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Hydrologic Data Analysis Report for Test Well CAV6002X in Cave Valley Hydrographic Area 180

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Hydrologic Data Analysis Report for Test Well CAV6002X in Cave Valley Hydrographic Area 180

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June 2011

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SOUTHERN NEVADA WATER AUTHORITY
Groundwater Resources Department
Water Resources Division
snwa.com

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ACRONYMS

Barker GRFM	Barker generalized radial flow model
EPA	U.S. Environmental Protection Agency
HSLA	high strength low alloy
MCL	maximum contaminant level
MS	mild steel
NAD83	North American Datum of 1983
SNWA	Southern Nevada Water Authority
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator

ABBREVIATIONS

°C	degrees Celsius
amsl	above mean sea level
bgs	below ground surface
cm	centimeter
ft	foot
gal	gallon
gpm	gallons per minute
I.D.	inside diameter (of casing)
in.	inch
in. Hg	inches of mercury
L	liter
m	meter
mEq	milliequivalent
mg	milligram
mi	mile
min	minute
ml	milliliter
mrem	millirem
µg	microgram
µS	microsiemen
NTU	nephelometric turbidity unit
O.D.	outside diameter (of casing)
‰	per mil

ABBREVIATIONS (CONTINUED)

pmc	percent modern carbon
pCi	picocurie
yr	year

ES.1.0 EXECUTIVE SUMMARY

In support of its Clark, Lincoln, and White Pine Counties Groundwater Development Project, Southern Nevada Water Authority (SNWA) installed test and monitor wells in Cave Valley (Hydrographic Area 180) to evaluate hydrogeologic conditions. This report documents the collection, analysis, and evaluation of data obtained during the well development and hydraulic testing of Test Well CAV6002X, 180W902M and Monitor Well CAV6002M2 located in southeastern Cave Valley, Lincoln County, Nevada. This report also presents groundwater-level data collected at the site post-test through January, 2011.

The development and hydraulic testing program at this site included development and testing at Test Well CAV6002X, using Monitor Wells 180W902M and CAV6002M2 as observation wells, then subsequent development and testing at Monitor Well 180W902M, using Test Well CAV6002X and Monitor Well CAV6002M2 as observation wells. This development and testing program was performed from November 22, 2007, through January 8, 2008.

The three wells, CAV6002X, 180W902M, and CAV6002M2 are completed stratigraphically in unconsolidated gravel to clayey gravel alluvium and the Guilmette Limestone and Simonson Dolomite Formations to depths of 917 ft bgs, 917 ft bgs, and 893 ft bgs, respectively. The aquifer is unconfined and exhibited a typical delayed gravity drainage response during hydraulic testing. Static depth to water in the wells are approximately 144, 142, and 139 ft bgs, respectively.

The development phase of pumping at Test Well CAV6002X extracted 6,057,000 gallons of water and improved specific capacity, a ratio of discharge (Q) to drawdown (s) in the test well, from 6.00 gpm/ft during development, to 10.67 gpm/ft during the step test, at 800 gpm for a 77.8 percent improvement. A four-interval step-drawdown test was conducted at discharge rates ranging from 800 to 1,500 gpm to evaluate the well performance over a range of pumping rates, evaluate well loss coefficients, and determine the optimal discharge rate for the constant-rate test. A step drawdown test was not performed on 180W902M.

Two 72-hour constant-rate tests were performed at discharge rates of 1,217 gpm and 1,112 gpm, at Test Well CAV6002X, and Monitor Well 180W902M, respectively. Specific capacity during the last 12 hours of the 1,217 gpm, 72-hour constant-rate test at Test Well CAV6002X ranged from 6.30 to 6.36 gpm/ft. Specific capacity during the last 12 hours of the 1,112 gpm, 72-hour constant-rate test at Well 180W902M ranged from 81.29 to 82.55 gpm/ft. A total of 11,875,200 gallons were pumped during development and testing at well CAV6002X, and a total of 7,984,250 gal were pumped at well 180W902M during development and testing at well 180W902M.

Site hydrogeologic data and diagnostic drawdown data plots indicated that an unconfined delayed gravity drainage response model is the most appropriate solution method. The Neuman unconfined solution (1974) was chosen as the primary solution for both constant-rate tests. A secondary

analytical solution using the Cooper-Jacob approximation (Cooper and Jacob, 1946) was also applied for comparison purposes on selected data sets with sufficient late time data after the delayed gravity drainage response. Analyses were performed using AQTESOLV evaluation software.

Results of the analyses suggest horizontal anisotropy as *T* values in the general north-south direction were higher than those in the northwest-southeast and east-west directions. The *T* value derived from CAV6002X and 180W902M with the Neuman unconfined solution is 23,600 ft^2/day. *T* values derived from observation well CAV6002M2 while pumping CAV6002X and 180W902M with the Neuman unconfined solution range from 9,100 to 12,000 ft^2/day. This equates to a range of hydraulic conductivity (*K*) from all data of approximately 11.7 to 30.4 ft/day assuming a saturated thickness of 776 ft. Specific yield values range from 0.001 to 0.12. The estimated effective saturated thickness used has a direct proportional relationship to the *K* value derived from *T.* Partial penetration of the test and monitor wells was also considered.

Groundwater samples were collected from Test Well CAV6002X and Monitor Well 180W902M and analyzed for a suite of chemical parameters. Stabilization of the water-quality parameters, measured in the field, was observed prior to sample collection. The chemistry of these samples was compared to that of other SNWA wells in the vicinity. All samples exhibited a calcium-magnesium-bicarbonate facies characteristic of groundwater of a carbonate-rock aquifer.

Light stable isotope (δD and $\delta^{18}O$) compositions, typical of recharge at high elevations and cold temperatures, were observed for all the groundwater samples. All the samples plotted below the GMWL and suggests slight evaporative enrichment prior to recharge. The isotopic composition of chloride ($^{36}Cl/Cl$) was also consistent with that of precipitation in the southwestern United States. The isotopic compositions of carbon (^{14}C and $\delta^{13}C$) and strontium ($^{87}Sr/^{86}Sr$) were indicative of groundwater interaction with carbonate minerals along the flow path.

1.0 INTRODUCTION

In support of its Clark, Lincoln, and White Pine Counties Groundwater Development Project, Southern Nevada Water Authority (SNWA) installed test and monitor wells in Cave Valley (Hydrographic Area 180) to evaluate hydrogeologic conditions. This report documents the collection, analysis, and evaluation of data obtained during the well development and hydraulic testing of Test Well CAV6002X and Monitor Wells 180W902M and CAV6002M2 located in southeastern Cave Valley, Lincoln County, Nevada. The three wells are completed within alluvial gravel to clayey gravel and fractured carbonate aquifer of the Guilmette and Simonson stratigraphic units. This report also presents groundwater-level data collected at the site post-test through January 2011.

Two separate documents entitled *Geologic Data Analysis Report for Monitor Well 180W902M in Cave Valley* (Eastman, 2007), and *Well Completion and Geologic Data Analysis Report for Monitor Well CAV6002M2 and Test Well CAV6002X in Cave Valley* (Baird, 2011) includes the documentation and detailed results for the drilling programs at these wells. The data in these reports includes evaluation of lithology, structural features, drilling parameters, and geophysical logs.

1.1 Program Objectives

The objectives of developing Test Well CAV6002X and Monitor Well 180W902M were to remove any remaining drilling fluids and improve the hydraulic connection with the formation. This phase of development consisted of pump and surge activities and was in addition to the airlifting and swabbing development that were performed immediately after well installation.

Hydraulic testing was performed to evaluate well performance and to provide data on the hydraulic properties of the carbonate-rock aquifer in the vicinity of the test and monitor wells. Groundwater samples were also collected from Test Well CAV6002X for laboratory analysis to evaluate the groundwater chemistry of the aquifer in the vicinity of the well.

1.2 Testing and Monitoring Program

The well development and hydraulic testing program was performed from November 22, 2007, through January 6, 2008, and consisted of the following activities:

- Final well development, using surging methods
- Well hydraulic testing and performance evaluation at well CAV6002X, using a four-interval step-drawdown test

- Aquifer-property evaluation testing, using two separate 72-hour constant-rate tests at wells CAV6002X and 180W902M and subsequent water-level recovery measurements

- Collection of groundwater samples from well CAV6002X for laboratory chemical analysis

A complete schedule of test program activities is presented in Section 3.1.

Monitor Well 180W902M is part of the Dry Lake, Delamar, and Cave Valley regional baseline water-level monitoring network. Water-level data have been collected continuously from this location since April 2007.

1.3 Report Organization

This report is divided into seven sections and two appendixes.

Section 1.0 presents introductory information about the testing program and this report.

Section 2.0 describes the well site hydrogeology and summarizes the well construction, borehole lithology, and water-level data for the test and monitor wells.

Section 3.0 describes the test program and presents information on test instrumentation and background data.

Section 4.0 presents the analysis and evaluation of the results from the test well development and performance step-drawdown testing.

Section 5.0 presents the analysis and evaluation of the constant-rate aquifer test.

Section 6.0 presents the groundwater-chemistry results and evaluation.

Section 7.0 provides a list of references cited in this report.

Appendix A presents site photos and documentation of site physical and transducer test data. The data package on the CD-ROM includes regional background monitor well water levels, barometric pressure, and hydrologic data collected from the test and monitor wells.

Appendix B presents the water-chemistry laboratory data reports.

2.0 WELL SITE DESCRIPTION

SNWA Test Well CAV6002X and Monitor Well 180W902M are located on the southeast side of Cave Valley, on Bureau of Land Management property, approximately 22 mi south of the Lincoln County and White Pine County boundary in Section 19, T06N, R64E. Access to the site is from U.S. Highway 93 along a dirt road to the west approximately 14 mi. A topographic map with the site location and other SNWA monitor wells installed as of June 2011 is presented on Figure 2-1.

The well site contains three wells. These three wells consist of one 20-in. exploratory well (CAV6002X), one 12-in. Monitor Well (180W902M), and one 6-in. Monitor Well (CAV6002M2). These wells were set up in two separate configurations for testing, based on which well was being pumped. The first configuration consisted of CAV6002X as the pumped well, with 180W902M and CAV6002M2 as the observation wells. The second configuration consisted of 180W902M as the pumped well, with CAV6002X and CAV6002M2 as the observation wells. One monitor well was used as the background well, USGS Well 382807114521001. This well was used as to observe background conditions during testing, is located approximately 8 mi northwest of the test well site.

2.1 Hydrogeologic Setting

This section presents the regional and local hydrogeologic setting of the Test Well CAV6002X well site. Previous studies and reports that detail the regional hydrogeology are referenced. A description of the local hydrogeologic setting is provided and is based on field mapping and review of existing hydrogeologic and geophysical information.

2.1.1 Regional Hydrogeologic Setting

Cave Valley, located in east-central Nevada, is approximately 40 mi in length and averages approximately 12 mi in width. The valley is located within the Basin and Range province and is part of the White River Flow System. It is bounded by the Egan Range to the west, the Schell Creek Range and the smaller Fairview Range to the east. Adjacent valleys are shown in Figure 2-1.

The primary aquifer systems within Cave Valley are carbonate and basin fill, with some volcanic rocks occurring in the southern portion of the valley. A northeast-southwest trending fault at Shingle Pass effectively partitions Cave Valley into two distinct but connected sub-basins. Extensive north-south-trending range-front faults and related structures are the primary control of groundwater flow in the carbonates and are present on both the east and west sides of the valley. Regional groundwater flow in Cave Valley is postulated to occur west through Shingle Pass into White River Valley, and south into Pahroc Valley.

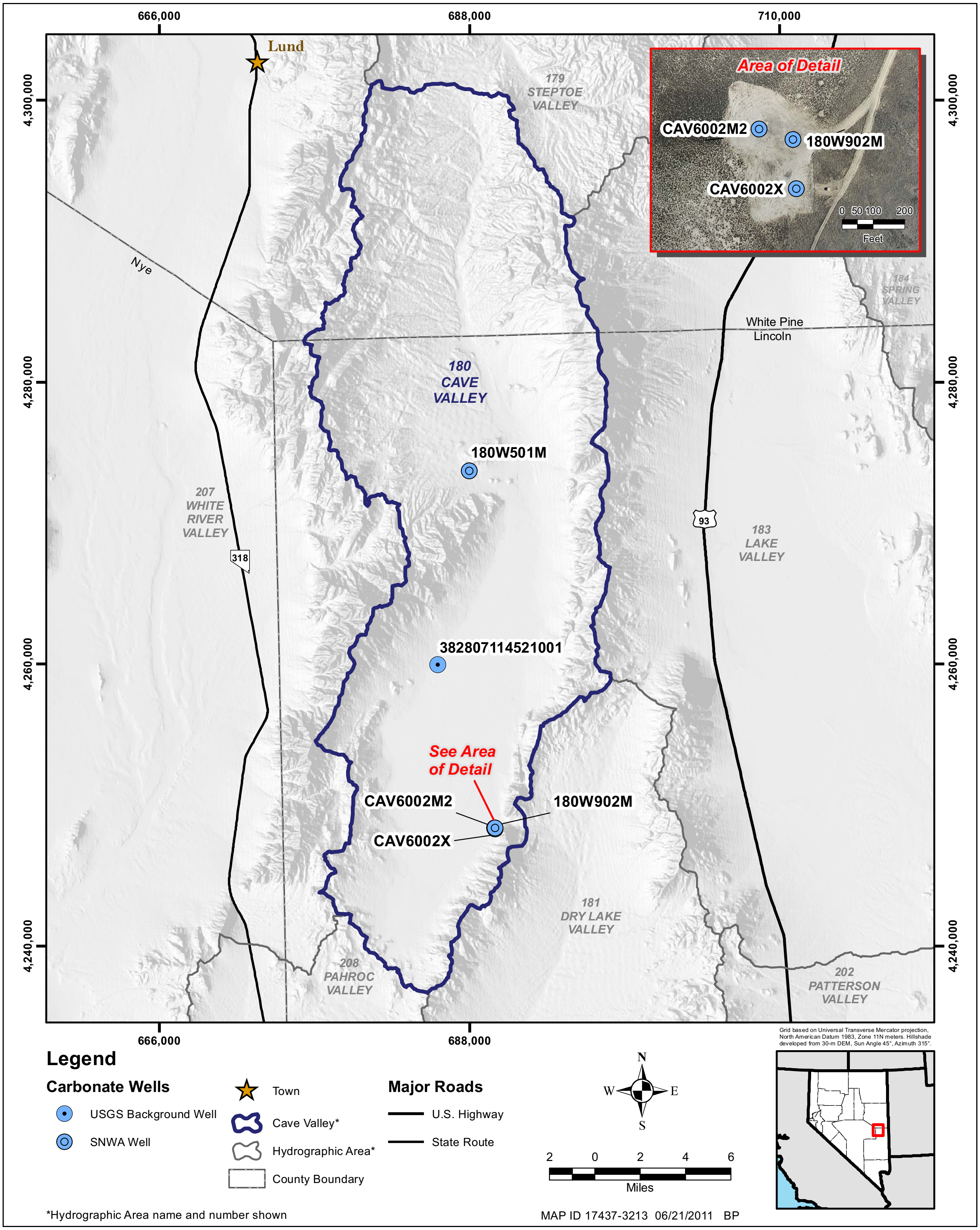


Figure 2-1
Monitor and SNWA Test Wells in Cave Valley (as of June 2011)

Numerous studies related to Cave Valley and adjacent basins have been performed since the late 1940s. These studies have included water-resource investigations, geologic and hydrogeologic investigations, recharge and discharge estimations, and other hydrologic studies. The regional hydrogeologic framework and a summary of results of previous studies have been presented in several reports. These reports include:

- *Ground-Water Appraisal of Cave Valley in Lincoln and White Pine Counties, Nevada* (Eakin, T. E., 1962)
- *Major Ground-Water Flow Systems in the Great Basin Region of Nevada, Utah, and Adjacent States* (Harrill et al., 1988)
- *Water Resources of the Basin and Range Carbonate-Rock Aquifer System, White Pine County Nevada, and Adjacent Areas in Nevada and Utah* (Welch et al., 2007)
- *Geology and Geophysics of Spring, Cave, Dry Lake, and Delamar Valleys, White Pine and Lincoln Counties and Adjacent Areas, Nevada and Utah: The Geologic Framework of Regional Groundwater Flow Systems* (Rowley, et al., 2011)
- *Hydrology and Water Resources of Spring, Cave, Dry Lake, and Delamar Valleys, Nevada and Vicinity* (Burns and Drici, 2011)
- *Committed Groundwater Resources in four Nevada Hydrographic Areas: Cave, Dry Lake, Delamar, and Spring Valleys* (Stanka, 2011)
- *SNWA Hydrologic Management Program for Groundwater Development in Spring, Cave, Dry Lake, and Delamar Valleys, Nevada* (Prieur, 2011)
- *Delamar, Dry Lake, and Cave Valley stipulation agreement hydrologic monitoring plan status and data report* (SNWA, 2008)
- *Delamar, Dry Lake, and Cave Valley stipulation agreement hydrologic monitoring plan status and historic data report* (SNWA, 2009)
- *2009 Delamar, Dry Lake, and Cave Valley Hydrologic Monitoring and Mitigation Plan Status and Data Report* (SNWA, 2010)
- *2010 Delamar, Dry Lake, and Cave Valley Hydrologic Monitoring and Mitigation Plan Status and Data Report* (SNWA, 2011)
- *Environmental Evaluation Regarding SNWA Applications in Spring, Cave, Dry Lake, and Delamar Valleys* (Marshall and Luptowitz, 2011)

2.1.2 Local Hydrogeologic Setting

The site location was selected after conducting a geologic reconnaissance of the area including field mapping, review of regional geophysical and well data, and evaluation of surface structural features using aerial photography. Regional data and geologic mapping in the vicinity indicate the presence of faulting and related structures at the site. A surface geophysical profile was performed in the vicinity of the well site by the U.S. Geological Survey (USGS) and SNWA. The results are discussed in *Audiomagnetotelluric data from Spring, Cave, and Coyote Spring valleys, Nevada* (McPhee et. al., 2006) and geologically interpreted in *Audiomagnetotelluric Investigations in Selected Basins in White Pine and Lincoln Counties, East-Central Nevada* (Pari and Baird, 2011).

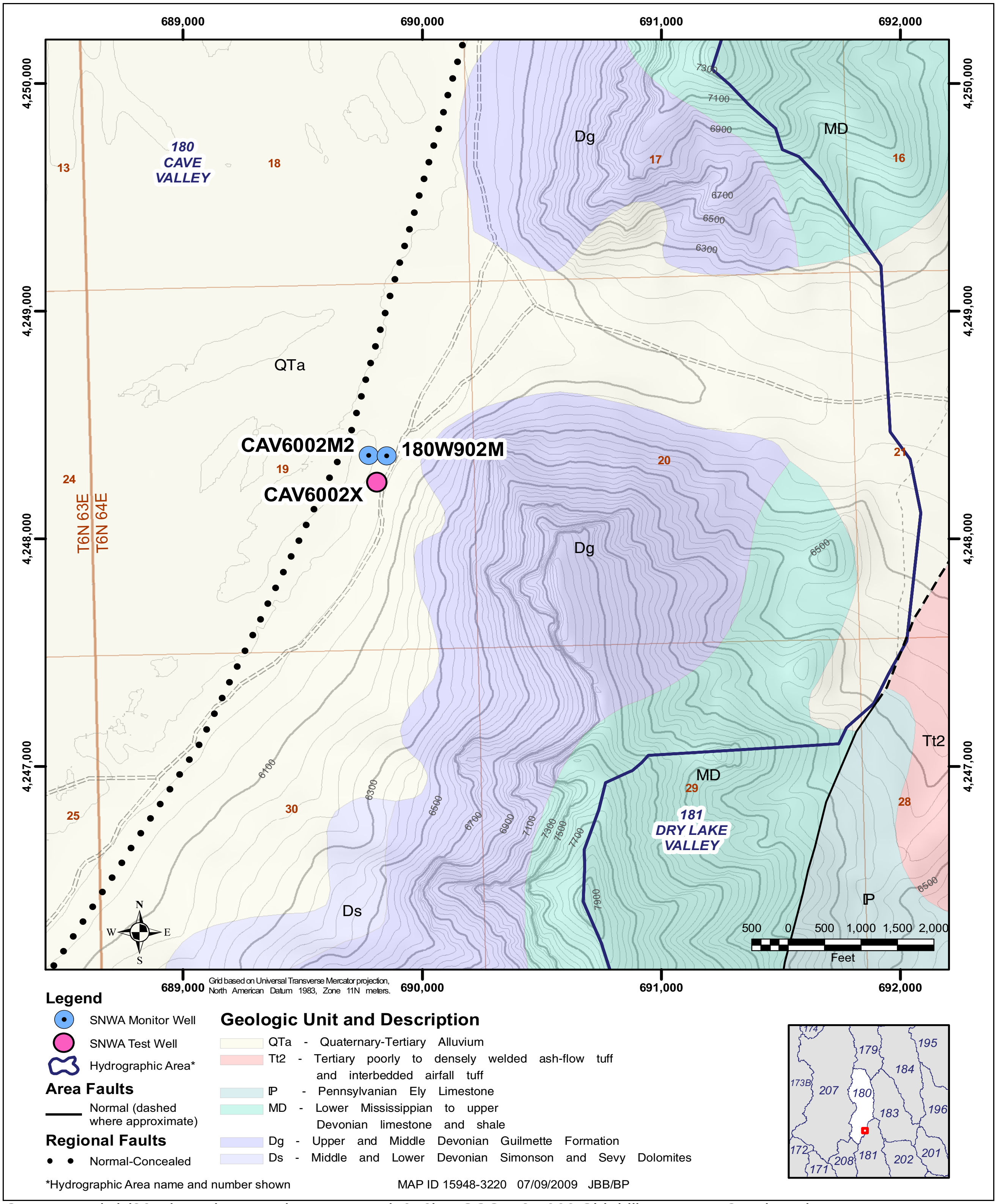
The existing Monitor Well 180W902M was completed in 2005 and provided data on specific hydrogeologic conditions at the site. Test and Monitor Wells CAV6002X and CAV6002M2 were completed at this location to supplement the data from 180W902M and provide more detailed aquifer property data. This provided a three-well configuration where multiple constant-rate aquifer tests could be conducted to evaluate the hydrogeologic properties of the site and influence of structural features.

Quaternary/Tertiary alluvium, composed of saturated gravel to clayey gravel, is underlain by carbonate formations at the well site with a contact depth of approximately 420 to 460 ft bgs. The Devonian Guilmette Formation is underlying the alluvium in wells 180W902M and CAV6002X, which is underlain in turn by the Devonian Simonson Dolomite. The Guilmette Formation is absent from well CAV6002M2, and the Simonson Dolomite directly underlays the alluvium. Groundwater levels at the three sites, as discussed later in this section, ranged from 136 to 144 ft bgs which corresponds to a ground water elevation range of 5,848 to 5,843 ft amsl.

The Guilmette Formation has a total thickness of about 2,000 ft in the southern Egan Range to the west of the well site. The lower member is primarily a massive limestone unit up to 660 ft thick, while the upper member is alternating massive limestone and brown silty dolomite layers. The Simonson Dolomite is approximately 1,200 ft thick (Kellog, 1963: Tschanz and Pampeyan, 1970). The primary difference between the Guilmette Formation and the Simonson Dolomite is that the Guilmette is dominantly a limestone with thin dolomite sequences between thick limestone sections, while the Simonson Dolomite is nearly all dolomite (Tschanz and Pampeyan, 1970).

The test and monitor wells are located east of a normal-concealed fault as depicted in Figure 2-2. More detailed discussion of local geologic structure is presented in (Baird, 2011). Fracturing associated with the fault zone may be present on site with primary fracture orientation parallel to the fault.

Detailed geologic data for lithologic and hydrogeologic evaluation were collected during drilling and field mapping. This included collection and identification of drill cuttings, documentation of drilling parameters including penetration rate, fluid loss and mud viscosity, and downhole geophysical logging. Presentations and analyses of the site geologic data, including local structural features and fracture distribution and characteristics observed in the downhole geophysical logging, are presented in the associated geologic data analysis reports (Baird, 2011; Eastman, 2007).



Source: Baird (2011); Tschanz and Pampeyan (1970); USGS 1:24,000 Sidehill Pass 7.5' Quadrangle.

Figure 2-2
Surficial Geology for Monitor Wells 180W902M and CAV6002M2, and Test Well CAV6002X

2.2 Testing Program Monitoring Locations

Four wells, consisting of the test well, two monitor wells, and one background well were monitored throughout the testing program. Site attribute, lithologic, and hydrologic information for the locations are present in this section. Historic hydrographs for each well through January 2011 is presented.

2.2.1 Monitor Well 180W902M

Monitor Well 180W902M was drilled to a total depth of 917 ft bgs between October 9 and October 19, 2005, using mud rotary techniques. A 24-in. O.D. conductor casing was placed to a depth of 77 ft bgs and grouted in place. After the borehole was advanced to completion depth, downhole geophysical logging was performed. A 12.75-in. O.D. (12-in. I.D.) completion string, including approximately 687 ft of slotted screen, was then installed. The gravel pack extends the from ground surface to the bottom of the borehole. A summary chart of Monitor Well 180W902M drilling and well construction statistics is presented in Table 2-1, and a well construction schematic is presented on Figure 2-3. The borehole lithologic log for Monitor Well 180W902M is presented in Figure 2-4.

2.2.2 Test Well CAV6002X

Test Well CAV6002X was completed at a depth of 917 ft bgs between October 17 and October 28, 2007. A 32-in. O.D. conductor casing was set to a depth of 60 ft bgs and grouted in place. A 26-in. borehole was then advanced to completion depth. The 20-in. nominal-diameter completion string, including 682 ft of slotted casing, was placed in the open borehole. The gravel pack extends from a depth of 55 ft to the bottom of the borehole. A summary chart of well drilling and well construction statistics for Test Well CAV6002X is presented in Table 2-2, and a well construction schematic is presented on Figure 2-5. The borehole lithologic log for Test Well CAV6002X is presented in Figure 2-6.

2.2.3 Monitor Well CAV6002M2

Monitor Well CAV6002M2 was completed at a depth of 893 ft bgs between October 7 and October 13, 2007. A 14-in. O.D. conductor casing was set to a depth of 80 ft bgs and grouted in place. A 12.25-in. borehole was then advanced to completion depth. The 6 in. nominal-diameter completion string, including 724 ft of slotted casing, was placed in the open borehole. The gravel pack extends from a depth of 50 ft to the bottom of the borehole. A summary chart of well drilling and well construction statistics for Test Well CAV6002M2 is presented in Table 2-3, and a well construction schematic is presented on Figure 2-7. The borehole lithologic log for Monitor Well CAV6002M2 is presented in Figure 2-8.

2.2.4 Background Well 382807114521001

Monitor Well was monitored during the hydraulic testing to observe regional groundwater trends and to identify outside influences affecting regional water levels, such as changes in barometric pressure, earthquakes, and lunar effects. The hydrologic conditions affecting the water levels in this well are

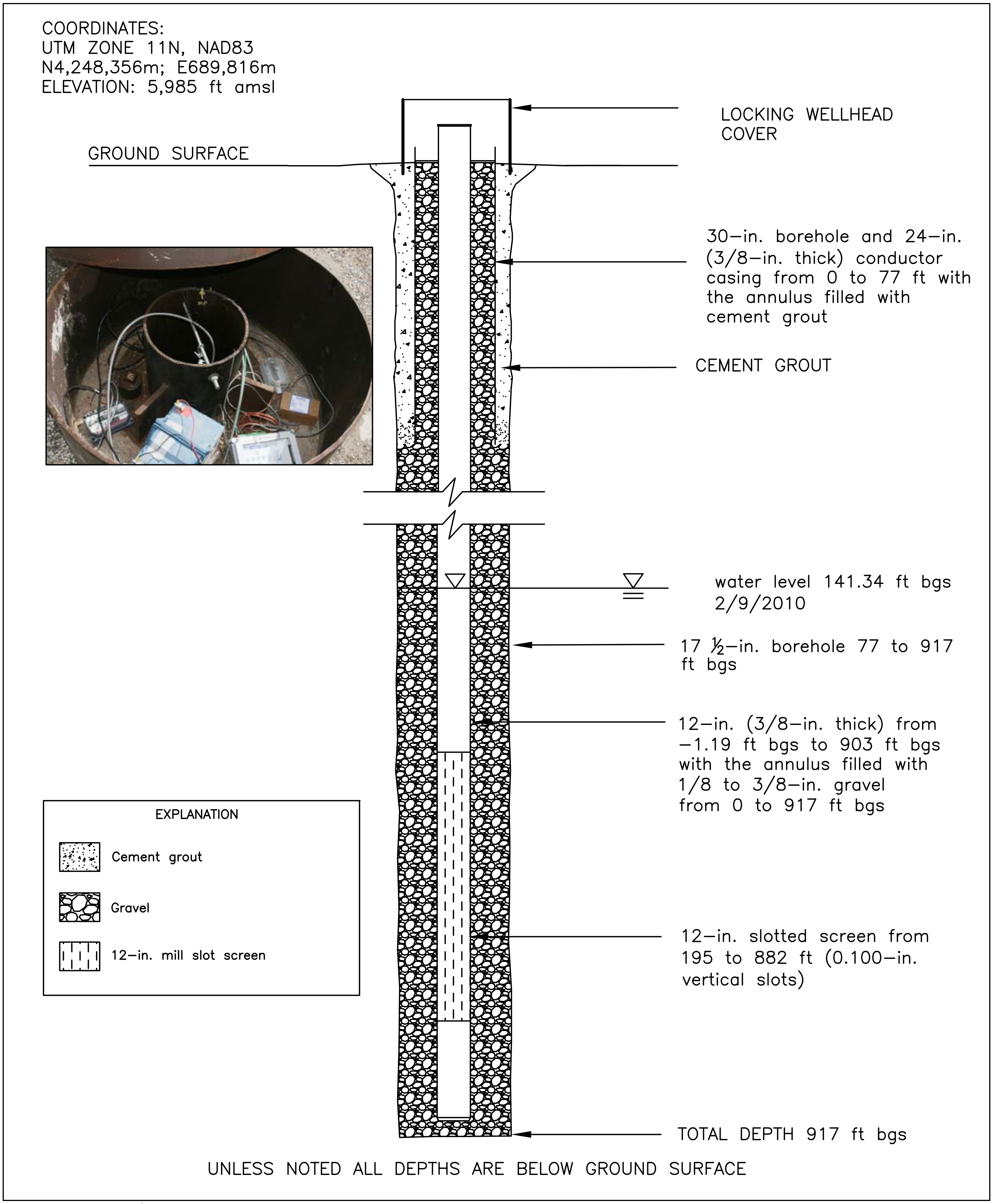
Table 2-1
Test Well 180W902M Borehole and Well Statistics

LOCATION DATA Coordinates	N 4,248,355.59 m; E 689,816.08 m (UTM, Zone 11, NAD83)
Ground Elevation	5,984.89 ft amsl
DRILLING DATA Spud Date	10/9/2005
Total Depth (TD)	917 ft bgs
Date TD Reached	10/17/2005
Date Well Completed	10/19/2005
Hole Diameter	30-in. from 0 to 77 ft bgs 17.5-in. from 77 to 917 ft bgs
Drilling Techniques	Conventional Circulation from 0 to 334 ft bgs Reverse Circulation from 334 to 917 ft bgs
Drilling Fluid Materials Used	Air/Foam
Drilling Fluid Properties	Not Tracked
CASING DATA	24-in. MS Conductor Casing from 0 to 77 ft bgs 12.75-in. MS Completion Casing from -1.19 to 917 ft bgs
WELL COMPLETION DATA	196.19 ft of blank MS 24-in. casing from -1.19 to 195 ft bgs 687 of 12-in. mill slot screen from 195 to 882 ft bgs 21 ft blank 12-in. sump MS casing and bullnose 882 to 903 ft bgs Cement, Plug and Gravel Pack Depth 0 to 77 ft on outside of conductor casing (cement) 0 to 917 ft from bottom of ground surface to TD (1/8 to 3/8-in. gravel pack)
WATER LEVEL	Static Water Level: 141.34 ft bgs (2/9/10) Groundwater Elevation: 5,843.55 ft amsl
DRILLING CONTRACTOR	WDC Exploration & Wells
GEOPHYSICAL LOGS BY	Raymond Federwisch, Geophysical Logging Services (Prescott, Arizona)
OVERSIGHT	S.M. Stoller Corp.

expected to be the same as those affecting the test well. This well is completed in the basin-fill aquifer system. The 10-in.-diameter well is completed at a depth of 460 ft bgs with a gravel pack interval of 190 to 460, and two perforation intervals from 210 to 250 and 375 to 435.

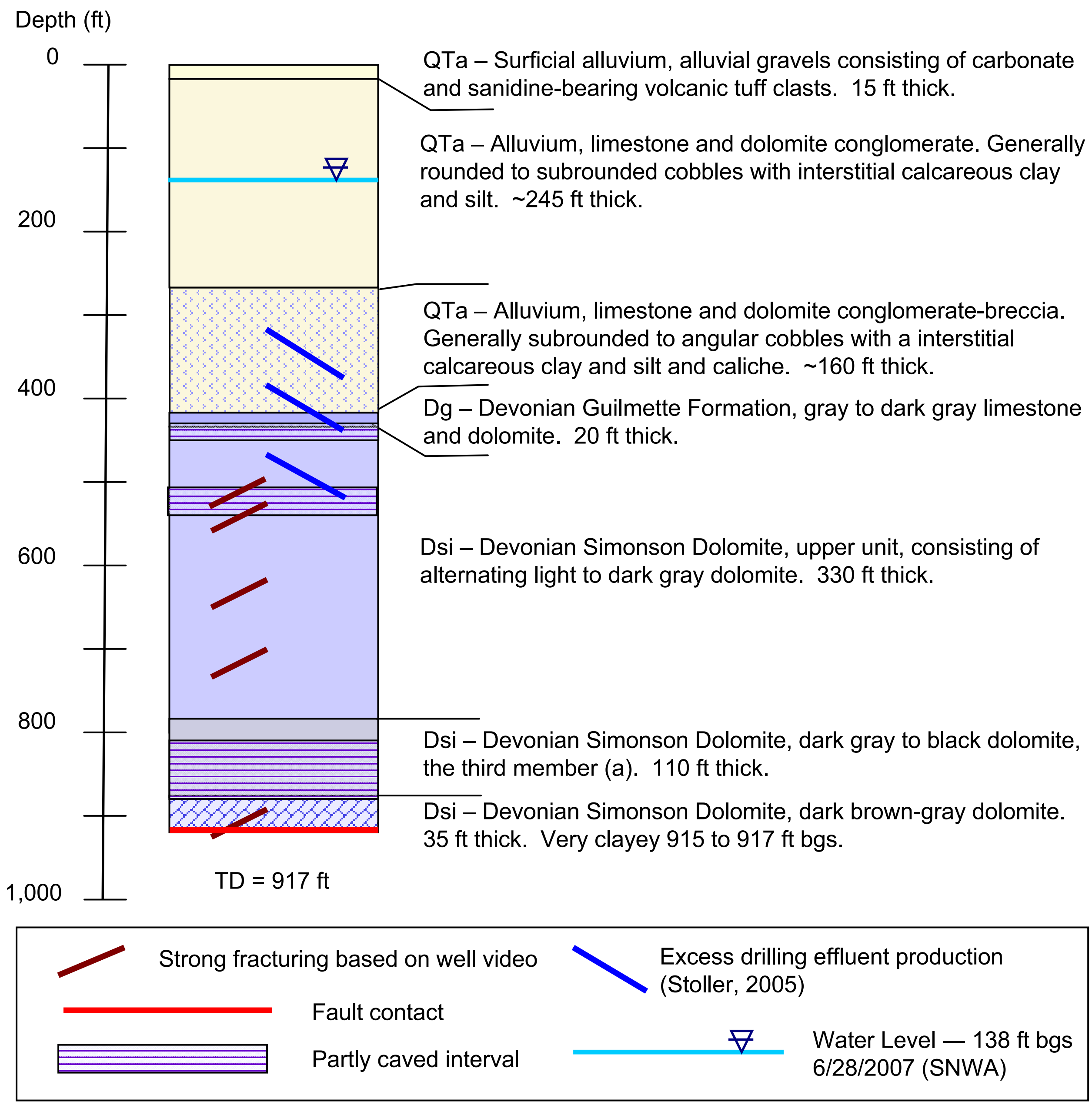
2.2.5 Well Survey and Water-Level Data

A professional survey of the wells utilized in the testing program was performed to determine the location and elevation of the measuring points and ground-surface elevations. Results of the survey of the wells are presented in Table 2-4.



Note: Not to scale

Figure 2-3
Test Well 180W902M Construction Schematic



Correlation of geologic units with RGUs (Dixon et al., 2007):
The surficial alluvium and older alluvium are part of the QTa RGU.
The Devonian Guilmette Formation is the Dg RGU.
The Devonian Simonson Dolomite is part of the Ds RGU.

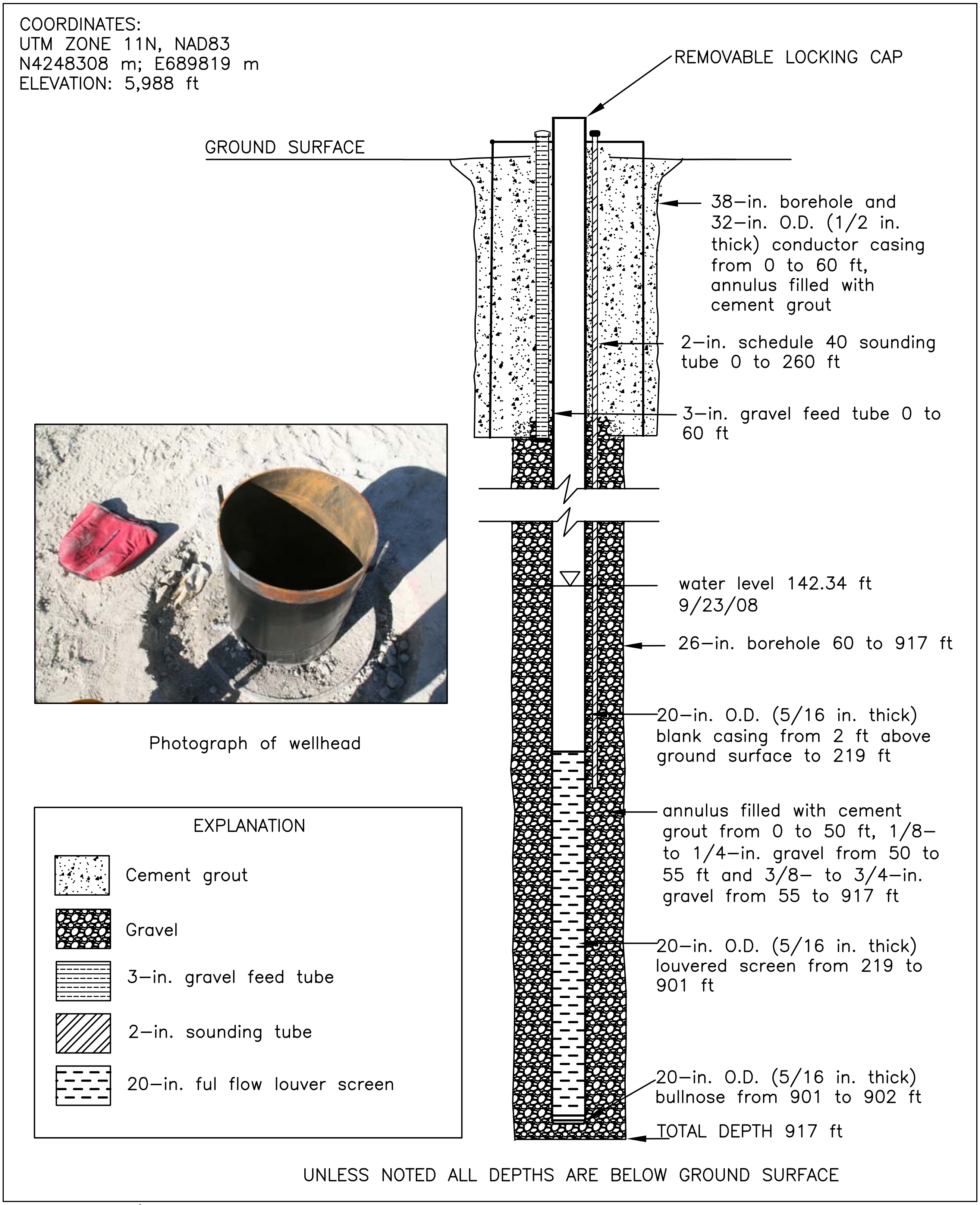
(a) Tschanz and Pampeyan (1970, p. 34).

Figure 2-4
Borehole Stratigraphic Column of Well 180W902M

Table 2-2
Monitor Well CAV6002X Borehole and Well Statistics

LOCATION DATA Coordinates	N 4,248,307.58 m; E 689,819.01 m (UTM, Zone 11, NAD83)
Ground Elevation	5,987.97 ft amsl
DRILLING DATA Spud Date	10/17/2007
Total Depth (TD)	917 ft bgs
Date TD Reached	10/26/2007
Date Well Completed	10/28/2007
Hole Diameter	38-in. from 0 to 60 ft bgs 26-in. from 60 to 917 ft bgs
Drilling Techniques	Conventional Circulation from 0 to 120 ft bgs Reverse Circulation from 120 to 917 ft bgs
Drilling Fluid Materials Used	Max-Gel = 150 lbs Soda Ash = 350 lbs PolyPac R = 800 lbs Sodium Bicarbonate = 500 lbs Detergent = 5 gal
Drilling Fluid Properties	Viscosity Range = 44 to 68 sec/qt Weight Range = 8.9 to 9.6 lbs/gal Filtrate Range = 6.1 to 10.8 ml Filter Cake Range = 1/32 to 3/32 in.
CASING DATA	32-in. O.D. MS Conductor Casing from 0 to 60 ft bgs 20-in. O.D. HSLA Completion Casing from +2 to 902 ft bgs
WELL COMPLETION DATA	60 ft of 3-in. gravel sounding tube from 0 to 60 ft bgs 260 ft of 2-in. schedule 40 sounding tube from 0 to 260 ft bgs 220.69 ft of blank HSLA 20-in. O.D. casing from -2 to 218.69 ft bgs 681.96 ft of 20-in. Ful-Flo louver screen from 218.69 to 900.65 ft bgs 0.7 ft bullnose CS casing from 900.65 to 901.35 ft bgs Cement Depth 0 to 60 ft on outside of conductor casing (cement) 0 to 50 ft bgs grout outside of competion casing, and inside of conductor 50 to 55 ft bgs gravel pack (1/8 to 1/4 in.) 55 to 917 ft bgs gravel pack (3/8 to 3/4 in.)
WATER LEVEL	Static Water Level: 143.83 ft bgs (2/9/10) Groundwater Elevation: 5,844.14
DRILLING CONTRACTOR	Boart Longyear Drilling
GEOPHYSICAL LOGS BY	Pacific Surveys
OVERSIGHT	Southern Nevada Water Authority

Depth-to-groundwater measurements were obtained, relative to the marked reference point, at the testing program well locations. Static water levels taken prior to the 72-hour constant-rate test at well CAV6002X were 141.43, 136.50, and 138.65 for wells CAV6002X, CAV6002M2, and 180W902M, respectively. The distance of the measuring points above land surface for these three wells was 6.05, 2.10, and 1.19 ft, respectively. Static water levels taken prior to the 72-hour constant-rate test at well 180W902M were 141.68, 136.61, and 139.34 for wells CAV6002X, CAV6002M2, and 180W902M, respectively. The distance of the measuring points above land surface for these three wells was 2.00, 2.10, and 3.61 ft, respectively.



Note: Not to scale

Figure 2-5
Test Well CAV6002X Construction Schematic

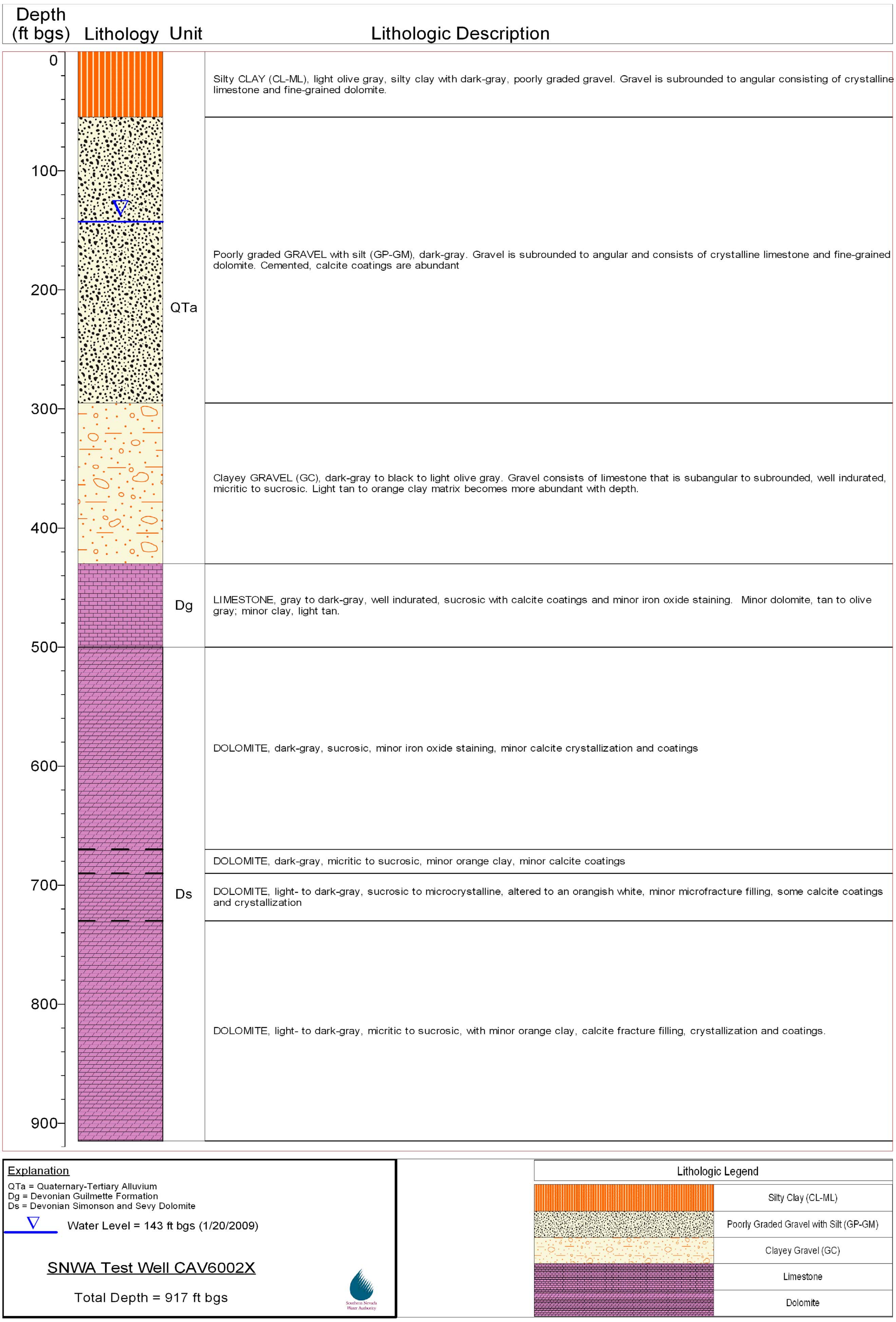
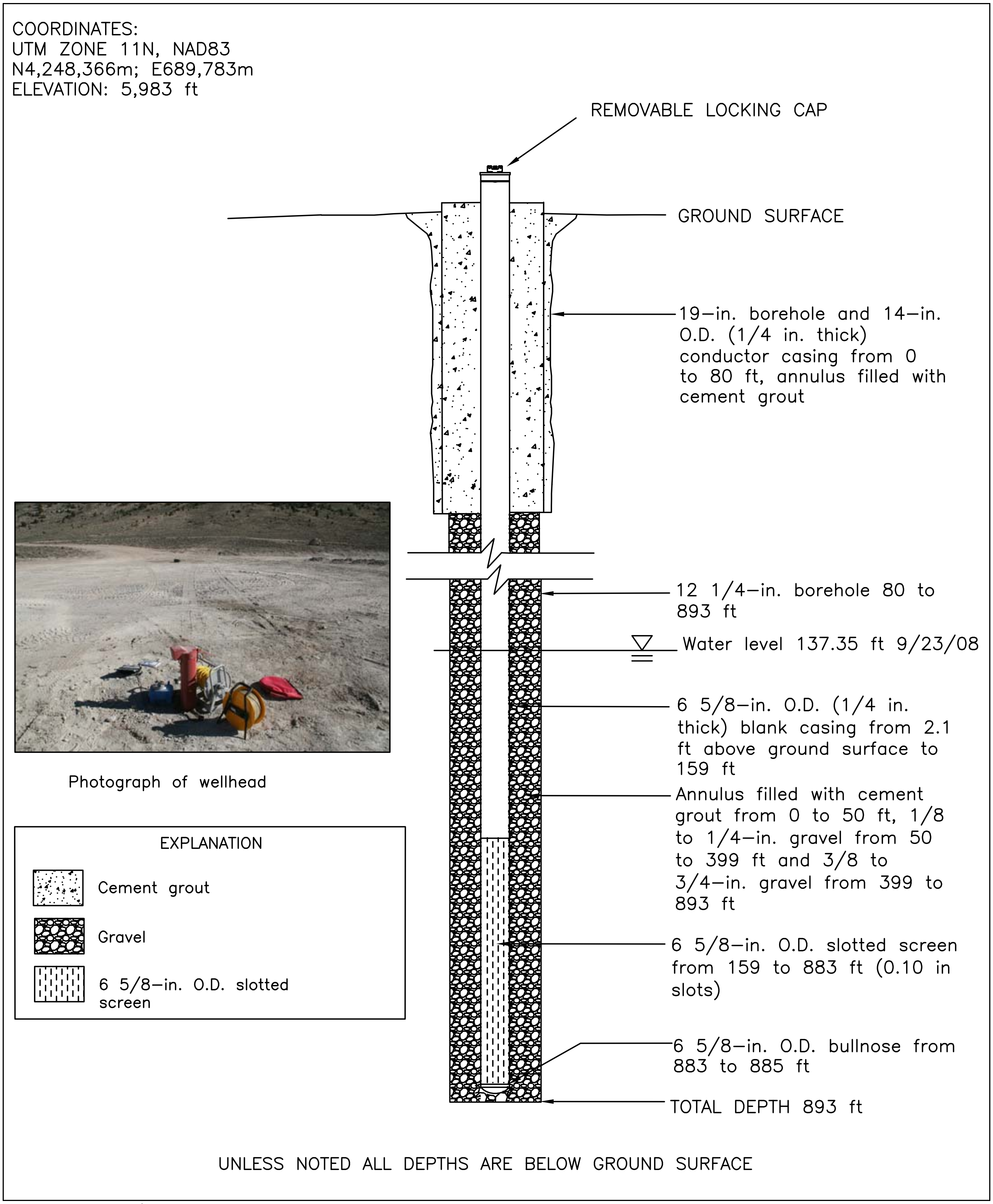


Figure 2-6
Borehole Stratigraphic Column of Monitor Well CAV6002X

Table 2-3
Test Well CAV6002M2 Borehole and Well Statistics

LOCATION DATA Coordinates	N 4,248,365.83 m; E 689,782.96 m (UTM, Zone 11, NAD83)
Ground Elevation	5,982.814 ft amsl
DRILLING DATA Spud Date	10/07/2007
Total Depth (TD)	893.44 ft bgs
Date TD Reached	10/12/2007
Date Well Completed	10/13/2007
Hole Diameter	19-in. from 0 to 80 ft bgs 12.25-in. from 80 to 893.44 ft bgs
Drilling Techniques	Conventional Circulation from 0 to 180 ft bgs Reverse Circulation from 180 to 893.44 ft bgs
Drilling Fluid Materials Used	Quick Gel = 3,750 lbs Max-Gel = 11,800 lbs Soda Ash = 350 lbs PolyPac R = 700 lbs Detergent = 6 gal
Drilling Fluid Properties	Viscosity Range = 48 to 82 sec/qt Weight Range = 8.5 to 8.9 lbs/gal Filtrate Range = 8.4 to 12.0 ml Filter Cake Range = 1/32 to 3/32 in.
CASING DATA	14-in. MS Conductor Casing from 0 to 80 ft bgs 6.625-in. MS Completion Casing from +2.1 to 884.88 ft bgs
WELL COMPLETION DATA	160.87 ft of blank MS 6.625-in. casing from +2.1 to 158.77 ft bgs 723.6 of 6.625-in. mill slot screen from 158.77 - 882.37 ft bgs 2.51 ft of 6.625-in. blank and bullnose MS casing from 882.37 to 884.88 ft bgs Cement, Plug and Gravel Pack Depth 0 to 80 ft on outside of conductor casing (cement) 0 to 50 ft between completion and conductor casing (cement) 50 to 399 ft (1/8 to 1/4 in. gravel pack) 399 to 893.44 ft bgs (3/8 to 3/4 in. gravel pack)
WATER LEVEL	Static Water Level: 139.34 ft bgs (5/3/2011) Groundwater Elevation: 5,843.47 ft amsl
DRILLING CONTRACTOR	Boart Longyear Exploration Drilling
GEOPHYSICAL LOGS BY	Pacific Surveys
OVERSIGHT	Southern Nevada Water Authority



Note: Not to scale

Figure 2-7
Test Well CAV6002M2 Construction Schematic

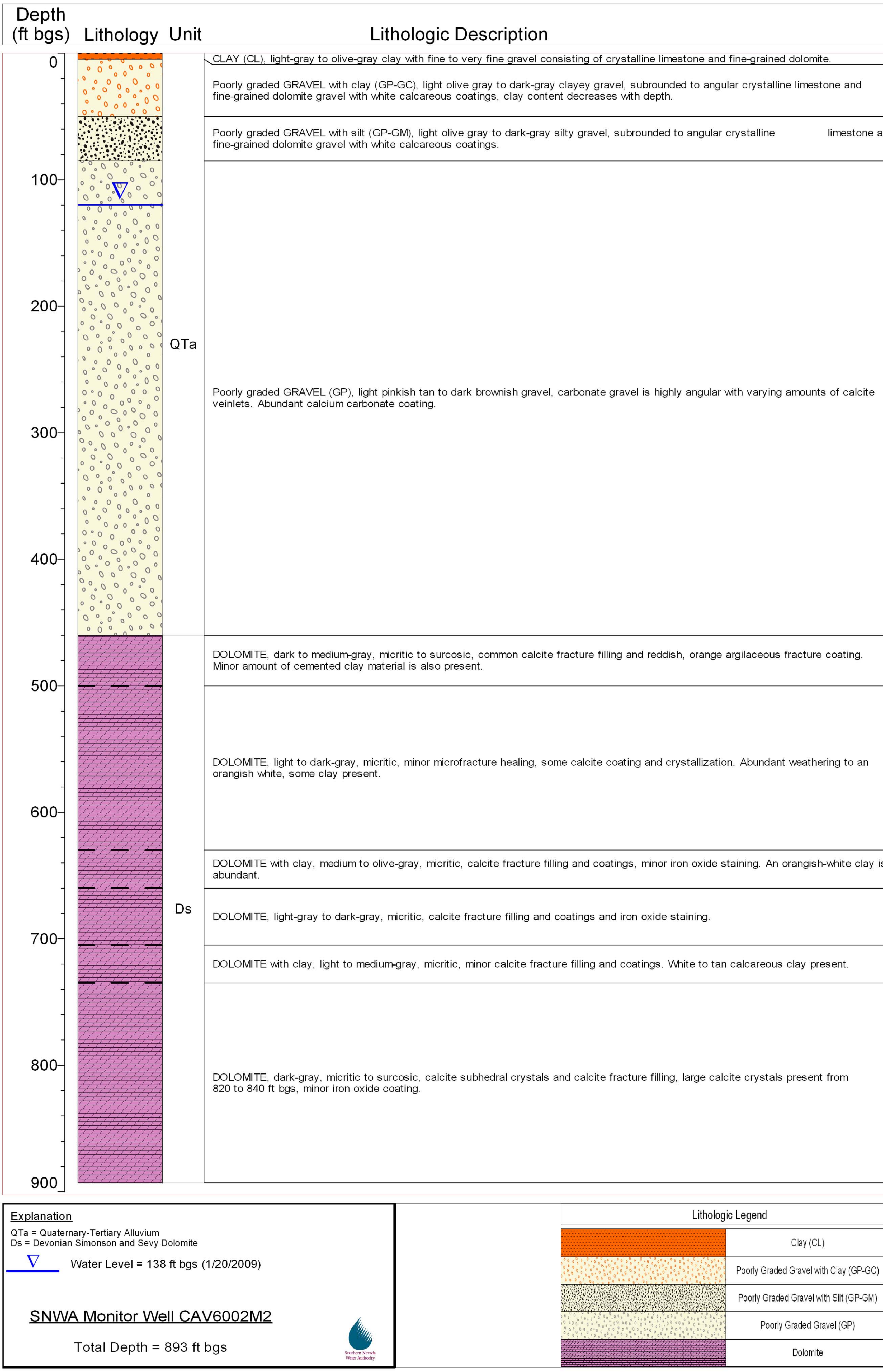


Figure 2-8
Borehole Stratigraphic Column of Test Well CAV6002M2

Table 2-4
Measuring-Point Information

Well ID	Well Use During Testing	Location[a]		Temporary MP[b] (ft amsl)	Permanent MP[b] (ft amsl)	Ground Surface Elevation[b] (ft amsl)
		UTM Northing (m)	UTM Easting (m)			
180W902M	Test	4,248,355.59	689,816.08	5,988.50	5,986.08	5,984.89
180W902M	Observation	4,248,355.59	689,816.08	5,986.08	5,986.08	5,984.89
CAV6002X	Test	4,248,307.58	689,819.01	5,994.02	5,988.97	5,987.97
CAV6002X	Observation	4,248,307.58	689,819.01	5,989.97	5,988.97	5,987.97
CAV6002M2	Observation	4,248,365.83	689,782.96	5,984.91	5,984.91	5,982.81
382807114521001	Background Well	4,259,963.15	685,737.56	6,014.39	6,014.39	6,012.39

[a]Universal Transverse Mercator, North American Datum of 1983, Zone 11N, Meters
[b]North American Vertical Datum of 1988 (NAVD88)
MP = Measuring Point

Static groundwater-elevation data have been collected on a continuous basis at Monitor Well 180W902M from April 10, 2007, to present. This well is currently equipped with an In-Situ Level Troll 500 15 psig pressure transducer and Design Analysis data logger. Physical measurements are collected from Test Well CAV6002X, Monitor Well 180W902M, and Monitor Well CAV6002M2 every six weeks, and at background well 382807114521001 to quarterly frequency. All four of these wells are included in the SNWA regional groundwater monitoring network.

Static groundwater elevation is approximately 5,844 to 5,847 ft amsl at Test Well CAV6002X, which corresponds to a depth to water of approximately 141 to 144 ft bgs. Static groundwater elevation at Monitor Well 180W902M is approximately 5,842 to 5,848 ft amsl, which corresponds to a depth to water of 137 to 142 ft bgs. Static groundwater elevation at CAV6002M2 is approximately 5,843 to 5,847 ft amsl and approximately 136 to 140 ft bgs. Background well 382807114521001 static groundwater elevation is approximately 5,794 ft amsl and approximately 218 ft bgs. Period-of-record hydrographs for the wells are presented on Figures 2-9 through 2-12. Static water levels have remained within a narrow range since the test period. A detailed background hydrograph at 382807114521001 during the testing period is presented in Section 3.4.

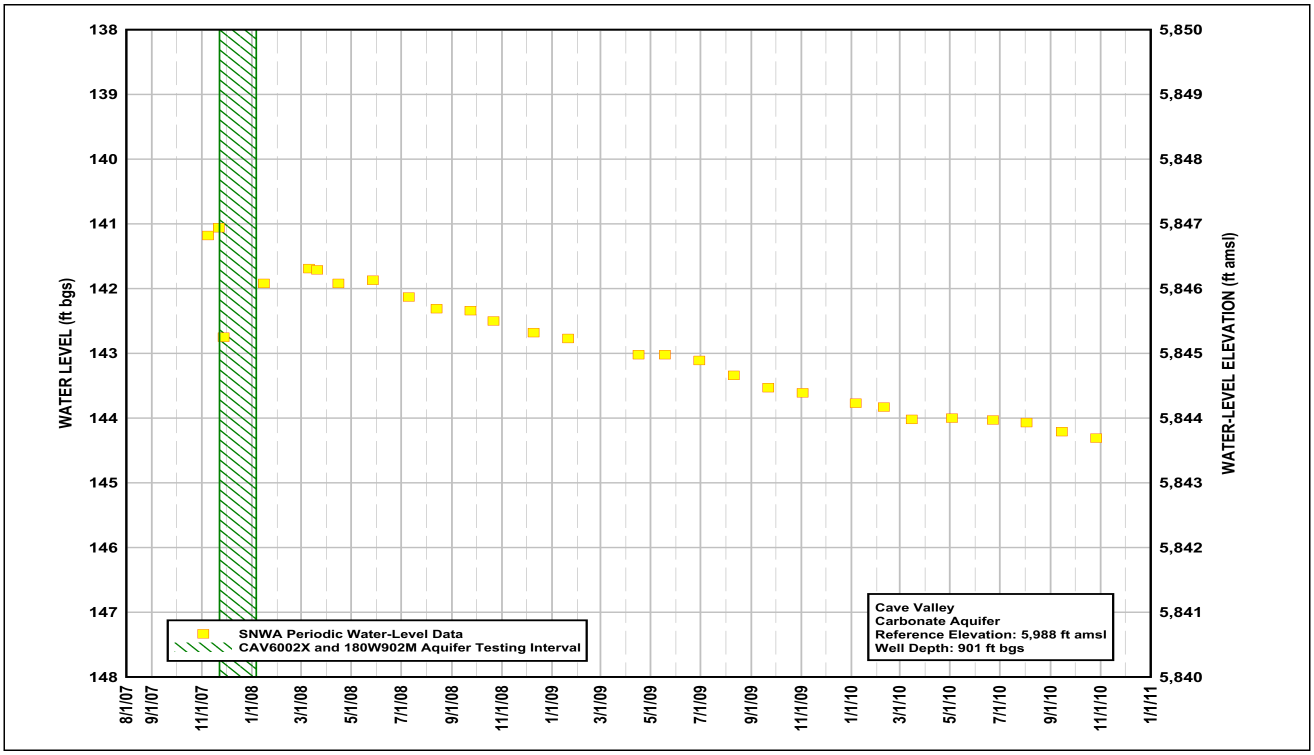


Figure 2-9
Historical Hydrograph for Test Well CAV6002X

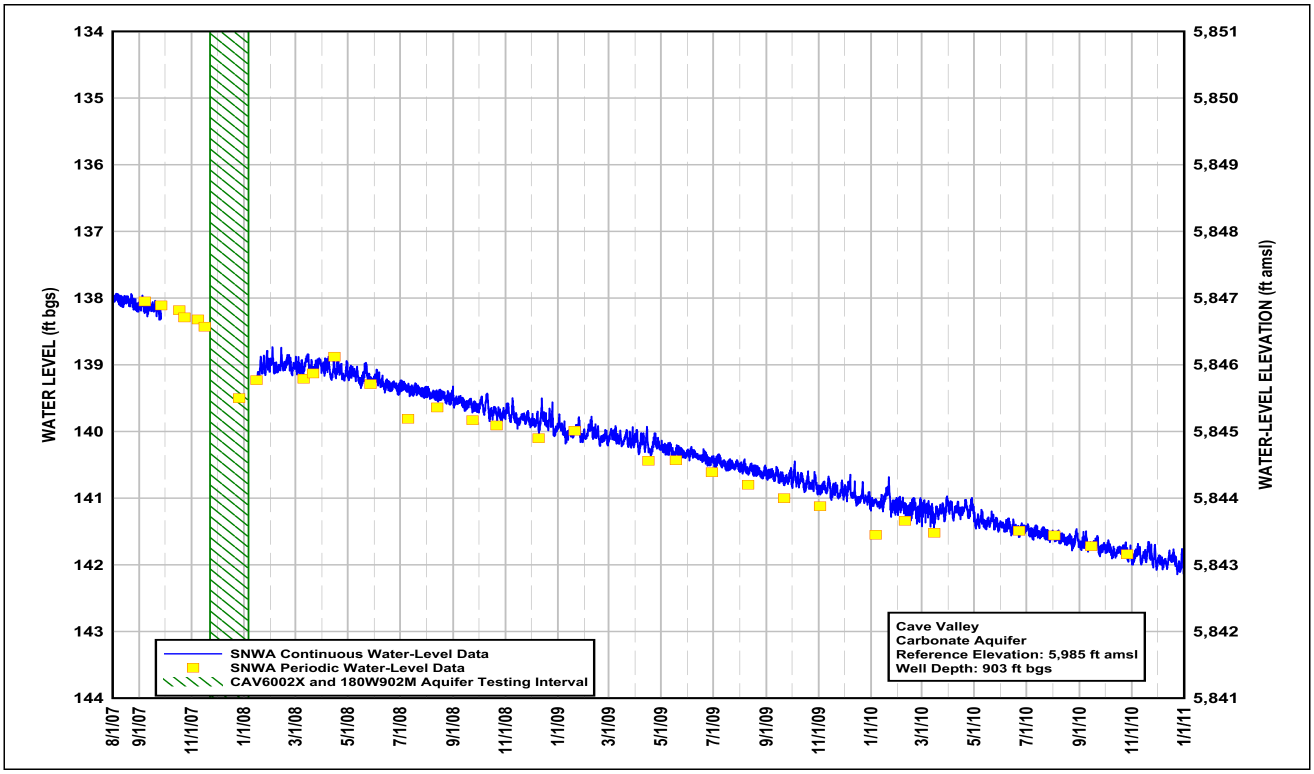


Figure 2-10
Historical Hydrograph for Monitor Well 180W902M

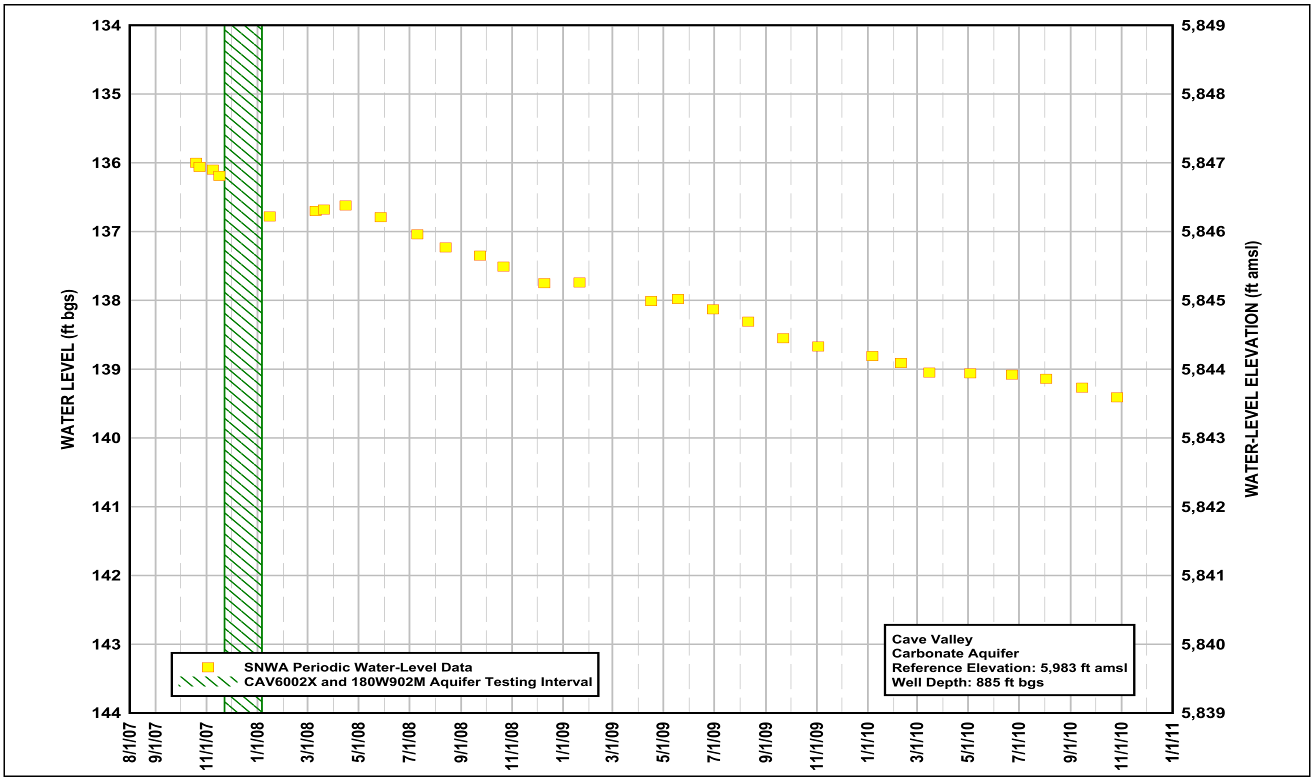


Figure 2-11
Historical Hydrograph for Monitor Well CAV6002M2

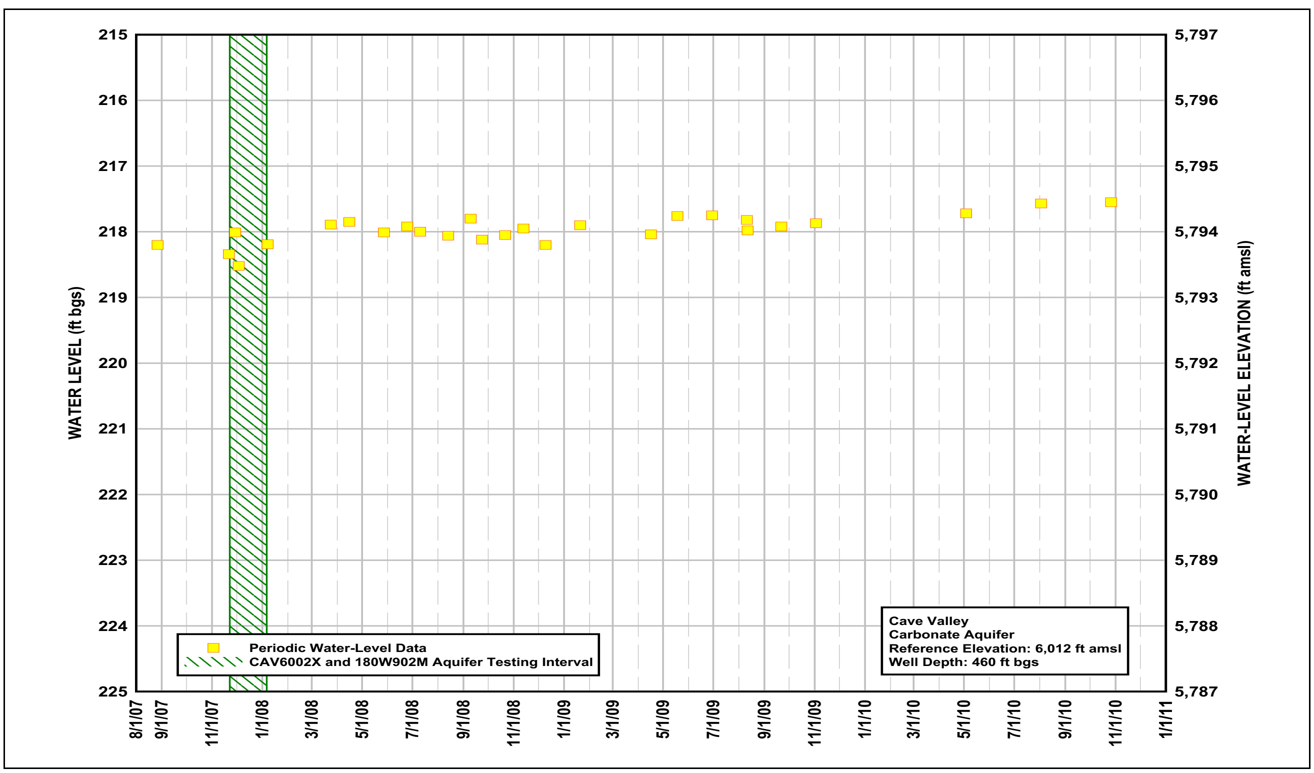


Figure 2-12
Historical Hydrograph for Background Well 382807114521001

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3.0 TEST DESCRIPTION AND BACKGROUND DATA

This section describes the activities, pump equipment, and monitoring instrumentation associated with development and hydraulic testing of Test Well CAV6002X and 180W902M. Background hydrologic data and regional trends associated with the testing program are also presented and evaluated in this section.

3.1 Site Activities

The following summarizes the development and testing activities performed in 2007 and 2008 at the well site:

- November 22 to 27, 2007: Developed well CAV6002X using surge and pump techniques.
- November 28: Performed a four interval step-drawdown test on well CAV6002X at rates ranging from 800 to 1,500 gpm.
- November 30 to December 3: Performed a 72-hour constant-rate test on well CAV6002X at 1,200 gpm and subsequent water-level recovery measurements.
- December 3: Collected groundwater samples for laboratory chemical analysis. Groundwater chemistry samples were collected from well Test Well CAV6002X at 6:30 a.m. during performance of the constant-rate test. A total of 11,729,000 gal of water had been extracted from the well (including pumping during well development, step test, and the constant-rate test) at the time of sampling.
- December 10 to 12: Developed well 180W902M using pumping techniques.
- December 13 to 14: Performed a 16-hour constant-rate test on well 180W902M at 900 gpm. Test was terminated early due to generator malfunction.
- December 17 and 18: Tested new generator and pump motor. Technician diagnosed the generator to be defective.
- December 20 to 22: Installation testing of new generator. Developed well using pumping techniques.
- January 3 to 7: Performed a 72-hour constant-rate test on well 180W902M at 1,100 gpm and subsequent water-level recovery measurements.

3.2 Test Equipment and Site Layout

An Ingersoll-Dresser Pump Company line shaft turbine pump was used in Test Well CAV6002X. The intake was set at 525 ft bgs. The transducer was set at approximately 480 ft below the measuring point. A Central Lift Company submersible 600 horsepower pump was used in Monitor Well 180W902M for development and testing. The intake was set at 209 feet below the measuring point. The transducer was set at approximately 181 ft below the measuring point. A discharge-line check valve was not used during either test to allow more effective development activities.

3.3 Discharge Information

Pumped water was discharged west of the site through approximately 1,200 ft of 12-in.-diameter piping. A total of 19,859,450 gal was pumped over the course of the development and testing periods for wells CAV6002X and 180W902M. Specifically, 11,875,200 gal were discharged during development and testing at well CAV6002X, with 5,259,200 gal pumped during the 72-hour constant-rate test, 559,000 gal during the step-drawdown test, and 6,057,000 during development. 7,984,250 gal were discharged during development and testing at well 180W902M, with 4,805,900 gal pumped during the 72-hour, constant-rate test, 2,228,300 gal during development, and 793,150 gal during the initial failed constant-rate test.

3.4 Instrumentation and Background Data

Regional and background water levels were continuously recorded prior to, during, and after the test period at Test Well CAV6002X and Monitor Wells CAV6002M2 and 180W902M. Throughout the course of development and testing activities at this site, Hermit 3000 data loggers with PXD-261 transducers were used to record groundwater levels at wells CAV6002X, CAV6002M2, 180W902M, and background well 382807114521001. At wells CAV6002M2 and 382807114521001 the range of the PXD-261 pressure transducers was 50 and 15 psig, respectively. During development and testing at well CAV6002X, the range of the PXD-261 pressure transducers was 100 and 250 psig for wells 180W902M and CAV6002X, respectively. During development and testing at well 180W902M, the range of the PXD-261 pressure transducers was 250 and 100 psig for wells 180W902M and CAV6002X, respectively. Background well 382807114521001 is located approximately 8 mi northwest of the site.

Data collected from background well 382807114521001 were used to identify any regional trend in groundwater level during the test period. A depth-to-water hydrograph for background well 382807114521001 during the testing period is presented on Figure 3-1. An extremely cold weather front moved through the valley during the constant-rate test and stayed there until just prior to the second constant-rate test at well 180W902M. The temperatures, which were dipping below -4 °F caused the barometric pressure sensor to malfunction, which in turn caused the water levels to artificially rise and fall on the order of approximately 2 ft. This data was removed from the water level record. This malfunction occurred after the end of the constant-rate test at well CAV6002X and prior to beginning the constant-rate test at well 180W902M. The water level trends in this data set have been confirmed by well 180W501M, which is located approximately 16 mi northwest of the site, and was equipped with a transducer and data logger throughout this period.

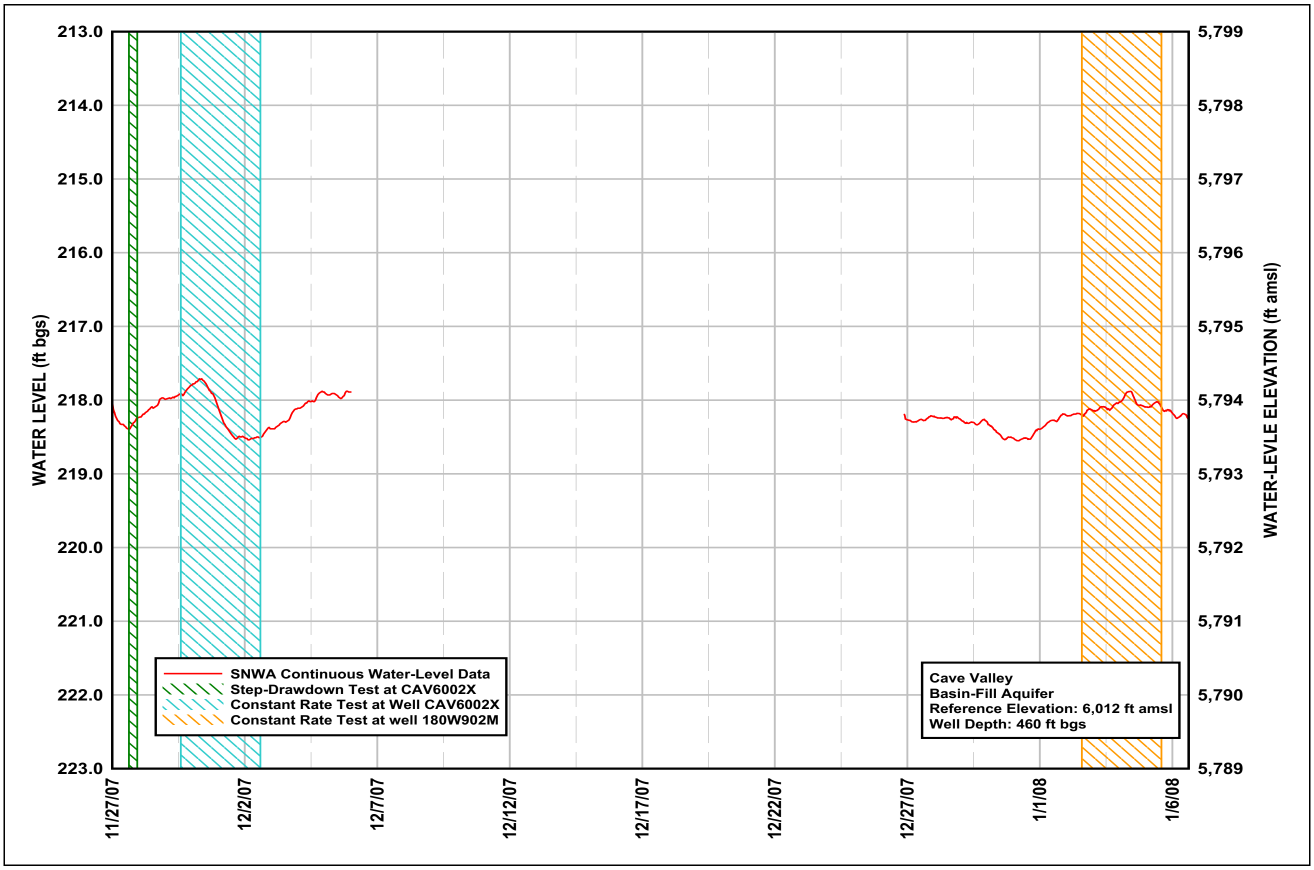

Figure 3-1
Hydrograph for Background Well 382807114521001 During Test Period

The hydrograph for background well 382807114521001 indicates no significant trend that would significantly influence the results of the tests. Trends observed were considered during the evaluation of test data. During the constant-rate test at well CAV6002X an average daily cycle of water-level change of 0.31 ft was observed. This background change is insignificant with respect to the magnitudes of drawdowns observed during testing. However, the change was considered in the analysis of the test. During the constant-rate test at 180W902M an average daily cycle of water-level change of 0.16 ft was observed. This background change is insignificant with respect to the magnitudes of drawdowns observed during testing. However, the change was considered in the analysis of the test.

An on-site barometric pressure sensor located at well 180W902M was used to measure barometric pressure fluctuations during the constant-rate tests. Figure 3-2 presents a plot of barometric-pressure data and drawdown measurements in Monitor Wells CAV6002M2 and 180W902M collected during the constant-rate test at well CAV6002M2. Figure 3-3 presents a plot of barometric-pressure data and drawdown measurements in Monitor Wells CAV6002M2 and CAV6002X collected during the constant-rate test at well 180W902M.

During the constant-rate test at well CAV6002X, the barometric pressure had a maximum variation from the beginning of the test of 0.57 in. Hg. This equates to 0.22 ft of head, based on a previously calculated well barometric efficiency of 35 percent. This is insignificant with respect to the magnitude of the drawdown in the wells. However, this variation was considered during evaluation of test data. The drawdown in the Monitor Wells CAV6002M2 and 180W902M along with the barometric pressure during the constant-rate test are shown in figure Figure 3-2. No other outside influences, such as the existence of other pumping wells in the vicinity of Test Well CAV6002X, were identified.

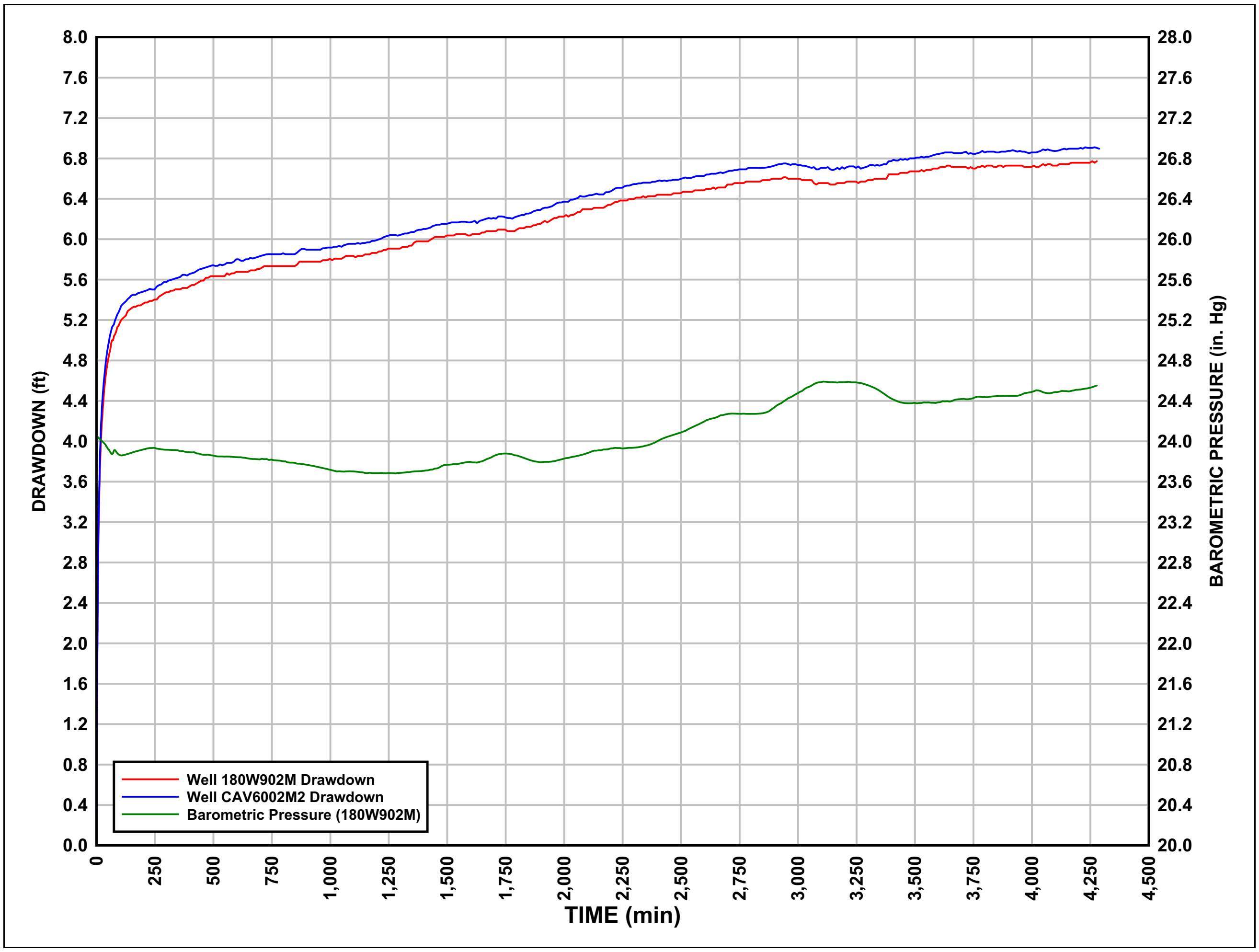

Figure 3-2
Local Barometric-Pressure Variation during Constant-Rate Test at CAV6002X and Drawdown at Monitor Well CAV6002M2 and 180W902M

During the constant-rate test at well 180W902M, the barometric pressure had a maximum variation from the beginning of the test of 0.62 in. Hg. This equates to 0.25 ft of head, based on a previously calculated well barometric efficiency of 35 percent. This change is insignificant when compared with the magnitude of the drawdown. However, this variation was considered during evaluation of test data. The drawdown response in Monitor Wells CAV6002X and CAV6002M2 along with the barometric record during the constant-rate test at well 180W902M are shown in Figure 3-2. No other outside influences, such as the existence of other pumping wells in the vicinity of Test Well CAV6002X, were identified.

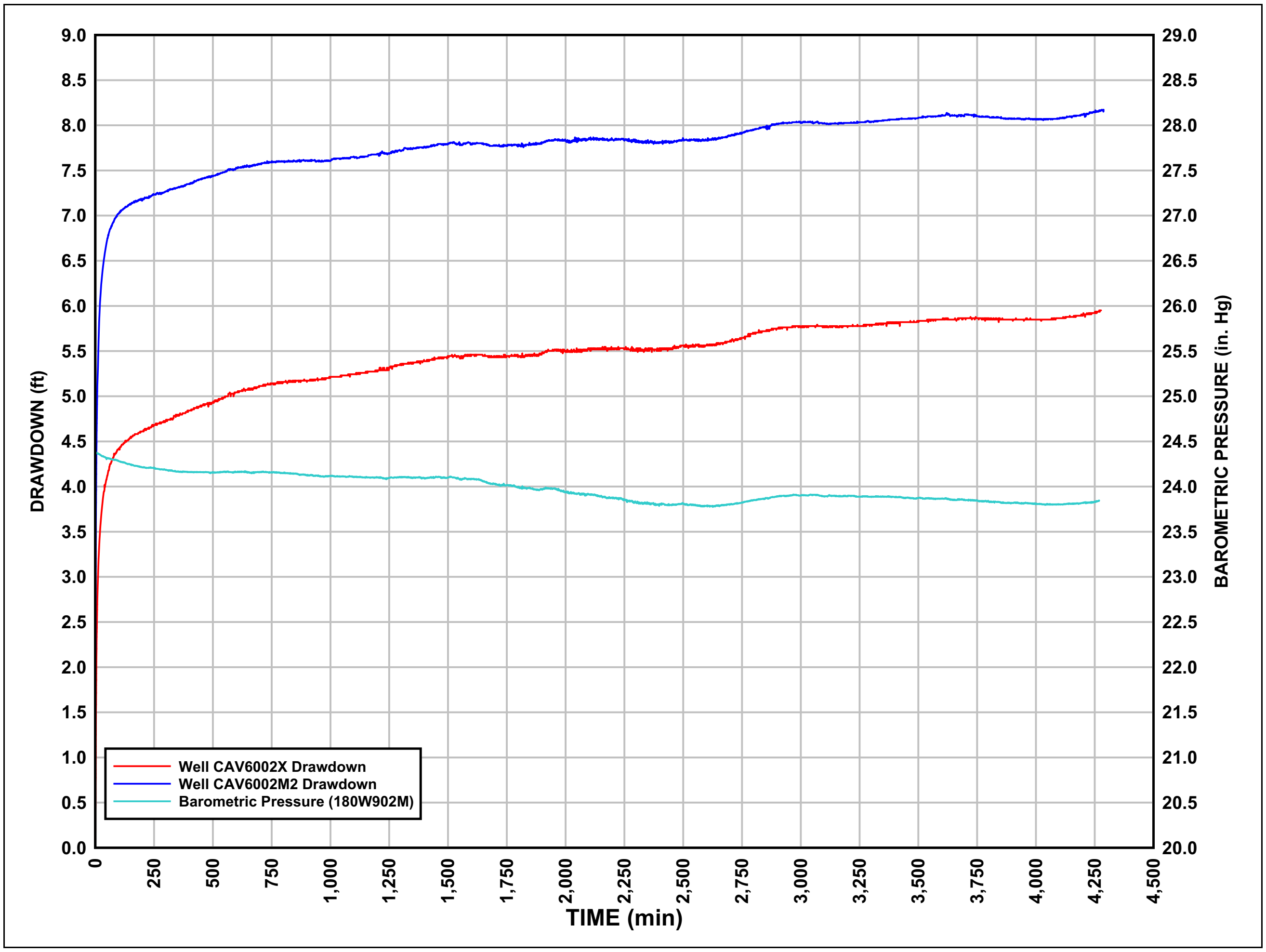

Figure 3-3
Local Barometric-Pressure Variation during Constant-Rate Test at 180W902M and Drawdown at Monitor Well CAV6002M2 and CAV6002X

Manual water level and flow measurements were collected at wells using Heron 1,500 and 2,000 ft electronic water-level indicator probes at prescribed intervals and in accordance at accordance with *SNWA Water Resources Division Field Operating Procedure for Well Development and Aquifer Testing* (SNWA, 2007). Field groundwater-quality samples were collected and analyzed on-site regularly for pH, conductivity, temperature, and turbidity throughout the testing period. Program test data are presented in data files on the CD-ROM that accompanies this report.

Transducer data at the test and monitor wells were compared to manual data collected throughout the test period. Evaluation of the data sets indicated no significant variations. Manually collected data at the test and monitor wells was used to check the transducer records at the test and monitor wells.

The respective borehole deviations for wells CAV6002X and CAV6002M2 are presented in the geophysical logs in the borehole deviation plots provided in the *Well Completion and Geologic Data Analysis Report for Monitor Well CAV6002M2 and Test Well CAV6002X in Cave Valley* (Baird, 2011). The borehole deviation for well 180W902M is presented in the in the geophysical logs in the Closure Distance plots provided in the *Geologic Data Analysis Report for Monitor Well 180W902M in Cave*

Valley (Eastman, 2007). Evaluation of borehole deviation and depth to groundwater indicated negligible influence on depth-to-water measurement results.

4.0 WELL HYDRAULICS AND PERFORMANCE TESTING

This section presents development results and analysis of the step-drawdown well performance testing.

4.1 Development

Prior to this phase of development, the wells were initially developed after drilling using a dual-swab technique. A dual swab was used prior to and after placement of the gravel pack. AQUA-CLEAR PFD, a polymer dispersant, was added to the well to break up residual drilling mud, and a final swab was performed the length of the screen.

Test Well CAV6002X was developed using a surging and pumping technique. The well was pumped at a constant rate for a short period of time (usually under an hour) until turbidity data reached a certain low threshold and then surged repeatedly. Water level, sand content, turbidity and other groundwater quality field data were collected during the pumping period. Specific capacity (discharge [Q] in gpm/drawdown[s] in ft) was determined during and at the end of each pumping period to evaluate development effectiveness and the need for additional development.

Well 180W902M was redeveloped by pumping at a sustained rate until the drawdown stabilized, then increasing the pumping rate until the drawdown had restabilized. Water level, sand content, turbidity and other groundwater quality field data were also collected during the redevelopment pumping.

4.1.1 Development Results

A total of 6,057,000 gal of water was pumped during this phase of pump development at well CAV6002X. Development at this site was very effective. Developmental effectiveness was quantified using a comparison of specific capacity at a discharge rate of 800 gpm between early development and the first step drawdown test interval. The specific capacity was 6.00 gpm/ft (133.08 ft of drawdown) on November 22, 2007 approximately 30 min after beginning development pumping at 800 gpm. The specific capacity was 10.67 gpm/ft (74.95 ft of drawdown) on November 28, 2007 after 30 min of pumping at a discharge rate of 800 gpm during the step-drawdown test. This is an improvement of 77.5 percent.

A total of 2,228,300 gal of water was pumped during the pump development phase at well 180W902M. During early development a pumping rate of 1,120 gpm was sustained for approximately 25 min, at which time the drawdown in well 180W902M stabilized at 13.19 ft, with a specific capacity of approximately 84.9 gpm/ft. At 25 min after beginning the constant-rate test the flow rate was approximately 1,120 gpm, the drawdown was 11.79 ft and the specific capacity was 95.0 gpm/ft. This is an improvement in specific capacity of 12 percent.

4.2 Step-Drawdown Test

A step-drawdown test was performed at Test Well CAV6002X using four different pumping rates intervals ranging from 800 to 1,500 gpm. A step-drawdown test was not performed at well 180W902M. The pumping period interval ranged from 60 to 90 min in duration and were continuous. Figure 4-1 presents a graph showing plots of the drawdown versus time for each pumping interval.

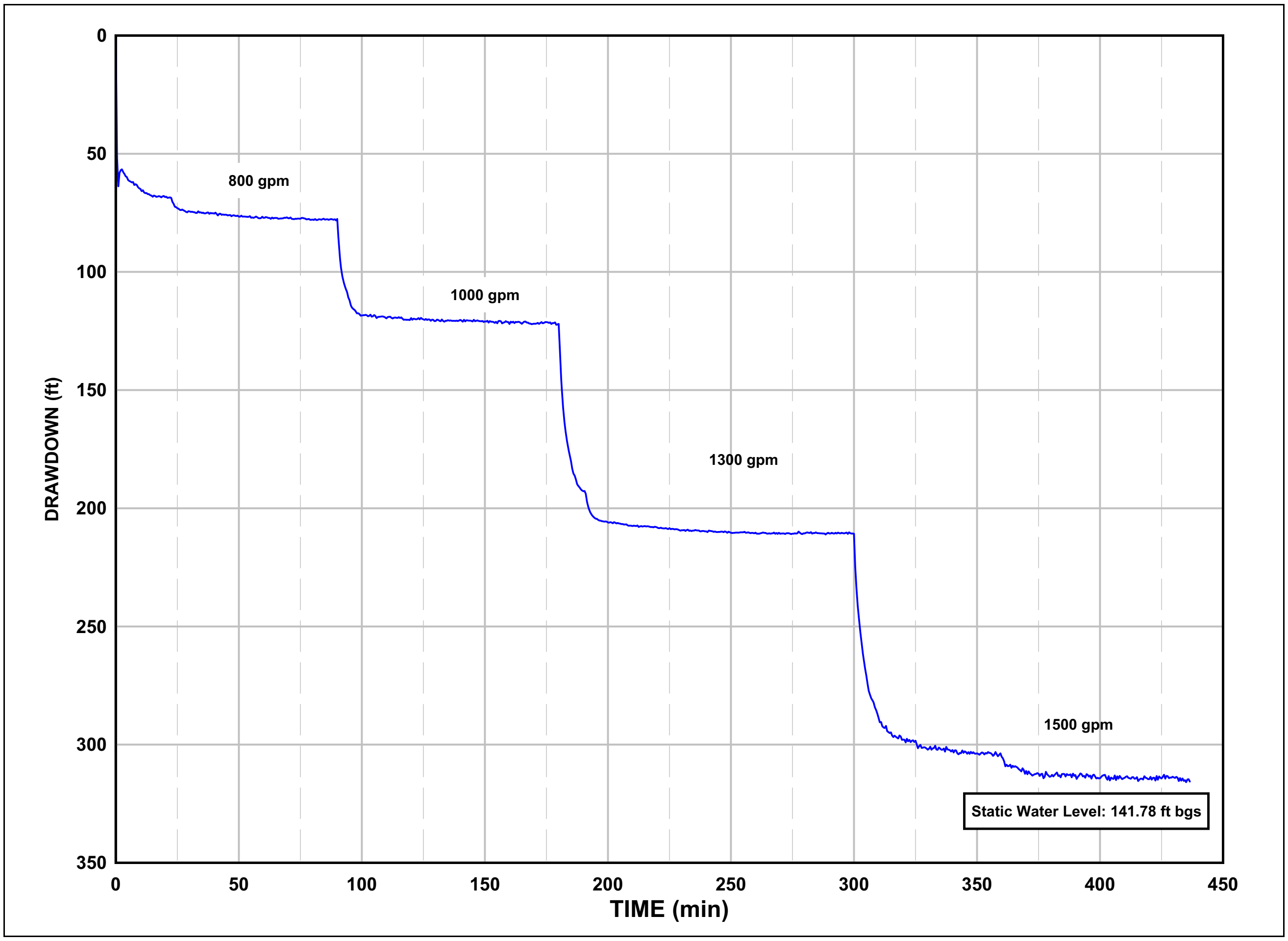

Figure 4-1
Linear Plot of Drawdown for Each Pumping Interval During Step-Drawdown Testing of Test Well CAV6002X

4.2.1 Well Performance and Specific Capacity

Specific capacity is a measure of well productivity and efficiency. Specific capacity usually decreases to some degree with time and increased discharge rate. Graphs of drawdown versus discharge rate and specific capacity versus discharge rate are presented on Figures 4-2 and 4-3, respectively.

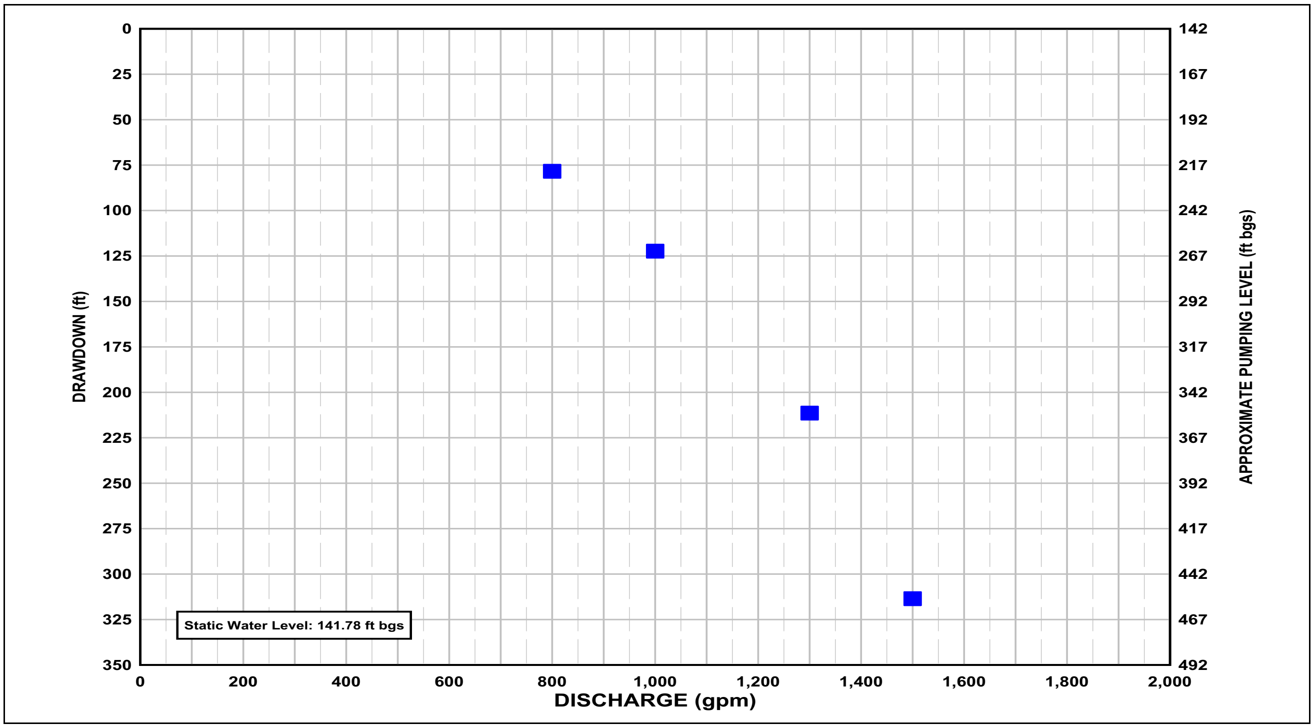

Figure 4-2
Linear Plot of Step-Test Drawdown and Depth-to-Pumping Level for Various Discharge Rates at Test Well CAV6002X

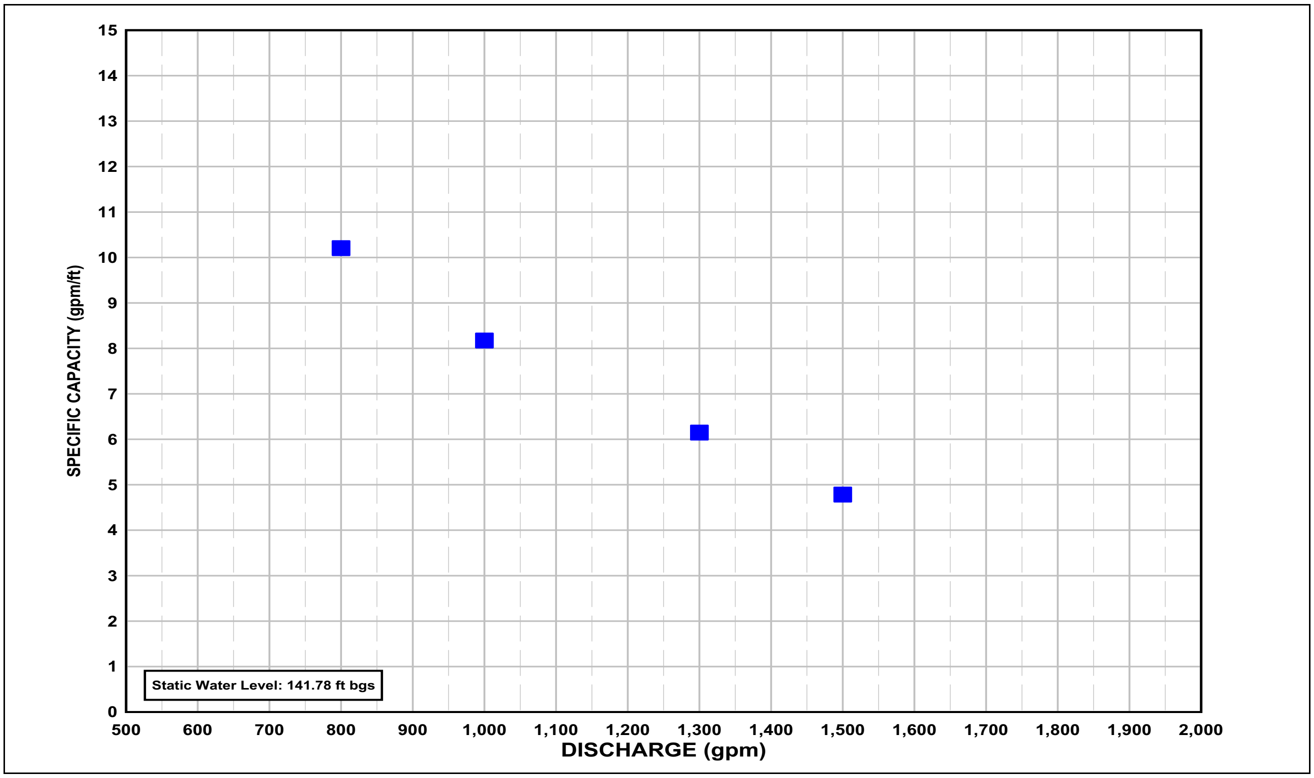

Figure 4-3
Step-Test Specific Capacity versus Discharge Rate for Test Well CAV6002X

Results of the step-drawdown test at well CAV6002X indicate specific capacity values of ranging from 4.78 to 10.21 gpm/ft for associated short-term pumping rates of 1,500 to 800 gpm, respectively. Specific capacity during the last 12 hours of the 72-hour, 1,200-gpm constant-rate test at well CAV6002X ranged from 6.30 to 6.36 gpm/ft. Specific capacity during the last 12 hours of the 72-hour constant-rate test at well 180W902M ranged from 81.25 to 82.55 gpm/ft.

4.2.2 Well Loss Analysis

The drawdown observed in a pumping well is the effect of aquifer and well losses. The aquifer loss is the theoretical drawdown expected at the pumping well in a perfectly efficient well where flow is laminar. The well loss is the additional drawdown in the pumping well caused by the turbulent flow and frictional head loss effects in or adjacent to the well. Loss components are also classified as linear and nonlinear losses. Linear well losses are usually caused by formation or damage to the formation during drilling, residual drilling fluids not removed during well development, or head losses as groundwater flows through the gravel pack and screen. Nonlinear head losses are caused by turbulent flow occurring inside the well screen, pump column, and the fracture zone adjacent to the well. Higher turbulent well losses caused by the formation are expected to occur more often in a fractured bedrock aquifer, especially those with low fracture density, than in granular porous media as flow into the well is concentrated in specific fractures.

Determination of well loss allows the calculation of a drawdown and specific capacity expected in the pumping well at various discharge rates. Evaluation of well loss also includes the evaluation of turbulent flow with increased pumping rate. Generally, specific capacity decreases at higher pumping rates due to increase of turbulent flow at the well and decrease in saturated thickness in unconfined conditions. The evaluation of well loss allows for better projection of the optimal pumping rate and estimation of actual drawdown in the aquifer near the well, removed from the effects of losses caused by pump and well inefficiencies, friction loss, and turbulent flow.

Head loss coefficients are calculated by the equation:

$$s = BQ + CQ^n \qquad \text{(Eq. 4-1)}$$

where,

s = Drawdown in the pumping well
B = Linear loss coefficient
C = Nonlinear well loss coefficient caused by turbulent flow
Q = Discharge rate
n = Constant greater than 1

Results of the evaluation and a graph of specific drawdown (drawdown/discharge) versus discharge rate used to evaluate head loss coefficients using the Rorabaugh method (Rorabaugh, 1953) are presented in Table 4-1.

The loss coefficient for *B* is 0.065, *C* equals 7.16128×10^{-9}, and *n* is 3.3 using the Rorbaugh Method. Using these values, specific capacity and drawdown estimates can be projected for any pumping rate using the equation:

$$Q/s = 1/(7.16128 \times 10^{-9} Q^{2.3} + 0.065) \quad \text{(Eq. 4-2)}$$

The reliability of the projection is highest within the discharge testing range of the step-drawdown test.

The percent of head loss attributed to laminar flow can also be estimated using the equation:

$$((BQ)/(BQ + CQ^{n})) \times 100 \quad \text{(Eq. 4-3)}$$

Table 4-1 shows that the nonlinear losses compose about 35 to 69 percent of the drawdown within the pumping discharge range of 800 to 1,500 gpm used in the step test, the percentage increasing with increasing production rate. The nonlinear losses at the pumping rate of 1,200 gpm used in the constant-rate test is 57 percent. This analysis indicates that the nonlinear losses are significant, which is reflected in a significant well loss contribution to pumping-well drawdown.

Table 4-1
Step-Drawdown Test Analysis

Q (gpm)	*s* (ft)	Q (cfs)	*s*/*Q*-B (ft/cfs)	Nonlinear Losses (ft)	Linear Losses (ft)	Total Losses (ft)	Nonlinear Total (%)
800	78.39	1.78240738	14.980	27.24	51.69	78.93	35
1,000	122.35	2.22800923	25.914	56.88	64.61	121.50	47
1,300	211.43	2.89641110	43.997	135.21	84.00	219.20	62
1,500	313.56	3.34201384	64.824	216.82	96.92	313.73	69

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5.0 CONSTANT-RATE TEST EVALUATION

This section summarizes the collection of hydraulic testing data, analytical solution selection, and analysis results of two 72-hour constant-rate and recovery tests conducted at Test Well CAV6002X and 180W902M. Two tests were performed on the wells to provide additional data on hydrogeologic properties of the site including quantification of horizontal anisotropy.

5.1 Data Review and Adjustments

Water-level data were collected with transducer and physical methods using the instrumentation described in Section 3.4. Data collection time intervals were logarithmic and in accordance with SNWA procedures and consistent with industry standards. The manual water-level measurements were used to confirm the transducer data. No significant variation between the two data sets was observed. Data from the constant-rate test records were extracted logarithmically, due to the large number of data points, in order to facilitate the data processing and analysis.

Outside effects, such as changes in barometric pressure, regional water-level trends, and precipitation events, were monitored during the test period. No influences that would significantly effect the test results were identified. Barometric variations during the test and those associated with an extreme cold front which moved through the area between tests were considered during the analysis. No other pumping wells were present in the area. A detailed discussion of background data and outside influences is presented in Section 3.4.

During the initial minute of both tests, small variations in drawdown were observed. These were the result of water filling the pump column and pressure variations at the flow control valve. Discharge rate was measured using a totalizing flowmeter which recorded discharge in 1,000 gallon increments. The totalizer was manually read and values documented throughout the two tests.

Vertical flow losses within the well were considered during the analysis. Upward flow within the well screen and casing to the pump intake is subject to friction losses that are a function of the screen and casing diameters, friction coefficient, and flow rate. Since the flow rate varies along the depth of the well screen because of distributed water intake along the screen, the losses vary with depth. Due to the large screen diameter, the friction losses within the well would have been relatively small compared to the drawdown imposed by testing.

Early-time recovery data after cessation of pumping was temporarily obscured due to the water in the pump column flowing back into the well. This creates a short-term injection pulse into the well that is superimposed on the test and monitor well recovery record. The pulse quickly reaches equilibrium and does not influence the analysis of the recovery data.

5.2 Constant-Rate Test Data

The data for the two constant-rate tests are summarized in this section.

5.2.1 CAV6002X Constant-Rate Test

The target pumping rate for the CAV6002X constant-rate test was 1,200 gpm. The pumping rate varied during first 10 minutes of the test and then stabilized. Totalizer readings indicated a total volume of 5,259,200 gal were pumped during the 72-hour test, an average of approximately 1,217 gpm. The pumping rate ranged from 1,200 to 1,267 gpm during the test.

The distances between the aquifer test pumping well CAV6002X and test observation wells are 157 ft to 180W902M and 225 ft to CAV6002M2.

Drawdown data for pumping well CAV6002X and the two observation wells used in this test are presented graphically in log-log and semi-log form on Figures B-1 through B-6. Transducer and physical test data are included on a CD ROM as explained in Appendix A. Recovery data were collected immediately upon cessation of pumping activities and discussed later in the section.

5.2.2 180W902M Constant-Rate Test

The target pumping rate for the 180W902M constant-rate test was 1,100 gpm. The pumping rate during initial startup varied but then stabilized rapidly. Totalizer readings indicated a total volume of 4,805,900 gal were pumped during the 72-hour test, an average of approximately 1,112 gpm. The pumping rate ranged from 1,033 to 1,135 gpm during the test.

The distances of the test observation wells from the second aquifer test pumping well 180W902M are 114 ft to CAV6002M2 and 157 ft to CAV6002X.

Drawdown data for pumping well 180W902M and the two observation wells used in this test are presented graphically in log-log and semi-log form on Figures C-1 through C-6. Transducer and physical test data are included on a CD ROM as explained in Appendix A. Recovery data were collected immediately upon cessation of pumping activities and discussed later in the section.

5.3 Analytical Model Selection

The analytical models used for the aquifer test evaluations were selected based upon observed site hydrogeologic conditions, diagnostic drawdown plots, and evaluation of applicability of potential analytical solutions appropriate for the site. The Neuman unconfined solution (1974) was determined to be the most appropriate solution for the site hydrogeologic conditions and response data. The Cooper Jacob approximation (1946) was selected as a secondary solution for comparison purposes.

The conceptual model was not clearly defined by drilling and well completion data. The basic analytical models that might be appropriate for analysis were identified and evaluation for applicability. The two wells that were tested, CAV6002X and 180W902M produce from both the alluvium and carbonate which are hydraulically connected. Both wells are completed with a gravel packed annulus extending from above the static water level to total depth, including both the alluvial and carbonate formations. The screen intervals extends from above the top of the carbonate to well completion depth. Data obtained from the tests provide compose information. The analysis is not able to evaluate the relative production from the two different formations to segregate hydraulic properties of each zone. The two zones are in hydraulic connection based up lithologic and response data observed during drilling.

The alluvial formation, generally described in the saturated zone as gravel to clayey gravel, was evaluated to potential alternative hydrogeologic behaviors. These include the alluvial formation behaving as an unconfined aquifer or an aquiclude, possibly leaky, with the base of the alluvium representing a confining boundary for the carbonate formation acting as an aquifer. Site data indicated unconfined conditions present and the presence of an aquiclude would be unlikely. The carbonate formation is fractured and could be expected to exhibit dual porosity.

The drawdown responses all exhibit a mid-time flattening and then resumption of increasing drawdown, indicating some sort of recharge variously from delayed gravity drainage (unconfined conditions), leakage (leaky aquitard), or matrix drainage (dual porosity). These different models affect the specification of the aquifer thickness, whether the alluvial thickness is considered part of the aquifer or not.

The total thickness of the carbonate is not known, and the extent to which the response would be affected by three-dimensional effects of partial penetration is not clear. There is also an indication of a range front fault zone trending north-south in the vicinity of the site. This could result in higher density of factures associated with the fault zone and fracture orientation resulting in horizontal aquifer anisotropy. The hydraulic characteristics of the fault and associated fractures such as: neutral, no-flow, or enhanced hydraulic conductivity compared to the surrounding materials, as well as horizontal anisotropy, would influence the drawdown response at the site. The elements of each of these models affect the response somewhat differently and attempts to fit each model revealed the applicability of the different models.

Alternate analytical models were tested including the Cooper-Jacob confined (1946), Neuman unconfined (1974), Moench unconfined (1997), Moench confined, leaky (1985), and the Barker Generalized Radial Flow Model (1988) confined with dual porosity and flow dimensions ranging from linear, radial to spherical. In addition, the models were tested both without and with a fault structure included as a no-flow boundary. The Cooper-Jacob approximation (simplified Theis model) was used to estimate T values for the mid-time and late-time slopes. The inclusion of a fault as a no-flow boundary was tested as an explanation of the increased slope from mid-time to late-time. A fault as a no-flow boundary should cause a doubling of the slope. The other three models would explain the response form, mid-time flattening and late-time increase in slope, as a function of mid-time recharge to the system from different potential sources: delayed gravity drainage, leakage from an overlying confining unit, or matrix drainage in the fractured formation.

The Neuman unconfined model incorporates delayed gravity drainage which could account for the mid-time flattening of drawdown. The Moench unconfined model, which includes casing storage and an additional factor for adjusting the delay of drainage, was used after the Neuman model to further refine the unconfined model analysis. The Moench confined, leaky model includes leakage from the confining layer which could also account for the mid-time flattening of drawdown. The Barker GRFM dual-porosity model includes matrix drainage, and was tested for ability to simulate the mid-time flattening. Each model produces distinct type curves when using parameter values within expected and plausible ranges for the formation type. After review of the alternatives, the Neuman unconfined (1974) analytical model was determined to be the most appropriate analytical solution and provide the optimal fit to the site data.

General assumptions associated with the Neuman unconfined solution (1974) are that the:

- aquifer has infinite areal extent and uniform extent of flow
- aquifer is homogeneous and has uniform thickness
- aquifer potentiometric surface is initially horizontal
- flow is unsteady
- pumping well is fully or partially penetrating
- aquifer is unconfined with delayed gravity drainage response, and
- diameter of pumping well is very small so that storage in the well can be neglected.

The complexities of the aquifer system do not fully conform to the assumptions of the analytical model. However, the Neuman solution is the most appropriate of the analytical solutions available for the observed hydrogeologic conditions at this location. While the assumptions related to aquifer and flow conditions are not perfectly satisfied, they are sufficiently satisfied to provide a reasonable estimate of aquifer parameters.

Cooper-Jacob approximation (Cooper and Jacob, 1946) was used as a secondary evaluation solution method for comparison purposes. This approach was used to fit late-time data for plots where sufficient late data was available reflecting radial flow condition. The convergence of the two solution methods would occur after the delayed gravity drainage response period and radial-flow conditions are present.

5.4 Constant-Rate and Recovery-Test Analysis

This section presents the aquifer test evaluation methodology, results, and analysis plots of the test drawdown and recovery data. The two constant-rate tests were first evaluated individually, and then a common hydrologic model that consistently accommodated both test results was developed.

5.4.1 Test Analysis Methodology

The aquifer test analysis software AQTESOLV V4.50 (Duffield, 1996-2007) was used for data processing and curve fitting. The data logger records of pressure transducer output were used to create AQTESOLV input files of the drawdown and recover data. The time representing the measurement at the start of identifiable drawdown at the test well was used as the start time to determine the elapsed time and drawdown magnitude.

The Neuman unconfined solution was fitted to the drawdown and recovery responses of both the test well and monitor well for both constant-rate tests to determine the model parameter set that would best fit all of the data. Selected late time data sets, with sufficient late time data which reflected radial flow conditions after the gravity drainage response, were analyzed using the Cooper-Jacob solution to compare results. The Theis Recovery Method was also applied to the recovery data set for additional comparison.

5.4.2 Test Analysis Results

The Neuman unconfined solution was fitted to the data iteratively to refine the fit and produce an overall model that was consistent with all site data to determine the parameter range in which the solution is optimized. The model fit to all of the data at each well and constraints is optimal within a relatively restricted range for the major parameters.

A correction equation for dewatering (Kruseman and De Ridder, 1994, p. 101)) was evaluated for application to the drawdown response to account for the reduction in saturated thickness during pumping. The amount of drawdown observed was small in comparison to the aquifer saturated thickness. As a result, a dewatering correction was not applied to the dataset.

Parameter symbols used in this section are presented below:

Kr = Aquifer radial hydraulic conductivity (ft/day)
Kz = Aquifer vertical hydraulic conductivity (ft/day)
Q = Pumping discharge rate (gpm)
Sw = Borehole skin factor or well loss coefficient value (dimensionless)
s = Drawdown
t = Time
T = Transmissivity (ft^2/day)
Sy = Specific Yield (dimensionless)
S = Storativity (dimensionless)
r = radial distance (ft)
b = saturated thickness (ft)

Well attribute and geologic formation data relevant to the analysis of the constant-rate tests are presented in Table 5-1. The basic input measurement and parameter values used for analyses are shown in Table 5-2.

The step-drawdown test analysis indicated that a large proportion of the Test Well CAV6002X drawdown was nonlinear losses, which typically are due to well losses. However, the well construction provides substantial screen-open area, and the gravel pack likewise should not be restrictive because of extensive well development. Consequently, the well losses are mainly attributed to the turbulent flow in the near-well radius that results from converging flow in the fractures, which are restrictive. The large proportion of drawdown attributed to nonlinear losses equates to a large well loss coefficient value (Sw). In turn, these large well losses account for the great difference in drawdown between the drawdown observed at CAV6002X and 180W902M

Table 5-1
Test and Observation Well Attributes

	CAV6002X	180W902M	CAV6002M2
Surface Elevation (ft amsl)	5,988	5,990	5,983
Depth to top of Guilmette LS (ft)	430	420	NA
Elevation top of Guilmette LS (ft amsl)	5,558	5,570	NA
Depth to top of Simonson DO (ft)	500	440	460
Elevation top of Simonson DO (ft amsl)	5,488	5,550	5,523
Well Depth (ft)	917	905	893
Elevation Base of Well (ft amsl)	5,071	5,085	5,090
Distance from CAV6002X (ft)	0	157 NNW	225 NW
Distance from 180W902M (ft)	157 SSE	0	114 WNW
Constant-Rate Test	11/30 - 12/3/2007	1/3 - 1/6/2008	---

Table 5-2
Measurement and Parameter Values Used for Analysis

r(w) - Radius of CAV6002X borehole	1.083 ft	Based on drilled diameter
r(c) - Radius of CAV6002X well casing	0.833 ft	ID of casing/screen
r(e) - Radius of production tubing	0.417 ft	OD of production tubing
r(w) - Radius of 180W902M borehole	0.729 ft	Based on drilled diameter
r(c) - Radius of 180W902M well casing	0.516 ft	ID of casing/screen
r(e) - Radius of production tubing	0.417 ft	OD of production tubing
r(w) - Radius of CAV6002M2	0.510 ft	Based on drilled diameter
r(c) - Radius of CAV6002M2 well casing	0.250 ft	ID of casing/screen
Saturated thickness (CAV6002X)	776 ft	SWL to TD

during the two constant-rate tests. The nonlinear well losses resulting from turbulent flow in restrictive fractures are greater at CAV6002X than 180W902M. This may be the result of formation lower facture density and formation connectivity at CAV6002X. Evaluation of well loss components provides an indication of drawdown in the formation in the vicinity of the test well outside of the drawdown distortion caused by well losses from turbulent flow and well construction. Drawdown without well losses provides a more realistic value of aquifer drawdown in the vicinity of the test well during testing and well production.

Semi-log time drawdown analysis plots using the optimal Neuman solution for the constant-rate test performed at CAV6002X are presented in Figures 5-1 and 5-2. The Cooper Jacob approximation plot for 180W902M is presented in Figure 5-3.

Results of the Neuman and Cooper-Jacob solutions for the constant-rate tests are summarized in Table 5-3. The representative solution analysis plots for each test and method are presented below:

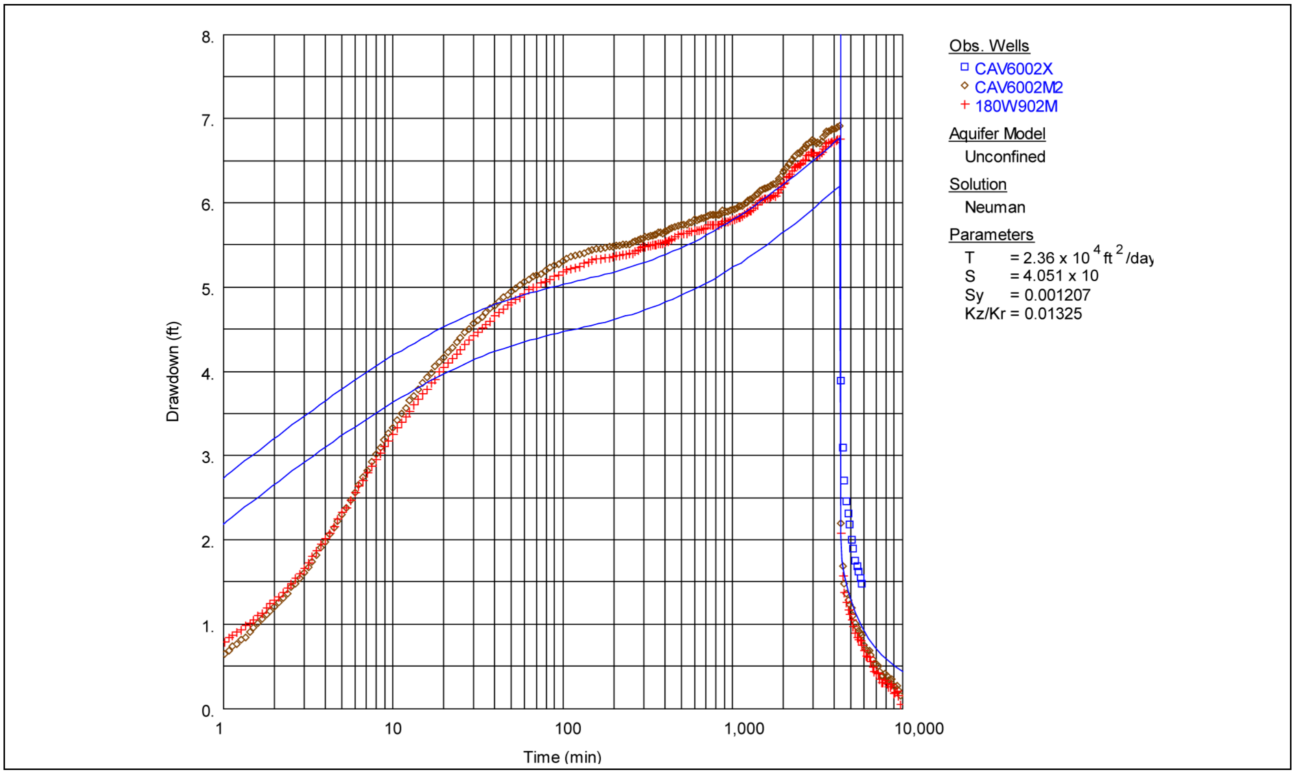


Figure 5-1
Neuman Solution for CAV6002X Test at 180W902M Semi-Log Plot

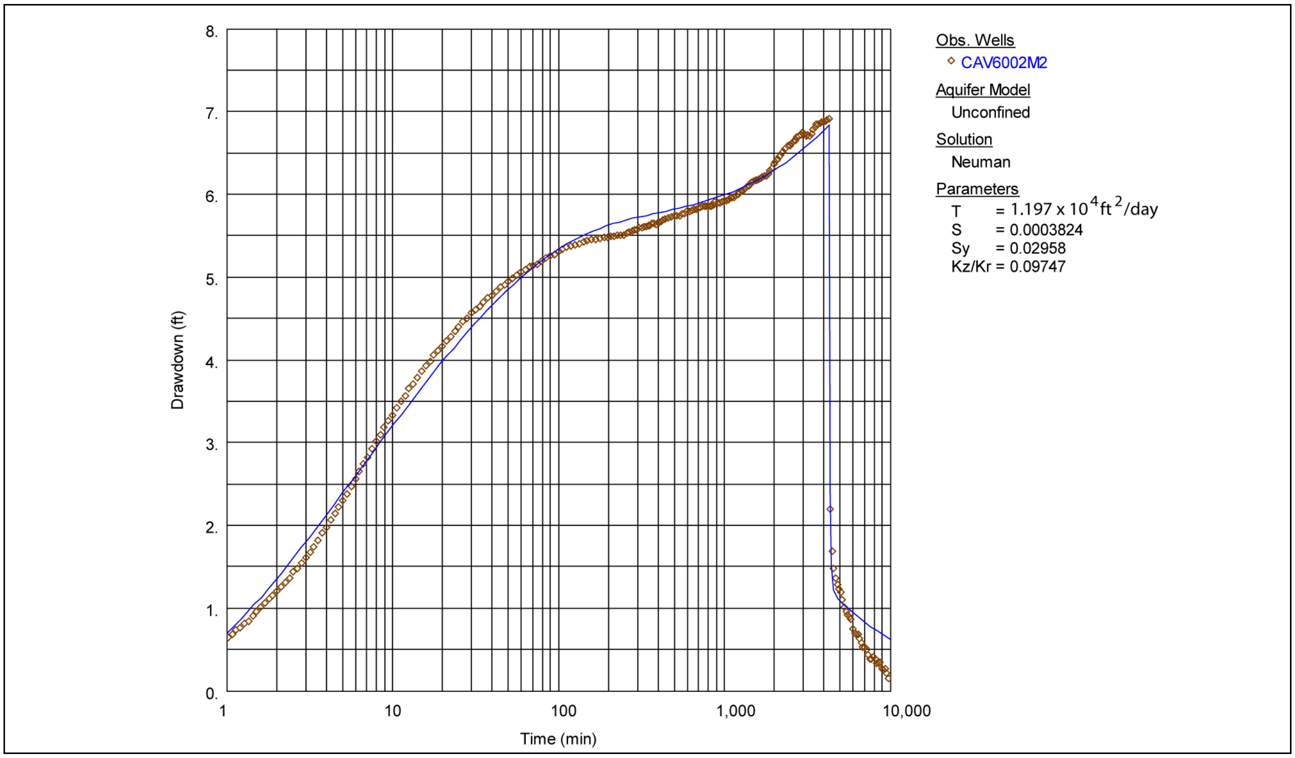


Figure 5-2
Neuman Solution for CAV6002X Test at CAV6002M2 Semi-Log Plot

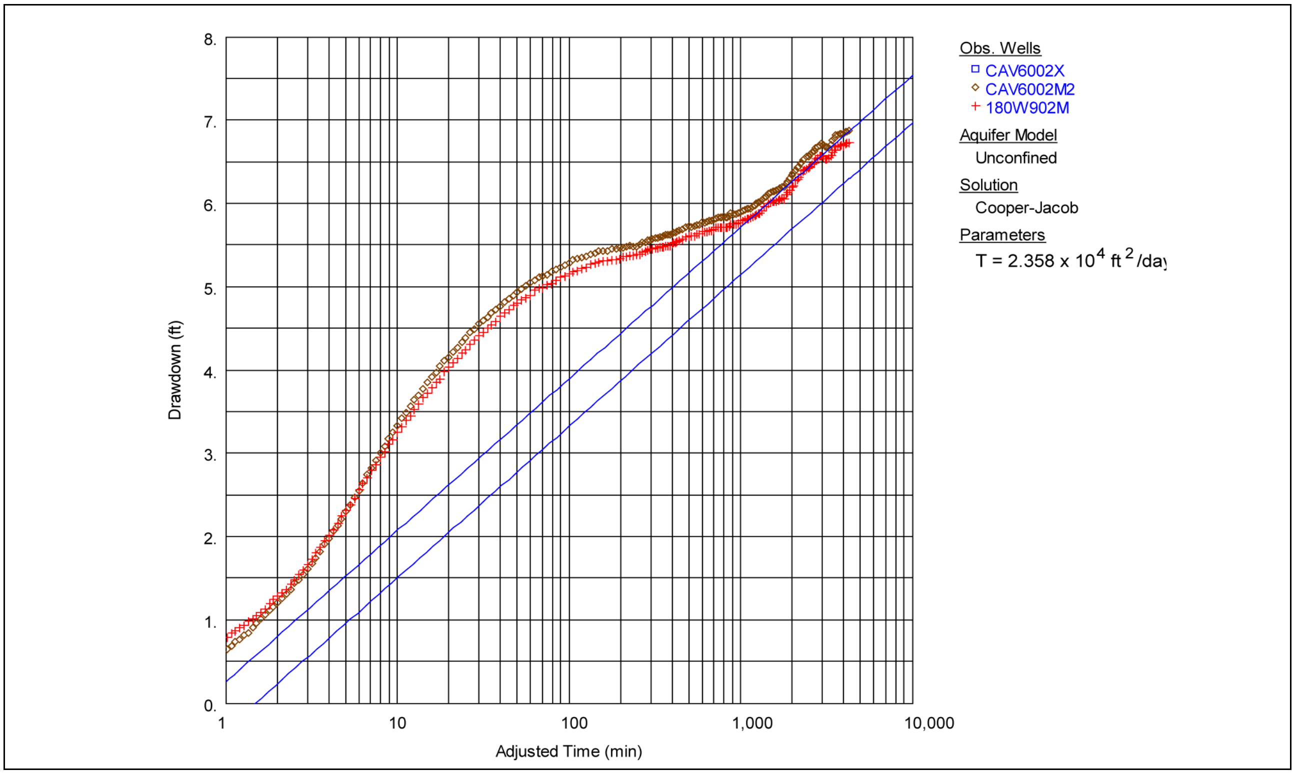


Figure 5-3
Cooper-Jacob Solution for CAV6002X Test at 180W902M Semi-Log Plot

Table 5-3
Hydraulic Parameter Results for Test Analyses

Pumping Well	Fit to Observation Well	Analytic Model	Figure	*T* *(ft²/day)*	*K* *(ft/day)*	*S*	*Sy*	*Kz/Kr*
CAV6002X	CAV6002X	Cooper-Jacob	-	5,700	7.40	-	-	-
CAV6002X	180W902M	Neuman unconfined	5-1	23,600	30.4	4.1×10^{-5}	0.001	0.01
CAV6002X	CAV6002M2	Neuman unconfined	5-2	12,000	15.4	3.824×10^{-4}	0.03	0.1
CAV6002X	180W902M	Cooper-Jacob	5-3	24,000	30.4	-	-	-
CAV6002X	CAV6002M2	Theis Recovery	5-8	13,000	16.8	-	-	-
180W902M	180W902M	Cooper-Jacob	5-7	21,000	27.1	-	-	-
180W902M	CAV6002X	Neuman unconfined	5-4	23,600	30.4	1.353×10^{-4}	0.001	0.02
180W902M	CAV6002M2	Neuman unconfined	5-6	9,100	11.7	4.445×10^{-4}	0.12	0.3
180W902M	CAV6002X	Cooper-Jacob	5-5	22,000	28.6	-	-	-
180W902M	CAV6002X	Theis Recovery	5-9	17,000	21.9	-	-	-

For Pumping well CAV6002X, the Neuman solution aquifer transmissivity (*T)* results for analysis of 180W902M observation well was 23,600 ft^2/day and were comparable with the Cooper-Jacob approximation. Results for the CAV6002M2 observation well using Neuman resulted in a *T* of 12,000 ft^2/day. Using a saturated thickness of 776 ft results in a hydraulic conductivity of 30.4 and 15.4 ft/day, respectively for the two tests. Specific yield ranged from 0.001 to 0.03. The Cooper-Jacob approximation analysis *T* at the CAV6002X pumping well is 5,700 ft^2/day. This value may be skewed by the high well losses resulting in substantial additional drawdown over what would be expected from aquifer losses only.

Drawdown analysis plots using the optimal Neuman solution and Cooper-Jacob approximation for the constant-rate test performed at 180W902M are presented in Figures 5-4 through 5-7.

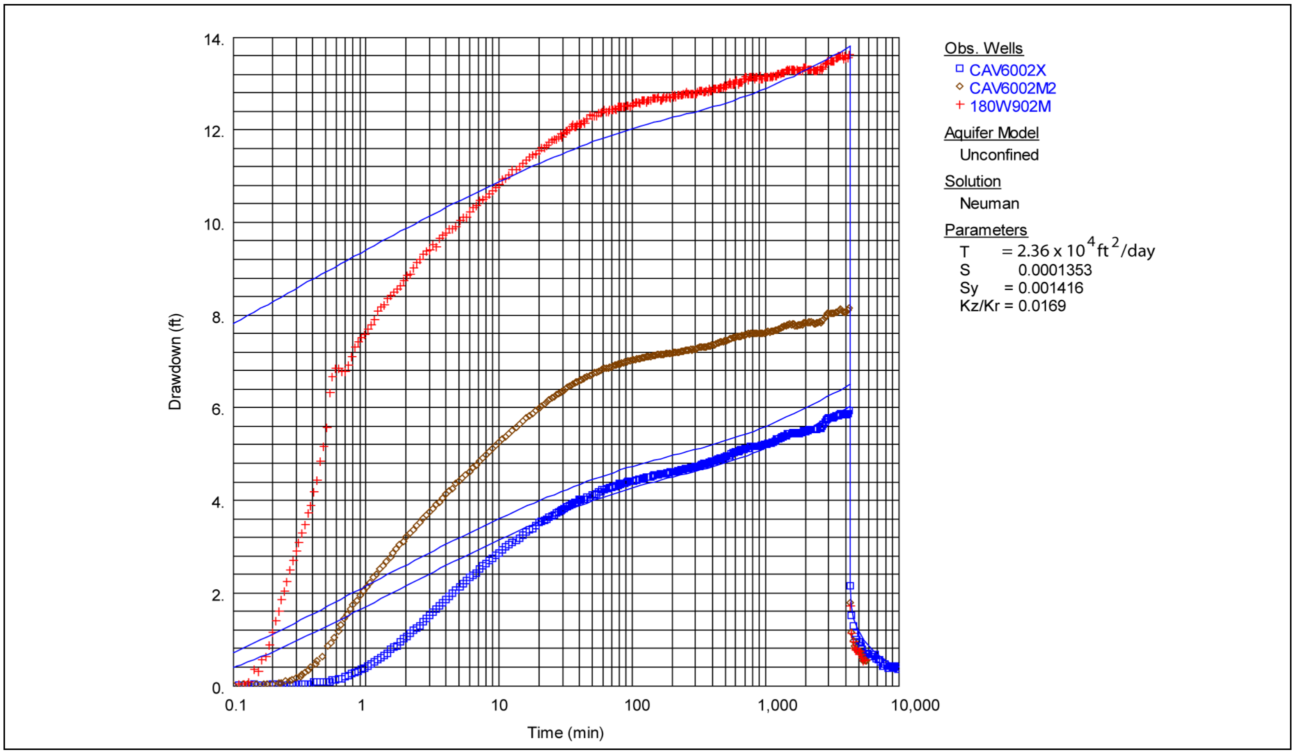


Figure 5-4
Neuman Solution for Test 180W902M at CAV6002X Semi-Log Plot

For pumping well 180W902M, the Neuman solution aquifer *T* results for analysis of CAV6002X observation well was 23,600 ft^2/day and were comparable with the Cooper-Jacob approximation value of 22,000 ft^2/day. Results for the CAV6002M2 observation well using Neuman resulted in a *T* of 9,100 ft^2/day. Using a saturated thickness of 776 ft results in a hydraulic conductivity of 30.4 and 11.7 ft/day, respectively for the two tests. Specific yield ranged from 0.001 to 0.12. The Cooper-Jacob approximation analysis plot of the 180W902M pumping well drawdown data is presented in Figure Figure 5-7 and resulted in a *T* value of 21,000 ft^2/d.

The Theis Recovery Method analysis was applied for comparison purposes to the recovery data collected from the test and monitor well for both tests. These figure presents a plot of residual drawdown versus log t/t' (ratio of total pumping elapsed time to time since pumping stopped). In

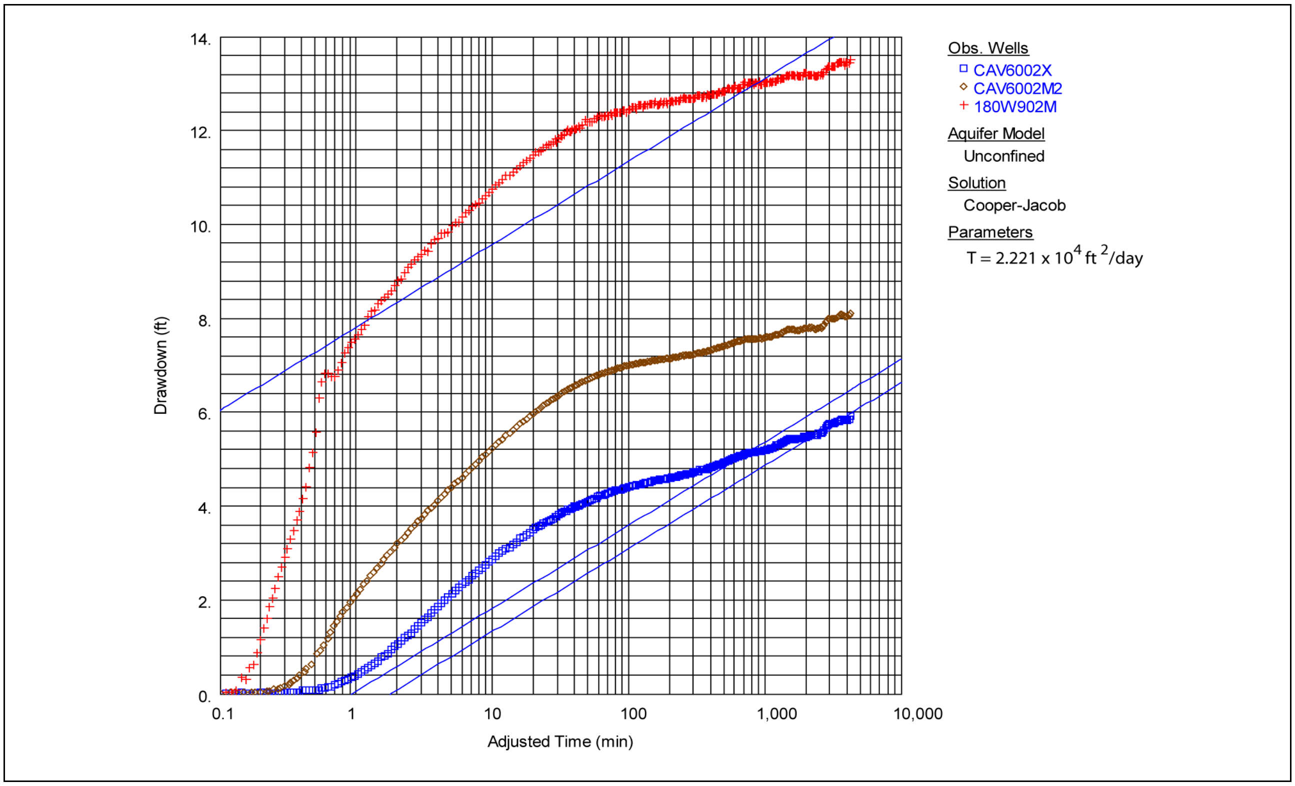


Figure 5-5
Cooper-Jacob Solution for Test 180W902M at CAV6002X Semi-Log Plot

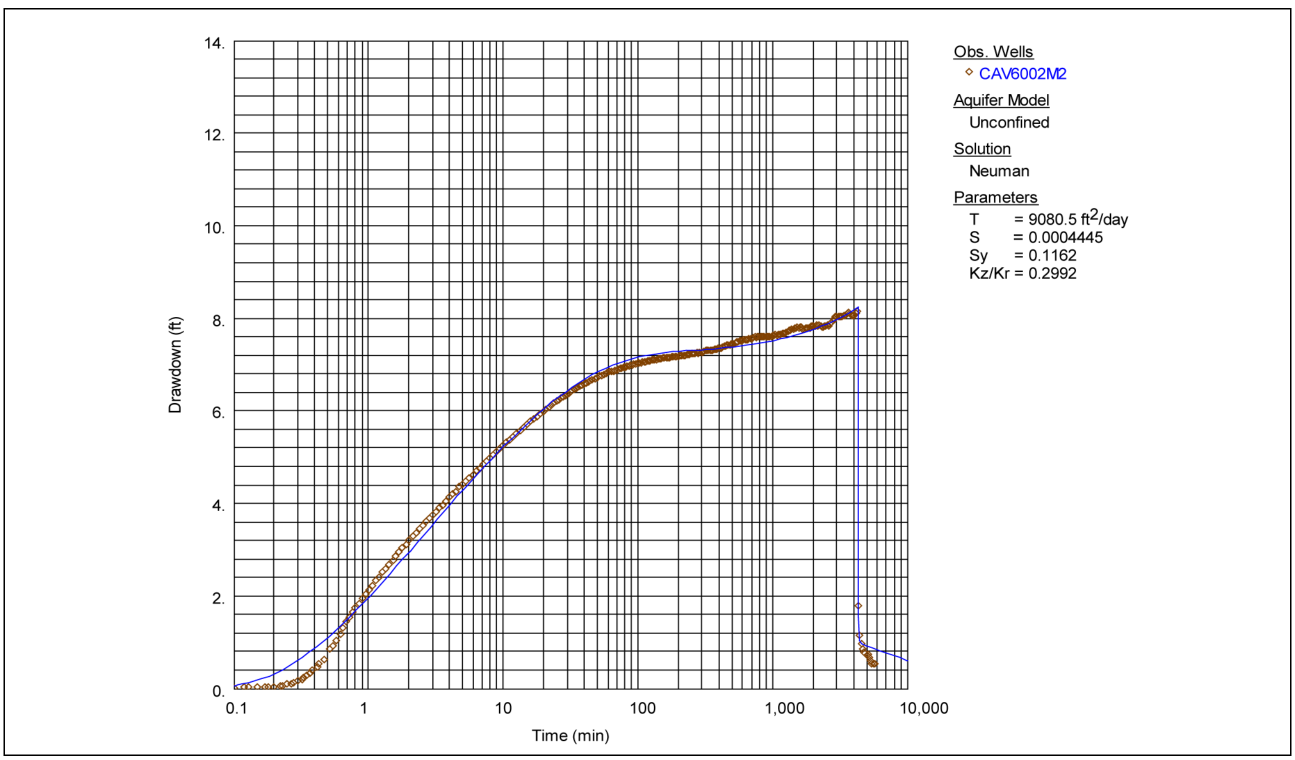


Figure 5-6
Neuman Solution for Test 180W902M at CAV6002M2 Semi-Log Plot

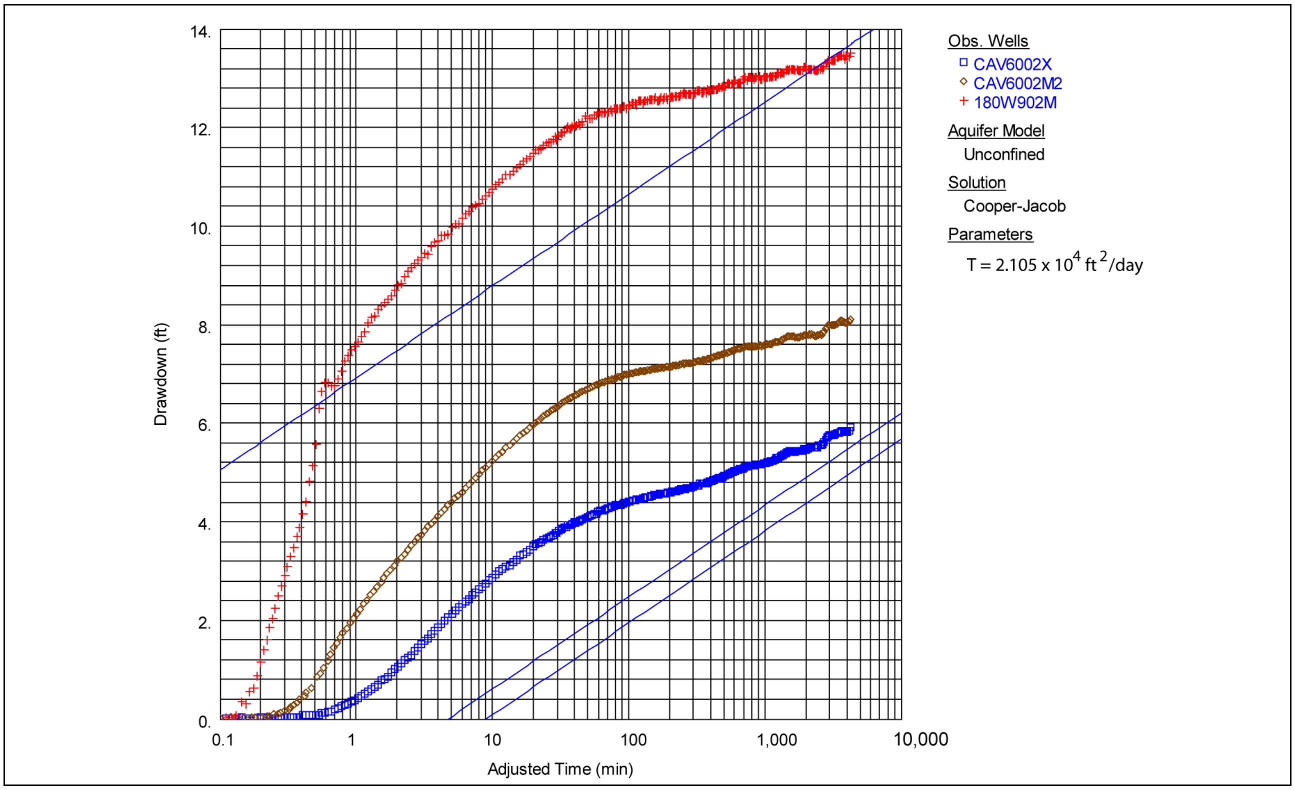


Figure 5-7
Cooper-Jacob Solution for Test 180W902M at 180W902M Semi-Log Plot

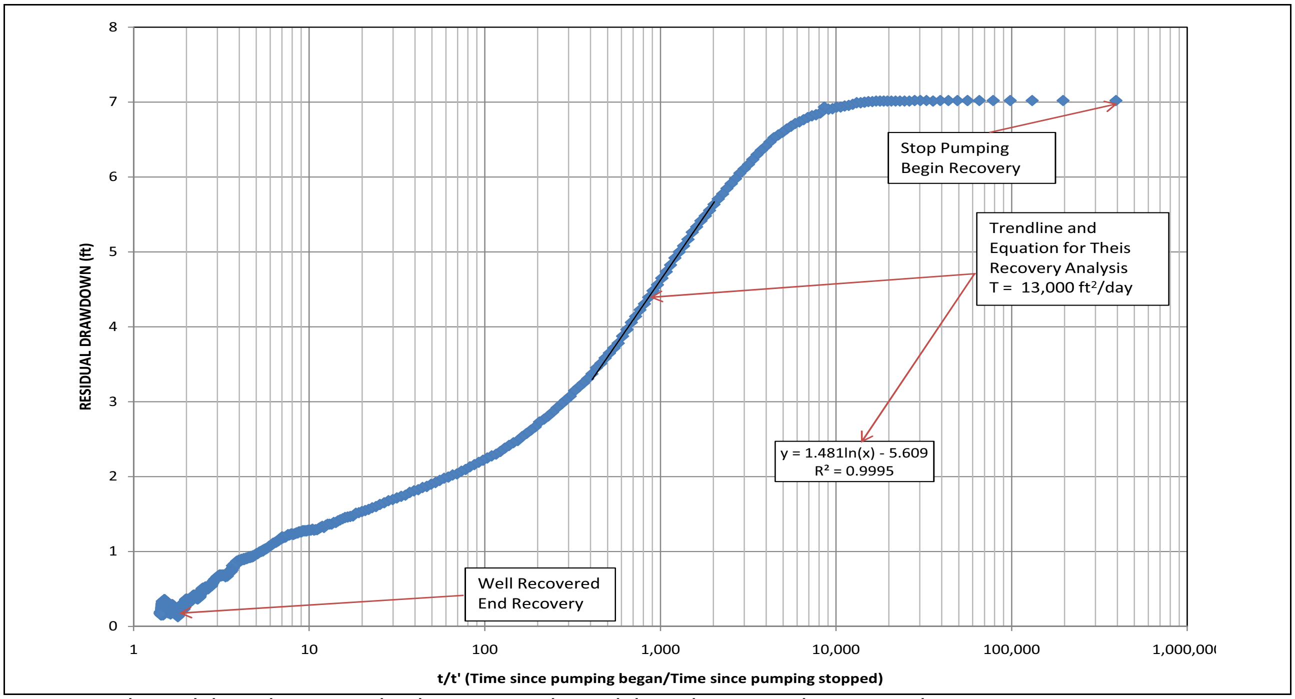
these plots, initial recovery is to the right and later recovery is to the left.Analysis plots of recovery at CAV6002M2 for the CAV6002 test is presented in Figure 5-8. The results indicated a *T* value of 13,000 ft^2/day**.** Analysis plots of recovery at CAV6002X for the 108W902M test is presented in Figure 5-9. The results indicated a *T* value of 17,000 ft^2/day.

5.5 Discussion

Analysis of the test results provides an estimate of aquifer property values *T* and *Sy* based upon the data collected during the two 72-hour constant-rate tests and subsequent recovery periods. The test provided representative data about the aquifer system without outside pumping or significant natural hydrologic variation influence. Diagnostic drawdown response plots and site hydrogeologic conditions were indicative of a unconfined aquifer system which exhibited delayed gravity drainage. The drawdown plots suggested late-time radial flow after the delayed gravity drainage response.

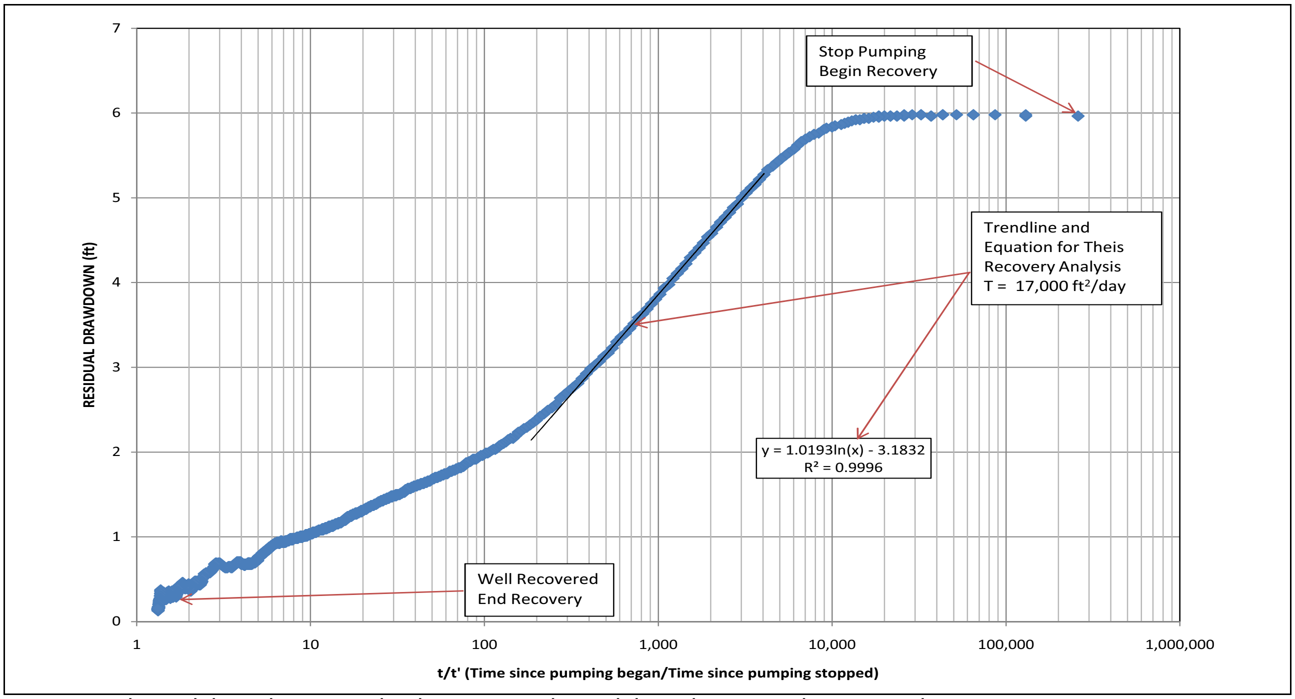
Results of the analyses suggest horizontal anisotropy as *T* values in the general north-south direction were higher than those in the northwest-southeast and east-west directions. The *T* value derived from CAV6002X and 180W902M with the Neuman unconfined solution is 23,600 ft^2/day. *T* values derived from observation well CAV6002M2 while pumping CAV6002X and 180W902M with the Neuman unconfined solution range from 9,100 to 12,000 ft^2/day.

The presence of significant boundaries and/or higher or lower hydraulic-conductivity zones cannot be evaluated until extended pumping is performed. Additional analysis and review should be performed



Note: t = Elapsed time since pumping began; t' = elapsed time since pumping stopped.

Figure 5-8
Monitor Well CAV6002M2 Recovery Data for Testing at CAV6002X Presenting Residual Drawdown versus the Log of the Ratio of t/t'



Note: t = Elapsed time since pumping began; t' = elapsed time since pumping stopped.

Figure 5-9
Monitor Well CAV6002X Recovery Data for Testing at 180W902M Presenting Residual Drawdown versus the Log of the Ratio of t/t'

as longer-term operational pumping data become available for the well site or as additional regional hydrogeologic data are obtained.

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6.0 WATER CHEMISTRY

Groundwater-chemistry data for Test Well CAV6002X and Monitor Well 180W902M are presented within this section. Additional data for other SNWA wells located within the vicinity of these wells (see Figure 2-1) are also presented for comparison.

6.1 Groundwater Sample Collection and Analysis

Water samples were collected from Test Well CAV6002X on December 3, 2007, at 07:00 after pumping over 5 million gallons (following well development, step-drawdown testing, and a portion of the constant-rate test). For these samples, turbidity, pH, specific conductance, and temperature were measured in the field. These parameters were also measured periodically during well development and testing. Sampling and field measurement of the water-quality parameters were performed using the *National Field Manual for the Collection of Water-Quality Data* (USGS, 2007) as the basis. All measurement equipment was calibrated according to the manufacturers' calibration procedures. Samples were sent to Weck Laboratories, Inc., (Weck) for analysis of a large suite of parameters including major solutes, minor and trace constituents, radiological parameters, and organic compounds. Weck is certified by the State of Nevada and performs all analyses according to U.S. Environmental Protection Agency (EPA) methods or methods published in *Standard Methods for the Examination of Water and Wastewater* (Eaton et al., 2005). The parameters analyzed and the corresponding analytical method are presented in Tables D-1 and D-2. Weck provided all sample containers and preservatives. Radiation Safety Engineering, Inc., and Frontier Analytical Laboratory were contracted by Weck for the analysis of radiological parameters and dioxin, respectively. In addition, samples were collected for analysis of oxygen and hydrogen isotopes by University of Waterloo's Environmental Isotope Laboratory, carbon isotopes (carbon-14 and $\delta^{13}C$) by University of Arizona's NSF-Arizona Accelerator Mass Spectrometry Laboratory, chlorine-36 by Purdue University's Purdue Rare Isotope Measurement (PRIME) Laboratory, in Indiana, and strontium and uranium isotopes (and uranium concentration) by the USGS Earth Surface Processes Radiogenic Isotope Laboratory in Denver.

Water samples were collected from Monitor Well 180W902M on May 18, 2006, at 13:30 after pumping approximately 197,100 gal. Samples were sent to Weck for analysis of major solutes and trace and minor constituents. A sample was also collected for the analysis of oxygen and hydrogen isotopes by University of Waterloo's Environmental Isotope Laboratory (Table D-1). The pH, specific conductance, and temperature associated with these samples were measured in the field.

For comparison, the groundwater chemistry of additional wells in the area are presented in this section. The three wells drilled by SNWA vary from a total depth of 893 to 917 feet below ground surface (bgs) and were completed in both the Quaternary-Tertiary alluvium and the Guilmette

Limestone and the Simonson Dolomite. The total depth of the Well 382807114521001 drilled by the USGS is 460 ft.bgs (see Figure 2-1). The wells and the total depths are given in Table 6-1 below:

Table 6-1
Total Depths of Wells Drilled by SNWA and the Well 382807114521001 in Cave Valley, Nevada

Well	Aquifer Material	Total Drilled Depth (ft bgs)
180W501M	Carbonate	1,215
180W902M	Carbonate	915
CAV6002X	Carbonate	917
382807114521001	Carbonate	460

6.2 EPA Drinking Water Standards

The national maximum contaminant levels (MCLs) for drinking water, established by the EPA and authorized by the Safe Drinking Water Act, are presented in Tables D-1 and D-2. These national health-based standards are to protect against both naturally occurring and man-made contaminants that may be found in drinking water. Also presented in Table D-1 are the secondary drinking water standards established by the EPA. These are nonenforceable guidelines that regulate contaminants that may cause cosmetic or aesthetic effects in drinking water. For the groundwater of Test Well CAV6002X, no constituent exceeded the Secondary MCL. No exceedances were also observed for the groundwater samples collected from Monitor Well 180W902M and Well 382807114521001. There were a few exceedances observed in Monitor Well 180W501M and this will be discussed in a later section.

6.3 Groundwater-Chemistry Results

In this section, the field measurements and analytical results for the groundwater of Test Well CAV6002X and Monitor Well 180W902M are presented and compared with those of groundwater samples from two other wells within the vicinity in Cave Valley.

6.3.1 Field Results

Field measurements of turbidity, pH, specific conductance, and temperature were performed periodically throughout development and testing of Test Well CAV6002X and for the sample collected for laboratory analysis (see Table D-1). Field measurements ranged from 0.33 to 7.91 nephelometric turbidity units (NTUs) for turbidity, 7.17 to 8.62 for pH, 342 to 533 µS/cm for specific conductance, and 14.2°C to 23°C for temperature over the period of pumping (71 hours) with no observable trends. Field measurements made at the time of sample collection are reported as 1.2 NTU, 468 µS/cm, 7.83, and 15.9°C, for turbidity, specific conductance, pH, and water temperature, respectively.

During the 72-hour constant-rate test for Monitor Well 180W902M, field measurements of turbidity, pH, specific conductance, and temperature ranged from 0.11 to 2.84 NTU, 7.14 to 7.64, 418 to 451 µS/cm and 13.9°C to 18.8°C, respectively. No dissolved oxygen concentration measurements were performed for the groundwater of Monitor Well 180W902M. Field measurements made at the time of sample collection are reported as 441 µS/cm, 7.58, and 18.2°C for specific conductance, pH, and water temperature, respectively.

The temperature of Test Well CAV6002X (15.9°C) was not significantly different from that of the Monitor Well 180W902M (18.2°C). Similarly, the specific conductivities were not very different in both the test and monitor wells (468 µS/cm (CAV6002X), and 441 µS/cm (180W902M)).

6.3.2 Major Constituents

The concentration of the major constituents in groundwater samples from Test Well CAV6002X and Monitor Well 180W902M are presented in Table D-1. Major constituents are defined as those commonly present in groundwater at concentrations greater than 1 mg/L and typically include bicarbonate (HCO_3), calcium (Ca), chloride (Cl), magnesium (Mg), potassium (K), silica (SiO_2), sodium (Na), and sulfate (SO_4). The sum of the charge of major cations should equal the sum of the charge of the major anions in solution (in milliequivalents per liter [mEq/L]); thus, calculation of the anion-cation (charge) balance is used to assess the accuracy of the analyses and to ensure that the full suite of anions and cations present as major constituents in the groundwater have been included in the analyses. The charge balances for the analysis of groundwater in Test Well CAV6002X and Monitor Well 180W902M are 0.9 and 1.4 percent respectively, and indicate that the analyses were performed adequately (Table D-1).

To illustrate the relative major-ion compositions in these groundwater samples, a Piper diagram of the Test Well CAV6002X, Monitor Well 180W902M, Monitor Well 180W501M, and Well 382807114521001 is presented in Figure 6-1. A Piper diagram consists of two triangular plots presenting the major cations (left triangle) and major anions (right triangle) in percent milliequivalents. The two triangular plots are then projected to a central diamond where the relative abundance of all major ions is presented. A Piper diagram is used to evaluate similarities in groundwater major-ion compositions, to identify the hydrochemical water type representing the aquifer(s) from which the groundwater was collected, and to assess possible evolutionary trends that have occurred along a flowpath. As shown in Figure 6-1, the relative concentrations of major ions are similar for all four groundwater samples. The groundwater samples all represent a calcium-magnesium-bicarbonate facies that is typical of dissolution of calcite and dolomite in waters of a carbonate-rock aquifer. The relative concentration of sulfate is however, greater in the Well 382807114521001, thus rendering it a Ca-Mg-HCO_3-SO_4 water.

Stiff diagrams for these groundwater samples are presented in Figure 6-2. Major solutes are presented in a Stiff diagram so that their relative proportions are identified by their shape and the magnitude of the concentrations by its size. As apparent in the Stiff diagrams in Figure 6-2, groundwater from the four wells, CAV6002X, 180W902, 180W501M, and Well 382807114521001 are nearly identical and are dominated by calcium, magnesium and carbonate, with a somewhat greater concentration of sulfate in the Well 382807114521001 rendering it a Ca-Mg-HCO_3-SO_4

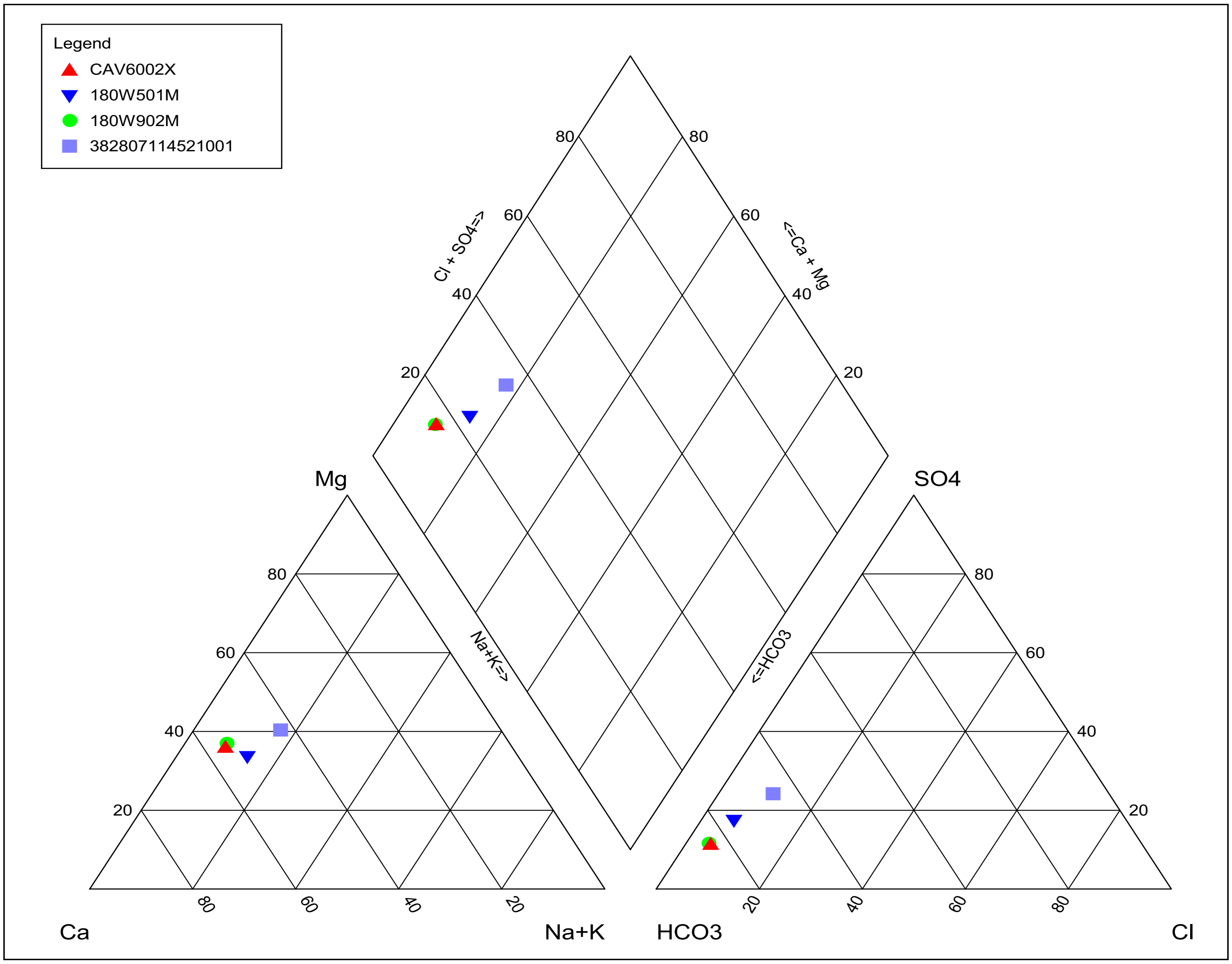

Figure 6-1
Piper Diagram Illustrating Relative Major-Ion Compositions of Groundwater in Cave Valley, Nevada

water. The concentrations of calcium and bicarbonate are greater in the groundwater samples from Test Well CAV6002X and Monitor Well 180W902M.

6.3.3 Trace and Minor Constituents

The concentrations of trace elements in the groundwater from Test Well CAV6002X, Monitor Well 180W902M, Monitor Well 180W501M, and Well 382807114521001 are presented in Table D-1. The dominant trace element present in the groundwater from Test Well CAV6002X, Well 382807114521001 and Monitor Well 180W902M is strontium (180 µg/L) which is consistent with the relatively high concentration of strontium in carbonate rocks (i.e., limestone) (Drever, 1988). The dominant trace element in Monitor Well 180W501M is iron (650 µg/L). All the trace element concentrations in Test Well CAV6002X, Well 382807114521001, and Monitor Well 180W501M were below the EPA's primary and secondary MCLs. The concentrations of iron and managanese in

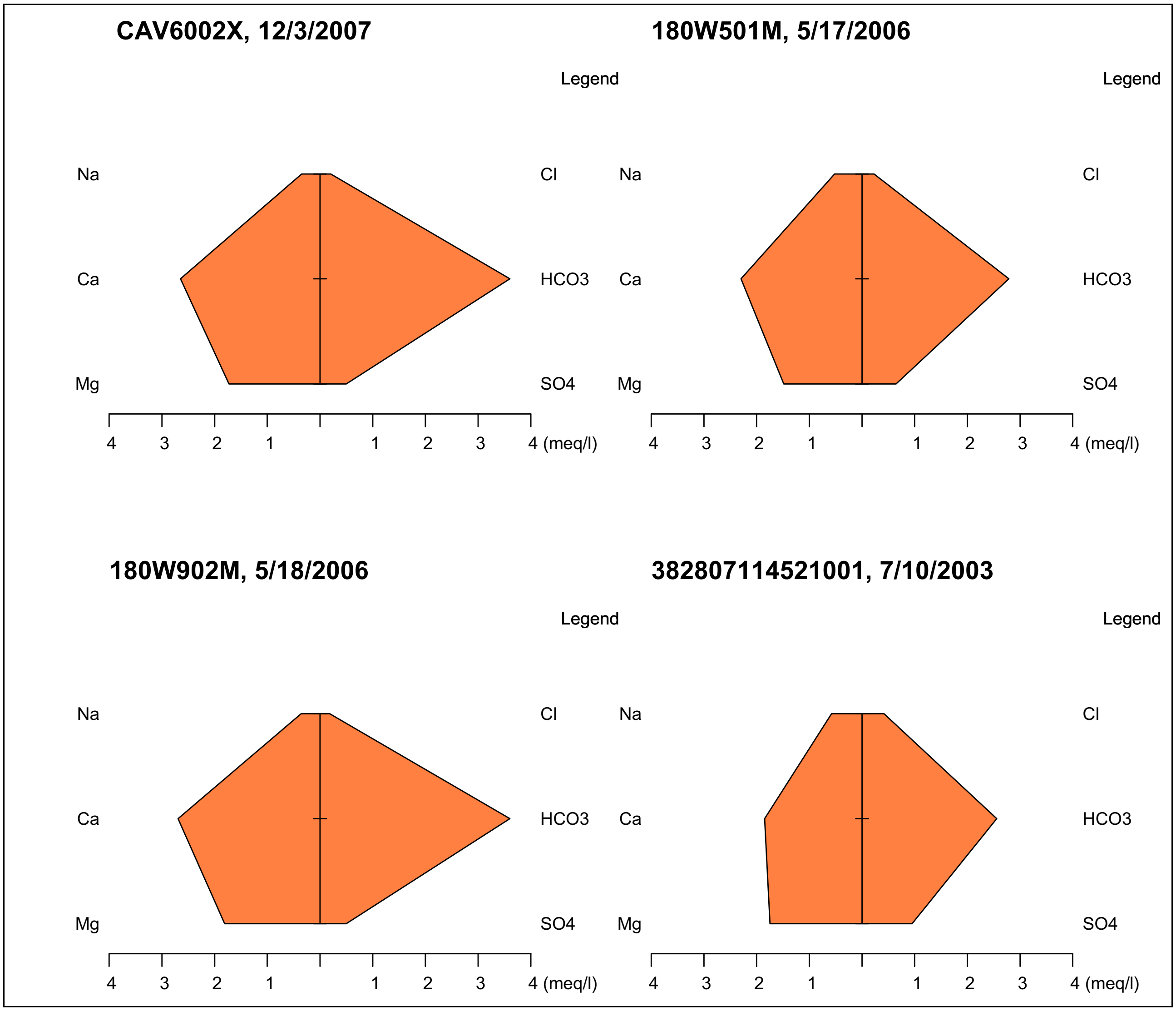

Figure 6-2
Stiff Diagram Illustrating Relative Major-Ion Compositions of Wells in Cave Valley, Nevada

Monitor Well 180W501M were 650 and 120 µg/L respectively and exceeded the secondary EPA MCLs (Table D-1).

6.3.4 Stable Isotopes and Environmental Tracers

The stable hydrogen, oxygen, and carbon isotopic compositions of the groundwater samples from Test Well CAV6002X, 180W902M and 180W501M, and the stable hydrogen and oxygen isotopic compositions of the groundwater samples of Well 382807114521001 are presented in Table D-1. Table D-1 also presents chlorine-36 for CAV6002X, and strontium-87/86 data for the groundwater samples collected from Monitor wells 180W501M and 180W902M.

6.3.4.1 Hydrogen and Oxygen Isotopes

Stable isotopes of hydrogen and oxygen behave conservatively in most groundwater systems and therefore can be used to indicate groundwater source, trace groundwater flowpaths, evaluate possible mixing of groundwater along a flowpath, and evaluate water budgets. Isotopic concentrations are reported using delta notation (δD and $\delta^{18}O$) as the relative difference between the isotopic ratio ($D/^{1}H$ or $^{18}O/^{16}O$) measured for the sample and that of the Vienna Standard Mean Ocean Water (VSMOW) reference standard. The analytical precisions for δD and $\delta^{18}O$ are typically ± 1‰ and ± 0.2‰, respectively.

The analytical results for δD and $\delta^{18}O$ for Test Well CAV6002X, Well 382807114521001, and Monitor wells 180W902M and 180W501M are presented in Table D-1 and Figure 6-3. Figure 6-3 presents data for the SNWA wells in Cave Valley and Well 382807114521001 along with the Global Meteoric Water Line (GMWL; $\delta D = 8\delta^{18}O + 10$) (Craig, 1961). These groundwater samples exhibit similar relatively light stable isotope ratios that are typical of recharge at high elevations in Cave Valley (Thomas and Mihevc, 2006). All the samples plot slightly below the Global Meteoric Water Line, suggesting that the water underwent slight evaporation prior to recharge.

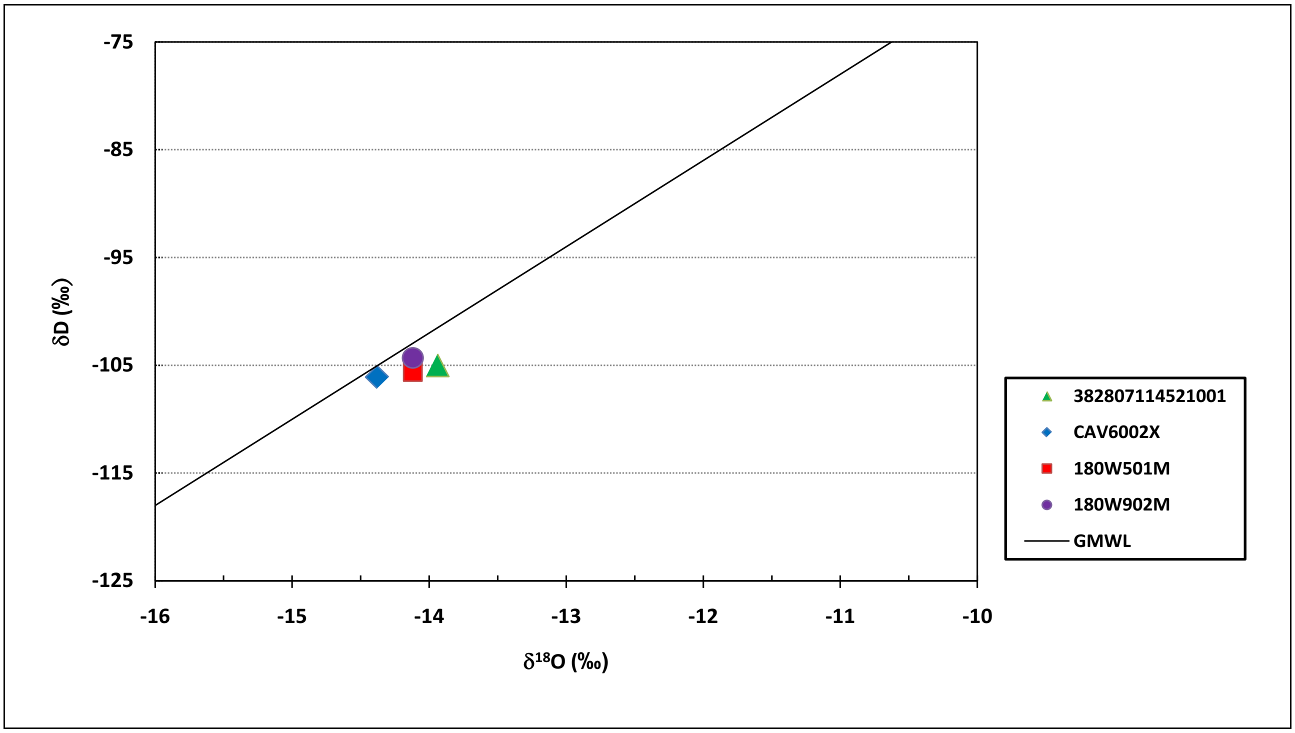

Figure 6-3
Plot of δD versus $\delta^{18}O$ of groundwater samples in Cave Valley, Nevada

6.3.4.2 Carbon Isotopes

The isotopic composition of stable carbon ($\delta^{13}C$) in groundwater is used to assess the extent of isotope mass transfer that occurred along a groundwater flowpath. Corrections based on this assessment can then be applied to Carbon-14 (^{14}C) data to determine the age of the groundwater. The

$\delta^{13}C$ composition is reported as the relative difference between the isotopic ratio, $^{13}C/^{12}C$, for the sample and that of the Pee Dee Belemnite (PDB) reference standard. The analytical precision for $\delta^{13}C$ is typically ± 0.3‰. Carbon-14 is reported as percent modern carbon (pmc), where modern carbon is defined as the approximate ^{14}C activity of wood grown in 1890 (13.56 disintegrations per minute per gram of carbon), before the dilution of ^{14}C in the atmosphere by burning fossil fuels. The analytical precision for ^{14}C in these groundwater samples is ± 0.1 pmc.

Relatively similar values of $\delta^{13}C$ and ^{14}C were measured in the groundwater of the Test Well: CAV6002X (-7.6‰, -12.49 pmc) and Monitor Well 180W902M (−7.1‰, 12.78 pmc). The $\delta^{13}C$ and ^{14}C values of Monitor Well 180W501M were respectively −8.7‰ and 25 pmc. Carbon isotopes were not measured for Well 382807114521001. The low ^{14}C and relatively heavy $\delta^{13}C$ values of Test Well CAV6002X and Monitor Well 180W902M suggest that the groundwater has interacted with isotopically heavy and ^{14}C-free carbonate minerals. From these data, it appears that water-rock interaction has occurred to a lesser extent for the groundwater in Monitor Well 180W501M as compared to the Test Well CAV6002X and Monitor Well 180W902M. This suggests a shorter residence time for the groundwater in Monitor Well 180W501M. Further evaluation of groundwater flowpaths is required to assess the extent of these reactions and to accurately estimate the groundwater age.

6.3.4.3 Chlorine-36/Chloride Ratios

The ratio of atoms of chlorine-36 to chloride ($^{36}Cl/Cl$) can be used to trace groundwater flow. Dominant factors controlling the observed $^{36}Cl/Cl$ ratios and Cl^- concentrations are the initial values inherited during recharge, the progressive dissolution of Cl-rich (low ^{36}Cl) carbonate rocks along the groundwater flowpath, and the mixing of water with different $^{36}Cl/Cl$ ratios (Moran and Rose, 2003). The interpretation of $^{36}Cl/Cl$ data requires knowledge of the compositions of the recharge water and the potential mixing components along the groundwater flow path. The $^{36}Cl/Cl$ ratio in precipitation varies with distance from the ocean and has not been previously evaluated in this region. Ratios measured in recently recharged groundwater and soils throughout the southwestern United States of 500×10^{-15} to 880×10^{-15} have been reported (Davis et al., 1998; Phillips, 2000).

The $^{36}Cl/Cl$ ratio of Test Well CAV6002X was 6.97 x $\times 10^{-13}$ and is consistent with precipitation in the southwestern United States. The chloride concentration for Test Well CAV6002X was 7.3 mg/L and is not significantly different from that of Monitor Well 180W902M (6.6 mg/l). The highest chloride concentration of 14.7 mg/L was measured in Well 382807114521001. There were no measurements of $^{36}Cl/Cl$ ratios for the monitor wells and Well 382807114521001.

6.3.4.4 Strontium Isotopes

The ratio of radiogenic to nonradiogenic strontium ($^{87}Sr/^{86}Sr$) has been used to identify groundwater sources, to evaluate potential mixing components, and to identify rock types through which groundwater has flowed. No $^{87}Sr/^{86}Sr$ analysis was performed for Test Well CAV6002X and Well 382807114521001. $^{87}Sr/^{86}Sr$ ratios for Monitor wells 180W902M and 180W501M were 0.70944 and 0.71099 are quite similar to those expected from water-rock interaction with marine carbonates

(0.707 to 0.709) (Peterman et al., 1970; Burke et al., 1982). The strontium concentrations were 180 and 160 μg/L for Monitor wells 180W902M and 180W501M, respectively.

6.3.5 Radiological Parameters

Radiological parameters were analyzed for groundwater from Test Well CAV6002X and Monitor Well 180WW501, and the corresponding results are presented in Table D-1. The reported activity for each of these parameters is consistent with background concentrations in natural groundwater.

6.3.6 Organic Compounds

A large suite of organic compounds was analyzed for groundwater samples collected from Test Well CAV6002X. The corresponding minimum detection levels and MCLs (if applicable) are presented in Table D-2. There were no analyses for organic compounds in the monitor wells. No organic compounds were detected in the Test Well CAV6002X. (Table D-2).

6.4 Summary

Groundwater samples were collected from Test Well CAV6002X and analyzed for a suite of chemical parameters. Field measurements of water-quality parameters were also performed during aquifer testing for the test well and used to demonstrate stabilization of the water chemistry prior to collection of the samples. The resulting data were compared with data from samples collected from Well 382807114521001 and other SNWA wells in the vicinity on a Piper diagram. All the wells were completed in a carbonate-rock aquifer and, as is characteristic with the dissolution of calcite and dolomite in waters of a carbonate-rock aquifer, the groundwater represents a calcium-magnesium-bicarbonate facies.

The light stable isotope ratios of the groundwater are typical of recharge waters at high elevations and cold temperatures in Cave Valley. However, all the samples plotted below the GMWL and suggest that the groundwater underwent some form of evaporative enrichment before recharge. The relatively low ^{14}C and relatively heavy values of $\delta^{13}C$ for CAV6002X and Monitor Well 180W902M suggest that the groundwater has interacted with isotopically heavy and ^{14}C-free carbonate minerals.

The $^{36}Cl/Cl$ ratio measured for the sample collected from Test Well CAV6002X was consistent with ratios for precipitation in the southwestern United States, and the $^{87}Sr/^{86}Sr$ ratios were similar between the samples collected from the Monitor wells 180W902M and 180W501M, and were typical of water-rock interaction with marine carbonates.

The data were also evaluated with respect to the EPA Safe Drinking Water Act standards. No exceedances were observed for the groundwater samples collected from Test Well CAV6002X, Monitor Well 180W902M and Well 382807114521001. Iron and manganese concentrations in Monitor Well 180W501M exceeded the secondary MCLs however the source may be associated with the well casing materials.

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Appendix A

CD-ROM Contents

A.1.0 INTRODUCTION

This appendix describes the digital contents of the CD-ROM that accompanies this report. The CD-ROM contains background water-level, barometric-pressure, step-drawdown test, and constant-rate test data. This CD-ROM also includes an electronic copy of the groundwater-chemistry data, as well as the AQTESOLV input files for the step-drawdown and constant-rate tests.

The original names of the test and monitor wells, CAV6002X and CAV6002M2, were 180W103 and 180W504M, respectively. A revised well naming system was developed for SNWA drilled wells, and the official names were changed for these wells after drilling, development, and testing operations were completed. The associated drilling and aquifer testing documentation uses these original well names in some places.

A.1.1 Photos

The following photos were taken during aquifer testing activities at well CAV6002X and show an overview of the site (Figure A-1), the pump and motor setup (Figure A-2), discharge line (Figure A-3), and energy dissipation at the termination of the discharge line for erosion prevention (Figure A-4).

The following photos were taken during aquifer testing activities at well 180W902M and show an overview of the site (Figure A-5) and the pump and motor setup (Figure A-6). The discharge line and energy dissipation remained unchanged after termination of the CAV6002X test.

A.1.2 Read-Me File

Included on the CD-ROM is a text file version of this appendix that describes the contents of the CD-ROM. There is also an index of the files and folders in the form of a PDF document.

A.1.3 Background Water-Level Data

A spreadsheet containing the continuous water-level data and corresponding chart from USGS MX well 382807114521001. This well was used to monitor background conditions during development and testing at Test Well CAV6002X and Monitor Well 180W902M.

A.1.4 Barometric-Pressure Data

Barometric-pressure data are located in the continuous record data files associated with Test Well CAV6002X and Monitor Well 180W902M. Multiple In-Situ HERMIT 3000 data loggers recorded

Figure A-1
Test Well CAV6002X Site, Facing East

Figure A-2
Test Well CAV6002X Wellhead and Equipment Layout

Figure A-3
Test Well CAV6002X Discharge Looking West

Figure A-4
Test Well CAV6002X Discharge and Energy Dissipation

Figure A-5
Well 180W902M Site, Facing South

Figure A-6
Well 180W902M Wellhead and Equipment Layout

the barometric pressure during the development and testing at wells CAV6002X and 180W902M. These data can be found in the sub-folder labeled for each constant-rate test located in the folder labeled "Constant-Rate Test," and in the spreadsheet labeled "CAV6002X Step Test Analysis.xls" for the development and the step-drawdown test.

All barometric-pressure data are reported in inches Hg.

A.1.5 Step-Drawdown Test Data

A summary spreadsheet for the step test which compiles all of the manual data is labeled "CAV6002X Step Test Manual Data.xls." Data collected at Monitor Wells 180W902M and CAV6002M2 are located in the spreadsheet labeled "CAV6002X Step Test Observation Well Manual Data.xls."

A.1.6 Constant-Rate Test Data

The constant-rate test data from Test Well CAV6002X are provided in the spreadsheets located in folder "Constant-Rate Test" and sub-folder "CAV6002X." The constant-rate test data from testing Monitor Well 180W902M is located in folder "Constant-Rate Test" and sub-folder "180W902M."

A.1.7 AQTESOLV

The input files for using AQTESOLV software for aquifer analysis are provided. The input files are in the form of an Excel spreadsheet with water-level and discharge data for both constant-rate tests. AQTESOLV files have also been included for the primary Neuman and secondary Cooper-Jacob solutions.

A.1.8 Water Chemistry

The laboratory results from Weck Labs, Inc., are included in PDF format and labeled "CAV6002X_7120458 FINAL.pdf" for Test Well CAV6002X and "180W902M_6052004.FINAL.pdf" for Monitor Well 180W902M.

Appendix B

Drawdown Plots for the CAV6002X Constant-Rate Test

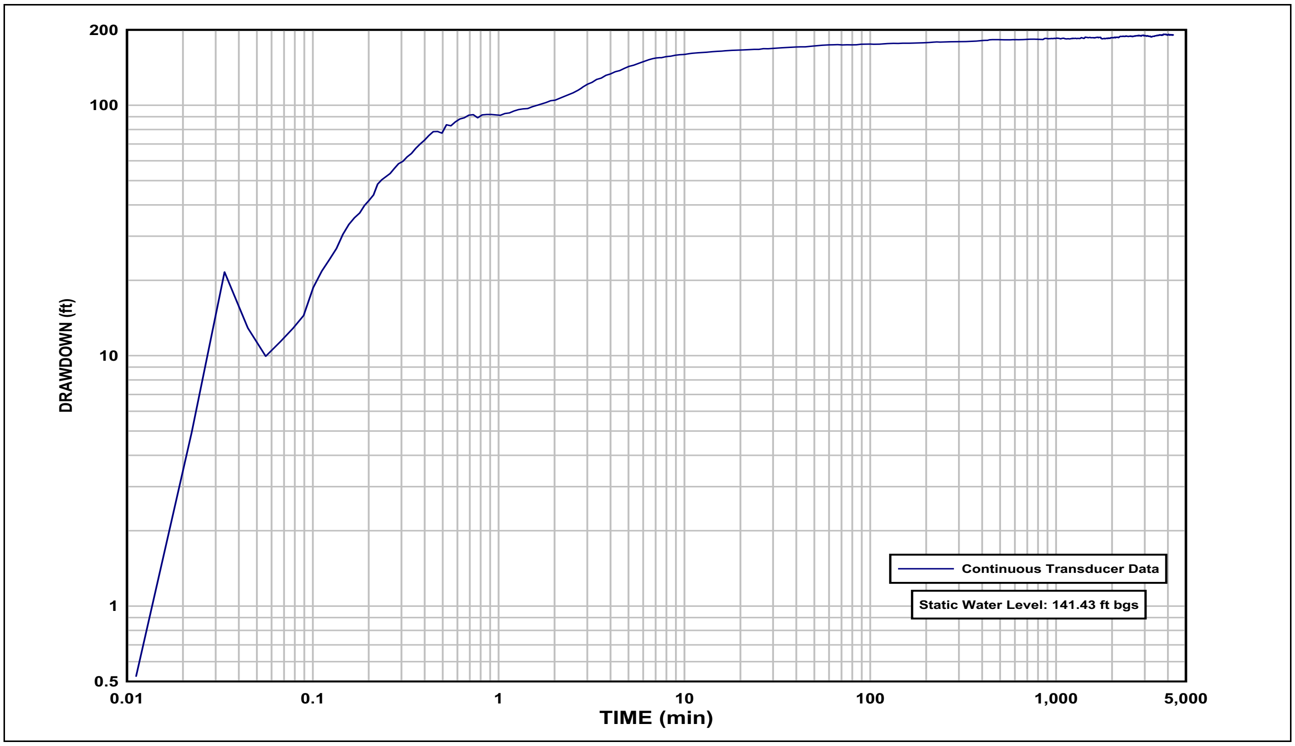

Figure B-1
Semi-Log Data Plot of Drawdown versus Time from Test Well CAV6002X During the CAV6002X Constant-Rate Test

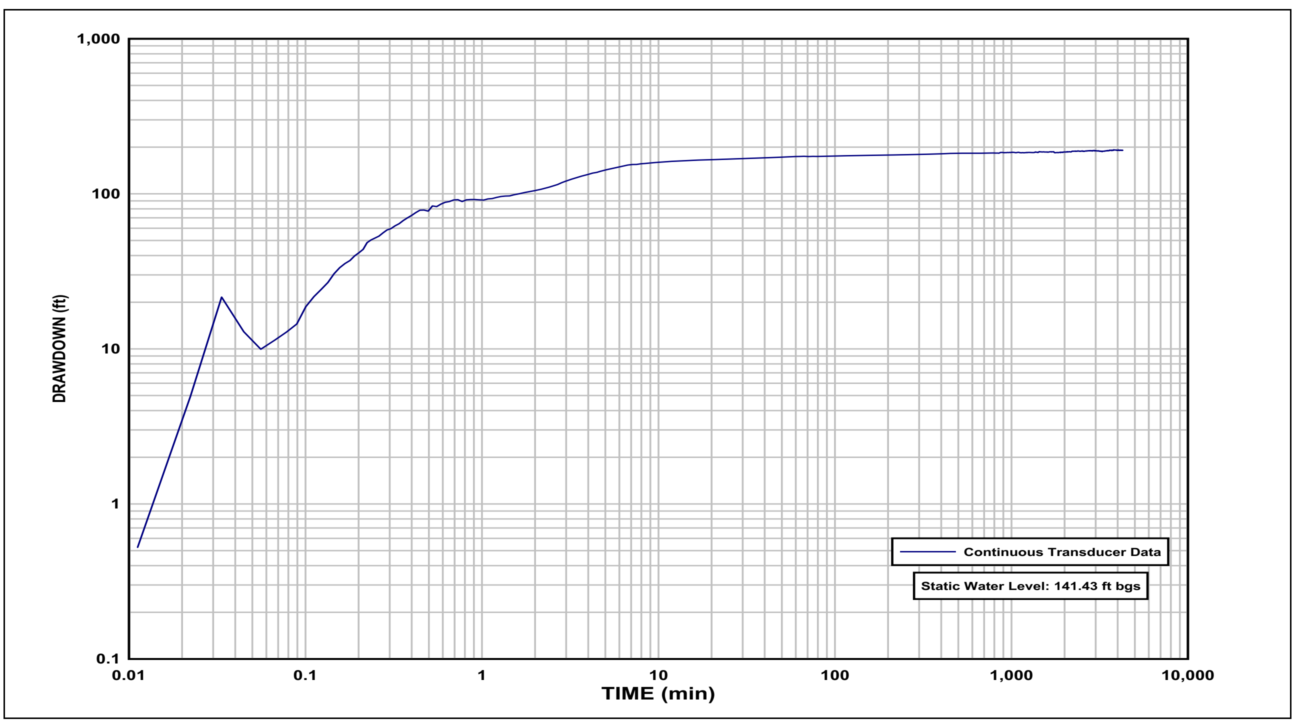

Figure B-2
Log-Log Data Plot of Drawdown versus Time from Test Well CAV6002X During the CAV6002X Constant-Rate Test

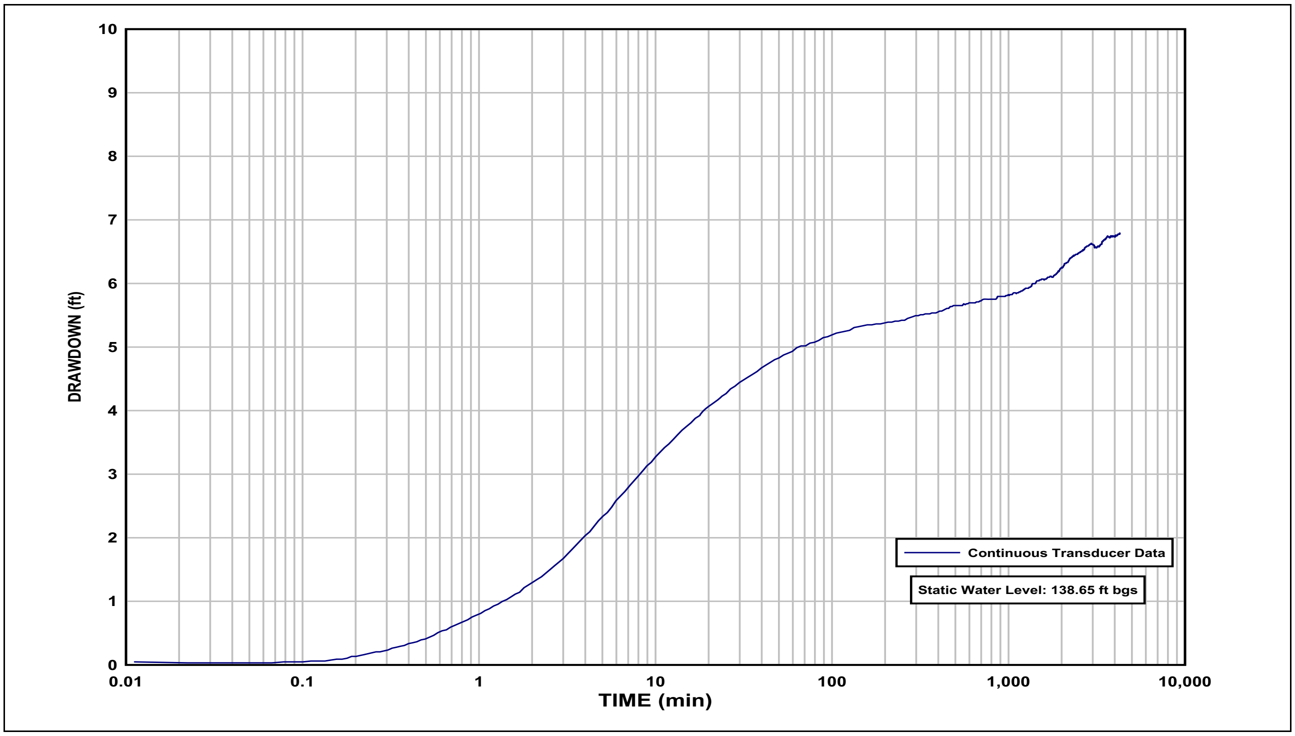

Figure B-3
Semi-Log Data Plot of Drawdown versus Time from Monitor Well 180W902M During the CAV6002X Constant-Rate Test

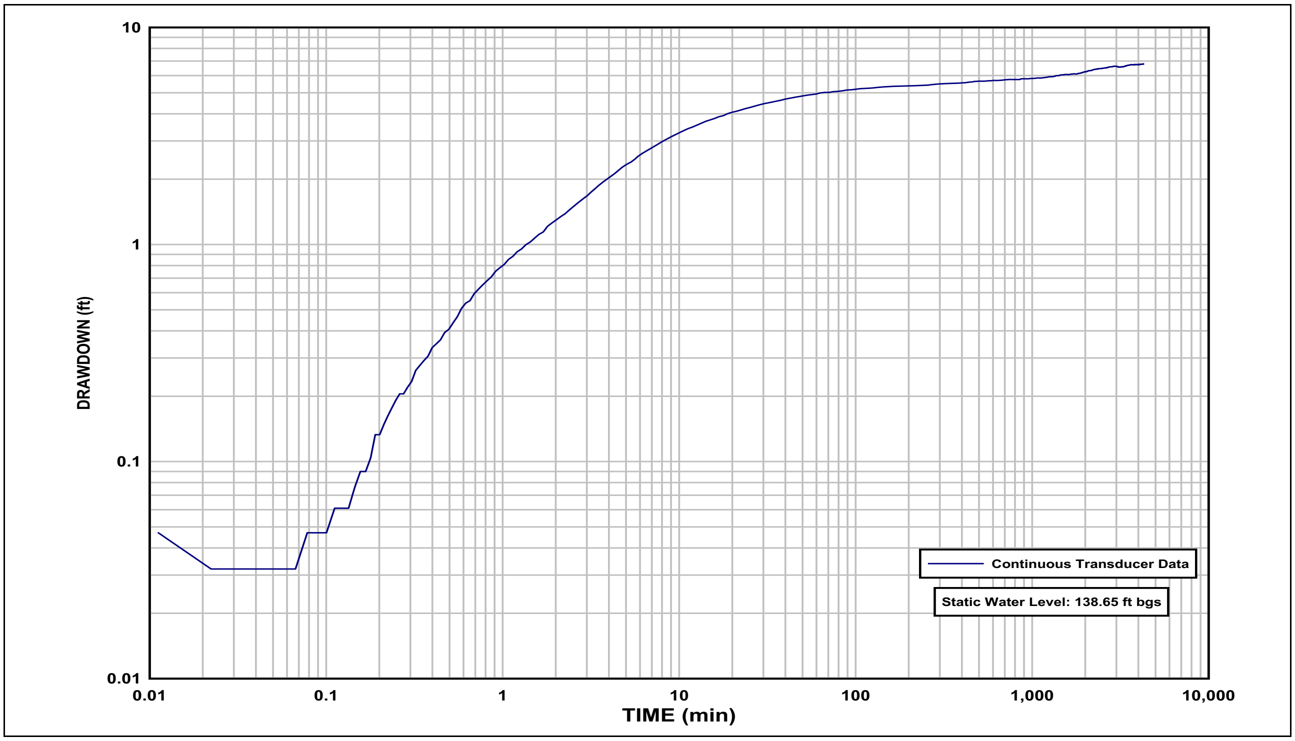

Figure B-4
Log-Log Data Plot of Drawdown versus Time from Monitor Well 180W902M During the CAV6002X Constant-Rate Test

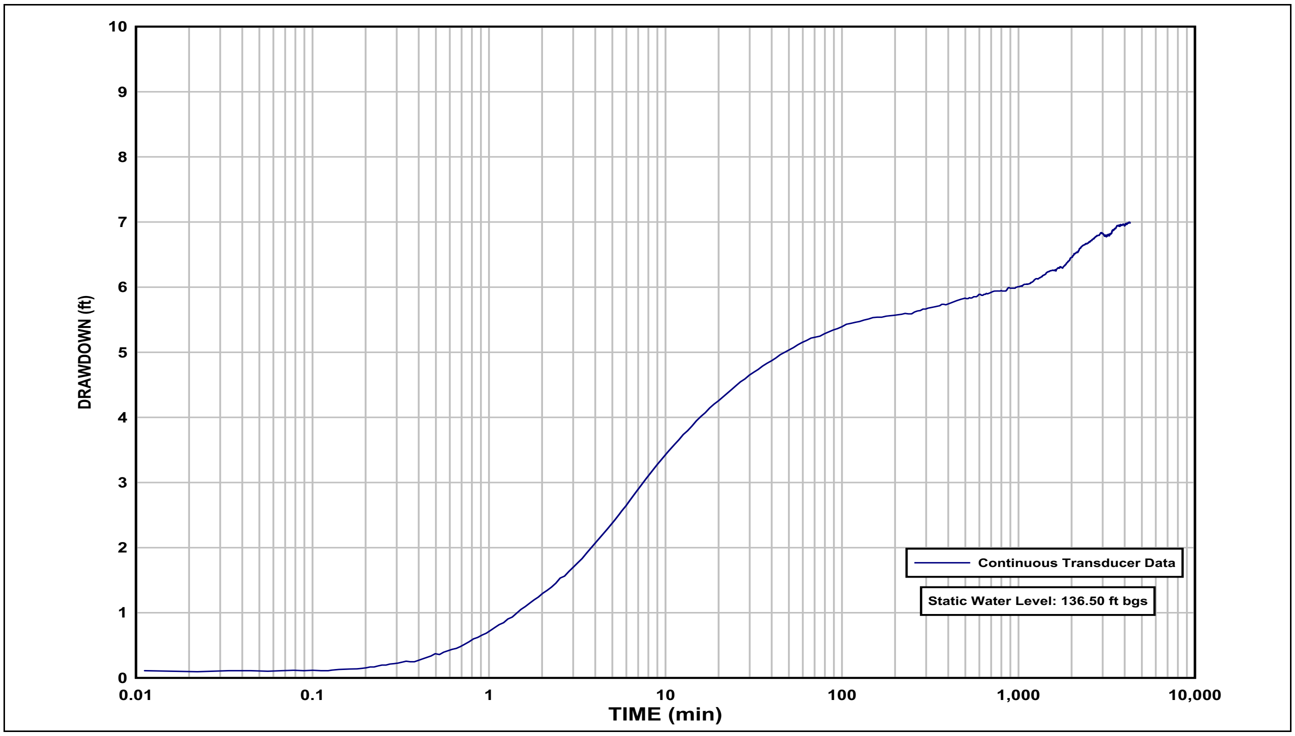

Figure B-5
Semi-Log Data Plot of Drawdown versus Time from Monitor Well CAV6002M2 During the CAV6002X Constant-Rate Test

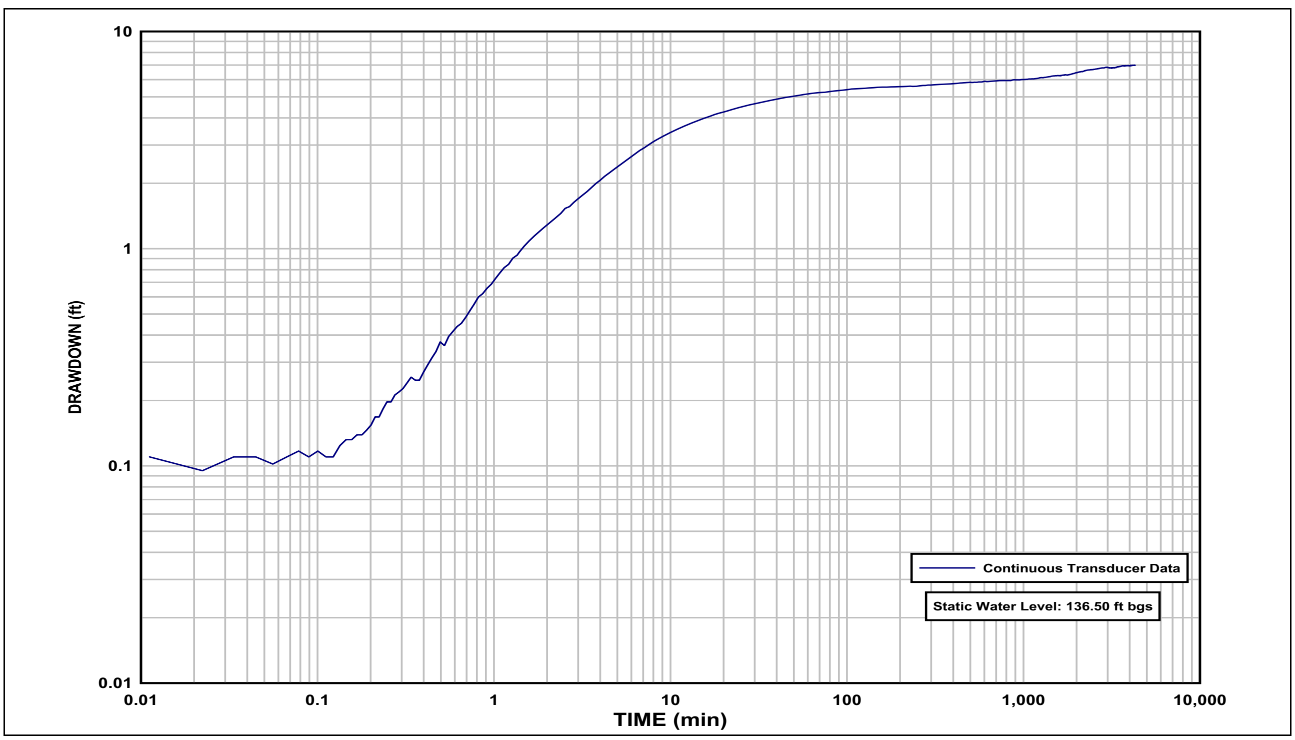

Figure B-6
Log-Log Data Plot of Drawdown versus Time from Monitor Well CAV6002M2 During the CAV6002X Constant-Rate Test

Appendix C

Drawdown Plots for the 180W902M Constant-Rate Test

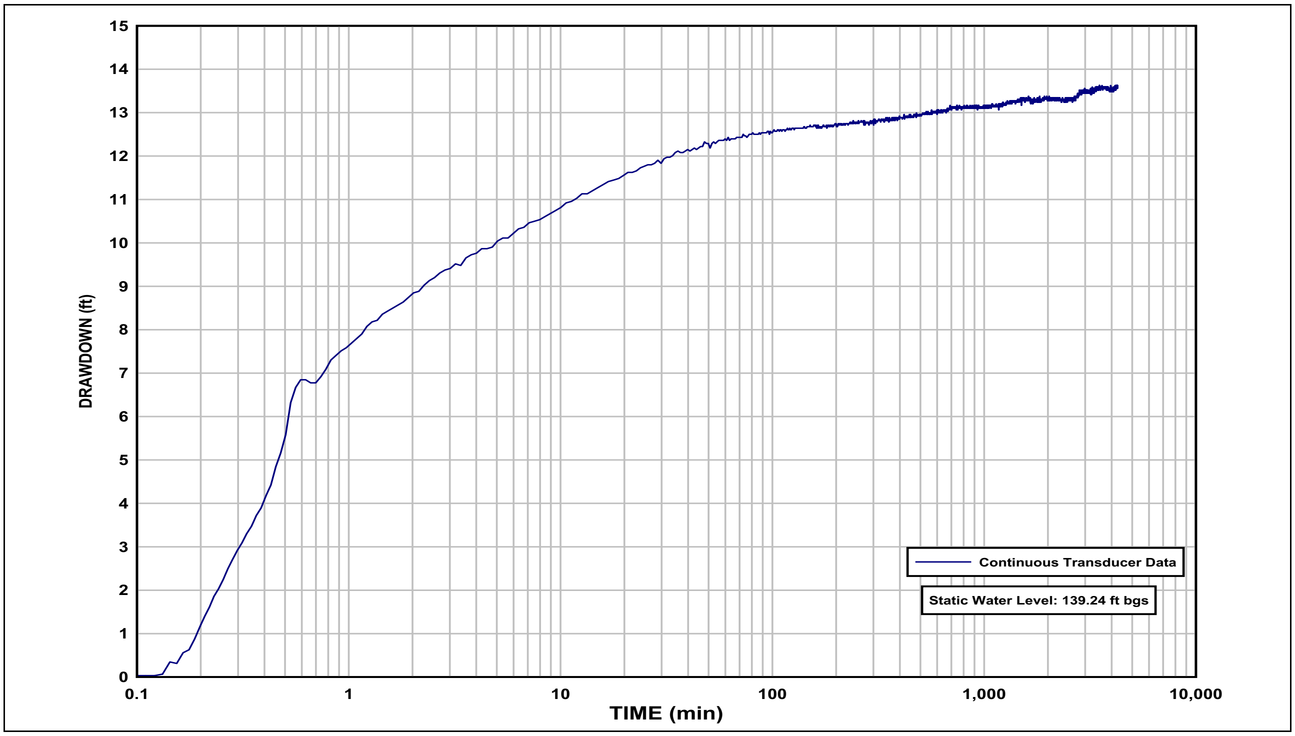

Figure C-1
Semi-Log Data Plot of Drawdown versus Time from Well 180W902M During the 180W902M Constant-Rate Test

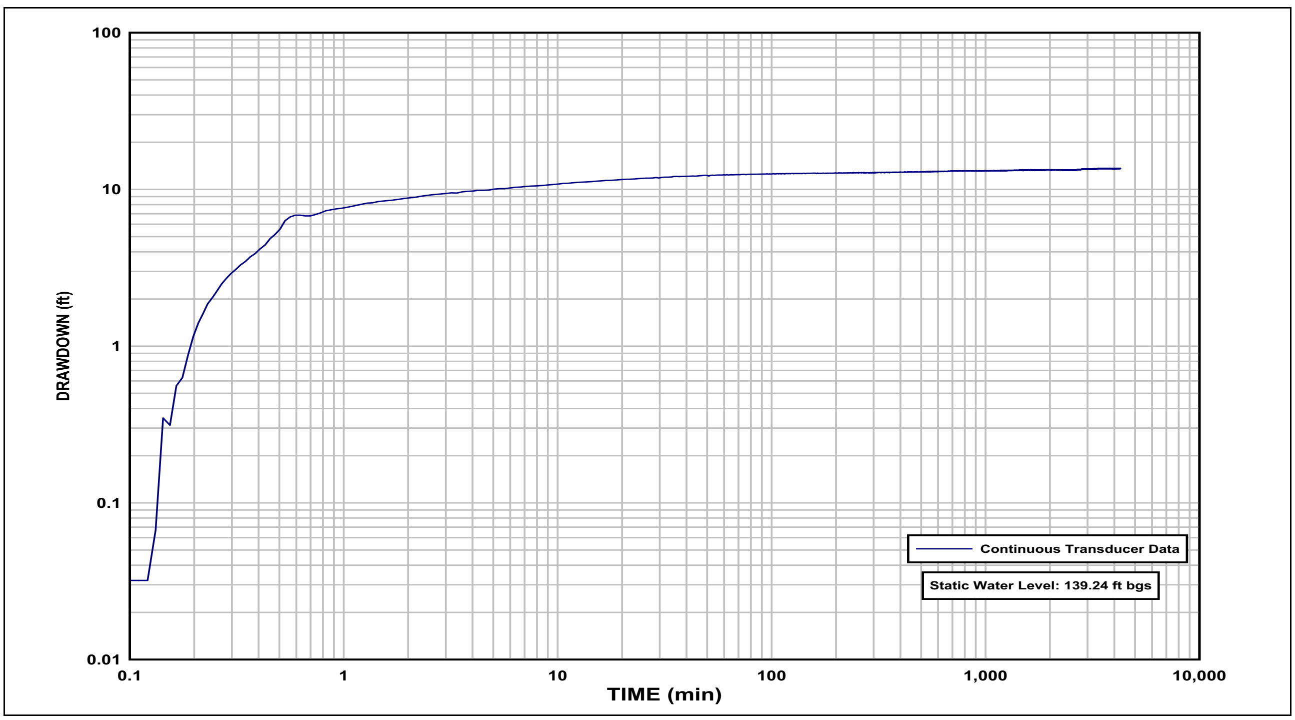

Figure C-2
Log-Log Data Plot of Drawdown versus Time from Well 180W902M During the 180W902M Constant-Rate Test

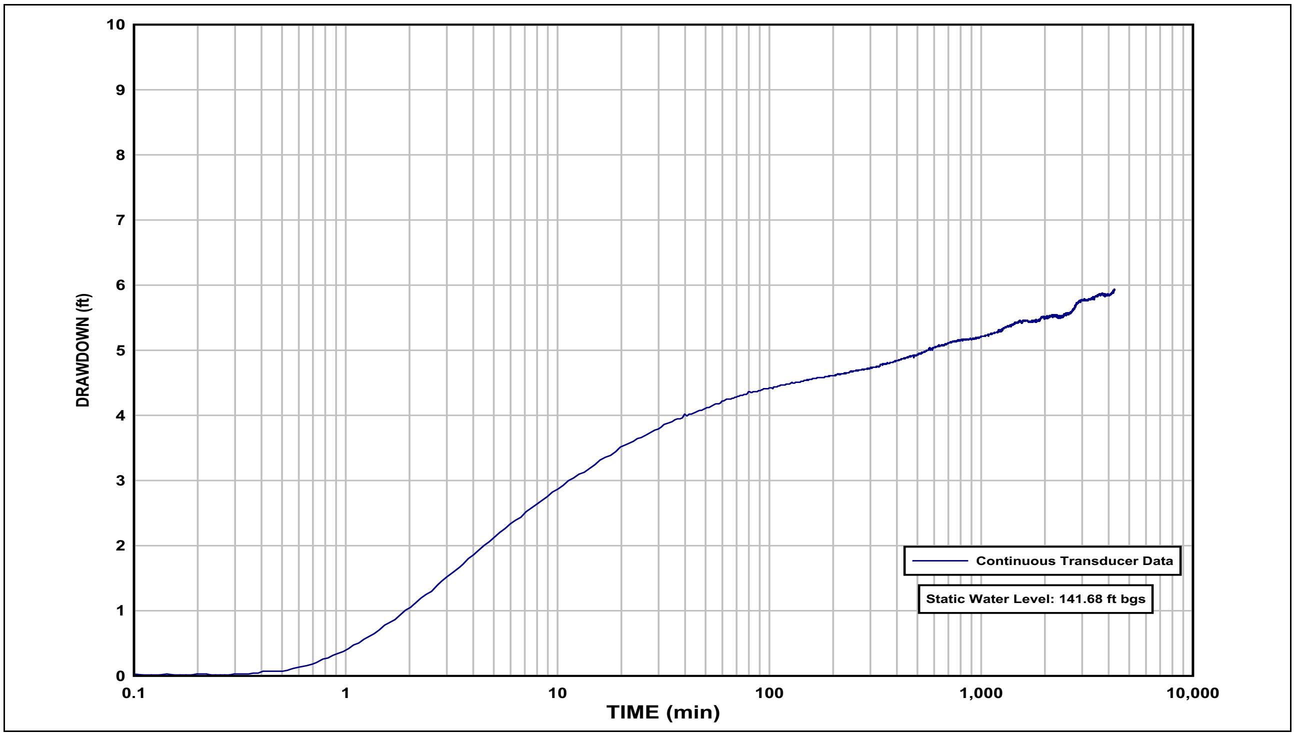

Figure C-3
Semi-Log Data Plot of Drawdown versus Time from Well CAV6002X During the 180W902M Constant-Rate Test

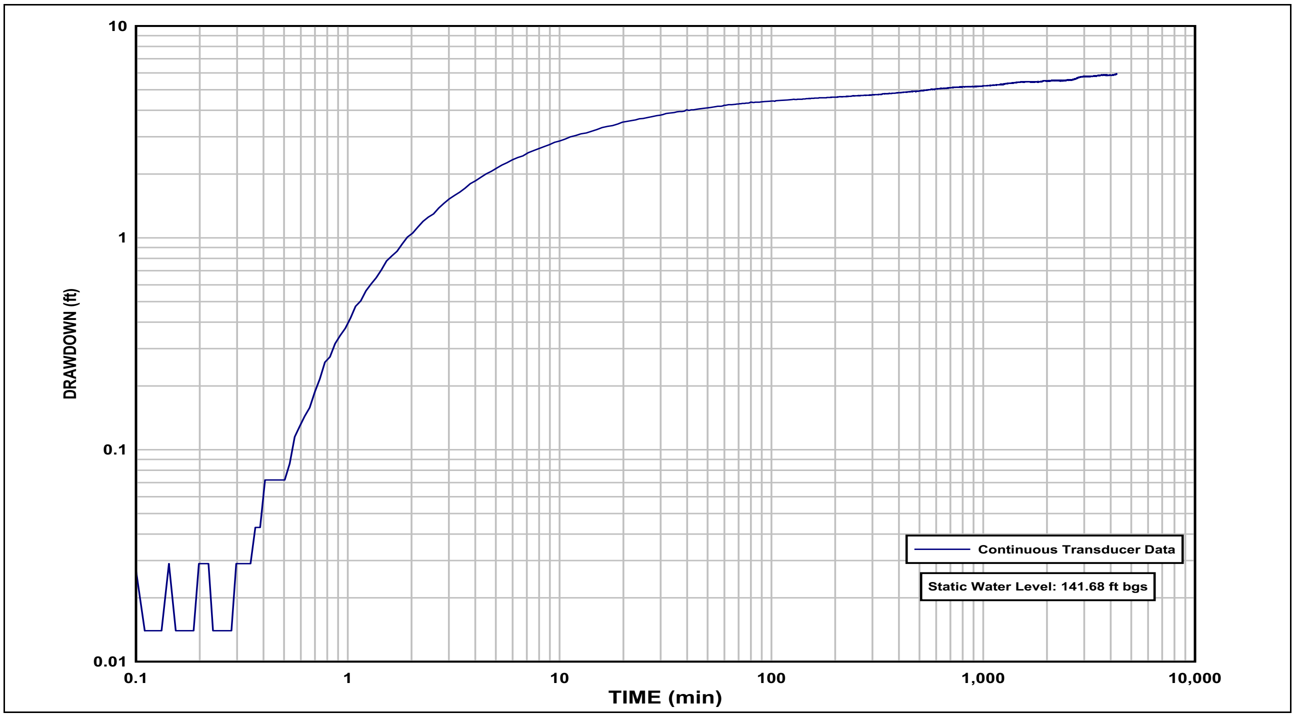

Figure C-4
Log-Log Data Plot of Drawdown versus Time from Well CAV6002X During the 180W902M Constant-Rate Test

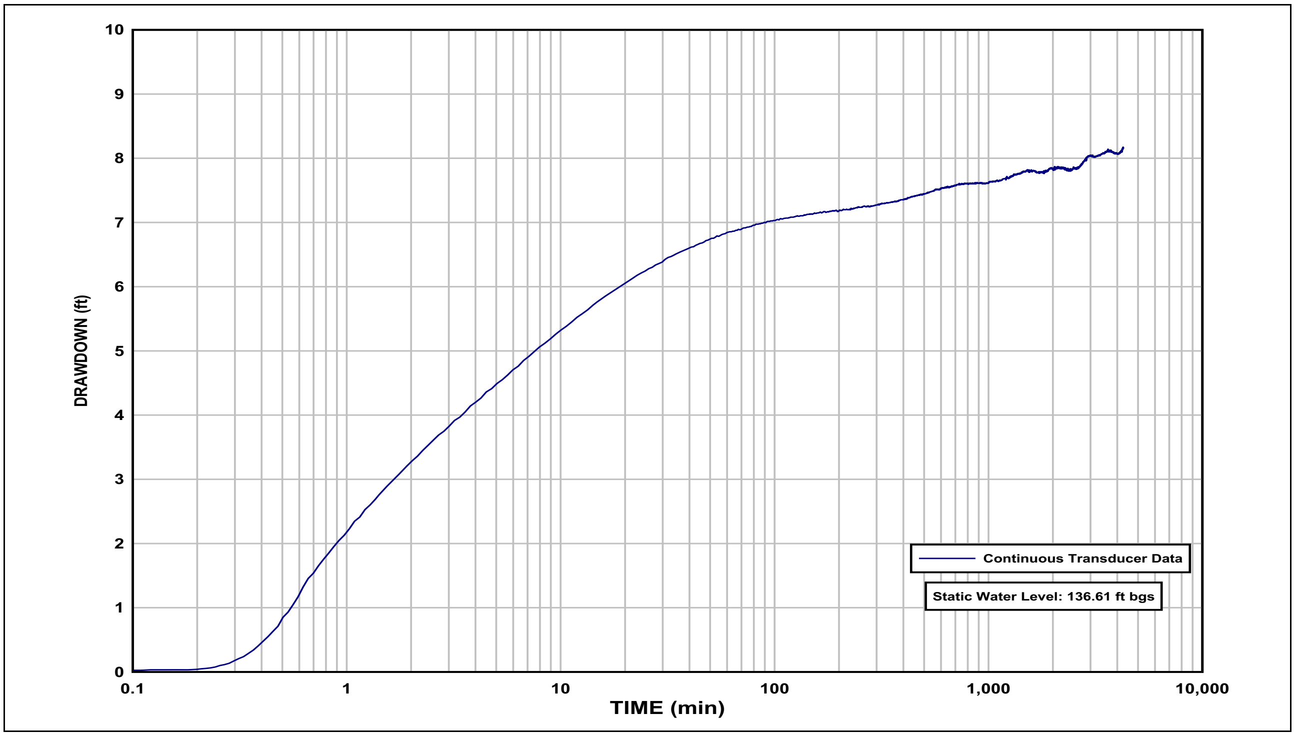

Figure C-5
Semi-Log Data Plot of Drawdown versus Time from Monitor Well CAV6002M2 During the 180W902M Constant-Rate Test

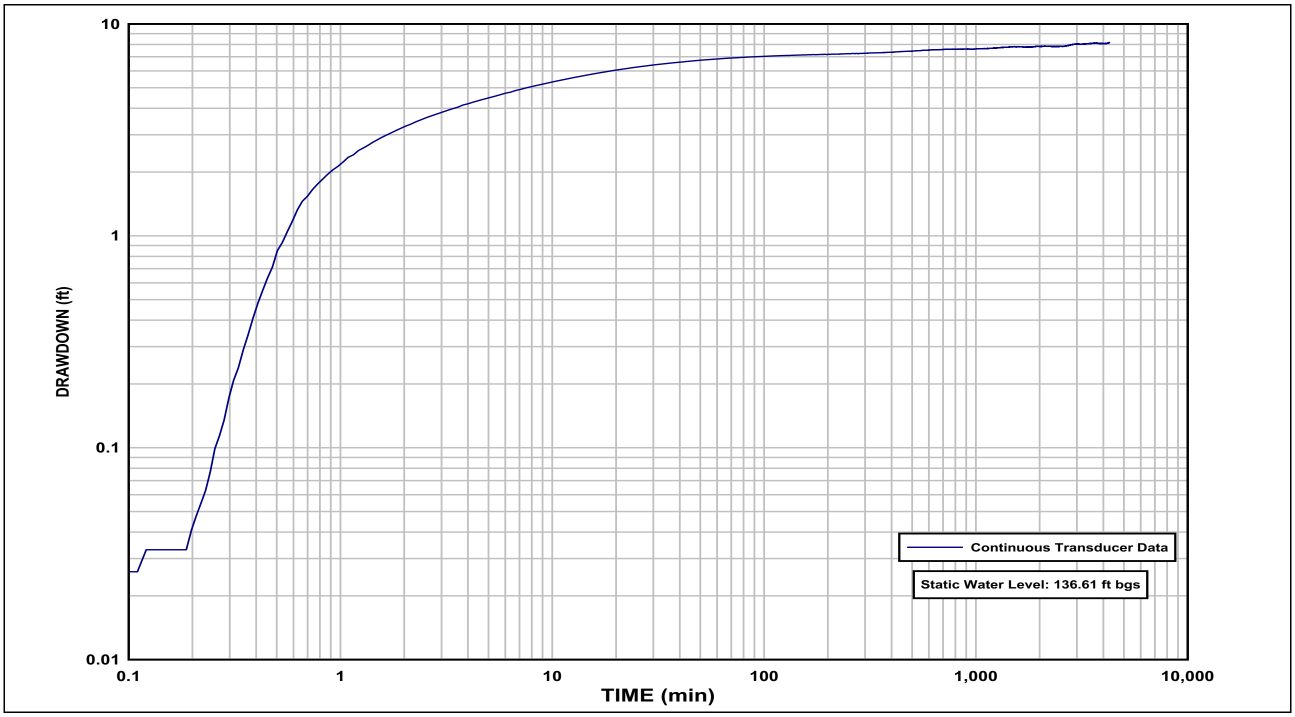

Figure C-6
Log-Log Data Plot of Drawdown versus Time from Monitor Well CAV6002M2 During the 180W902M Constant-Rate Test

Appendix D

Groundwater-Chemistry Data

Table D-1
Field and Analytical Results, Analytical Methods, Reporting Limits, and MCLs for Inorganic, Stable Isotopic, and Radiological Constituents in Groundwater Samples from Test Well CAV6002X, Well 382807114521001, and Monitor Wells 180W902M and 180W501M
(Page 1 of 3)

Constituent Name	Unit	Analysis Method	RL	CAV6002X (180W103) 12/03/2007 07:00	180W902M 05/18/2006 13:30	Well 382807114521001 07/10/2003 09:00[a]	180W501M 05/17/2006	Primary MCL	Secondary MCL
Field Measured									
pH	units	Field	---	7.83	7.58	7.80	7.43	---	6.5 to 8.5
Conductivity	µS/cm	Field	---	468	441	388	394	---	---
Temperature	°C	Field	---	15.9	18.2	13.0	18.5	---	---
Turbidity	NTU	Field	---	1.2	---	---	---	---	---
Stable Isotopes and Environmental Tracers									
Carbon-14 (^{14}C)	pmc	NA	---	12.49	12.78	---	25	---	---
Carbon-13/12 ($\delta^{13}C$)	per mil (‰)	NA	---	-7.6	-7.1	---	-8.7	---	---
Strontium-87/86	ratio	NA	---	---	0.70944	---	0.71099	---	---
Chlorine-36/Chloride ($^{36}Cl/Cl$)	ratio	NA	---	6.97E-13	---	---	---	---	---
Hydrogen-2/1 (δD)	per mil (‰)	NA	---	-106.31	-104.68	-105	-105.56	---	---
Oxygen-18/16 ($\delta^{18}O$)	per mil (‰)	NA	---	-14.27	-14.12	-13.94	-14.12	---	---
Tritium	TU	NA	0.8	ND	ND	ND	ND	---	---
Major Solutes									
Alkalinity Bicarbonate	mg/L as HCO_3	SM 2320B	2.0	270	270	190	210	---	---
Alkalinity Carbonate	mg/L as $CaCO_3$	SM 2320B	2.0	220	220	---	ND	---	---
Alkalinity Hydroxide	mg/L as $CaCO_3$	SM 2320B	2.0	ND	ND	---	ND	---	---
Alkalinity Total	mg/L as $CaCO_3$	SM 2320B	2.0	---	---	156	170	---	---
Calcium	mg/L	EPA 200.7	0.10	53 | 53[c]	54	37	46	---	---
Chloride	mg/L	EPA 300.0	0.50	7.3	6.6	14.7	8.1	---	250
Fluoride	mg/L	EPA 300.0	0.10	0.17	0.16	ND	0.16	4	2.0
Magnesium	mg/L	EPA 200.7	0.10	21 | 22[c]	22	21	18	---	---
Nitrate	mg/L as N	EPA 353.2/300.0	0.10	1.1	---	1.38	8.6	10	---
Potassium	mg/L	EPA 200.7	1.0 | 0.10	1.7 | 1.7[c]	1.6	5.9	3.0	---	---
Silica	mg/L	EPA 200.7	0.10	24	24	45.6	31	---	---
Sodium	mg/L	EPA 200.7	1.0 | 0.50	8.0 | 8.3[c]	8.2	13.3	12	---	---
Sulfate	mg/L as SO_4	EPA 300.0	0.50	16	15	17	12	---	250
Cation/Anion Balance	%	Calculation	0.01	2.8	1.4	---	4.2	---	---

Table D-1
Field and Analytical Results, Analytical Methods, Reporting Limits, and MCLs for Inorganic, Stable Isotopic, and Radiological Constituents in Groundwater Samples from Test Well CAV6002X, Well 382807114521001, and Monitor Wells 180W902M and 180W501M
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Constituent Name	Unit	Analysis Method	RL	CAV6002X (180W103) 12/03/2007 07:00	180W902M 05/18/2006 13:30	Well 382807114521001 07/10/2003 09:00[a]	180W501M 05/17/2006	Primary MCL	Secondary MCL
Trace and Minor Constituents									
Aluminum	µg/L	EPA 200.8	5.0	ND | ND[c]	ND	2	15	---	50 to 200
Antimony	µg/L	EPA 200.8	0.50	ND | 0.51[c]	ND	0.19	1.0	6	---
Arsenic	µg/L	EPA 200.8	0.40	2.5 | 2.4[c]	2.9	1.8	3.8	10	---
Arsenic (III)	µg/L	EPA 200.8	1.0	2.2	---	---	---	---	---
Arsenic (V)	µg/L	EPA 200.8	1.0	ND	---	---	---	---	---
Barium	µg/L	EPA 200.8	0.50	60 | 56[c]	55	45	220	2,000	---
Beryllium	µg/L	EPA 200.8	0.10	ND | ND[c]	ND	0.06	ND	4	---
Boron	µg/L	EPA 200.7	10	40 |41[c]	31	53	38	---	---
Bromide	µg/L	EPA 300.1	10	73	82	---	91	---	---
Cadmium	µg/L	EPA 200.8	0.10	ND | ND[c]	ND	0.04	ND	5	---
Chlorate	µg/L	EPA 300.1	10	ND	ND	---	ND	---	---
Chromium	µg/L	EPA 200.8	0.20	0.25 | 0.29[c]	0.37	0.50	0.99	100	---
Chromium (III)	µg/L	Calculation	0.20	ND	---	---	---	---	---
Chromium (VI)	µg/L	EPA 218.6	0.30	0.84	---	---	---	---	---
Copper	µg/L	EPA 200.8	0.50	3.2 | 6.8[c]	0.94	0.20	1.2	1,300[d]	1,000
Iron	µg/L	EPA 200.7	20	ND | ND[c]	49	54	650	---	300
Lead	µg/L	EPA 200.8	0.20	1.8 | 1.1[c]	0.91	0.08	1.4	15[d]	---
Lithium	µg/L	EPA 200.7	10	ND | ND[c]	ND	10.3	ND	---	---
Manganese	µg/L	EPA 200.8	0.20	1.8 | 1.4[c]	1.8	28	120	---	50
Mercury	µg/L	EPA 245.1	0.10	ND | ND[c]	ND	---	ND	2.0	---
Molybdenum	µg/L	EPA 200.8	0.10	1.6 | 1.8[c]	---	0.4	---	---	---
Nickel	µg/L	EPA 200.8	0.80	1.0 | ND[c]	2.0	1.11	17	---	---
Nitrite	µg/L as N	EPA 353.2	100	ND	ND	0.004	ND	1	---
Orthophosphate	µg/L as P	EPA 365.1	2.0	11	7.7	0.01	ND	---	---
Phosphorus	µg/L as P	EPA 365.1	10	ND	ND	---	ND	---	---
Selenium	µg/L	EPA 200.8	0.40	2.0 | 1.7[c]	2.1	1.0	0.85	50	---
Silver	µg/L	EPA 200.8	0.20	ND | ND[c]	ND	0.2	ND	---	100

Table D-1
Field and Analytical Results, Analytical Methods, Reporting Limits, and MCLs for Inorganic, Stable Isotopic, and Radiological Constituents in Groundwater Samples from Test Well CAV6002X, Well 382807114521001, and Monitor Wells 180W902M and 180W501M
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Constituent Name	Unit	Analysis Method	RL	CAV6002X (180W103) 12/03/2007 07:00	180W902M 05/18/2006 13:30	Well 382807114521001 07/10/2003 09:00[a]	180W501M 05/17/2006	Primary MCL	Secondary MCL
Trace and Minor Constituents (Continued)									
Strontium	µg/L	EPA 200.7	5.0	180 | 180[c]	180	206	160	---	---
Thallium	µg/L	EPA 200.8	0.20	ND | ND[c]	ND	0.04	2.2	2	---
Vanadium	µg/L	EPA 200.8	0.50	3.1 | 3.3[c]	4.0	2.5	4.1	---	---
Zinc	µg/L	EPA 200.8	5.0	ND | 8.8[c]	3.0	2.0	8.7	---	5,000
Miscellaneous Parameters									
Total Dissolved Solids	mg/L	SM 2540C	10	280	210	251	210	---	500
Total Organic Carbon	mg/L	SM 5310C	0.30	ND	ND	0.4	4.0	---	---
Total Suspended Solids	mg/L	EPA 2540D	5	ND	ND	---	ND	---	---
Hardness	mg/L as $CaCO_3$	EPA 200.7	1.0	220	220	---	190	---	---
Langelier Index	@ 60°C	SM 2330B	-10.0	0.994	0.777	---	0.446	---	---
Langelier Index	@ Source Temp.	SM 2330B	-10.0	0.413	0.228	---	-0.099	---	---
MBAS	mg/L	SM 5540 C	0.050	ND	ND	---	0.42	---	---
Cyanide	mg/L	SM 4500CN E	0.010	ND	ND	---	ND	0.2	---
Radiochemical Parameters									
Gross Alpha	pCi/L	EPA 900.0	---	4.9	3.4	---	6.2	15	---
Gross Beta	pCi/L	EPA 900.0	---	4.5	1.7	---	3.0	4 mrem/yr	---
Radium, total gross	pCi/L	EPA 903.1	---	ND	0.700	---	2.40	5	---
Radium-226	pCi/L	EPA 903.1	---	ND	0.700	---	2.40	---	---
Radium-228	pCi/L	EPA 904	0.300	ND	ND	---	ND	---	---
Radon-222	pCi/L	SM 7500 RN	---	316	---	---	269	---	---
Strontium-90	pCi/L	EPA 905.0	0.600	ND	ND	---	ND	---	---
Tritium	pCi/L	EPA 906.0	483	ND	ND	---	ND	---	---
Uranium	pCi/L	EPA 200.8	0.13	1.7	1.3	---	0.67	30 µg/L	---

[a]Data reported by USGS; concentrations represent dissolved constituent.
[b]Holding time was exceeded.
[c]Sample was filtered; concentration represents dissolved constituent.
[d]Reported value is the action limit.
H = Holding time was exceeded for this analyte.
MBAS = Methylene blue active substances
mrem/yr = Millirem per year

NA = Not available; laboratory procedure is used.
ND = Not detected
RL = Reporting limit
SM = Standard method (Eaton et al., 2005)
TU = Tritium Unit

Table D-2
Organic Compounds Analyzed in Groundwater Samples from Test Well CAV6002X, Including the EPA Method, Reporting Limit, and Maximum Contaminant Level
(Page 1 of 2)

*Chlorinated Pesticides by EPA 508 (µg/L)								
Analyte	**RL**	**MCL**	**Analyte**	**RL**	**MCL**	**Analyte**	**RL**	**MCL**
Aldrin	0.050	---	Endosulfan II	0.010	---	PCB 1016 Aroclor	0.10	---
BHC (Alpha)	0.010	---	Endosulfan sulfate	0.050	---	PCB 1221 Aroclor	0.10	---
BHC (Beta)	0.050	---	Endrin	0.050	2	PCB 1232 Aroclor	0.10	---
BHC (Delta)	0.050	---	Endrin aldehyde	0.050	---	PCB 1242 Aroclor	0.10	---
Chlordane (tech)	0.10	2	Heptachlor	0.010	0.4	PCB 1248 Aroclor	0.10	---
Chlorothalonil	0.050	---	Heptachlor Epoxide	0.010	0.2	PCB 1254 Aroclor	0.10	---
4,4'-DDD	0.020	---	Hexachlorobenzene	0.50	1.0	PCB 1260 Aroclor	0.10	---
4,4'-DDE	0.010	---	Hexachlorocyclopentadiene	0.050	50	Propachlor	0.50	---
4,4'-DDT	0.020	---	Lindane	0.050	0.2	Toxaphene	1.0	3
Dieldrin	0.020	---	Methoxychlor	0.050	40	Trifluralin	0.010	---
Endosulfan I	0.020	---	Polychlorinated biphenyls (PCBs)	0.50	0.5			
***Purgeable Organic Compounds by EPA 524.2 (µg/L)**								
tert-Amyl methyl ether	3.0	---	Di-isopropyl ether	3.0	---	Methyl tertiary butyl ether (MTBE)	3.0	---
Benzene	0.50	5	1,1-Dichloroethane	0.50	---	Naphthalene	0.50	---
Bromobenzene	0.50	---	1,2-Dichloroethane	0.50	---	n-Propylbenzene	0.50	---
Bromochloromethane	0.50	---	1,1-Dichloroethene	0.50	5	Styrene	0.50	100
Bromodichloromethane	0.50	---	cis-1,2-Dichloroethene	0.50	7	Tetrachloroethylene	0.50	5
Bromoform	0.50	---	trans-1,2-Dichloroethene	0.50	70	1,1,1,2-Tetrachloroethane	0.50	---
2-Butanone	5.0	---	Dichlorodifluoromethane	0.50	100	1,1,2,2-Tetrachloroethane	0.50	---
n-Butylbenzene	0.50	---	1,2-Dichloropropane	0.50	---	Toluene	0.50	1,000
sec-Butylbenzene	0.50	---	1,3-Dichloropropane	0.50	5	1,2,3-Trichlorobenzene	0.50	---
tert-Butylbenzene	0.50	---	2,2-Dichloropropane	0.50	---	1,2,4-Trichlorobenzene	0.50	70
tert-Butyl ethyl ether	3.0	---	1,1-Dichloropropene	0.50	---	1,1,1-Trichloroethane	0.50	200
Carbon tetrachloride	0.50	5	cis-1,3-Dichloropropene	0.50	---	1,1,2-Trichloroethane	0.50	5
Chlorobenzene	0.50	100	trans-1,3-Dichloropropene	0.50	---	Trichloroethylene	0.50	5
Chloroethane	0.50	---	total-1,3-Dichloropropene	0.50	---	Trichlorofluoromethane	5.0	---
2-Chloroethyl vinyl ether	1.0	---	Ethylbenzene	0.50	700	1,2,3-Trichloropropane	0.50	---
Chloroform	0.50	---	Hexachlorobutadiene	0.50	---	1,1,2-Trichloro-1,2,2-trifluoroethane	5.0	---
2-Chlorotoluene	0.50	---	2-Hexanone	5.0	---	1,2,4-Trimethylbenzene	0.50	---
4-Chlorotoluene	0.50	---	Isopropylbenzene	0.50	---	1,3,5-Trimethylbenzene	0.50	---
Dibromochloromethane	0.50	---	p-Isopropyltoluene	0.50	---	Vinyl chloride	0.50	2
Dibromomethane	0.50	---	Bromomethane	0.50	---	mp-Xylene	1.0	---
m-Dichlorobenzene	0.50	---	Chloromethane	0.50	---	Xylenes, total	0.50	10,000
o-Dichlorobenzene	0.50	600	Methylene chloride	0.50	5	o-Xylene	0.50	---
p-Dichlorobenzene	0.50	75	4-Methyl-2-pentanone	5.0	---			

Table D-2
Organic Compounds Analyzed in Groundwater Samples from Test Well CAV6002X, Including the EPA Method, Reporting Limit, and Maximum Contaminant Level
(Page 2 of 2)

***Organic Compounds by EPA 525.2 (µg/L)**								
Alachlor	0.10	2	Bis(2-ethylhexyl) phthalate	3.0	6	Prometon	0.20	---
Atrazine	0.10	3	Diazinon	0.10	---	Prometryn	0.10	---
Benzo(a)pyrene	0.10	0.2	Dimethoate	0.20	---	Simazine	0.10	4
Bromacil	1.0	---	Metolachlor	0.10	---	Thiobencarb	0.20	---
Butachlor	0.20	---	Metribuzin	0.10	---			
Bis(2-ethylhexyl) adipate	5.0	400	Molinate	0.10	---			
***Chlorinated Acids by EPA 515.3 (µg/L)**								
2,4,5-T	0.20	---	Acifluorfen	0.40	---	Dichlorprop	0.30	---
2,4,5-TP (Silvex)	0.20	50	Bentazon	2.0	---	Dinoseb	0.40	7
2,4-D	0.40	70	Dalapon	0.40	200	Pentachlorophenol	0.20	1
2,4-DB	2.0	---	DCPA	0.10	---	Picloram	0.60	500
3,5-Dichlorobenzoic acid	1.0	---	Dicamba	0.60	---			
***N-Methylcarbamoyloximes and N-Methylcarbamates by EPA 531.1 (µg/L)**								
3-Hydroxycarbofuran	2.0	---	Baygon	5.0	---	Methomyl	2.0	---
Aldicarb	2.0	---	Carbaryl	2.0	---	Oxamyl (Vydate)	2.0	200
Aldicarb sulfone	2.0	---	Carbofuran	5.0	40			
Aldicarb sulfoxide	2.0	---	Methiocarb	3.0	---			
***Organics by Other EPA Methods (µg/L)**								
Glyphosate (EPA 547)	5.0	700	Diquat (EPA 549.2)	4.0	20	1,2-Dibromo-3-chloropropane (EPA 504.1)	0.010	0.2
Endothall (EPA 548.1)	45	100	Dioxin (EPA 1613)	5.00 pg/L	30 pg/L	Ethylene dibromide (EPA 504.1)	0.020	0.05

MCL = Maximum contaminant level
RL = Reporting Limit
* = All analysis for organic compounds were non-detect

References

Eaton, A.D., Clesceri, L.S., Rice, E.W., Greenberg, A.E., and Franson, M.H., eds., 2005, Standard methods for the examination of water and wastewater. Twenty-first edition: Washington, D.C., American Public Health Association.