.

5.5.1 Additional Hydraulic Data and Transport Calculations Related to Geologic Model Development

As discussed in Section 3.3, Westbay® pressure/temperature measuring probes were placed in each zone in pumping well 22S and each of the six observation strings in the piezometers. Preliminary analysis of the pressure response during tracer tests between the active well 22S and the observation wells 22PA Deep and 22PC Deep indicates that permeability is slightly higher (approximately 15%) between 22PC Deep and 22S than between 22PA Deep and 22S. This result clearly does not support the concept that a large permeability contrast between 22PA and 22PC is the driving force behind the rapid breakthrough time observed from 22PA to 22S. Rather, it provides supporting evidence that a low effective porosity is primarily responsible for the rapid breakthrough. The preliminary analysis of the pressure response is discussed in Appendix C.

Additionally, the observed breakthrough time from 22PC Deep to 22S was similar to the original breakthrough time estimates made in WP-9 (NWRPO, 2003a), which used an effective porosity of 30%. This result suggests that the low effective porosity, which is likely responsible for the early breakthrough between 22PA and 22S in Zone 2, is not widely distributed around the Site 22 location.

5.5.2 Tracer Breakthrough Curves and Geologic Model Development

A model that could support the observed results and that is geologically reasonable for the depositional environment is a sinuous channel system. Figure 45 shows an aerial view of Site 22. The channel system observed in nearby Fortymile Wash provides a possible template for the presence of one or more geologically supported paleochannels at depth beneath Site 22.

Qualitative and quantitative analyses (see Section 6 for the latter) of the tracer responses suggest that 22S lies on the edge of a low effective porosity paleochannel.

One semi-quantitative method used was derivative analysis. Assuming that major tracer response trends are results of the geology and not experimental error, the derivative analysis suggests that more than three different tracer responses (i.e., breakthrough curves) occurred at 22S from 22PA Deep, as illustrated in Figure 46. These different responses suggest different pathways between 22S and 22PA. In contrast, the derivate analysis of tracer response from 22PC Deep to 22S was fairly smooth and indicates a single tracer breakthrough curve, as shown in Figure 47. The single tracer breakthrough curve indicates that tracer traveled from 22PC to 22S via a single, relatively homogenous pathway.

One conceptual model of adjacent paleochannels that would account for these pathways is shown as a horizontal plane through Site 22 in

Figure 48. These channels are oriented approximately north-south, and their widths are expected to be at least 10 meters, based on the width of present-day Fortymile Wash.

This conceptual horizontal plane through Zone 2 shows that: the 22PA Deep screen is located in the center of a very coarse-grained channel (the western channel), with a very low effective porosity; the 22PC Deep screen is located in the center of an adjacent channel (the eastern channel) with an intermediate effective porosity; and 22S Zone 2 is located at the edge of this same intermediate effective-porosity channel, which abuts the channel with very low effective porosity.

Clearly, variations in the general shape, width, and thickness of these channels at different depths in Zone 2, as well as variations in the location of the injection wells and the pumping well within these channels, could result in several different pathways and, thus, several different breakthrough curves. For example, placing 22S in the simulated low effective porosity paleochannel decreases the time to first arrival of the tracer from 22PC Deep to 22S; and placing the well too far from this paleochannel delays the breakthrough from 22PA to 22S.

An alternative conceptual geologic model could include a series (e.g., three) of separate narrow paleochannels, each a few meters wide that pass close to both 22PA Deep and 22S. This seems unlikely, however, since no geophysical or hydrogeologic information is available that indicates the presence of a system of narrow confined channels where the tracer could become trapped and unable to move laterally into the larger alluvial aquifer system. No evidence has been found of low-permeability boundaries, such as cementation or depositional bounding surfaces, in the alluvium at Site 22. It is also very unlikely that the vertical wells drilled at Site 22 would have intercepted a channel in a system that connected 22PA and 22S if the channel was only a few meters wide. This suggests that the aerial extent of the paleochannels is similar to modern-day Fortymile Wash channel widths, which are 10 meters (or more) wide.

The hypothesis that 22S is situated near the edge of the paleochannel was independently supported through the model calibration described in Section 6. Placing 22S in the center of the paleochannel impeded model calibration, since the lower effective porosity reduced the breakthrough time of tracer from 22PC to 22S.

As mentioned previously, it is important to note that any modeling effort is nonunique. Multiple models can be calibrated to match the observed tracer response. The goal of the analysis is to match the observed responses with a reasonable geologic model, which can then be used to gain an understanding of the modeled flow system.

Even though the derivative curve indicates multiple paths between 22PA Deep and 22S in Zone 2, time, budgetary, and software constraints limited modeling efforts to three vertical zones: the upper and lower bounding layers and the zone of interest (Zone 2). Reducing the zonal resolution resulted in an averaging of layer properties in the model. This simplified model is shown schematically in Figure 49 in cross-section.

Because of the nonunique nature of the model, one possible alternative model would be to divide Zone 2 into three layers with different effective porosities. It would then be possible to calibrate the model by varying the properties of the three layers. The resulting understanding of the layer properties may not be significantly different than the understanding achieved with the simplified model shown in Figure 49. Additionally, because of the nonunique calibrated models, the understanding of the transport system may not be measurably improved through a finer vertically gridded simulation.

It is important to recognize that no vertical tracer response data were gathered during the testing nor was it physically possible to gather these data at the pump well (22S). All water from Zone 2's screened interval of 661.2 to 760.6 ft bgs is produced from a single pumping port located at 752.9 ft bgs. Efforts to identify vertical entry points for tracer at 22PA Deep indicated generally uniform injection as discussed in Section 3.5.2.

5.6 Specific Calibration Procedures

Once the geologically reasonable model described in Section 5.5 was developed (based on preliminary tracer response and related hydraulic data capable of accounting for fast pathways between 22PA and 22S and slower pathways between 22PC and 22S), these calibration procedures were followed:

- The model was populated with hydraulic and transport parameters obtained from previous testing and from published or public data sources.
- The geologically reasonable model was calibrated to conservative tracer responses observed among the three wells (22S, 22PA Deep, and 22PC Deep).The hydraulic and transport parameters were adjusted in a defensible manner to obtain a reasonable match between observed and simulated tracer response data.
- The configuration of the paleochannels with respect to the locations of the three wells was also adjusted during model calibration as described in Section 5.5.2.
- Sensitivity analysis was used to study how the hydraulic gradient magnitude and azimuth affected response of curves following pump downtime.
- Hydraulic properties were adjusted to refine the calibration of observed and simulated hydraulic head data.
- The ratio of longitudinal to vertical dispersivity was kept at 100, for the reasons discussed in Section 5.5.2.
- The single-well push/pull tracer test was modeled using hydraulic properties from calibrated cross-hole tracer tests; changes to relevant transport properties were made as needed for calibration.

As mentioned previously, the cross-hole tracers used in the quantified calibration were bromide injected into 22PA Deep and 2,6-DFBA injected into 22PC Deep. In these tests, the observed tracer response data were measured and the matched tracer response data were simulated at the 22S pumping well. Iodide responses in 22S following injection and during recovery, were used in the quantified calibration of transport properties of the single-well push/pull tracer tests. The results of these quantified calibrations are shown and discussed in Section 6.

6.0 CROSS-HOLE QUANTITATIVE TRACER TEST ANALYSIS RESULTS

This section describes quantitative calibrations that resulted in a geologically reasonable model that captured the large-scale behavior of the fast flow path between 22PA Deep and 22S while maintaining the slower tracer breakthrough observed between 22PC Deep and 22S. As discussed previously, the pump downtime period during the cross-hole test presented an unanticipated opportunity to observe the response of the tracer mass to the natural gradient.

To quantitatively calibrate the cross-hole model to the observed data, conservative tracer responses from 22PA Deep (bromide) and 22PC Deep (2,6-DFBA) were used. The model was not calibrated to the responses of nonconservative tracers such as lithium due to budgetary and time constraints. The use of conservative tracers permitted quantitative calibration efforts to focus on the following parameters:

- Hydraulic conductivity
- Effective porosity
- Dispersivity (longitudinal, transverse, and vertical)
- Paleochannel geometry
- Hydraulic gradient magnitude
- Hydraulic gradient azimuth
- Diffusivity

Parameters were generally calibrated in the order listed above. However, the calibration process was not necessarily done in series. After one parameter is adjusted during calibration, previously calibrated parameters may need to be readjusted to obtain the best fit of the simulated to measured results. This calibration process continued until a best fit visual match of the simulated versus measured breakthrough curves was achieved.

6.1 22PA Deep Bromide Tracer Test 1 Cross-Hole Calibrations

6.1.1 Bromide Tracer Response Calibration

Final calibration parameters that resulted in the best match between observed and simulated tracer responses are shown in Table 17. Figure 50 displays the calibration match obtained for bromide. The calibration curve agrees quite well with the observed data in breakthrough timing and in the match of the peak response. However, observed data falls faster than the calibrated data. This may be the result of the limited three-layer model. In the model, the screen interval (Zone 2) is represented by a single layer with an average effective porosity, whereas the derivative analysis appears to suggest that the actual geologic setting may contain more than three distinct effective porosity values.

After the 159-day pump downtime, a good match of the second peak was obtained using a hydraulic gradient of 0.00014 ft/ft north to south. Once again, however, the observed tracer decline after the second peak was faster than in the calibrated model. This is likely the result of the simplified geologic model.

The tracer concentration once pumping was restarted after the 159-day interruption is higher than the tracer concentration immediately prior to the interruption. Continued tracer mass movement toward 22S, due to the natural gradient, was the reason for this large increase in tracer concentration (nearly 67%). The quick decline observed after the second peak is the result of rapid dilution of the tracer plume in unaffected water surrounding 22S, as illustrated in Figure 51. Only a portion of the radial drainage area surrounding 22S contains the tracer plume from 22PA Deep (Figure 51). When pumping was restarted, the near wellbore environment was produced first, and this area almost completely comprised the tracer plume. As pumping continued, water was produced in a radial fashion expanding away from the 22S wellbore. The expanding cylinder of water contained less and less of the tracer plume, and the composite tracer concentration produced from the well declined, until it reached the concentration prior to the pumping interruption. From this point, concentration continued to decline with production, consistent with behavior before the interruption.

6.1.2 Bromide Tracer Test Head Calibration

Head data obtained during the tracer test were also used in the calibration. Due to the fact that Visual MODFLOW does not account for well efficiency, heads were matched based on the drawdown corrected for well efficiency as determined in NWRPO, 2004. The simulation showed almost no tracer response sensitivity to hydraulic conductivity. Variations in hydraulic conductivity affected the simulated head values only to a small extent, which was expected, due to the very high conductivities observed at Site 22 (NWRPO, 2004). Simulated and observed head data are shown in Table 18.

6.2 22PC Deep 2,6-DFBA Tracer Test 2 Calibrations

6.2.1 2,6-DFBA Tracer Response Calibrations

Final calibration parameters, which produced the best match between observed and simulated 2,6-DFBA, are shown in Table 19. Figure 52 displays the calibration match obtained for 2,6-DFBA. This figure shows that the simulated calibration curve agrees quite well with the observed data in breakthrough timing, peak response, and post-peak decline.

The match of the second peak observed after the extended pump downtime was obtained using a hydraulic gradient of 0.00014 ft/ft north to south. The calibrated model does not match the magnitude of the observed peak, but does exhibit the drop in tracer concentration after pumping interruption, followed by a rise in tracer concentration after the restart of pumping, as found in the observed data.

After the pumping interruption, there was an observed decreasing tracer concentration (i.e., valley). The mechanism responsible for this was continued tracer mass movement away from 22S caused by the natural gradient. The observed tracer rebound (i.e., the subsequent second peak) is a result of the tracer plume being pulled into 22S from the forced gradient that developed after the pump was restarted. Figure 52 demonstrates that the second peak is just slightly greater than the projected tracer decline and may even be within the uncertainty band of this analysis. This behavior of decreasing tracer concentration, coupled with a rebound to tracer concentration decline observed prior to pumping interruptions, is supportive of the concept of the tracer plume moving away from 22S due to the natural gradient.

A more refined geologic model might facilitate an improved match of the second peak response and/or rotation of the gradient from a strictly north-south azimuth to a slightly northeast-southwest azimuth. Again, time and budgetary constraints limited the final match.

6.2.2 2,6-DFBA Tracer Test Head Calibration

Head data obtained during the tracer test were also used in the calibration. As discussed previously, modifications to hydraulic conductivity had little effect on tracer response, because the time to initial breakthrough was dominated by the effective porosity, and the impact on tracer response after pumping interruption was dominated by the hydraulic gradient. Simulated and observed head data are shown in Table 18.

6.3 Cross-Hole Tracer Test Sensitivity Analysis Results

One benefit of using a numerical simulation to study tracer response is the ability to easily perform sensitivity analyses on selected calibration parameters. Qualitative analysis of the tracer response after pumping interruption, prior to quantitative simulation, suggested that both the magnitude and azimuth of the hydraulic gradient could be affecting the response, and that the tracer response contained information about these parameters.

6.3.1 Gradient Magnitude and Azimuth Sensitivity

Sensitivity analysis was performed during and after calibration on both the magnitude and azimuth of the hydraulic gradient. The best fit was obtained using the published values of 0.00014 ft/ft, north to south (BSC, 2003). Sensitivity cases that were run include the following:

- 0.00014 ft/ft east to west.
- 0.000875 ft/ft (6.25 times the published value) north to south and east to west.
- 0.00175 ft/ft (12.5 times the published value) north to south and east to west.
- No gradient.

Results from the sensitivity analysis for bromide response from 22PA Deep are shown in Figure 53. As shown on the plot, the magnitude and azimuth of the gradient profoundly affect the tracer concentration curves upon reactivation of pumping. As described in Sections 6.1 and 6.2, the azimuth of the natural gradient will either drive the tracer plumes toward or away from 22S. This in turn will affect the initial post recovery tracer concentrations, driving the response either below the previous tracer tail decline or above it. History matching of these responses confirms the expected general north-south azimuth of the natural gradient at Site 22S. Figure 53 illustrates the effect of gradient magnitude on the movement of the tracer plume. A high gradient drives the plume too quickly through the 22S wellbore, resulting in a tracer response that peaks lower than the observed data. A lack of gradient results in no plume movement, and the tracer response lacks the observed higher concentration after the restart of pumping.

The close spacing of the wells at Site 22, coupled with the high conductivity, does not allow for the measurement of an accurate gradient due to the limited accuracy of the available water level measurement method; therefore, from onsite measurement, the gradient appears to be zero. However, the tracer response clearly indicates that a gradient is present.

The sensitivity analysis also confirms that the previously extrapolated gradient, obtained through mapping the available head data over the larger alluvial aquifer (BSC, 2003), is likely the gradient that currently exists at Site 22, within an order of magnitude.

6.3.2 Geologic Model Sensitivity

Qualitative analysis, as described in Section 5.5.2, was used to assist in the development of the geologic model. Sensitivity analysis performed on the geologic model supports the conclusion that 22S lies on the edge of a low effective porosity channel rather than in a more central location of this feature. Figure 54 displays the results obtained from setting the hydraulic properties of the eastern channel equal to those of the western channel. Changing the geologic model so that it has just the western channel properties results in a higher peak tracer breakthrough of 2,6-DFBA in addition to a lower secondary peak response upon the restart of pumping. In contrast, changing the channels to have the eastern channel properties has little effect on the match of 2,6-DFBA. These results support the placement of 22S on the eastern edge of the western channel and in the eastern channel, as determined qualitatively from the derivative analysis.

6.3.3 Hydraulic Conductivity Sensitivity

As described in Sections 6.1.2 and 6.2.2, the model was calibrated to the observed head data obtained during the tracer testing. Hydraulic conductivity sensitivity analysis was performed to determine the effects on the tracer response calibration since this parameter is often believed to have a first-order effect on tracer response. Figure 55 displays tracer response sensitivity to hydraulic conductivity. Changes to the hydraulic conductivity do influence the tracer response curves, similar to the types of changes observed with changes in effective porosity.

However, this requires changing the hydraulic conductivity by a factor greater than 3.5 to change the peak tracer response by a factor of only 1.3. Alternatively, changing the effective porosity by a factor of 3 changes peak tracer response by a factor of 2.9, while maintaining head calibration match. Note that head calibration match is lost with changes to hydraulic conductivity.

7.0 SINGLE-WELL PUSH/PULL QUANTITATIVE TRACER TEST ANALYSIS RESULTS

After modeling the multiple-well cross-hole tracer tests conducted in saturated alluvium at Site 22, the push/pull tests were simulated using the same geologic model. Figure 56 displays the match obtained on the first push/pull test. This match was obtained through a change in dispersivity, a scale-dependent factor, but there were no changes to the geologic model. Calibration match parameters for Push/Pull Test 1 are shown in Table 20.

Figure 57 displays the match obtained on the second push/pull test. Again, the match was obtained through a change in the dispersivity, a scale-dependent factor, but there were no changes to the geologic model. Calibration match parameters for Push/Pull Test 2 are shown in Table 21.

Tracers with different diffusion coefficients were injected in both the cross-hole and single-well tests in the anticipation that potential diffusion into stagnant layers could be identified. No conclusive evidence of diffusion was determined in any of the tests given the uncertainty in laboratory analysis. A review of the fundamental equations governing dispersion provides insight into the observed results. As shown in the equation below for dispersion in one direction (x tensor; S.S. Papadopulos & Associates, Inc., 1990):

$$D_{xx} = \alpha_L \frac{v_x^2}{|v|} + \alpha_{TH} \frac{v_y^2}{|v|} + \alpha_{TV} \frac{v_z^2}{|v|} + D^*$$

Where

D_{xx} = principal component of the dispersion tensor, ft^2/day

α_L = Longitudinal dispersivity, ft

α_{TH} = Transverse dispersivity, ft

α_{TV} = Vertical dispersivity, ft

v = velocity in x, y, or z direction, ft/day

D* = effective molecular diffusion coefficient, ft^2/day

$|v| = \sqrt{v_x^{\ 2} + v_y^{\ 2} + v_z^{\ 2}}$ = magnitude of the velocity vector, ft/day

A quick review of the calibration parameters used in the analysis (as shown in Table 21) illustrates the insignificance of diffusion in the tracer dispersion. In the cross-hole tests diffusion was expected to account for much less than one tenth of 1% of the dispersion. Diffusion becomes more important in extremely low velocity tests, such as natural gradient testing, and to a lesser extent, the single-well push/pull tests. However, in each of these low velocity tests, placement of the tracer into the formation is accomplished at a relatively high velocity, which can then dominate the tracer dispersion and subsequent analysis.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The multiple tracer tests that were conducted in saturated alluvium at Site 22 in lower Fortymile Wash indicate that, for the tracers used and for duration of the tests, the aquifer tested had the following properties:

- The aquifer was in an oxidizing state.
- Little to no diffusion into stagnant layers occurs.
- A fast pathway, best modeled as a low effective porosity system, exists between 22PA Deep and 22S.
- The calibrated effective porosities of the western and eastern channels (as modeled) were 8.2% and 24%, respectively. Both porosity values are within the ranges utilized in the Site-Scale Saturated Zone Flow Model ([SSFM] BSC, 2003)
- The modeled longitudinal dispersivity values (calibrated to the cross-hole test data) for the western and eastern channels were 20 ft and 7 ft, respectively. Both values are within the ranges utilized in the SSFM.
- Modeled longitudinal dispersivity values, calibrated to the first and second single-well push/pull test data, were 0.2 ft and 1 ft, respectively. These values are very close to the lower limits utilized in the SSFM.
- The natural gradient is best modeled (as determined during sensitivity analysis) with a north-to-south azimuth and a magnitude of approximately 0.00014 ft/ft (value published in BSC, 2003).
- Microspheres and lithium tracers displayed complex behavior with rapid breakthroughs, rapid initial declines, then very shallow declines.
- Single-well push/pull tests provide near-wellbore hydraulic information, but cannot replace cross-hole tests for aquifer characterization.
- Cross-hole tracer testing using multiple wells provides a better estimation of distributed hydraulic parameters than single-well testing due to the greater amount of aquifer tested.
- Use of tracers with diffusion coefficients less than two orders of magnitude different in the alluvium during forced-gradient cross-hole tracer testing leads to ambiguous results and is not cost-effective.

The model, as calibrated, suggests that a small volume, low effective porosity channel system is present in the tested pore space at Site 22. This low effective porosity channel was modeled as a paleochannel using the modern day Fortymile Wash as a guide. If this paleochannel system is continuous over large north-south lateral distances, as suggested by Fortymile Wash, the effective porosity of the total alluvial aquifer should be on the lower end of the distribution currently modeled in the SSFM.

Longitudinal dispersivity values from the calibrated model suggest that the current distribution utilized in the SSFM is skewed toward larger values than what may be reasonable for the alluvial aquifer.

8.1 Recommendations

- Confirm the magnitude and azimuth of the natural gradient by conducting a natural-gradient tracer test.
- Consider pumping interruptions during tracer tails for future tracer testing.
- Incorporate numerical modeling into analyses of multiple-well cross-hole tracer tests.
- Incorporate numerical modeling sensitivity analyses during the design of future tracer tests.
- Revised distributions of both effective porosity and longitudinal dispersivity for the alluvial aquifer system should be considered for the SSFM based upon the model calibration results discussed in this report.

9.0 REFERENCES

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FIGURES

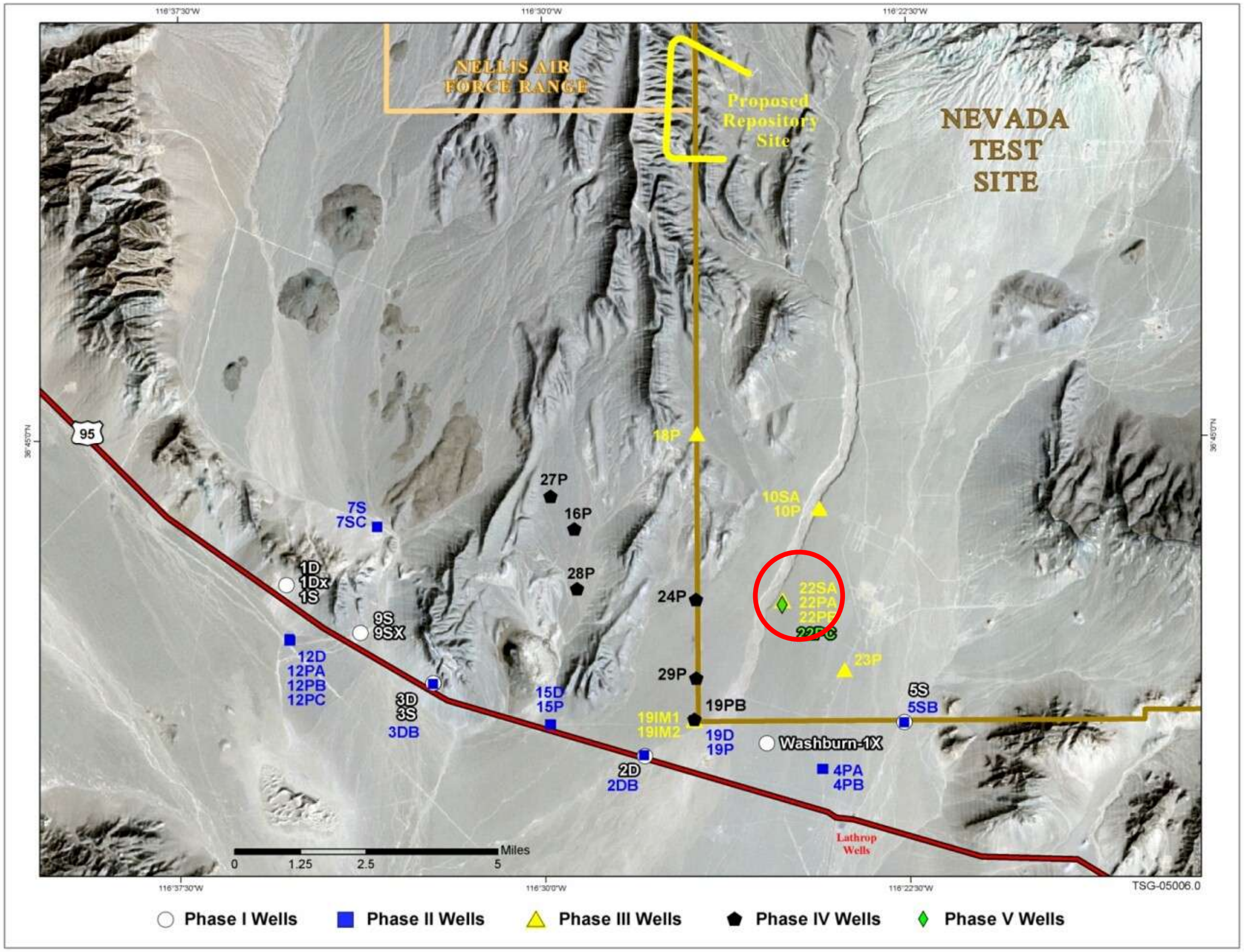

Figure 1. Location of Site 22 (shown with a red circle) in relation to other nearby EDWP wells and the proposed Yucca Mountain repository site.

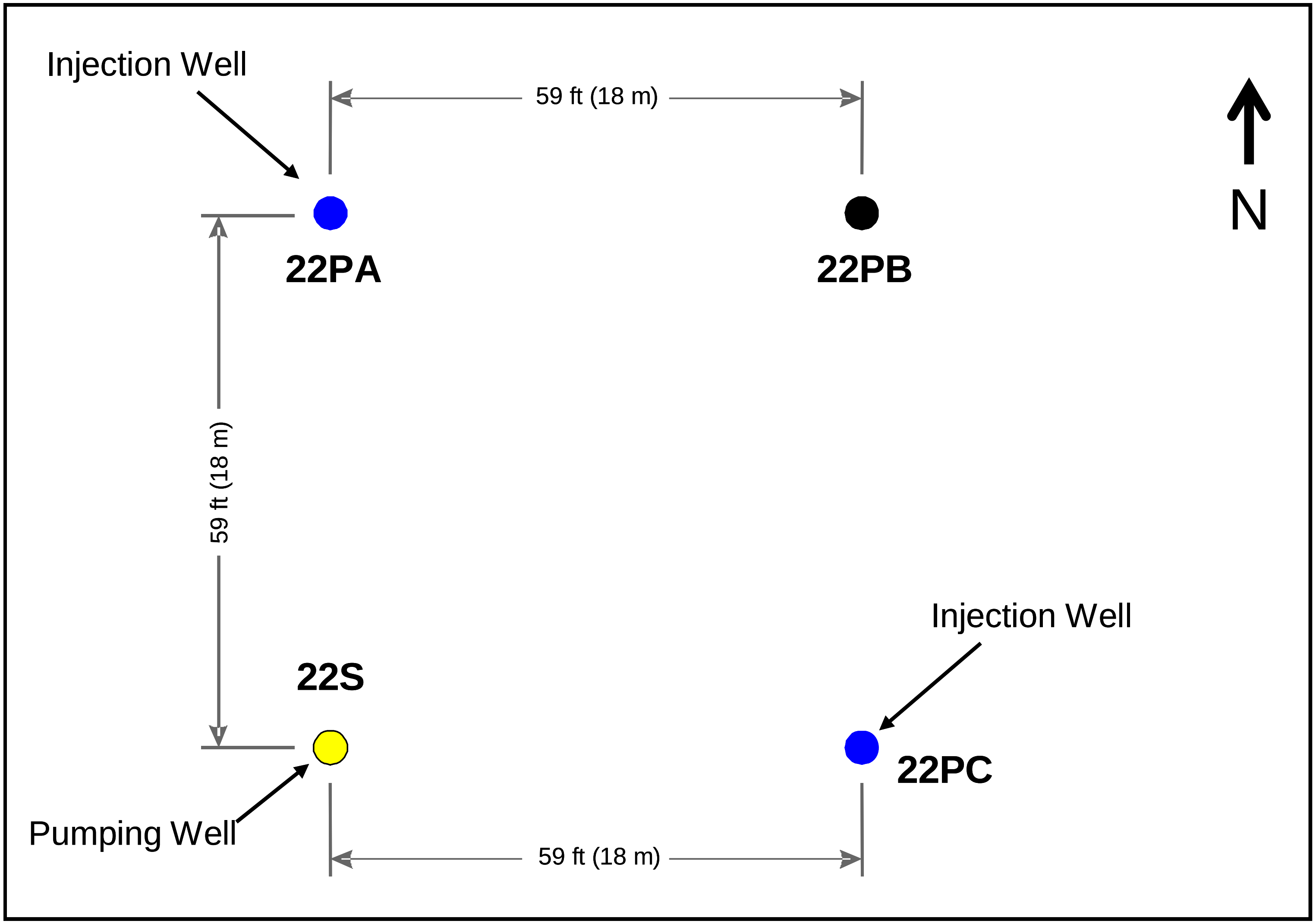

Figure 2. Surface layout of Site 22.

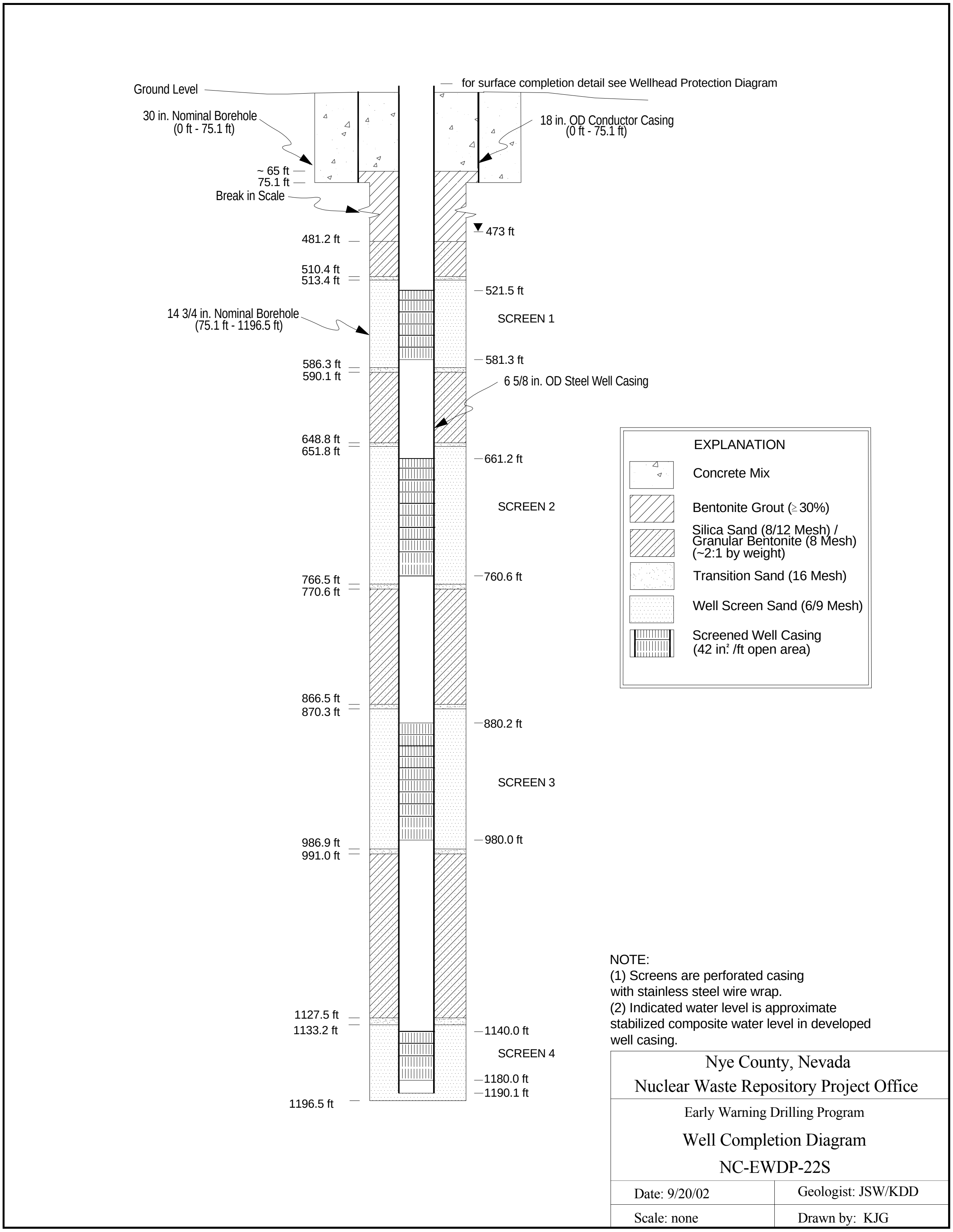

Figure 3. Well completion diagram for 22S.

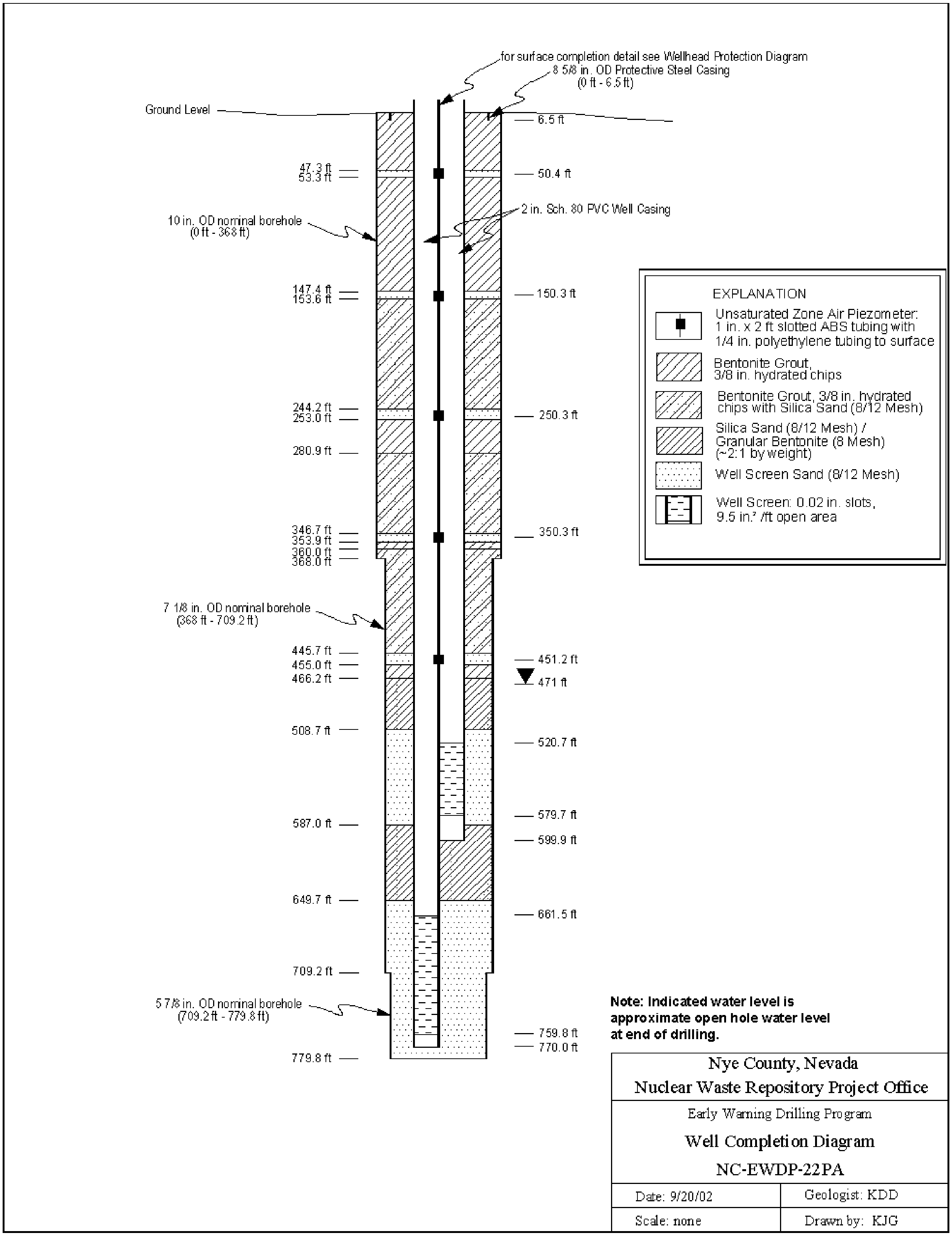

Figure 4. Well completion diagram for 22PA.

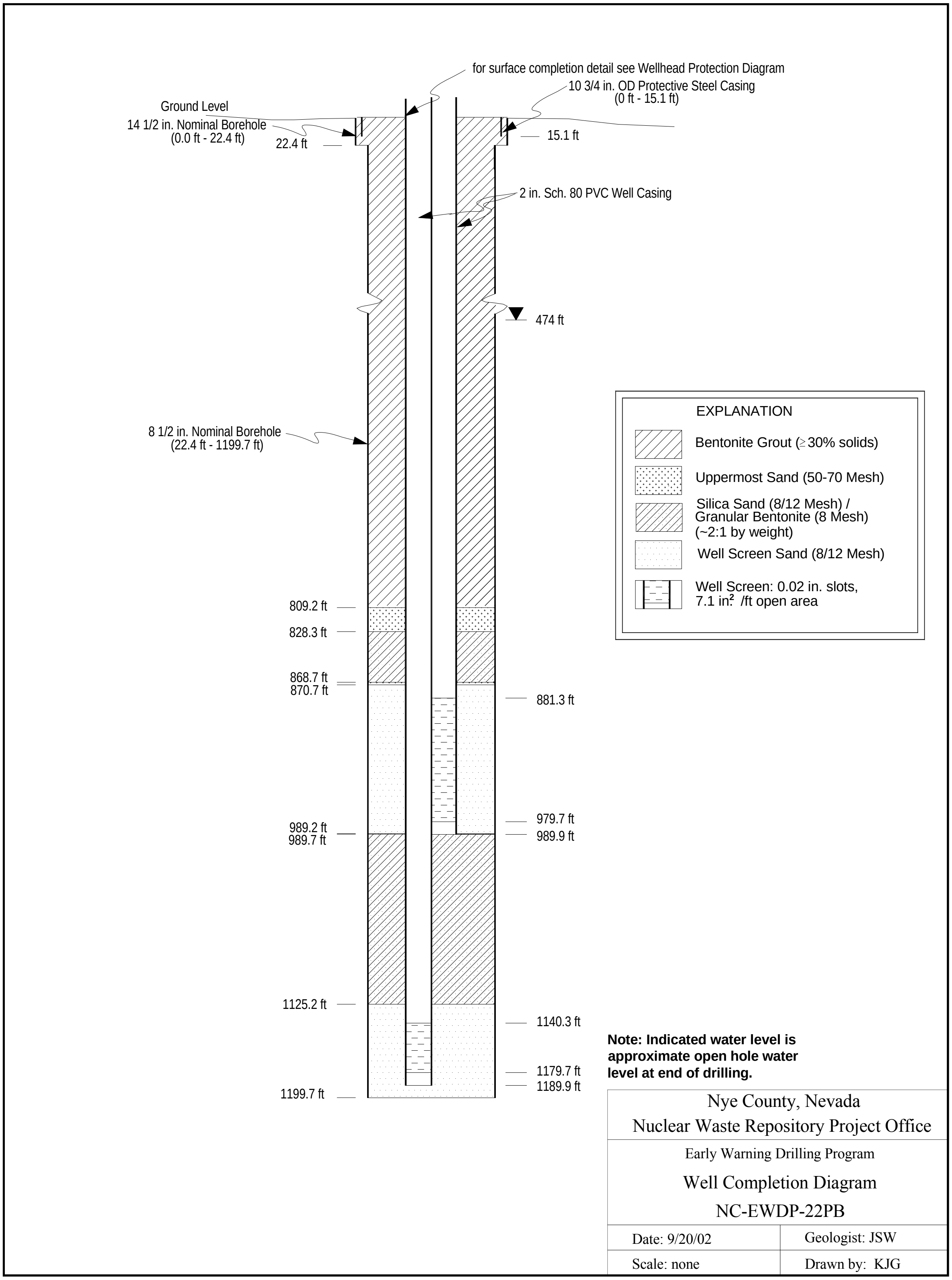

Figure 5. Well completion diagram for 22PB.

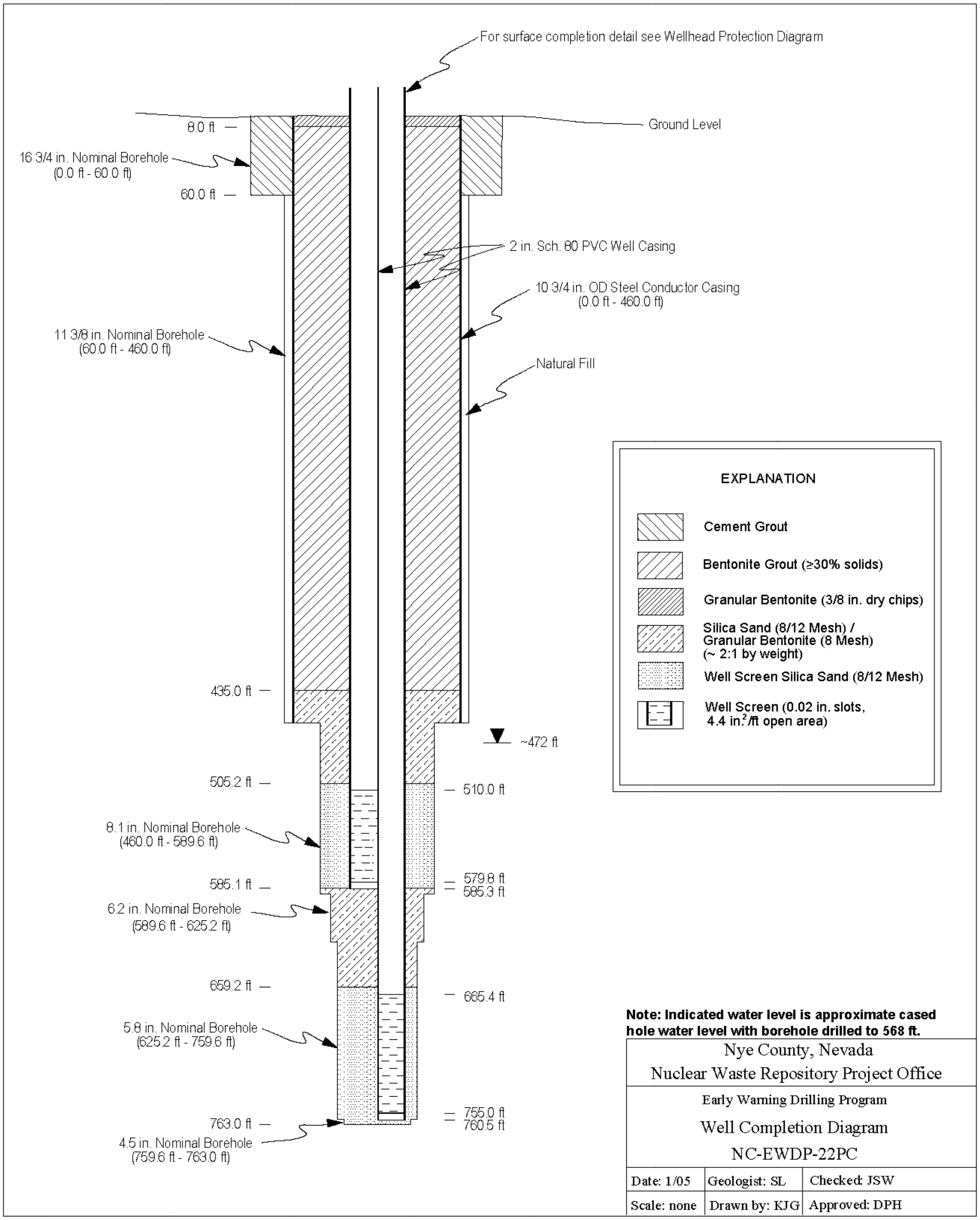

Figure 6. Well completion diagram for 22PC.

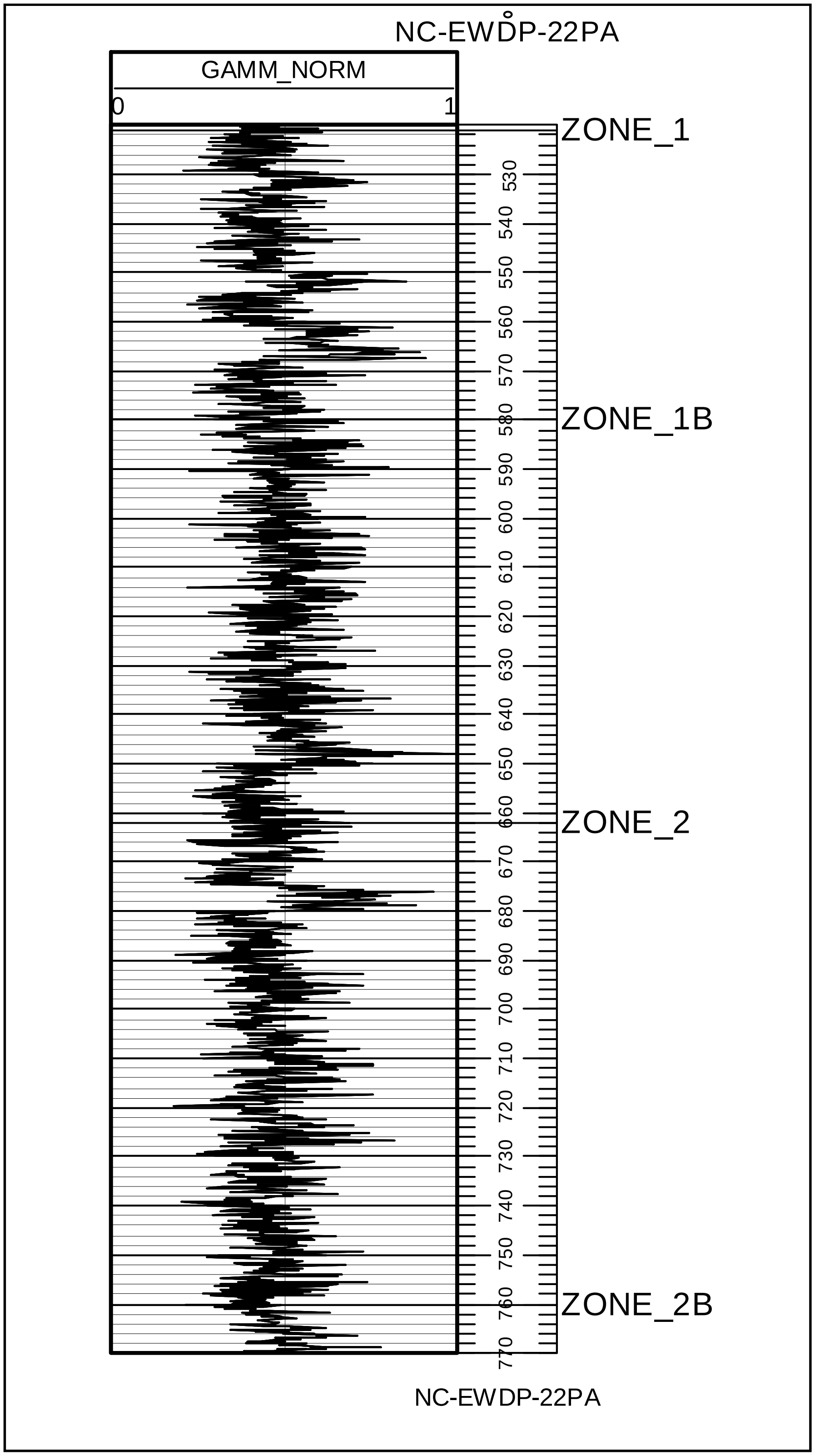

Figure 7. Normalized gamma ray log for 22PA indicates no obvious confining layers between Zones 1, 2, and 3.

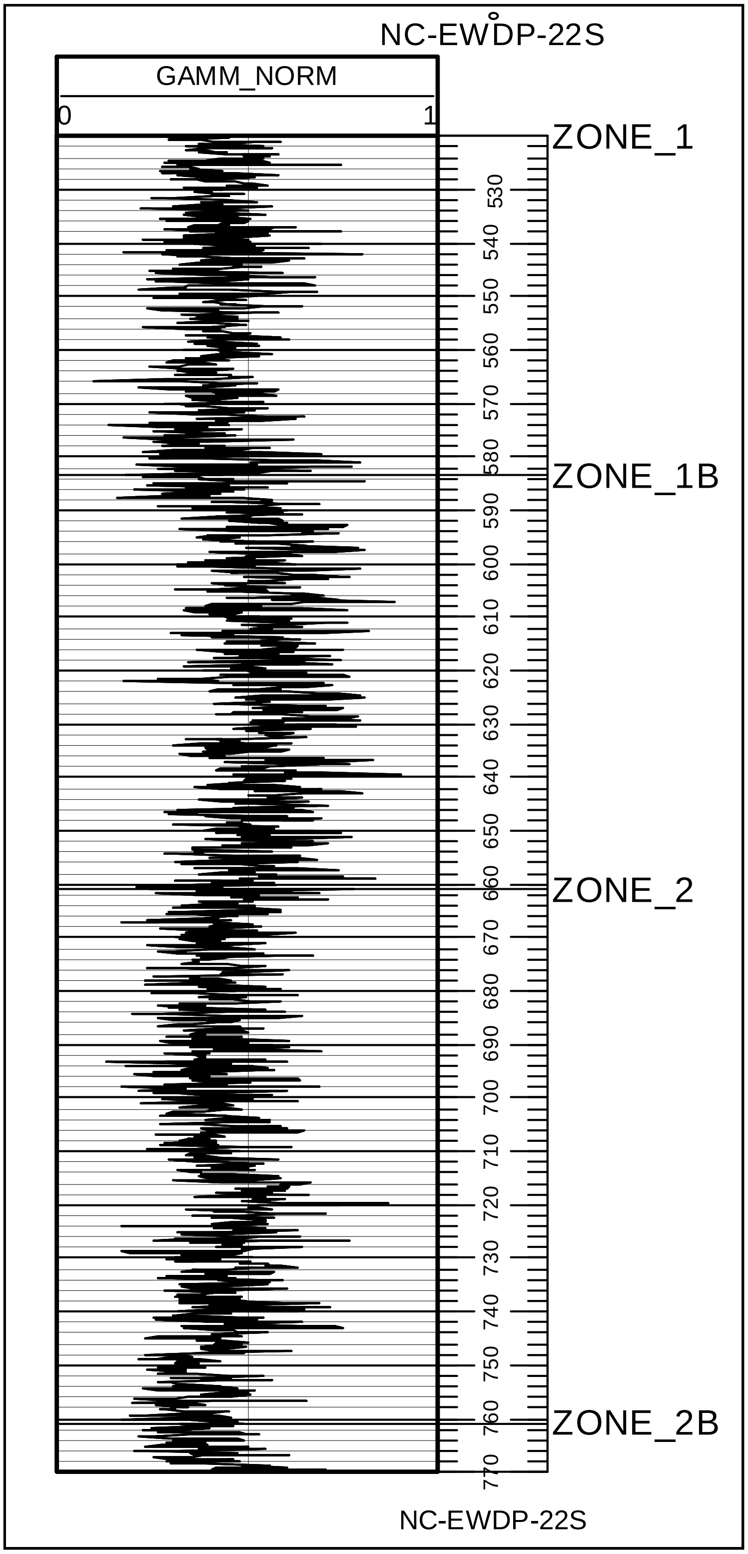

Figure 8. Normalized gamma ray log for 22S indicates no obvious confining layers between Zones 1, 2, and 3.

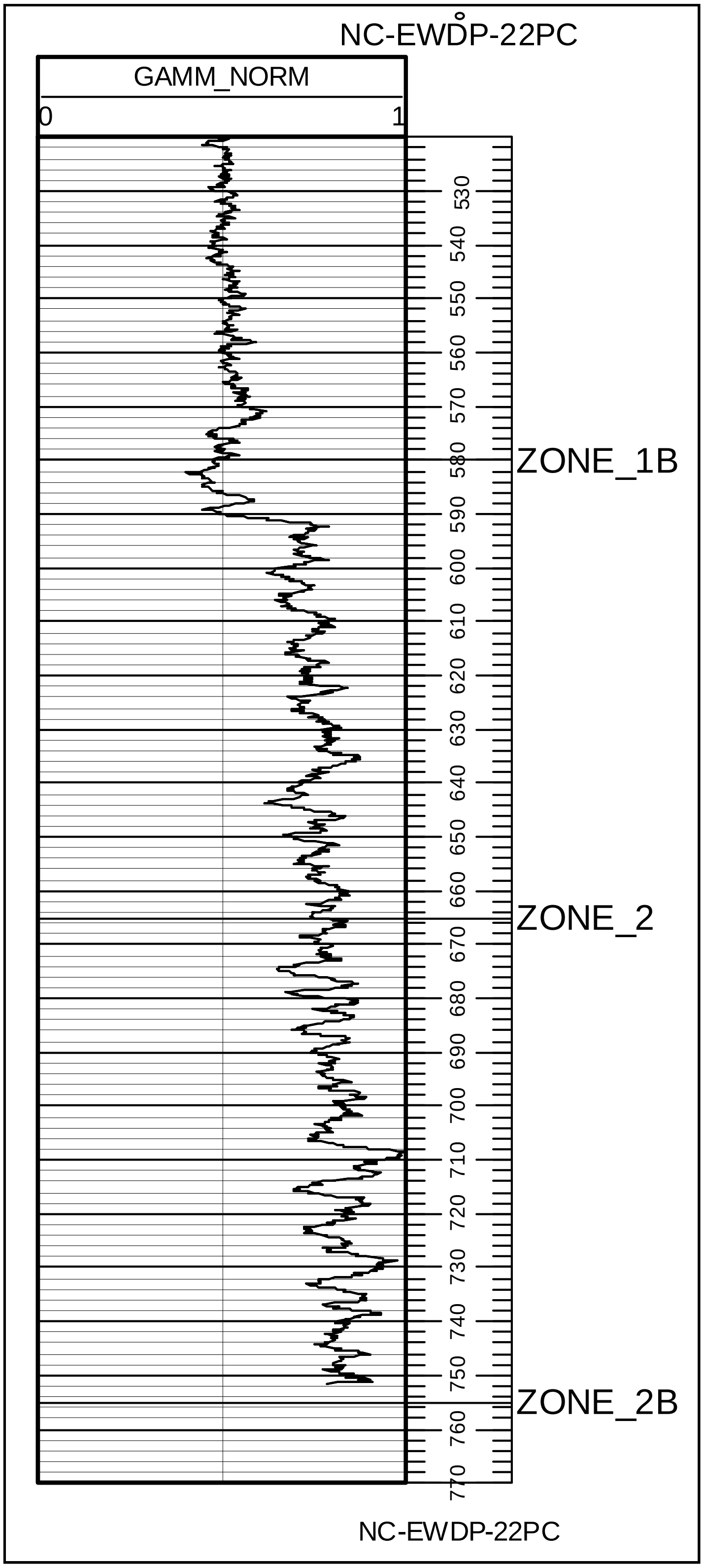

Figure 9. Normalized gamma ray log for 22PC indicates no obvious confining layers between Zones 1, 2, and 3.

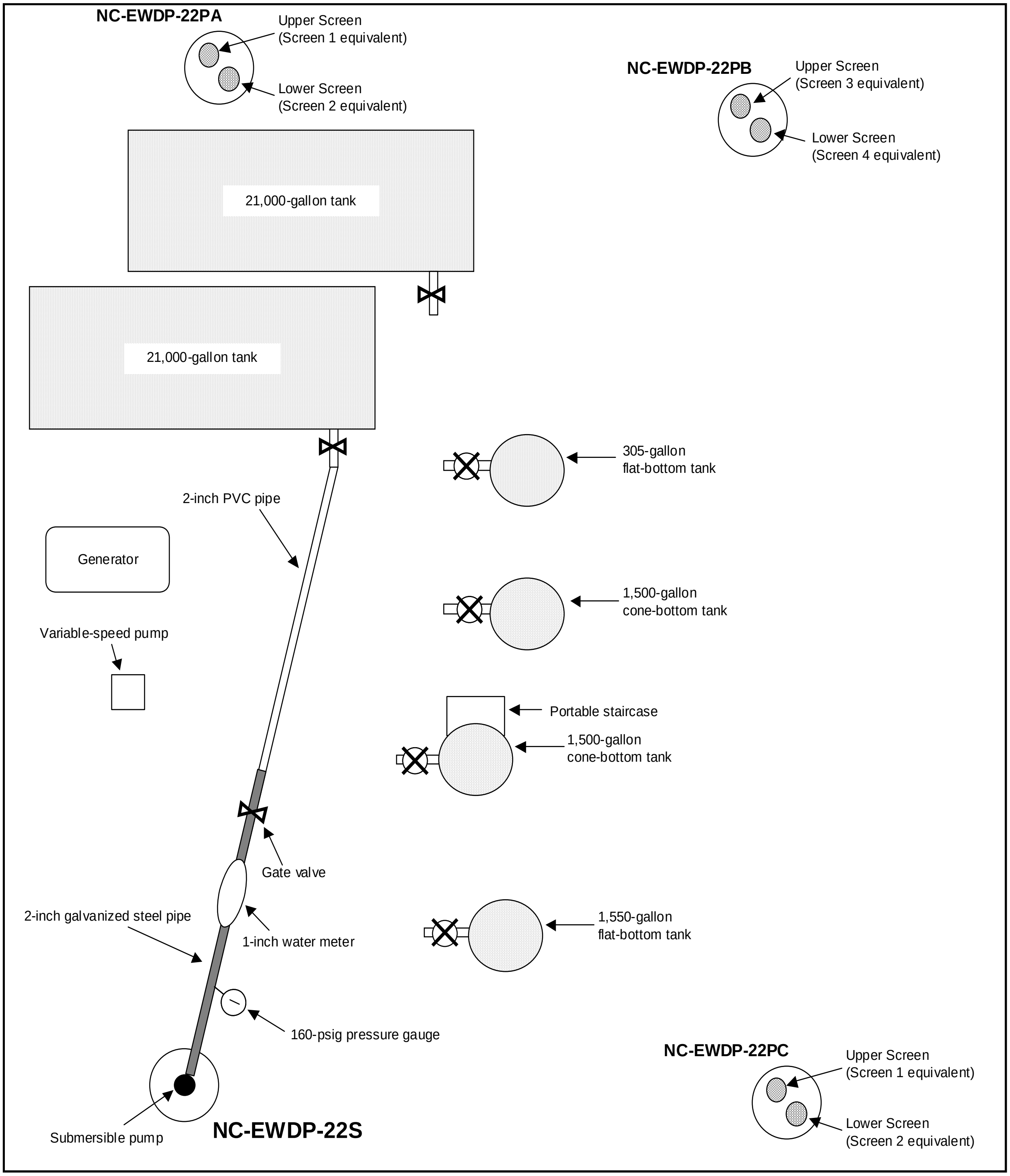

Figure 10. Schematic diagram showing tanks on Site 22 and the piping/plumbing used to fill the tanks. Note that figure not drawn to scale.

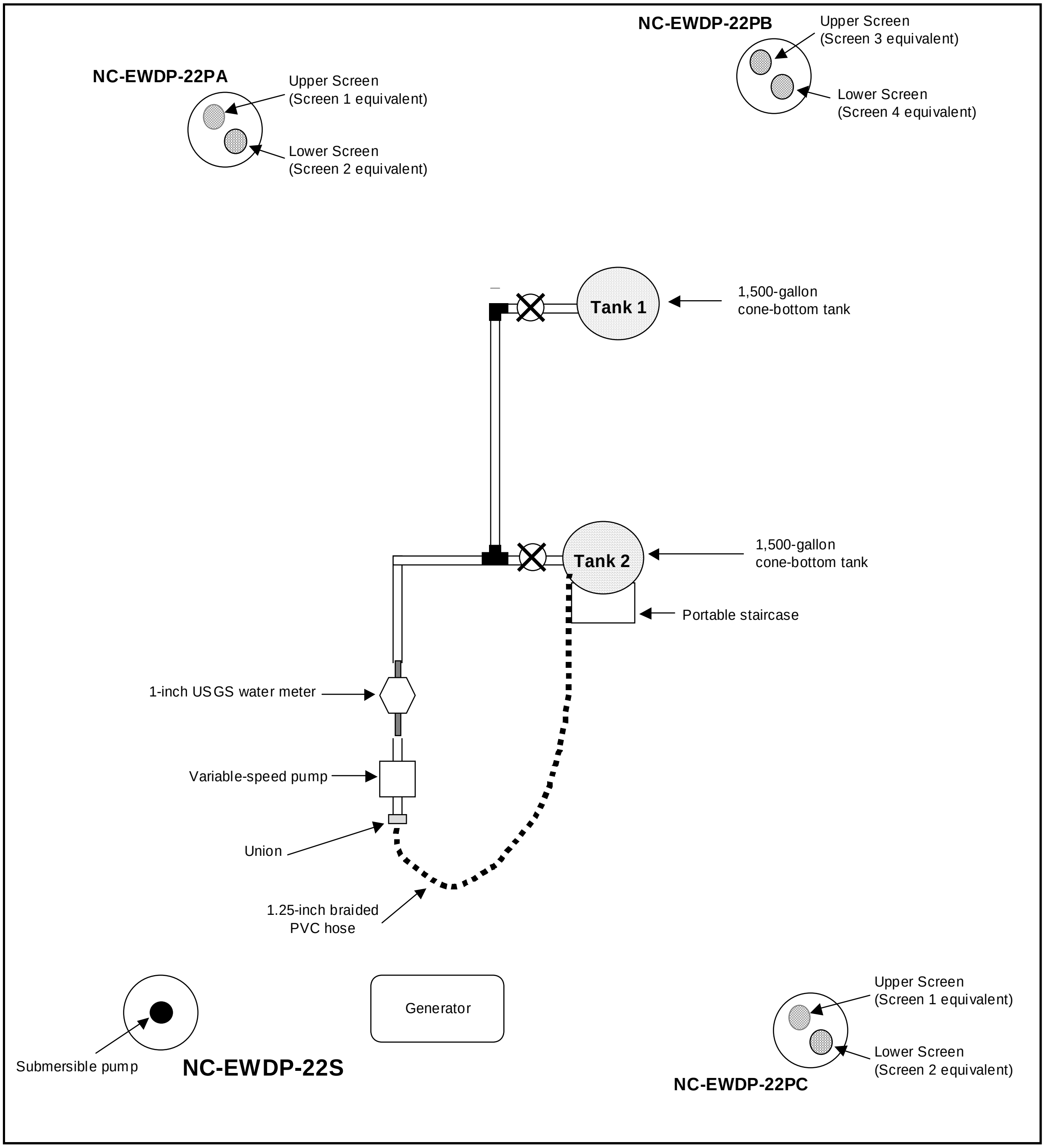

Figure 11. Circulation of the cone bottom injectant tank with a small centrifugal pump. Note that figure is not drawn to scale.

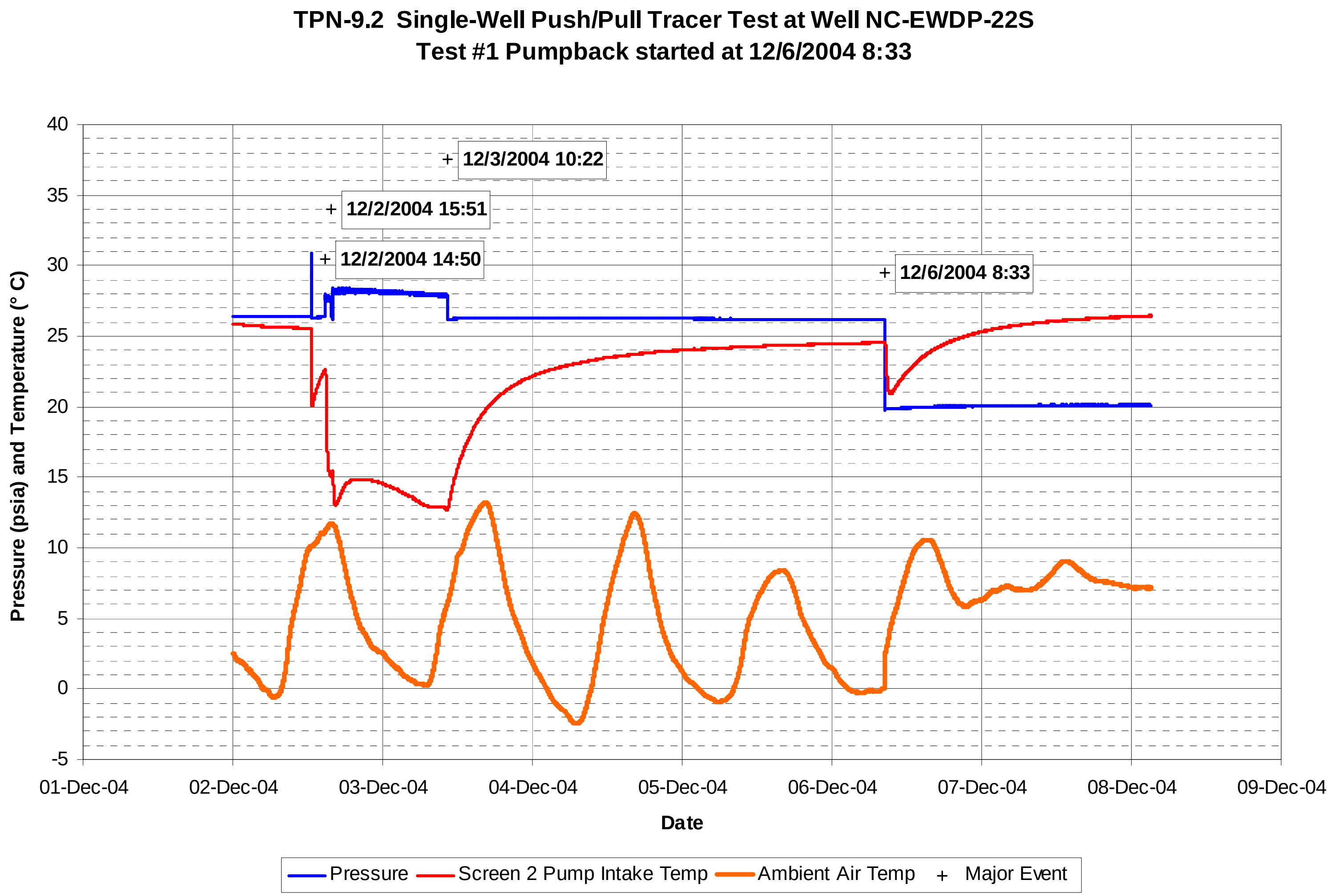

Figure 12. Temperature and pressure observed during injection and the beginning of the pumpback along with the ambient temperatures.

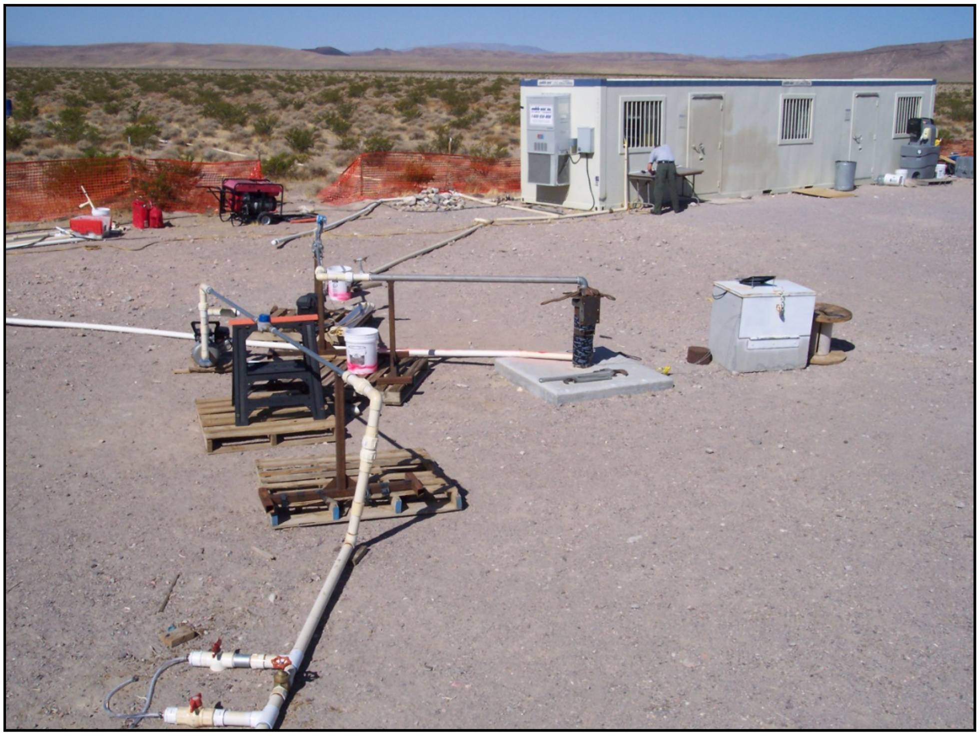

Figure 13. Bypass loop installation to bringing produced fluids back through "Mobile Mini" trailer on location.

Figure 14. Integrated fluid samples were obtained though the use of an autosampler provided by LANL.

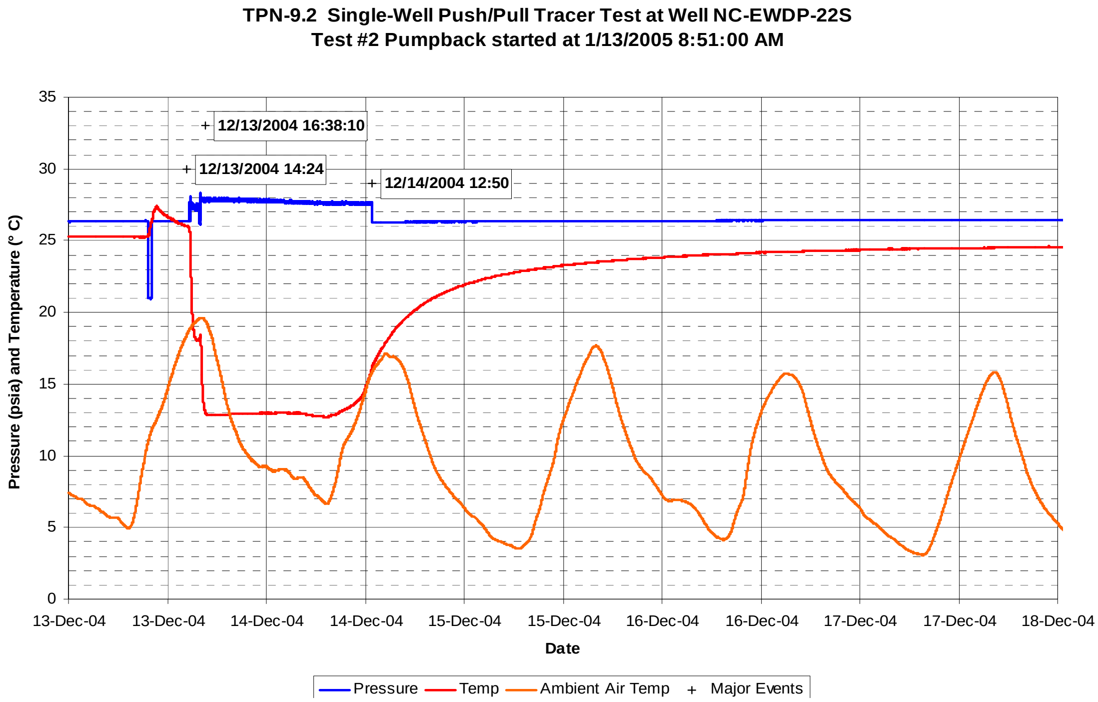

Figure 15. Temperature and pressure observed during injection along with the ambient temperatures during injection of the second push/pull tracers.

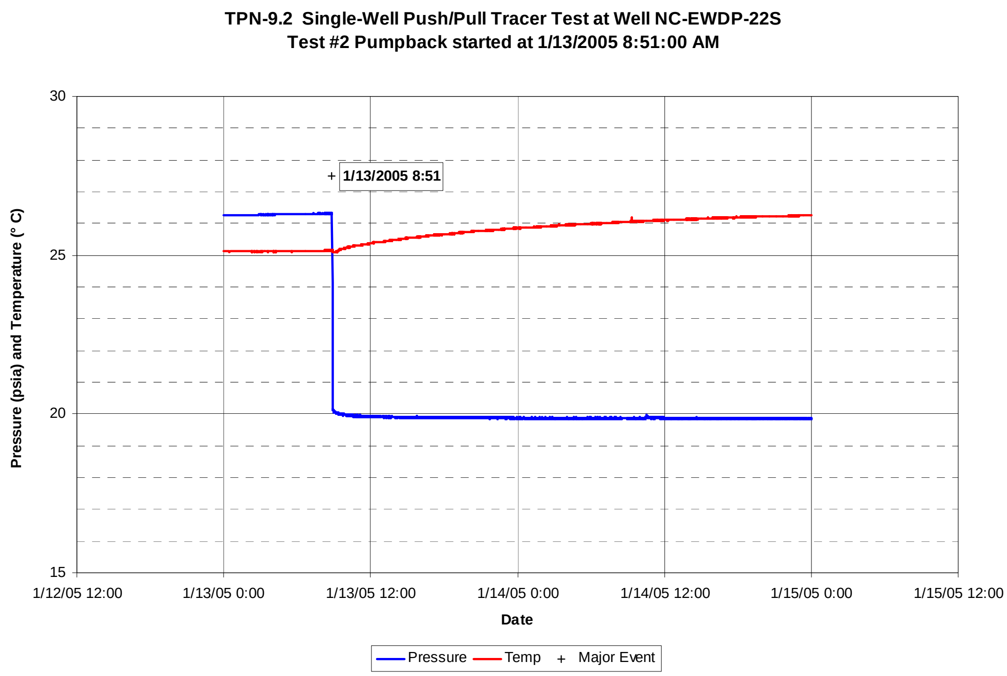

Figure 16. Stabilized flow was obtained in 22S prior to cross-hole tracer injection by starting up the pump in 22S on 1/13/05 @ 8:51 hrs.

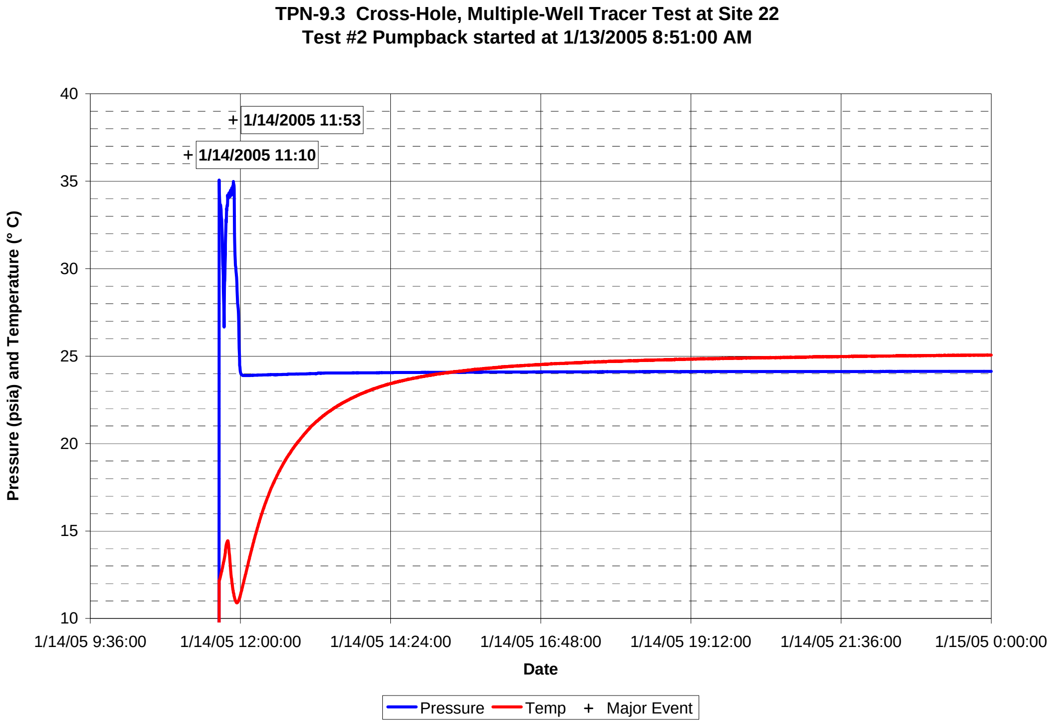

Figure 17. Temperature and pressure observed during injection of Cross-Hole Test 2 at 22PC Deep.

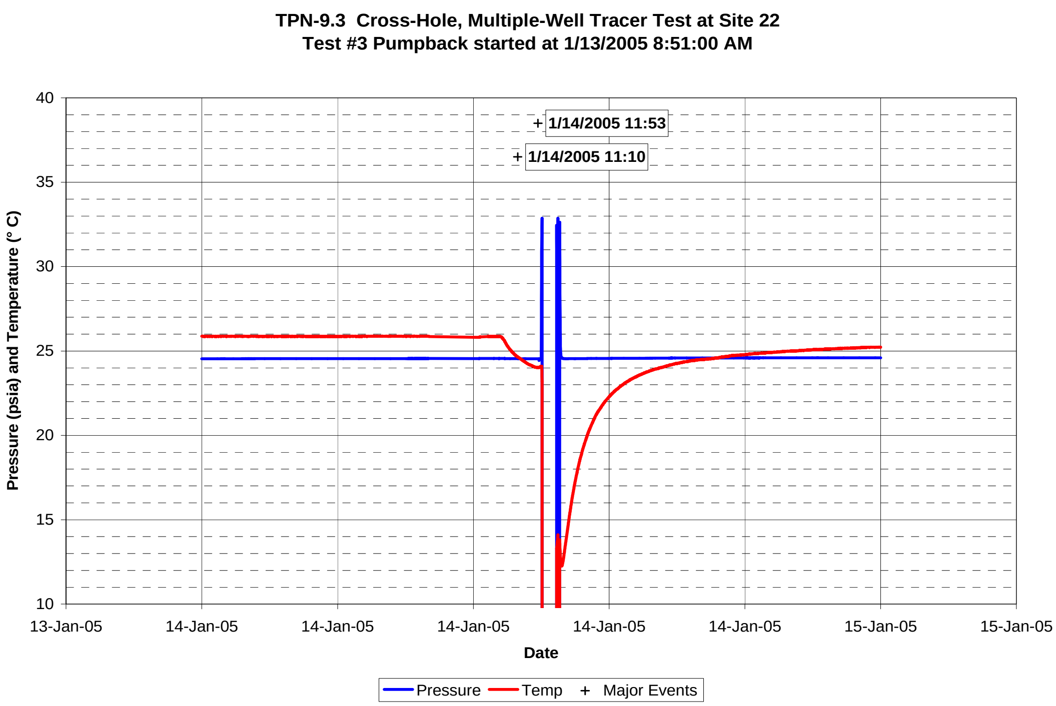

Figure 18. Temperature and pressure observed during injection of Cross-Hole Test 3 at 22PA Shallow.

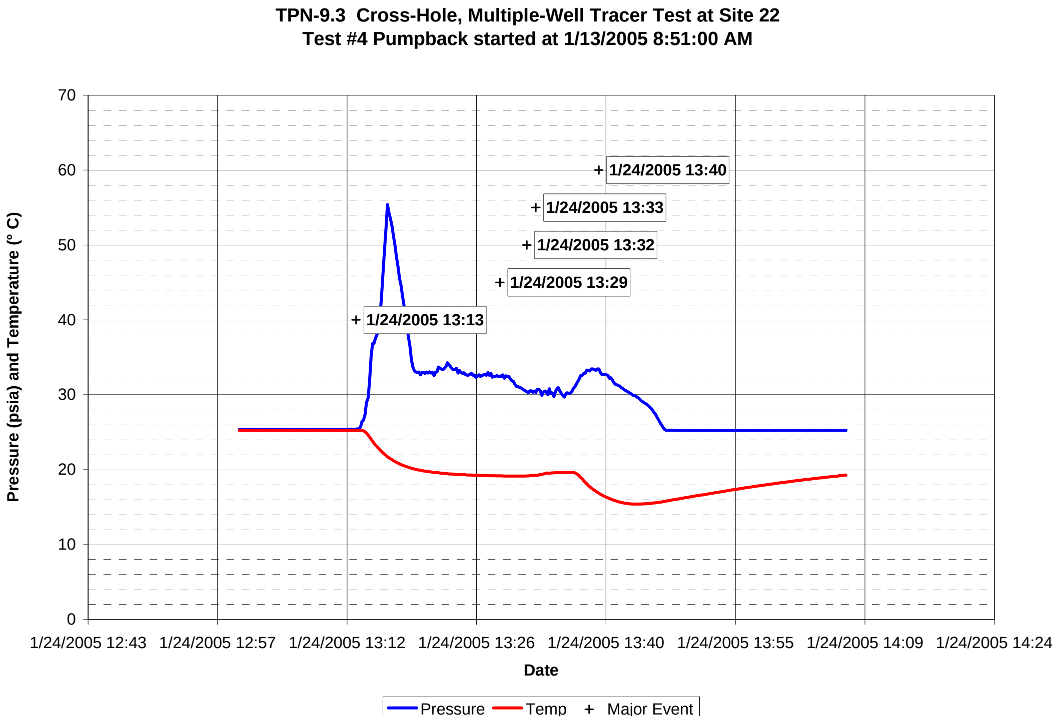

Figure 19. Temperature and pressure observed during injection of microspheres during Cross-Hole Test 4 at 22PA Deep.

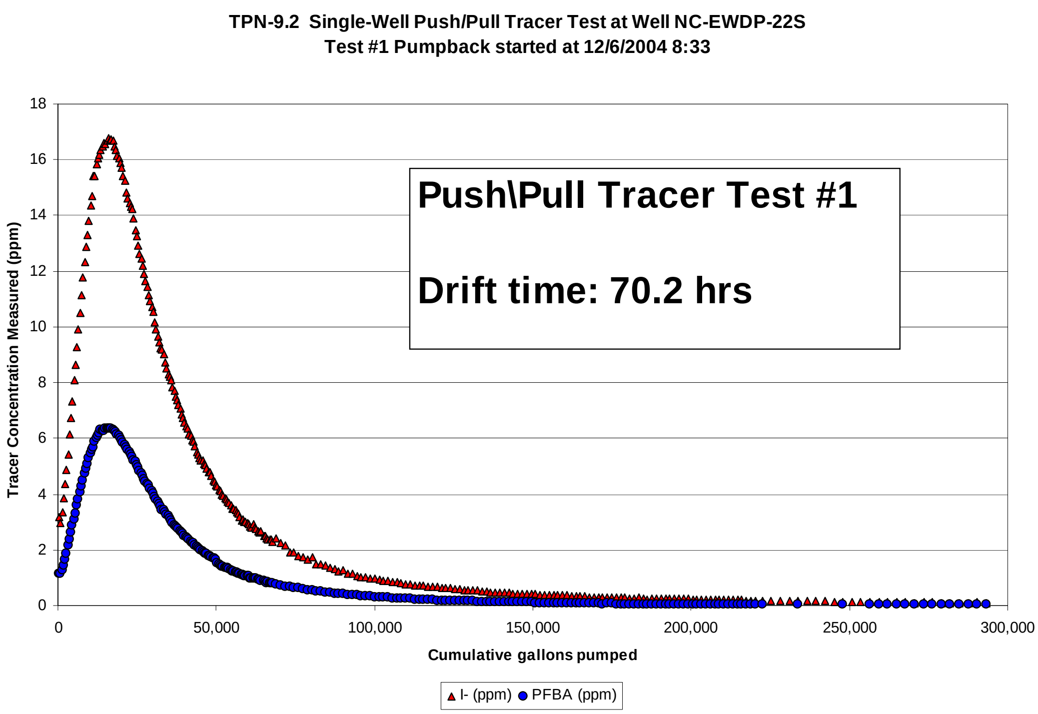

Figure 20. Measured tracer concentrations in parts per million (ppm) in the produced water versus cumulative gallons of water produced.

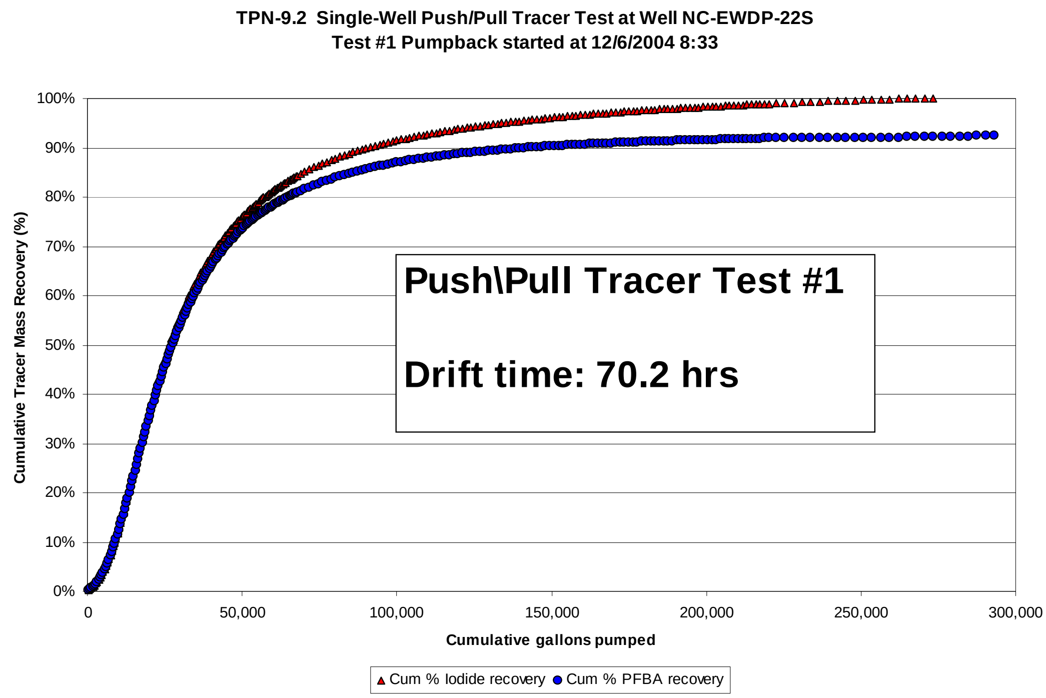

Figure 21. High cumulative mass recovery of tracers was observed.

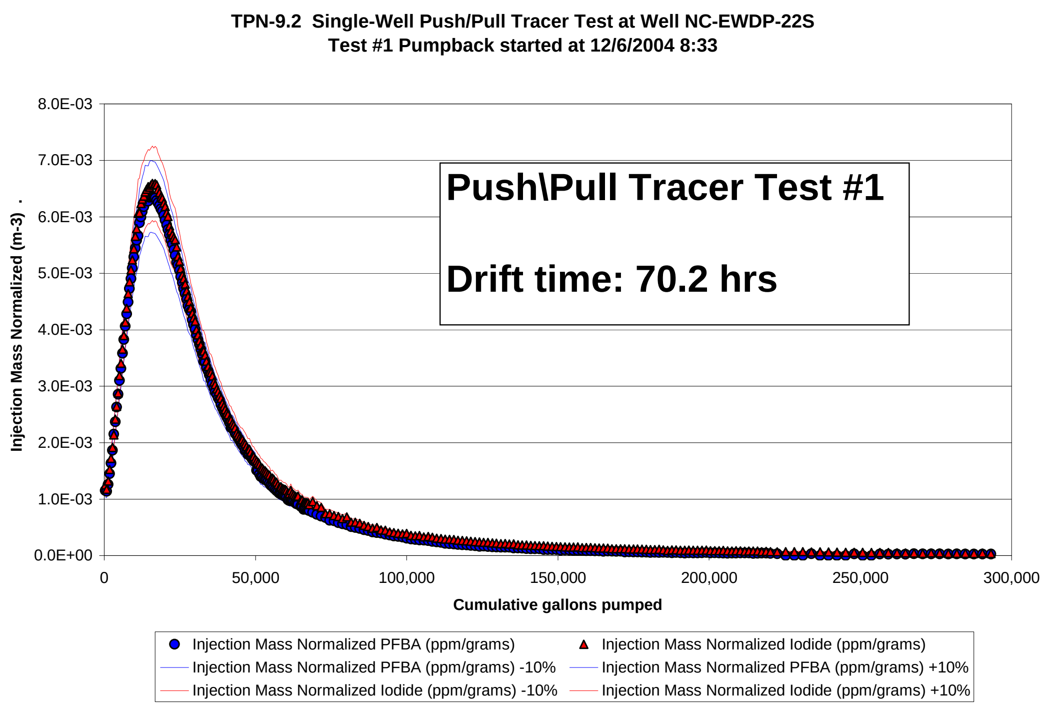

Figure 22. Nearly identical mass-normalized tracer recovery curves indicate no diffusion into stagnant water layers.

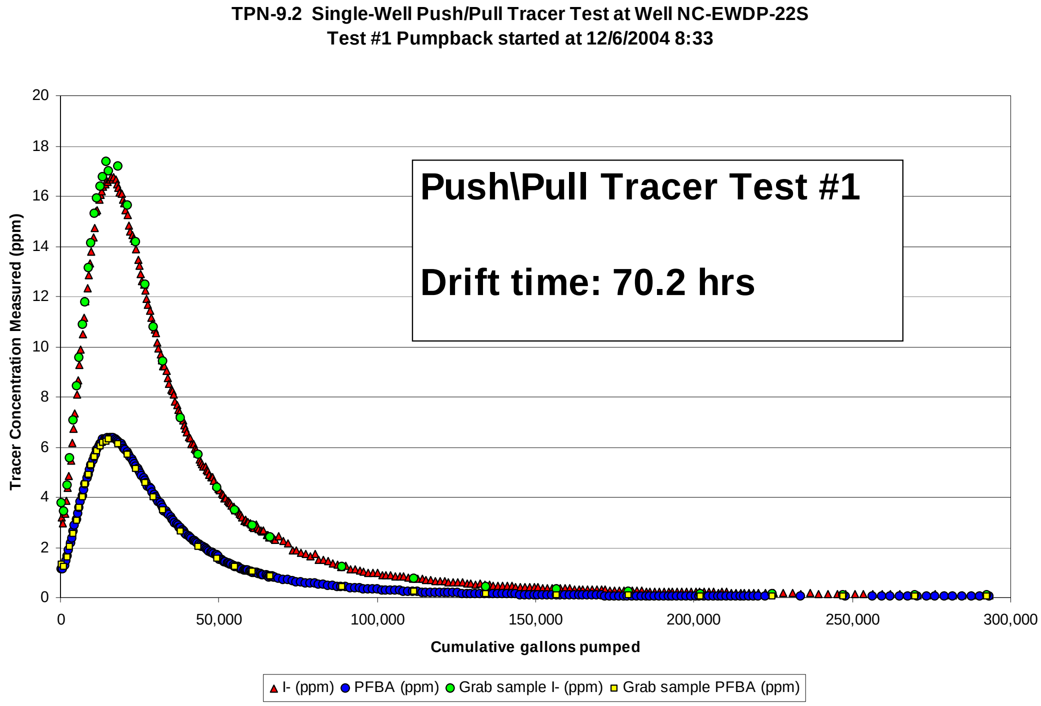

Figure 23. Comparison of tracer recovery curves generated by the higher-frequency integrated sampling versus grab sampling methods.

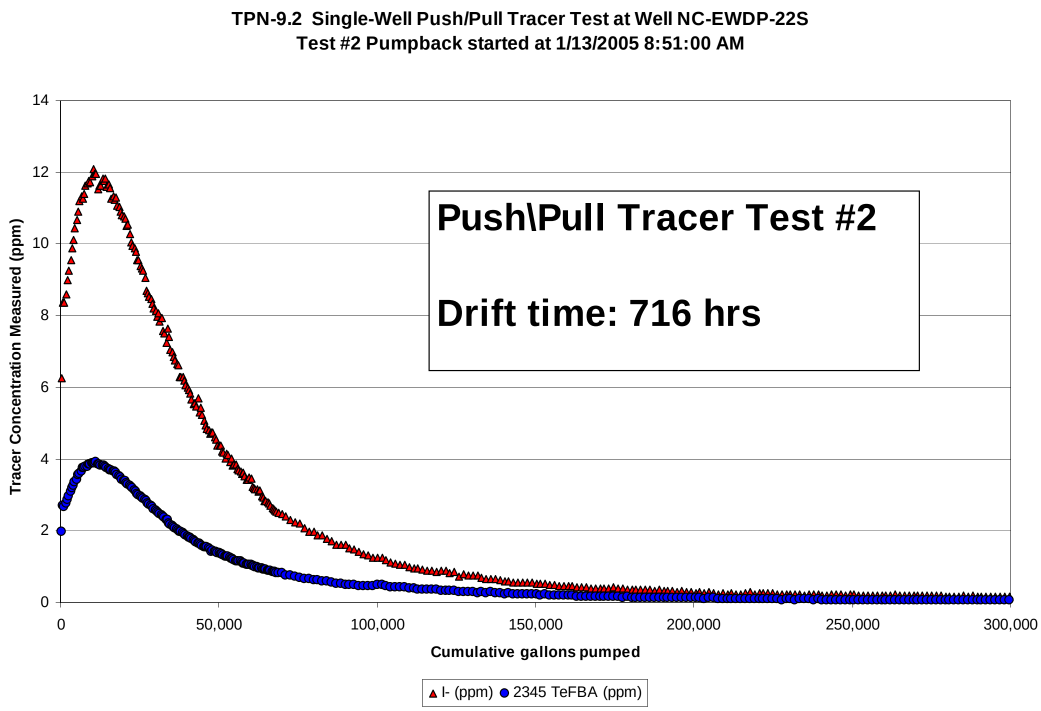

Figure 24. Measured tracer concentrations in parts per million (ppm) in the produced water versus cumulative gallons of water produced

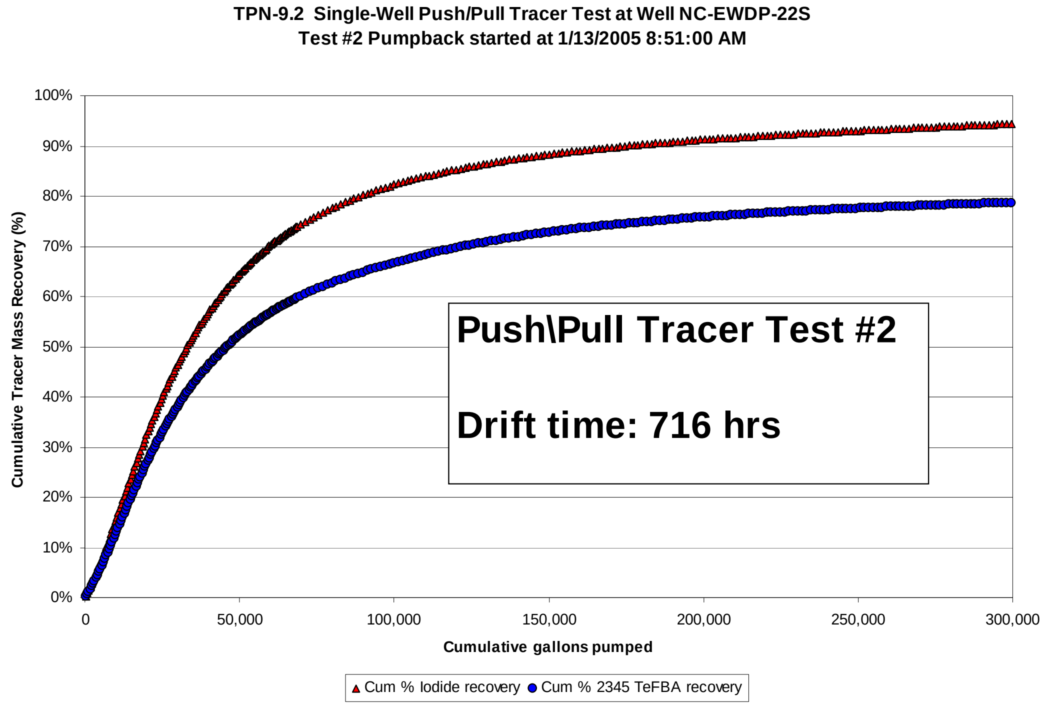

Figure 25. High cumulative mass recovery of tracers was observed.

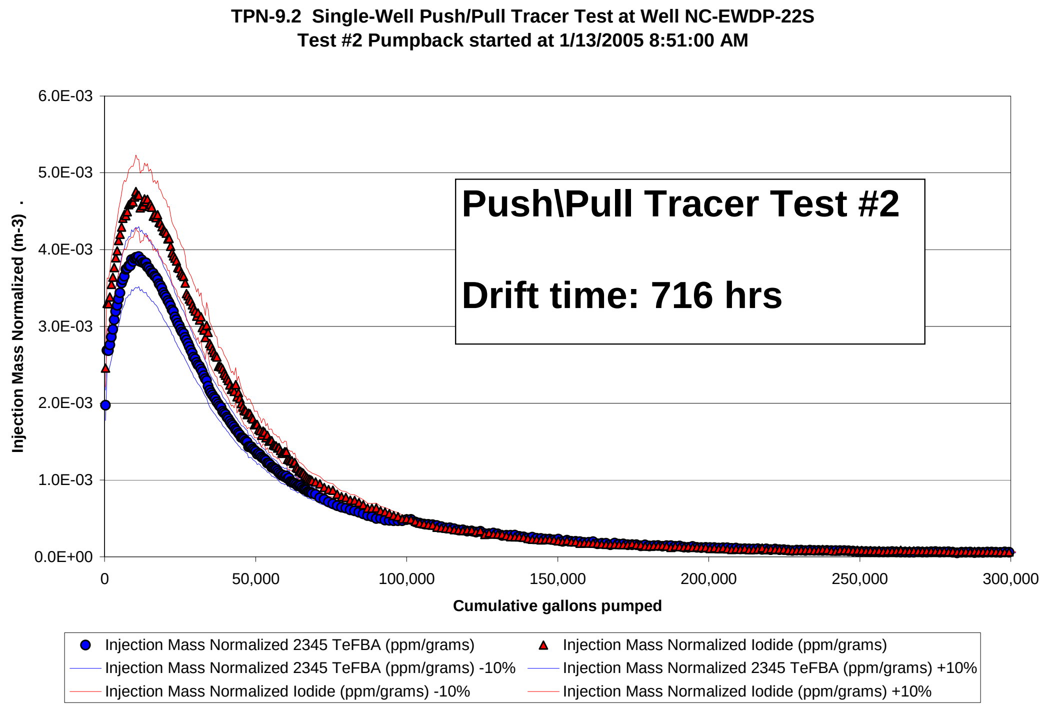

Figure 26. Mass-normalized tracer recovery curves suggest limited potential diffusion into stagnant water layers.

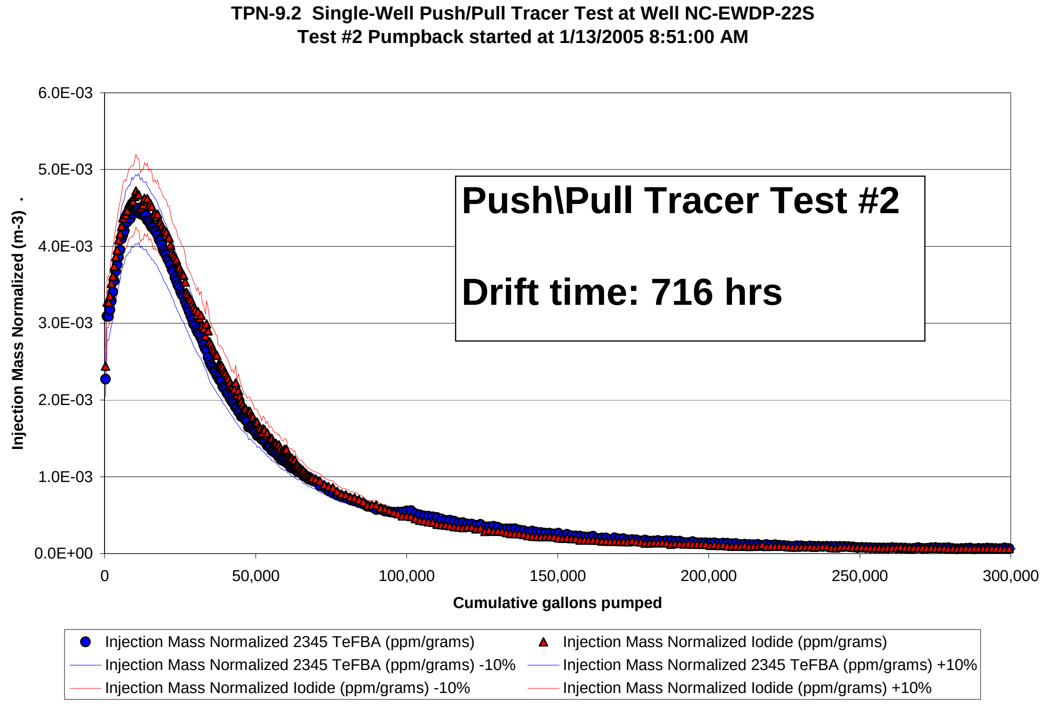

Figure 27. Calculated mass-normalized tracer recovery curves indicate no diffusion into stagnant water layers.

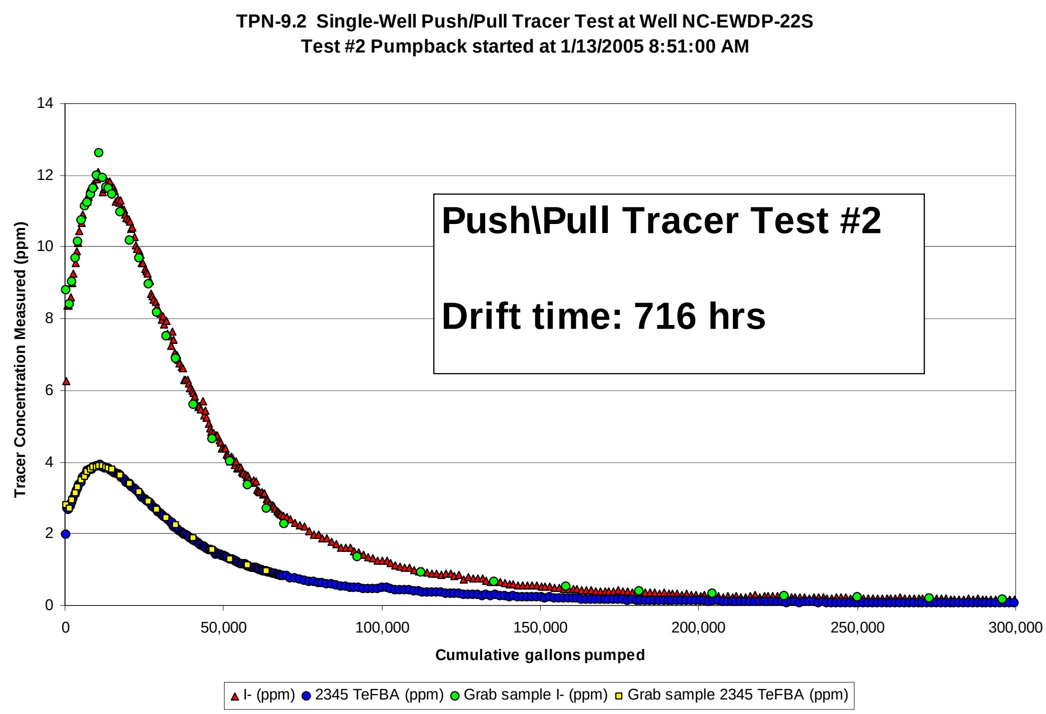

Figure 28. Comparison of tracer recovery curves generated by the higher-frequency integrated sampling versus grab sampling methods.

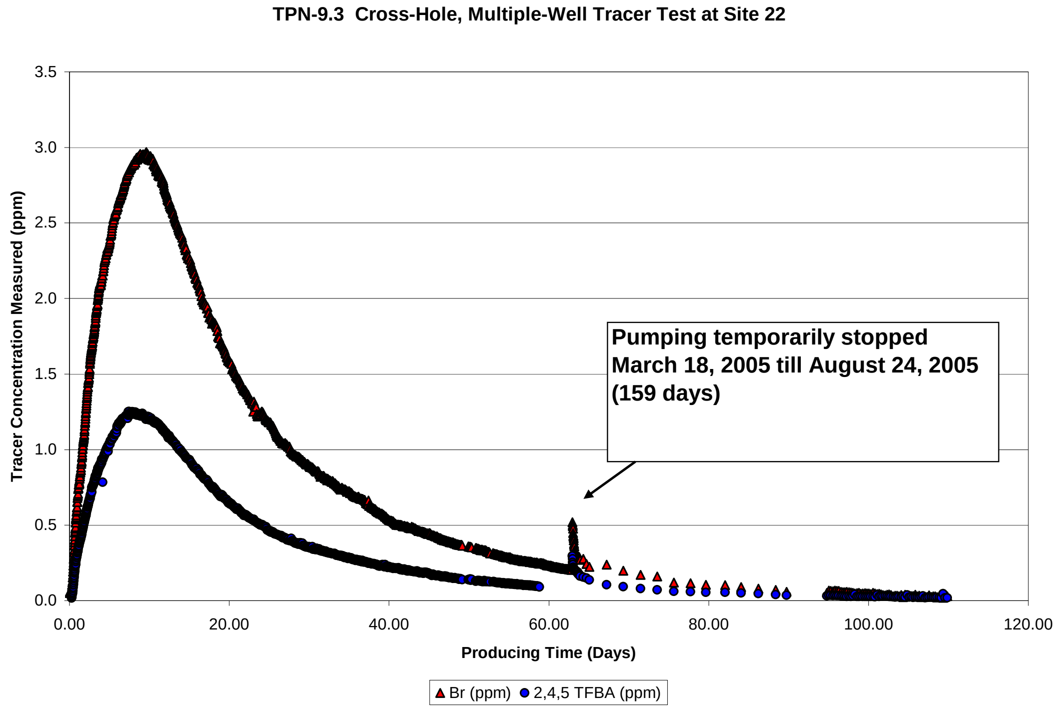

Figure 29. Cross-hole tracer concentration observed in 22S versus normalized producing time in days.

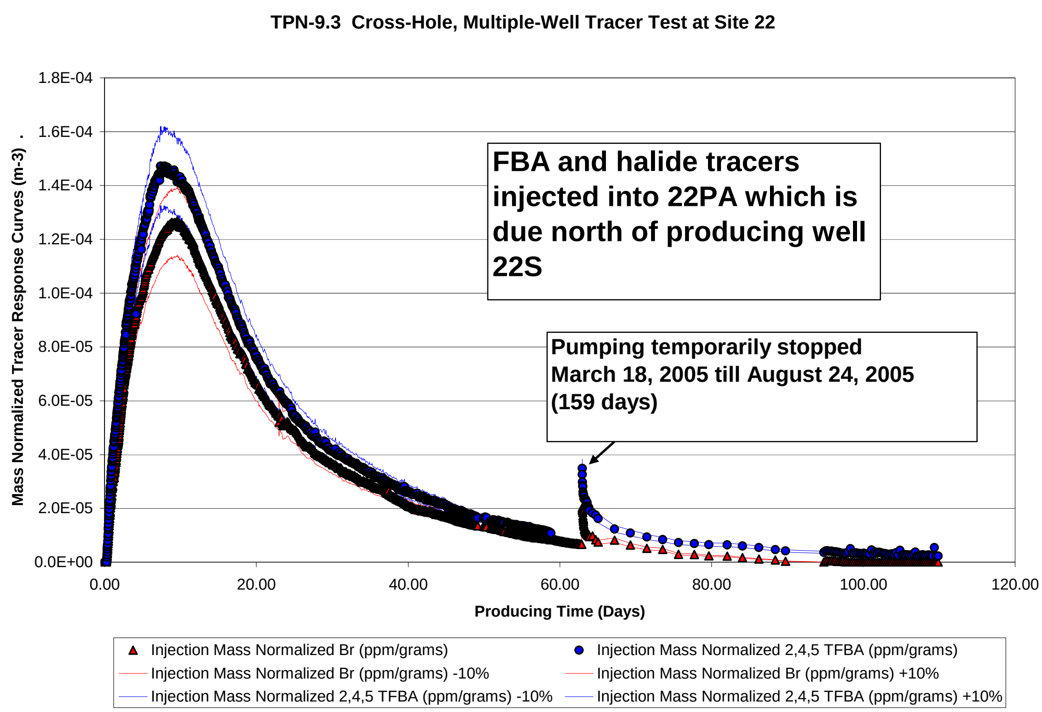

Figure 30. Injection mass-normalized response curves for tracers injected in 22PA Deep.

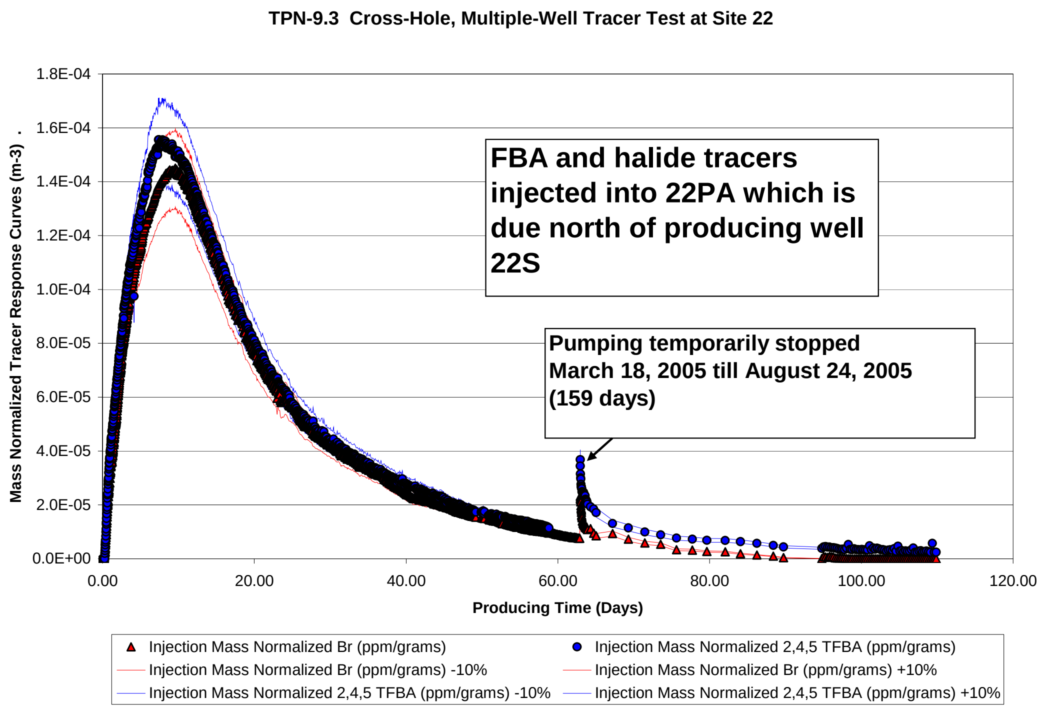

Figure 31. Calculated injected tracer mass-normalized tracer response curves injected in 22PA Deep.

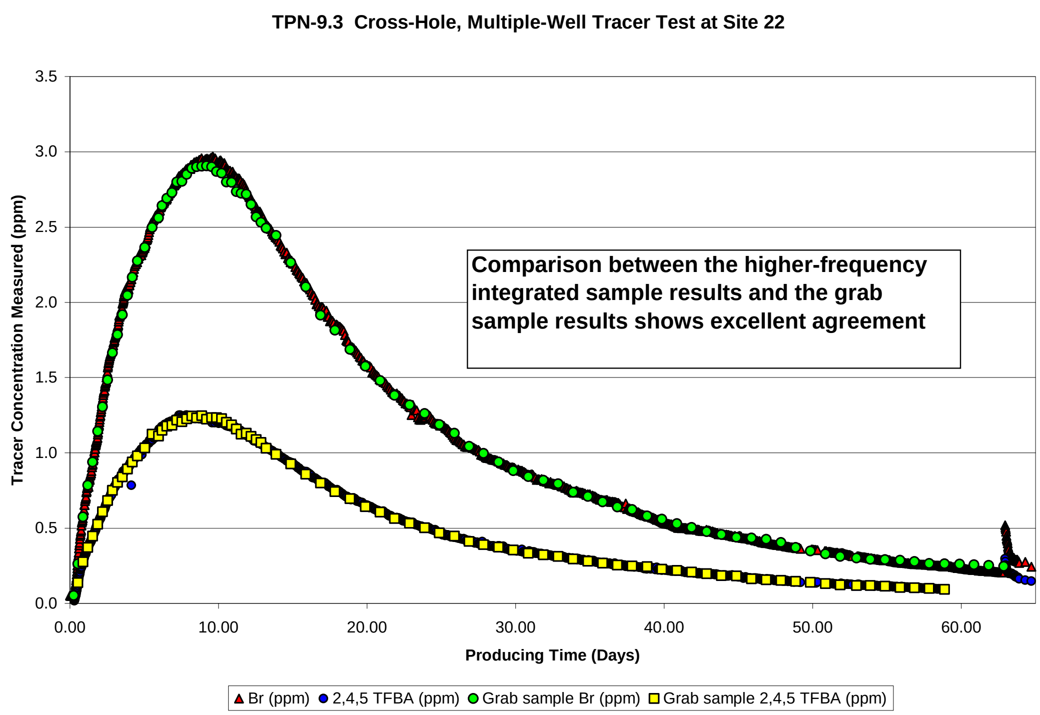

Figure 32. Comparison of tracer recovery curves generated by the higher-frequency integrated sampling versus grab sampling methods.

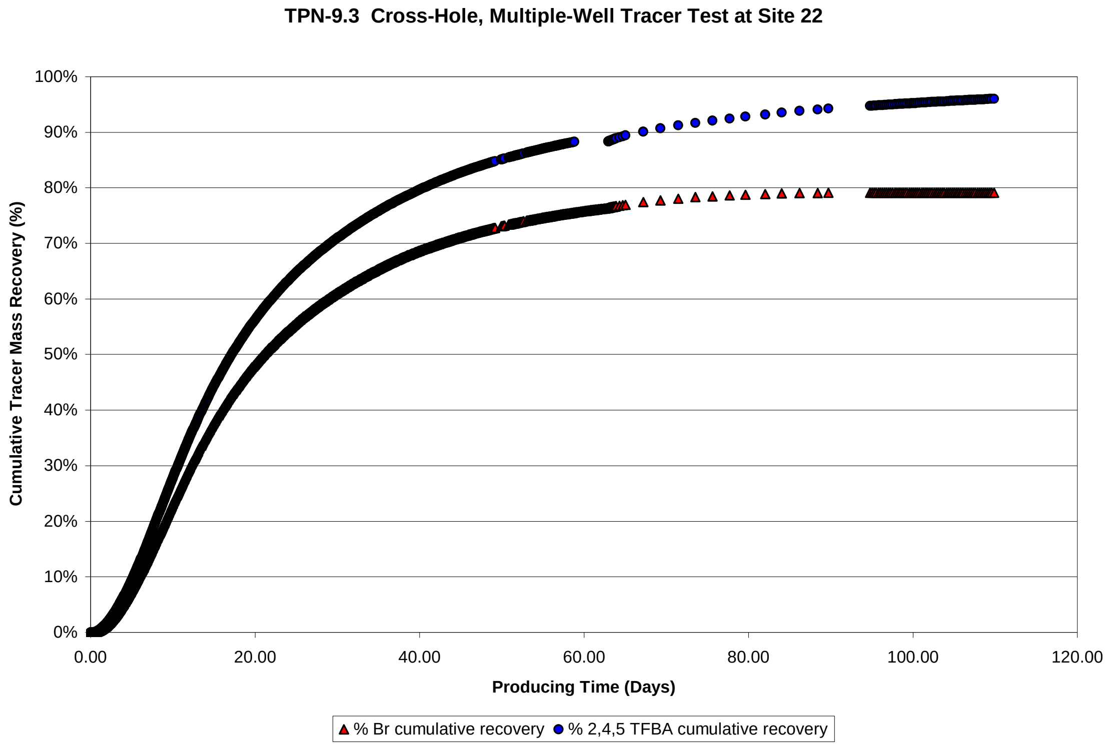

Figure 33. High cumulative mass recovery of tracers was observed.

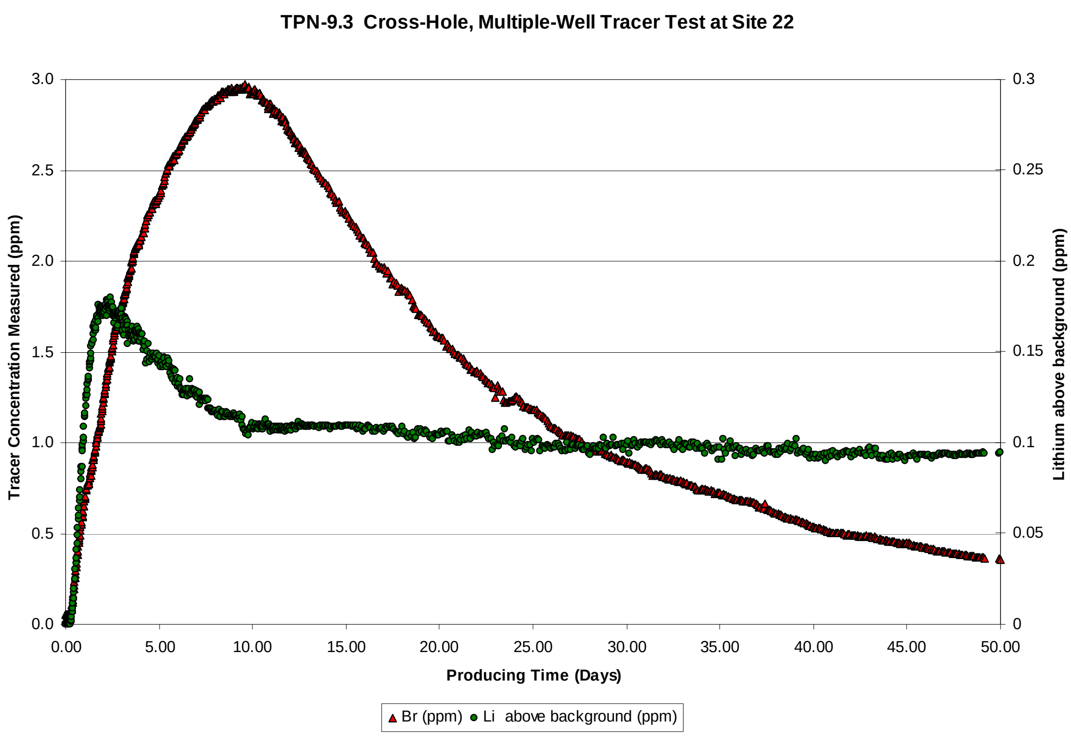

Figure 34. Lithium tracer response compared to bromide response from 22PA Deep to 22S.

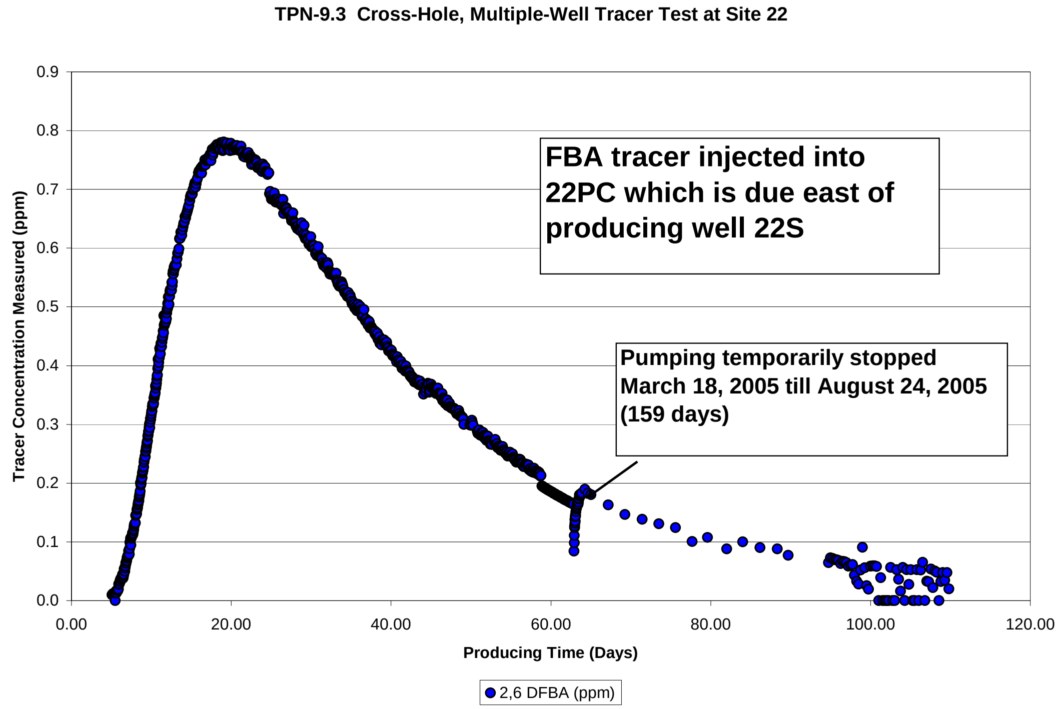

Figure 35. Cross-hole tracer concentration observed in 22S versus normalized producing time in days.

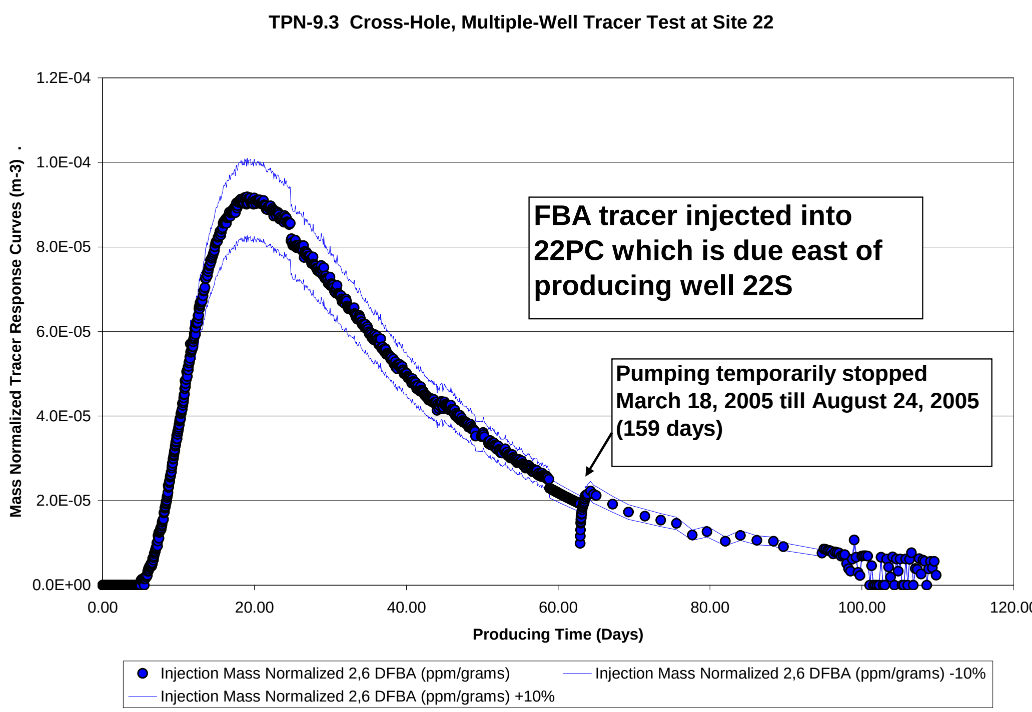

Figure 36. Mass-normalized tracer response curves for 2,6 DFBA.

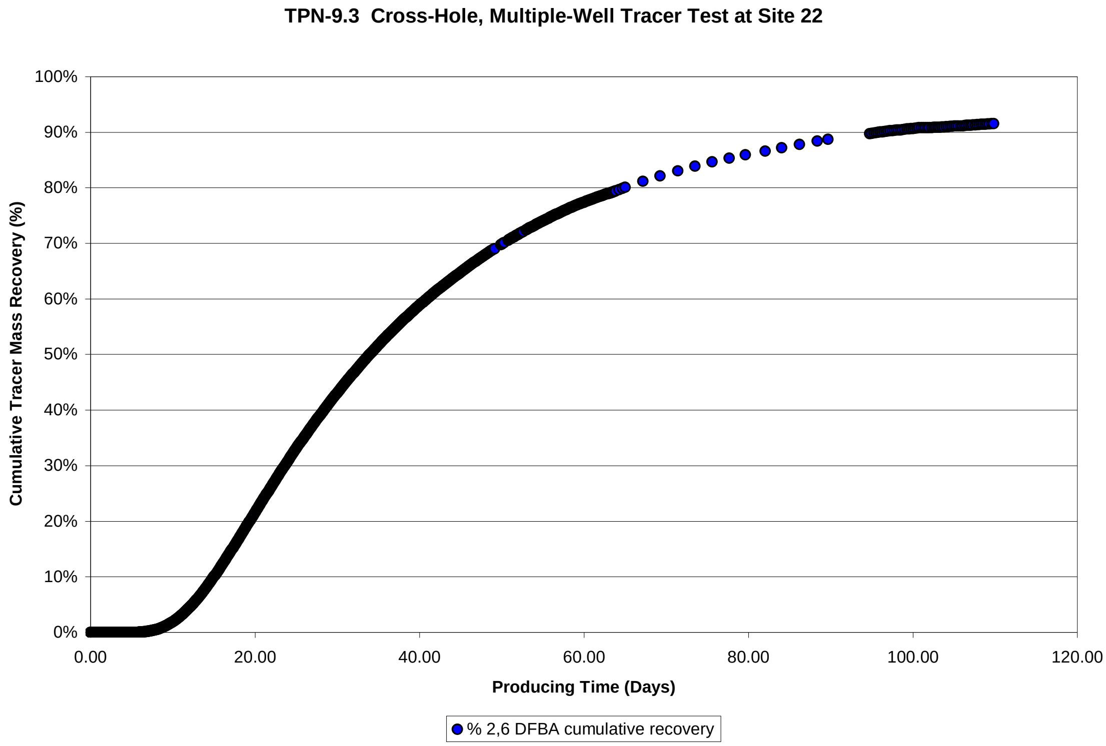

Figure 37. High cumulative mass recovery of tracers was observed.

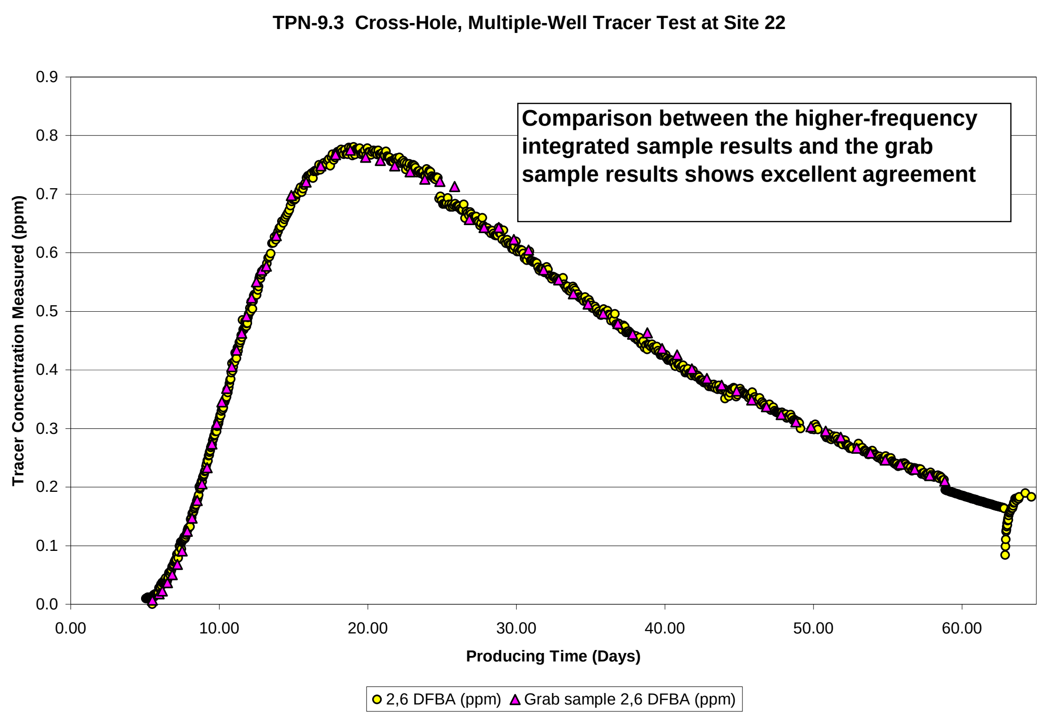

Figure 38. Comparison of tracer recovery curves generated by the higher-frequency integrated sampling versus grab sampling methods.

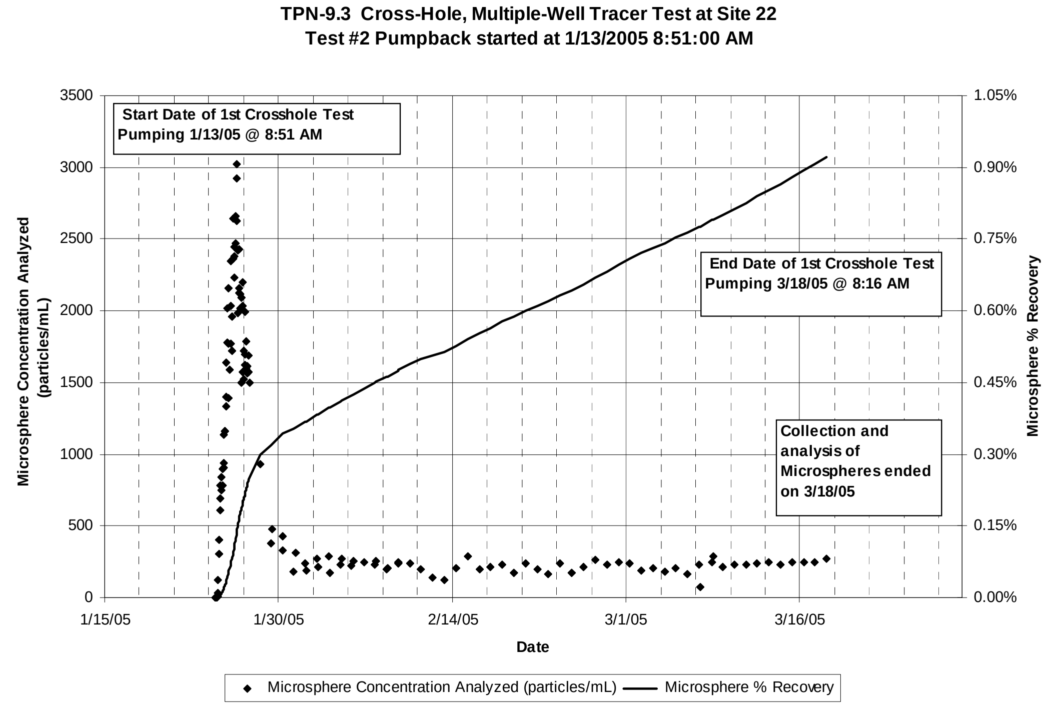

Figure 39. Microsphere response curve and percent cumulative recovery.

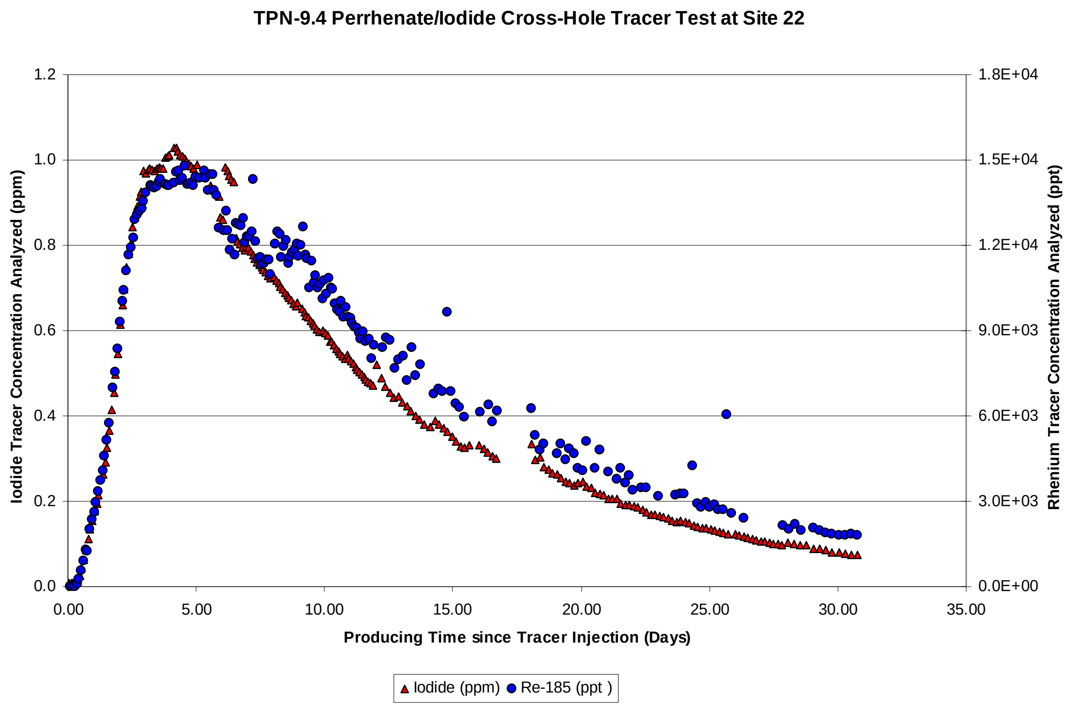

Figure 40. Tracer response curves from Cross-Hole Test 5 of iodide (ppm) and rhenium Re-185 (ppt).

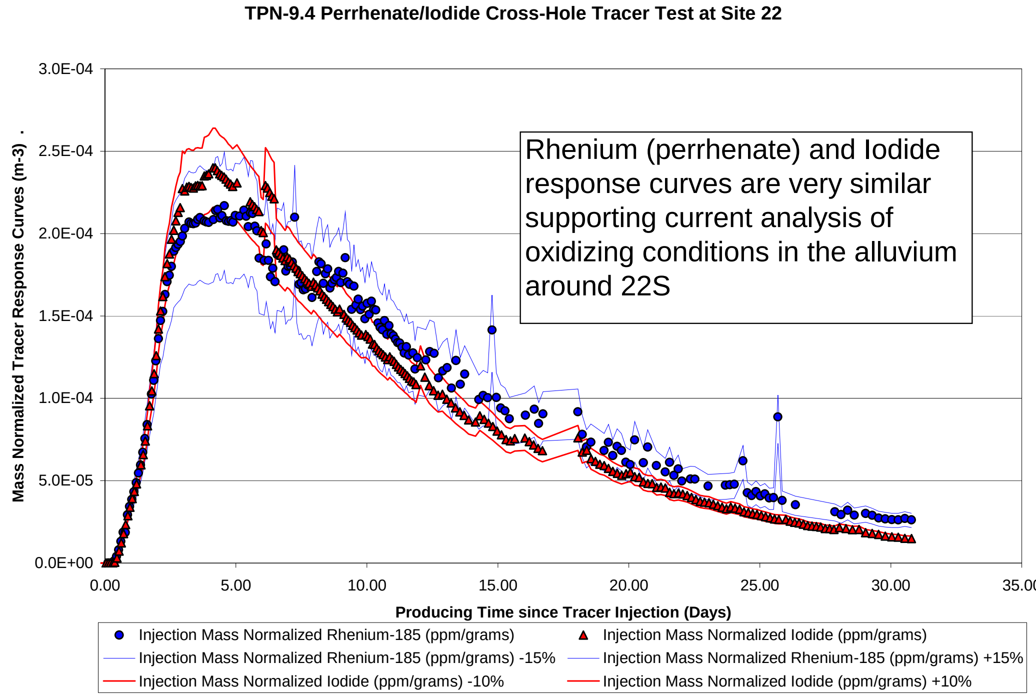

Figure 41. Mass-normalized tracer response curves indicating oxidizing conditions at site 22S.

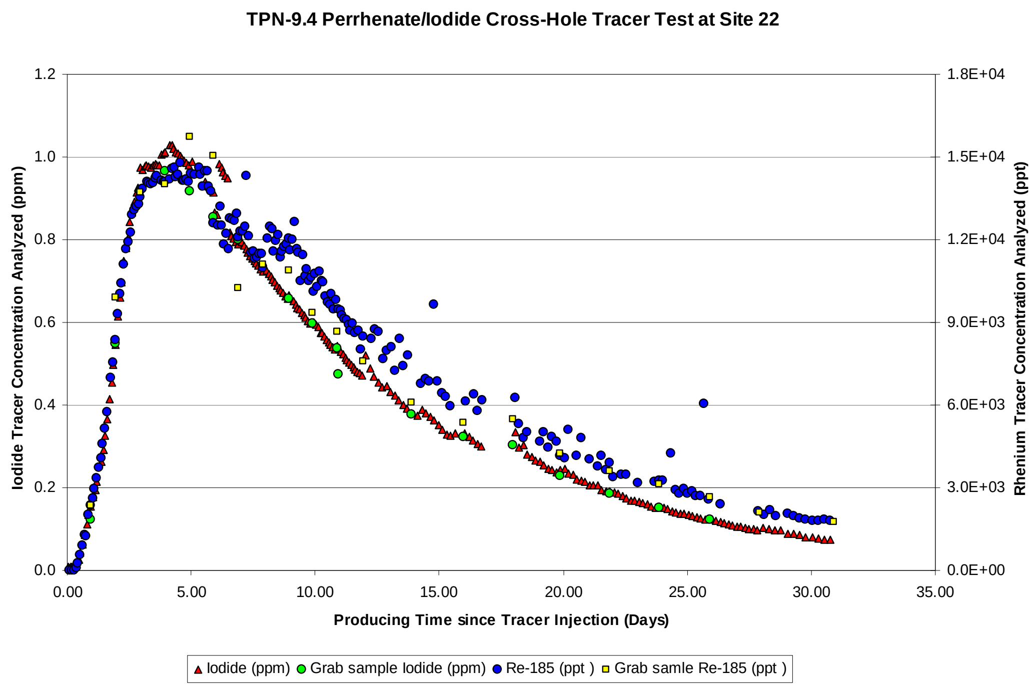

Figure 42. Comparison of tracer recovery curves generated by the higher-frequency integrated sampling versus grab sampling methods.

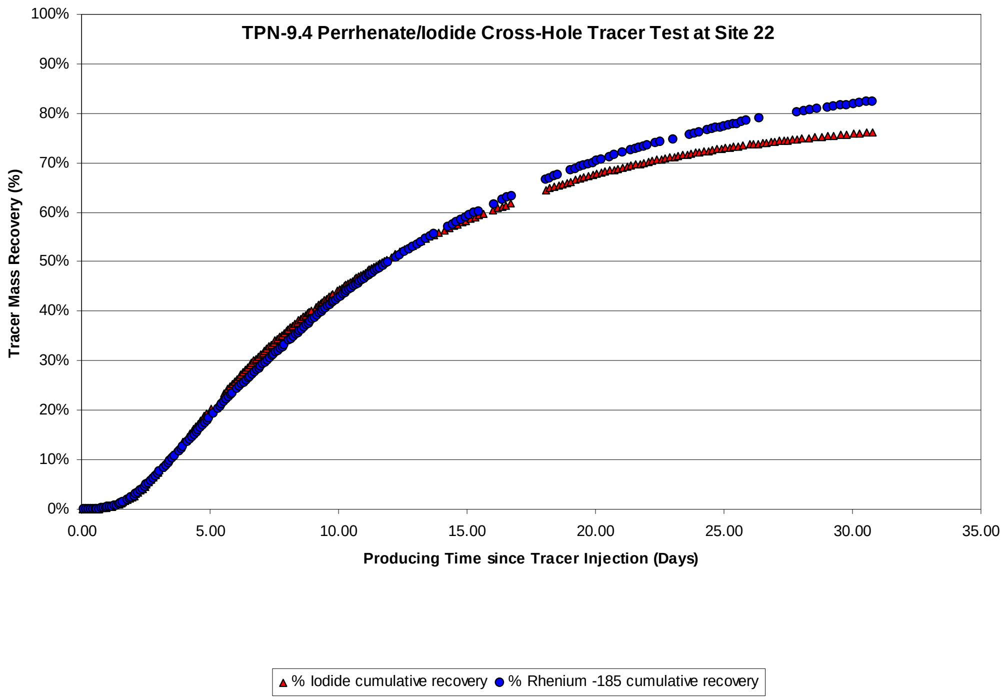

Figure 43. High cumulative mass recovery of tracers was observed.

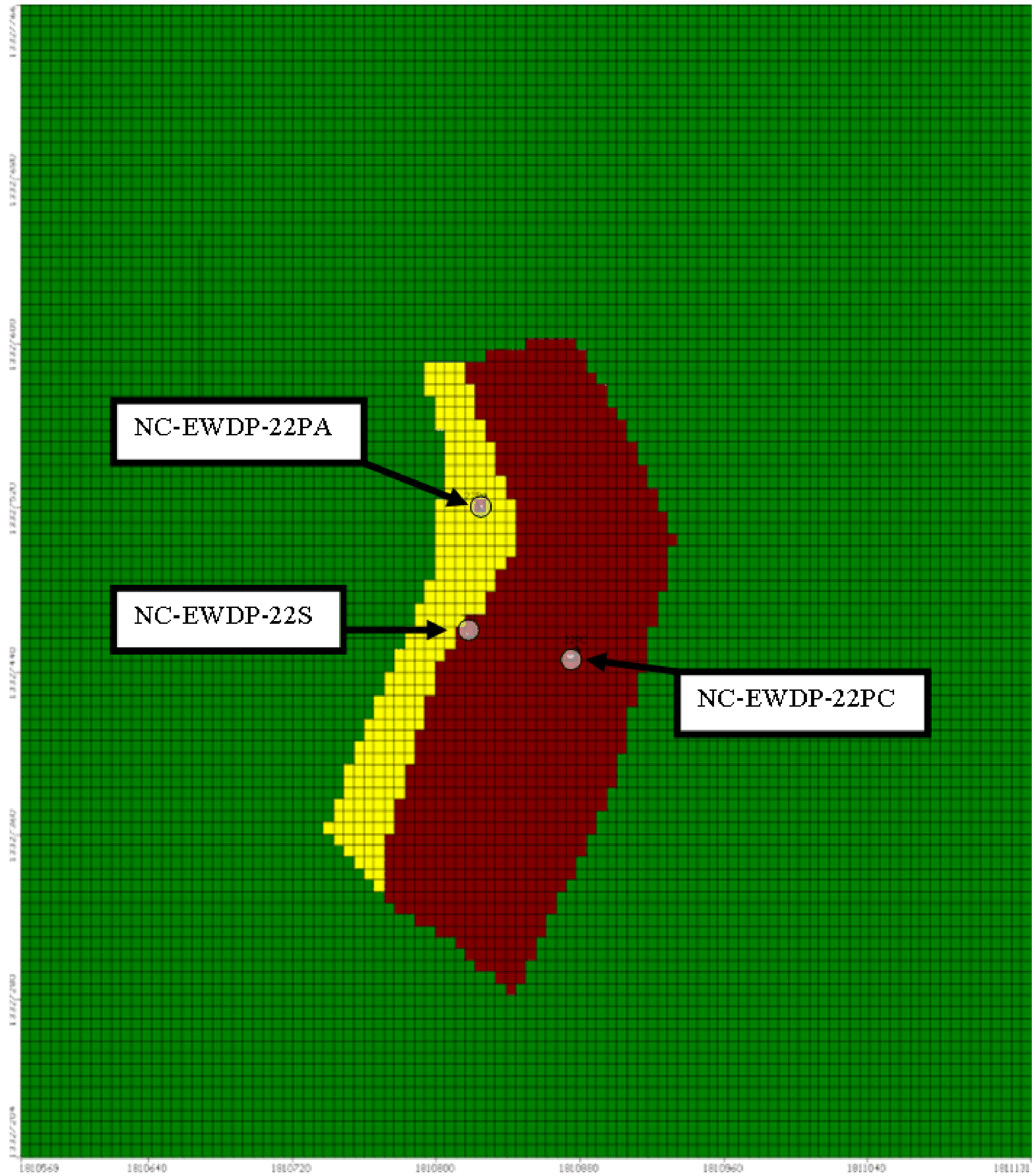

Figure 44. MODFLOW model geometry in map view.

Figure 45. Aerial view of Site 22 and the channel system observed in nearby Fortymile Wash.

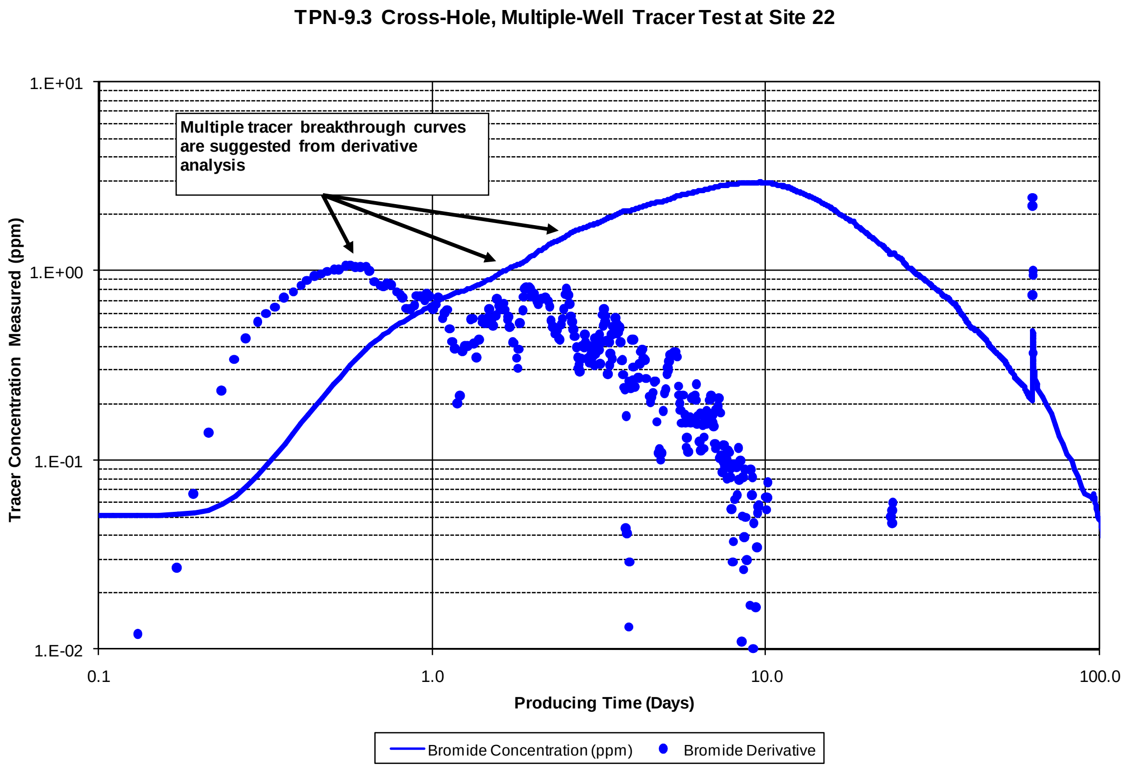

Figure 46. Derivative analysis of bromide response curve from 22PA Deep to 22S.

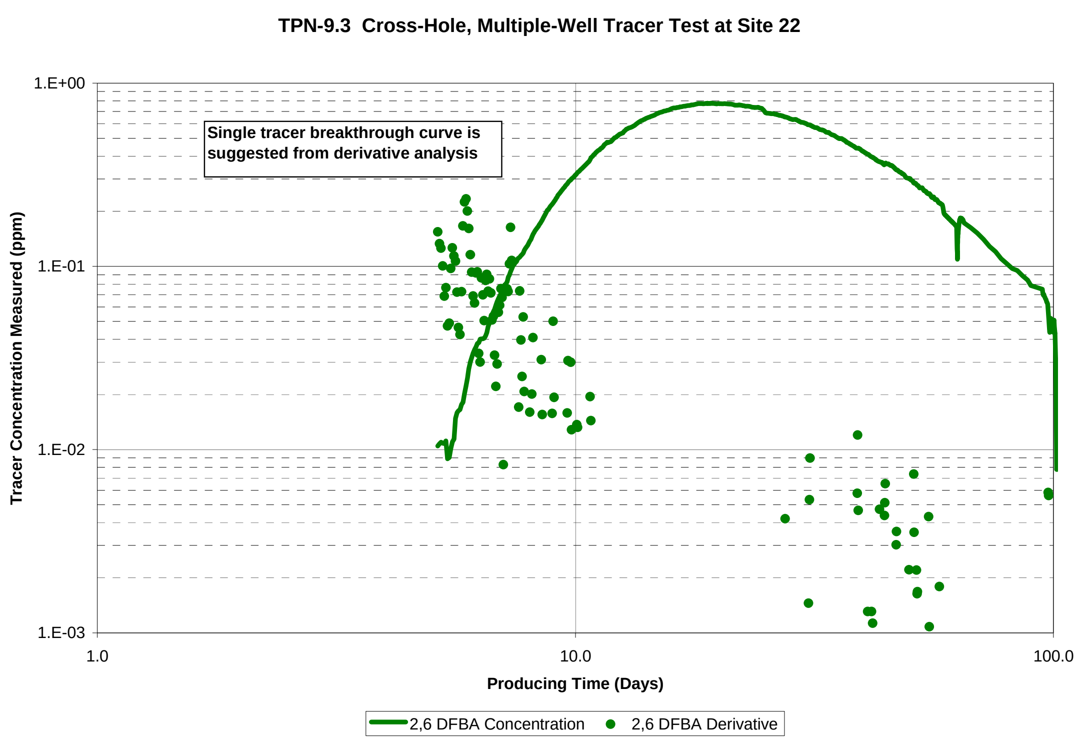

Figure 47. Derivative analysis of 2,6 DFBA response curve from 22PC Deep to 22S.

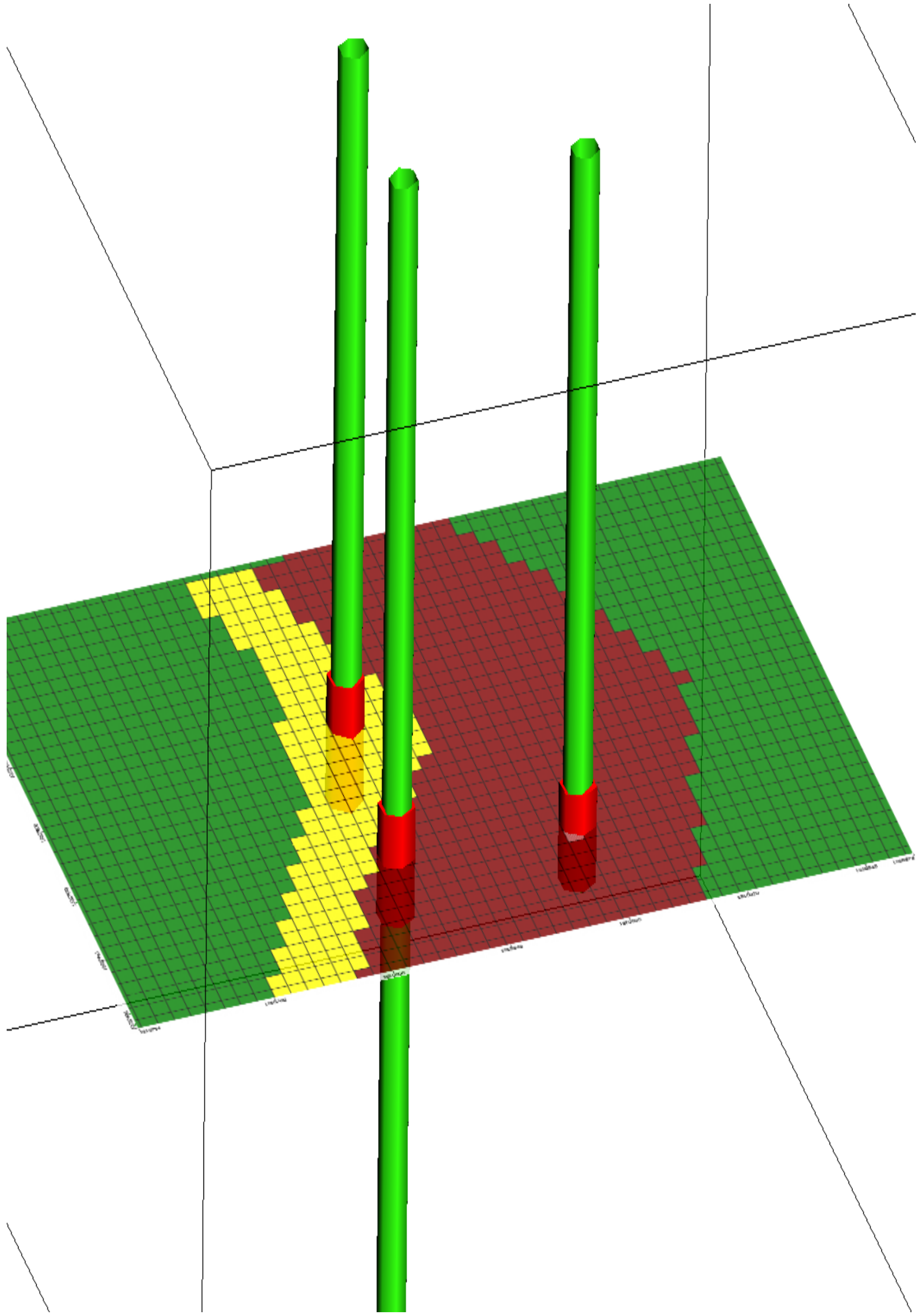

Figure 48. Conceptual model of adjacent paleochannels.

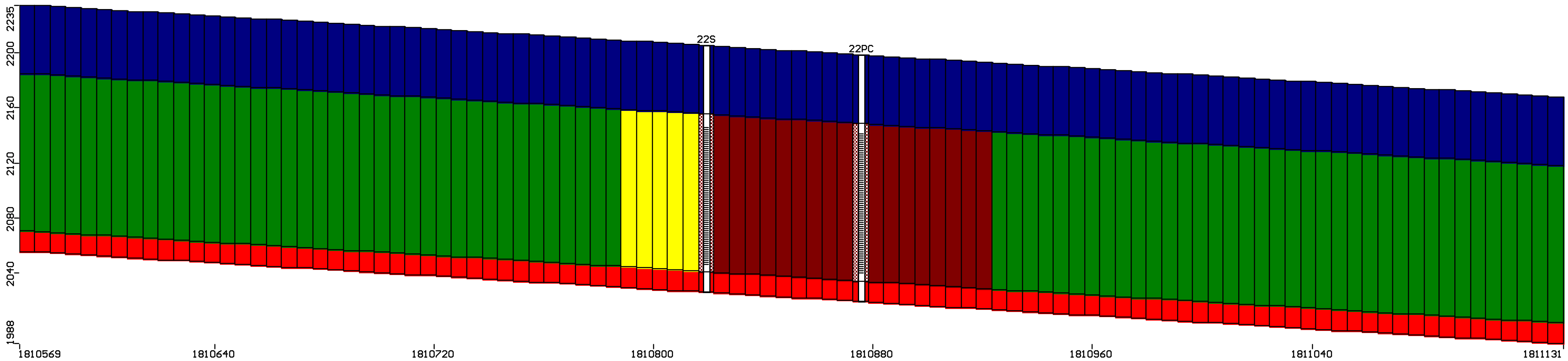

Figure 49. Simplified model in cross section showing wells 22S and 22PC.

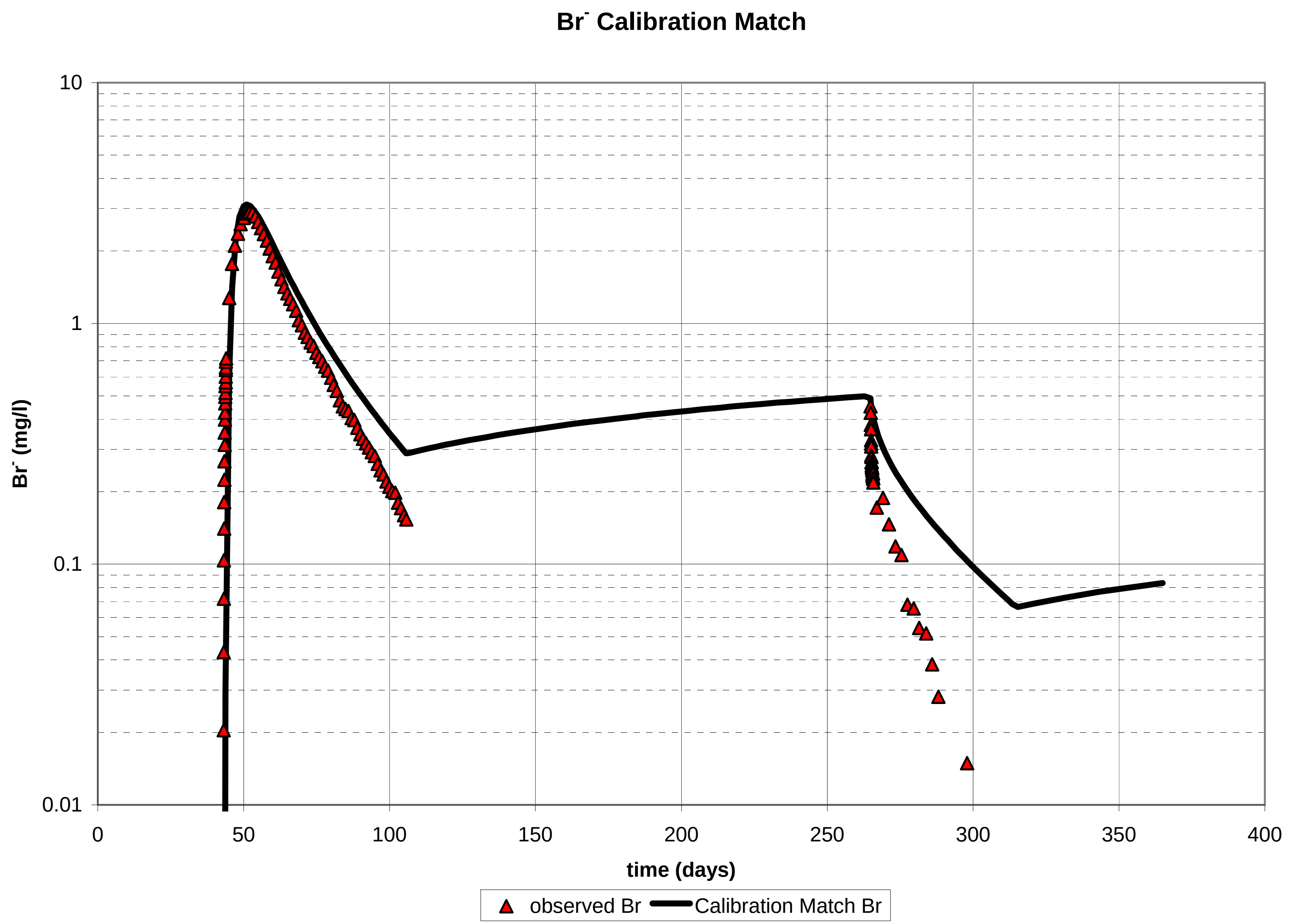

Figure 50. Calibration match obtained for bromide.

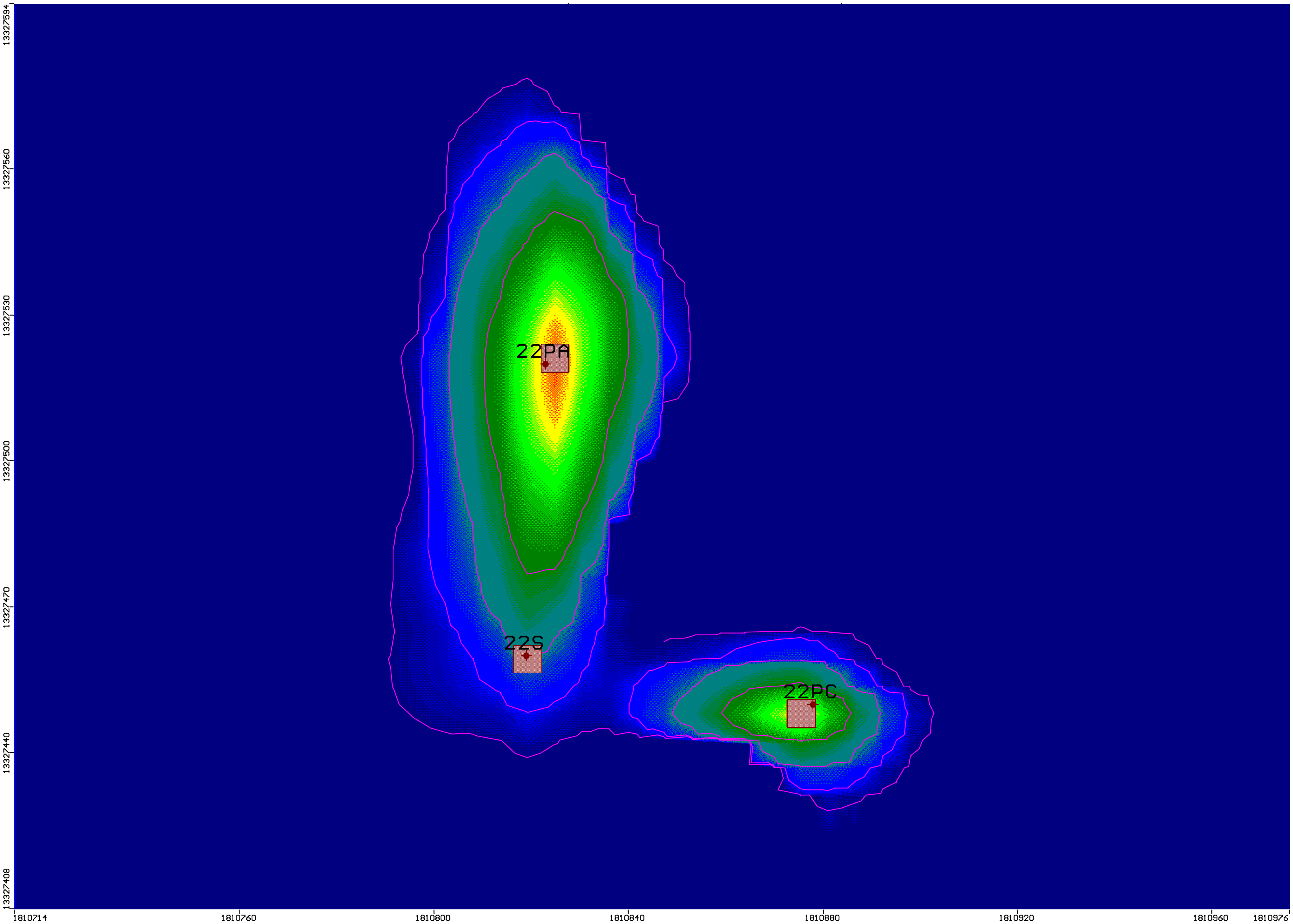

Figure 51. Example of tracer plume position immediately prior to pumping restart after extended downtime.

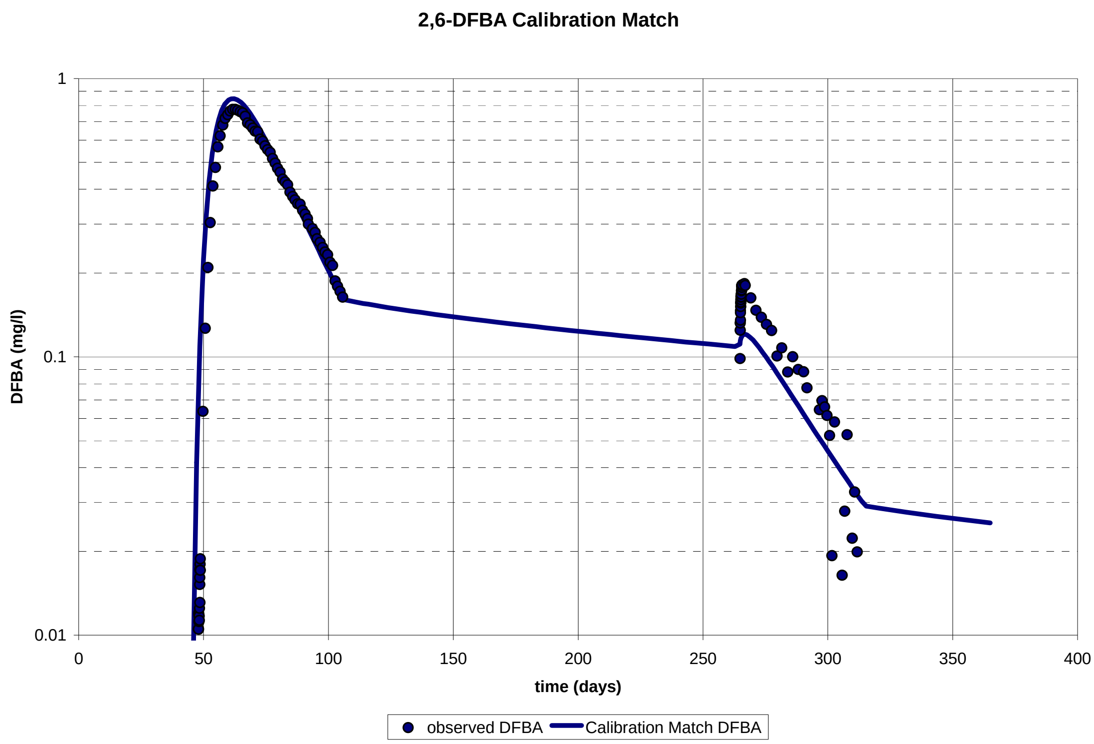

Figure 52. Calibration match obtained for 2,6-DFBA.

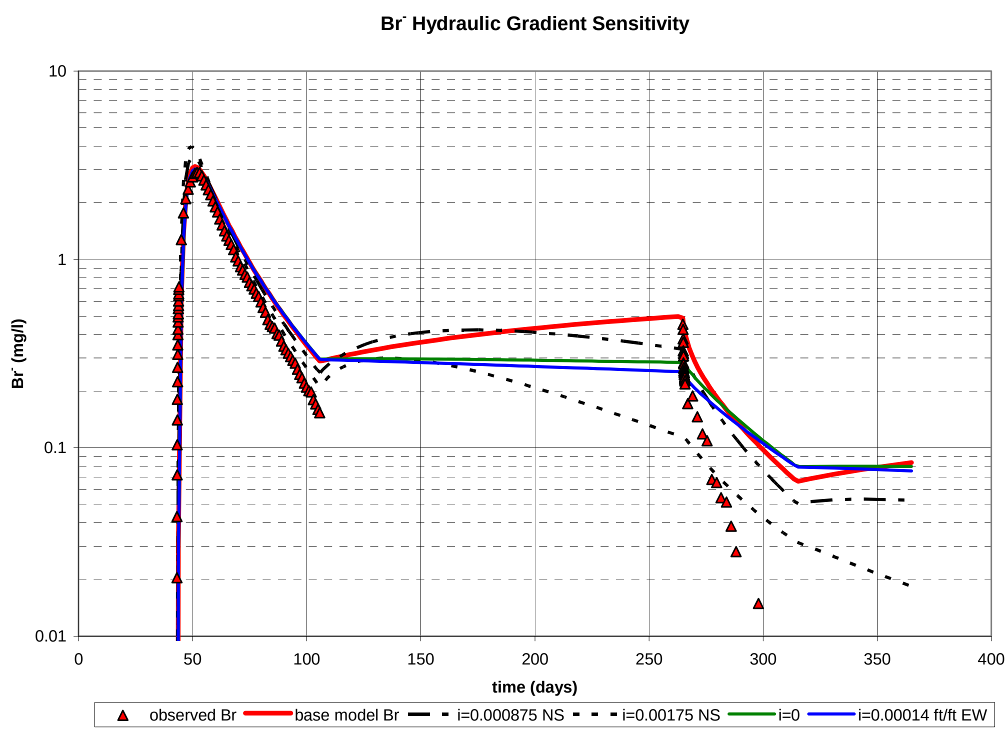

Figure 53. Hydraulic gradient sensitivity analysis for bromide.

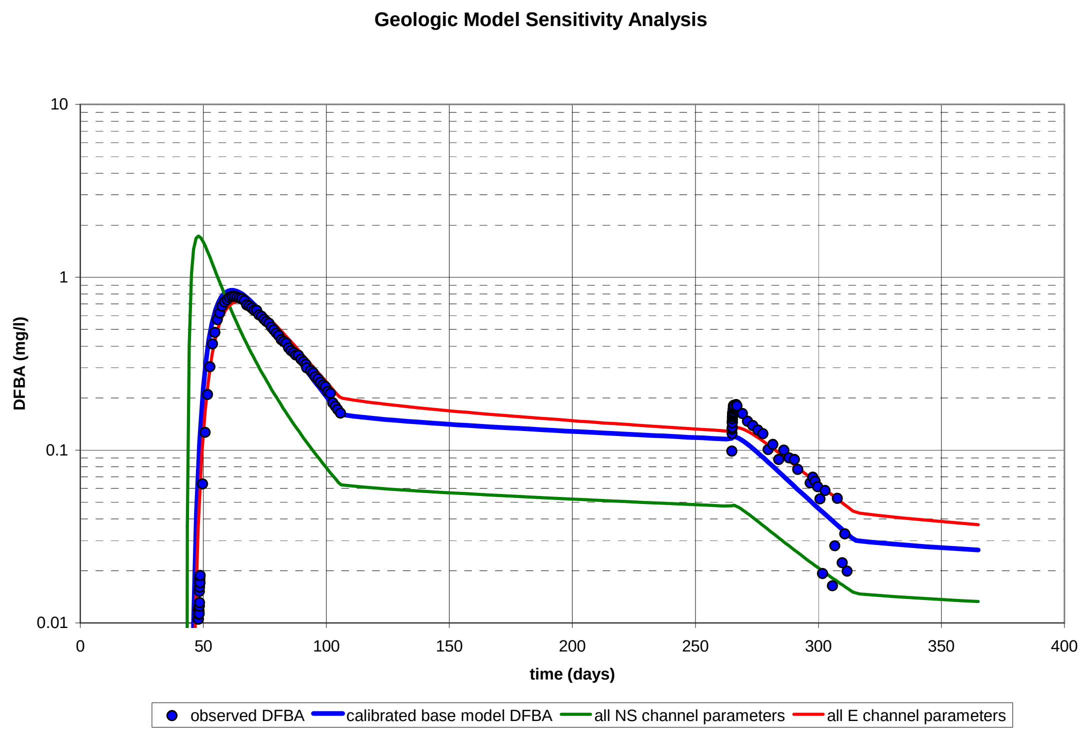

Figure 54. Geologic model sensitivity analysis for 2,6-DFBA.

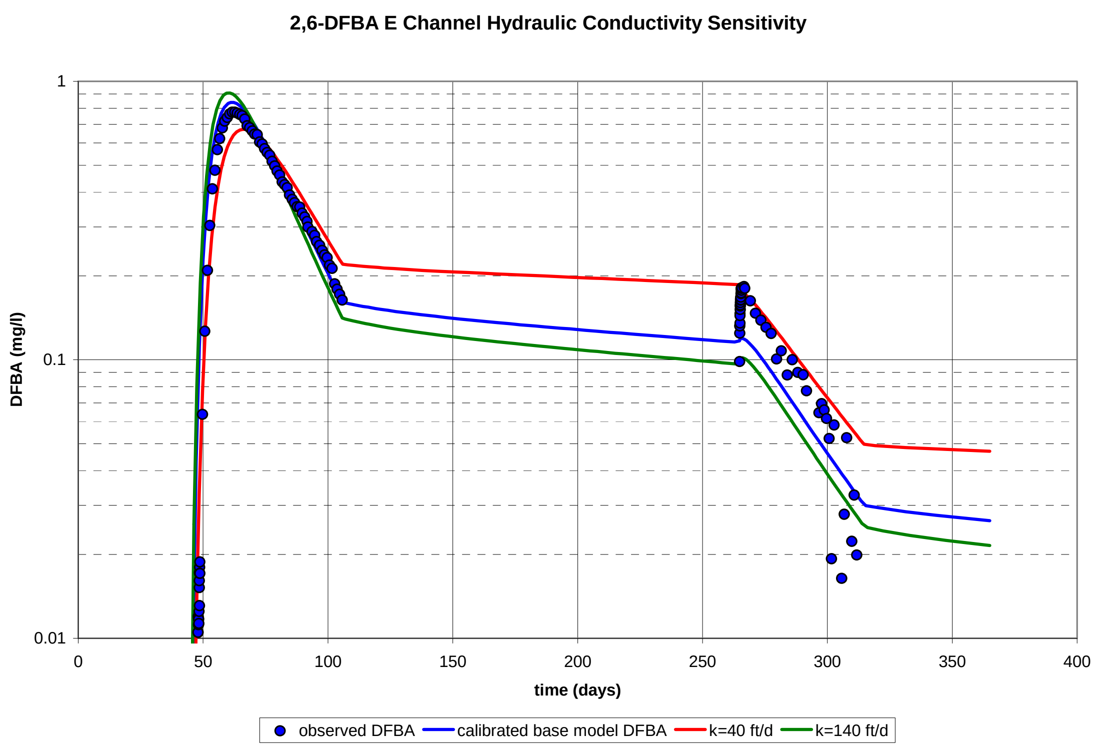

Figure 55. Hydraulic conductivity sensitivity analysis for 2,6-DFBA.

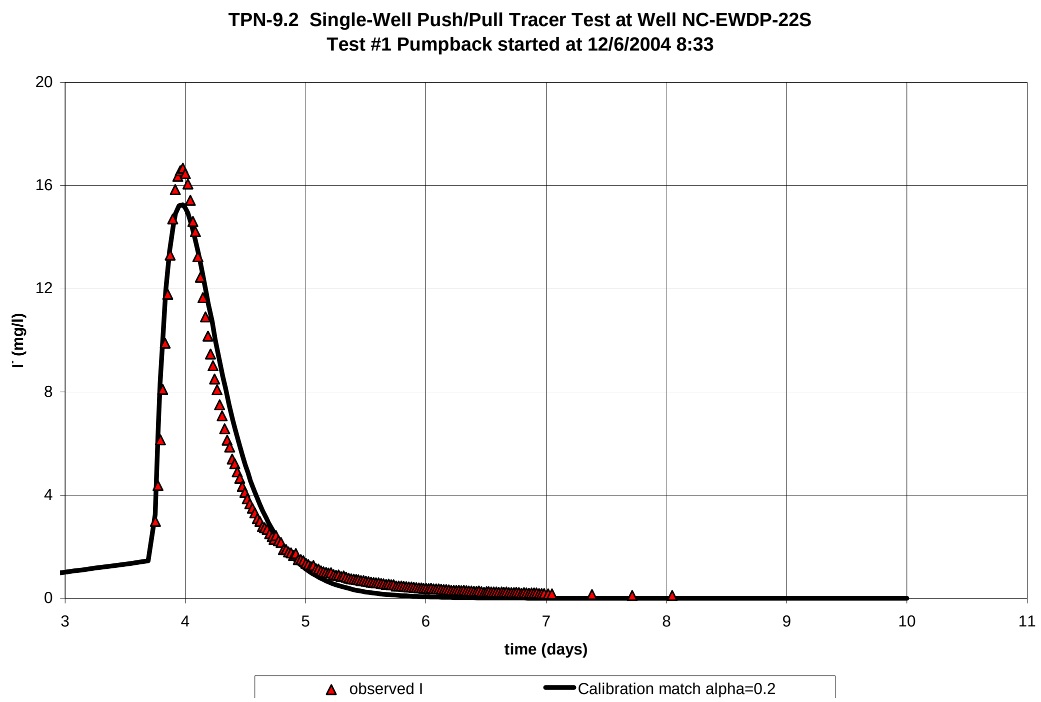

Figure 56. Longitudinal dispersivity (alpha) calibration match obtained for iodide on Push/Pull Tracer Test 1.

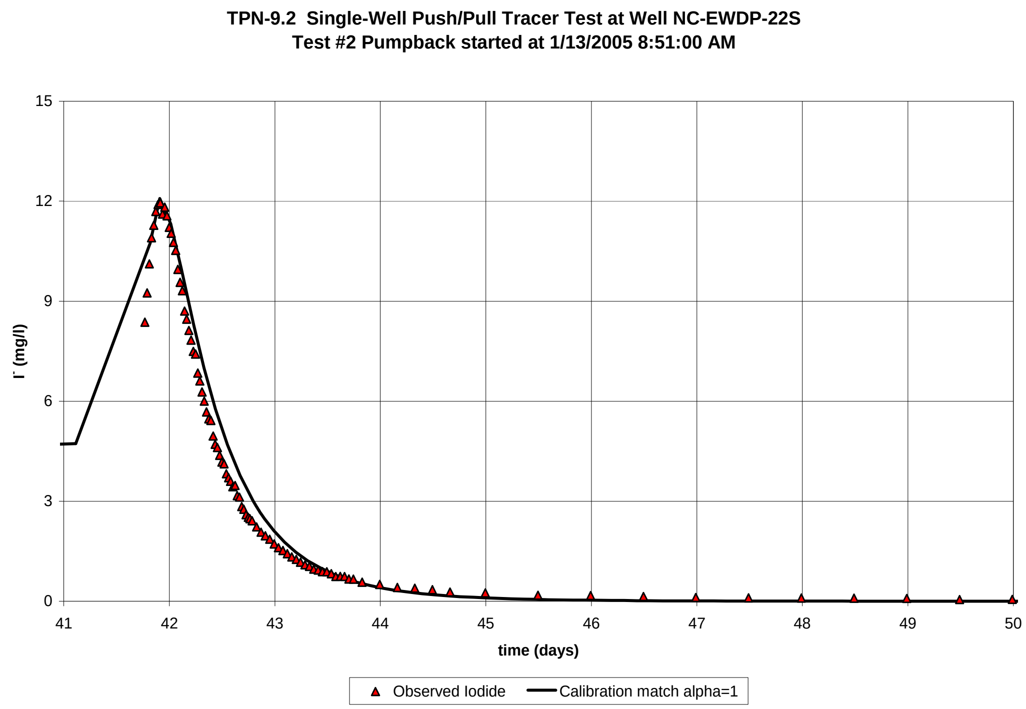

Figure 57. Longitudinal dispersivity (alpha) calibration match obtained for iodide on Push/Pull Tracer Test 2.

TABLES

Table 1. Zones and Screen Depths in Site 22 Wells.

Well Name	Well Zone	Sand Pack Depth Interval (feet below ground surface [feet bgs])	Sand Pack Height (feet)	Screen Top to Bottom Measured Depth (feet bgs)	Screen Height (feet)
22S	1	513.4 – 586.3	72.9	521.5 – 581.3	59.8
	2	651.8 – 766.5	114.7	661.2 – 760.6	99.4
	3	870.3 – 986.9	116.6	880.2 – 980.0	99.8
	4	1,133.2 – 1,196.5	63.3	1,140.0 – 1,180.0	40.0
22PA	1	508.7 – 587.0	78.3	520.7 – 579.7	58.8
	2	649.7 – 779.8	130.1	661.5 – 759.8	98.3
22PB	3	870.7 – 989.2	118.5	881.3 – 979.7	98.4
	4	1,125.2 – 1,199.7	74.5	1,140.3 – 1,179.7	39.4
22PC	1	505 – 585	80	510 - 580	70
	2	660 – 760	100	665 - 755	90

Table 2. Summary of preliminary and individual zone tests for site 22 pumping and observation wells.

Preliminary Analysis based on Combined Pump Spinner Test					
Observation Well	22PA Zone 1	22PA Zone 2	22PB Zone 3	22PB Zone 4	Total or Average
Thickness (feet)	73	115	117	64	369
Allocated Rate (gallons/minute [gpm])	44	53	23	13	133
Transmissivity (square feet/day [ft^2/d])	3,400	5,900	2,550	2,900	15,500
Permeability (darcy)	16	17.7	7.5	15.4	14.5
Storage Coefficient (dimensionless)	0.0016	0.00031	0.00002	0.00023	0.00216
Analysis based on Individual 11-hour Constant Discharge Tests of Discrete Zones					
	Test 1	Test 2	Test 3	Test 4	Total or Average
Pump Rate (gpm)	43.5	44.1	27.1	20.5	135.2
Transmissivity (ft^2/d)	2,600	4,600	1,500	2,000	10,700
Permeability (darcy)	12	14	4.5	11	10
Storage Coefficient (dimensionless)	0.00116	0.00035	0.0001	0.00021	0.00182
Leakance (feet)	98	279	355	750	370

Table 3. Summary of pumping well response analysis results for 11-hour pump tests.

Results from Pumping Well Response Analysis					
	Zone 1	Zone 2	Zone 3	Zone 4	Average
Skin Factor	+12	+33	+17	+7	+17
Well Efficiency	30%	16%	27%	15%	22%

Table 4. Nye County tracer test summary.

		Tracer Injection Information							Chase Water Information				Pumping Well Information					
Tracer Test Type and Number	Test Number	Injection Well or Piezometer No.	Injection Zone	Tracers	Tracer Mass (Kg)	Tracer Solution Volume (gals)	Tracer Injection Start (date/time)	Tracer Injection Rate (gpm)	Chase Water Volume (gals)	Chase Water Injection Start Date/Time	Chase Water Injection Rate (gpm)	Temp Monitored Injection Well or Piezometer	Pumping Well	Pumping Zone	Pumping Start (Date/Time)	Pumping Stop (Date/Time)	Average Pumping Rate (gpm)	Recovery Volume (gals)
Single-Well Push/Pull	1	22S	2	NaI	3	1.054	12/2/04 14:51	17.3	19,842	12/2/04 15:52	17.9	Yes	22S	2	12/6/2004	12/10/2004	47.3	295,060
				PFBA	1													
	2	22S	2	NaI	3	1032	12/13/04 14:42	15.4	19,534	12/13/04 15:49	16.3	Yes	22S	2	1/13/2005	3/20/2005	47.8	4,334,277
				2,3,4,5-TeFBA	1													
Cross-Hole	1	22PA Deep	2	LiBr	25	256.7	1/14/05 10:27	11.7	95.5	1/14/05 10:49	6.8	Yes	22S	2	1/13/2005 8:51	10/13/2005 9:41	48.0	7,691,185
				LiCl	97													7,691,185
				2,4,5-TFBA	8.5													7,691,185
	2	22PC Deep	2	2,6-DFBA	8.5	275.9	1/14/05 11:10	11.7	98.6	1/14/05 11:32	6.8	Yes	22S	2	1/13/2005 8:51	10/13/2005 9:41	48.0	7,691,185
	3	22PA Shallow	1	2,5-DFBA	1.5	278.5	1/14/05 11:59	9.0	32.8	1/14/05 12:30	4.7	Yes	22S	2	1/13/2005 8:51	10/13/2005 9:41	48.0	7,691,185
	4	22PA Deep	2	Micro-sphere Colloids	2.E-03	271.8	1/24/05 13:12	15.0	87.9	1/24/05 13:25	12.8	Yes	22S	2	1/13/2005 8:51	10/13/2005 9:41	48.0	4,334,277
	5	22PA Deep	2	NaI	5	254.5	8/25/05 12:06	11.2	95.4	8/25/05 12:29	10.0	Yes	22S	2	8/24/2005 11:03	10/13/2005 9:41	49.3	3,356,908
				$NaReO_4$	1.E-01													3,356,908

Table 5. Tracer masses and concentrations for Push/Pull Test 1.

Tracer	Tracer mass delivered (grams)	Calculated Initial Concentration (ppm)	UNLV measured Initial Concentration (ppm)	Concentration based tracer mass injected (grams)
Iodide	2,540.7	636.8	636.1	2,537.9
PFBA	1,001.00	250.9	249.1	993.8

Table 6. Autosampler sampling schedule for Push/Pull Test 1.

Elapsed Time	Frequency	Total Number of Samples	Minimum Number of Analyses
Hours 0 – 24	Every 10 minutes	144	12
Days 1 – 3	Every 30 minutes	96	6
Days 3 – 6	Every hour	72	9
Days 6 – 15	Every 3 hours	72	12

Table 7. Manual sampling schedule for Push/Pull Test 1.

Elapsed Time	Frequency	Total Number of Samples
Hours 0 – 5	Every 20 minutes	15
Hours 5 – 12	Every hour	7
Hours 12 – 24	Every 2 hours	6
Days 1 – 6	Every 8 hours	15
Days 6 – 15	Twice a day	18

Table 8. Tracer masses and concentrations for Push/Pull Test 2.

Tracer	Tracer mass delivered (grams)	Calculated Initial Concentration (ppm)	UNLV measured Initial Concentration (ppm)	Concentration based tracer mass injected (grams)
Iodide	2,539.9	650.2	654.9	2,558.2
2345 TeFBA	1,000.0	256.0	222.5	869.1

Table 9. Autosampler sampling schedule for Push/Pull Test 2.

Elapsed Time	Frequency	Total Number of Samples	Minimum Number of Analyses
Hours 0 – 24	Every 10 minutes	144	12
Days 1 – 5	Every 30 minutes	192	10
Days 5 – 14	Every hour	216	18
Days 14 –120	Every 2 hours	1272	92

Table 10. Manual sampling schedule for Push/Pull Test 2.

Time	Frequency	Total Number of Samples
Hours 0 – 5	Every 20 minutes	15
Hours 5 – 12	Every hour	7
Hours 12 – 24	Every 2 hours	6
Days 1 – 14	Every 8 hours	39
Days 14 –120	Every day	106

Table 11. Tracer masses and concentrations for Phase II cross-hole, multiple-well tracer test.

Tracer	Tracer mass delivered (grams)	Calculated Initial Concentration (ppm)	UNLV measured Initial Concentration (ppm)	Concentration based tracer mass injected (grams)
245-TFBA	8,500.0	8,747.4	8,277.8	8,043.7
Bromide	23,002.5	23,672.2	20,705.2	20,119.4
Lithium	18,451.2	18,988.3	17,915.7	17,408.9
26-DFBA	8,500.00	8,138.7	8,365.2	8,736.5
25-DFBA	1,500.00	1,422.8	1,422.9	1,500.1

Table 12. Tracer masses and concentrations for Phase I cross-hole, multiple-well tracer test.

Tracer	Tracer mass delivered (grams)	Calculated Initial Concentration (ppm)	UNLV measured Initial Concentration (ppm)	Concentration based tracer mass injected (grams)
Perrhenate	68.16	70.7	56.1	54.1
Iodide	4,233.13	4,394.0	3,414.6	3,289.6

Table 13. Autosampler sampling schedule for Phase I cross-hole, multiple-well tracer test.

Elapsed Time	Frequency	Total Number of Samples	Minimum Number of Analyses
Hours 0 – 24	Every 10 minutes	144	12
Days 1 – 5	Every 30 minutes	192	10
Days 5 – 14	Every hour	216	18
Days 14 –120	Every 2 hours	1,272	92

Table 14. Manual sampling schedule for Phase I cross-hole, multiple-well tracer test.

Time	Frequency	Total Number of Samples
Hours 0 – 5	Every 20 minutes	15
Hours 5 – 12	Every hour	7
Hours 12 – 24	Every 2 hours	6
Days 1 – 14	Every 8 hours	39
Days 14 –120	Every day	106

Table 15. Initial hydrogeologic parameters and model dimensions.

Area	Model encompasses an area surrounding three groundwater wells (22PA, 22PC, 22S) where push/pull and cross well tracer testing was conducted						
Type of model	Groundwater flow and mass transport						
Code	Visual MODFLOW® v. 3.1.0.86 with MT3DMS						
Time modeled	Transient flow and transport simulations for 365 days from start of first push/pull test						
Dimensions	X = 562 feet, Y = 562 feet (~7.25 acres)						
X coords	World: 1,810,569 – 1,811,131 ft; Model: 0 – 562 ft						
Y coords	World: 13,327,204 – 13,327,766 ft; Model: 0 – 562 ft						
Coordinate System	UTM feet NAD83 Zone 11						
Rows, columns, layers	100 x 100 x 3 (total 30,000 cells)						
Grid spacing	5.62 feet						
Lateral boundaries	Constant head boundaries along north and south model edges; no flow boundaries along east and west model edges.						
Surfaces	Model layers are level surfaces based on average gravel pack interval in the wells						
Layers and Properties	Kx,	Kz (ft/d)	Ss (1/ft)	Φ	λ (ft)	D (ft^2/d)	Kd (l/mg)
Screened interval	52	Kx,y/10	3.0x10^{-6}	0.3 background	7 Push/pull tests: 0.2	0.2	Li: 7x10^{-7}
Overlying and underlying layers	52	Kx,y/10	3.0x10^{-6}	0.3	7	0.2	Li: 7x10^{-7}
Hydraulic gradient	0.00014 ft/ft north to south						
Wells	Well 22S – injection/production well for push pull test, production well for cross						
Recharge	No recharge boundaries – time frame of model precludes the effect of recharge						
Solver	WHS (Waterloo Hydrogeologic Solver) with MODFLOW 2000 BCF engine. Upstream finite difference GCG solver with MT3DMS engine						
Layer type	Layers 1-3 Type 3 Confined/Unconfined acting as confined						

Table 16. Pumping stress intervals.

All Times PST					
Date and Time	Pump Status	Event	Elapsed time (days)	Pump uptime (days)	Pump downtime (days)
12/2/2004 14:51:30	Off	Start injection of tracers for 1st Push/Pull test	0.0000		0.0000
12/3/2004 10:22:30	Off	End of displacement of 1st Push/Pull test	0.8132		0.8132
12/6/2004 8:33:10	On	Pump back 1st Push/Pull test	3.7373		2.9241
12/10/2004 16:52:58	Off	End of pump back of 1st Push/Pull test	8.0844	4.3471	
12/13/2004 14:44:00	Off	Start injection of tracers for 2nd Push/Pull test	10.9948		2.9104
12/14/2004 12:51:20	Off	End of displacement of 2nd Push/Pull test	11.9166		0.9218
1/13/2005 8:51:50	On	Pump back 2nd Push/Pull test / Start of 1st Cross-Hole Test	41.7502		29.8337
1/24/2005 10:07:40	Off	Temp pump Shut In (SI)	52.8029	11.0527	
1/24/2005 10:27:00	On	Pump restarted	52.8163		0.0134
1/24/2005 11:00:50	Off	Temp pump SI	52.8398	0.0235	
1/24/2005 11:02:20	On	Pump restarted	52.8409		0.0010
3/7/2005 12:20:00	Off	Temp pump SI	94.8948	42.0539	
3/7/2005 12:21:00	On	Pump restarted	94.8955		0.0007
3/18/2005 8:35:20	Off	Pump shut in for extended period prior to permitting 2nd Cross-Hole Test	105.7388	10.8433	
8/24/2005 9:02:20	On	Pump restarted	264.7575		159.0188
8/24/2005 9:24:30	Off	Temp pump SI	264.7729	0.0154	
8/24/2005 9:29:30	On	Pump restarted	264.7764		0.0035
8/24/2005 9:57:10	Off	Temp pump SI	264.7956	0.0192	
8/24/2005 10:04:10	On	Pump restarted for extended period for 2nd Cross-Hole Test	264.8005		0.0049
9/8/2005 10:34:50	Off	Temp pump SI	279.8218	15.0213	
9/8/2005 12:10:00	On	Pump restarted	279.8878		0.0661
9/11/2005 6:34:00	Off	Temp pump SI	282.6545	2.7667	
9/12/2005 10:40:30	On	Pump restarted	283.8257		1.1712
10/13/2005 8:41:30	Off	Pump SI for end of 2nd Cross-Hole Test	314.7431	30.9174	

Table 17. Final calibration parameters for bromide match (western channel).

Effective porosity %	Dispersivity (longitudinal) ft	Dispersivity (tranverse) ft	Dispersivity (vertical) ft	Hydraulic gradient magnitude ft/ft	Hydraulic gradient azimuth	Hydraulic conductivity ft/day	Diffusivity Coefficient ft^2/day
8.2	20	4	0.2	0.00014	North to South	35	0.0002

Table 18. Calibrated versus measured head drawdown.

Well	Measured (ft)	Calibrated (ft)
22S	1.8*	1.4
22PA Deep	0.53	0.53
22PC Deep	0.46	0.49

* Calculated based upon observed data less head loss due to completion efficiency (wellbore friction drop)

Table 19. Final calibration parameters for 2,6-DFBA match (eastern channel).

Effective porosity %	Dispersivity (longitudinal) ft	Dispersivity (tranverse) ft	Dispersivity (vertical) ft	Hydraulic gradient magnitude ft/ft	Hydraulic gradient azimuth	Hydraulic conductivity ft/day	Diffusivity Coefficient ft^2/day
24	7	1.4	0.07	0.00014	North to South	65	0.0002

Table 20. Calibration match parameters for Push/Pull Test 1.

Effective porosity %	Dispersivity (longitudinal) ft	Dispersivity (tranverse) ft	Dispersivity (vertical) ft	Hydraulic gradient magnitude ft/ft	Hydraulic gradient azimuth	Hydraulic conductivity ft/day	Diffusivity Coefficient ft^2/day
0.24	0.2	0.02	0.002	0.00014	North to South	65	0.0002

Table 21. Calibration match parameters for Push/Pull Test 2.

Effective porosity %	Dispersivity (longitudinal) ft	Dispersivity (tranverse) ft	Dispersivity (vertical) ft	Hydraulic gradient magnitude ft/ft	Hydraulic gradient azimuth	Hydraulic conductivity ft/day	Diffusivity Coefficient ft^2/day
0.24	1	0.1	0.01	0.00014	North to South	65	0.0002

Appendix A
Wet Sieve Data

22PC Wet Sieve Data - Lab

LabSNo	Test Date	Sample Weight	M Correction	Text83	3 Passing	11/2 Passing	3/4 Passing	3/8 Passing	4 Passing	10 Passing	40 Passing	100 Passing	200 Passing
22PC-522.7-525.5-SC	12/14/04	1536.20	0.97	1483.60	100.00	100.00	84.80	71.80	56.10	35.30	18.80	13.40	11.20
22PC-525.5-526.5-SC	12/14/04	1074.80	0.97	1041.60	100.00	91.60	90.00	80.80	70.30	59.20	39.70	31.80	29.00
22PC-526.5-529.8-SC	12/14/04	902.70	0.95	859.90	100.00	89.20	73.90	67.50	58.90	45.70	24.40	16.30	13.40
22PC-529.8-531.3-SC	12/14/04	848.10	0.95	806.70	100.00	88.60	71.30	62.30	50.00	38.90	21.30	14.30	12.20
22PC-531.3-533.1-SC	12/15/04	1166.50	0.96	1115.40	100.00	100.00	86.60	76.30	63.40	47.30	27.20	20.00	17.00
22PC-533.1-534.1-SC	12/15/04	1138.30	0.95	1082.50	100.00	86.80	77.10	60.80	49.50	38.00	21.80	14.30	11.80
22PC-534.1-536.6-SC	12/15/04	2405.90	0.94	2255.30	100.00	96.40	89.60	80.30	66.50	44.80	20.60	13.70	11.40
22PC-536.6-537.8-SC	12/15/04	969.40	0.96	926.20	100.00	100.00	86.00	76.80	65.10	50.90	30.00	21.80	18.90
22PC-537.8-544.0-SC	12/15/04	1750.50	0.95	1656.80	100.00	89.30	79.70	72.60	59.90	45.30	25.00	16.60	13.90
22PC-544.2-546.7-SC	12/15/04	1490.00	0.95	1409.00	100.00	91.00	70.60	60.50	51.90	40.60	19.30	11.80	9.60
22PC-546.7-547.5-SC	12/15/04	664.40	0.95	633.50	100.00	100.00	96.80	92.70	84.00	64.00	25.40	13.50	10.70
22PC-547.5-549.5-SC	12/15/04	1033.60	0.95	982.10	100.00	79.40	66.80	58.40	51.50	40.50	21.90	13.60	11.10
22PC-549.5-550.2-SC	12/16/04	471.60	0.95	449.30	100.00	79.30	70.60	65.50	60.80	55.30	32.60	17.50	14.20
22PC-550.2-552.8-SC	12/16/04	1093.20	0.96	1051.70	100.00	70.40	60.50	50.60	41.30	29.70	14.50	8.70	6.80
22PC-552.8-554.5-SC	12/16/04	641.20	0.97	618.80	100.00	100.00	87.20	75.60	60.80	46.70	28.00	18.40	14.60
22PC-554.5-560.2-SC	12/16/04	2879.80	0.94	2693.00	100.00	80.80	62.50	53.50	42.70	29.10	13.30	8.50	6.50
22PC-560.2-562.8-SC	12/16/04	851.00	0.96	817.60	100.00	81.20	65.90	50.70	40.50	29.60	17.90	12.00	9.80
22PC-562.8-565.4-SC	12/16/04	1156.00	0.97	1119.50	100.00	100.00	92.60	80.20	63.90	43.70	19.50	12.10	9.50
22PC-565.4-567.1-SC	12/16/04	666.00	0.96	639.80	100.00	70.70	63.70	49.10	38.30	27.30	15.30	9.80	7.90
22PC-567.1-568.1-SC	12/16/04	712.00	0.95	676.70	100.00	100.00	78.50	66.00	56.70	46.60	30.40	22.30	19.30
22PC-568.1-569.9-SC	12/16/04	1848.90	0.94	1743.70	100.00	83.50	57.20	48.20	36.90	25.80	12.30	7.50	6.00
22PC-569.9-571.3-SC	12/17/04	1344.30	0.95	1281.50	100.00	100.00	87.80	79.00	64.00	44.40	21.10	12.50	9.80
22PC-571.3-578.1-SC	12/17/04	1823.10	0.94	1720.60	100.00	96.60	80.70	65.00	51.20	38.50	22.20	16.00	13.30
22PC-578.1-578.6-SC	12/17/04	745.90	0.96	718.60	100.00	100.00	84.50	71.30	58.00	39.90	21.60	14.90	12.30
22PC-578.6-582.8-SC	12/17/04	2326.50	0.94	2195.10	100.00	100.00	81.20	67.80	56.50	43.80	22.90	15.30	12.90
22PC-582.8-585.3-SC	12/17/04	1140.90	0.95	1083.70	100.00	85.20	64.00	55.80	43.60	31.60	17.30	11.60	9.40
22PC-585.3-586.2-SC	12/17/04	2003.70	0.96	1923.90	100.00	77.50	69.50	54.90	44.70	34.80	21.90	15.60	13.30
22PC-586.2-587.0-SC	12/17/04	1966.10	0.95	1867.70	100.00	93.40	84.60	75.00	63.30	39.70	20.90	14.70	12.20
22PC-587.0-587.8-SC	12/17/04	1373.50	0.95	1304.80	100.00	89.40	79.60	69.10	59.30	49.20	31.40	23.30	20.60
22PC-587.8-594.5-SC	12/20/04	2211.60	0.96	2130.00	100.00	88.90	79.90	70.10	57.70	47.10	28.20	21.30	18.50
22PC-594.5-595.0-SC	12/20/04	933.30	0.97	901.70	100.00	90.40	75.40	64.90	55.70	45.10	29.40	21.60	18.70

22PC Wet Sieve Data - Lab

LabSNo	Test Date	Sample Weight	M Correction	Text83	3 Passing	11/2 Passing	3/4 Passing	3/8 Passing	4 Passing	10 Passing	40 Passing	100 Passing	200 Passing
22PC-595.0-595.7-SC	12/20/04	310.70	0.96	297.80	100.00	100.00	68.70	56.50	44.60	31.10	17.60	11.50	9.80
22PC-595.7-597.3-SC	12/20/04	639.00	0.95	606.60	100.00	100.00	86.00	71.00	56.60	39.30	20.80	13.70	11.20
22PC-597.3-599.6-SC	12/20/04	1348.30	0.96	1288.80	100.00	89.90	78.70	64.00	49.10	34.40	28.10	22.70	20.20
22PC-599.6-600.3-SC	12/20/04	1061.60	0.94	998.10	100.00	100.00	73.50	64.20	54.70	38.80	18.70	12.90	10.50
22PC-600.3-601.9-SC	12/21/04	1248.40	0.95	1189.70	100.00	100.00	82.50	72.50	58.90	42.20	23.70	16.10	13.50
22PC-601.9-604.1-SC	12/21/04	1219.30	0.93	1136.30	100.00	90.90	72.50	62.40	51.70	40.30	23.20	15.50	12.90
22PC-604.1-604.7-SC	12/21/04	1402.90	0.94	1311.40	100.00	100.00	92.10	81.60	68.30	50.10	25.90	18.10	15.10
22PC-604.7-606.3-SC	12/21/04	831.60	0.96	797.70	100.00	100.00	77.40	68.30	56.70	44.60	30.70	21.70	18.30
22PC-606.6-609.3-SC	12/21/04	1079.00	0.94	1014.20	100.00	90.60	82.50	77.70	67.20	50.40	26.00	17.00	14.10
22PC-609.3-610.1-SC	12/21/04	2176.40	0.95	2059.70	100.00	81.10	68.70	56.80	44.90	33.20	17.80	12.10	10.10
22PC-610.1-611.8-SC	12/21/04	1373.50	0.96	1318.30	100.00	94.50	83.50	63.20	48.60	35.20	20.60	14.90	12.60
22PC-611.8-613.6-SC	12/21/04	1058.00	0.94	991.40	100.00	90.20	70.50	63.00	53.20	42.90	27.90	19.40	16.40
22PC-613.6-615.4-SC	12/21/04	1328.10	0.95	1266.30	100.00	91.90	81.80	73.40	60.90	42.80	22.70	15.10	12.20
22PC-615.5-618.5-SC	12/22/04	1696.00	0.95	1618.30	100.00	100.00	89.70	80.80	68.60	47.50	22.70	14.60	11.90
22PC-618.5-620.0-SC	12/22/04	865.40	0.97	835.30	100.00	88.60	78.40	68.20	56.00	39.80	17.50	10.80	8.70
22PC-620.0-621.1-SC	12/22/04	628.70	0.96	601.10	100.00	100.00	82.40	76.20	67.40	50.40	18.20	10.10	7.90
22PC-621.1-623.0-SC	12/22/04	1453.00	0.96	1387.90	100.00	84.60	70.50	54.80	43.50	29.60	14.20	9.20	7.00
22PC-623.0-623.7-SC	12/22/04	767.60	0.96	733.40	100.00	83.50	69.80	62.10	48.90	35.00	21.20	15.40	13.20
22PC-625.2-629.1-SC	12/27/04	461.10	0.96	440.90	100.00	100.00	77.40	64.10	55.10	44.30	27.20	20.10	16.70
22PC-629.1-629.7-SC	12/27/04	549.70	0.96	526.50	100.00	100.00	91.10	71.90	62.10	49.70	28.70	20.60	17.30
22PC-629.7-631.0-SC	12/27/04	341.70	0.97	330.90	100.00	100.00	84.10	79.60	71.60	57.00	28.80	20.00	16.50
22PC-631.0-631.9-SC	12/27/04	757.60	0.96	726.20	100.00	100.00	81.40	71.50	58.70	47.10	28.30	21.30	17.80
22PC-632.1-634.1-SC	12/27/04	953.50	0.97	927.90	100.00	100.00	89.60	77.60	63.60	48.40	28.10	21.10	17.70
22PC-634.1-635.8-SC	1/3/05	739.40	0.97	715.90	100.00	100.00	86.80	75.80	63.90	50.50	30.70	22.60	19.50
22PC-636.1-637.7-SC	1/3/05	676.70	0.96	648.80	100.00	81.20	65.80	59.30	51.60	44.10	29.40	20.40	18.10
22PC-637.7-639.1-SC	1/3/05	490.90	0.96	471.90	100.00	100.00	87.30	74.80	67.40	56.20	36.60	27.30	23.80
22PC-639.1-641.3-SC	1/3/05	994.20	0.96	953.50	100.00	100.00	93.30	81.30	69.30	58.00	41.80	33.80	29.80
22PC-641.6-642.1-SC	1/3/05	367.00	0.97	354.00	100.00	100.00	91.80	89.70	83.90	70.80	48.60	38.40	34.80
22PC-642.1-645.0-SC	1/5/05	816.10	0.96	780.60	100.00	89.50	78.30	66.90	58.20	45.90	24.00	17.20	14.60
22PC-645.0-646.8-SC	1/5/05	807.10	0.96	778.00	100.00	88.20	82.50	74.20	65.70	54.00	37.20	28.40	25.00
22PC-646.8-648.4-SC	1/5/05	533.60	0.97	519.40	100.00	100.00	88.20	86.00	77.70	63.90	34.80	22.50	17.50

22PC Wet Sieve Data - Lab

LabSNo	Test Date	Sample Weight	M Correction	Text83	3 Passing	11/2 Passing	3/4 Passing	3/8 Passing	4 Passing	10 Passing	40 Passing	100 Passing	200 Passing
22PC-648.4-651.6-SC	1/5/05	1040.20	0.97	1003.80	100.00	100.00	100.00	92.50	78.40	58.90	30.50	23.00	20.30
22PC-651.6-652.8-SC	1/5/05	560.30	0.96	540.10	100.00	100.00	79.90	72.40	61.10	48.80	27.00	19.40	16.70
22PC-652.8-655.6-SC	1/5/05	1133.10	0.97	1094.90	100.00	87.20	77.90	71.60	64.70	54.70	36.30	27.50	23.80
22PC-655.6-656.8-SC	1/6/05	856.10	0.97	833.00	100.00	100.00	90.30	80.90	71.90	60.60	39.00	30.30	26.70
22PC-656.8-658.3-SC	1/6/05	493.40	0.96	471.80	100.00	100.00	69.60	62.30	54.60	43.20	25.40	17.90	14.90
22PC-658.3-659.5-SC	1/6/05	497.20	0.97	479.90	100.00	100.00	89.00	84.60	73.80	59.00	27.10	17.50	14.70
22PC-659.5-661.2-SC	1/6/05	754.00	0.96	724.50	100.00	100.00	77.00	62.90	51.80	41.10	24.80	16.90	14.10
22PC-661.2-663.3-SC	1/13/05	1041.80	0.91	946.10	100.00	87.00	81.60	72.00	60.70	44.70	20.50	11.60	8.70
22PC-663.3-666.2-SC	1/13/05	1503.30	0.93	1402.10	100.00	92.30	82.20	71.30	62.40	50.50	29.90	21.40	18.00
22PC-666.2-668.0-SC	1/13/05	1057.80	0.96	1014.80	100.00	82.70	72.20	64.00	55.30	45.30	28.80	20.70	17.60
22PC-668.0-670.7-SC	1/13/05	873.40	0.95	827.50	100.00	94.00	87.70	79.00	68.50	54.80	36.20	28.40	24.40
22PC-670.7-673.2-SC	1/13/05	1239.90	0.96	1186.10	100.00	90.80	81.30	71.50	62.10	52.00	36.70	28.10	24.20
22PC-673.9-675.3-SC	1/18/05	606.90	0.96	585.20	100.00	100.00	90.70	74.10	62.80	47.50	23.40	15.50	12.20
22PC-675.3-677.3-SC	1/18/05	1162.40	0.97	1130.70	100.00	88.50	78.10	69.70	60.10	48.80	31.80	23.80	20.30
22PC-678.1-679.4-SC	1/18/05	879.00	0.96	845.40	100.00	100.00	92.70	85.50	73.60	53.70	25.90	17.30	14.10
22PC-679.4-684.2-SC	1/18/05	967.20	0.96	928.30	100.00	77.70	52.60	43.10	35.60	27.40	14.40	9.20	7.10
22PC-684.2-686.9-SC	1/18/05	918.10	0.96	882.80	100.00	100.00	88.60	75.70	64.20	51.20	28.90	19.90	16.20
22PC-686.9-687.4-SC	1/18/05	669.70	0.97	648.40	100.00	100.00	76.50	62.30	51.50	41.60	24.40	17.00	13.70
22PC-688.1-689.3-SC	1/18/05	653.40	0.95	618.90	100.00	100.00	82.90	72.80	64.10	51.70	28.80	19.10	15.20
22PC-689.3-690.1-SC	1/18/05	476.60	0.96	457.70	100.00	100.00	90.40	81.80	72.50	57.10	36.40	26.50	21.30
22PC-690.3-691.9-SC	1/18/05	966.60	0.94	904.40	100.00	100.00	85.60	72.90	62.40	48.40	26.70	18.70	14.90
22PC-691.9-692.7-SC	1/18/05	1093.70	0.95	1038.60	100.00	100.00	90.40	75.90	61.70	45.00	23.50	15.80	13.00
22PC-692.7-696.1-SC	1/20/05	955.10	0.96	912.50	100.00	80.80	64.70	58.60	48.90	36.80	21.00	15.10	12.40
22PC-696.1-699.2-SC	1/20/05	829.60	0.96	795.80	100.00	87.40	76.40	67.70	56.30	41.50	25.30	18.80	15.60
22PC-699.2-699.8-SC	1/20/05	625.90	0.93	581.40	100.00	100.00	82.70	76.60	67.70	53.60	31.90	20.50	16.20
22PC-699.8-701.0-SC	1/20/05	803.80	0.93	747.90	100.00	100.00	90.00	76.00	59.90	45.20	26.40	18.20	14.60
22PC-701.0-703.4-SC	1/20/05	942.20	0.93	872.10	100.00	100.00	88.80	76.80	64.70	52.00	34.00	24.80	20.30
22PC-703.4-704.9-SC	1/21/05	733.20	0.95	697.90	100.00	100.00	87.00	79.70	70.90	60.00	38.10	26.30	21.80
22PC-706.1-707.0-SC	1/21/05	1235.90	0.92	1142.20	100.00	100.00	91.40	83.70	74.80	62.20	38.60	23.20	18.60
22PC-707.0-709.0-SC	1/21/05	1853.70	0.94	1737.50	100.00	92.10	77.50	68.40	58.50	48.70	34.10	23.80	19.40
22PC-709.0-712.1-SC	1/21/05	1118.90	0.94	1050.30	100.00	87.50	65.50	55.60	47.80	38.60	22.20	15.10	11.20

22PC Wet Sieve Data - Lab

LabSNo	Test Date	Sample Weight	M Correction	Text83	3 Passing	11/2 Passing	3/4 Passing	3/8 Passing	4 Passing	10 Passing	40 Passing	100 Passing	200 Passing
22PC-712.1-714.0-SC	1/21/05	744.20	0.93	690.10	100.00	100.00	83.10	76.40	70.20	60.90	39.00	25.20	20.50
22PC-714.0-715.6-SC	1/25/05	963.50	0.95	910.10	100.00	100.00	81.80	64.80	56.90	49.70	28.70	19.00	15.50
22PC-715.6-718.7-SC	1/25/05	1509.00	0.95	1430.30	100.00	100.00	87.10	72.90	63.00	53.40	34.60	25.60	21.30
22PC-719.0-719.5-SC	1/25/05	763.20	0.94	719.60	100.00	100.00	95.10	85.90	75.10	59.80	33.40	23.30	19.20
22PC-719.5-720.4-SC	1/25/05	646.40	0.94	609.00	100.00	82.60	70.40	64.60	56.00	45.20	28.00	19.90	16.60
22PC-720.4-720.9-SC	1/25/05	486.20	0.95	460.10	100.00	100.00	91.70	81.40	72.40	58.80	37.70	27.80	23.60
22PC-721.5-725.5-SC	1/25/05	978.90	0.97	948.30	100.00	75.70	66.50	57.70	49.40	39.80	26.50	19.00	16.00
22PC-725.5-726.0-SC	1/25/05	773.20	0.97	750.40	100.00	100.00	93.50	82.20	72.80	57.10	33.20	25.20	21.60
22PC-726.0-728.8-SC	1/25/05	585.60	0.97	568.80	100.00	100.00	83.20	75.60	67.00	55.90	36.50	28.20	24.20
22PC-729.9-731.5-SC	1/25/05	663.30	0.97	640.10	100.00	100.00	89.40	81.30	67.20	54.10	34.30	25.90	22.40
22PC-731.5-733.2-SC	1/25/05	613.80	0.96	591.50	100.00	100.00	93.60	86.50	76.40	59.20	33.90	25.60	21.30
22PC-734.8-736.4-SC	1/26/05	689.10	0.93	643.40	100.00	100.00	91.50	80.80	70.20	56.30	36.10	26.30	22.40
22PC-736.4-737.1-SC	1/26/05	1083.60	0.94	1018.80	100.00	100.00	91.80	81.90	69.40	52.30	30.80	22.90	18.80
22PC-737.1-739.6-SC	1/26/05	1403.20	0.95	1330.30	100.00	100.00	94.40	84.90	74.30	59.80	38.20	29.20	25.00
22PC-739.9-741.8-SC	1/26/05	677.70	0.94	634.80	100.00	100.00	92.60	80.40	70.70	58.00	36.20	25.50	21.00
22PC-741.8-743.1-SC	1/26/05	777.60	0.95	739.50	100.00	87.40	84.30	78.40	67.00	49.50	26.70	18.90	15.30
22PC-743.1-745.9-SC	2/4/05	848.30	0.96	812.20	100.00	100.00	85.60	76.30	64.90	53.50	36.40	27.80	23.60
22PC-747.0-747.4-SC	2/4/05	461.30	0.96	441.90	100.00	100.00	90.50	82.50	72.20	59.20	38.30	28.30	23.40
22PC-747.4-749.1-SC	2/4/05	881.70	0.96	846.50	100.00	100.00	94.20	89.90	77.20	57.20	28.00	19.00	15.20
22PC-749.1-752.9-SC	2/4/05	1386.60	0.96	1329.80	100.00	92.80	81.70	69.50	59.10	46.90	28.50	21.20	17.80
22PC-752.9-754.9-SC	2/4/05	865.00	0.95	822.30	100.00	90.30	88.40	78.20	66.70	52.10	30.70	22.30	18.60
22PC-754.9-755.5-SC	2/7/05	645.70	0.97	626.50	100.00	100.00	85.10	74.00	62.10	47.40	30.90	23.10	19.10
22PC-755.5-759.2-SC	2/7/05	1093.30	0.95	1041.40	100.00	74.80	68.10	61.10	53.30	44.80	31.00	24.30	20.70
22PC-759.2-759.5-SC	2/7/05	400.70	0.98	391.90	100.00	100.00	88.70	74.70	64.30	50.60	29.20	19.10	14.90
22PC-759.5-761.3-SC	2/7/05	1019.30	0.98	999.50	100.00	100.00	91.30	84.60	75.50	65.30	37.20	24.40	19.10
22PC-761.3-762.4-SC	2/8/05	758.40	0.98	743.70	100.00	100.00	74.00	61.00	49.20	37.20	22.20	16.50	13.90
22PC-762.4-762.8-SC	2/8/05	677.00	0.97	657.40	100.00	100.00	98.10	87.30	72.40	60.80	42.90	33.40	28.60

Appendix B: Alluvium Core Logging Report

22PC ALLUVIUM CORE LOGGING REPORT

Date Logged	Logged By	Date Checked	Checked By	Core Run Number	Core Sample Type	Sample Number	Depth From	Depth To	Drilling Rate	Sample Recovery	Borehole Diameter	Tare Weight	Sample Plus Tare	Sample Weight	Munsell	Gravel	Sand	Silt	Clay	Text 2607	USCS Group	Volcanics
26-Oct-04	DD/BW	27-Oct-04	BW	1	D	22PC-460-460.5-SC	460.00	460.50			6.20	0.20	6.00	5.80								
26-Oct-04	DD/BW	27-Oct-04	BW	1	L	22PC-460-460.5-SCA	460.00	460.50				0.82	6.40	5.58	5YR 4/6	37	47	6	10	16	SC	100
26-Oct-04	DD/BW	27-Oct-04	BW	1	R	22PC-460-463.7-SC	460.00	463.70	0.80	3.70												
26-Oct-04	DD/BW	27-Oct-04	BW	1	L	22PC-460.5-461.1-SC	460.50	461.10				0.81	9.65	8.84	10YR 4/3	46	40	4	10	14	GP-GC	100
26-Oct-04	DD/BW	27-Oct-04	BW	1	D	22PC-460.5-461.3-SC	460.50	461.30			6.20	0.20	13.75	13.55								
26-Oct-04	DD/BW	27-Oct-04	BW	1	L	22PC-461.1-461.8-SC	461.10	461.80				0.85	6.75	5.90	5YR 4/6	52	36	5	7	12	GW-GC	100
26-Oct-04	DD/BW	27-Oct-04	BW	1	D	22PC-461.3-462-SC	461.30	462.00			6.20	0.20	11.30	11.10								
26-Oct-04	DD/BW	27-Oct-04	BW	1	LX	22PC-461.8-463.7-SC	461.80	463.70				0.85	9.40	8.55	10YR 4/3	44	36	6	14	20	GC	100
26-Oct-04	DD/BW	27-Oct-04	BW	1	D	22PC-462-462.9-SC	462.00	462.90			6.20	0.20	13.95	13.75								
26-Oct-04	DD/BW	27-Oct-04	BW	1	D	22PC-462.9-463.7-SC	462.90	463.70			6.20	0.20	12.05	11.85								
26-Oct-04	DD/BW	27-Oct-04	BW	2	LX	22PC-463.7-464.2-SC	463.70	464.20				0.82	4.75	3.93	5YR 5/6	13	61	8	18	26	SC	100
26-Oct-04	DD/BW	27-Oct-04	BW	2	D	22PC-463.7-464.9-SC	463.70	464.90			6.20	0.20	12.55	12.35								
26-Oct-04	DD/BW	27-Oct-04	BW	2	R	22PC-463.7-471.4-SC	463.70	471.40	1.70	7.70												
26-Oct-04	DD/BW	27-Oct-04	BW	2	L	22PC-464.2-466.3-SC	464.20	466.30				0.86	10.85	9.99	5YR 6/4	59	32	3	6	9	GW-GC	100
26-Oct-04	DD/BW	27-Oct-04	BW	2	D	22PC-464.9-466.5-SC	464.90	466.50			6.20	0.20	18.85	18.65								
26-Oct-04	DD/BW	27-Oct-04	BW	2	L	22PC-466.3-468.1-SC	466.30	468.10				0.81	9.95	9.14	5YR 6/4	64	29	2	5	7	GW-GC	100
26-Oct-04	DD/BW	27-Oct-04	BW	2	D	22PC-466.5-468.2-SC	466.50	468.20			6.20	0.20	20.20	20.00								
26-Oct-04	DD/BW	27-Oct-04	BW	2	L	22PC-468.1-469.1-SC	468.10	469.10				0.82	10.50	9.68	5YR 6/4	24	54	7	15	22	SC	100
26-Oct-04	DD/BW	27-Oct-04	BW	2	D	22PC-468.2-469.8-SC	468.20	469.80			6.20	0.20	18.05	17.85								
26-Oct-04	DD/BW	27-Oct-04	BW	2	LX	22PC-469.1-471.4-SC	469.10	471.40				0.84	9.75	8.91	5YR 5/4	41	44	6	9	15	SC	100
26-Oct-04	DD/BW	27-Oct-04	BW	2	D	22PC-469.8-471.4-SC	469.80	471.40			6.20	0.20	19.40	19.20								
26-Oct-04	DD/BW	27-Oct-04	BW	3	D	22PC-471.4-473.2-SC	471.40	473.20			6.20	0.20	24.35	24.15								
26-Oct-04	DD/BW	27-Oct-04	BW	3	LX	22PC-471.4-473.2-SCA	471.40	473.20				0.85	8.95	8.10	5YR 5/8	22	66	4	8	12	SW-SC	100
26-Oct-04	DD/BW	27-Oct-04	BW	3	R	22PC-471.4-481.8-SC	471.40	481.80	2.30	10.50												
26-Oct-04	DD/BW	27-Oct-04	BW	3	L	22PC-473.2-474.5-SC	473.20	474.50				0.82	6.00	5.18	5YR 5/8	43	43	4	10	14	GW-GC/SW-SC	100
26-Oct-04	DD/BW	27-Oct-04	BW	3	D	22PC-473.2-475-SC	473.20	475.00			6.20	0.20	20.75	20.55								
26-Oct-04	DD/BW	27-Oct-04	BW	3	L	22PC-474.5-476.2-SC	474.50	476.20				0.83	10.75	9.92	5YR 5/8	37	52	4	7	11	SW-SC	100
26-Oct-04	DD/BW	27-Oct-04	BW	3	D	22PC-475-476.8-SC	475.00	476.80			6.20	0.20	17.45	17.25								
26-Oct-04	DD/BW	27-Oct-04	BW	3	LX	22PC-476.2-481.8-SC	476.20	481.80				0.81	14.15	13.34	5YR 4/6	39	49	4	8	12	SW-SC	100
26-Oct-04	DD/BW	27-Oct-04	BW	3	D	22PC-476.8-478.5-SC	476.80	478.50			6.20	0.20	18.30	18.10								
26-Oct-04	DD/BW	27-Oct-04	BW	3	D	22PC-478.5-480-SC	478.50	480.00			6.20	0.20	18.10	17.90								
26-Oct-04	DD/BW	27-Oct-04	BW	3	D	22PC-480-481.8-SC	480.00	481.80			6.20	0.20	20.30	20.10								
26-Oct-04	DD/BW	27-Oct-04	BW	3	LC	22PC-481.8-483.7-SC	481.80	483.70														
26-Oct-04	DD/BW	27-Oct-04	BW	4	LX	22PC-483.7-484.6-SC	483.70	484.60				0.85	6.00	5.15	10YR 4/2	59	33	2	6	8	GW-GC	100
26-Oct-04	DD/BW	27-Oct-04	BW	4	D	22PC-483.7-485.4-SC	483.70	485.40			6.20	0.20	20.35	20.15								
26-Oct-04	DD/BW	27-Oct-04	BW	4	R	22PC-483.7-492.1-SC	483.70	492.10	1.10	8.10												
26-Oct-04	DD/BW	27-Oct-04	BW	4	L	22PC-484.6-488.8-SC	484.60	488.80				0.85	11.30	10.45	5YR 4/6	42	46	4	8	12	SW-SC	100
26-Oct-04	DD/BW	27-Oct-04	BW	4	D	22PC-485.4-486.9-SC	485.40	486.90			6.20	0.20	19.05	18.85								
26-Oct-04	DD/BW	27-Oct-04	BW	4	D	22PC-486.9-488.5-SC	486.90	488.50			6.20	0.20	19.20	19.00								
26-Oct-04	DD/BW	29-Oct-04	BW	4	D	22PC-488.5-490-SC	488.50	490.00			6.20	0.20	17.90	17.70								
26-Oct-04	DD/BW	29-Oct-04	BW	4	LX	22PC-488.8-491.8-SC	488.80	491.80				0.82	8.90	8.08	5YR 4/6	31	48	6	15	21	SC	100
26-Oct-04	DD/BW	29-Oct-04	BW	4	D	22PC-490-491.8-SC	490.00	491.80			6.20	0.20	19.75	19.55								
26-Oct-04	DD/BW	29-Oct-04	BW	4	LC	22PC-491.8-492.1-SC	491.80	492.10													SW	
26-Oct-04	DD/BW	29-Oct-04	BW	5	D	22PC-492.1-492.7-SC	492.10	492.70			6.20	0.20	8.25	8.05								

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Date Logged	Logged By	Date Checked	Checked By	Core Run Number	Core Sample Type	Sample Number	Depth From	Depth To	Drilling Rate	Sample Recovery	Borehole Diameter	Tare Weight	Sample Plus Tare	Sample Weight	Munsell	Gravel	Sand	Silt	Clay	Text 2607	USCS Group	Volcanics
26-Oct-04	DD/BW	29-Oct-04	BW	5	L	22PC-492.1-493.8-SC	492.10	493.80				0.81	7.25	6.44	5YR 4/6	52	38	4	6	10	GW-GC	100
26-Oct-04	DD/BW	29-Oct-04	BW	5	R	22PC-492.1-494.2-SC	492.10	494.20	1.00	2.10												
26-Oct-04	DD/BW	29-Oct-04	BW	5	D	22PC-492.7-494.2-SC	492.70	494.20			6.20	0.20	18.60	18.40								
26-Oct-04	DD/BW	29-Oct-04	BW	5	LX	22PC-493.8-494.2-SC	493.80	494.20														
27-Oct-04	BW	29-Oct-04	BW	6	LX	22PC-493.8-494.6-SC	493.80	494.60				0.86	9.35	8.49	10YR 6/3	38	46	6	10	16	SC	100
27-Oct-04	BW	29-Oct-04	BW	6	D	22PC-494.2-494.6-SC	494.20	494.60			6.20	0.20	4.55	4.35								
27-Oct-04	BW	29-Oct-04	BW	6	R	22PC-494.2-504.2-SC	494.20	504.20	1.20	10.00												
27-Oct-04	BW	29-Oct-04	BW	6	D	22PC-494.6-496.3-SC	494.60	496.30			6.20	0.20	23.50	23.30								
27-Oct-04	BW	29-Oct-04	BW	6	L	22PC-494.6-497.2-SC	494.60	497.20				0.82	10.00	9.18	5YR 6/6	49	42	3	6	9	GW-GC	100
27-Oct-04	BW	29-Oct-04	BW	6	D	22PC-496.3-497.7-SC	496.30	497.70			6.20	0.20	18.00	17.80								
27-Oct-04	BW	29-Oct-04	BW	6	L	22PC-497.2-499.6-SC	497.20	499.60				0.81	12.00	11.19	5YR 6/6	31	55	5	9	14	SW-SC	100
27-Oct-04	BW	29-Oct-04	BW	6	D	22PC-497.7-499.3-SC	497.70	499.30			6.20	0.20	20.70	20.50								
27-Oct-04	BW	29-Oct-04	BW	6	D	22PC-499.3-500.9-SC	499.30	500.90			6.20	0.20	18.95	18.75								
27-Oct-04	BW	29-Oct-04	BW	6	L	22PC-499.6-501.4-SC	499.60	501.40				0.85	9.00	8.15	5YR 6/6	47	40	5	8	13	GW-GC	100
27-Oct-04	BW	29-Oct-04	BW	6	D	22PC-500.9-502.5-SC	500.90	502.50			6.20	0.20	16.80	16.60								
27-Oct-04	BW	29-Oct-04	BW	6	LX	22PC-501.4-504.2-SC	501.40	504.20				0.82	12.90	12.08	7.5YR 5/4	51	29	7	13	20	GC	100
27-Oct-04	BW	29-Oct-04	BW	6	D	22PC-502.5-504.2-SC	502.50	504.20			6.20	0.20	18.10	17.90								
27-Oct-04	BW	29-Oct-04	BW	7	LX	22PC-504.2-505.0-SC	504.20	505.00				0.82	9.55	8.73	2.5YR 6/8	45	45	3	7	10	GW-GC/SW-SC	100
27-Oct-04	BW	29-Oct-04	BW	7	D	22PC-504.2-505.8-SC	504.20	505.80			6.20	0.20	19.50	19.30								
27-Oct-04	BW	29-Oct-04	BW	7	R	22PC-504.2-509.1-SC	504.20	509.10	1.40	4.90												
27-Oct-04	BW	29-Oct-04	BW	7	LX	22PC-505.0-509.1-SC	505.00	509.10				0.81	11.35	10.54	5YR 5/6	36	54	3	7	10	SW-SC	100
27-Oct-04	BW	29-Oct-04	BW	7	D	22PC-505.8-507.4-SC	505.80	507.40			6.20	0.20	21.30	21.10								
27-Oct-04	BW	29-Oct-04	BW	7	D	22PC-507.4-509.1-SC	507.40	509.10			6.20	0.20	18.20	18.00								
27-Oct-04	EJH	29-Oct-04	BW	8	LX	22PC-509.1-509.4-SC	509.10	509.40				0.86	4.05	3.19	7.5YR 5/6	27	62	4	7	11	SW-SC	100
27-Oct-04	EJH	29-Oct-04	BW	8	D	22PC-509.1-510.0-SC	509.10	510.00			6.20	0.20	0.85	0.65								
27-Oct-04	EJH	29-Oct-04	BW	8	R	22PC-509.1-519.3-SC	509.10	519.30	3.20	10.00												
27-Oct-04	EJH	29-Oct-04	BW	8	L	22PC-509.4-513.5-SC	509.40	513.50				0.82	10.85	10.03	7.5YR 5/6	33	59	3	5	8	SW-SC	100
27-Oct-04	EJH	29-Oct-04	BW	8	D	22PC-510-511.5-SC	510.00	511.50			6.20	0.20	18.15	17.95								
27-Oct-04	EJH	29-Oct-04	BW	8	D	22PC-511.5-513.3-SC	511.50	513.30			6.20	0.20	19.80	19.60								
27-Oct-04	EJH	29-Oct-04	BW	8	D	22PC-513.3-515.3-SC	513.30	515.30			6.20	0.20	20.30	20.10								
27-Oct-04	EJH	29-Oct-04	BW	8	L	22PC-513.5-516.2-SC	513.50	516.20				0.83	10.95	10.12	5YR 6/6	51	37	4	8	12	GW-GC	100
27-Oct-04	EJH	29-Oct-04	BW	8	D	22PC-515.3-517.4-SC	515.30	517.40			6.20	0.20	22.40	22.20								
27-Oct-04	EJH	29-Oct-04	BW	8	LX	22PC-516.2-519.2-SC	516.20	519.20				0.82	5.85	5.03	5YR 6/6	45	49	2	4	6	SW-SC	100
27-Oct-04	EJH	29-Oct-04	BW	8	D	22PC-517.4-519.2-SC	517.40	519.20			6.20	0.20	17.80	17.60								
27-Oct-04	EJH	29-Oct-04	BW	8	LC	22PC-519.2-519.3-SC	519.20	519.30														
27-Oct-04	EJH	01-Nov-04	BW	9	LC	22PC-519.3-520.4-SC	519.30	520.40														
27-Oct-04	EJH	29-Oct-04	BW	9	R	22PC-519.3-526.5-SC	519.30	526.50	1.00	6.10												
27-Oct-04	EJH	01-Nov-04	BW	9	D	22PC-520.4-520.7-SC	520.40	520.70			6.20	0.20	2.80	2.60								
27-Oct-04	EJH	01-Nov-04	BW	9	LX	22PC-520.4-521.1-SC	520.40	521.10				0.82	7.45	6.63	7.5YR 6/6	50	40	3	7	10	GW-GC	100
27-Oct-04	EJH	01-Nov-04	BW	9	D	22PC-520.7-522.1-SC	520.70	522.10			6.20	0.20	17.50	17.30								
27-Oct-04	EJH	01-Nov-04	BW	9	L	22PC-521.1-521.8-SC	521.10	521.80				0.85	4.95	4.10	7.5YR 5/6	32	62	2	4	6	SW-SC	100
27-Oct-04	EJH	01-Nov-04	BW	9	L	22PC-521.8-522.7-SC	521.80	522.70				0.86	6.10	5.24	7.5YR 5/6	65	26	3	6	9	GW-GC	100
27-Oct-04	EJH	01-Nov-04	BW	9	D	22PC-522.1-523.5-SC	522.10	523.50			6.20	0.20	17.75	17.55								
27-Oct-04	EJH	01-Nov-04	BW	9	L	22PC-522.7-525.5-SC	522.70	525.50				0.82	8.70	7.88	5YR 6/6	46	44	4	6	10	GW-GC	100

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Date Logged	Logged By	Date Checked	Check ed By	Core Run Number	Core Sample Type	Sample Number	Depth From	Depth To	Drilling Rate	Sample Recovery	Borehole Diameter	Tare Weight	Sample Plus Tare	Sample Weight	Munsell	Gravel	Sand	Silt	Clay	Text 2607	USCS Group	Volcanics
27-Oct-04	EJH	01-Nov-04	BW	9	D	22PC-523.5-525.1-SC	523.50	525.10			6.20	0.20	19.70	19.50								
27-Oct-04	EJH	01-Nov-04	BW	9	D	22PC-525.1-526.5-SC	525.10	526.50			6.20	0.20	17.25	17.05								
27-Oct-04	EJH	01-Nov-04	BW	9	LX	22PC-525.5-526.5-SC	525.50	526.50				0.87	6.30	5.43	5YR 5/6	49	40	4	7	11	GW-GC	100
28-Oct-04	DD	01-Nov-04	BW	10	D	22PC-526.5-528.2-SC	526.50	528.20			6.20	0.20	17.40	17.20								
28-Oct-04	DD	01-Nov-04	BW	10	LX	22PC-526.5-529.8-SC	526.50	529.80				0.86	5.45	4.59	2.5YR 5/8	39	44	7	10	17	SC	100
28-Oct-04	DD	01-Nov-04	BW	10	R	22PC-526.5-533.1-SC	526.50	533.10	2.20	6.60												
28-Oct-04	DD	01-Nov-04	BW	10	D	22PC-528.2-529.8-SC	528.20	529.80			6.20	0.20	17.05	16.85								
28-Oct-04	DD	01-Nov-04	BW	10	L	22PC-529.8-531.3-SC	529.80	531.30				0.87	4.55	3.68	2.5YR 5/8	42	41	7	10	17	GC	100
28-Oct-04	DD	01-Nov-04	BW	10	D	22PC-529.8-531.6-SC	529.80	531.60			6.20	0.20	19.50	19.30								
28-Oct-04	DD	01-Nov-04	BW	10	LX	22PC-531.3-533.1-SC	531.30	533.10				0.83	5.75	4.92	2.5YR 5/8	27	56	7	10	17	SC	100
28-Oct-04	DD	01-Nov-04	BW	10	D	22PC-531.6-533.1-SC	531.60	533.10			6.20	0.20	16.75	16.55								
28-Oct-04	DD	01-Nov-04	BW	11	R	22PC-533.1-534.1-SC	533.10	534.10	0.30	1.00												
28-Oct-04	DD	01-Nov-04	BW	11	D	22PC-533.1-534.1-SCA	533.10	534.10			6.20	0.20	12.35	12.15								
28-Oct-04	DD	01-Nov-04	BW	11	LX	22PC-533.1-534.1-SCB	533.10	534.10				0.81	6.45	5.64	2.5YR 6/8	42	41	7	10	17	GC	100
28-Oct-04	DD	01-Nov-04	BW	12	D	22PC-534.1-534.5-SC	534.10	534.50			6.20	0.20	4.65	4.45								
28-Oct-04	DD	01-Nov-04	BW	12	LX	22PC-534.1-536.6-SC	534.10	536.60				0.83	11.75	10.92	5YR 5/6	31	52	7	10	17	SC	100
28-Oct-04	DD	01-Nov-04	BW	12	R	22PC-534.1-544.2-SC	534.10	544.20	1.70	9.90												
28-Oct-04	DD	01-Nov-04	BW	12	D	22PC-534.5-536.2-SC	534.50	536.20			6.20	0.20	19.00	18.80								
28-Oct-04	DD	01-Nov-04	BW	12	D	22PC-536.2-537.8-SC	536.20	537.80			6.20	0.20	19.10	18.90								
28-Oct-04	DD	01-Nov-04	BW	12	L	22PC-536.6-537.8-SC	536.60	537.80				0.85	5.10	4.25	5YR 5/6	53	35	4	8	12	GW-GC	100
28-Oct-04	DD	01-Nov-04	BW	12	D	22PC-537.8-539.2-SC	537.80	539.20			6.20	0.20	16.60	16.40								
28-Oct-04	DD	01-Nov-04	BW	12	LX	22PC-537.8-544.0-SC	537.80	544.00				0.86	8.70	7.84	5YR 5/6	36	50	4	10	14	SW-SC	100
28-Oct-04	DD	01-Nov-04	BW	12	D	22PC-539.2-540.8-SC	539.20	540.80			6.20	0.20	18.25	18.05								
28-Oct-04	DD	01-Nov-04	BW	12	D	22PC-540.8-542.4-SC	540.80	542.40			6.20	0.20	19.70	19.50								
28-Oct-04	DD	01-Nov-04	BW	12	D	22PC-542.4-544.0-SC	542.40	544.00			6.20	0.20	18.20	18.00								
28-Oct-04	DD	01-Nov-04	BW	12	LC	22PC-544.0-544.2-SC	544.00	544.20														
28-Oct-04	DD	01-Nov-04	BW	13	D	22PC-544.2-545.1-SC	544.20	545.10			6.20	0.20	9.70	9.50								
28-Oct-04	DD	01-Nov-04	BW	13	LX	22PC-544.2-546.7-SC	544.20	546.70				0.82	7.30	6.48	5YR 5/6	44	44	4	8	12	GW-GC/SW-SC	100
28-Oct-04	DD	01-Nov-04	BW	13	R	22PC-544.2-550.2-SC	544.20	550.20	1.20	6.00												
28-Oct-04	DD	01-Nov-04	BW	13	D	22PC-545.1-546.7-SC	545.10	546.70			6.20	0.20	17.80	17.60								
28-Oct-04	DD	01-Nov-04	BW	13	L	22PC-546.7-547.5-SC	546.70	547.50				0.83	4.65	3.82	5YR 4/6	19	66	5	10	15	SC	100
28-Oct-04	DD	01-Nov-04	BW	13	D	22PC-546.7-548.5-SC	546.70	548.50			6.20	0.20	18.60	18.40								
28-Oct-04	DD	01-Nov-04	BW	13	L	22PC-547.5-549.5-SC	547.50	549.50				0.83	6.25	5.42	5YR 5/8	55	34	4	7	11	GW-GC	100
28-Oct-04	DD	01-Nov-04	BW	13	D	22PC-548.5-550.2-SC	548.50	550.20			6.20	0.20	18.75	18.55								
28-Oct-04	DD	01-Nov-04	BW	13	LX	22PC-549.5-550.2-SC	549.50	550.20				0.82	3.40	2.58	5YR 4/6	43	46	4	7	11	SW-SC	100
28-Oct-04	DD	01-Nov-04	BW	14	D	22PC-550.2-551.8-SC	550.20	551.80			6.20	0.20	17.30	17.10								
28-Oct-04	DD	01-Nov-04	BW	14	LX	22PC-550.2-552.8-SC	550.20	552.80				0.83	5.10	4.27	2.5YR 5/8	70	24	2	4	6	GW-GC	100
28-Oct-04	DD	01-Nov-04	BW	14	R	22PC-550.2-560.2-SC	550.20	560.20	2.50	10.00												
28-Oct-04	DD	01-Nov-04	BW	14	D	22PC-551.8-553.6-SC	551.80	553.60			6.20	0.20	18.15	17.95								
28-Oct-04	DD	01-Nov-04	BW	14	L	22PC-552.8-554.5-SC	552.80	554.50				0.87	3.80	2.93	2.5YR 5/6	49	38	5	8	13	GW-GC	100
28-Oct-04	DD	01-Nov-04	BW	14	D	22PC-553.6-555.3-SC	553.60	555.30			6.20	0.20	17.30	17.10								
28-Oct-04	DD	01-Nov-04	BW	14	LX	22PC-554.5-560.2-SC	554.50	560.20				0.87	13.25	12.38	5YR 5/6	56	37	2	5	7	GW-GC	100
28-Oct-04	DD	01-Nov-04	BW	14	D	22PC-555.3-556.8-SC	555.30	556.80			6.20	0.20	18.55	18.35								
28-Oct-04	DD	01-Nov-04	BW	14	D	22PC-556.8-558.5-SC	556.80	558.50			6.20	0.20	18.20	18.00								

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Date Logged	Logged By	Date Checked	Checked By	Core Run Number	Core Sample Type	Sample Number	Depth From	Depth To	Drilling Rate	Sample Recovery	Borehole Diameter	Tare Weight	Sample Plus Tare	Sample Weight	Munsell	Gravel	Sand	Silt	Clay	Text 2607	USCS Group	Volcanics
28-Oct-04	DD	01-Nov-04	BW	14	D	22PC-558.5-560.2-SC	558.50	560.20			6.20	0.20	18.15	17.95								
29-Oct-04	DD	01-Nov-04	BW	15	D	22PC-560.2-560.6-SC	560.20	560.60			6.20	0.20	4.75	4.55								
29-Oct-04	DD	01-Nov-04	BW	15	LX	22PC-560.2-562.8-SC	560.20	562.80				0.83	4.20	3.37	2.5YR 5/8	62	31	2	5	7	GW-GC	100
29-Oct-04	DD	01-Nov-04	BW	15	R	22PC-560.2-565.4-SC	560.20	565.40	1.70	5.20												
29-Oct-04	DD	01-Nov-04	BW	15	D	22PC-560.6-562.2-SC	560.60	562.20			6.20	0.20	15.60	15.40								
29-Oct-04	DD	01-Nov-04	BW	15	D	22PC-562.2-563.8-SC	562.20	563.80			6.20	0.20	15.85	15.65								
29-Oct-04	DD	01-Nov-04	BW	15	LX	22PC-562.8-565.4-SC	562.80	565.40				0.86	5.65	4.79	2.5YR 5/8	18	76	2	4	6	SW-SC	100
29-Oct-04	DD	01-Nov-04	BW	15	D	22PC-563.8-565.4-SC	563.80	565.40			6.20	0.20	16.45	16.25								
29-Oct-04	DD	01-Nov-04	BW	16	D	22PC-565.4-566.2-SC	565.40	566.20			6.20	0.20	8.25	8.05								
29-Oct-04	DD	01-Nov-04	BW	16	LX	22PC-565.4-567.1-SC	565.40	567.10				0.83	3.70	2.87	5YR 5/8	51	42	2	5	7	GW-GC	100
29-Oct-04	DD	02-Nov-04	BW	16	R	22PC-565.4-568.1-SC	565.40	568.10	0.70	2.70												
29-Oct-04	DD	02-Nov-04	BW	16	D	22PC-566.2-568.1-SC	566.20	568.10			6.20	0.20	16.60	16.40								
29-Oct-04	DD	02-Nov-04	BW	16	LX	22PC-567.1-568.1-SC	567.10	568.10				0.87	4.70	3.83	2.5YR 5/8	47	41	4	8	12	GW-GC	100
29-Oct-04	DD	02-Nov-04	BW	17	D	22PC-568.1-569.6-SC	568.10	569.60			6.20	0.20	16.20	16.00								
29-Oct-04	DD	02-Nov-04	BW	17	LX	22PC-568.1-569.9-SC	568.10	569.90				0.82	8.95	8.13	5YR 5/8	36	59	2	3	5	SW-SC	100
29-Oct-04	DD	02-Nov-04	BW	17	R	22PC-568.1-578.1-SC	568.10	578.10	2.00	10.00												
29-Oct-04	DD	02-Nov-04	BW	17	D	22PC-569.6-571.3-SC	569.60	571.30			6.20	0.20	16.75	16.55								
29-Oct-04	DD	02-Nov-04	BW	17	L	22PC-569.9-571.3-SC	569.90	571.30				0.86	7.30	6.44	5YR 5/8	66	24	3	7	10	GW-GC	100
29-Oct-04	DD	02-Nov-04	BW	17	D	22PC-571.3-572.9-SC	571.30	572.90			6.20	0.20	14.95	14.75								
29-Oct-04	DD	02-Nov-04	BW	17	LX	22PC-571.3-578.1-SC	571.30	578.10				0.83	9.70	8.87	5YR 5/8	44	46	3	7	10	SW-SC	100
29-Oct-04	DD	02-Nov-04	BW	17	D	22PC-572.9-574.7-SC	572.90	574.70			6.20	0.20	16.35	16.15								
29-Oct-04	DD	02-Nov-04	BW	17	D	22PC-574.7-576.3-SC	574.70	576.30			6.20	0.20	16.05	15.85								
29-Oct-04	DD	02-Nov-04	BW	17	D	22PC-576.3-578.1-SC	576.30	578.10			6.20	0.20	17.90	17.70								
29-Oct-04	DD	02-Nov-04	BW	18	LX	22PC-578.1-578.6-SC	578.10	578.60				0.82	5.00	4.18	5YR 5/4	52	43	2	3	5	GW-GC	100
29-Oct-04	DD	02-Nov-04	BW	18	D	22PC-578.1-578.8-SC	578.10	578.80			6.20	0.20	8.40	8.20								
29-Oct-04	DD	02-Nov-04	BW	18	R	22PC-578.1-585.3-SC	578.10	585.30	1.40	7.20												
29-Oct-04	DD	02-Nov-04	BW	18	L	22PC-578.6-582.8-SC	578.60	582.80				0.82	11.65	10.83	5YR 5/6	40	52	3	5	8	SW-SC	100
29-Oct-04	DD	02-Nov-04	BW	18	D	22PC-578.8-580.6-SC	578.80	580.60			6.20	0.20	20.70	20.50								
29-Oct-04	DD	02-Nov-04	BW	18	D	22PC-580.6-581.9-SC	580.60	581.90			6.20	0.20	15.85	15.65								
29-Oct-04	DD	02-Nov-04	BW	18	D	22PC-581.9-583.6-SC	581.90	583.60			6.20	0.20	19.30	19.10								
29-Oct-04	DD	02-Nov-04	BW	18	LX	22PC-582.8-585.3-SC	582.80	585.30				0.86	6.05	5.19	5YR 5/6	48	45	2	5	7	GW-GC	100
29-Oct-04	DD	02-Nov-04	BW	18	D	22PC-583.6-585.3-SC	583.60	585.30			6.20	0.20	17.20	17.00								
01-Nov-04	DD	02-Nov-04	BW	19	LX	22PC-585.3-586.2-SC	585.30	586.20				0.84	9.45	8.61	7.5YR 5/6	45	48	3	4	7	SW-SC	100
01-Nov-04	DD	02-Nov-04	BW	19	D	22PC-585.3-586.8-SC	585.30	586.80			6.20	0.20	16.30	16.10								
01-Nov-04	DD	02-Nov-04	BW	19	R	22PC-585.3-595.0-SC	585.30	595.00	1.00	9.80												
01-Nov-04	DD	02-Nov-04	BW	19	L	22PC-586.2-587.0-SC	586.20	587.00				0.83	10.55	9.72	7.5YR 5/6	28	62	4	6	10	SW-SC	100
01-Nov-04	DD	02-Nov-04	BW	19	D	22PC-586.8-588.4-SC	586.80	588.40			6.20	0.20	18.20	18.00								
01-Nov-04	DD	02-Nov-04	BW	19	L	22PC-587.0-587.8-SC	587.00	587.80				0.82	9.00	8.18	7.5YR 5/4	55	40	2	3	5	GW-GC	100
01-Nov-04	DD	02-Nov-04	BW	19	L	22PC-587.8-594.5-SC	587.80	594.50				0.83	9.60	8.77	7.5YR 5/6	40	52	3	5	8	SW-SC	100
01-Nov-04	DD	02-Nov-04	BW	19	D	22PC-588.4-589.9-SC	588.40	589.90			6.20	0.20	19.30	19.10								
01-Nov-04	DD	02-Nov-04	BW	19	D	22PC-589.9-591.6-SC	589.90	591.60			6.20	0.20	17.45	17.25								
01-Nov-04	DD	02-Nov-04	BW	19	D	22PC-591.6-593.3-SC	591.60	593.30			6.20	0.20	16.75	16.55								
01-Nov-04	DD	02-Nov-04	BW	19	D	22PC-593.3-595.0-SC	593.30	595.00			6.20	0.20	17.60	17.40								
01-Nov-04	DD	02-Nov-04	BW	19	LX	22PC-594.5-595.0-SC	594.50	595.00				0.83	5.35	4.52	5YR 5/8	52	43	2	3	5	GW-GC	100

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Date Logged	Logged By	Date Checked	Checked By	Core Run Number	Core Sample Type	Sample Number	Depth From	Depth To	Drilling Rate	Sample Recovery	Borehole Diameter	Tare Weight	Sample Plus Tare	Sample Weight	Munsell	Gravel	Sand	Silt	Clay	Text 2607	USCS Group	Volcanics
01-Nov-04	DD	02-Nov-04	BW	20	LX	22PC-595.0-595.7-SC	595.00	595.70				0.82	2.40	1.58	7.5YR 5/4	67	31	1	1	2	GW	100
01-Nov-04	DD	02-Nov-04	BW	20	D	22PC-595.0-596.6-SC	595.00	596.60			6.20	0.20	19.15	18.95								
01-Nov-04	DD	02-Nov-04	BW	20	R	22PC-595.0-599.6-SC	595.00	599.60	0.90	4.60												
01-Nov-04	DD	02-Nov-04	BW	20	L	22PC-595.7-597.3-SC	595.70	597.30				0.83	3.50	2.67	7.5YR 5/6	37	53	3	7	10	SW-SC	100
01-Nov-04	DD	02-Nov-04	BW	20	D	22PC-596.6-598.2-SC	596.60	598.20			6.20	0.20	17.30	17.10								
01-Nov-04	DD	02-Nov-04	BW	20	LX	22PC-597.3-599.6-SC	597.30	599.60				0.86	7.20	6.34	7.5YR 5/6	45	47	3	5	8	SW-SC	100
01-Nov-04	DD	02-Nov-04	BW	20	D	22PC-598.2-599.6-SC	598.20	599.60			6.20	0.20	16.15	15.95								
01-Nov-04	DD	02-Nov-04	BW	21	LX	22PC-599.6-600.3-SC	599.60	600.30				0.82	5.80	4.98	2.5YR 5/6	38	58	1	3	4	SW	100
01-Nov-04	DD	02-Nov-04	BW	21	D	22PC-599.6-600.5-SC	599.60	600.50			6.20	0.20	11.50	11.30								
01-Nov-04	DD	02-Nov-04	BW	21	R	22PC-599.6-606.6-SC	599.60	606.60	1.20	7.00												
01-Nov-04	DD	02-Nov-04	BW	21	L	22PC-600.3-601.9-SC	600.30	601.90				0.82	7.65	6.83	2.5YR 5/8	40	54	2	4	6	SW-SC	100
01-Nov-04	DD	02-Nov-04	BW	21	D	22PC-600.5-602.0-SC	600.50	602.00			6.20	0.20	16.65	16.45								
01-Nov-04	DD	02-Nov-04	BW	21	L	22PC-601.9-604.1-SC	601.90	604.10				0.82	6.85	6.03	2.5YR 6/8	44	48	3	5	8	SW-SC	100
01-Nov-04	DD	02-Nov-04	BW	21	D	22PC-602.0-603.5-SC	602.00	603.50			6.20	0.20	17.00	16.80								
01-Nov-04	DD	02-Nov-04	BW	21	D	22PC-603.5-604.9-SC	603.50	604.90			6.20	0.20	15.65	15.45								
01-Nov-04	DD	02-Nov-04	BW	21	L	22PC-604.1-604.7-SC	604.10	604.70				0.83	8.35	7.52	.	26	65	3	6	9	SW-SC	100
01-Nov-04	DD	02-Nov-04	BW	21	LX	22PC-604.7-606.3-SC	604.70	606.30				0.86	6.05	5.19	2.5YR 5/8	45	48	2	5	7	SW-SC	100
01-Nov-04	DD	02-Nov-04	BW	21	D	22PC-604.9-606.3-SC	604.90	606.30			6.20	0.20	16.40	16.20								
01-Nov-04	DD	02-Nov-04	BW	21	LC	22PC-606.3-606.6-SC	606.30	606.60														
01-Nov-04	BW	02-Nov-04	BW	22	D	22PC-606.6-607.9-SC	606.60	607.90			6.20	0.20	14.95	14.75								
01-Nov-04	BW	02-Nov-04	BW	22	LX	22PC-606.6-609.3-SC	606.60	609.30				0.86	6.25	5.39	5YR 5/8	51	45	1	3	4	GW	100
01-Nov-04	BW	02-Nov-04	BW	22	R	22PC-606.6-615.5-SC	606.60	615.50	1.60	8.80												
01-Nov-04	BW	02-Nov-04	BW	22	D	22PC-607.9-609.3-SC	607.90	609.30			6.20	0.20	17.15	16.95								
01-Nov-04	BW	02-Nov-04	BW	22	L	22PC-609.3-610.1-SC	609.30	610.10				0.86	10.95	10.09	5YR 5/8	54	41	2	3	5	GW-GC	100
01-Nov-04	BW	02-Nov-04	BW	22	D	22PC-609.3-611.0-SC	609.30	611.00			6.20	0.20	19.35	19.15								
01-Nov-04	BW	02-Nov-04	BW	22	L	22PC-610.1-611.8-SC	610.10	611.80				0.86	6.80	5.94	2.5YR 6/8	52	43	2	3	5	GW-GC	100
01-Nov-04	BW	02-Nov-04	BW	22	D	22PC-611.0-612.6-SC	611.00	612.60			6.20	0.20	16.45	16.25								
01-Nov-04	BW	03-Nov-04	BW	22	L	22PC-611.8-613.6-SC	611.80	613.60				0.82	6.40	5.58	5YR 5/8	46	47	2	5	7	SW-SC	100
01-Nov-04	BW	03-Nov-04	BW	22	D	22PC-612.6-614.1-SC	612.60	614.10			6.20	0.20	18.90	18.70								
01-Nov-04	BW	03-Nov-04	BW	22	LX	22PC-613.6-615.4-SC	613.60	615.40				0.86	6.90	6.04	5YR 6/8	32	61	2	5	7	SW-SC	100
01-Nov-04	BW	03-Nov-04	BW	22	D	22PC-614.1-615.4-SC	614.10	615.40			6.20	0.20	15.70	15.50								
01-Nov-04	BW	03-Nov-04	BW	22	LC	22PC-615.4-615.5-SC	615.40	615.50														
02-Nov-04	DD	03-Nov-04	BW	23	D	22PC-615.5-616.9-SC	615.50	616.90			6.20	0.20	14.85	14.65								
02-Nov-04	DD	03-Nov-04	BW	23	LX	22PC-615.5-618.5-SC	615.50	618.50				0.81	8.00	7.19	5YR 5/8	24	71	2	3	5	SW-SC	100
02-Nov-04	DD	03-Nov-04	BW	23	R	22PC-615.5-625.2-SC	615.50	625.20	1.60	8.20												
02-Nov-04	DD	03-Nov-04	BW	23	D	22PC-616.9-618.5-SC	616.90	618.50			6.20	0.20	15.10	14.90								
02-Nov-04	DD	03-Nov-04	BW	23	L	22PC-618.5-620.0-SC	618.50	620.00				0.79	4.80	4.01	7.5YR 5/4	33	64	1	2	3	SW	100
02-Nov-04	DD	03-Nov-04	BW	23	D	22PC-618.5-620.5-SC	618.50	620.50			6.20	0.20	23.95	23.75								
02-Nov-04	DD	03-Nov-04	BW	23	L	22PC-620.0-621.1-SC	620.00	621.10				0.79	3.45	2.66	5YR 5/6	18	77	2	3	5	SW-SC	100
02-Nov-04	DD	03-Nov-04	BW	23	D	22PC-620.5-622.1-SC	620.50	622.10			6.20	0.20	15.65	15.45								
02-Nov-04	DD	03-Nov-04	BW	23	L	22PC-621.1-623.0-SC	621.10	623.00				0.80	7.55	6.75	5YR 5/6	48	46	2	4	6	GW-GC	100
02-Nov-04	DD	03-Nov-04	BW	23	D	22PC-622.1-623.7-SC	622.10	623.70			6.20	0.20	16.10	15.90								
02-Nov-04	DD	03-Nov-04	BW	23	LX	22PC-623.0-623.7-SC	623.00	623.70				0.83	5.60	4.77	7.5YR 5/6	65	33	1	1	2	GW	100
02-Nov-04	DD	03-Nov-04	BW	23	LC	22PC-623.7-625.2-SC	623.70	625.20														

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Date Logged	Logged By	Date Checked	Checked By	Core Run Number	Core Sample Type	Sample Number	Depth From	Depth To	Drilling Rate	Sample Recovery	Borehole Diameter	Tare Weight	Sample Plus Tare	Sample Weight	Munsell	Gravel	Sand	Silt	Clay	Text 2607	USCS Group	Volcanics
03-Nov-04	BW	03-Nov-04	BW	24	D	22PC-625.2-626.7-SC	625.20	626.70			4.70	0.10	7.55	7.45								
03-Nov-04	BW	03-Nov-04	BW	24	LX	22PC-625.2-629.1-SC	625.20	629.10				0.82	3.75	2.93	5YR 5/6	38	46	6	10	16	SC	100
03-Nov-04	BW	03-Nov-04	DD	24	R	22PC-625.2-632.1-SC	625.20	632.10	0.80	6.70												
03-Nov-04	BW	03-Nov-04	DD	24	D	22PC-626.7-628.4-SC	626.70	628.40			4.70	0.10	8.70	8.60								
03-Nov-04	BW	03-Nov-04	DD	24	D	22PC-628.4-630.2-SC	628.40	630.20			4.70	0.10	8.95	8.85								
03-Nov-04	BW	03-Nov-04	DD	24	L	22PC-629.1-629.7-SC	629.10	629.70				0.81	2.30	1.49	5YR 6/6	27	60	5	8	13	SW-SC	100
03-Nov-04	BW	03-Nov-04	DD	24	L	22PC-629.7-631.0-SC	629.70	631.00				0.81	3.25	2.44	5YR 6/6	40	45	5	10	15	SC	100
03-Nov-04	BW	03-Nov-04	DD	24	D	22PC-630.2-631.9-SC	630.20	631.90			4.70	0.10	8.25	8.15								
03-Nov-04	BW	03-Nov-04	DD	24	LX	22PC-631.0-631.9-SC	631.00	631.90				0.81	2.60	1.79	5YR 6/6	44	39	7	10	17	GC	100
03-Nov-04	BW	03-Nov-04	DD	24	LC	22PC-631.9-632.1-SC	631.90	632.10														
03-Nov-04	BW	03-Nov-04	DD	25	D	22PC-632.1-632.7-SC	632.10	632.70			4.70	0.10	3.50	3.40								
03-Nov-04	BW	03-Nov-04	DD	25	LX	22PC-632.1-634.1-SC	632.10	634.10				0.81	4.60	3.79	5YR 6/6	37	53	3	7	10	SW-SC	100
03-Nov-04	BW	03-Nov-04	DD	25	R	22PC-632.1-636.1-SC	632.10	636.10	0.50	3.70												
03-Nov-04	BW	03-Nov-04	DD	25	D	22PC-632.7-634.3-SC	632.70	634.30			4.70	0.10	8.90	8.80								
03-Nov-04	BW	03-Nov-04	DD	25	LX	22PC-634.1-635.8-SC	634.10	635.80				0.79	4.65	3.86	5YR 5/4	42	39	7	12	19	GC	100
03-Nov-04	BW	03-Nov-04	DD	25	D	22PC-634.3-635.8-SC	634.30	635.80			4.70	0.10	8.65	8.55								
03-Nov-04	BW	03-Nov-04	DD	25	LC	22PC-635.8-636.1-SC	635.80	636.10														
03-Nov-04	BW	03-Nov-04	DD	26	D	22PC-636.1-636.7-SC	636.10	636.70			4.70	0.10	5.15	5.05								
03-Nov-04	BW	03-Nov-04	DD	26	LX	22PC-636.1-637.7-SC	636.10	637.70				0.83	3.60	2.77	5YR 5/3	48	29	7	16	23	GC	100
03-Nov-04	BW	03-Nov-04	DD	26	R	22PC-636.1-641.6-SC	636.10	641.60	0.20	5.30												
03-Nov-04	BW	03-Nov-04	DD	26	D	22PC-636.7-637.9-SC	636.70	637.90			4.70	0.10	6.25	6.15								
03-Nov-04	BW	04-Nov-04	DD/BW	26	L	22PC-637.7-639.1-SC	637.70	639.10				0.82	2.98	2.16	7.5YR 4/2	23	56	7	14	21	SC	100
03-Nov-04	BW	04-Nov-04	DD/BW	26	D	22PC-637.9-639.2-SC	637.90	639.20			4.70	0.10	7.10	7.00								
03-Nov-04	BW	04-Nov-04	DD/BW	26	LX	22PC-639.1-641.3-SC	639.10	641.30				0.80	5.00	4.20	5YR 5/8	33	50	7	10	17	SC	100
03-Nov-04	BW	04-Nov-04	DD/BW	26	D	22PC-639.2-640.3-SC	639.20	640.30			4.70	0.10	8.20	8.10								
03-Nov-04	BW	04-Nov-04	DD/BW	26	D	22PC-640.3-641.3-SC	640.30	641.30			4.70	0.10	6.95	6.85								
03-Nov-04	BW	04-Nov-04	DD/BW	26	LC	22PC-641.3-641.6-SC	641.30	641.60														
03-Nov-04	BW	04-Nov-04	DD/BW	27	LX	22PC-641.6-642.1-SC	641.60	642.10				0.82	2.30	1.48	5YR 4/6	14	60	10	16	26	SC	100
03-Nov-04	BW	04-Nov-04	DD/BW	27	D	22PC-641.6-643.3-SC	641.60	643.30			4.70	0.10	10.65	10.55								
03-Nov-04	BW	04-Nov-04	DD/BW	27	R	22PC-641.6-648.4-SC	641.60	648.40	0.60	6.80												
03-Nov-04	BW	04-Nov-04	DD/BW	27	L	22PC-642.1-645.0-SC	642.10	645.00				0.81	4.70	3.89	2.5YR 5/6	26	55	4	15	19	SC	100
03-Nov-04	BW	04-Nov-04	DD/BW	27	D	22PC-643.3-644.6-SC	643.30	644.60			4.70	0.10	8.10	8.00								
03-Nov-04	BW	04-Nov-04	DD/BW	27	D	22PC-644.6-645.9-SC	644.60	645.90			4.70	0.10	8.20	8.10								
03-Nov-04	BW	04-Nov-04	DD/BW	27	L	22PC-645.0-646.8-SC	645.00	646.80				0.80	4.55	3.75	2.5YR 5/6	47	37	6	10	16	GC	100
03-Nov-04	BW	04-Nov-04	DD/BW	27	D	22PC-645.9-647.1-SC	645.90	647.10			4.70	0.10	7.85	7.75								
03-Nov-04	BW	04-Nov-04	DD/BW	27	LX	22PC-646.8-648.4-SC	646.80	648.40				0.80	3.15	2.35	2.5YR 5/6	8	69	8	15	23	SC	100
03-Nov-04	BW	04-Nov-04	DD/BW	27	D	22PC-647.1-648.4-SC	647.10	648.40			4.70	0.10	7.80	7.70								
04-Nov-04	DD	04-Nov-04	DD/BW	28	D	22PC-648.4-649.0-SC	648.40	649.00			4.70	0.10	4.15	4.05								
04-Nov-04	DD	04-Nov-04	DD/BW	28	LX	22PC-648.4-651.6-SC	648.40	651.60				0.86	5.45	4.59	2.5YR 5/8	29	55	6	10	16	SC	100
04-Nov-04	DD	04-Nov-04	DD/BW	28	R	22PC-648.4-656.8-SC	648.40	656.80	1.20	8.40												
04-Nov-04	DD	04-Nov-04	DD/BW	28	D	22PC-649.0-650.4-SC	649.00	650.40			4.70	0.10	8.20	8.10								
04-Nov-04	DD	05-Nov-04	BW	28	D	22PC-650.4-651.7-SC	650.40	651.70			4.70	0.10	8.50	8.40								
04-Nov-04	DD	05-Nov-04	BW	28	L	22PC-651.6-652.8-SC	651.60	652.80				0.83	3.45	2.62	2.5YR 5/8	46	42	4	8	12	GW-GC	100
04-Nov-04	DD	05-Nov-04	BW	28	D	22PC-651.7-653.1-SC	651.70	653.10			4.70	0.10	8.40	8.30								

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Date Logged	Logged By	Date Checked	Checked By	Core Run Number	Core Sample Type	Sample Number	Depth From	Depth To	Drilling Rate	Sample Recovery	Borehole Diameter	Tare Weight	Sample Plus Tare	Sample Weight	Munsell	Gravel	Sand	Silt	Clay	Text 2607	USCS Group	Volcanics
04-Nov-04	DD	05-Nov-04	BW	28	L	22PC-652.8-655.6-SC	652.80	655.60				0.83	6.05	5.22	2.5YR 5/8	33	47	5	15	20	SC	100
04-Nov-04	DD	05-Nov-04	BW	28	D	22PC-653.1-654.5-SC	653.10	654.50			4.70	0.10	7.75	7.65								
04-Nov-04	DD	05-Nov-04	BW	28	D	22PC-654.5-655.8-SC	654.50	655.80			4.70	0.10	8.00	7.90								
04-Nov-04	DD	05-Nov-04	BW	28	LX	22PC-655.6-656.8-SC	655.60	656.80				0.87	4.25	3.38	2.5YR 5/6	26	52	7	15	22	SC	100
04-Nov-04	DD	05-Nov-04	BW	28	D	22PC-655.8-656.8-SC	655.80	656.80			4.70	0.10	7.80	7.70								
04-Nov-04	DD	05-Nov-04	BW	29	D	22PC-656.8-658.3-SC	656.80	658.30			4.70	0.10	9.05	8.95								
04-Nov-04	DD	05-Nov-04	BW	29	LX	22PC-656.8-658.3-SCA	656.80	658.30				0.86	3.50	2.64	2.5YR 5/6	36	49	5	10	15	SC	100
04-Nov-04	DD	05-Nov-04	BW	29	R	22PC-656.8-661.2-SC	656.80	661.20	0.60	4.40												
04-Nov-04	DD	05-Nov-04	BW	29	L	22PC-658.3-659.5-SC	658.30	659.50				0.77	2.90	2.13	2.5YR 5/6	29	58	3	10	13	SW-SC	100
04-Nov-04	DD	05-Nov-04	BW	29	D	22PC-658.3-659.7-SC	658.30	659.70			4.70	0.10	8.10	8.00								
04-Nov-04	DD	05-Nov-04	BW	29	LX	22PC-659.5-661.2-SC	659.50	661.20				0.81	3.95	3.14	5YR 5/6	46	38	6	10	16	GC	100
04-Nov-04	DD	05-Nov-04	BW	29	D	22PC-659.7-661.2-SC	659.70	661.20			4.70	0.10	9.25	9.15								
04-Nov-04	DD	05-Nov-04	BW	30	D	22PC-661.2-662.1-SC	661.20	662.10			4.70	0.10	5.50	5.40								
04-Nov-04	DD	05-Nov-04	BW	30	LX	22PC-661.2-663.3-SC	661.20	663.30				0.83	5.75	4.92	5YR 5/4	20	66	5	9	14	SW-SC	100
04-Nov-04	DD	05-Nov-04	BW	30	R	22PC-661.2-668.0-SC	661.20	668.00	0.60	6.80												
04-Nov-04	DD	05-Nov-04	BW	30	D	22PC-662.1-663.7-SC	662.10	663.70			4.70	0.10	9.15	9.05								
04-Nov-04	DD	05-Nov-04	BW	30	L	22PC-663.3-666.2-SC	663.30	666.20				0.87	7.05	6.18	5YR 5/6	50	37	6	7	13	GW-GC	100
04-Nov-04	DD	05-Nov-04	BW	30	D	22PC-663.7-665.2-SC	663.70	665.20			4.70	0.10	9.55	9.45								
04-Nov-04	DD	09-Nov-04	BW/EJH	30	D	22PC-665.2-666.8-SC	665.20	666.80			4.70	0.10	9.05	8.95								
04-Nov-04	DD	09-Nov-04	BW/EJH	30	LX	22PC-666.2-668.0-SC	666.20	668.00				0.86	5.05	4.19	5YR 4/4	46	38	6	10	16	GC	100
04-Nov-04	DD	09-Nov-04	BW/EJH	30	D	22PC-666.8-668.0-SC	666.80	668.00			4.70	0.10	8.00	7.90								
04-Nov-04	EJH	09-Nov-04	BW/EJH	31	D	22PC-668.0-669.0-SC	668.00	669.00			4.70	0.10	5.60	5.50								
04-Nov-04	EJH	09-Nov-04	BW/EJH	31	LX	22PC-668.0-670.7-SC	668.00	670.70				0.82	5.85	5.03	5YR 5/6	23	54	8	15	23	SC	100
04-Nov-04	EJH	09-Nov-04	BW/EJH	31	R	22PC-668.0-673.9-SC	668.00	673.90	0.50	5.20												
04-Nov-04	EJH	09-Nov-04	BW/EJH	31	D	22PC-669.0-670.5-SC	669.00	670.50			4.70	0.10	7.50	7.40								
04-Nov-04	EJH	09-Nov-04	BW/EJH	31	D	22PC-670.5-672.0-SC	670.50	672.00			4.70	0.10	7.95	7.85								
04-Nov-04	EJH	09-Nov-04	BW/EJH	31	LX	22PC-670.7-673.2-SC	670.70	673.20				0.83	6.30	5.47	5YR 5/6	50	35	5	10	15	GC	100
04-Nov-04	EJH	09-Nov-04	BW/EJH	31	D	22PC-672.0-673.2-SC	672.00	673.20			4.70	0.10	7.90	7.80								
04-Nov-04	EJH	09-Nov-04	BW/EJH	31	LC	22PC-673.2-673.9-SC	673.20	673.90														
05-Nov-04	BW	09-Nov-04	BW/EJH	32	D	22PC-673.9-674.4-SC	673.90	674.40			4.70	0.10	2.86	2.76								
05-Nov-04	BW	09-Nov-04	BW/EJH	32	LX	22PC-673.9-675.3-SC	673.90	675.30				0.82	3.50	2.68	5YR 5/6	30	64	2	4	6	SW-SC	100
05-Nov-04	BW	09-Nov-04	BW/EJH	32	R	22PC-673.9-678.1-SC	673.90	678.10	0.50	3.30												
05-Nov-04	BW	09-Nov-04	BW/EJH	32	D	22PC-674.4-675.9-SC	674.40	675.90			4.70	0.10	9.40	9.30								
05-Nov-04	BW	09-Nov-04	BW/EJH	32	LX	22PC-675.3-677.3-SC	675.30	677.30				0.83	5.65	4.82	5YR 5/6	36	45	7	12	19	SC	100
05-Nov-04	BW	09-Nov-04	BW/EJH	32	D	22PC-675.9-677.3-SC	675.90	677.30			4.70	0.10	8.95	8.85								
05-Nov-04	BW	09-Nov-04	BW/EJH	32	LC	22PC-677.3-678.1-SC	677.30	678.10														
05-Nov-04	BW	09-Nov-04	BW/EJH	33	D	22PC-678.1-678.9-SC	678.10	678.90			4.70	0.10	5.45	5.35								
05-Nov-04	BW	09-Nov-04	BW/EJH	33	LX	22PC-678.1-679.4-SC	678.10	679.40				0.83	2.30	1.47	5YR 6/6	26	68	2	4	6	SW-SC	100
05-Nov-04	BW	09-Nov-04	EJH	33	R	22PC-678.1-688.1-SC	678.10	688.10	1.20	9.30												
05-Nov-04	BW	09-Nov-04	EJH	33	D	22PC-678.9-680.3-SC	678.90	680.30			4.70	0.10	8.25	8.15								
05-Nov-04	BW	09-Nov-04	EJH	33	L	22PC-679.4-684.2-SC	679.40	684.20				0.86	2.55	1.69	5YR 5/6	58	34	3	5	8	GW-GC	100
05-Nov-04	BW	09-Nov-04	EJH	33	D	22PC-680.3-681.9-SC	680.30	681.90			4.70	0.10	10.95	10.85								
05-Nov-04	BW	09-Nov-04	EJH	33	D	22PC-681.9-683.3-SC	681.90	683.30			4.70	0.10	9.35	9.25								
05-Nov-04	BW	09-Nov-04	EJH	33	D	22PC-683.3-684.7-SC	683.30	684.70			4.70	0.10	8.85	8.75								

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Date Logged	Logged By	Date Checked	Checked By	Core Run Number	Core Sample Type	Sample Number	Depth From	Depth To	Drilling Rate	Sample Recovery	Borehole Diameter	Tare Weight	Sample Plus Tare	Sample Weight	Munsell	Gravel	Sand	Silt	Clay	Text 2607	USCS Group	Volcanics
05-Nov-04	BW	09-Nov-04	EJH	33	L	22PC-684.2-686.9-SC	684.20	686.90				0.86	2.25	1.39	5YR 5/6	20	66	6	8	14	SW-SC	100
05-Nov-04	BW	09-Nov-04	EJH	33	D	22PC-684.7-686.1-SC	684.70	686.10			4.70	0.10	9.35	9.25								
05-Nov-04	BW	09-Nov-04	EJH	33	D	22PC-686.1-687.4-SC	686.10	687.40			4.70	0.10	9.35	9.25								
05-Nov-04	BW	09-Nov-04	EJH	33	LX	22PC-686.9-687.4-SC	686.90	687.40				0.82	1.20	0.38	7.5YR 5/4	52	35	5	8	13	GW-GC	100
05-Nov-04	BW	09-Nov-04	EJH	33	LC	22PC-687.4-688.1-SC	687.40	688.10														
08-Nov-04	BW	09-Nov-04	EJH	34	D	22PC-688.1-688.4-SC	688.10	688.40			4.70	0.10	1.90	1.80								
08-Nov-04	BW	09-Nov-04	EJH	34	LX	22PC-688.1-689.3-SC	688.10	689.30				0.86	2.90	2.04	5YR 6/6	32	53	5	10	15	SC	100
08-Nov-04	BW	09-Nov-04	EJH	34	R	22PC-688.1-690.3-SC	688.10	690.30	0.20	2.00												
08-Nov-04	BW	09-Nov-04	EJH	34	D	22PC-688.4-690.1-SC	688.40	690.10			4.70	0.10	9.45	9.35								
08-Nov-04	BW	09-Nov-04	EJH	34	LX	22PC-689.3-690.1-SC	689.30	690.10				0.81	4.00	3.19	5YR 6/6	27	51	7	15	22	SC	100
08-Nov-04	BW	09-Nov-04	EJH	34	LC	22PC-690.1-690.3-SC	690.10	690.30														
08-Nov-04	BW	09-Nov-04	EJH	35	D	22PC-690.3-691.4-SC	690.30	691.40			4.70	0.10	6.65	6.55								
08-Nov-04	BW	09-Nov-04	EJH	35	LX	22PC-690.3-691.9-SC	690.30	691.90				0.86	4.75	3.89	5YR 5/6	18	67	5	10	15	SC	100
08-Nov-04	BW	09-Nov-04	EJH	35	R	22PC-690.3-699.2-SC	690.30	699.20	0.70	8.90												
08-Nov-04	BW	09-Nov-04	EJH	35	D	22PC-691.4-692.9-SC	691.40	692.90			4.70	0.10	8.75	8.65								
08-Nov-04	BW	09-Nov-04	EJH	35	L	22PC-691.9-692.7-SC	691.90	692.70				0.82	5.60	4.78	5YR 5/6	41	53	2	4	6	SW-SC	100
08-Nov-04	BW	09-Nov-04	EJH	35	L	22PC-692.7-696.1-SC	692.70	696.10				0.86	4.55	3.69	5YR 5/6	53	34	6	7	13	GW-GC	100
08-Nov-04	BW	09-Nov-04	EJH	35	D	22PC-692.9-694.3-SC	692.90	694.30			4.70	0.10	8.25	8.15								
08-Nov-04	BW	09-Nov-04	EJH	35	D	22PC-694.3-695.6-SC	694.30	695.60			4.70	0.10	7.50	7.40								
08-Nov-04	BW	09-Nov-04	EJH	35	D	22PC-695.6-696.9-SC	695.60	696.90			4.70	0.10	7.45	7.35								
08-Nov-04	BW	09-Nov-04	EJH	35	LX	22PC-696.1-699.2-SC	696.10	699.20				0.82	4.55	3.73	5YR 5/6	32	48	5	15	20	SC	100
08-Nov-04	BW	09-Nov-04	EJH	35	D	22PC-696.9-698.1-SC	696.90	698.10			4.70	0.10	7.10	7.00								
08-Nov-04	BW	09-Nov-04	EJH	35	D	22PC-698.1-699.2-SC	698.10	699.20			4.70	0.10	6.45	6.35								
08-Nov-04	BW	09-Nov-04	EJH	36	LX	22PC-699.2-699.8-SC	699.20	699.80				0.81	3.50	2.69	5YR 6/6	35	47	7	11	18	SC	100
08-Nov-04	BW	09-Nov-04	EJH	36	D	22PC-699.2-700.9-SC	699.20	700.90			4.70	0.10	8.85	8.75								
08-Nov-04	BW	09-Nov-04	EJH	36	R	22PC-699.2-706.1-SC	699.20	706.10	0.60	5.60												
08-Nov-04	BW	09-Nov-04	EJH	36	L	22PC-699.8-701.0-SC	699.80	701.00				0.86	3.90	3.04	5YR 6/6	38	46	6	10	16	SC	100
08-Nov-04	BW	09-Nov-04	EJH	36	D	22PC-700.9-702.1-SC	700.90	702.10			4.70	0.10	6.95	6.85								
08-Nov-04	BW	09-Nov-04	EJH	36	L	22PC-701.0-703.4-SC	701.00	703.40				0.87	5.20	4.33	5YR 5/4	37	44	7	12	19	SC	100
08-Nov-04	BW	09-Nov-04	EJH	36	D	22PC-702.1-703.7-SC	702.10	703.70			4.70	0.10	8.85	8.75								
08-Nov-04	BW	09-Nov-04	EJH	36	LX	22PC-703.4-704.9-SC	703.40	704.90				0.82	4.45	3.63	5YR 6/8	37	45	6	12	18	SC	100
08-Nov-04	BW	09-Nov-04	EJH	36	D	22PC-703.7-704.9-SC	703.70	704.90			4.70	0.10	7.90	7.80								
08-Nov-04	BW	11-Nov-04	EJH	36	LC	22PC-704.9-706.1-SC	704.90	706.10														
08-Nov-04	BW	11-Nov-04	EJH	37	D	22PC-706.1-706.4-SC	706.10	706.40			4.70	0.10	2.15	2.05								
08-Nov-04	BW	11-Nov-04	EJH	37	LX	22PC-706.1-707.0-SC	706.10	707.00				0.82	6.05	5.23	5YR 5/6	21	58	6	15	21	SC	100
08-Nov-04	BW	11-Nov-04	EJH	37	R	22PC-706.1-709.0-SC	706.10	709.00	0.40	2.90												
08-Nov-04	BW	11-Nov-04	EJH	37	D	22PC-706.4-707.8-SC	706.40	707.80			4.70	0.10	8.60	8.50								
08-Nov-04	BW	11-Nov-04	EJH	37	LX	22PC-707.0-709.0-SC	707.00	709.00				0.82	7.65	6.83	5YR 5/6	40	45	5	10	15	SC	100
08-Nov-04	BW	11-Nov-04	EJH	37	D	22PC-707.8-709.0-SC	707.80	709.00			4.70	0.10	8.35	8.25								
09-Nov-04	BW	11-Nov-04	EJH	38	D	22PC-709.0-710.6-SC	709.00	710.60			4.70	0.10	9.10	9.00								
09-Nov-04	BW	11-Nov-04	EJH	38	LX	22PC-709.0-712.1-SC	709.00	712.10				0.81	5.80	4.99	7.5YR 5/2	44	45	4	7	11	SW-SC	100
09-Nov-04	BW	11-Nov-04	EJH	38	R	22PC-709.0-719.0-SC	709.00	719.00	0.40	9.60												
09-Nov-04	BW	11-Nov-04	EJH	38	D	22PC-710.6-712.1-SC	710.60	712.10			4.70	0.10	9.05	8.95								
09-Nov-04	BW	11-Nov-04	EJH	38	D	22PC-712.1-713.6-SC	712.10	713.60			4.70	0.10	8.80	8.70								

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Date Logged	Logged By	Date Checked	Checked By	Core Run Number	Core Sample Type	Sample Number	Depth From	Depth To	Drilling Rate	Sample Recovery	Borehole Diameter	Tare Weight	Sample Plus Tare	Sample Weight	Munsell	Gravel	Sand	Silt	Clay	Text 2607	USCS Group	Volcanics
09-Nov-04	BW	11-Nov-04	EJH	38	L	22PC-712.1-714.0-SC	712.10	714.00				0.82	4.15	3.33	5YR 5/6	33	55	4	8	12	SW-SC	100
09-Nov-04	BW	11-Nov-04	EJH	38	D	22PC-713.6-715.0-SC	713.60	715.00			4.70	0.10	7.90	7.80								
09-Nov-04	BW	11-Nov-04	EJH	38	L	22PC-714.0-715.6-SC	714.00	715.60				0.86	5.85	4.99	5YR 5/6	30	57	5	8	13	SW-SC	100
09-Nov-04	BW	11-Nov-04	EJH	38	D	22PC-715.0-717.1-SC	715.00	717.10			4.70	0.10	10.95	10.85								
09-Nov-04	BW	11-Nov-04	EJH	38	LX	22PC-715.6-718.7-SC	715.60	718.70				0.86	7.45	6.59	5YR 5/6	42	41	5	12	17	GC	100
09-Nov-04	BW	11-Nov-04	EJH	38	D	22PC-717.1-718.7-SC	717.10	718.70			4.70	0.10	10.10	10.00								
09-Nov-04	BW	11-Nov-04	EJH	38	LC	22PC-718.7-719.0-SC	718.70	719.00														
09-Nov-04	BW	11-Nov-04	EJH	39	LX	22PC-719.0-719.5-SC	719.00	719.50				0.85	4.10	3.25	7.5YR 5/4	19	61	5	15	20	SC	100
09-Nov-04	BW	11-Nov-04	EJH	39	D	22PC-719.0-719.7-SC	719.00	719.70			4.70	0.10	4.36	4.26								
09-Nov-04	BW	11-Nov-04	BW	39	R	22PC-719.0-721.5-SC	719.00	721.50	0.30	1.90												
09-Nov-04	BW	11-Nov-04	EJH	39	L	22PC-719.5-720.4-SC	719.50	720.40				0.83	3.15	2.32	5YR 5/6	34	49	7	10	17	SC	100
09-Nov-04	BW	11-Nov-04	EJH	39	D	22PC-719.7-720.9-SC	719.70	720.90			4.70	0.10	9.35	9.25								
09-Nov-04	BW	11-Nov-04	EJH	39	LX	22PC-720.4-720.9-SC	720.40	720.90				0.83	3.25	2.42	7.5YR 5/4	41	42	7	10	17	SC	100
09-Nov-04	BW	11-Nov-04	EJH	39	LC	22PC-720.9-721.5-SC	720.90	721.50														
09-Nov-04	BW	11-Nov-04	EJH	40	D	22PC-721.5-722.3-SC	721.50	722.30			4.70	0.10	6.31	6.21								
09-Nov-04	BW	11-Nov-04	EJH	40	LX	22PC-721.5-725.5-SC	721.50	725.50				0.83	4.95	4.12	7.5YR 5/6	62	28	4	6	10	GW-GC	100
09-Nov-04	BW	11-Nov-04	EJH	40	R	22PC-721.5-729.9-SC	721.50	729.90	0.70	7.30												
09-Nov-04	BW	11-Nov-04	EJH	40	D	22PC-722.3-723.7-SC	722.30	723.70			4.70	0.10	9.50	9.40								
09-Nov-04	BW	11-Nov-04	EJH	40	D	22PC-723.7-725.0-SC	723.70	725.00			4.70	0.10	8.80	8.70								
09-Nov-04	BW	11-Nov-04	EJH	40	D	22PC-725.0-726.4-SC	725.00	726.40			4.70	0.10	9.35	9.25								
09-Nov-04	BW	11-Nov-04	EJH	40	L	22PC-725.5-726.0-SC	725.50	726.00				0.83	4.20	3.37	5YR 6/6	27	55	8	10	18	SC	100
09-Nov-04	BW	11-Nov-04	EJH	40	LX	22PC-726.0-728.8-SC	726.00	728.80				0.83	3.50	2.67	7.5YR 5/6	32	50	8	10	18	SC	100
09-Nov-04	BW	11-Nov-04	EJH	40	D	22PC-726.4-727.8-SC	726.40	727.80			4.70	0.10	8.60	8.50								
09-Nov-04	BW	11-Nov-04	EJH	40	D	22PC-727.8-728.8-SC	727.80	728.80			4.70	0.10	7.90	7.80								
09-Nov-04	BW	11-Nov-04	EJH	40	LC	22PC-728.8-729.9-SC	728.80	729.90														
10-Nov-04	BW	11-Nov-04	EJH	41	D	22PC-729.9-730.4-SC	729.90	730.40			4.70	0.10	2.70	2.60								
10-Nov-04	BW	11-Nov-04	EJH	41	LX	22PC-729.9-731.5-SC	729.90	731.50				0.83	3.95	3.12	5YR 5/6	27	51	7	15	22	SC	100
10-Nov-04	BW	11-Nov-04	EJH	41	R	22PC-729.9-734.8-SC	729.90	734.80	0.50	3.20												
10-Nov-04	BW	11-Nov-04	EJH	41	D	22PC-730.4-731.8-SC	730.40	731.80			4.70	0.10	8.40	8.30								
10-Nov-04	BW	11-Nov-04	EJH	41	LX	22PC-731.5-733.2-SC	731.50	733.20				0.82	3.85	3.03	5YR 5/8	20	58	7	15	22	SC	100
10-Nov-04	BW	11-Nov-04	EJH	41	D	22PC-731.8-733.2-SC	731.80	733.20			4.70	0.10	9.05	8.95								
10-Nov-04	BW	11-Nov-04	EJH	41	LC	22PC-733.2-734.8-SC	733.20	734.80														
10-Nov-04	BW	11-Nov-04	EJH	42	D	22PC-734.8-735.7-SC	734.80	735.70			4.70	0.10	5.25	5.15								
10-Nov-04	BW	11-Nov-04	EJH	42	LX	22PC-734.8-736.4-SC	734.80	736.40				0.85	3.78	2.93	5YR 5/4	21	49	10	20	30	SC	100
10-Nov-04	BW	11-Nov-04	EJH	42	R	22PC-734.8-739.9-SC	734.80	739.90	0.60	4.80												
10-Nov-04	BW	11-Nov-04	EJH	42	D	22PC-735.7-737.0-SC	735.70	737.00			4.70	0.10	9.00	8.90								
10-Nov-04	BW	11-Nov-04	EJH	42	L	22PC-736.4-737.1-SC	736.40	737.10				0.85	6.20	5.35	5YR 5/8	26	52	8	14	22	SW-SC	100
10-Nov-04	BW	11-Nov-04	EJH	42	D	22PC-737.0-738.3-SC	737.00	738.30			4.70	0.10	10.15	10.05								
10-Nov-04	BW	11-Nov-04	EJH	42	LX	22PC-737.1-739.6-SC	737.10	739.60				0.85	7.10	6.25	5YR 5/6	31	48	7	14	21	SC	100
10-Nov-04	BW	11-Nov-04	EJH	42	D	22PC-738.3-739.6-SC	738.30	739.60			4.70	0.10	9.10	9.00								
10-Nov-04	BW	11-Nov-04	EJH	42	LC	22PC-739.6-739.9-SC	739.60	739.90														
10-Nov-04	BW	11-Nov-04	EJH	43	D	22PC-739.9-740.5-SC	739.90	740.50			4.70	0.10	3.80	3.70								
10-Nov-04	BW	11-Nov-04	EJH	43	LX	22PC-739.9-741.8-SC	739.90	741.80				0.80	4.65	3.85	5YR 6/6	18	63	9	10	19	SC	100
10-Nov-04	BW	11-Nov-04	EJH	43	R	22PC-739.9-747.0-SC	739.90	747.00	0.50	6.00												

22PC ALLUVIUM CORE LOGGING REPORT

Date Logged	Logged By	Date Checked	Checked By	Core Run Number	Core Sample Type	Sample Number	Depth From	Depth To	Drilling Rate	Sample Recovery	Borehole Diameter	Tare Weight	Sample Plus Tare	Sample Weight	Munsell	Gravel	Sand	Silt	Clay	Text 2607	USCS Group	Volcanics
10-Nov-04	BW	11-Nov-04	EJH	43	D	22PC-740.5-742.0-SC	740.50	742.00			4.70	0.10	9.15	9.05								
10-Nov-04	BW	11-Nov-04	EJH	43	L	22PC-741.8-743.1-SC	741.80	743.10				0.80	495.00	494.20	5YR 5/6	32	56	4	8	12	SW-SC	100
10-Nov-04	BW	11-Nov-04	EJH	43	D	22PC-742.0-743.4-SC	742.00	743.40			4.70	0.10	8.70	8.60								
10-Nov-04	BW	11-Nov-04	EJH	43	LX	22PC-743.1-745.9-SC	743.10	745.90				0.80	4.90	4.10	5YR 5/8	23	46	11	20	31	SC	100
10-Nov-04	BW	11-Nov-04	EJH	43	D	22PC-743.4-745.0-SC	743.40	745.00			4.70	0.10	8.90	8.80								
10-Nov-04	BW	11-Nov-04	EJH	43	D	22PC-745.0-745.9-SC	745.00	745.90			4.70	0.10	7.05	6.95								
10-Nov-04	BW	11-Nov-04	EJH	43	LC	22PC-745.9-747.0-SC	745.90	747.00														
10-Nov-04	BW	11-Nov-04	EJH	44	D	22PC-747.0-747.4-SC	747.00	747.40			4.70	0.10	2.20	2.10								
10-Nov-04	BW	11-Nov-04	EJH	44	LX	22PC-747.0-747.4-SCA	747.00	747.40				0.80	2.95	2.15	5YR 6/6	46	42	4	8	12	GW-GC	100
10-Nov-04	BW	11-Nov-04	EJH	44	R	22PC-747.0-754.9-SC	747.00	754.90	0.90	7.90												
10-Nov-04	BW	11-Nov-04	EJH	44	D	22PC-747.4-748.8-SC	747.40	748.80			4.70	0.10	9.50	9.40								
10-Nov-04	BW	11-Nov-04	EJH	44	L	22PC-747.4-749.1-SC	747.40	749.10				0.85	5.00	4.15	5YR 6/6	16	71	5	8	13	SW-SC	100
10-Nov-04	BW	11-Nov-04	EJH	44	D	22PC-748.8-750.2-SC	748.80	750.20			4.70	0.10	9.20	9.10								
10-Nov-04	BW	11-Nov-04	EJH	44	L	22PC-749.1-752.9-SC	749.10	752.90				0.85	6.80	5.95	5YR 6/6	39	40	7	14	21	SC	100
10-Nov-04	BW	11-Nov-04	EJH	44	D	22PC-750.2-751.7-SC	750.20	751.70			4.70	0.10	9.40	9.30								
10-Nov-04	BW	11-Nov-04	EJH	44	D	22PC-751.7-753.2-SC	751.70	753.20			4.70	0.10	9.15	9.05								
10-Nov-04	BW	11-Nov-04	EJH	44	LX	22PC-752.9-754.9-SC	752.90	754.90				0.85	5.10	4.25	5YR 6/6	26	58	6	10	16	SC	100
10-Nov-04	BW	11-Nov-04	EJH	44	D	22PC-753.2-754.9-SC	753.20	754.90			4.70	0.10	8.75	8.65								
10-Nov-04	BW	11-Nov-04	EJH	45	LX	22PC-754.9-755.5-SC	754.90	755.50							5YR 6/6	32	47	7	14	21	SC	100
10-Nov-04	BW	11-Nov-04	EJH	45	D	22PC-754.9-756.3-SC	754.90	756.30			4.70	0.10	7.15	7.05								
10-Nov-04	BW	11-Nov-04	EJH	45	R	22PC-754.9-759.5-SC	754.90	759.50	0.20	4.70												
10-Nov-04	BW	11-Nov-04	EJH	45	L	22PC-755.5-759.2-SC	755.50	759.20				0.85	6.60	5.75	5YR 6/6	41	37	8	14	22	GC	100
10-Nov-04	BW	11-Nov-04	EJH	45	D	22PC-756.3-758.1-SC	756.30	758.10			4.70	0.10	9.50	9.40								
10-Nov-04	BW	11-Nov-04	EJH	45	D	22PC-758.1-759.5-SC	758.10	759.50			4.70	0.10	9.35	9.25								
11-Nov-04	BW	02-Jun-05	DD	45	LX	22PC-759.2-759.5-SC	759.20	759.50				0.80	2.50	1.70	5YR 6/4	29	57	5	9	14	SW-SC	100
11-Nov-04	BW	02-Jun-05	DD	46	D	22PC-759.5-760.3-SC	759.50	760.30			4.70	0.10	6.75	6.65								
11-Nov-04	BW	02-Jun-05	DD	46	LX	22PC-759.5-761.3-SC	759.50	761.30				0.82	6.05	5.23	5YR 5/4							100
11-Nov-04	BW	02-Jun-05	DD	46	R	22PC-759.5-763.0-SC	759.50	763.00	0.30	3.30												
11-Nov-04	BW	02-Jun-05	DD	46	D	22PC-760.3-761.6-SC	760.30	761.60			4.70	0.10	10.80	10.70								
11-Nov-04	BW	02-Jun-05	DD	46	L	22PC-761.3-762.4-SC	761.30	762.40				0.82	4.10	3.28	5YR 5/4							100
11-Nov-04	BW	02-Jun-05	DD	46	D	22PC-761.6-762.8-SC	761.60	762.80			4.70	0.10	10.80	10.70								
11-Nov-04	BW	02-Jun-05	DD	46	LX	22PC-762.4-762.8-SC	762.40	762.80				0.82	4.50	3.68	5YR 5/4							100
11-Nov-04	BW	02-Jun-05	DD	46	LC	22PC-762.8-763.0-SC	762.80	763.00														

Appendix C: Hydraulic Conductivity

Preliminary Pressure Transient Analysis of 22PA and 22PC

Preliminary analysis of the pressure response during tracer tests between the active well 22S and the observation wells 22PA Deep and 22PC Deep indicates that permeability is slightly higher (approximately 15% higher) between 22PC Deep and 22S than between 22PA Deep and 22S.) This result clearly does not support the concept that a large permeability contrast between 22PA and 22PC is the driving force behind the rapid breakthrough time observed from 22PA to 22S. Rather, it provides supporting evidence that a low effective porosity is primarily responsible for the rapid breakthrough.

The observed pressure response at 22S, 22PA, and 22PC during the tracer test is shown in Figure C.1, and average drawdown is shown in Table C.1.

The equation for determining hydraulic conductivity for confined conditions is (Driscoll, 1986):

$$K = \frac{528Q \log r_2 / r_1}{b(h_2 - h_1)}$$

Where

Q = pumping rate in gpm

K = hydraulic conductivity in gpd/ft

b = aquifer thickness in ft

h_2 = head in ft measured at r_2

h_1 = head in ft measured at r_1

r_2 = distance to farthest observation well in ft

r_1 = distance to closest observation well in ft

Since Q, b, r_2, and r_1 are equal for both 22PA and 22PC, the only remaining variables are $(h_2 - h_1)$. Therefore, for this example:

$$K \propto \frac{1}{(h_2 - h_1)}$$

Where the drawdown or delta height (Δh)

$$\Delta h = (h_2 - h_1)$$

From Table C.1 and Figure C.1, we see that Δh is greater between 22PA and 22S than between 22PC and 22S. Thus, the hydraulic conductivity must be greater between 22PC and 22S than between 22PA and 22S.

Preliminary analysis was also performed using Saphir type curve analysis for interference tests. The results are shown in Figures C.2 and C.3. As expected, the type curve analysis indicates that the hydraulic conductivity (permeability) is directly proportional to the drawdown observed with 22PC calculating approximately 15% higher than 22PA.

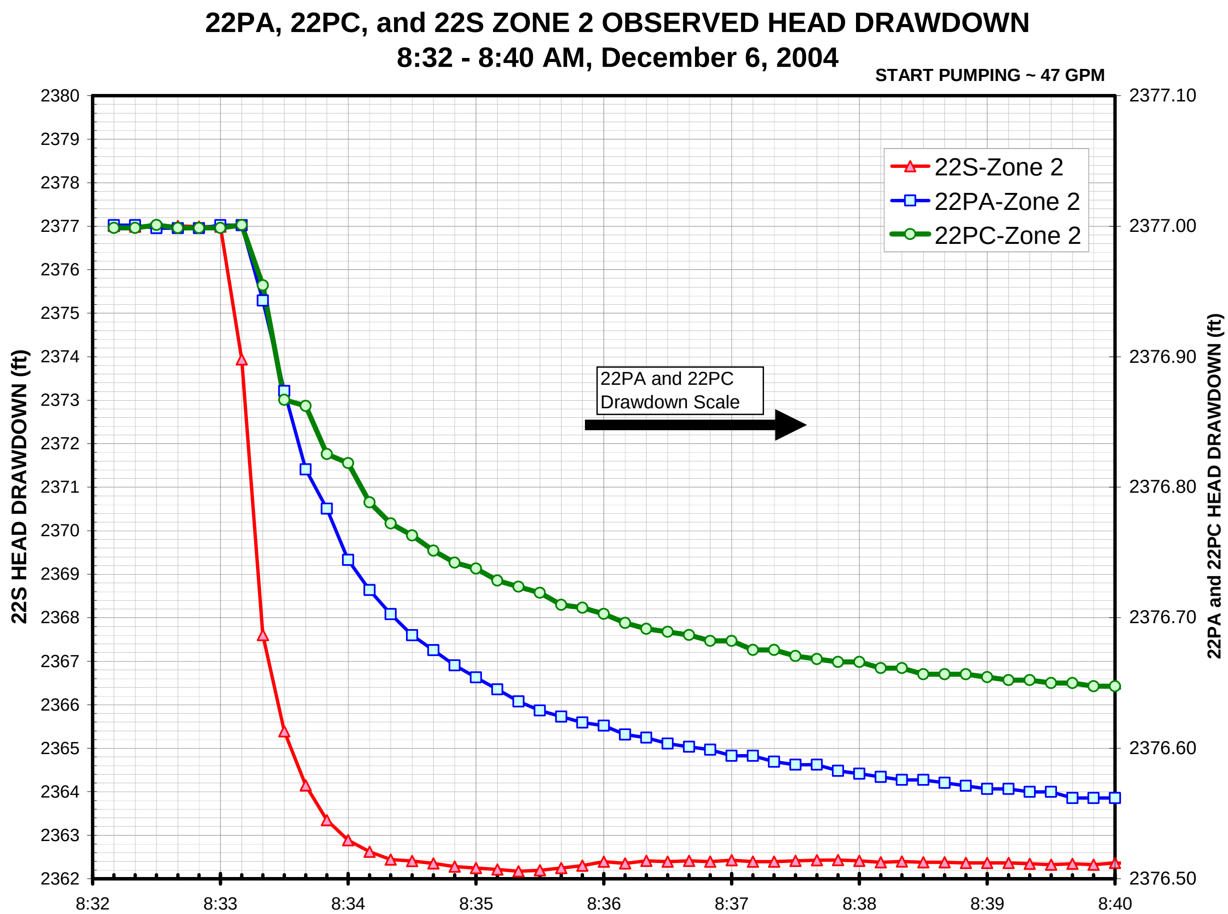
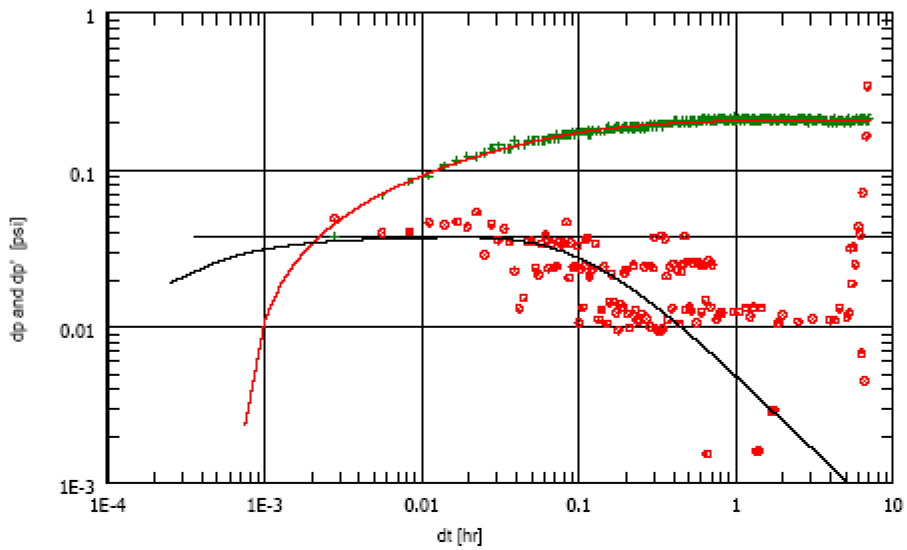


Figure C.1 Head drawdown observed at Site 22 showing larger drawdown at 22PA compared to 22PC, thereby supporting a higher hydraulic conductivity between 22S and 22PA than between 22S and 22PC.

Log-Log plot	line source
Company Nye County Well Observation	Field 22S Site on NTS Test Name / #



Dec10_PB1_22PA_Press build-up #1

Rate	0 STB/D
Rate change	1618.3 STB/D
P@dt=0	25.779 psia
Pi	25.9895 psia
Smoothing	0.3

Selected Model

Model Option	Standard Model
Well	Line source
Reservoir	Homogeneous
Boundary	Rectangle

Main Model Parameters

TMatch	1400 1/hr
PMatch	13.3 1/psia
Phi	0.229
Phi.h	26.3 ft
k.h, total	3.04E+6 md.ft
k, average	26500 md
Pi	25.9895 psia
Well distance	59 ft

Model Parameters

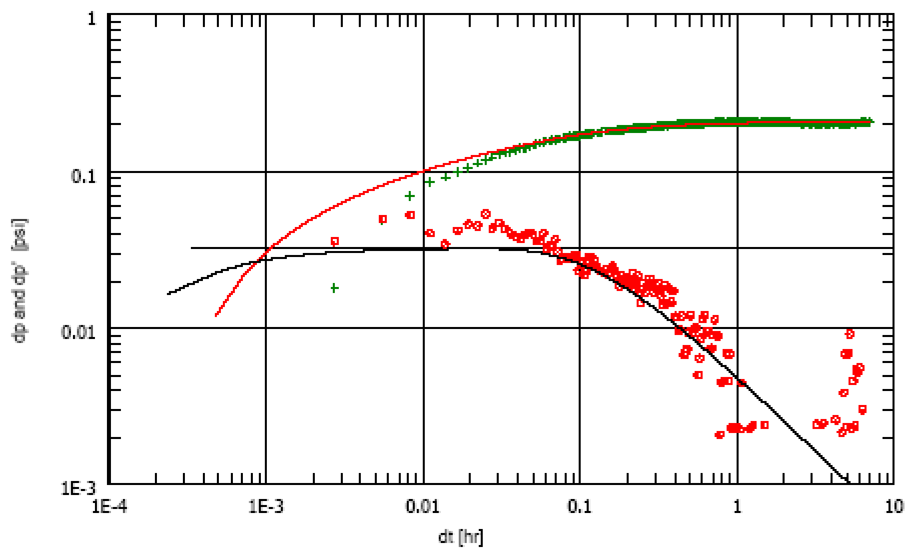
Reservoir & Boundary parameters

Pi	25.9895 psia
k.h	3.04E+6 md.ft
k	26500 md
Phi	0.229
Phi.h	26.3 ft
S - None	N/A ft
E - None	N/A ft
N - Constant P.	805 ft
W - None	N/A ft

Derived & Secondary Parameters

Figure C.2. Type curve match of pressure transient from pumping at 22S observed at 22PA.

Log-Log plot	line source 2
Company Nye County Well Observation	Field 22S Site on NTS Test Name / #



Dec10_PB1_22PC_Press build-up #1
Rate 0 STB/D
Rate change 1618.3 STB/D
P@dt=0 23.917 psia
Pi 24.125 psia
Smoothing 0.2

Selected Model
Model Option Standard Model
Well Line source
Reservoir Homogeneous
Boundary Rectangle

Main Model Parameters
TMatch 1470 1/hr
PMatch 15.4 1/psia
Phi 0.252
Phi.h 29 ft
k.h, total 3.53E+6 md.ft
k, average 30700 md
Pi 24.125 psia
Well distance 59 ft

Model Parameters
Reservoir & Boundary parameters
Pi 24.125 psia
k.h 3.53E+6 md.ft
k 30700 md
Phi 0.252
Phi.h 29 ft
S - None N/A ft
E - None N/A ft
N - Constant P. 898 ft
W - None N/A ft

Derived & Secondary Parameters

Figure C.3. Type curve match of pressure transient from pumping at 22S observed at 22PC.

Table C.1. Measured head drawdown.

Well	Measured (ft)
22S	14.7 / 1.8*
22PA Deep	0.53
22PC Deep	0.46

* Calculated based on observed data less head loss due to completion efficiency (wellbore friction drop)