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Hydrologic Data and Evaluation for Wells Near the Faultless Underground Nuclear Test, Central Nevada Test Area

Prepared by

Brad Lyles, Phil Oberlander, David Gillespie, Dee Donithan, and Jenny Chapman

submitted to

Nevada Site Office
National Nuclear Security Administration
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ABSTRACT

In 2005, a drilling campaign was performed at the Central Nevada Test Area (CNTA) to provide information for model validation, emplace long-term monitoring wells, and develop baseline geochemistry for long term hydrologic monitoring. Water levels were monitored in the previously drilled wells in the vicinity of UC-1, HTH-1 and PS-1, as well as in the newly drilled wells, MV-1, MV-2 and MV-3.

Lithium bromide was added as a chemical tracer to drilling fluids during the drilling of the monitoring and validation (MV) wells. The low hydraulic conductivity of the aquifers, required a lengthy purge period to remove introduced drilling fluids as evidenced by bromide concentration. MV-1 and MV-3 produced less than 1 gallon per minute (GPM); pump limitations only allowed the wells to be pumped for a few hours before the pump controller would shut off the pump. Therefore, the wells were pumped once weekly for several months until the bromide concentration was less then 1 milligram per liter (mg/L). MV-2 produces about 3 GPM and could sustain pumping for about 6 hours; it was also pumped weekly until bromide concentrations were less then 1 mg/L.

Aquifer tests were performed in each MV well once the bromide purging was complete. Water level data from the aquifer tests and from the well purging were used to compute aquifer hydraulic conductivity and transmissivity.

Water quality samples were collected after the aquifer testing was completed. Tritium scans were preformed prior to other analyses to ensure the absence of high levels of radioactivity; all tritium scans were less than 300 pico-curies per liter. Samples were then analyzed for carbon-14 and iodine-129, stable isotopes of oxygen and hydrogen, as well as major cations and anions.

ACKNOWLEDGMENTS

The drilling and completion of the MV wells at CNTA was a complex operation that benefited from the skill and dedication of many people. The authors would like to particularly acknowledge contributions to the data included in this report made by Tim Echelard, Richard Findlay, Greg Studley, and Robert Dickerson, all of Stoller-Navarro Joint Venture. Some of the pre-MV data included in this report were collected by Todd Mihevc, DRI. Karl Pohlmann, also of DRI, provided an invaluable bridge between the CNTA groundwater model and the activities in the field. Chuck Russell, DRI, was a key part of the sampling team and developed the sample and analysis plan. The authors are grateful for the opportunity to work with these people in furthering the understanding of CNTA hydrogeology.

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LIST OF ACRONYMS

bgs	below ground surface
CADD/CAP	Corrective Action Decision Document/Corrective Action Plan
CNTA	Central Nevada Test Area
DOE	U.S. Department of Energy
GPM	gallons per minute
NNSA/NSO	National Nuclear Security Administration/Nevada Site Office
pCi/L	pico Curies per liter
SNJV	Stoller-Navarro Joint Venture
USGS	United States Geological Survey

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INTRODUCTION

The Central Nevada Test Area (CNTA) was created to provide a supplemental site for underground nuclear tests that could not be conducted at the Nevada Test Site because of ground motion potential in Las Vegas high-rise buildings. One nuclear test was performed at CNTA: the Faultless test, in January 1968, at a depth of 3,200 ft below land surface. The CNTA was decommissioned as a testing facility in 1973. Activities over the following decades were focused on groundwater monitoring through the Long-term Hydrologic Monitoring Program, operated by the U.S. Environmental Protection Agency.

In the late 1980s, DOE established an Environmental Management (EM) program to systematically evaluate and remediate locations affected by Cold War activities. For locations in the state of Nevada, EM activities are performed in accordance with a Federal Facility Agreement and Consent Order (FFACO) between the U.S. Department of Energy, the U.S. Department of Defense, and the State of Nevada (FFACO, 1996). The FFACO prescribes a Corrective Action Strategy for underground nuclear test locations.

For CNTA, the first step in the Corrective Action Strategy was approval of the Corrective Action Investigation Plan (CAIP; DOE, 1999). There were three principal parts to the investigation: collecting data, modeling groundwater flow and contaminant transport, and assessing uncertainty through a Data Decision Analysis. The ultimate objective was development of a contaminant boundary encompassing radionuclide migration through a 1,000-year time period. The investigation primarily relied on information obtained during the nuclear testing time period; new data collection was limited to measurement of water levels and laboratory sorption experiments.

A Corrective Action Decision Document/Corrective Action Plan (CADD/CAP) presented the results of the investigation, the calculated contaminant boundary, a negotiated compliance boundary, and a plan for model validation and monitoring (DOE, 2004). The CADD/CAP required drilling three new boreholes around the Faultless test, and installating monitoring wells and piezometers. The boreholes dictated by the CADD/CAP were drilled during spring and summer 2005, and represent the first major subsurface field activity at CNTA since site decommissioning. Drilling and well construction activities are recorded in a well installation report (DOE, 2006). This report presents data and analysis pertinent to reaching the objectives of the wells. Much of the testing and development reported here occurred after the conclusion of the drilling activities recorded in DOE (2006).

Following this introduction, the objectives for the wells and background information on the site and well locations are presented. This is followed by summaries of the hydraulic, lithologic, and water chemistry data. Detailed information for each of the three MV wells is then presented, followed by a summary and discussion of ongoing and planned work. Digital data for the MV wells are included on the attached compact disc.

OBJECTIVES FOR THE WELLS

The objectives for the Faultless drilling and testing program were: (1) monitoring well installation and, (2) model validation. The wells, MV-1, MV02, and MV-3, were designed to meet both objectives.

Monitoring Objective

Analysis of the flow and transport model results indicated that the optimum monitoring well location is due north of ground zero at a depth of 1,075 m (100 m below the working point) (Hassan, 2003). In addition to monitoring the radiochemical composition of the groundwater, there is a "system" monitoring parameter specified in the CAP. Hydraulic head is to be monitored to ensure that the groundwater system continues to behave as predicted in the modeling. As a result, wells are located to the northeast and west of ground zero (in addition to due north), to laterally distribute head measurements; and two piezometers are located in each borehole to distribute head measurements vertically.

Validation Objective

The validation targets for the Faultless flow and transport models are as follows:

1. Flow directions.
2. Presence or absence of welded tuff near the emplacement location.
3. Contaminant transport predictions (absence of transport above the maximum containment level [MCL]).
4. Hydraulic conductivity range.

Confirming hydraulic gradients is vital to the effectiveness of groundwater monitoring. Determining whether or not the welded tuff exists near the emplacement horizon is also important because only those simulations with welded tuff predicted any significant transport. Confirming the transport predictions (essentially ruling out fast pathways) is desirable, despite the low probability of detectable transport predicted by the groundwater model. Comparing the range of hydraulic conductivity in new wells with that used in the model will confirm a major parameter leading to the slow, predicted velocities.

The corresponding approach used to reach each validation target is summarized below:

1. Flow directions: Measure hydraulic head in units distributed both laterally and vertically around the site. In particular, the confirmation of downward-directed vertical and northward-directed lateral gradients at the test horizon is critical.
2. Welded tuff: Log (including geophysical logs) the lithologic section in boreholes distributed around the emplacement hole.
3. Contaminant transport: Collect and analyze groundwater samples for radionuclides.
4. Hydraulic conductivity: Perform aquifer tests.

The well locations were selected to obtain data from areas around the nuclear test where no wells were previously located, and to distribute the hydraulic head data for gradient determination. Well MV-3 is located due north of the nuclear test, according to the transport predictions. The well depths were targeted to be deeper than the elevation of the nuclear test, to reduce uncertainty in the transport pathways below the nuclear test horizon.

SITE LOCATION AND GENERAL GEOLOGIC SETTING

The Central Nevada Test Area is in south-central Nevada in Hot Creek Valley (Figure 1). Hot Creek Valley extends approximately 70 miles between north-south-oriented mountain ranges, with the valley width ranging between 5 and 20 miles. West of the valley is the Hot Creek Range, rising to a maximum elevation of 10,200 ft at Morey Peak. The valley floor elevation varies from 5,180 to 6,000 ft. The Faultless site within CNTA is on the western alluvial fan at an elevation of approximately 6,100 ft. Hot Creek Valley drains southeastward to Railroad Valley in the vicinity of Twin Springs Ranch, though there is little streamflow on the valley floor except during periods of heavy runoff from the mountain streams.

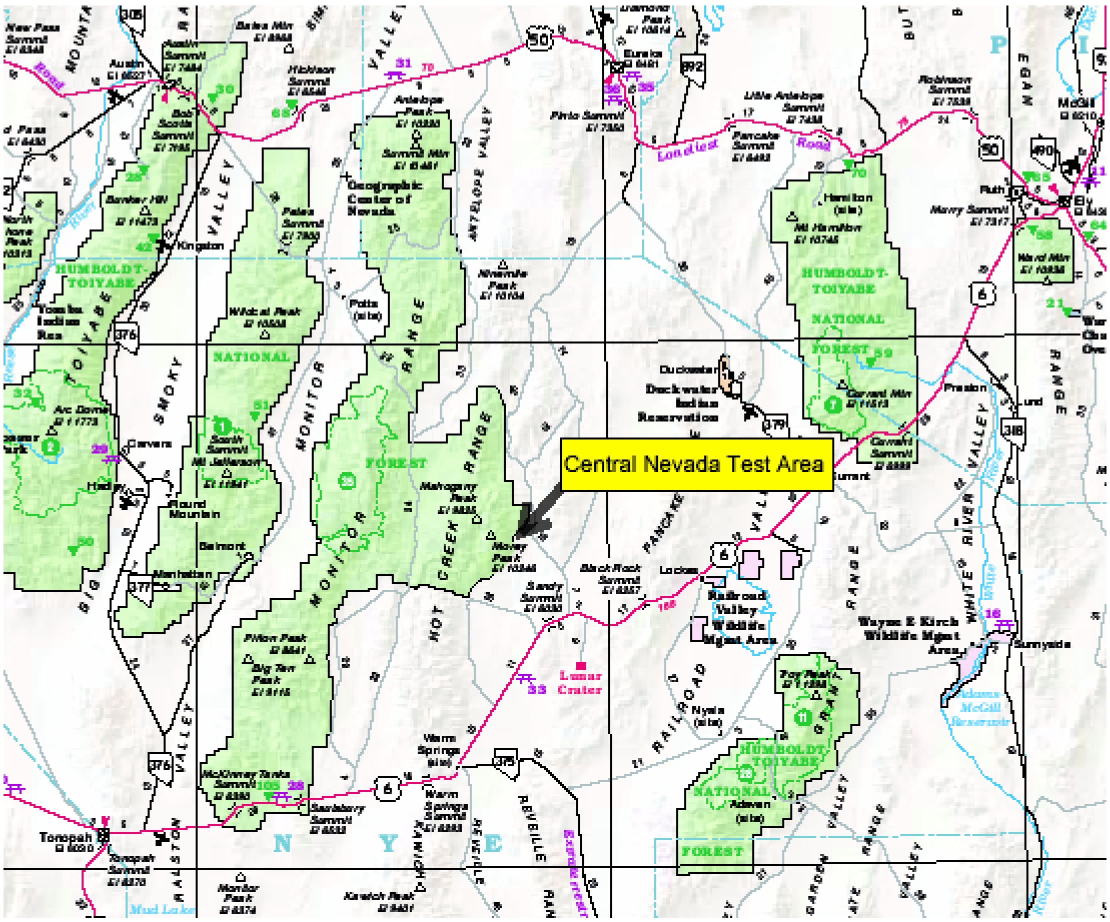

Figure 1. Location of the Central Nevada Test Area in Hot Creek Valley, Nevada.

The climate in Hot creek Valley is semi-arid, with annual precipitation averaging 7.6 in/yr at the Blue Jay weather station on U.S. Highway 6, south of Faultless. The average snowfall is 5 in/yr. Large diurnal and seasonal temperature changes occur. January is the coldest month, with an average maximum temperature of 45°F and an average minimum temperature of 13°F. July is the warmest month, with an average maximum temperature of 94°F and an average minimum temperature of 50°F. The valley floor is dominated by sagebrush, while the higher elevations support pinyon pine and juniper.

Hot Creek Valley is a long graben containing a thick sequence of Quaternary- and Tertiary-age fill (up to 3,900 ft) underlain by a thick section of Tertiary-age volcanic rock. The bounding ranges on either side of the valley are also comprised of volcanics. The contact between the valley and ranges is defined by north-south-trending high-angle faults. The Faultless site occurs within the Morey Peak-Hot Creek Caldera complex. The volcanic rocks are heavily faulted, including normal, thrust, and strike-slip faults. Volcanism was active during the early deposition of the alluvium, demonstrated by interbedding of the deeper alluvium with undisturbed tuffs and tuffaceous sediments.

The Tertiary volcanics consist of tuffs, tuffaceous sediments, sandstones, basalts, and rhyolite lavas. The tuffs can be fine-grained and densely welded. The Tertiary tuffaceous sediments include consolidated clastics derived from the surrounding volcanic rocks and Paleozoic sediments. The alluvium consists of pebble- to boulder-size fragments of welded tuff and rare Paleozoic rocks, enclosed in a clay-cemented matrix of sand-sized crystal grains, particles of welded tuff, and some Paleozoic chert, siltstone, and carbonate fragments.

BOREHOLE AND WELL LOCATIONS

The Faultless test was conducted in the UC-1 borehole (Figure 2 and Table 1). Borehole UC-1 penetrated 2,400 ft of alluvium underlain by volcanic sediments to a depth of 3,275 ft. The Faultless device was detonated at a depth of 3,200 ft on January 19, 1968. Other tests were originally planned for CNTA, but never conducted. Exploratory boreholes are located elsewhere in Hot Creek Valley and adjacent valleys, and two additional emplacement holes were drilled at CNTA, but not used. The unused emplacement hole to the north of Faultless is UC-4, and the one to the south is UC-3.

In the immediate Faultless area, several instrument holes were drilled and logged, two hydrologic test wells were constructed, and two post-test holes were drilled, all prior to the 2005 field effort. The instrument holes were cemented prior to the nuclear test for containment purposes. The hydrologic and post-test wells remain accessible as of 2006.

Existing wells and the MV wells were location surveyed by Summit Engineering. Results of their survey are listed in Table 1 (Appendix A includes a copy of the surveyor's report). Elevation measurements are to the top of the casing for all wells, except for those listed as "CONC," which is the top of the concrete. Water level elevations are measured with respect to a land surface datum.

The MV wells were drilled and completed as prescribed by the CADD-CAP. The objectives guiding their location and completion intervals are provided in the previous section. Each of the MV wells has a primary well string (designated by a "W" on Table 1) completed within a densely welded tuff and outfitted with a submersible pump. In addition, the wells were constructed with two piezometers; one screened in the alluvium (designated by a "U" in Table 1) and one screened in the volcanic section (designated by an "L" in Table 1). Details regarding the drilling and construction of the MV wells can be found in the CNTA well installation report (DOE, 2006) and are summarized in later sections.

Well HTH-1 is located about a half-mile due south of UC-1. It was completed to a depth of 3,704 ft, with 10 screened intervals. HTH-1 encountered 2,390 ft of alluvium, a 78-ft-thick densely welded tuff at the top of the volcanic section, and layered tuffs and tuffaceous sediments to total depth. As described in detail by Dinwiddie and Schroder

(1971), the U.S. Geological Survey (USGS) conducted packer tests of the screened intervals, providing a profile of hydraulic head with depth. Well HTH-2 was drilled 505 ft adjacent to HTH-1 and completed in alluvium to a depth of 1,000 ft. HTH-2 served as an observation well for an aquifer test performed in HTH-1.

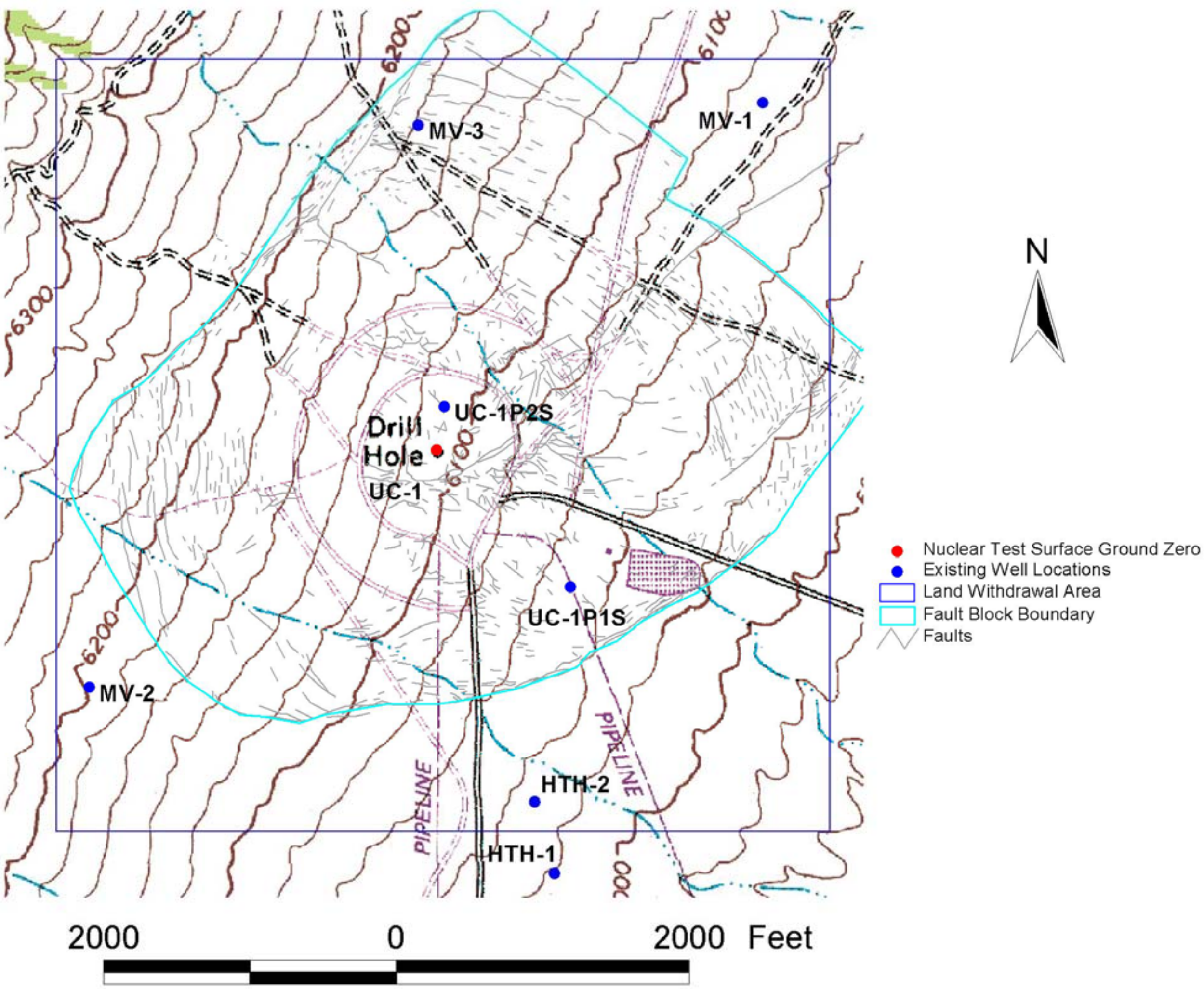

Figure 2. Location of boreholes near the Faultless underground nuclear test.

Table 1. CNTA well location coordinates (UTM-Zone 11, NAD 27, NAVD 29) in meters.

Station	Northing	Easting	Elevation
HTH-1	4275398.58	568542.94	1,832.37
HTH-2	4275546.93	568501.90	1,836.65
UC-1	4276279.40	568298.87	1,852.77
UC-1-1-2	4276272.90	568275.35	1,852.99
UC-1-1-1	4276255.84	568291.54	1,853.00
UC-1-P-1S	4275995.57	568576.04	1,838.30
UC-1-P-2SR	4276369.79	568314.39	1,852.89
MV-1 CONC	4277003.27	568977.45	1,849.89
MV-1 W	4277003.05	568977.31	1,850.12
MV-1 L	4277002.93	568977.35	1,850.11
MV-1 U	4277002.86	568977.56	1,850.13
MV-2 CONC	4275787.57	567575.03	1,886.64
MV-2 W	4275787.44	567574.96	1,886.85
MV-2 L	4275787.50	567574.88	1,886.84
MV-2 U	4275787.33	567575.30	1,886.92*
MV-3 CONC	4276956.42	568260.47	1,879.70
MV-3 W	4276956.30	568260.56	1,879.90
MV-3 L	4276956.36	568260.66	1,879.89
MV-3 U	4276956.48	568260.83	1,879.91

*elevation is estimated given that the surveyor's report is in error.

UC-1-P-1S was the first post-test hole drilled after the Faultless test. According to the drilling reports, land subsidence was continuing in the area as the well (artesian) was being drilled. The hole is strongly deviated toward UC-1 and proved unstable, leading to abandonment. The drill pipe was cut off and left in the hole between a drilled depth of 964 and 2,734 ft, and 4.3-inch casing was installed above that point and slotted between the drilled depths of 34 and 922 ft below land surface. UC-1-P-2SR was the second post-test hole. The primary hole (UC-1-P-2) was drilled to 2,700 ft, from which point it had several sidetracks. The cased sidetrack is 2SR and was drilled to 3,600 ft. During drilling, there was a complete loss of circulation below 1,978 ft, and thousands of gallons of drilling mud were lost to the formations penetrated by the borehole. UC-1-P-2SR has a complex casing arrangement, but is gun-perforated from 1,148 to 2,790 ft, though many of the perforations are considered plugged (Dinwiddie and West, 1970). The casing is crimped (or otherwise blocked) at 2,615 ft, making the lower part of the well inaccessible.

DATA SUMMARY

Hydraulic Head Data

Water levels were measured in the previously drilled wells near the UC-1 site. HTH-2 was used as the construction water source during the MV well drilling project; as a result of the pump configuration, water levels could not be measured. Water levels in UC-1-P-2SR are still recovering from the nuclear test detonation. A summary of the water level measurements are listed in Table 2. Historic measurements for the older site wells are presented in Appendix B.

Table 2. Summary of water level measurements.

Well	Hydrostratigraphic unit	Date	Water level, depth below land surface (ft)	Elevation of hydraulic head (ft)
HTH-1	alluvium/volcanic	3/15/2006	535.5	5,476.2
HTH-2	alluvium	11/25/1997	554.5	5,471.3
UC-1-P-1S	alluvium	3/15/2006	273.3	5,757.9
UC-1-P-2SR	volcanic	7/16/2005	555.18	5,523.9
MV-1	densely welded tuff	7/27/2005	508.54	5,561.4
MV-1 Upper Piezometer	alluvium	3/15/2006	316.4	5,753.6
MV-1 Lower Piezometer	tuffaceous sediments	6/13/2005	131.4	5,938.5
MV-2	densely welded tuff	3/14/2006	327.5	5,863.0
MV-2 Upper Piezometer	alluvium	3/15/2006	356.7	5,834.0*
MV-2 Lower Piezometer	densely welded tuff	3/15/2006	432.7	5,757.7
MV-3	densely welded tuff	3/14/2006	630.28	5,537.4
MV-3 Upper Piezometer	alluvium	3/15/2006	370.25	5,797.4
MV-3 Lower Piezometer	tuffaceous sediments	3/15/2006	214.05	5,953.6

*using the estimated correct elevation.

Transducers were installed in HTH-1 and UC-1-P-1S, and water levels were recorded on dataloggers. Due to equipment failures, the data records are incomplete (Figure 3). Water levels in HTH-1 show a decrease in head as a function of time; this is thought to be caused by construction water pumping from HTH-2 and not from drilling activities at the MV wells. Head measurements in UC-1-P-1S did not show a trend that could be correlated to drilling activities.

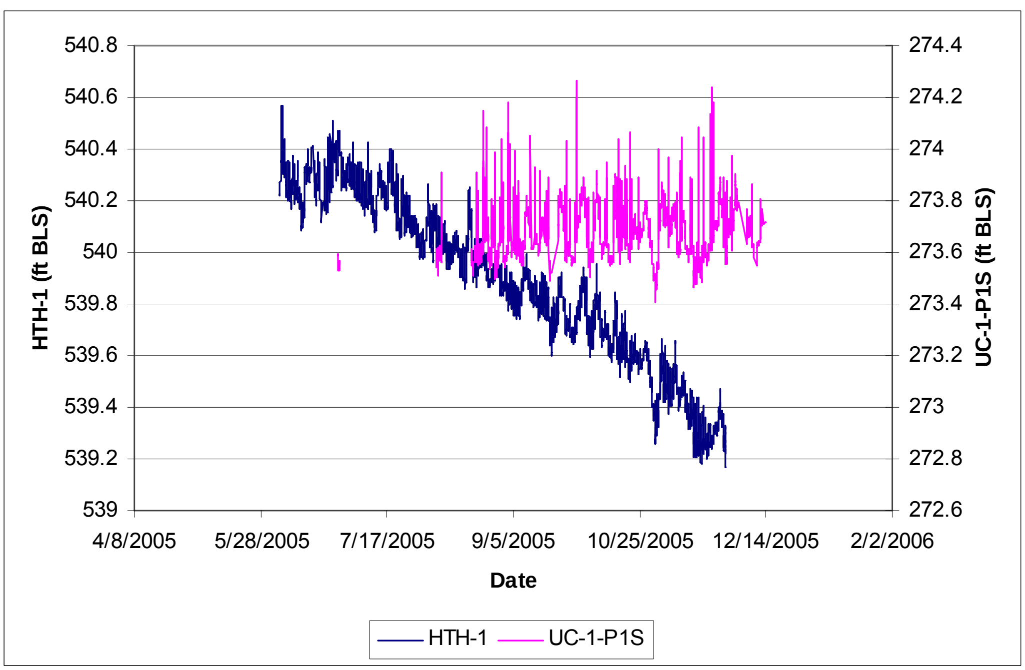

Figure 3. CNTA head measurements versus time for wells HTH-1 and UC-1-P-1S.

Once well development at each MV well was completed, pressure transducers were installed in the lower piezometer and main well. Campbell Scientific, Inc., CR-10X dataloggers were used to measure Geokon vibrating wire transducers; 10-PSI transducers were installed in the piezometers and 500-PSI transducers were used in the main wells during aquifer testing. Flowmeters were installed to measure the discharge during the well purging and during the aquifer tests. The datalogger was equipped with an LCD display enabling real-time measurements of water levels and discharge. Periodic fluid level measurements were made with electric tapes in the upper piezometers, and water level measurements were performed in all wells in March 2006, except for the MV-1 low piezometer and main well, which were still in recovery mode from the aquifer test.

Head measurements are plotted versus time over the period of the project for the MV wells. Bromide development and aquifer testing activities can be clearly seen in these plots (Figures 4, 5 and 6, for wells MV-1, MV-2, and MV-3, respectively).

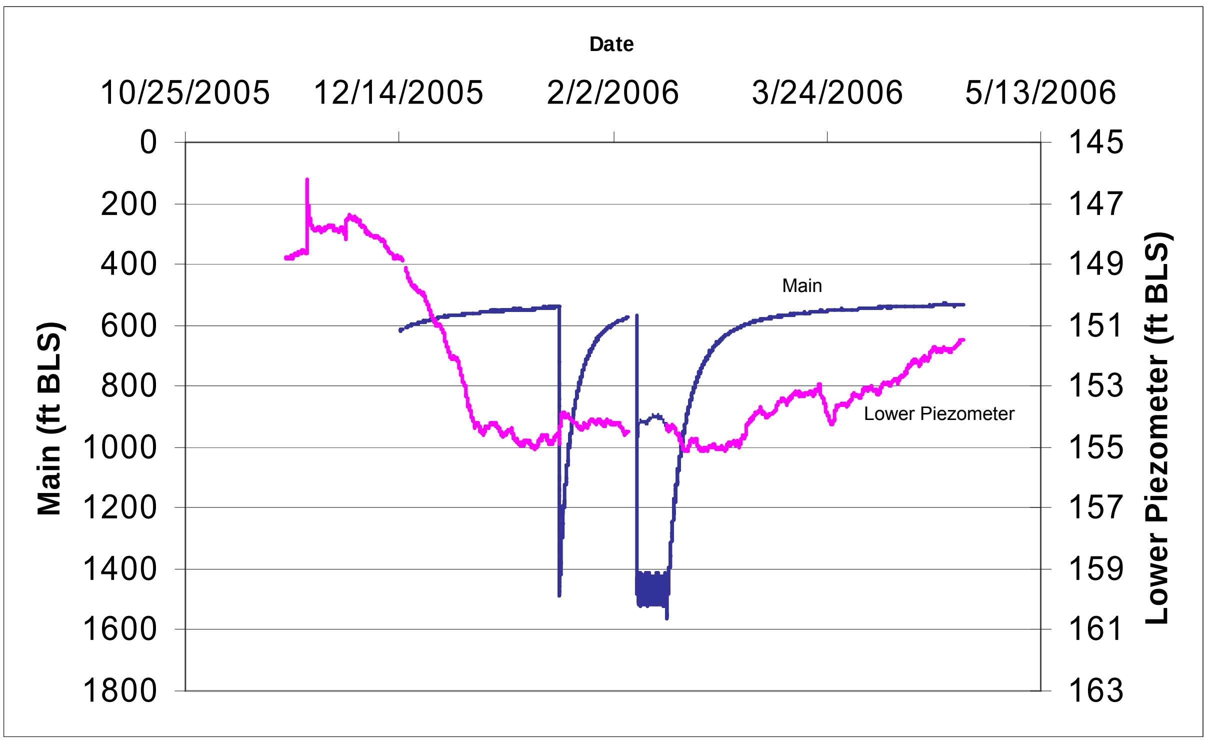

Figure 4. CNTA well MV-1 and lower piezometer head versus time.

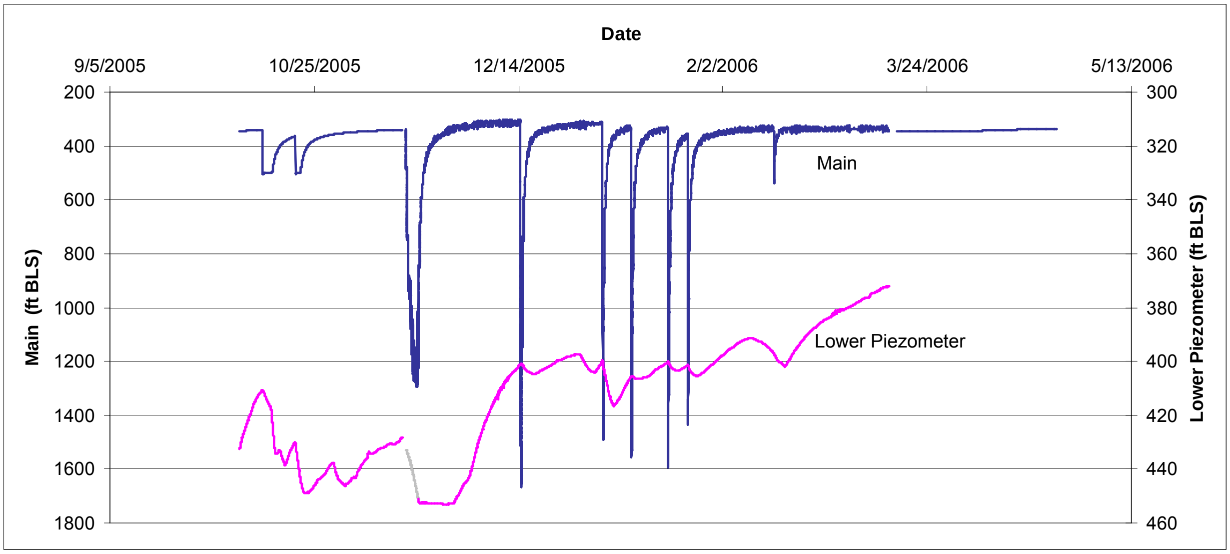

Figure 5. CNTA well MV-2 and lower piezometer head versus time.

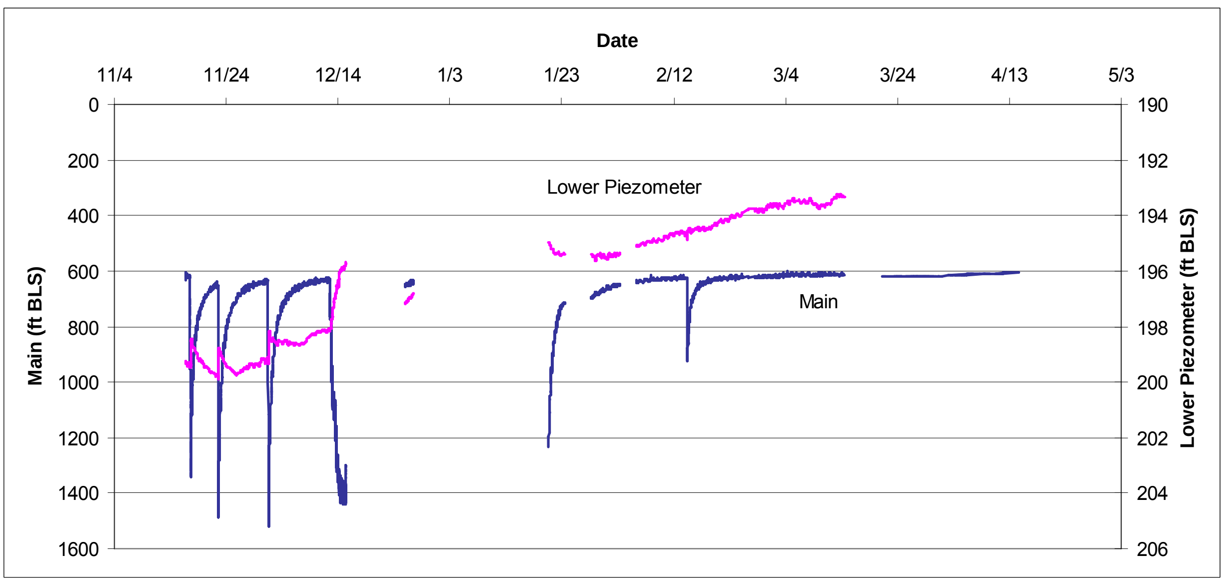

Figure 6. CNTA well MV-3 and lower piezometer head versus time.

Hydraulic Conductivity and Storage

Estimates of hydraulic conductivity are available from four wells near Faultless, including the three MV wells. Each of the MV wells tested a densely welded tuff intercepted by the main well screen. Nine packer tests were performed in HTH-1, testing intervals in the alluvium and volcanic sections. A pumping test was also performed in the alluvium at HTH-1, using HTH-2 as an observation well. The hydraulic conductivity of the densely welded tuff intervals in the MV wells is substantially lower than that reported for the single volcanic interval in well HTH-1 (Table 3). Additional hydraulic data for wells farther away from Faultless in Hot Creek Valley are summarized in Appendix 1 of Pohlmann *et al*. (1999).

Table 3. Summary of hydraulic data from straddle packer tests and pumping tests at the Faultless test site. Details of the tests in the MV wells are provided in later sections. HTH-1 data are from Dinwiddie and Schroder (1971).

Well	Test	Year	Interval top, depth (ft)	Interval bottom, depth (ft)	K (ft/d)	S	Lithology
MV-1	Pump	2006	3,752	3,912	2.8e-5		Densely welded tuff
MV-2	Pump	2005	3,039	3,202	2.5e-4	4.6e-5	Densely welded tuff
MV-3	Pump	2006	3,300	3,420	2.2e-4	1.5e-4	Densely welded tuff
HTH-1	Packer	1967	700	850	1.2		Alluvium
	Packer	1967	950	1,150	1.7e-1	6.1e-7	Alluvium
	Packer	1967	1,400	1,500	6.6e-2	6.1e-6	Alluvium
	Packer	1967	1,660	1,720	1.3e-2	6.1e-7	Alluvium
	Packer	1967	1,850	1,980	6.9e-3	6.1e-7	Alluvium
	Packer	1967	2,200	2,300	2.0e-4	6.1e-3	Alluvium
	Packer	1967	2,400	2,460	5.9e-2	6.1e-7	Welded tuff
	Packer	1967	2,640	2,710	1.8e-1	6.1e-7	Tuffaceous sediments
	Packer	1967	2,950	3,010	8.9e-1	6.1e-4	Tuffaceous sediments
	Pump	1967	553	1,150	1.8-3.2	3e-3	alluvium

Lithologic Data

The MV wells penetrated the expected subsurface sequence of a thick section of alluvium underlain by Tertiary-age volcanics comprised principally of tuffs and tuffaceous sediments with minor occurrences of densely welded tuff. Detailed lithologic descriptions are in the CNTA well installation report (DOE, 2006). A summary of the geology encountered in each MV well, based upon geophysical log interpretation, is presented in Table 4.

Table 4. Summary geology of the MV wells, based on geophysical logs.

Well	Top (Depth in ft)	Base (Depth in ft)	Lithology
MV-1	0	-2,240	Alluvium
	-2,240	-3,120	Tuffaceous sediments
	-3,120	-3,163	Nonwelded to partly welded tuff
	-3,163	-3,775	Partly welded tuff
	-3,775	-3,812	Moderately welded tuff
	-3,812	-3,875	Densely welded tuff
	-3,875	-4,100	Nonwelded tuff
MV-2	0	-2,370	Alluvium
	-2,370	-2,822	Tuffaceous sediments
	-2,822	-3,006	Nonwelded tuff
	-3,006	-3,044	Moderately welded tuff
	-3,044	-3,199	Densely welded tuff
	-3,199	-3,254	Nonwelded to partly welded tuff
	-3,254	-3,271	Densely welded tuff
	-3,271	-3,321	Nonwelded to partly welded tuff
	-3,321	-3,343	Moderately welded tuff
	-3,343	-3,425	Nonwelded to moderately welded tuff
	-3,425	-3,595	Moderately to densely welded tuff
	-3,595	-3,666	Nonwelded tuff

Table 4. Summary geology of the MV wells, based on geophysical logs (continued).

Well	Top (Depth in ft)	Base (Depth in ft)	Lithology
MV-3	0	-2,520	Alluvium
	-2,520	-3,212	Tuffaceous sediments
	-3,212	-3,360	Nonwelded tuff
	-3,360	-3,392	Densely welded tuff
	-3,392	-3,652	Nonwelded tuff
	-3,652	-3,740	Moderately welded tuff
	-3,740	-3,800	Densely welded tuff
	-3,800	-3,827	Moderately welded tuff
	-3,827	-3,942	Partly welded tuff
	-3,942	-4,046	Moderately welded tuff
	-4,046	-4,148	Densely welded tuff

Geochemical Data

Water samples were collected after the drilling fluids were developed from the MV wells, as described later in this report. Analytical results are listed in Table 5; representative results from other wells in the area are also listed for comparison. Note that fluoride must be included in the major ion analyses to achieve adequate charge balance. Groundwater from the MV wells is classified as sodium-potassium-bicarbonate type water, similar to the water in HTH-1 and UC-1-P-2SR (Figure 7), though the MV wells have higher dissolved ion concentrations. As the pH effects from well construction activities equilibrate to the *in situ* pH of the volcanic aquifer, the carbonate speciation should move toward bicarbonate speciation. Groundwater from HTH-2 and UC-1-P-1S has a higher proportion of calcium indicating that groundwater in the alluvium is of a calcium bicarbonate type.

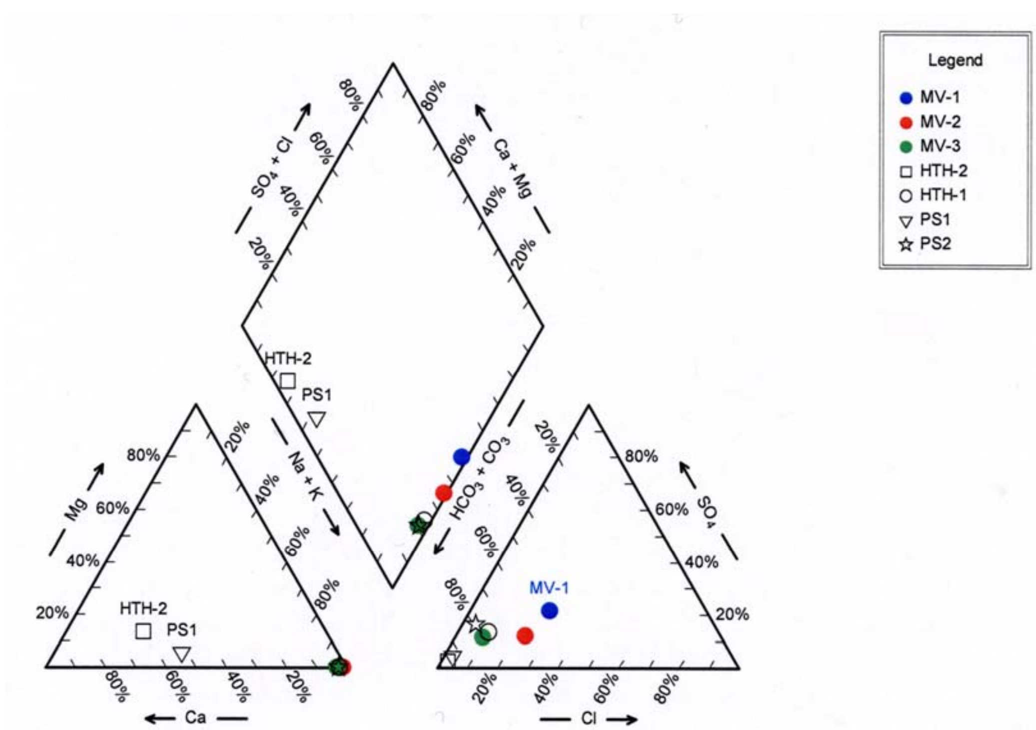

Figure 7. CNTA water chemistry piper diagram of MV wells and nearby wells.

Table 5a. Water chemistry data from wells near the Faultless test.

Well	Depth (ft)	Date	T (°C)	pH*	EC* (µS/cm)	SiO_2	Ca	Mg	Na	K	Cl	SO_4	HCO_3*	CO_3	NO_3	F	$\delta^{18}O$ (‰)	δD (‰)
HTH-1	2,674	07/29/1992	26.5	8.15/8.24	508/561	66.2	2.93	0.07	129	1.55	19.1	34.5	205/249		<.04	10.4	-15.5	-118
HTH-2	750	07/29/1992	19.5	7.84/8.10	303/300	29.2	40.8	5.52	19.0	1.47	2.6	4.08	177/196		2.22	0.08	-14.2	-107
UC-1-P-1S	750	05/23/1993		8.16	217	24.5	23.1	1.70	23.0	1.36	2.9	0.64	134		1.37		-14.1	-105
UC-1-P-2SR	1,886	10/23/1997	17.3	9.93/9.70	244/281	17.5	1.57	<0.1	60.7	1.09	4.5	22.1	63.2	34.9	0.04		-15.1	-116
MV-1	3,830	02/14/2006		9.59	790	pend	3.21	<0.1	179	3.22	56.7	63.5	76.1	57.6	<.01	27.0	-15.1	-116
MV-2	3,120	03/16/2006		9.79	898	pend	2.3	<0.1	182	26.4	66.8	47.7	90.3	115.	<.01	14.8	-15.3	-117
MV-3	4,127	03/16/2006		8.35	648	pend	4.52	0.16	155	1.93	18.8	31.8	277	0.8	<.01	18.1	-15.5	-118

*First number is a measurement in the field at the time of sample collection. Second number is a laboratory measurement. If there is only one number, it is a laboratory measurement (concentrations in µg/L, unless noted otherwise)
µS/cm = microseimen per centimeter
‰ = per mil

Table 5b. Radiochemical data from wells near the Faultless test.

Well	Depth (ft)	Date	^3H (pCi/L)
HTH-1	2,674	10/27/1997	<5
HTH-2	750	10/27/1997	<5
UC-1-P-1S	750	10/2719/97	<1<5
UC-1-P-2SR	1,886	10/2319/97	4,020 ± 1<50
MV-1	3,830	02/14/2006	<3
MV-2	3,120	03/16/2006	<3
MV-3	4,127	03/16/2006	<3

pCi/L = picocuries per liter

Oxygen and hydrogen stable isotopes were analyzed for the MV well samples. The data were plotted along with other local wells for comparison (Figure 8). The stable isotopic composition of groundwater from the MV wells is most similar to samples from UC-1-P-2SR; well MV-1 and UC-1-P-2SR have identical results. Values from UC-1-P-1S and HTH-2 are more enriched in the heavier isotopes than the MV groundwater, suggesting a warmer temperature of condensation for precipitation recharging the aquifer in the alluvium. Together, the groundwater near Faultless defines a local meteoric water line described by the equation $\delta D = 9.4\ \delta^{18}O + 26.9$.

Water samples from the MV wells were sampled for three radionuclides: tritium, carbon-14 and iodine-129. The results from the tritium analyses can be seen in Table 5. Tritium activities were all below detection limits (less than 3 pCi/L). Samples were also collected for I-129 and C-14 analysis. Problems with the analytical laboratory, IsoTrace, have significantly delayed the analyses so that they cannot be reported here. The results for these isotopes will be included in the annual monitoring report for fiscal year 2006.

Additional analytical results for the older CNTA wells are presented in Appendix C.

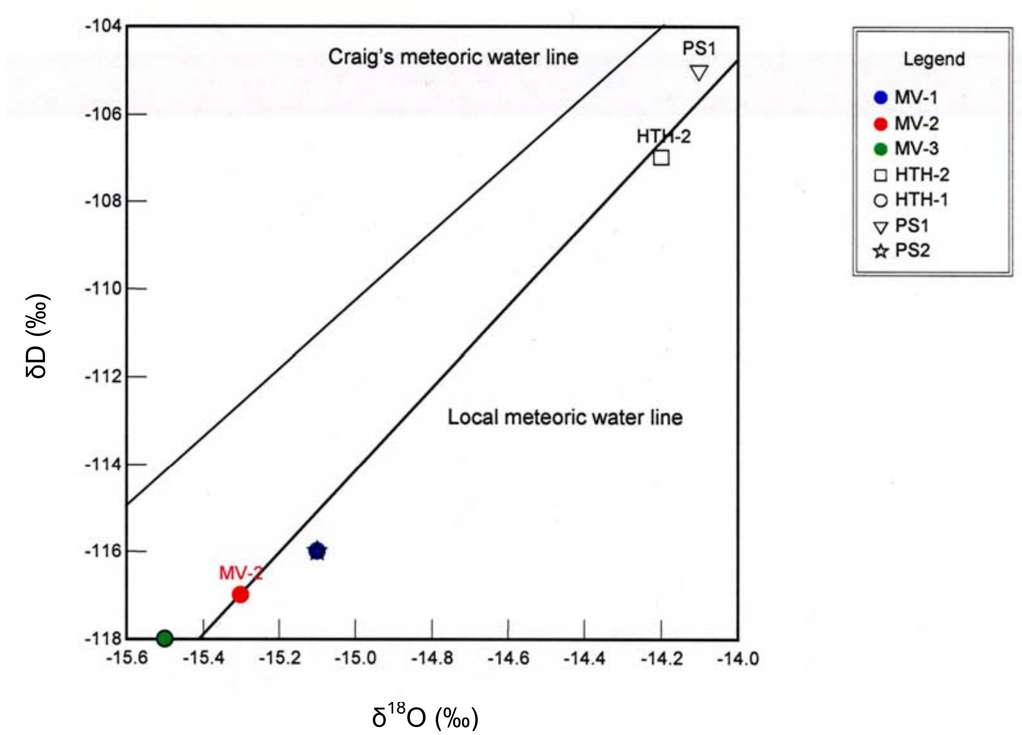

Figure 8. CNTA stable isotope plot of oxygen versus hydrogen. Craig's meteoric water line ($\delta D = 8\ \delta^{18}O + 10$) and the local meteoric water line ($\delta D = 9.4\ \delta^{18}O + 26.9$) are shown for reference. (Note: PSI = UC-1-P-1S also PS2 = UC-1-P-2SR.)

CNTA WELL MV-1

Drilling History

The borehole was drilled with the flooded reverse circulation drilling method, starting April 9, 2005, and was constructed by May 22, 2005. Details regarding the drilling and construction of well MV-1 can be found in the CNTA well installation report (DOE, 2006). Below is a summary to orient the reader and highlight matters of possible significance to the well and piezometers. Note that depths for the densely welded tuffs are per the geophysical logs and thus may differ slightly from depth reported in the lithologic logs of the CNTA well installation report (DOE, 2006).

MV-1 was the first well constructed at CNTA in 2005. Drilling progressed without incident or difficulty. The basic well construction was as designed, with the main well string as the bottom completion, and two piezometers completed higher in the borehole (Figure 9). The upper piezometer was placed within the alluvium with the intention to monitor water levels in the shallower part of the saturated section. The screen for the main well was placed to intersect the densely welded tuff interval encountered between the depths of 3,812 and 3,875 ft (the screen slots span the depths of 3,750 to 3,910 ft). This densely welded tuff provided the only strong responses to the geophysical logs (resistivity, density, gamma, spontaneous potential, and sonic velocity) such that it was the best screening target. Optimum location for the lower piezometer was less clear-cut. The location, from 3,000 to 3,060 ft, was chosen because it avoided a clayey interval of tuffaceous sediments (spanning 3,002 to 3,062 ft), and it is within an interval containing two zones that appear to be better welded. The placement also satisfied the need to vertically distribute the head measurements.

On June 7, 2005, the total depth (TD) of the main well was 3,942.7 ft below land surface (measured with DRI wireline), some 33 ft lower than the bottom of the well screen. On June 23, 2005, the DRI wireline was used to measure the total depth of each piezometer. The lower piezometer TD had a soft set 3,038 to 3,042 ft, indicating fine-grained sediment is in the piezometer. The screened interval is from 3,002 to 3,062 ft; therefore, the lower 30 percent or so of the piezometer filled with sediment. The upper piezometer TD was 926 ft; the screened interval was from 879 to 939 ft. Therefore, about 20 percent of the piezometer screen is filled with sediment.

Development History

Initial development of the main well was performed by air-lift development with the drill rig. HQ core rods were placed in the sump below the well screen, a combination of BQ and AQ rods were used as air eductor lines and water was discharged to land surface from the HQ pipe. Air-lift operations were performed intermittently between the final cementing operations from May 23, 2005 until May 25, 2005, when operations were stopped and the rig was moved to drill well MV-2.

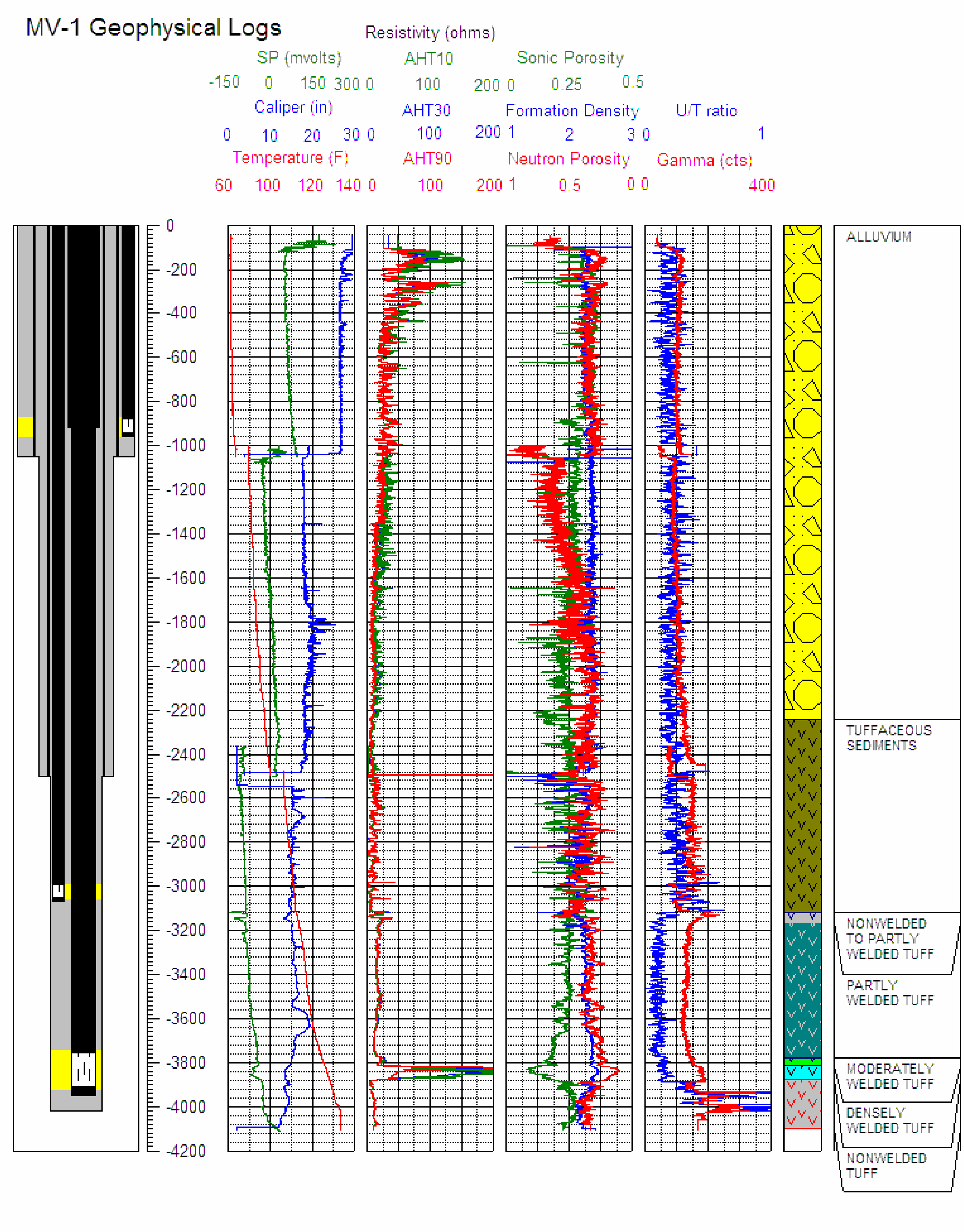

Figure 9. MV-1 well and piezometer completions, geophysical logs, and geology interpreted from the logs.

Precise discharge measurements were not made; it is assumed based on wellbore volume estimates that approximately 3,300 gallons were displaced from the wellbore and an additional 1,000 gallons were developed from the formation. Bromide analyses at the end of air-lifting averaged about 5 mg/L. Piezometer development was performed via bailing and air-lift techniques. Merchant one-half-inch black-iron pipe was used to deliver air into the piezometer tubing; tensile strength concerns limited the black-iron pipe to 1,000 ft maximum depth. Bailing operations were also performed in both piezometers. Approximately 5,950 gallons were produced at an average of 15.7 GPM from the upper piezometer. Only 260 gallons were produced from the lower piezometer at a rate of about 0.1 GPM.

A second phase of air-lift development was performed in the main well, August 19 to 20, 2005. Relatively detailed discharge measurements were made during this development; as the eductor was lowered, discharge measurements were recorded as a function of time. This technique was basically a constant head variable discharge aquifer test. These data were collected by Stoller-Navarro Joint Venture (SNJV) and are included in the data disc included in this report. An interesting sinusoidal response was observed in these data at various eductor depths; this response is not completely understood, but is thought to be in response to the pressure shockwave in the aquifer from the air-lifting (Figure 10).

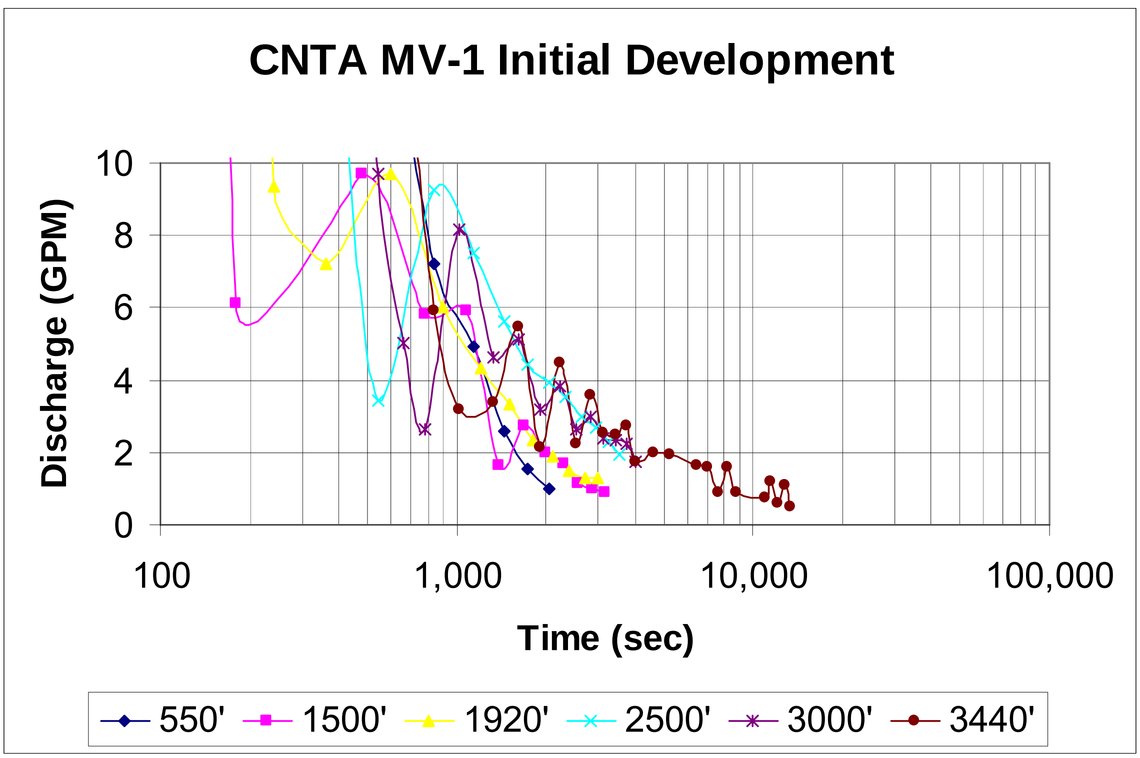

Figure 10. CNTA well MV-1 initial development, discharge versus time at various airlift eductor depths.

Bromide development was performed by SNJV from October 1, 2005, until December 1, 2005, on a semi-weekly basis. Due to the low productivity of the well, it was only possible to pump the well for about 2 hours before the pump controller shuts the pump off. The pump column contained about 168 gallons of water, based on the pump characteristics derived from the pump manufacture's pump curve; it took approximately 17 minutes to displace this stagnant water. Discharge measurements were recorded and bromide samples were collected during each pumping episode. An estimate of the amount of water lost to the formation during flooded reverse circulation drilling was performed by SNJV. A lower bound was estimated based on the amount of time the screened interval was exposed to flooded drilling pressure head at a flow rate determined from air-lift development (assuming the aquifer accepted the same flow rate during drilling as the well produced at similar hydraulic head during air-lifting). An upper bound was estimated based on the water truck deliveries to each well. Water volume produced versus bromide is shown in Figure 11.

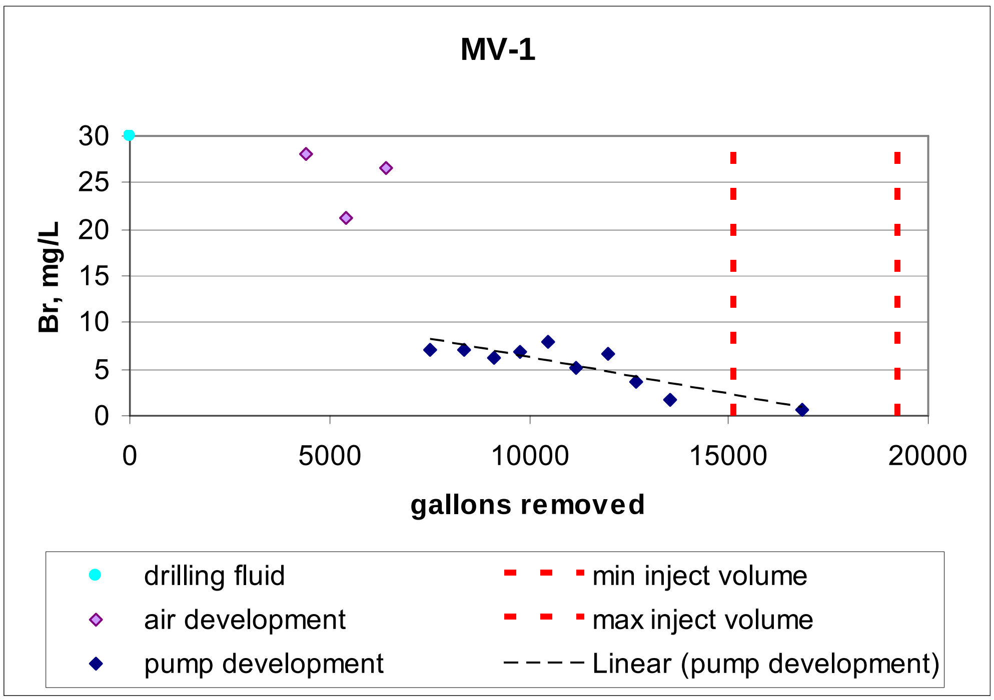

Figure 11. CNTA well MV-1 bromide development, bromide concentration versus water removed.

Geophysical Log Interpretation

As described above, the geophysical logs were interpreted in the field to guide screen placement. The AHT90 resistivity profile was also used for additional analysis to categorize the degree of welding. Resistivity values above 30 Ω-m were assigned a value of 3 and correspond to densely welded tuff (the threshold of 30 Ω-m was used in the CNTA flow model to identify densely welded tuffs from the original site well logs). Resistivity values between 20 and 30 Ω-m were assigned a value of two, corresponding to moderate welding. A value of one was assigned for resistivity values between 10 and 20 Ω-m, and a value of zero for resistivities below 10 Ω-m. The resulting designations are shown in Figure 12, next to the AHT90 data, with tabulated data on the enclosed data disc.

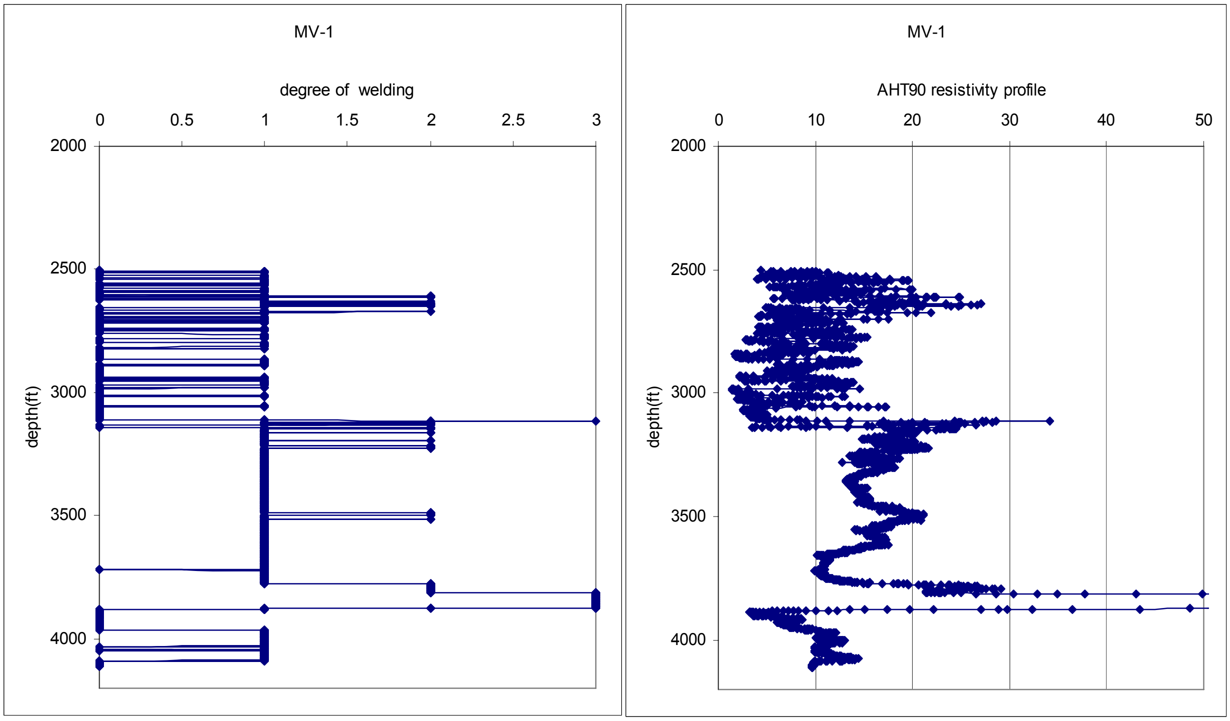

Figure 12. MV-1 resistivity profile in the volcanic section (right), with associated interpretation of degree of welding (left).

Aquifer Test Analysis

Introduction

Water levels were measured with an electric water level indicator (i.e., etape) and pressure transducers connected to an automatically recording datalogger. The transducers are located at about 1,713.3 ft bgs in the main well and at about 152.3 ft bgs in the lower piezometer. The upper piezometer was not monitored during the aquifer testing. Other data recorded automatically during the test include the amount of water discharged at land surface, barometric air pressure, and water temperature at the lower pressure transducer.

During well development, the well produced about 4.2 gpm with over 940 ft of water level drawdown. Water level recovery in the main well typically takes over 60 days to reequilibrate to the static water level. Water level monitoring with an etape was started on February 7, 2005, following the construction completion and well development. These data were used to determine when the water levels had stabilized following well construction.

MV-1 is completed in a fractured, densely welded tuff layer. This lithology has been identified at CNTA as being the most permeable unit in the volcanic section. Permeability within the fractured tuff at the CNTA site is generally low. Well performance and hydraulic testing indicate that the main well is screened in very low permeability material and/or the welded tuff is limited in extent and surrounded by low permeability material.

Water Level and Pumping Data - Main Well

Water level monitoring with a pressure transducer in the lower piezometer and the datalogger started November 17, 2005. The main well was monitored with a pressure transducer and datalogger starting December 14, 2005. The well was pumped to remove drilling water from the formation on January 20, 2006. Well pumping during water level monitoring is illustrated in Figure 13.

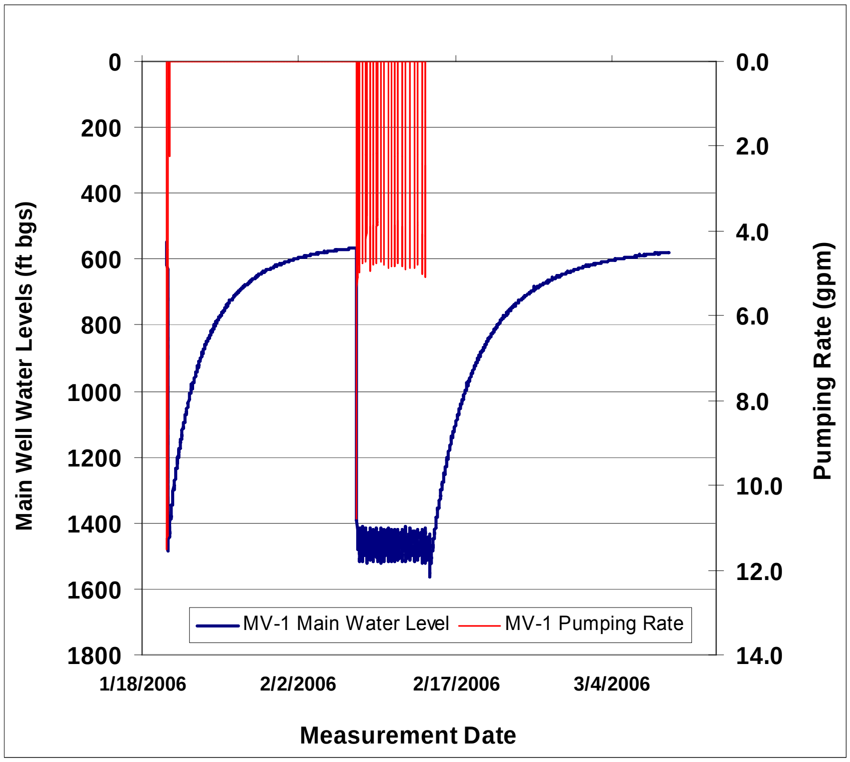

Figure 13. MV-1 water level response to pumping.

The rapid removal and long time for water level recovery contained in the January 20, 2006, pumping event illustrated in Figure 13 is similar to a "slug" test where a volume of water is rapidly displaced in the well and the change in water levels with time are interpreted. Calculation of the amount of water discharged from the well and the volumetric decline in water levels indicates that essentially all of the water discharged during the short-term pumping periods came from casing storage as intended in a slug test. The relatively short duration of the pumping periods (e.g., 95 minutes) in relation to the long period of well recovery (e.g., 25,000 minutes) suggests that slug test methodologies are valid even though the water displacement was not instantaneous.

The January 20, 2006, well pumping is analyzed as a slug test. Aquifer test analysis was performed using U.S. Geological Survey software developed by Halford and Kuniansky (2002). The interpretation methods of Cooper *et al*. (1967), as modified by Greene and Shapiro (1995) for confined aquifers, are used for the slug test analysis. The aquifer is believed to be confined based on the materials encountered during drilling. The short-duration pumping period is analyzed in Figure 14. The calculated transmissivity is

5.00E-2 ft^2/d. The aquifer thickness is assumed to coincide with the Moores Station Butte tuff positioned between 3,140 and 4,088 ft bgs. The estimated hydraulic conductivity is 5.30E-5 ft/d assuming a 948-ft aquifer thickness. Assuming the water production is from only the 160-ft screened interval, the estimated hydraulic conductivity is 3.12E-4 ft/d.

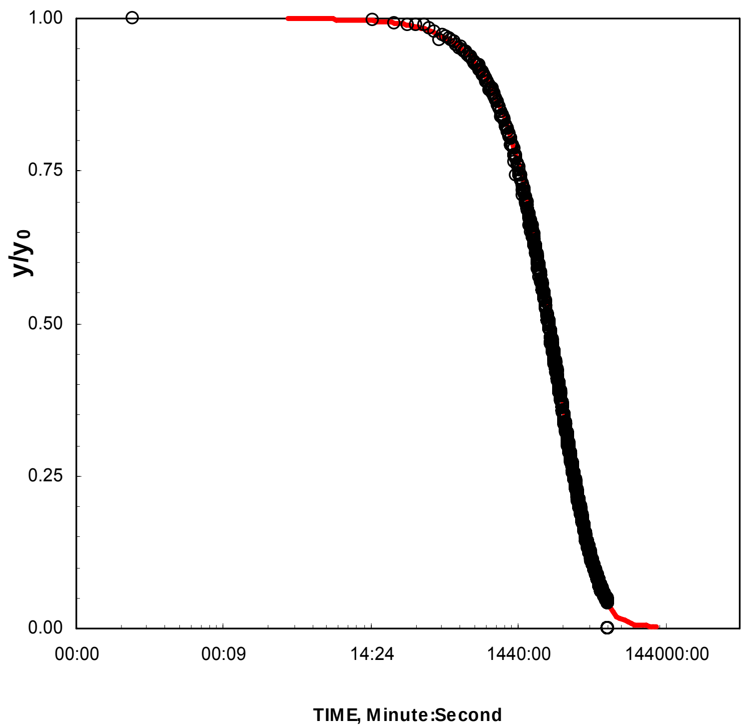

Figure 14. Analysis of drawdown data from the MV-1 slug test.

The water level data from the aquifer test conducted between February 7 and March 9, 2006, are also analyzed. The well was pumped at about 5 gpm until the pumping lift of 1,518 ft approached the amperage limit of the pump motor. The well was then shut off and was allowed to recover to about 1,421 ft bgs before pumping was resumed. This pumping schedule was designed to remove water relatively rapidly from the aquifer. Pumping the well at a steady rate during the long-term aquifer test would require a constant pumping rate of less than 1 gpm. Achieving such a low constant pumping rate was impractical with the existing equipment. The well was cycled on and off a total of 22 times between February 7 and February 14, 2006, and pumped 7,151 gallons.

Two analytical approaches were used to estimate aquifer transmissivity from the long-term aquifer test. The first approach is less rigorous and assumes that the well was pumped constantly at the average pumping rate (i.e., 0.7 gpm) over the 7-day pumping period. The recovery water levels are analyzed using the Cooper-Jacob technique. The water level recovery data are plotted in Figure 15 and demonstrate that the late-time data are linear, suggesting the relatively short-term hiatuses in pumping are not significant with regard to the long duration of water level recovery. The aquifer transmissivity and hydraulic conductivity calculated by this method are 2.18E-2 ft^2/d and 2.30E-5 ft/d, respectively. These values are similar to those calculated by the slug test interpretation.

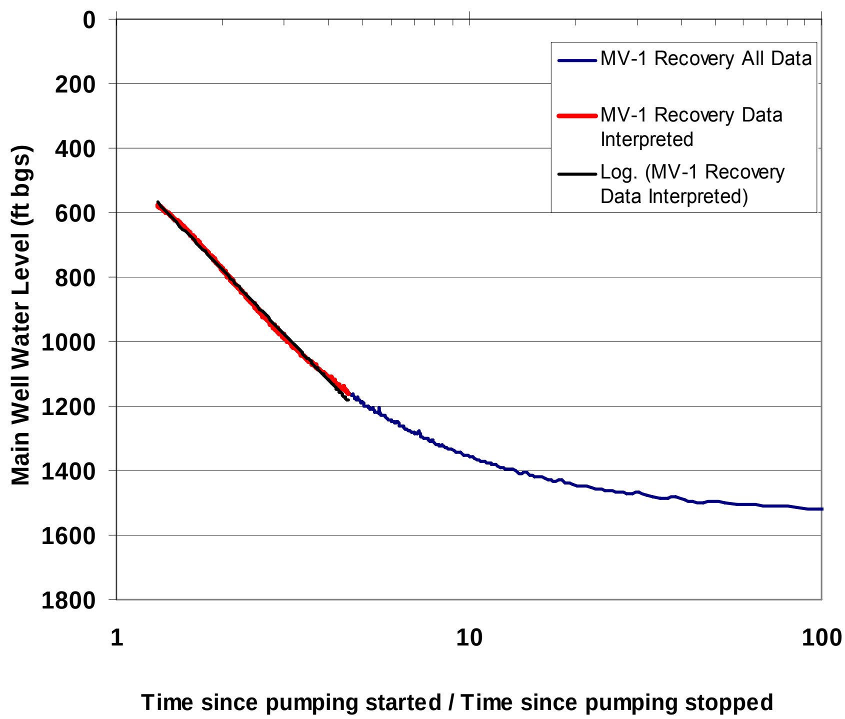

Figure 15. Analysis of the MV-1 pumping test using the Cooper-Jacob technique.

The aquifer test recovery data are also analyzed using the Birsoy-Summer method that accounts for the intermittent pumping rates and varying pumping durations (Kruseman and de Ridder, 1994). This technique is more appropriate than the Cooper-Jacob technique, but makes additional theoretical assumptions concerning water level recovery between each pumping period. The Birsoy-Summer technique is illustrated in Figure 16 and resulted in a calculated transmissivity of 6.44E-3 ft^2/d and a hydraulic conductivity of 6.79E-6 ft/d. These values are slightly lower, but similar to the values calculated above.

<u>Water Level Data – Lower Piezometer</u>

Water levels were monitored in the lower piezometer at the same time frequency as the main well. Water levels in the main well and the lower piezometer are presented in Figure 17. Water levels in the lower piezometer were dropping and then stabilized several days before the start of the short-duration pumping event. This lowering of water level was likely caused by the lower piezometer reaching hydraulic and thermal equilibrium following well drilling and development. At the start of the January 20, 2006, pumping, water levels increased abruptly in the lower piezometer.

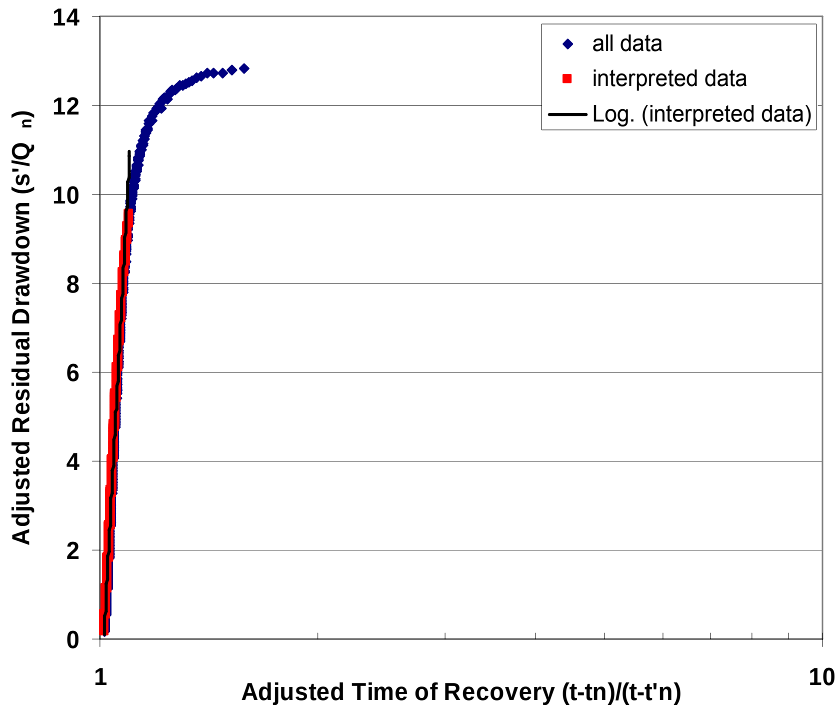

Figure 16. Analysis of MV-1 pumping test using the Birsoy-Summer method.

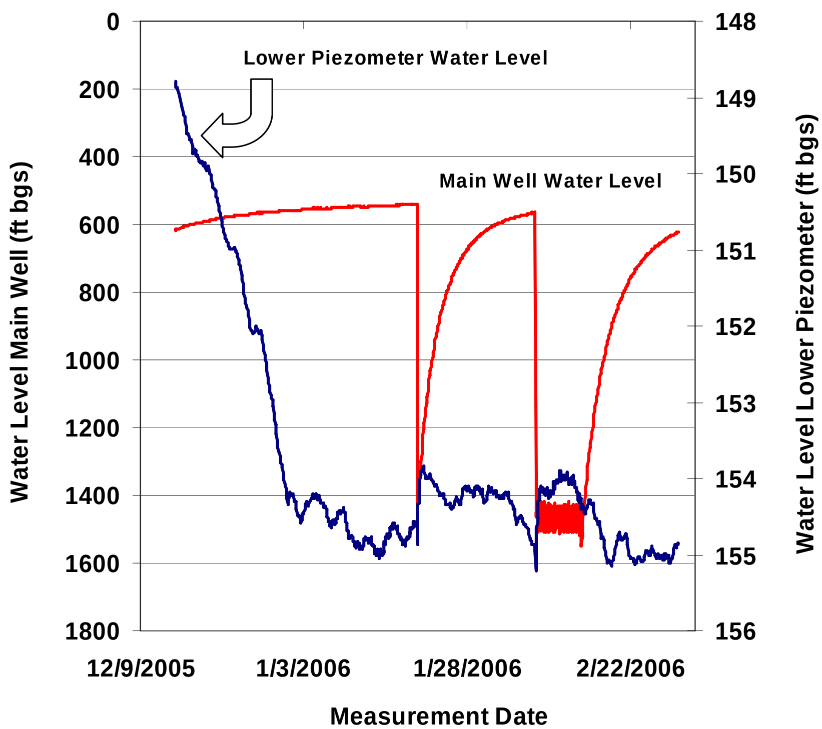

Figure 17. Water level response in the lower piezometer during MV-1 pumping.

The rise of water levels in piezometers constructed in the same borehole as pumping wells has been observed in other deep wells at CNTA and at other sites. The water level rise is caused primarily by the thermal conditions in the well during pumping. The well was in quasi-thermal equilibrium with the surrounding material before pumping with cooler water at the top of the water column and warmer water at the bottom. Pumping the main well replaced the cooler water in the fluid column with warmer water. This heat was then conducted to the lower piezometer through the direct physical contact between the steel casings of the main well and the lower piezometer.

As the water in the lower piezometer warmed over time, it expanded and increased the water level in the lower piezometer. This is evidenced by the increase in water temperature within the pressure transducer located near the top of the fluid column of the lower piezometer as illustrated in Figure 18. The figure shows that the water at the top of the fluid column is slowly decreasing in temperature and that an abrupt rise is fluid temperature results in a corresponding water level rise. The data for the lower piezometer are not analyzed for hydraulic properties. Examination of data from the lower piezometer indicates the water level response is not anomalous.

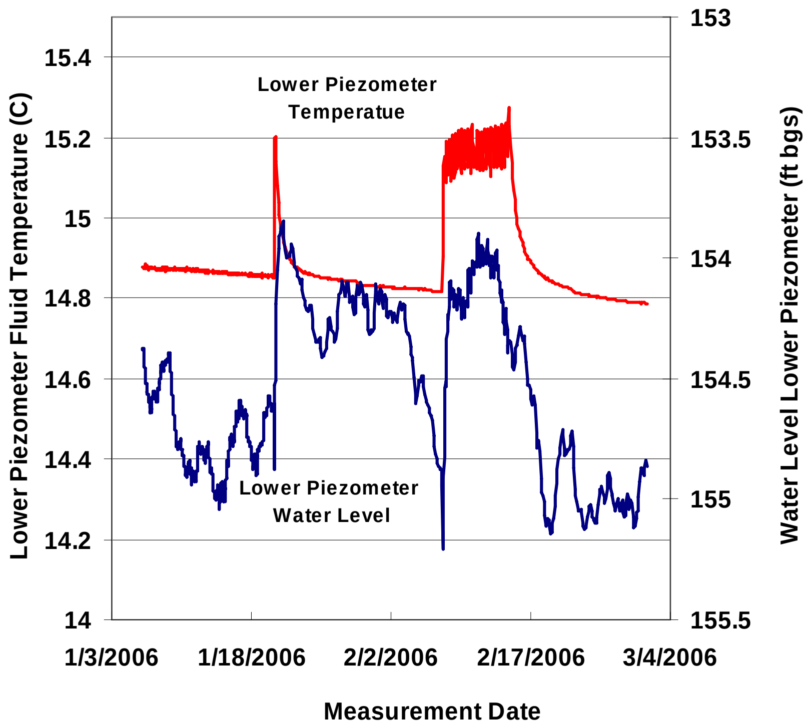

Figure 18. Temperature and water level record for the MV-1 lower piezometer.

Sampling Protocol and Results

Due to the low yield of the well, no commercially available pump could be found that would pump less than 1 GPM with a pump lift of 3,600 ft. Many well purge procedures have been developed for low production wells, commonly referred to as “low purge” or “low discharge" purge techniques; however, no standard procedures have been developed for wells with this much borehole storage.

A 4-inch submersible pump was installed, with a pump intake 3,719 ft bgs (31 ft above the screen). This pump is capable of lifting water from about 1,700 ft; the pump curve for the Grundfos 10S50-58DS is included in Appendix D. The pump is capable of discharging about 800 gallons from the well before the pump controller turns the pump off. On January 20, 2006, the pump ran for 104 minutes and 795 gallons were discharged from the well (Figure 19). Full recovery takes several weeks, but approximately 290 gallons had flowed back into the well in 24 hours (Figure 20). Once the 153 gallons are displaced from the pump column, the next water from the well should be predominately formation water, presuming recharging water from the well screens is displacing the wellbore water upward. Therefore, it is proposed that several screen volumes be displaced, rather than a well volume. This technique will be tested in a future sampling trip; however, these samples were collected at the end of the long-term aquifer test.

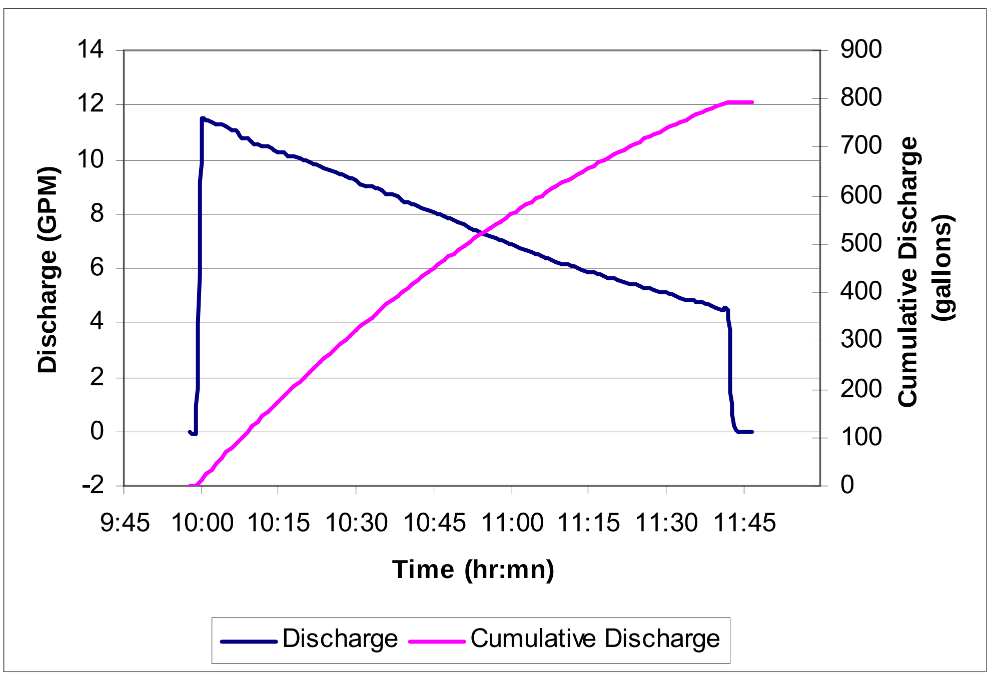

Figure 19. CNTA Well MV-1 discharge versus time from a pumping event on January 20, 2006.

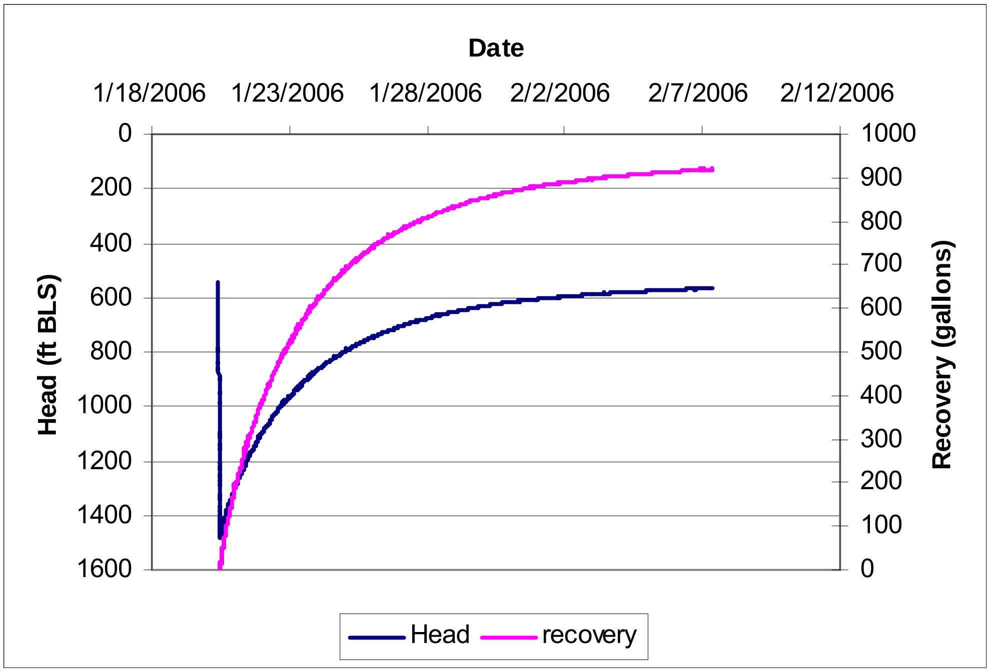

Figure 20. CNTA Well MV-1 water level and recovery related to the January 20, 2006, pumping event.

As previously discussed, the aquifer test was performed by cycling the pump on and off based on water level. This cycling was performed 20 times over a 7-day period with a total discharge of 2,489 gallons; one well volume is approximately 3,884 gallons (Table 6).

Table 6. CNTA Well MV-1 wellbore volume estimate.

water table (ft)	508
screen bottom depth (ft)	3,910
casing inside dia. (in)	5
volume (gal)	3,475
gravel top	3,704
gravel bottom	3,969
casing outside dia. (in)	5.5
nominal borehole dia. (in)	12.5
volume 30% porosity (gal)	409
total volume (gal)	3,884

The well was allowed to recover for about 4 hours prior to sample collection. Results of chemical analyses are listed in Table 5. Water from the well has a moderate to strong H_2S smell, is slightly reddish, and it is difficult for the pH and EC meter to equilibrate. The chemical and stable isotope compositions are similar to water samples from other wells in the area completed in volcanic units. No elevated radioactivity was detected.

CNTA WELL MV-2

Drilling History

The MV-2 borehole was drilled with the flooded reverse circulation drilling method, starting May 27, 2005, and was constructed by July 6, 2005. Details regarding the drilling and construction of well MV-2 can be found in the CNTA well installation report (DOE, 2006). Below is a summary to orient the reader and highlight matters of possible significance to the well and piezometers. Note that depths for the densely welded tuffs are per the geophysical logs and thus may differ slightly from depth reported in the lithologic logs of the CNTA well installation report (DOE, 2006).

MV-2 was the second well constructed at CNTA in 2005. Its location was selected to provide information imporatnt for confirming hydraulic gradients around Faultless, but it was not placed in an expected downgradient direction. As a result, the elevation of the main well screen relative to the underground test was not as important a consideration as it was for MV-1 and MV-3. As a result of that flexibility, and cost and schedule concerns, MV-2 was only drilled to a total depth of 3,660 ft, rather than the target of 4,000 ft. Schedule concerns resulted from more time spent drilling and constructing MV-1 than anticipated, as well as issues at MV-2 itself. Penetration rates were often slow at MV-2, sometimes due to well-indurated formations or to clay adhering to the bit. The bottom hole assembly twisted off at 3,460 ft, but was readily fished out of the hole.

There were several changes to the planned well construction. The relative positions of the main well screen and the lower piezometer are opposite of their construction in the other wells. The main well screen was located to intersect the thick, densely welded tuff interval encountered between the depths of 3,044 and 3,199 ft (the screen slots span the depth of 3,039 and 3,202 ft) (Figure 21). This is in contrast to screening at or below the cavity elevation in the other wells, but consistent with the difference in monitoring objective for MV-2. Given that the degree of welding increases toward the bottom of the borehole, the lower piezometer screen was located between the depths of 3,546 and 3,606 ft, rather than between the main well screen and the upper piezometer, as in the other wells.

The upper piezometer is screened between the depths of 960 and 1,010 ft, consistent with monitoring head in the alluvial section. Either during construction or well development activities, the upper piezometer screen was damaged and subsequently failed during development. Airlifting began to produce stemming material (the emplaced gravel pack and sand), indicating that the screen had punctured. Subsequent tags found the total depth above the top of the screen (see details below). Water level recovery has been very slow in this piezometer as a result of the fill and the degree of connection with the formation is unknown. Note that the alluvial aquifer encountered in the upper piezometers of the other wells (and at HTH-1 and HTH-2) is relatively responsive. The stemming operation for the upper MV-2 piezometer also encountered significant problems due to attempts to gravity feed the gravel through the water column. A bridge developed at 930 ft, with a void space of unknown extent below it.

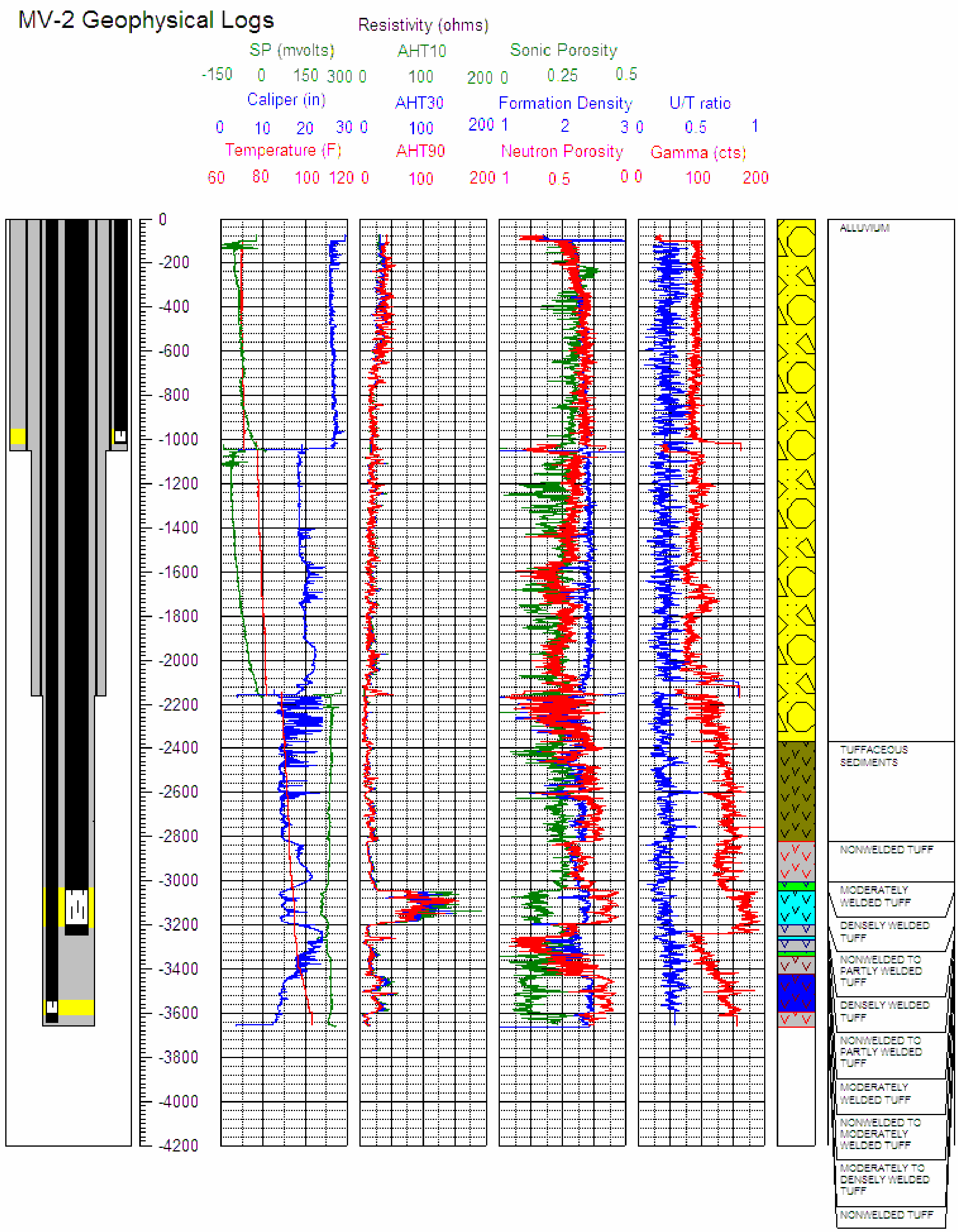

Figure 21. MV-2 well and piezometer completions, geophysical logs, and geology interpreted from the logs.

On August 6, 2005, the total depth (TD) of the main well was 3,235.8 ft bgs (measured with the DRI wireline), some 33.8 ft lower than the bottom of the well screen. The lower piezometer TD was 3,550.8 ft bgs. The screened interval is from 3,546.5 to 3,606.5 ft; therefore, the lower 92 percent or so of the piezometer is filled with sediment. The upper piezometer TD was 850.5 ft; the screened interval was from 960 to 1,010 ft. Therefore, the fill is 110 ft above the top of the screen.

Development History

Initial development of the main well was performed, similar to MV-1, by air-lift development with the drill rig. HQ core rods were placed in the sump below the well screen, and a combination of BQ and AQ rods was used as air eductor lines and water was discharged to land surface from the HQ pipe. Air-lift operations were performed intermittently between the final cementing operations from July 5, 2005, until July 6, 2005, when operations were stopped and the rig was moved to drill well MV-3.

Precise discharge measurements were not made; it is assumed based on wellbore volume estimates that approximately 1,470 gallons were displaced from the wellbore and an additional 2,100 gallons were developed from the formation. Bromide analyses at the end of air-lifting averaged about 16 mg/L.

Piezometer development was performed via bailing and air-lift techniques. Merchant half-inch black-iron pipe was used to deliver air into the piezometer tubing; tensile strength concerns limited the black-iron pipe to 1,000 ft maximum depth. Bailing operations were also performed in both piezometers. The upper piezometer screen failed; the failure occurred during airlift development when the eductor was lowered into the sump below the well screen; the flow rate went from 10 GPM to less then 0.1 GPM, when the screen failure occurred. In time the piezometer should equilibrate and can be used as a water level measurement point, but would not be a reliable geochemical monitoring well. Only 745 gallons were produced from the lower piezometer at a rate of about 0.1 GPM.

A second phase of air-lift development was performed in the main well, August 17 and 18, 2005. Few measurements were made while the eductor was lowered into the well; however, many measurements were performed with the eductor at 2,740 ft. These data were collected by SNJV and are included in the data disk.

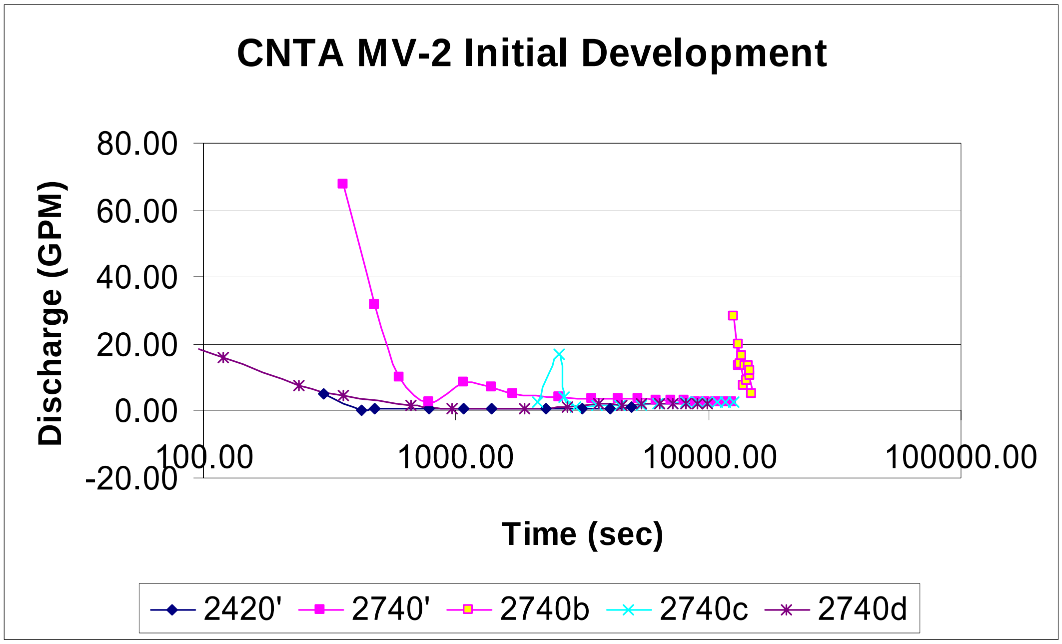

Figure 22. CNTA well MV-2 initial development, discharge versus time at various airlift eductor depths.

Well development was performed by SNJV from September 24, 2005 until January 23, 2006, on a semi-weekly basis. It was possible to pump this well for 4 to 6 hours before the pump controller would shut off the pump. The pump column contained about 112 gallons of water, based on the pump riser pipe calculations and pumping rate; it took approximately 11 minutes to displace this stagnant water. Discharge measurements were recorded and bromide samples were collected during each pumping episode. An estimate of the amount of water lost to the formation during flooded reverse circulation drilling was made by SNJV. A lower bound was estimated based on the amount of time the screened interval was exposed to flooded drilling pressure head at a flow rate determined from airlift development (assuming the aquifer accepted the same flow rate during drilling as the well produced at similar hydraulic head during airlifting). An upper bound was estimated based on the water truck deliveries to each well. Water volume produced versus bromide is shown in Figure 23.

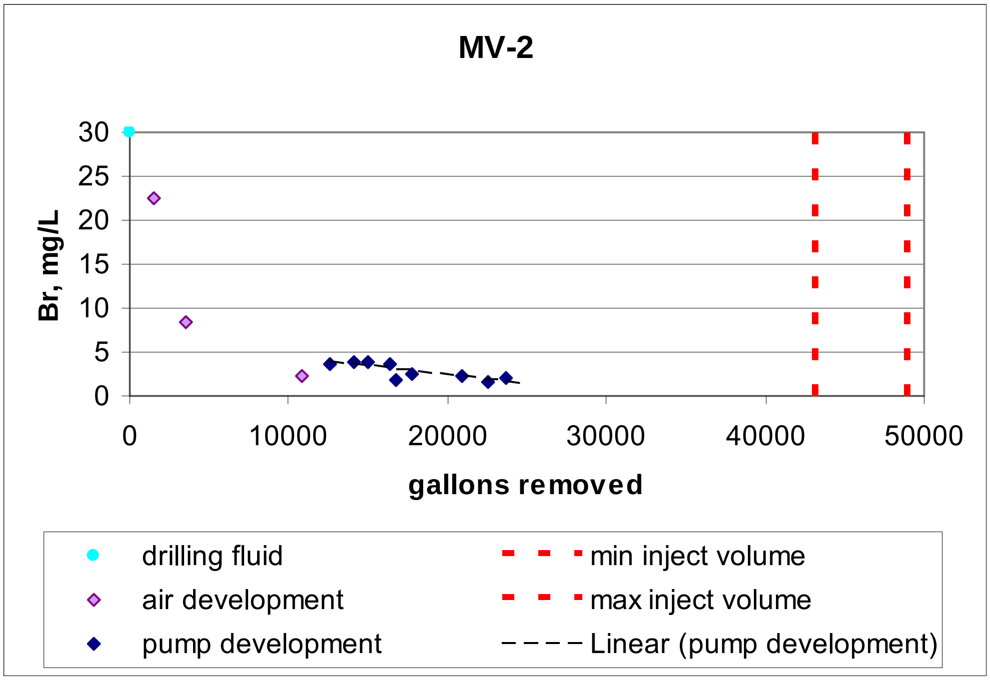

Figure 23. CNTA well MV-2 bromide development, bromide concentration versus water removed.

Geophysical Log Interpretation

The geophysical logs were key in guiding the screen placement during well construction. The AHT90 resistivity profile was also used for additional analysis to categorize the degree of welding. Resistivity values above 30 Ω-m were assigned a value of 3 and correspond to densely welded tuff (the threshold of 30 Ω-m was used in the CNTA flow model to identify densely welded tuffs from the original site well logs). Resistivity values between 20 and 30 Ω-m were assigned a value of two, corresponding to moderate welding. A value of one was assigned for resistivity values between 10 and 20 Ω-m, and a value of zero for resistivities below 10 Ω-m. The resulting designations are shown in Figure 24, next to the AHT90 data, with tabulated data included on the data disc.

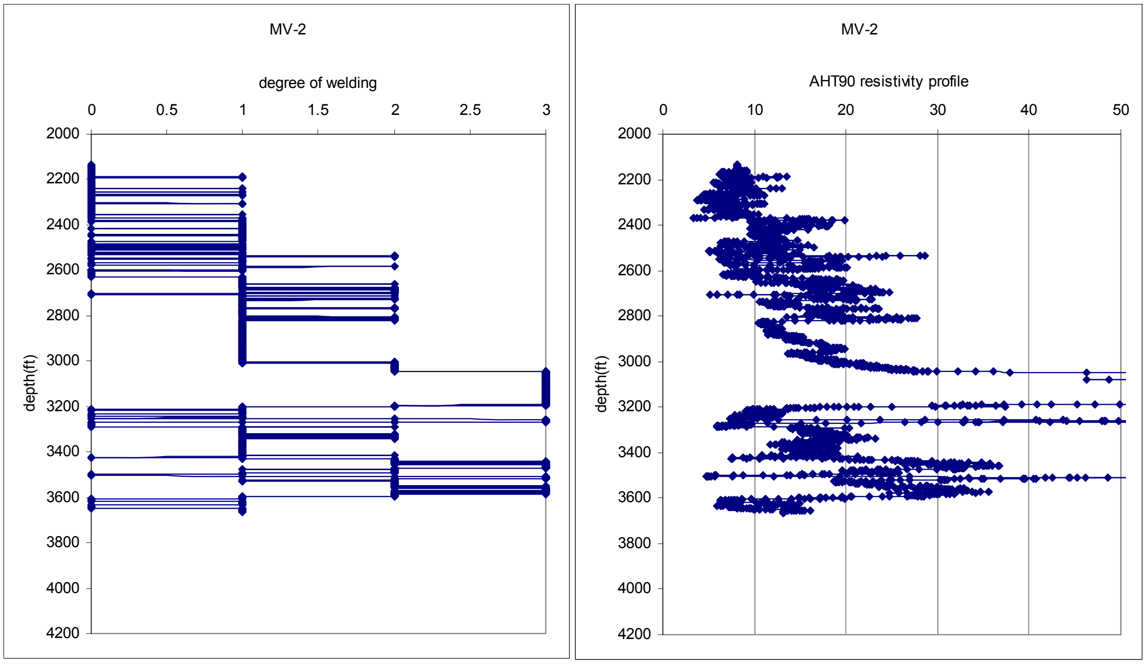

Figure 24. MV-2 resistivity profile in the volcanic section (right), with associated interpretation of degree of welding (left).

Aquifer Test Analysis

Introduction

Water levels were measured with an electric water level indicator (i.e., an etape) and pressure transducers connected to an automatically recording datalogger. The transducers are located at a depth of about 1,648 ft bgs in the main well and about 446 ft bgs in the lower piezometer. Water levels in the upper piezometer were not monitored during aquifer testing. Other data recorded automatically during the test include the amount of water discharged at land surface, barometric air pressure, and water temperature adjacent to the lower pressure transducer.

During well development, the well produced 2.5 gpm with about 1,000 ft of water level drawdown. Water level recovery following pumping of the main well typically takes over 15 days to reestablish the static water level. Water level monitoring with an etape was started on July 7, 2005, following well completion and development. Those data were used to determine when the water levels had stabilized following well construction.

MV-2 is completed in a fractured densely welded tuff layer. This lithology has been identified at CNTA as being the most permeable unit in the volcanic section. Permeability within the fractured tuff at the CNTA site is generally low. Well performance and hydraulic testing indicate that the main well is screened in very low permeability material and/or the welded tuff is limited in extent and surrounded by low permeability material.

Water Level and Pumping Data - Main Well

Water level monitoring with pressure transducers and datalogger started October 06, 2005. The water level data and the pumping rates for the main well are presented in Figure

25. The figure shows two pumping and drawdown events. The first is a long-term aquifer test and the second is short-duration pumping to remove drilling water from the formation.

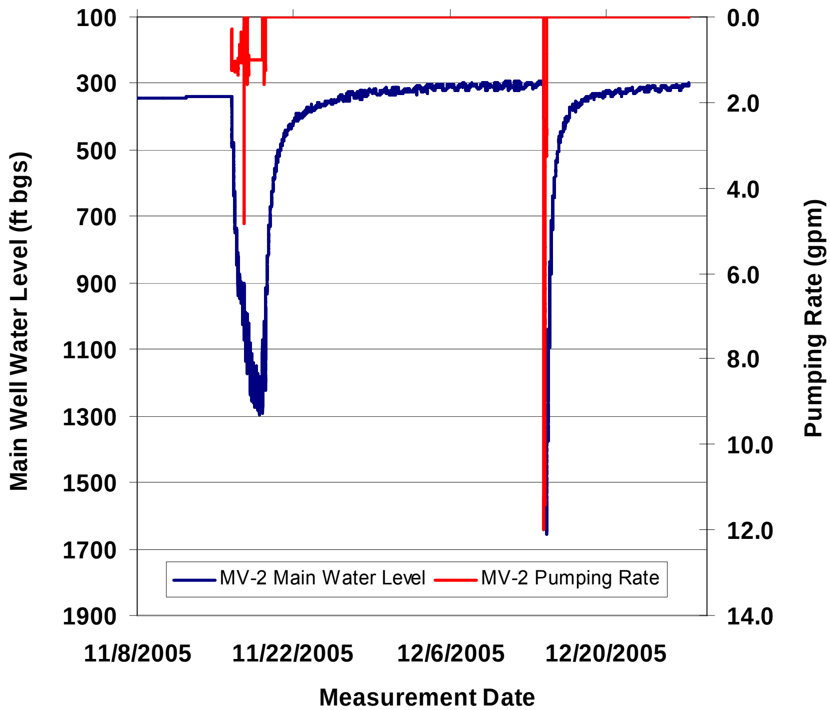

Figure 25. MV-2 water level and pumping rate during aquifer test (November) and development (December).

An expansion of the constant rate aquifer test is provided in Figure 26. The pumping rate varies during the test because of the difficulty in manually maintaining a nominal 1.0 gpm pumping rate under the condition of a 900 ft drawdown. Interpretation of the water level drawdown and recovery test is predicated on meeting several simplifying assumptions. These include that the water from the well is mainly from the formation and not from removal of water stored inside the well casing (Driscol, 1986). The effects of casing storage in a water production well are typically negligible following a short duration of pumping. However, this well produces a minimal flow rate and casing storage is an important issue for interpretation of hydraulic properties.

Analysis of casing storage is presented in Figure 27 based on Driscoll (1986). The upper line on the figure is the estimate of pumping time until casing storage can be ignored. As the well is pumped, the estimate increases to over 12,000 minutes (8 days) of pumping and continues to increase. The lower line is the relationship between pumping time and the time for negligible casing storage. The drawdown data cannot be reliably analyzed using the Theis or similar methods until the upper line crosses the lower line. Casing storage is estimated to influence water level drawdown for the first 10 days of pumping. Calculation of approximate aquifer properties was performed for the long-duration aquifer test, but is not presented because a better data set exists for hydraulic analysis as discussed below.

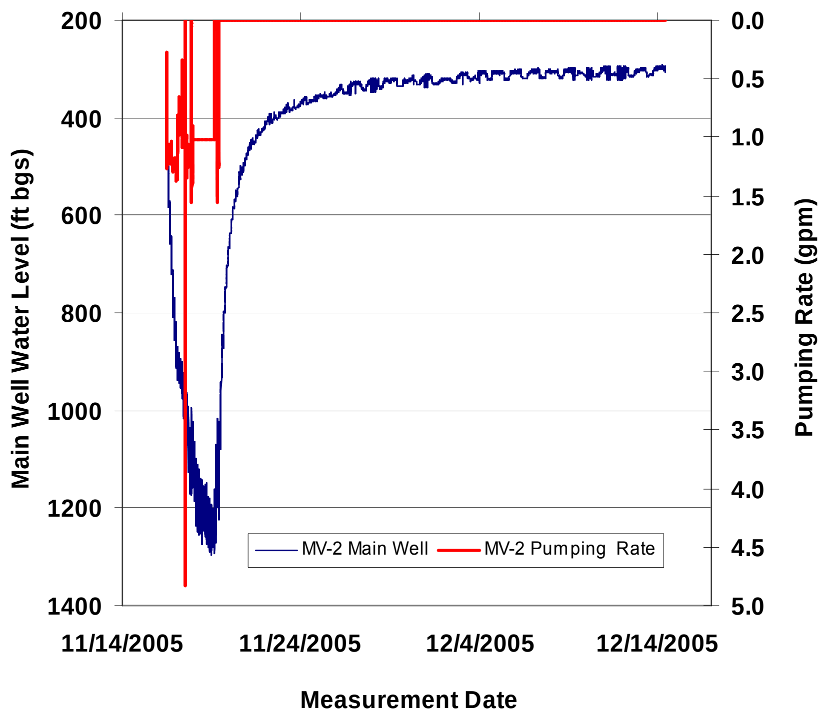

Figure 26. Detail of the water level and pumping rate during the MV-2 aquifer test shown on Figure 25.

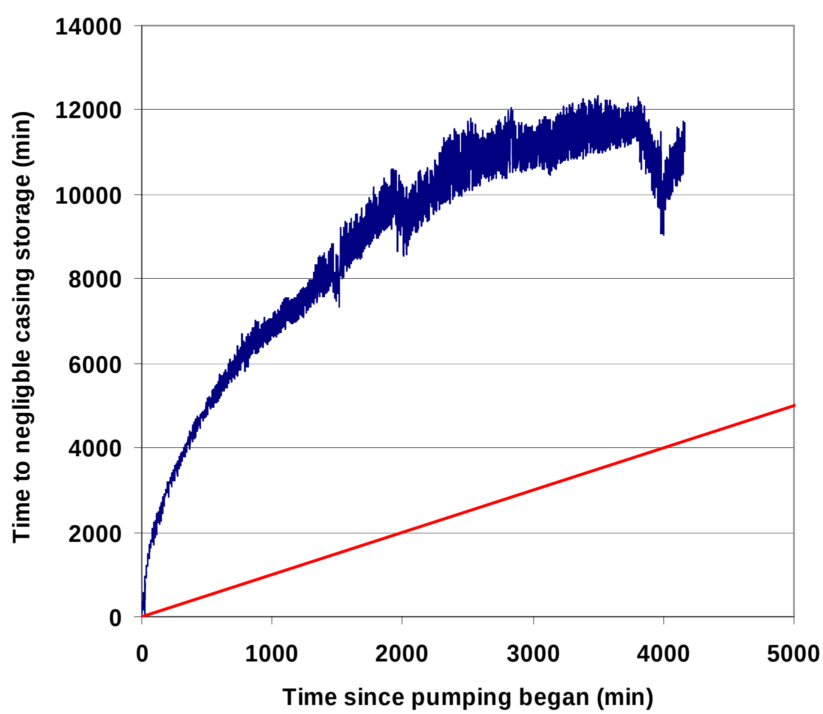

Figure 27. MV-2 casing storage analysis based on Driscoll (1986).

The rapid removal and long time of water level recovery contained in the short-duration pumping event illustrated in Figure 27 is similar to a “slug” test where a volume of water is rapidly displaced in the well and the change in water levels with time are interpreted. Calculation of the amount of water discharged from the well and the volumetric decline in water levels indicates that 73 percent of the water discharged during the short-term pumping period came from casing storage as intended in a slug test. The relatively short duration of the pumping periods (e.g., 300 minutes) in relation to the long period of well recovery (e.g., 20,000 minutes) suggests that slug test methodologies are valid even though the water displacement was not instantaneous.

Aquifer properties are estimated from the short-duration pumping event using U.S. Geological Survey software documented in Halford and Kuniansky (2002). The interpretation methods of Cooper, Bredehoeft, and Papadopulos as modified by Greene and Shapiro (1995) for confined aquifers are used for the slug test analysis. The aquifer is believed to be confined based on the materials encountered during drilling. The short-duration pumping period is analyzed as a slug test in Figure 28. The estimated aquifer transmissivity is 2.10E-1 ft^2/d. The aquifer thickness of 840 ft is assumed to coincide with the Moores Station Butte tuff. The calculated hydraulic conductivity is 2.5E-4 ft/day. Assuming water production was only from turf adjacent to the 163 ft screened interval, the hydraulic conductivity is 1.29E-3 ft/d. The method also provides a storativity of 4.62E-5 (dimensionless), but this value is less certain than the hydraulic conductivity.

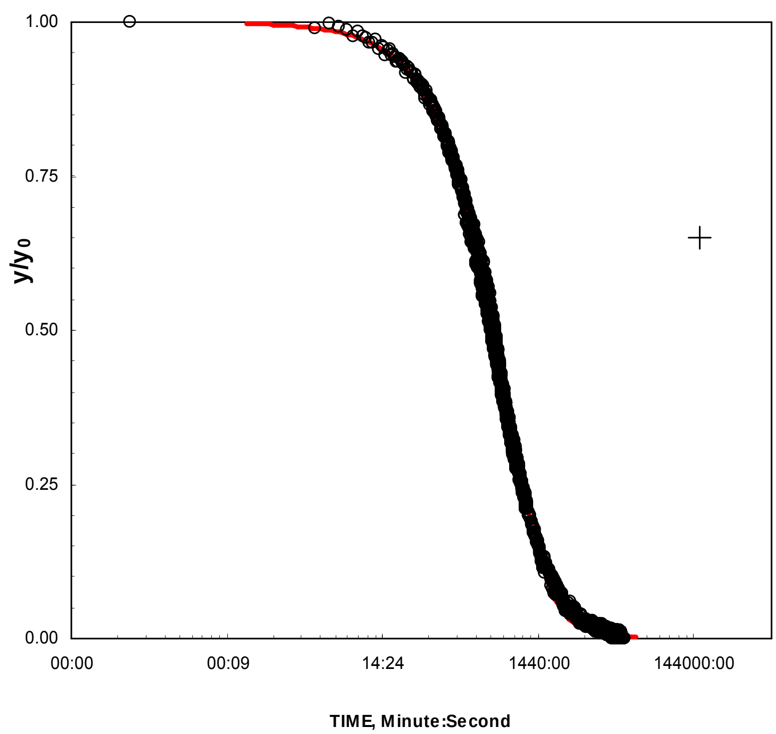

Figure 28. MV-2 slug test analysis.

Water Level Data – Lower Piezometer

The lower piezometer was monitored at the same time and frequency as in the main well. Water levels in the lower piezometer and pumping rates in the main well are presented in Figure 29. Water levels in the lower piezometer show a hydraulic response to pumping. Water levels below 446 ft bgs are not valid because they are below the depth of the pressure transducer.

The lower piezometer responded to both the long-term and short-term pumping in the main well, indicating a hydraulic connection between these two locations. The data are impacted by a change in thermal conditions during well pumping. Pumping the main well replaced the cooler water in the upper portion of the fluid column with warmer water. This heat was then conducted to the lower piezometer through direct physical contact of the steel casings of the main well and the lower piezometer. As the water in the lower piezometer warmed over time, it expanded and affected the water level in the lower piezometer.

This thermal effect tended to decrease the amount of water level drawdown in the lower piezometer during pumping because of thermal expansion and accentuate water level recovery following pumping because of thermal contraction. A cursory evaluation of Figure 29 suggests that this may be occurring, but there are also many other changes in water level on the figure that are likely caused by unmonitored well pumping that complicates the data interpretation.

The temperature change in the pressure transducer located near the top of the water column in the lower piezometer is presented with the pumping rates in the main well are presented in Figure 30.

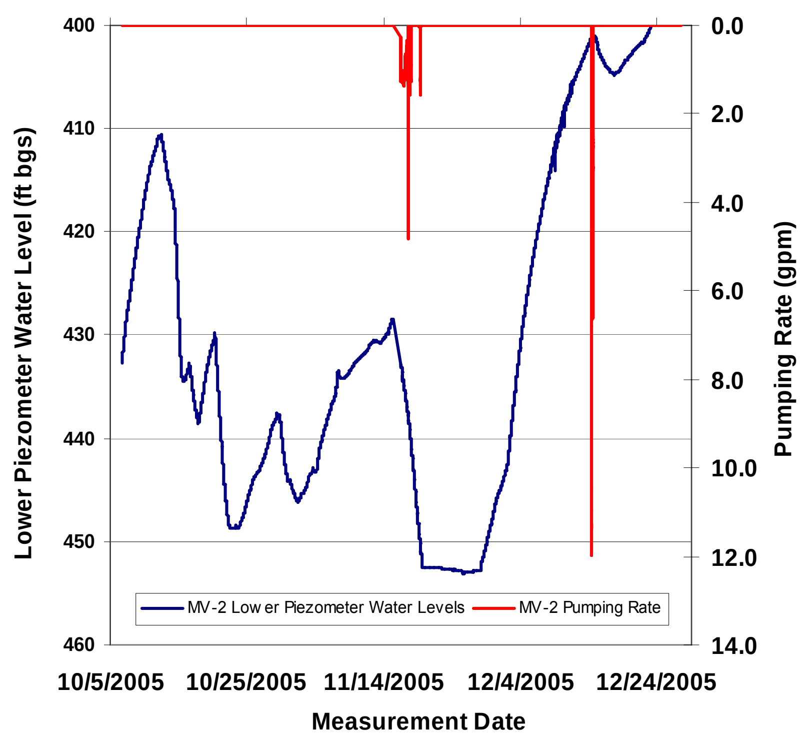

Figure 29. Water levels in the MV-2 lower piezometer, shown with pumping rates in the main well.

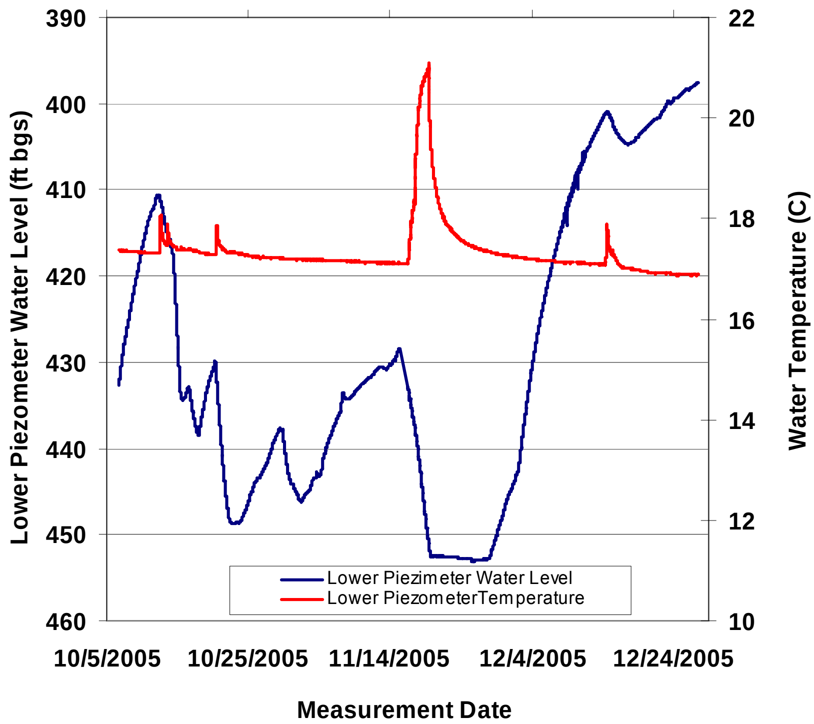

Figure 30. Temperature and water level in the MV-2 lower piezometer during the pumping periods.

Sampling Protocol and Results

A 4-inch submersible pump was installed, with a pump intake 1,741 ft bgs. This pump is capable of lifting water from about 1,700 ft; the pump curve for the Grundfos 10S50-58DS is included in Appendix D. The pump is capable of discharging approximately one well volume before the pump controller turns the pump off.

On March 15, 2006 at 2:40 P.M., the pump was turned on; pH, water temperature and electrical conductance were monitored prior to sample collection (3 to 4 percent variability and no trends were observed). At 10:44 A.M., on March 16, 2006, the pump was turned off after the samples were collected. A total of 3,265 gallons were pumped; one well volume is approximately 3,188 gallons (Table 7).

Table 7. CNTA Well MV-2 wellbore volume estimate.

water table	327.5 ft
screen bottom depth	3,202 ft
casing inside dia.	5 in
volume	2,936 gal
gravel top	3,066
gravel bottom	3,260
casing outside dia.	5.5 in
nominal borehole dia.	12.5 in
volume 30% porosity	252 gal
total volume	3,188 gal

Analytical results were reviewed and were found to be similar to the water samples from the other wells in the area (see Table 5). No radioactivity was detected.

CNTA WELL MV-3

Drilling History

The MV-3 borehole was drilled with the flooded reverse circulation drilling method, starting July 9, 2005 and was constructed by August 11, 2005. Details regarding the drilling and construction of well MV-3 can be found in the CNTA well installation report (DOE, 2006). Below is a summary to orient the reader and highlight matters of possible significance to the well and piezometers.

MV-3 was the final well constructed at CNTA in 2005. Drilling progressed without incident and the basic well construction was as designed, with the main well string as the bottom completion, and two piezometers completed higher in the borehole (Figure 31). The upper piezometer was placed within the alluvium (screen depth from 880 to 940 ft) to monitor water levels in the shallower part of the saturated section. The screened interval was noted as being comprised of cobbles, coarse gravel, and medium-coarse sand. It was noted as a zone of drilling fluid loss, and potentially a fault zone.

The total depth of the borehole was somewhat deeper than planned (4,220 ft versus 4,100) due to encountering a densely welded tuff near the bottom, and concerns about potential sloughing between the end of drilling and well construction. The screen for the main well was placed to intersect the densely welded tuff interval encountered between depths of 4,046 and 4,148 ft (the screen slots span the depths of 4,046 to 4,208 ft). The screened interval for the lower piezometer spans another densely welded tuff located between 3,360 and 3,392 ft (screen spans the depths of 3,300 and 3,420 ft). This zone had a stronger resistivity response, indicating a greater degree of welding, compared to a third zone identified from 3,740 to 3,800 ft. Selection of the densely welded tuff at 3,360 ft also better satisfied the need to vertically distribute the head measurements.

No geophysical logs were run in the upper portion of the borehole (above 1,055 ft) because the logging company could not arrive in a timely manner and the cost of waiting outweighed the information from the logs, given the interval is alluvium.

Development History

Initial development of the main well was performed by air-lift development with the drill rig. HQ core rods were placed in the sump below the well screen, a combination of BQ and AQ rods was used as air eductor lines, and water was discharged to land surface from the HQ pipe. Air-lift operations were performed intermittently between the final cementing operations from August 13, 2005, until August 15, 2005, when operations were stopped and the drill rig was demobilized from the site.

Relatively detailed discharge measurements were made during this development; as the eductor was lowered, discharge measurements were recorded as a function of time. This technique was basically a constant head variable discharge aquifer test. These data were collected by SNJV and are included in the data disk. An interesting sinusoidal response was observed in these data at various eductor depths; this response is not completely understood, but is thought to be in response to the pressure shockwave in the aquifer from the air-lifting (Figure 32).

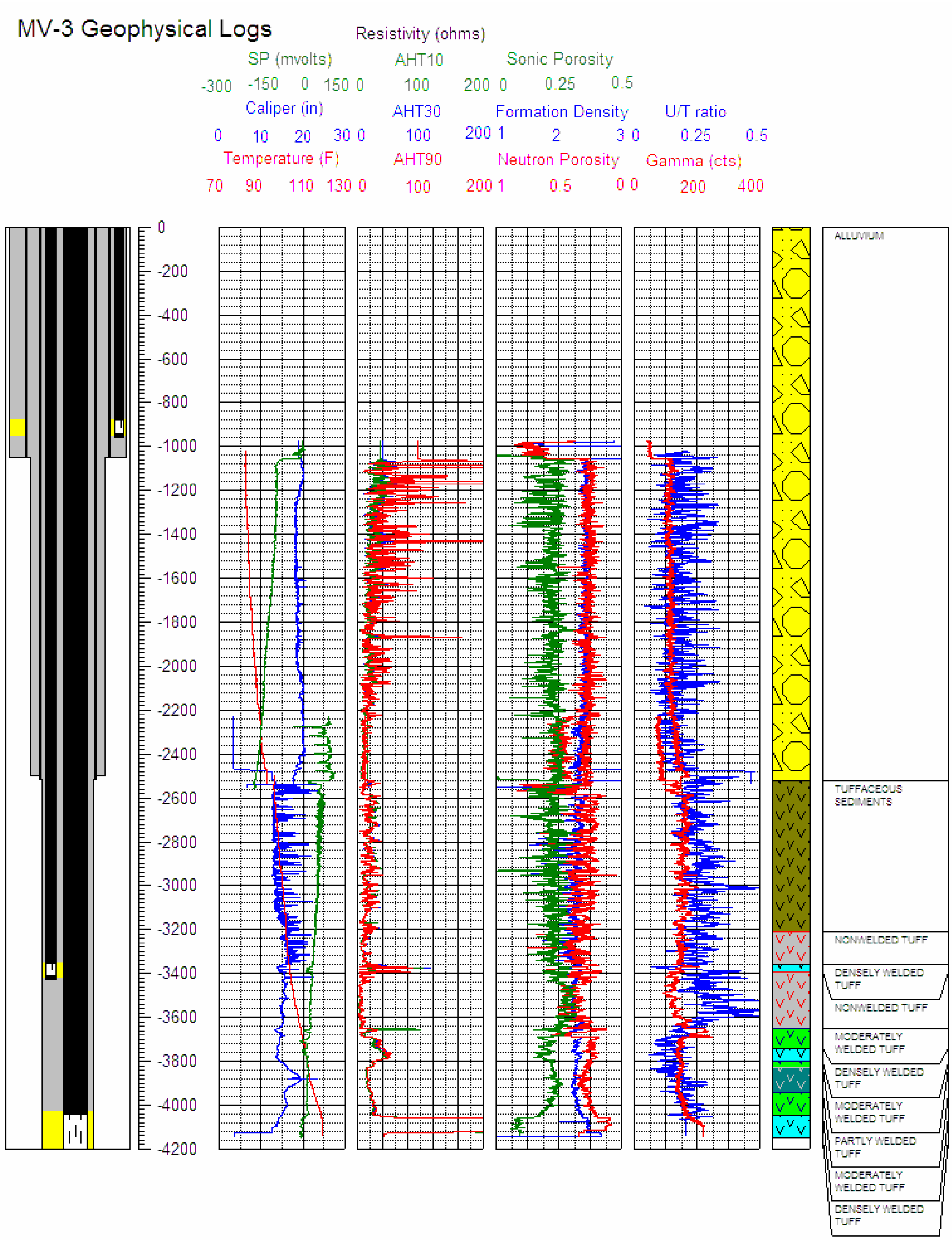

Figure 31. MV-3 well and piezometer completions, geophysical logs, and geology interpreted from the logs. No geophysical logs were run above a depth of 1,055 ft.

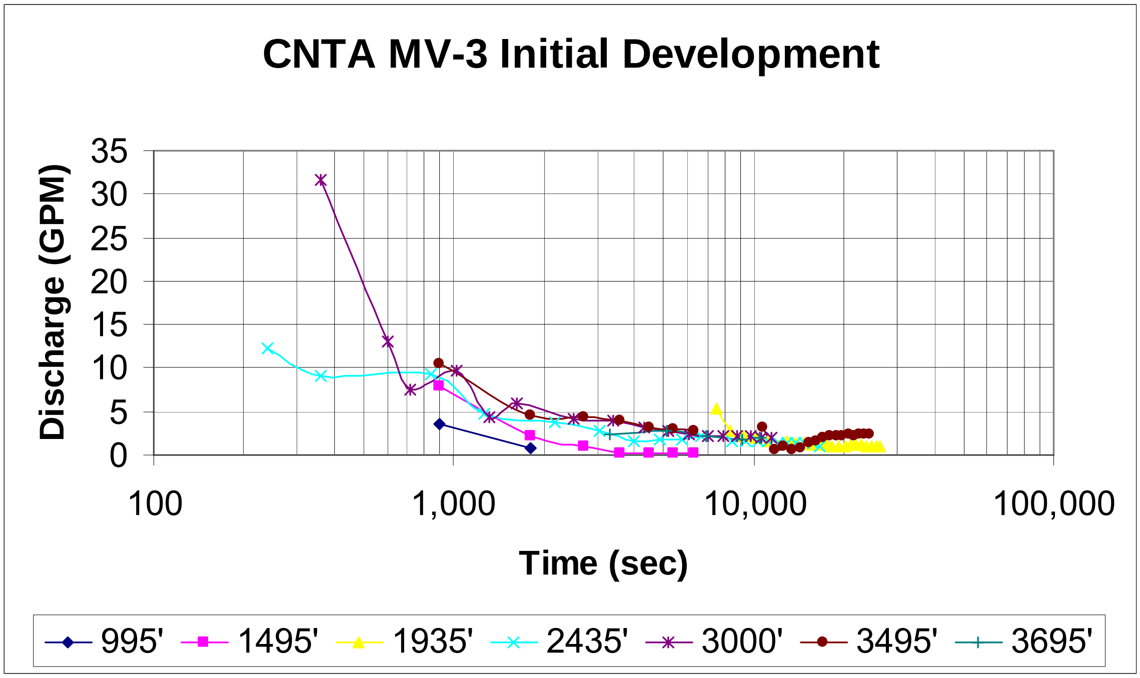

Figure 32. CNTA well MV-3 initial development, discharge versus time at various airlift eductor depths.

Piezometer development was performed via bailing and air-lift techniques. Merchant half-inch black-iron pipe was used to deliver air into the piezometer tubing; tensile strength concerns limited the black-iron pipe to 1,000 ft maximum depth. Bailing operations were also performed in both piezometers. Approximately 1,940 gallons were produced from the upper piezometer. Only 2,160 gallons were produced from the lower piezometer at a rate of about 1.2 GPM.

On August 17, 2005, the TD of the main well was 4,202.2 ft bgs (measured with the DRI wireline), some 5.5 ft above the bottom of the well screen (approximately 3% of the screened interval is blocked). On September 22, 2005, the DRI wireline was used to measure the total depth of each piezometer. The lower piezometer TD had a soft set at 3,385.0, indicating fine-grained sediment is in the piezometer. The screened interval is from 3,300 to 3,420 ft; therefore, the lower 30 percent or so of the piezometer is filled with sediment. The upper piezometer TD was 955.3 ft; the screened interval was from 880 to 940 ft. Therefore, 0 percent of the piezometer screen is filled with sediment.

Well development was performed by SNJV from September 28, 2005, until January 23, 2006, on a semi-weekly basis. Due to the low productivity of the well, it was only possible to pump the well for about 2 hours before the pump controller shut the pump off. The pump column contained about 182 gallons of water, based on the pump characteristics derived from the pump manufactures pump curve; it took approximately 18 minutes to displace this stagnant water. Discharge measurements were recorded and bromide samples were collected during each pumping episode. An estimate of the amount of water lost to the formation during flooded reverse circulation drilling was made by SNJV. A lower bound was estimated based on the amount of time the screened interval was exposed to flooded drilling pressure head at a flow rate determined from airlift development (assuming the aquifer accepted the same flow rate during drilling as the well produced at similar hydraulic head during airlifting). An upper bound was estimated based on the water truck deliveries to each well. Water volume produced versus bromide is shown in Figure 33.

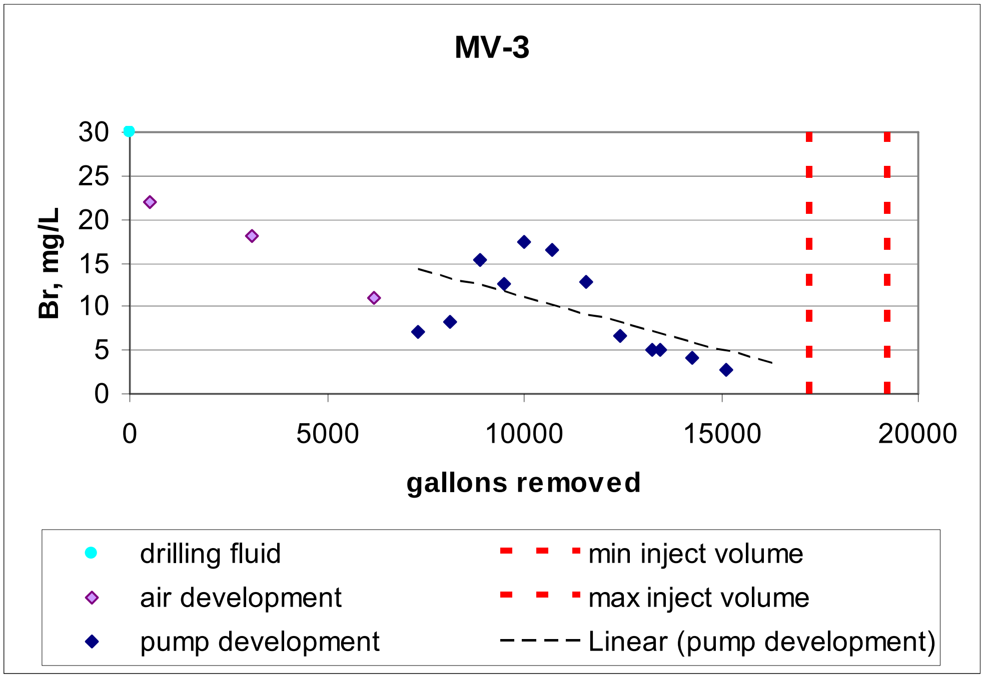

Figure 33. CNTA well MV-3 bromide development, bromide concentration versus water removed.

Geophysical Log Interpretation

The geophysical logs were key in guiding the screen placement during well construction. The AHT90 resistivity profile was also used for additional analysis to categorize the degree of welding. Resistivity values above 30 Ω-m were assigned a value of 3 and correspond to densely welded tuff (the threshold of 30 Ω-m was used in the CNTA flow model to identify densely welded tuffs from the original site well logs). Resistivity values between 20 and 30 Ω-m were assigned a value of two, corresponding to moderate welding. A value of one was assigned for resistivity values between 10 and 20 Ω-m, and a value of zero for resistivities below 10 Ω-m. The resulting designations are shown in Figure 34, next to the AHT90 data, with tabulated data included on the data disc.

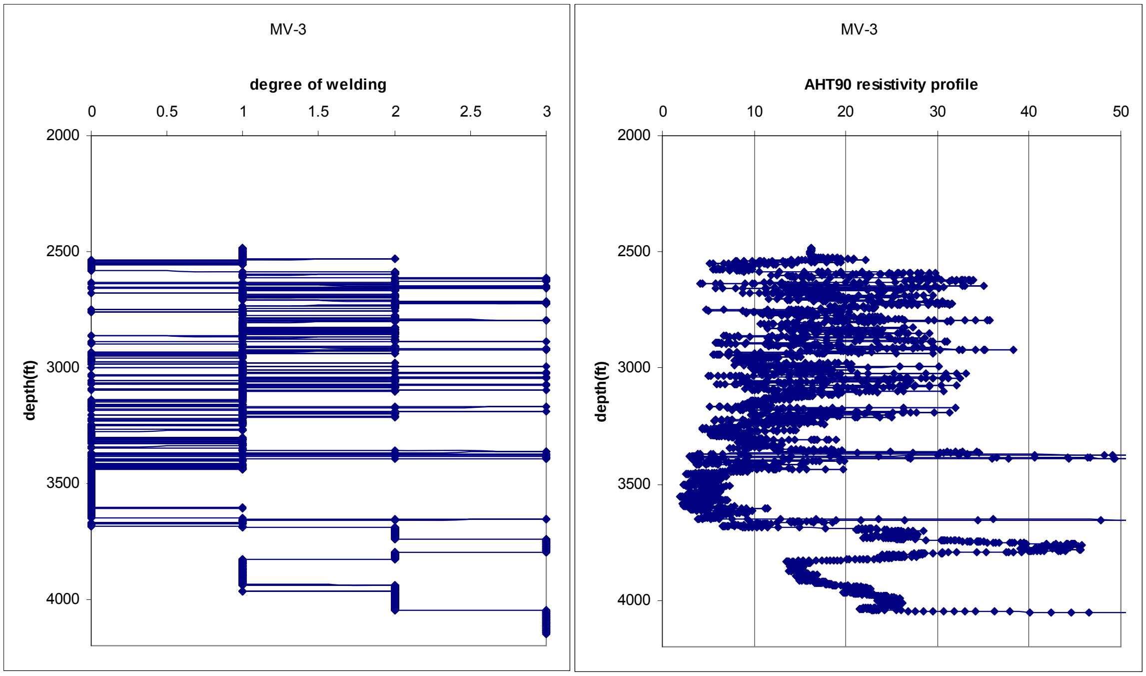

Figure 34. MV-3 resistivity profile in the volcanic section (right), with associated interpretation of degree of welding (left).

Aquifer Test Analysis

Introduction

Water levels were measured with an electric water level indicator (i.e., an etape) and pressure transducers connected to an automatically recording datalogger. The transducers are located at about 1,573 ft bgs in the main well and about 229 ft bgs in the lower piezometer. The upper piezometer was not monitored during the aquifer testing. Other data recorded automatically during the test include the amount of water discharged at land surface, barometric air pressure and water temperature adjacent to the lower pressure transducer.

During well development, the well produced about 1.5 gpm with over 900 ft of water level drawdown. Water level recovery in the main well typically takes over 10 days to reequilibrate to the static water level. Water level monitoring with an e-tape was started on September 21, 2005, following the well completion and development. These data were used to determine when the water levels had stabilized following well construction.

The MV-3 monitoring well is completed in a fractured, densely welded tuff layer. This lithology has been identified at CNTA as being the most permeable unit in the volcanic section. Permeability within the fractured tuff at the CNTA site is generally low. Well performance and hydraulic testing indicate that the main well is screened in very low permeability material and/or the welded tuff is limited in extent and surrounded by low permeability material.

Water Level and Pumping Data - Main Well

Water level monitoring with transducers and the datalogger started November 16, 2005. The water level data and the pumping rates for the main well are presented in Figure

35. The figure shows several interesting aspects of pumping the main well. Specifically, the first three drawdown events are pumping to remove water added to the formation during drilling. Figure 35 indicates the well draws down about 900 ft when pumped at an average rate of about 7.0 gpm. The pumping rate in these tests decreases with time as the pumping lift increases. After about 100 minutes of pumping, the pumping lift is near the amperage limit of the electric motor's capacity and pumping is terminated. The fourth drawdown event was intended to be a constant rate aquifer test while pumping at about 0.6 gallons per minute. There were difficulties in maintaining a constant discharge rate because of the large amount of water level drawdown and mechanical limitations of the equipment. A datalogger failure prevented data collection for much of the water level recovery for the constant rate aquifer test.

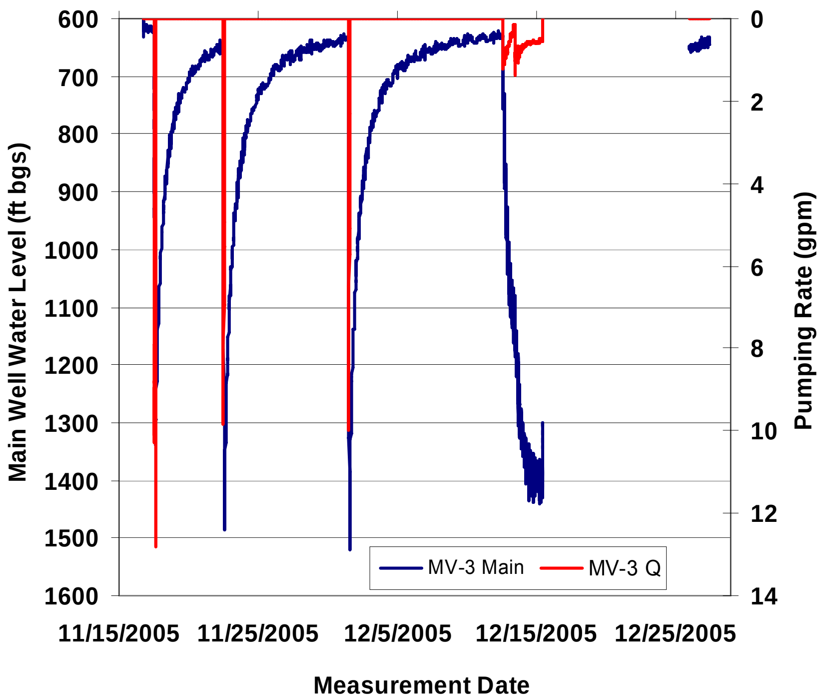

Figure 35. MV-3 water levels and pumping rates during testing.

An expansion of the constant rate aquifer test is provided in Figure 36. Interpretation of the water level drawdown and recovery test is predicated on meeting several simplifying assumptions. These include the water being discharged is mainly from the formation and not from removal of water stored inside the well casing (Driscol, 1986). The effects of casing storage are typically negligible following a short duration of pumping. However, this well produces very low flow rates and has over 800 ft of drawdown while pumping. An analysis of casing storage is presented in Figure 37 based on Driscoll (1986). The upper line on the figure is the estimate of pumping time until casing storage can be ignored. As the well is pumped, the estimate increases to over 16,000 minutes (11 days) and continues to increase. The lower line is the relationship between pumping time and the time for negligible casing storage. The drawdown data cannot be reliably analyzed using the Theis or Cooper-Jacob methods until the upper line crosses the lower line. Casing storage is estimated to influence water level drawdown for the first 16 days of pumping. Calculation of approximate aquifer properties was performed for the long-duration aquifer test, but is not presented because a better data set exists for hydraulic analysis as discussed below.

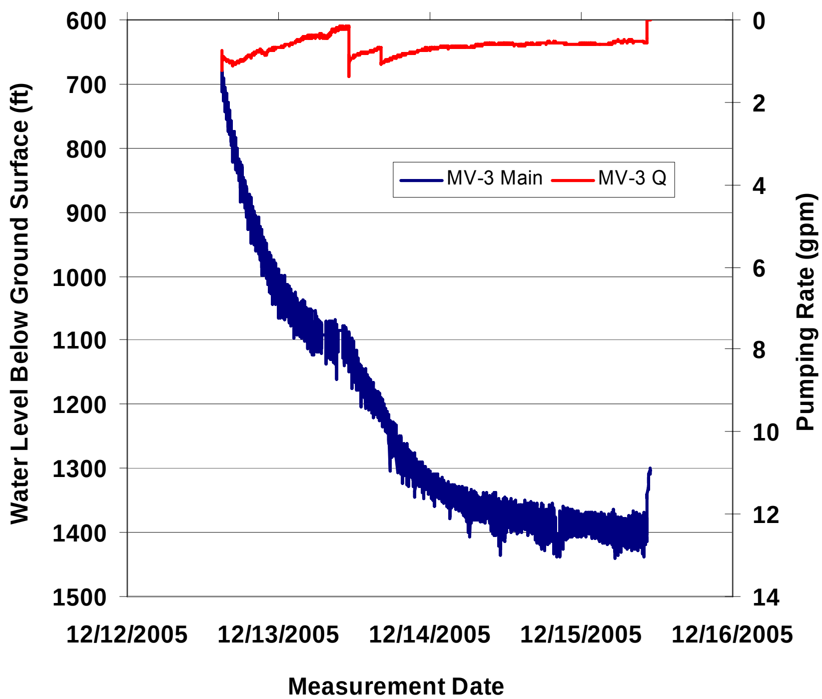

Figure 36. Detail of the constant rate aquifer test in MV-3 as shown on Figure 35.

The rapid removal and long time of water level recovery contained in the first three pumping events illustrated in Figure 37 are similar to a “slug” test where a volume of water is rapidly displaced in the well and the change in water levels with time are interpreted. Calculation of the amount of water discharged from the well and the volumetric decline in water levels indicates that over 95 percent of the water discharged during the short-term pumping periods came from casing storage as intended in a slug test. The relatively short duration of the pumping periods (e.g., 100 minutes) in relation to the long period of well recovery (e.g., 15,000 minutes) suggests that slug test methodologies are valid even though the water displacement was not instantaneous.

The three periods of well pumping preceding the long-term aquifer testing are analyzed as slug tests. Aquifer testing analysis was performed using U.S. Geological Survey software developed by Halford and Kuniansky (2002). The interpretation methods of Cooper *et al.* (1967), as modified by Greene and Shapiro (1995) for confined aquifers, are used for the slug test analysis. The aquifer is believed strongly confined based on the materials encountered during drilling. The three short-duration pumping periods analyzed as slug tests are shown in Figures 38 through 40.

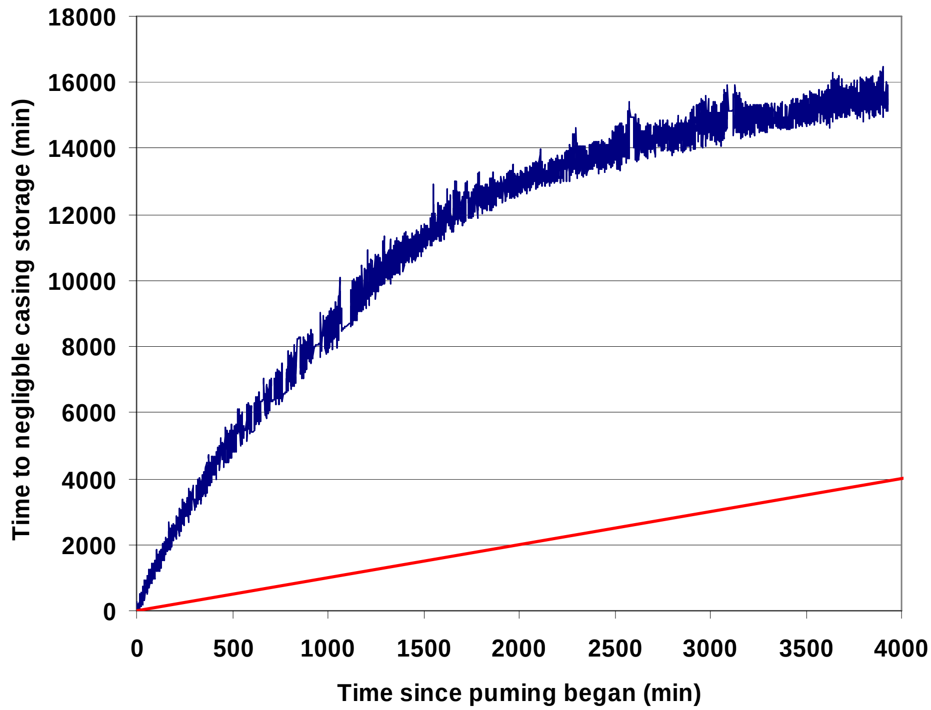

Figure 37. Analysis of casing storage in MV-3, using the method of Driscoll (1986).

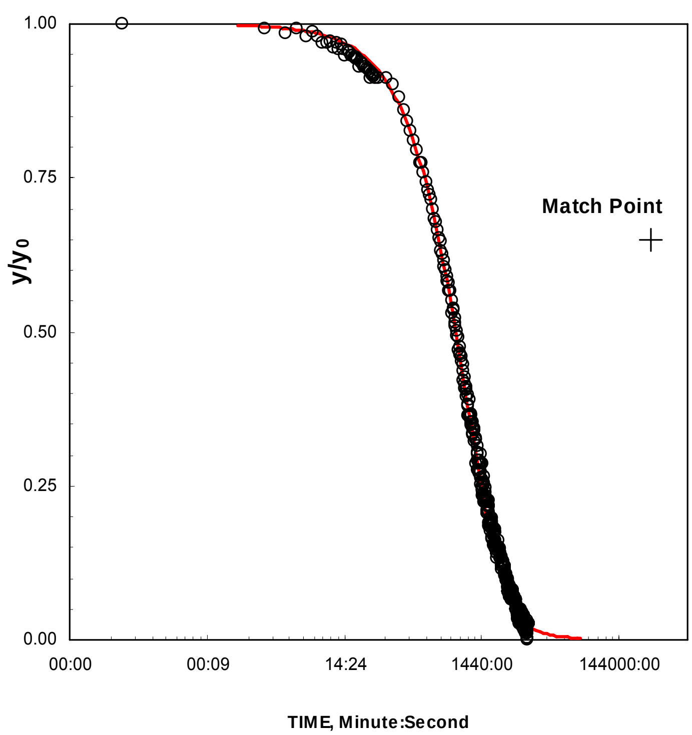

Figure 38. Slug test analysis for the first MV-3 pumping period.

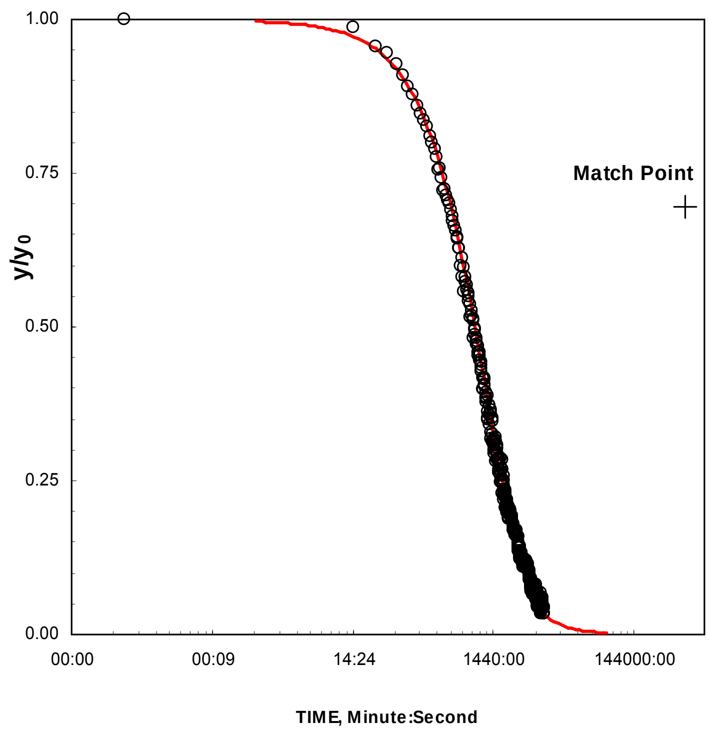

Figure 39. Slug test analysis for the second MV-3 pumping period.

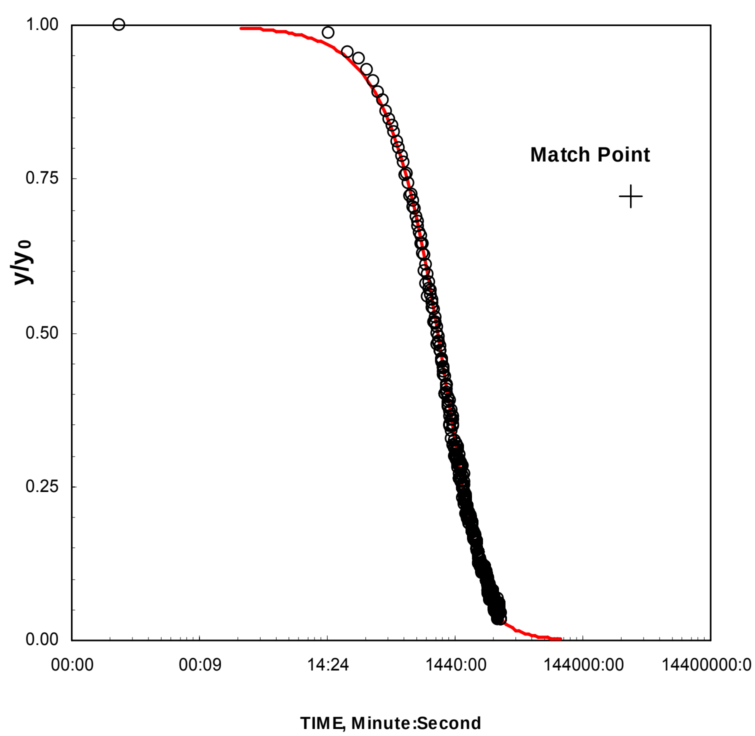

Figure 40. Slug test analysis for the third MV-3 pumping period.

The calculated aquifer properties are presented in Table 8.

Table 8. Summary of aquifer testing analysis.

Data Location	Data Set	Interpretation Method	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/d)	Storativity (dimensionless)	Interpretation Confidence (heuristic)	Comments
Main Well	Slug Test "a" Recovery	Cooper-Greene	9.50E-02	1.80E-04	2.50E-04	Good	Interpretation method appropriate to data
Main Well	Slug Test "b" Recovery	Cooper-Greene	9.90E-02	1.90E-04	1.40E-04	Good	Interpretation method appropriate to data
Main Well	Slug Test "c" Recovery	Cooper-Greene	1.50E-01	2.80E-04	5.00E-05	Good	Interpretation method appropriate to data
Lower Piezometer	Constant Rate Drawdown	None	-	-	-	-	Data influenced by thermal effects from pumping

These hydraulic conductivity values are based on the assumption that the entire 520-ft thick section of Moores Station tuff is contributing water to the well. Assuming that only the tuff adjacent to the screen is producing water, the average hydraulic conductivity is 7.15E-4 ft/d.

Water Level Data – Lower Piezometer

Water levels were monitored in the lower piezometer at the same time frequency as the main well. Water levels in the lower piezometer are presented in Figure 41. Water levels in the lower piezometer were rising before the start of the long-duration aquifer test because of water-level recovery from previous pumping. At the start of the aquifer test, water levels increased abruptly in the lower piezometer.

Figure 41. Water levels in the MV-3 lower piezometer, plotted with the pumping rate in the main well.

The rise of water levels in piezometers constructed in the same borehole as pumping wells has been observed in other deep wells at the CNTA site and is caused by the thermal conditions in the well during pumping. The well was in thermal equilibrium with the surrounding material before pumping; with cooler water at the top of the water column and warmer water at the bottom. Pumping the main well replaced the cooler water in the entire fluid column with warm water. This heat was then conducted to the lower piezometer through the direct physical contact of the steel casings of the main well and the lower piezometer. As the water in the lower piezometer warmed over time, it expanded and increased the water level in the lower piezometer. This is evidenced by the increase in water temperature within the pressure transducer located near the top of the fluid column of the lower piezometer.

Water levels in the lower piezometer were converted to approximate pressures at the bottom of the lower piezometer by considering the height of the water column, gravitational acceleration, and the temperature-dependent water density. The pressure values were then converted to an equivalent water level assuming a constant 65-degree Fahrenheit water temperature within the lower piezometer. Figure 42 presents the temperature and pressure information for the lower piezometer, and indicates that although the water level increased during pumping, the fluid pressure decreased in response to pumping.

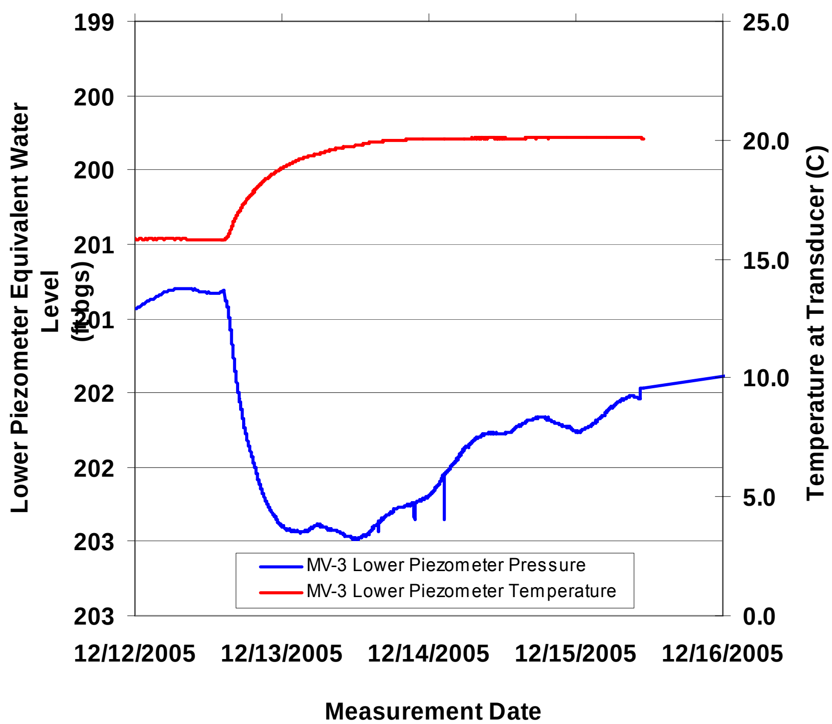

Figure 42. Temperature and water level in the MV-3 lower piezometer.

These data are not analyzed for hydraulic properties because the temperature at the bottom of the water column in the lower piezometer was not measured directly. The temperature at the bottom of the fluid column was estimated for scoping purposes as the equilibrium temperature at the top of the fluid column during pumping, making the pressure estimation approximate. The evaluation of data from the lower piezometer indicates the water level response is not anomalous and that the lower piezometer is in hydraulic communication with the main well.

Sampling Protocol and Results

Due to the low yield of the well, no commercially available pump could be found that would pump less than 1 GPM with a pump lift of 3,600 ft. Many well purge procedures have been developed for low production wells, commonly referred to as "low purge" or "low discharge" purge techniques; however, no standard procedures have been developed for wells with this much borehole storage.

A 4-inch submersible pump was installed, with a pump intake 3,987.5 ft bgs (58.5 ft above the screen). This pump is capable of lifting water from about 1,700 ft; the pump curve for the Grundfos 10S50-58DS is included in Appendix D. The pump is capable of discharging about 800 gallons from the well before the pump controller turns the pump off. On December 1, 2005, the pump ran for approximately 100 minutes and 867 gallons were discharged from the well (Figure 43). Full recovery takes several weeks, but approximately 655 gallons flow back into the well in 24 hours (Figure 44). Once the 182 gallons are displaced from the pump column, the next water from the well should be predominately formation water, presuming recharging water from the well screens is displacing the wellbore water upward. Therefore, it is proposed that several screen volumes be displaced, rather than a well volume. This technique will be tested in a future sampling trip; however, these samples were collected at the end of the long-term aquifer test.

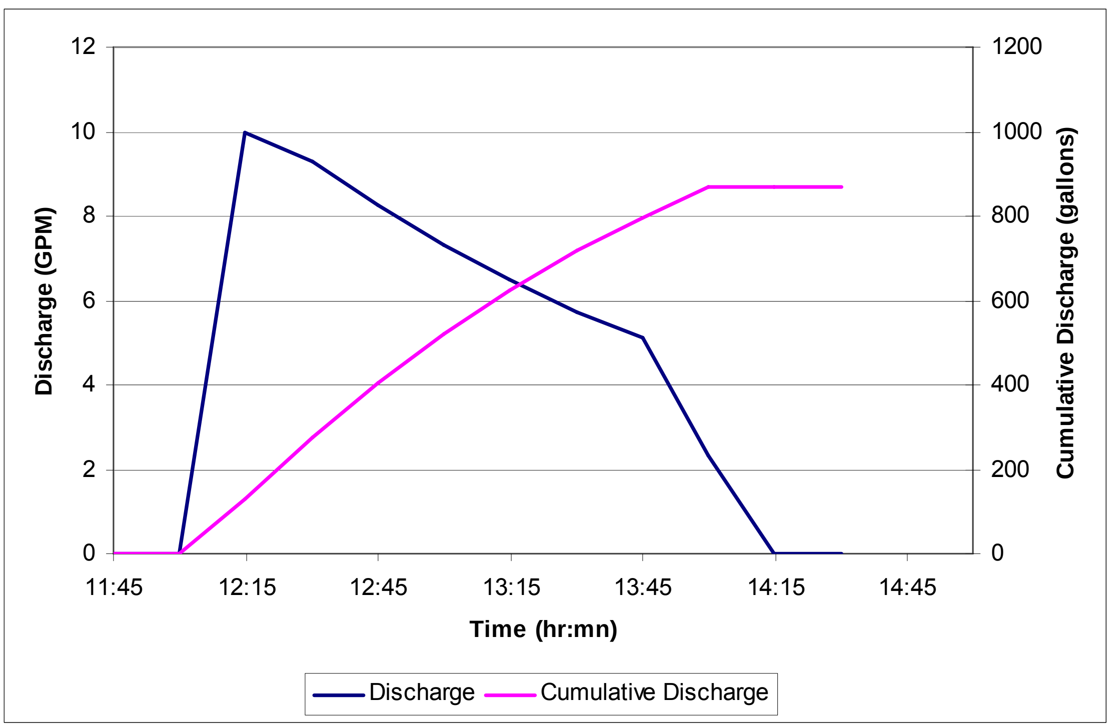

Figure 43. CNTA Well MV-3 discharge versus time from a test on December 1, 2005.

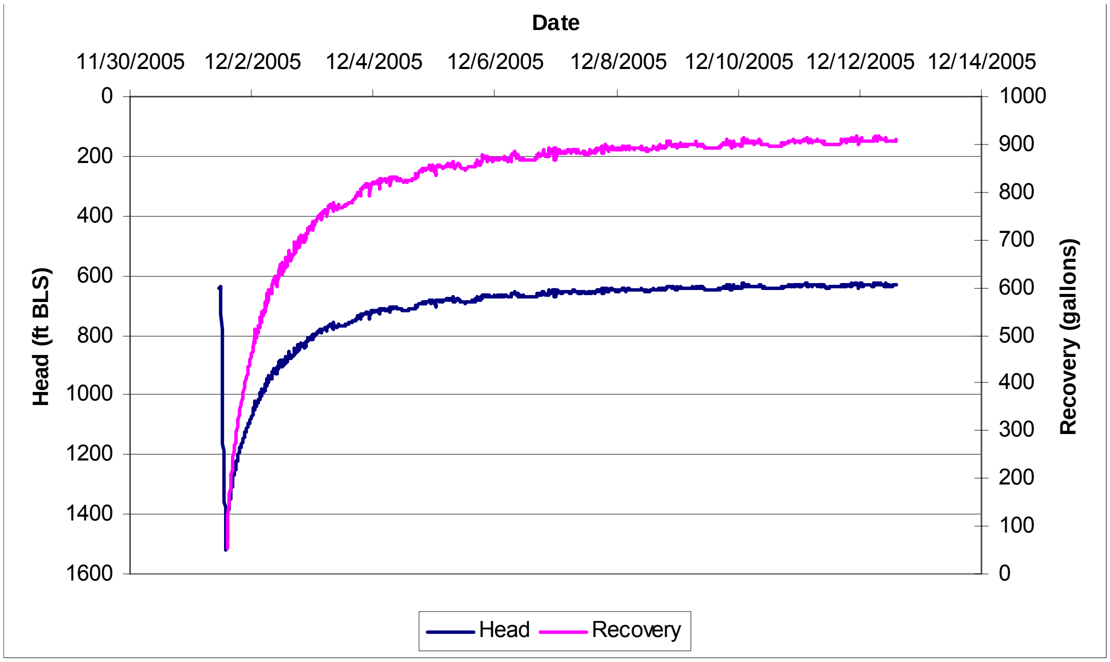

Figure 44. CNTA Well MV-3 water level and recovery related to the December 1, 2005 test.

On March 15, 2006, the pump was turned on at 10:22 A.M., and it was automatically turned off at 2:40 P.M., when the pump controller reached an under current of less than six amps. A total of 1,048.4 gallons were pumped; one well volume is approximately 3,902 gallons (Table 9).

Table 9. CNTA Well MV-3 wellbore volume estimate.

water table	630.28 ft
screen bottom depth	4,207 ft
casing inside dia.	5 in
volume	3,653 gal
gravel top	3,790
gravel bottom	4,220
casing outside dia.	5.5 in
nominal borehole dia.	12.5 in
volume 30% porosity	249 gal
total volume	3,902 gal

The well was allowed to recover for about 23 hours prior to sample collection. On March 16, 2006, at 1:32 P.M., the pump started and 232 gallons were discharge prior to sample collection. Results of chemical analyses are listed in Table 5. An additional 335 gallons were pumped during the sample collection. Water from the well has a slight H_2S smell, slightly foamy and oily to the touch, and has a black precipitant. Analytical results are similar to other wells in the area and there was no radioactivity detected.

SUMMARY AND FUTURE WORK

Three wells were drilled and constructed during 2005 in the vicinity of the Faultless underground nuclear test. These wells, MV-1, MV-2, and MV-3, are providing information for groundwater model validation and serving as long-term monitoring locations. Each of the wells is completed in a densely welded tuff interval at depths ranging from 3,000 to 4,000 ft. Two piezometers are adjacent to each well and provide access for monitoring water levels in the alluvium and tuffaceous sediments. Despite the expectation that densely welded tuff units tend to have relatively high hydraulic conductivity, the three MV wells intercept tight formations. The low productivity of the wells resulted in a prolonged period of development to remove drilling fluids, and is causing slow equilibration of water levels after drilling and development activities.

Geologic data are available in the form of geologist's logs and geophysical logs. Aquifer tests have been conducted in the wells, water levels are being monitored, and water quality samples collected. These data are being analyzed in the context of the numerical groundwater flow and transport model. The model validation process, including evaluation of the data relative to model predictions, will be reported separately.

Future monitoring will continue tracking water levels in the wells and piezometers. In addition to identifying stable, equilibrated, head values, natural fluctuations in head will be quantified for use in interpreting long-term water level monitoring results per the CADD-CAP. For example, fluctuation due to barometric pressure changes and earth tides will be assessed. Head values for the upper piezometer at MV-2 must be monitored to determine if the loss of the well screen compromises the quality of the water level information.

The low productivity of the wells and deep-set of two of the pumps suggest that purging prior to water quality sampling should be modified from the program outlined in the CADD-CAP. Data from the first round of sampling reported here will be combined with additional sampling and process development to present a modified purging and sampling plan for consideration by DOE and the State regulator.

REFERENCES

Cooper, H.H, J.D. Bredehoeft, and I.S. Papadopulos, 1967. Response to a finite diameter well to an instantaneous charge of water. *Water Resources Research* 3:263-269.

Dinwiddie, G.A. and L.J. Schroder, 1971. Summary of hydraulic testing in and chemical analyses of water samples from deep exploratory holes in Little Fish Lake, Monitor, Hot Creek, and Little Smoky Valleys, Nevada. U.S. Geological survey report USGS-474-90, 66p.

Dinwiddie, G.A., and S.W. West, 1970. Hydrologic phenomena at the Faultless Site, Hot Creek Valley, Nevada. U.S. Geological Survey unnumbered report, 24p.

Driscoll, F.G., 1986. Groundwater and Wells, Second Edition, Johnson Division, St. Paul, Minnesota.

FFACO, 1996. Federal Facility Agreement and Consent Order (as amended). Agreed to by the State of Nevada, U.S. Department of Energy, and U.S. Department of Defense.

Greene, E.A. and A.M. Shapiro, 1995. Methods of conducting air-pressurized slug tests and computation of type curves for estimating transmissivity and storativity. U.S. Geological Survey Open-File Report 95-424, 43 p.

Halford, K.J., and E.L. Kuniansky, 2002. Documentation of Spreadsheets for the Analysis of Aquifer-Test and Slug-Test Data, Open-File Report 02-197, U.S. Geological Survey.

Hassan, A.E., 2003. Long-term Monitoring Plan for the Central Nevada Test Area. Desert Research Institute, Division of Hydrologic Sciences, Publication No. 45201, DOE/NV/13609-30.

Kruseman, G.P. and N.A. de Ridder. 1994, Analysis and Evaluation of Pumping Test Data, Second Edition, Publication 47, International Institute for Land Reclamation and Improvement.

Pohlmann, K., J. Chapman, A. Hassan, and C. Papelis, 1999. Evaluation of Groundwater Flow and Transport at the Faultless Underground Nuclear Test, Central Nevada Test Area. Desert Research Institute, Water Resources Center Publication No. 45165, DOE/NV/11508-41, 129 p.

U.S. Department of Energy (DOE), 1999. Corrective Action Investigation Plan for the Central Nevada Test Area Subsurface Sites (Corrective Action Unit No. 443). Nevada. U.S. Department of Energy, Nevada Operations Office report DOE/NV-483-Rev 1, 86p.

U.S. Department of Energy (DOE), 2004. Corrective Action Decision Document/Corrective Action Plan for Corrective Action Unit 443: Central Nevada Test Area-Subsurface, Central Nevada Test Area. Nevada. National Nuclear Security Administration, Nevada Site Office report DOE/NV--977, 138p.

U.S. Department of Energy (DOE), 2006. Well Installation Report for the Central Nevada Test Area, Nye County, Nevada. National Nuclear Security Administration, Nevada Site Office report DOE/NV--1102, 66p.

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APPENDIX A. Licensed Surveyor Report for CNTA Well Locations.

STOLLER-NAVARRO JOINT VENTURE

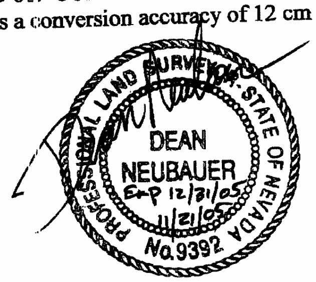
PROJECT : CNTA SITE

SUMMIT ENGINEERING CORPORATION — NOVEMBER 21, 2005

COORDINATE SYSTEM: UTM – ZONE 11
HORIZONTAL DATUM : NAD 27
VERTICAL DATUM : NAVD 29
UNITS : METERS

POINT #	NORTHING	EASTING	ELEVATION	STATION
100	4282057.217	571421.431	1967.527	Tri Sta SMOKY
101	4280577.350	571674.516	1816.040	CP-1
102	4275891.051	569366.331	1818.280	CP-2
103	4275546.933	568501.902	1836.645	HTH-2
104	4275398.582	568542.941	1832.373	HTH-1
105	4275787.443	567574.959	1886.848	MV-2 W
106	4275787.497	567574.882	1886.839	MV-2 L
107	4275787.326	567575.301	1866.918	MV-2 U
108	4275787.569	567575.033	1886.635	MV-2 CONC
109	4276956.419	568260.465	1879.699	MV-3 CONC
110	4276956.303	568260.559	1879.897	MV-3 W
111	4276956.364	568260.664	1879.891	MV-3 L
112	4276956.478	568260.827	1879.906	MV-3 U
113	4277003.054	568977.307	1850.118	MV-1 W
114	4277002.932	568977.354	1850.109	MV-1 L
115	4277002.857	568977.561	1850.128	MV-1 U
116	4277003.273	568977.447	1849.893	MV-1 CONC
117	4276279.398	568298.871	1852.770	UC-1
118	4276272.899	568275.354	1852.992	UC-1-I-2
119	4276255.837	568291.539	1853.002	UC-1-I-1
120	4275995.565	568576.041	1838.304	UC-I-P-1S
121	4276369.793	568314.392	1852.894	UC-I-P-2SR
122	4271596.377	574699.932	1819.006	CP-3
123	4270095.184	577358.546	1786.39	BM 119DOR

The above coordinates were converted from the coordinates created in a field survey conducted in NAD 83 and NAVD 88. CORPSON V6.0.1 was used to convert the coordinates. CORPSCON reports a conversion accuracy of 12 cm to 18 cm form NAD 83 to NAD 27.



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APPENDIX B. Water Level Data for Wells HTH-1, HTH-2, UC-1-P-1S, and UC-1-P-2SR

Sources include the following, as well as internal Desert Research Institute records:

Chapman, J.B., T.M. Mihevc, and B.F. Lyles, 1994. The application of Borehole Logging to Characterize the Hydrogeology of the Faultless Site, Central Nevada Test Area. Desert Research Institute, Water Resources Center publication #45119, DOE/NV/10845-35.

Mihevc, T. and B. Lyles, 1998. Summary of Field Activities at the Faultless Site, Nevada. Desert Research Institute, Water Resources Center Letter Report.

Thordarson, W., 1985. Hydrogeologic Monitoring at the Faultless Site, Nye County, Nevada. U.S. Geological Survey Open-File Report 84-580.

Thordarson, W., 1987. Hydrogeology of the Faultless Site, Nye County, Nevada. U.S. Geological Survey Water-Resources Investigations Report 86-4342.

Table B-1. Water level measurements for HTH-1.

Elevation – 6,010.8 (ft)
Depth – 3,690 (ft)

Date	Water level depth (ft)	Organization
11/21/2005	537.94	DRI
5/16/2005	537.94	DRI
5/15/2005	538.19	DRI
4/14/2005	538.16	DRI
8/31/1998	536.4	DRI (by video log)
10/22/1997	537.4	DRI
10/26/1995	535.08	DRI
5/19/1993	535.35	DRI
7/28/1992	532.2	DRI
5/11/1992	532	USGS
9/19/1991	532	USGS
4/25/1991	532	USGS
12/6/1990	533	USGS
12/6/1990	533	USGS
4/5/1990	532	USGS
10/31/1989	532	USGS
9/21/1989	532	USGS
7/6/1989	533	USGS
7/9/1983	533	USGS
5/6/1976	528	USGS
2/13/1976	528	USGS
8/14/1975	529	USGS
3/12/1975	527	USGS
1/29/1975	529	USGS
9/12/1972	524	USGS
1/13/1972	522	USGS
3/31/1971	517	USGS
10/27/1970	516	USGS
6/12/1970	514	USGS
9/24/1969	504	USGS
5/13/1969	494	USGS
1/14/1969	485	USGS
10/22/1968	476	USGS
9/9/1968	473	USGS
7/17/1968	465	USGS
5/2/1968	431	USGS
4/6/1968	425	USGS
3/27/1968	423	USGS
3/15/1968	413	USGS
2/29/1968	395	USGS
2/19/1968	379	USGS
1/22/1968	337	USGS
1/20/1968	383	USGS
1/19/1968	550	USGS

Table B-2. Water level measurements for HTH-2.

Elevation – 6,024.8 (ft)
Depth – 1,000 (ft)

Date	Water level depth (ft)	Organization
11/25/1997	554.46	DRI
10/26/1995	554.43	DRI
5/19/1993	553.42	DRI
7/29/1992	553.2	DRI
5/11/1992	553	USGS
12/2/1991	556	USGS
10/21/1991	556	USGS
9/19/1991	553	USGS
6/26/1991	553	USGS
4/25/1991	552	USGS
3/6/1991	553	USGS
12/6/1990	554	USGS
4/5/1990	552	USGS
10/31/1989	552	USGS
9/21/1989	552	USGS
7/6/1989	552	USGS
7/9/1983	553	USGS
5/6/1976	553	USGS
2/13/1976	556	USGS
8/14/1975	555	USGS
3/12/1975	552	USGS
1/29/1975	555	USGS
4/9/1974	551	USGS
12/7/1973	555	USGS
6/12/1973	550	USGS
9/12/1972	554	USGS
3/31/1971	551	USGS
10/27/1970	551	USGS
6/12/1970	552	USGS
9/24/1969	555	USGS
5/13/1969	556	USGS
1/14/1969	557	USGS
10/22/1968	556	USGS
9/9/1968	556	USGS
7/17/1968	557	USGS
5/2/1968	557	USGS
4/6/1968	557	USGS
3/27/1968	558	USGS
3/15/1968	558	USGS
2/29/1968	557	USGS
2/19/1968	554	USGS
1/22/1968	493	USGS
1/20/1968	442	USGS
1/19/1968	562	USGS

Table B-3. Water level measurements for UC-1-P-1S.

Elevation – 6,034.5 ft (1,839.3 m)
Depth

Date	Water level depth (ft)	Organization
11/21/2005	274.64	DRI
5/15/2005	274.64	DRI
11/25/1997	273.3	DRI
10/27/1997	271.2	DRI
10/22/1995	273.2	DRI
5/23/1993	271.6	DRI
9/12/1972	266.1	USGS
3/31/1971	263.1	USGS
10/27/1970	264.1	USGS
6/12/1970	260	USGS
9/24/1969	261.2	USGS
5/13/1969	260	USGS
1/14/1969	256	USGS
10/31/1968	254	USGS
9/9/1968	253	USGS
3/1/1968	221.1	USGS
2/11/1968	flowing 0.95 l/s	USGS
2/2/1968	flowing 0.32 l/s	USGS

Table B-4. Water level measurements for UC-1-P-2SR.

Elevation – 6,084.5 ft
Depth – 2,730 ft

Water level record date	Water level depth (ft)	Organization
7/16/2005	555.18	DRI
9/1/1998	621	DRI – video log
10/23/1997	637.8	DRI
10/24/1995	672.9	DRI
5/24/1993	727.7	DRI
8/6/1992	750.6	DRI
5/11/1992	758	USGS
12/2/1991	769	USGS
10/21/1991	773	USGS
9/19/1991	775	USGS
6/26/1991	780	USGS
4/25/1991	788	USGS
3/6/1991	774	USGS
12/6/1990	798	USGS
11/13/1990	793	USGS
4/5/1990	817	USGS
10/31/1989	831	USGS
9/21/1989	834	USGS
7/6/1989	841	USGS
4/3/1989	850	USGS
10/19/1988	866	USGS
5/25/1988	881	USGS
10/21/1987	904	USGS
7/1/1987	917	USGS
7/22/1986	960	USGS
10/30/1985	984	USGS
4/2/1985	1,022	USGS
1/22/1985	1,031	USGS
10/31/1984	1,044	USGS
1/19/1984	1,081	USGS
10/18/1983	1,099	USGS
7/18/1983	1,117	USGS
4/8/1983	1,138	USGS
1/13/1983	1,155	USGS
11/16/1982	1,165	USGS
7/21/1982	1,189	USGS
7/19/1982	1,188	USGS
4/7/1982	1,210	USGS
1/27/1982	1,222	USGS
10/7/1981	1,248	USGS
6/24/1981	1,269	USGS
3/14/1981	1,294	USGS
12/2/1980	1,317	USGS
7/15/1980	1,353	USGS

Table B-4. Water level measurements for UC-1-P-2SR (continued).

Elevation – 6,084.5 ft
Depth – 2,730 ft

Water level record date	Water level depth (ft)	Organization
2/28/1980	1,389	USGS
12/4/1979	1,411	USGS
9/9/1979	1,443	USGS
5/22/1979	1,470	USGS
12/11/1978	1,523	USGS
9/14/1978	1,554	USGS
6/13/1978	1,590	USGS
10/20/1977	1,694	USGS
6/15/1977	1,757	USGS
2/28/1977	1,804	USGS
11/18/1976	1,843	USGS
8/30/1976	1,879	USGS
5/6/1976	1,925	USGS
2/13/1976	1,965	USGS
11/13/1975	2,007	USGS
8/14/1975	2,058	USGS
5/15/1975	2,116	USGS
4/14/1975	2,137	USGS
3/13/1975	2,150	USGS
2/6/1975	2,183	USGS
9/24/1974	2,283	USGS
4/10/1974	2,287	USGS
4/9/1974	2,285	USGS
12/10/1973	2,285	USGS
12/7/1973	2,286	USGS
6/12/1973	2,284	USGS
6/11/1973	2,284	USGS
9/12/1972	2,280	USGS
1/12/1972	2,277	USGS
10/28/1971	2,274	USGS
9/23/1971	2,272	USGS
8/24/1971	2,275	USGS
8/10/1971	2,277	USGS
7/15/1971	2,284	USGS
3/31/1971	2,292	USGS
12/1/1970	2,296	USGS
10/27/1970	2,296	USGS
6/12/1970	2,268	USGS
4/11/1970	2,339	USGS
9/24/1969	2,223	USGS
5/13/1969	2,216	USGS
1/14/1969	2,203	USGS
7/13/1968	2,132	USGS
6/5/1968	2,120	USGS
4/9/1968	2,144	USGS

APPENDIX C. Chemical and Isotopic Data from Wells HTH-1, HTH-2, UC-1-P-1S, and UC-1-P-2SR.

Table C-1. Chemical and isotopic analysis of groundwater samples from the Faultless site. All units are mg/L unless noted otherwise (from Chapman *et al*. (1994) and Mihevc and Lyles (1998).

Well	Depth (m)	Date	T (C°)	pH* (S.U.)	EC* (μS/cm)	SiO_2	Ca	Mg	Na	K	Cl	SO_4	HCO_3^*	CO_3	NO_3	F	^{13}Cl (‰)	^{14}Cl (pmc)	^{14}C age (yr)	$\delta^{18}O$ (‰)	δD (‰)	^3H (pCi/L)
HTH-1	183	14-Nov-93																				<10
HTH-1	236	28-Jul-92	23	8.23/8.40	536/545	55.4	3.28	0.10	126	1.52	16.7	33.5	189/238	4.1	<.04	9.4	-2.4	1.7	32,730	-15.4	-117	214 ± 7
HTH-1	236	14-Nov-1993																				<10
HTH-1	236	27-Oct-1997																				<10
HTH-1	274	14-Nov-1993																				<10
HTH-1	320	28-Jul-1992	26	8.35/8.31	519/539	56.0	3.10	0.07	125	1.39	16.8	33.4	217/243	0.6	<.04	10.4				-15.4	-117	33 ± 1
HTH-1	320	14-Nov-1993																				<10
HTH-1	442	28-Jul-1992	26	8.38/8.30	542/542	56.5	3.53	0.07	125	1.37	16.8	33.5	211/244	0.4	<.04	10.4				-15.4	-117	
HTH-1	501	14-Nov-1993																				<10
HTH-1	515	28-Jul-1992	26	8.27/8.43	516/546	57.5	4.51	0.09	125	1.37	16.8	33.4	220/238	4.7	<.04	10.5				-15.4	-117	
HTH-1	578	28-Jul-1992	25	8.34/8.32	524/540	56.8	3.22	0.07	127	1.37	16.8	33.1	211/242	0.9	<.04	10.5				-15.4	-118	
HTH-1	686	28-Jul-1992	24	8.44/8.40	516/543	57.1	3.06	0.05	125	1.42	17.0	33.5	226/237	3.6	<.04	10.5				-15.5	-118	
HTH-1	741	29-Jul-1992	24.5	8.25/8.27	509/548	64.3	2.95	0.06	128	1.55	18.2	33.4	199/247		<.04	9.4				-15.4	-118	<10
HTH-1	741	27-Oct-1997	20.1	8.32/8.40	546/547		2.77	<0.1	124	1.41	17.2	34.6	/240	3	<.04							<5
HTH-1	815	29-Jul-1992	26.5	8.15/8.24	508/561	66.2	2.93	0.07	129	1.55	19.1	34.5	205/249		<.04	10.4	-2.4	1.4	35,110	-15.5	-118	
HTH-1	853	20-May-1993		8.17	588	68.4	3.0	0.1	134	2.16	21.4	38.9	261		<.04							
HTH-1	853	27-Oct-1997	18.4	8.36/8.29	603/593	69.9	2.9	<0.1	136	1.54	20.5	36.2	260	1.1	<.01							<5
HTH-2	174	22-May-1993		8.01	287	28.3	36.9	5.24	19.1	1.44	4.1	0.66	177		3.19					-14.1	-107	<10
HTH-2	174	27-Oct-1997	16.9	8.24/8.20	255/286	28.8	36.0	5.17	17.9	1.50	4.5	5.93	174		3.63							<5
HTH-2	198	6-Aug-1992		8.27	304	28.9	40.7	5.48	19.0	1.47	2.7	4.11	194		2.13					-14.3	-108	<10
HTH-2	229	29-Jul-1992	19.5	7.84/8.10	303/300	29.2	40.8	5.52	19.0	1.47	2.6	4.08	177/196		2.22	0.08	-7.3	75.5	2,320	-14.2	-107	
HTH-2	229	22-May-1993																		-14.3	-106	
HTH-2	274	22-May-1993																		-13.9	-105	
HTH-2	297	29-Jul-1992	20.5	7.94/8.13	299/293	29.5	40.8	5.49	18.4	1.44	2.6	4.08	161/197		2.22	0.06				-14.2	-107	
HTH-2	297	27-Oct-1997	18.6	8.10	272																	<5

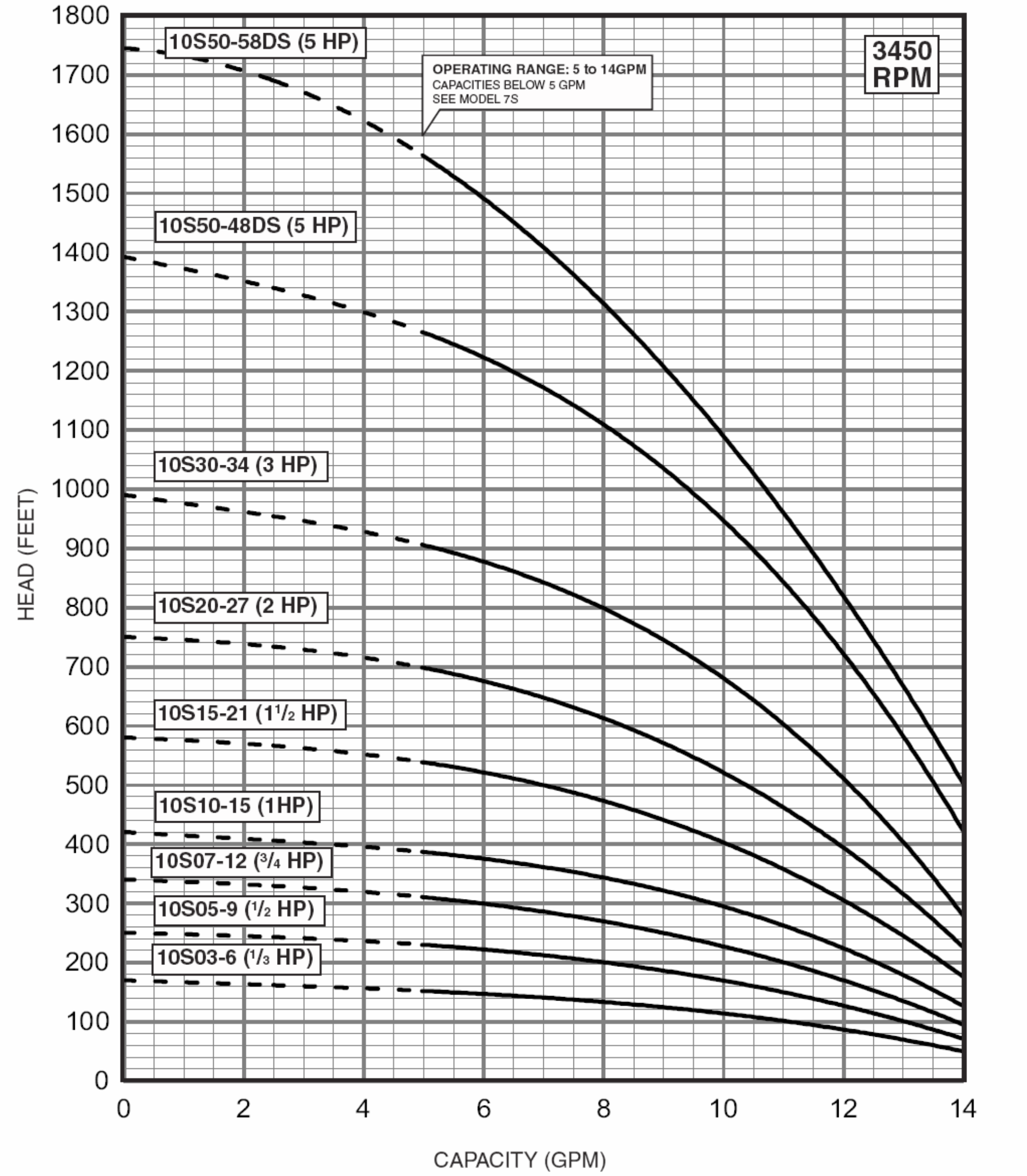
Table C-1. Chemical and isotopic analysis of groundwater samples from the Faultless site. All units are mg/L unless noted otherwise (from Chapman *et al*. (1994) and Mihevc and Lyles (1998) (continued).

Well	Depth (m)	Date	T (C°)	pH* (S.U.)	EC* (µS/cm)	SiO_2	Ca	Mg	Na	K	Cl	SO_4	HCO_3^*	CO_3	NO_3	F	^{13}Cl (‰)	^{14}Cl (pmc)	^{14}C age (yr)	$\delta^{18}O$ (‰)	δD (‰)	^3H (pCi/L)
UC-1-P-1S	91	23-May-1993		8.27	217	25.5	23.5	1.78	23.1	1.38	2.6	0.62	134		1.33					-14.1	-104	<10
UC-1-P-1S	150	27-Oct-1997	19.8	7.96/8.33	196/213	22.3	22.5	1.59	22.2	1.40	2.8	5.24	128		1.33							<5
UC-1-P-1S	229	23-May-1993		8.16	217	24.5	23.1	1.70	23.0	1.36	2.9	0.64	134		1.37					-14.1	-105	<10
UC-1-P-1S	229	27-Oct-1997	20.2	7.87/8.24	205/217	24.9	24.4	1.65	22.0	1.43	2.4	5.01	134		1.02							<5
UC-1-P-2SR	208	26-Oct-1995																				4870 ± 242
UC-1-P-2SR	238	July-1992															-6.5	30.4	9,340			6760 ± 234
UC-1-P-2SR	238	24-May-1993		9.86	277	6.0	1.40	0.22	59.9	1.32	7.6	16.6	58.0	38.9	<.04					-15.1	-114	8680 ± 407
UC-1-P-2SR	238	15-Nov-1993																				6760 ± 234
UC-1-P-2SR	320	26-Oct-1995																				4520 ± 241
UC-1-P-2SR	471	29-Jul-1992																		-15.1	-115	
UC-1-P-2SR	485	29-Jul-1992															-8.6	32.3	9,340	-15.1	-115	
UC-1-P-2SR	485	24-May-1993		9.86	282	15.4	1.80	0.22	61.6	1.15	5.0	21.1	53.6	41.1	<.04					-15.1	-114	5210 ± 329
UC-1-P-2SR	485	15-Nov-1993																				4510 ± 285
UC-1-P-2SR	485	26-Oct-1995																				4510 ± 225
UC-1-P-2SR	485	23-Oct-1997	19.2	9.74/9.72	253/281	17.6	1.69	<0.1	59.8	1.06	4.5	22.1	63.4	35.1	0.09							4020 ± 1180
UC-1-P-2SR	561	26-Oct-1995																				4340 ± 244
UC-1-P-2SR	575	23-Oct-1997	17.3	9.93/9.70	244/281	17.5	1.57	<0.1	60.7	1.09	4.5	22.1	63.2	34.9	0.04					-15.1	-116	4020 ± 1190
UC-1-P-2SR	668	29-Jul-1992																		-15.1	-116	
UC-1-P-2SR	668	24-May-1993		9.10	343	30.6	2.69	<.1	78.1	0.80	6.1	30.7	124	19.8	<.04					-15.4	-115	220,000 ± 1840
UC-1-P-2SR	668	15-Nov-1993																				6600 ± 245
UC-1-P-2SR	668	26-Oct-1995																				143,000 ± 1100
UC-1-P-2SR	786	24-May-1993																		-13.1	0	

APPENDIX D. Specifications for the Pumps in the MV Wells.

PERFORMANCE CURVES 10 GPM MODEL 10S

FLOW RANGE: 5 -14 GPM OUTLET SIZE: 1¼ " NPT NOMINAL DIA. 4"



SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.
4" MOTOR STANDARD, 3450 RPM.

Performance conforms to ISO 9906. 1999 (E) Annex A
Minimum submergance is 2 feet.

GRUNDFOS 4-15

DIMENSIONS AND WEIGHTS

MODEL NO.	FIG.	HP	MOTOR SIZE	DISCH. SIZE	DIMENSIONS IN INCHES A	B	C	D	E	APPROX. SHIP WT.
10S03-6	A	1/3	4"	1 1/4" NPT	19.9	8.8	11.1	3.8	3.9	26
10S05-9	A	1/2	4"	1 1/4" NPT	23.0	9.5	13.5	3.8	3.9	29
10S07-12	A	3/4	4"	1 1/4" NPT	26.7	10.7	16.0	3.8	3.9	32
10S10-15	A	1	4"	1 1/4" NPT	30.3	11.8	18.5	3.8	3.9	34
10S15-21	A	1 1/2	4"	1 1/4" NPT	37.1	13.6	23.5	3.8	3.9	44
10S20-27	A	2	4"	1 1/4" NPT	43.5	15.1	28.4	3.8	3.9	49
10S30-34	A	3	4"	1 1/4" NPT	54.7	20.6	34.1	3.8	3.9	83
10S50-48DS	A	5	4"	1 1/4" NPT	71.3	23.6	47.7	3.8	3.9	115
10S50-58DS*	B	5	4"	1 1/4" MPT	88.2	23.6	64.5	3.8	4.3	142

NOTES: All models suitable for use in 4" wells, unless otherwise noted.
Weights include pump end with motor in lbs.
* Built into sleeve 1¼" MPT discharge, 5" min. well dia.

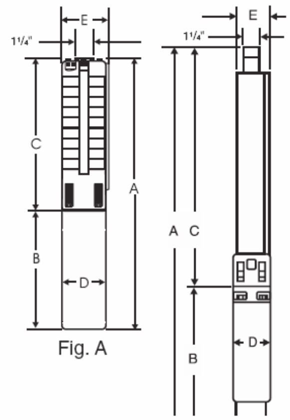


Fig. A Fig. B

MATERIALS OF CONSTRUCTION

COMPONENT	SPLINED SHAFT (6-27 Stgs.)	CYLINDRICAL SHAFT (34-48 Stgs.)	DEEP SET (58 Stgs.)
Check Valve Housing	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel
Check Valve	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel
Diffuser Chamber	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel
Impeller	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel
Suction Interconnector	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel
Inlet Screen	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel
Pump Shaft	304 Stainless Steel	431 Stainless Steel	431 Stainless Steel
Straps	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel
Cable Guard	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel
Priming Inducer	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel
Coupling	316/431 Stainless Steel	316/431 Stainless Steel	316/431 Stainless Steel
Check Valve Seat	NBR/304 Stainless Steel	NBR/316 Stainless Steel	NBR/316 Stainless Steel
Top Bearing	NBR	NBR/316 Stainless Steel	NBR/316 Stainless Steel
Impeller Seal Ring	NBR/PBT (Valox®)	NBR/PPS (Ryton®)	NBR/PPS (Ryton®)
Intermediate Bearings	NBR	304 Stainless Steel	NBR/316 Stainless Steel
Shaft Washer	Not Required	LCP (Vectra®)	LCP (Vectra®)
Split Cone	Not Required	304 Stainless Steel	304 Stainless Steel
Split Cone Nut	Not Required	316 Stainless Steel	304 Stainless Steel
Sleeve	Not Required	Not Required	316 Stainless Steel
Sleeve Flange	Not Required	Not Required	Zincless Bronze*

NOTES: Specifications subject to change without notice.
Valox® is a registered trademark of General Electric Co.
Vectra® is a registered trademark of Hoechast Calanese Corporation.
Ryton® is a registered trademark of Phillips 66.
*** Stainless Steel option available.**

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