Doc No. DAR-ED-0006

Southern Nevada Water Authority

Hydrologic Data Analysis Report for Test Well SPR7008X in Spring Valley Hydrographic Area 184

June 2011

Suggested citation:
Prieur, J.P., Acheampong, S.Y., Ashinhurst, C.S., and Fryer, W., 2011, Hydrologic data analysis report for Test Well SPR7008X in Spring Valley Hydrographic Area 184: Southern Nevada Water Authority, Las Vegas, Nevada, Doc. No. DAR-ED-0006, 83 p.

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Hydrologic Data Analysis Report for Test Well SPR7008X in Spring Valley Hydrographic Area 184

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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

EPA	U.S. Environmental Protection Agency
ET	Evapotranspiration
GMWL	Global Meteoric Water Line
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
d	day
ft	foot
gal	gallon
gpm	gallons per minute
I.D.	inside diameter (of casing)
in.	inch
in. Hg	inches of mercury
L	liter
lb	pound
m	meter
mEq	milliequivalent
mg	milligram
mi	mile
min	minute
ml	milliliter
mrem	millirem
NTU	nephelometric turbidity unit
µg	microgram

ABBREVIATIONS (CONTINUED)

µS	microsiemen
O.D.	outside diameter (of casing)
‰	per mil
pmc	percent modern carbon
pCi	picocurie
psi	pounds per square inch
yr	year

ES.1.0 EXECUTIVE SUMMARY

The development and hydrologic testing program at Test Well SPR7008X, located on the east side of Spring Valley (hydrographic area 184), White Pine County, Nevada was performed from January 25 through February 2, 2008. The test well and associated Monitor Well SPR7008M are completed within the basin fill aquifer in silty to clayey gravel. A shallow clay unit was observed in the monitor well boring. Test Well SPR7008X and Monitor Well SPR7008M are completed to depths of 970 and 960 ft bgs, respectively. Static depth to water is approximately 14 ft bgs in both wells.

Four wells (test, two monitor, and background), one spring (Layton), and one flowing well were monitored throughout the testing program. Analysis of the data collected from both of the spring and the flowing well indicate that they were not influenced by either the step or constant-rate tests.

The development and test pumping extracted 13,122,316 gal of water. Development pumping improved specific capacity, a ratio of discharge (Q) to drawdown (s) in the test well, from 14.82 to 14.95 gpm/ft at a comparable duration of pumping at approximately 1,500 gpm. A five-interval well performance step test was conducted at discharge rates ranging from 1,460 to 3,280 gpm to estimate the range of operational pumping rates, evaluate well loss coefficients, and determine the optimal discharge rate for the constant-rate test.

A 72-hour constant-rate test was performed at a target discharge rate of 2,000 gpm. Site hydrogeologic data and diagnostic log-log and derivative drawdown data plots indicated that a leaky-confined model is the most appropriate primary solution method. The leaky-confined Moench Solution, which considers, an leaky-confining layer, delayed gravity drainage, wellbore storage and well bore skin effect, was selected as the primary solution and applied to the test and monitor well pumping and recovery data. A secondary solution using the Theis recovery method was performed for comparison. Analyses were performed using AQTESOLV software.

Results of the Moench evaluation indicate a best-fit estimated hydraulic conductivity (K) range of 4.15 to 5.91 ft/day which corresponds to a transmissivity (T) of 3,320 to 4,730 ft^2/day, assuming a saturated thickness of 800 ft (saturated interval below the clay layer to the base of the wells). A sensitivity analysis evaluating two distinct borehole diameters (nominal drilling diameter and caliper downhole log measured diameter) and varying the wellbore skin factor were performed using the Moench solution to estimate variation in T. The wellbore skin factor was varied between 2.2 and 5.3, and the borehole diameter was varied between 28 and 36 in. Specific capacity during the last 12 hours of the 2,000 gpm, 72-hour constant-rate test ranged from 11.70 to 11.77 gpm/ft.

Groundwater samples were collected from Test Well SPR7008X and Monitor Well SPR7008M for laboratory chemical analysis after development and testing. In each case, samples were collected after the water-quality parameters (pH, temperature, and specific conductance) had stabilized. Groundwater in both wells was calcium-magnesium-bicarbonate facies typical of the dissolution of calcite and dolomite in carbonate rock aquifers. Relatively higher concentrations of aluminum, boron, iron, and manganese were observed in the groundwater from Monitor Well SPR7008M in comparison with concentrations in the Test Well SPR7008X probably due to the shortness of the aquifer testing of the Monitor Well SPR7008M.

The stable isotopic compositions were very light and plotted above the Global Meteoric Water Line and are typical of recharge at high elevations and cold temperatures and had not undergone any significant secondary processes (e.g. evaporation) prior to recharge.

The tritium concentration of Test Well SPR7008X was less than the reporting limit of 0.8 TU and is very different from the value of 9.2 TU measured in precipitation collected in the area by SNWA in 2008. The low titium concentration and relatively low ^{14}C activity of 21.6 pmc suggest long residence time for the groundwater; the low ^{14}C activity also suggests that the groundwater has interacted with isotopically heavy carbonate mineral. The $^{36}Cl/Cl$ ratio of Test Well SPR7008X is consistent with modern precipitation in the southwestern United States.

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 Hydrographic Area 184, Spring Valley, Nevada 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 SPR7008X and Monitor Well SPR7008M.

The two SNWA wells are completed within the basin fill aquifer in silty to clayey gravels. This report also presents groundwater-level data collected at the site post-test through January 2011. A separate document entitled *Geologic Data Analysis Report for Monitor Well SPR7008M and Test Well SPR7008X in Spring Valley* (Mace and Muller, 2010) includes the documentation and detailed results for the surface geophysics profiles and drilling program, including evaluation of lithology, structural features, drilling parameters, and geophysical logs.

1.1 Program Objectives

Hydraulic testing was performed to evaluate well performance and to provide representative data on the hydraulic properties of the alluvial aquifer in the vicinity of the test well. Groundwater samples were also collected for laboratory analysis to evaluate the groundwater chemistry of the aquifer in the vicinity of the well.

Prior to hydraulic testing, Test Well SPR7008X was developed to remove any remaining drilling fluids and improve the hydraulic connection with the formation. The development performed consisted of pump and surge activities. This was in addition to airlifting and swabbing development that were performed earlier immediately after well installation.

1.2 Testing and Monitoring Program

The well development and hydraulic testing program was performed from January 25 to February 2, 2008, and consisted of the following activities:

- Developed the test well using airlift and dual swab techniques
- Final well development, using surging and pumping methods
- Well hydraulic testing and performance evaluation, using a five-interval step-drawdown test
- Aquifer-property evaluation testing, using a 72-hour constant-rate test and subsequent water-level recovery measurements

- Collection of groundwater samples for laboratory chemical analysis

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

Monitor Well SPR7008M is part of the SNWA Spring Valley regional water-level monitoring network. Water-level data have been collected regularly from this location since the hydraulic testing program and is currently equipped with continuous water level recording instrumentation.

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 SPR7008X site is located on the east side of Spring Valley, on public land managed by Bureau of Land Management just west of U.S. Highway 50 approximately 12 mi northeast of the intersection of U.S. Highways 50 and 93. The test well is located in Section 26, T15N, R67E at an elevation of approximately 5,704 ft amsl. Access to the site is west along a dirt road adjacent to the highway. A map showing the site location and other SNWA test and monitor wells in Spring Valley installed as of January 2011 is presented on Figure 2-1. This section presents an overview of the hydrogeologic setting and description of the test and monitor wells including construction details and historic water level hydrographs.

2.1 Hydrogeologic Setting

This subsection presents the regional and local hydrogeologic setting of the Test Well SPR7008X 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, drilling data, and review of existing hydrogeologic and geophysical information.

2.1.1 Regional Hydrogeologic Setting

Spring Valley, located in east-central Nevada, is approximately 120 mi in length and averages approximately 16 mi in width. The valley is located within the Basin and Range province and is an upgradient basin within the Great Salt Lake Desert Flow System. It is bounded by the Schell Creek Range to the west, the Antelope Range to the north, the Snake Range and Limestone Hills to the east, the Wilson Creek Range to the south, and the Fortification Range to the southwest.

The primary aquifer systems within Spring Valley are carbonate and basin fill, with a volcanic aquifer occurring in the southwest portion of the valley. 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. The local discharge of groundwater in central Spring Valley in the vicinity of the well site is through the basin fill generally toward the central axis of the valley with discharge occurring through evapotranspiration (ET).

Numerous studies related to Spring 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 and recent monitoring results have been presented in several reports. These historic as well as most recent reports are presented below:

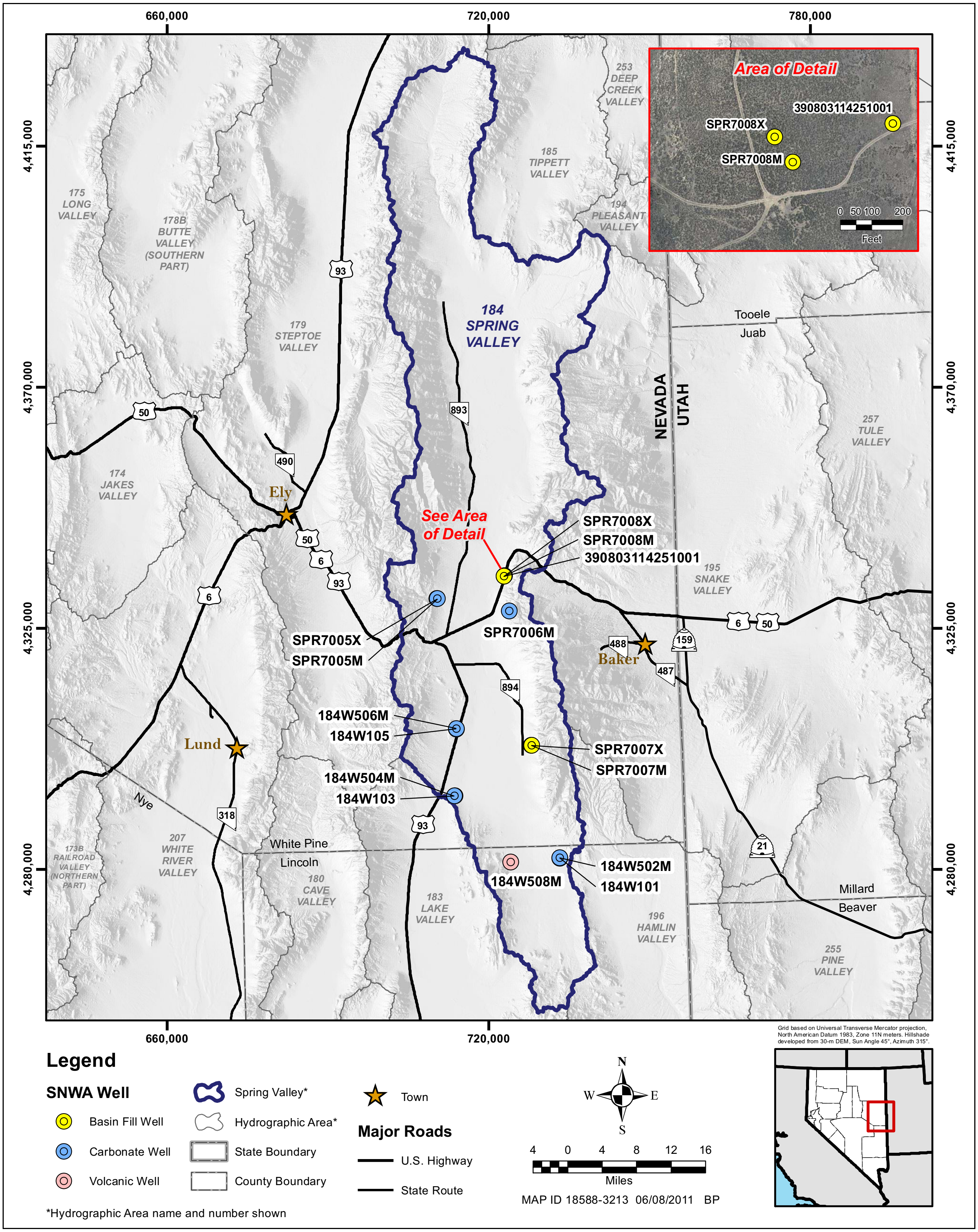


Figure 2-1
SNWA Exploratory and Test Wells in Spring Valley (as of August 2010)

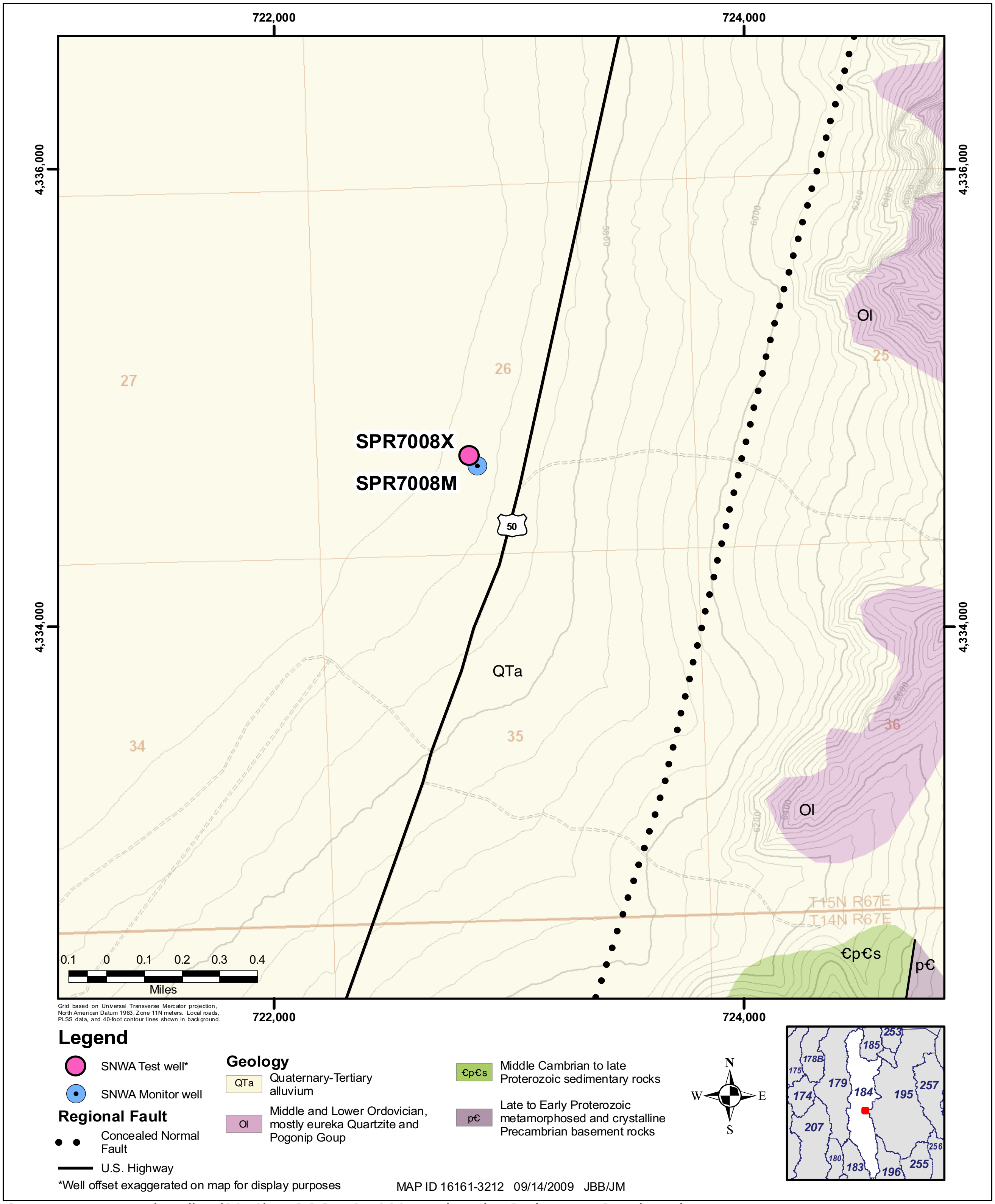
- *Water Resources Appraisal of Spring Valley, White Pine and Lincoln Counties, Nevada* (Rush and Kazmi, 1965)
- *Major Ground-Water Flow Systems in the Great Basin Region of Nevada, Utah, and Adjacent States* (Harrill et al., 1988)
- *Water Resources of the Basin and Range Carbonate-Rock Aquifer System, White Pine County Nevada, and Adjacent Areas in Nevada and Utah* (Welch et al., 2007)
- *2008 Spring Valley Hydrologic Monitoring and Mitigation Plan Status and Data Report* (SNWA, 2009)
- *2009 Spring Valley Hydrologic Monitoring and Mitigation Plan Status and Data Report* (SNWA, 2010)
- *2010 Spring Valley Hydrologic Monitoring and Mitigation Plan Status and Data Report* (SNWA, 2011)
- *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)

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, evaluation of surface structural features using aerial photography, and evaluation of local geophysical data.

A regional gravity survey was performed by U.S. Geological Survey (USGS) to estimate the structure and depth of the basins in eastern Nevada. Gravity data for Spring and Snake Valley are presented in USGS Open File Report 2006-1160 (Mankinen et al., 2006).

A site map presenting the surficial geology, test and monitor well locations are presented in Figure 2-2. A further discussion of geophysical profiles, local geologic structure, and detailed lithologic descriptions of the stratigraphic units encountered are presented in Mace and Muller (2010).



Source: Mace and Muller (2010); USGS 1:24,000 North Point Spring 7.5' Quadrangle.

Figure 2-2
Surficial Geology and Structural Features at Monitor Well SPR7008M and Test Well SPR7008X

2.2 Testing Program Monitoring Locations

Three on-site well locations were monitored as part of the testing program, two background wells, one spring, and a flowing well were also monitored. The primary sites consist of the Test Well SPR7008X, Monitor Well SPR7008M, and 184 N15 E67 26CA 1 USGS MX 390803114251001 (USGS MX Observation Well). Monitor Well SPR7008M and the USGS MX observation wells are located 100 and 376 ft from the test well, respectively. Two off site monitoring locations included Layton Spring discharge, located 2.5 mi SW of the site and a flowing well located 0.7 mi north of the site were also monitored. Background wells SPR7006M and 390352114305401, located approximately 4.1 mi southeast, and 7 mi southwest of the site, respectively. were monitored to identify regional trends and influences during the testing period. Site attributes, lithologic, and hydrologic information for the locations are presented in this section.

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. A detailed presentation and analysis of the geologic data at this site, including local structural features, are presented in the *Geologic Data Analysis Report for Monitor Well SPR7008M and Test Well SPR7008X in Spring Valley* (Mace and Muller, 2010). Summary data for these wells are provided in Sections 2.2.1 and 2.2.2 of this report.

2.2.1 Test Well SPR7008X

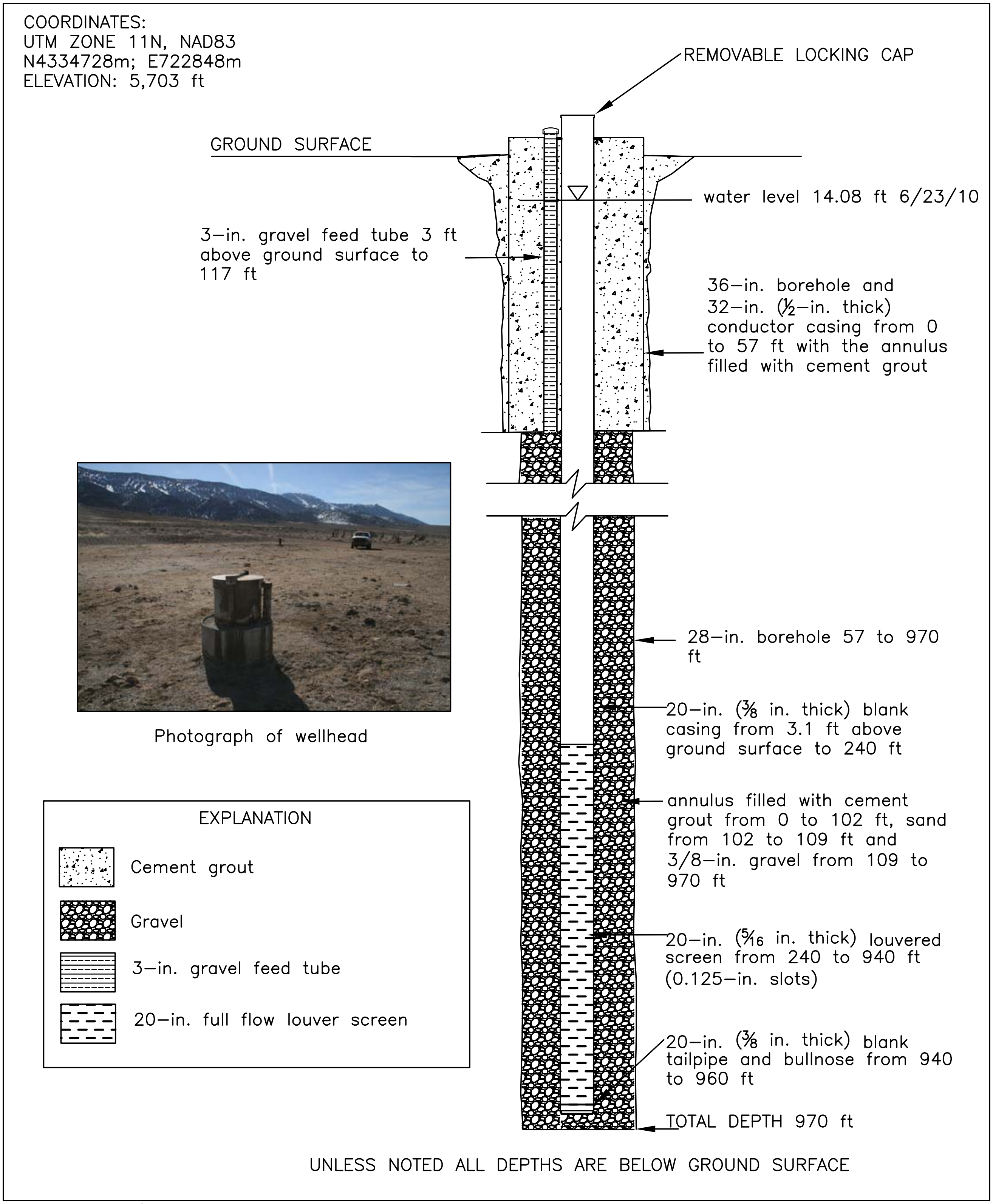
SPR7008X was drilled to a total depth of 970 ft bgs between October 30 and November 27, 2007, using mud rotary techniques. A 32-in. O.D. conductor casing was placed to a depth of 57 ft bgs and grouted in place. After the borehole was advanced to completion depth, downhole geophysical logging was performed. A 20-in. I.D. completion string was then installed, including approximately 700 ft of Ful-Flo louvered screen from 240 to 940 ft bgs. The sand and gravel pack extends from the base of the grout at a depth of 102 ft bgs to the bottom of the borehole. A summary chart of Test Well SPR7008X 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 Test Well SPR7008X is presented in Figure 2-4.

2.2.2 Observation Wells and Background Monitoring

Monitor Well SPR7008M was completed at a depth of 960 ft bgs between July 13 and July 25, 2007. A 20-in. O.D. conductor casing was set to a depth of 56 ft bgs and grouted in place. A 16-in. borehole was then advanced to completion depth. The 8-in. I.D. completion string, including approximately 700 ft of slotted casing, was placed in the open borehole to a depth of 926 ft bgs. The sand and gravel pack extends from the base of the grout at a depth of 54 ft to the bottom of the borehole. A summary chart of well drilling and well construction statistics for Monitor Well SPR7008M is presented in Table 2-2, and a well construction schematic is presented on Figure 2-5. The borehole lithologic log for the monitor well is presented in Figure 2-6.

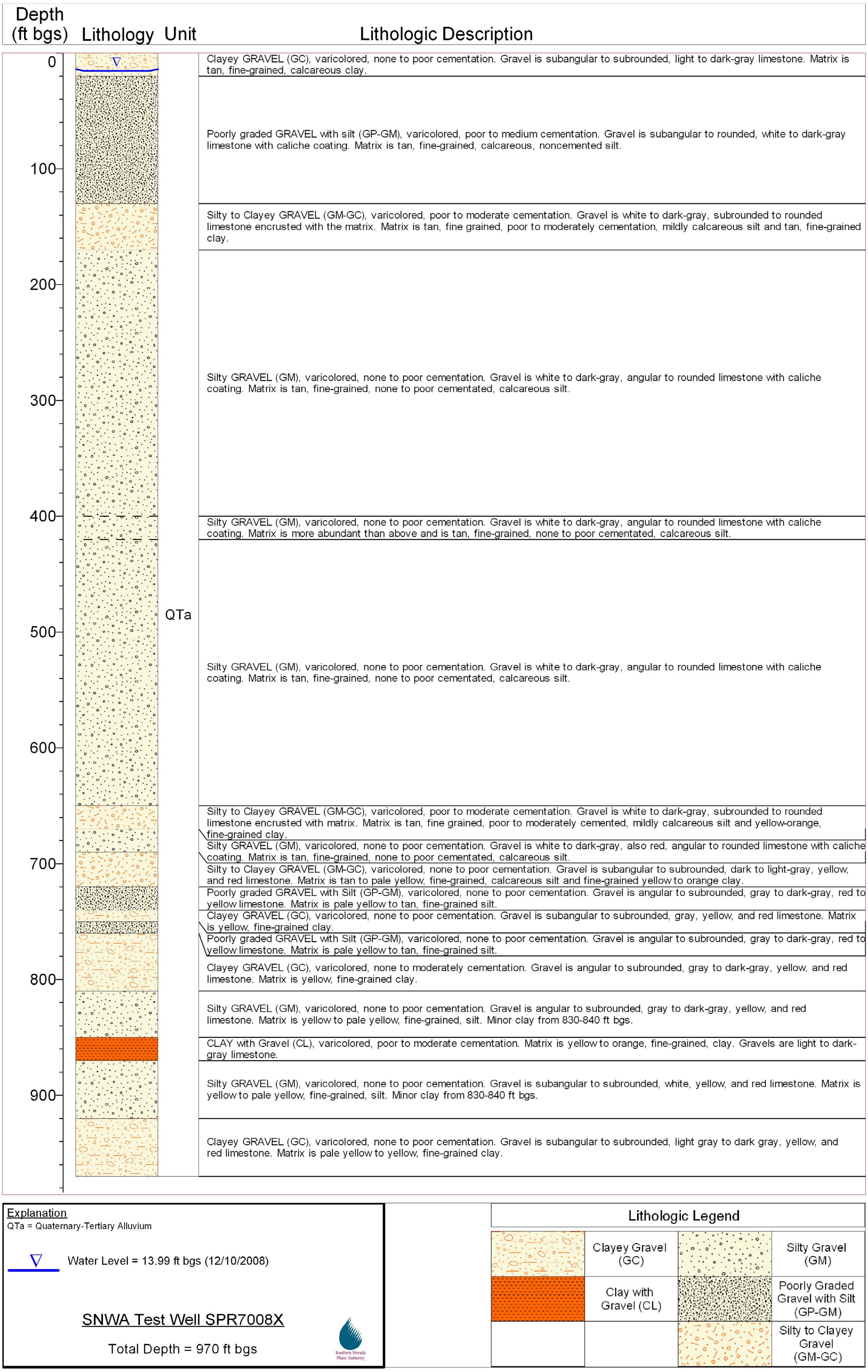
Table 2-1
Test Well SPR7008X Borehole and Well Statistics

LOCATION DATA Coordinates	N 4,334,727.66 m; E 722,847.72 m (UTM, Zone 11, NAD83)
Ground Elevation	5,702.99 ft amsl
DRILLING DATA Spud Date	10/30/2007
Total Depth (TD)	970 ft bgs
Date TD Reached	11/12/2007
Date Well Completed	11/27/2007
Hole Diameter	36-in. from 0 to 57 ft bgs 28-in. from 57 to 970 ft bgs
Drilling Techniques	Conventional Circulation from 0 to 57 ft bgs Reverse Circulation from 57 to 970 ft bgs
Drilling Fluid Materials Used	Soda Ash (28) 50-lb bags DrisPac (7) 50-lb bags Gel (120) 50-lb bags EZ Mud Gold (4) 5-gal buckets
Drilling Fluid Properties	Viscosity Range = 29 to 48 sec/qt Weight Range = 8.7 to 9.7 lbs/gal Filtrate Range = 3 to 18 ml Filter Cake Range = 1/64 to 3/64 in.
CASING DATA	32-in. MS Conductor Casing from 0 to 57 ft bgs 20-in. HSLA Completion Casing from +3.1 to 960.10 ft bgs
WELL COMPLETION DATA	119.78 ft of 3-in. gravel sounding tube from -2.78 to 117 ft bgs 243.1 ft of blank HSLA 20-in. casing from -3.1 to 240.00 ft bgs 700.00 of 20-in. Ful Flow Louver screen from 240.00 to 940.00 ft bgs 20.10 ft blank 20-in. sump/bullnose MS casing from 940.00 to 960.10 ft bgs Cement, Plug and Gravel Pack Depth 0 to 57 ft on outside of conductor casing (cement) 0 to 102 ft between completion casing and conductor casing (cement) 102 to 109 ft bgs sand 109 to 970 ft bgs 3/8 in. gravel pack
MONITOR WELL	Static Water Level: 13.09 ft bgs (6/23/10) Groundwater Elevation: 5,689.90 ft amsl
DRILLING CONTRACTOR	WDC Drilling
GEOPHYSICAL LOGS BY	Pacific Surveys
OVERSIGHT	SM Stoller Corporation



Note: Not to scale

Figure 2-3
Test Well SPR7008X Construction Schematic



Source: Mace and Muller (2010)

Figure 2-4
Borehole Stratigraphic Column of Test Well SPR7008X

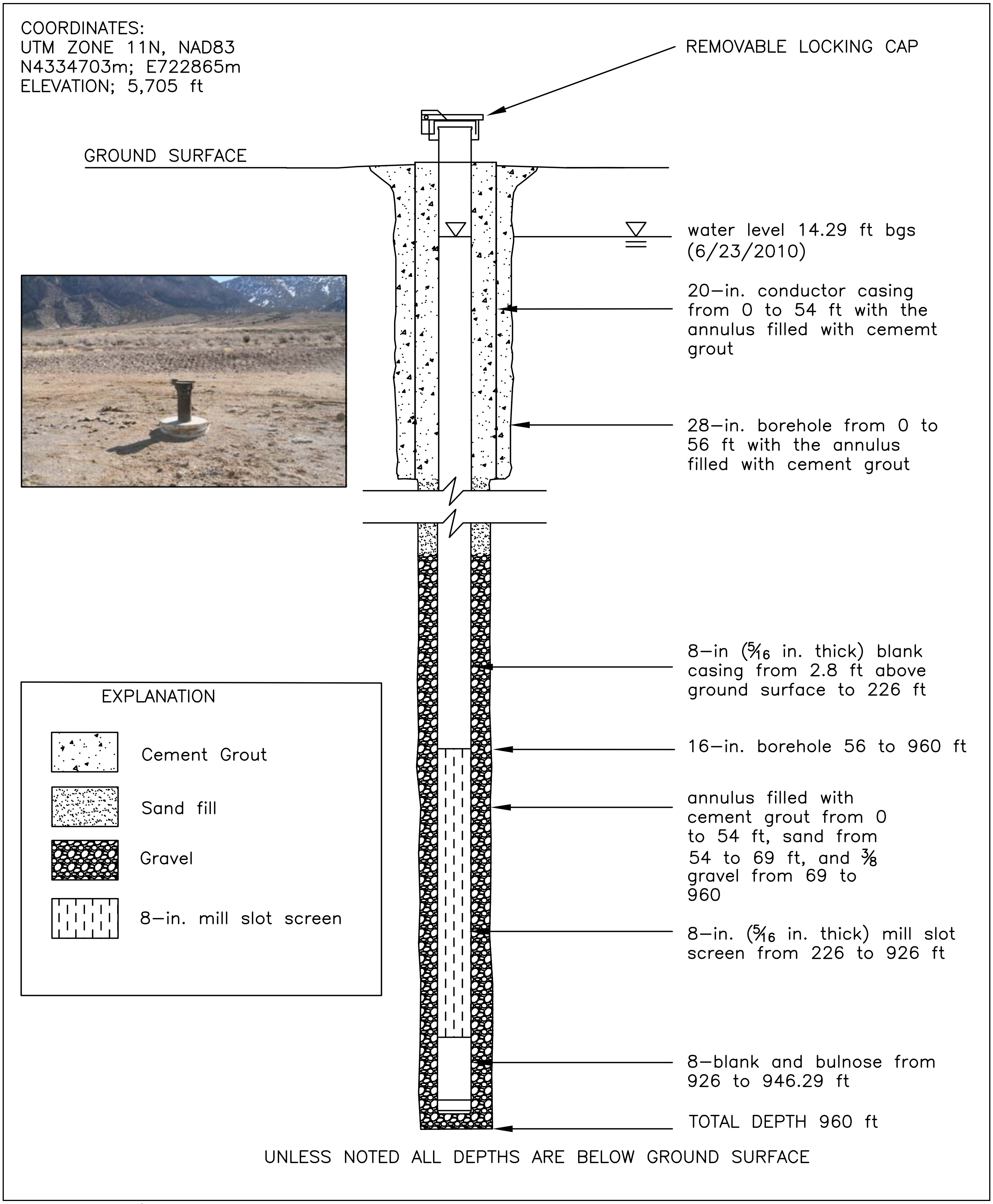
USGS MX Well 390803114251001 was completed at an approximate depth of 200 ft. The completion date is unknown as well as the drilled depth. The completion string is 2-in. diameter, and is reported to have an open interval from 50 to 200 ft bgs, based on information received from the USGS.

Water levels at Monitor Well SPR7006M and 390352114305401 were collected as part of the hydraulic testing program to observe regional groundwater trends and to identify potential outside influences affecting water levels, such as changes in barometric pressure, earthquakes, and lunar effects. Regional hydrologic influence which may affecting the water levels in the background wells were evaluated as an indicator of potential effects on the test and observation wells. Historic hydrographs (presented later in this section) indicate different behavior over time between Well SPR7006M and test and observation wells. Hydrologic influences at Well SPR7006M may not be similar to those in the test well due to differences in hydrogeologic setting including depth to groundwater and relative hydraulic conductivity. Well SPR7006M is completed in the unconfined, fractured carbonate-aquifer system. The 8-in.-diameter well is completed at a depth of 1,700 ft bgs with an open borehole interval of 167 to 1,720 ft bgs. Casing is slotted from 980 to 1,680 ft bgs. Depth to groundwater is approximately 770 ft bgs.

Hydrologic influences at Well 390352114305401 also may not be similar to those in the test well due to possible communication problems between the well and the surrounding aquifer which may limit response to changes in water levels in the aquifer. This is discussed in further detail in Section 3.4.

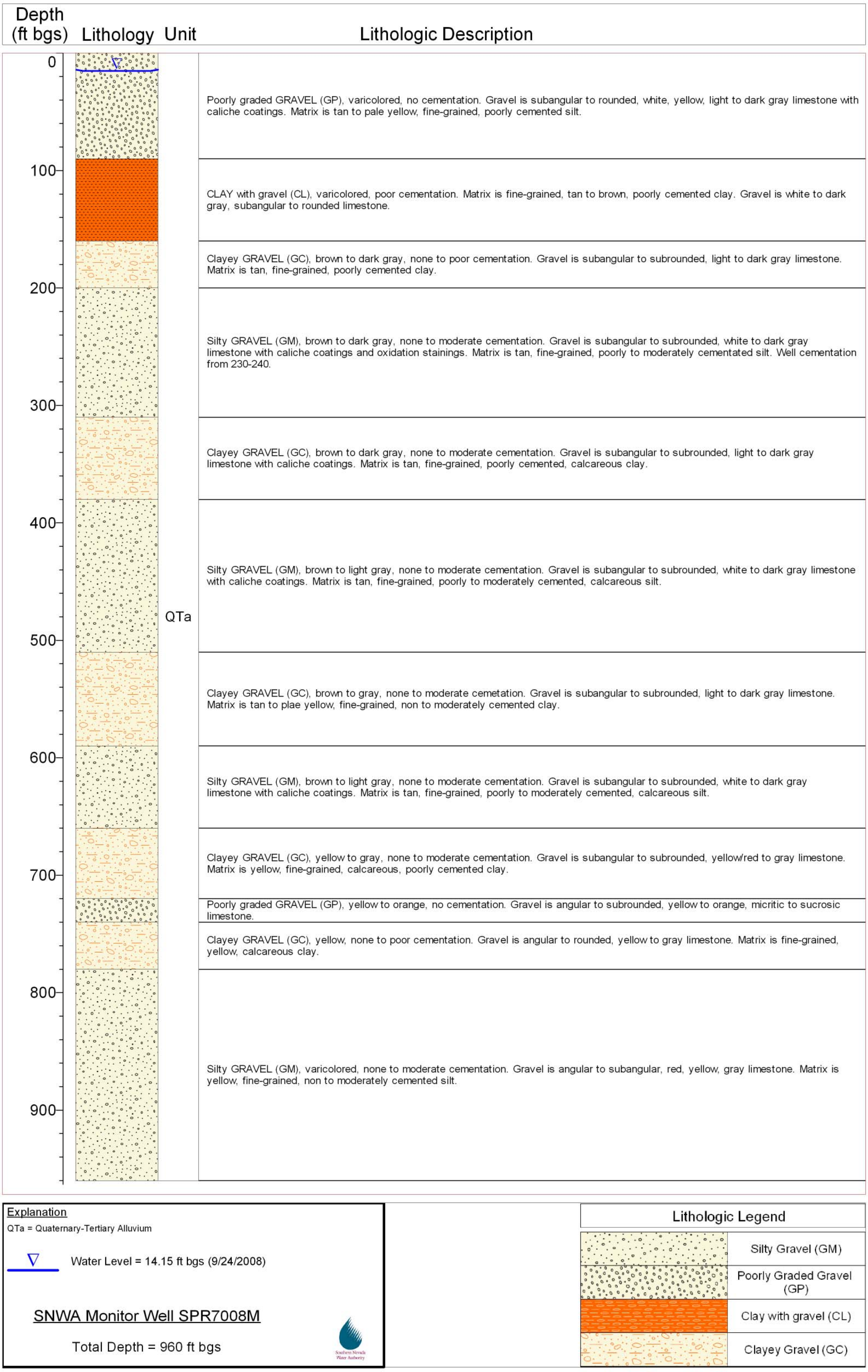
Table 2-2
Monitor Well SPR7008M Borehole and Well Statistics

LOCATION DATA Coordinates	N 4,334,702.61 m; E 722,865.27 m (UTM, Zone 11, NAD83)	
Ground Elevation	5,704.86 ft amsl	
DRILLING DATA Spud Date	7/13/2007	
Total Depth (TD)	960 ft bgs	
Date TD Reached	7/18/2007	
Date Well Completed	7/25/2007	
Hole Diameter	28-in. from 0 to 56 ft bgs 16-in. from 56 to 960 ft bgs	
Drilling Techniques	Conventional Circulation from 0 to 56 ft bgs Reverse Circulation from 56 to 960 ft bgs	
Drilling Fluid Materials Used	Soda Ash = (2) 50-lb bags EZ-Mud = (7) 5-gal buckets Gel = (26) 50-lb bags	Mud = (81) 50-lb bags EZ-Mud Gold = (8) 5-gal buckets
Drilling Fluid Properties	Viscosity Range = 32 to 66 sec/qt Weight Range = 8.6 to 9.6 lbs Filtrate Range = 9.6 to 16.8 ml Filter Cake Range = 1/32 to 4/32 in.	
CASING DATA	20-in. MS Conductor Casing from 0 to 54 ft bgs 8-in. MS Completion Casing from -2.8 to 946.29 ft bgs	
WELL COMPLETION DATA	228.80 ft of blank MS 8-in. casing from -2.8 to 226.00 ft bgs 700.00 ft of slotted MS 8-in. casing from 226.00 to 926.00 ft bgs 20.29 ft blank 8.625-in sump/bullnose MS casing from 926.0 to 946.29 ft bgs <u>Cement Depth</u> 0 to 56 ft on outside of conductor casing 0 to 54 ft between conductor and completion casing (cement) 54 to 69 ft bgs sand 69 to 960 ft bgs 3/8-in gravel pack	
WATER	Static Water Level: 14.29 ft bgs on 6/23/2010 Groundwater Elevation: 5,690.57 ft amsl	
DRILLING CONTRACTOR	WDC Drilling	
GEOPHYSICAL LOGS BY	Pacific Surveys	
OVERSIGHT	S.M. Stoller Corporation	



Note: Not to scale

Figure 2-5
Monitor Well SPR7008M Construction Schematic



Source: Mace and Muller (2010)

Figure 2-6
Borehole Stratigraphic Column of Test Well SPR7008M

2.2.3 Well Survey and Water Level Data

A professional survey was performed on the wells utilized in the testing program 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 2-3.

Table 2-3
Well Survey Data and Measuring-Point Information

Well ID	Well Use During Testing	Location[a] UTM Northing (m)	Location[a] UTM Easting (m)	Temporary MP (ft amsl)	Permanent MP (ft amsl)	Ground Surface Elevation (ft amsl)
SPR7008X	Test Well	4,334,728	722,848	5,706.24	5,706.09	5,702.99
SPR7008M	Observation Well	4,334,703	722,865	5,707.66	5,707.66	5,704.86
390803114251001	Observation Well	4,334,740	722,963	5,729.41	5,729.41	5,727.21
390352114305401	Background Well	4,326,894	714,874	5,849.04	5,849.04	5,846.04
SPR7006M	Background Well	4,328,163	723,873	6,527.86	6,527.86	6,525.18

[a]Universal Transverse Mercator, North American Datum of 1983, Zone 11N, Meters
MP = Measuring Point

Static groundwater-elevation data have been collected at Monitor Wells SPR7006M, SPR7008M, and 390803114251001 from just preceding the test to present. Static groundwater-elevation data have been collected on a continuous basis at Monitor Wells SPR7008M and 390803114251001 from August, 2009 to present. These wells are currently equipped with Design Analysis, H-312 transducers and an XL-500 data logger. Water levels are currently collected hourly. The three monitor wells are included in the SNWA regional groundwater monitoring network. Physical measurements are collected from the test well on a six week to quarterly frequency.

Static groundwater elevation is approximately 5,690 ft amsl at Test Well SPR7008X, which corresponds to a depth to water of approximately 16 ft bgs. Static groundwater elevation at Monitor Well SPR7008M is approximately 5,690 ft amsl, which corresponds to a depth to water of approximately 14 ft bgs. Static groundwater elevation at well 390803114251001 is approximately 5,687 ft amsl, which corresponds to a depth to water of approximately 40 ft bgs. Background wells 390352114305401 and SPR7006M static groundwater elevations are approximately 5,807 and 5,755 ft amsl, respectively, which corresponds to depths to water of approximately 39 and 770 ft bgs, respectively. Period-of-record hydrographs for the wells are presented on Figures 2-7 through 2-11. The hydrographs highlights the hydraulic testing duration time interval. Static water levels have remained within a narrow range since the test period. A detailed background hydrograph at SPR7006M during the testing period is presented in Section 3.4.

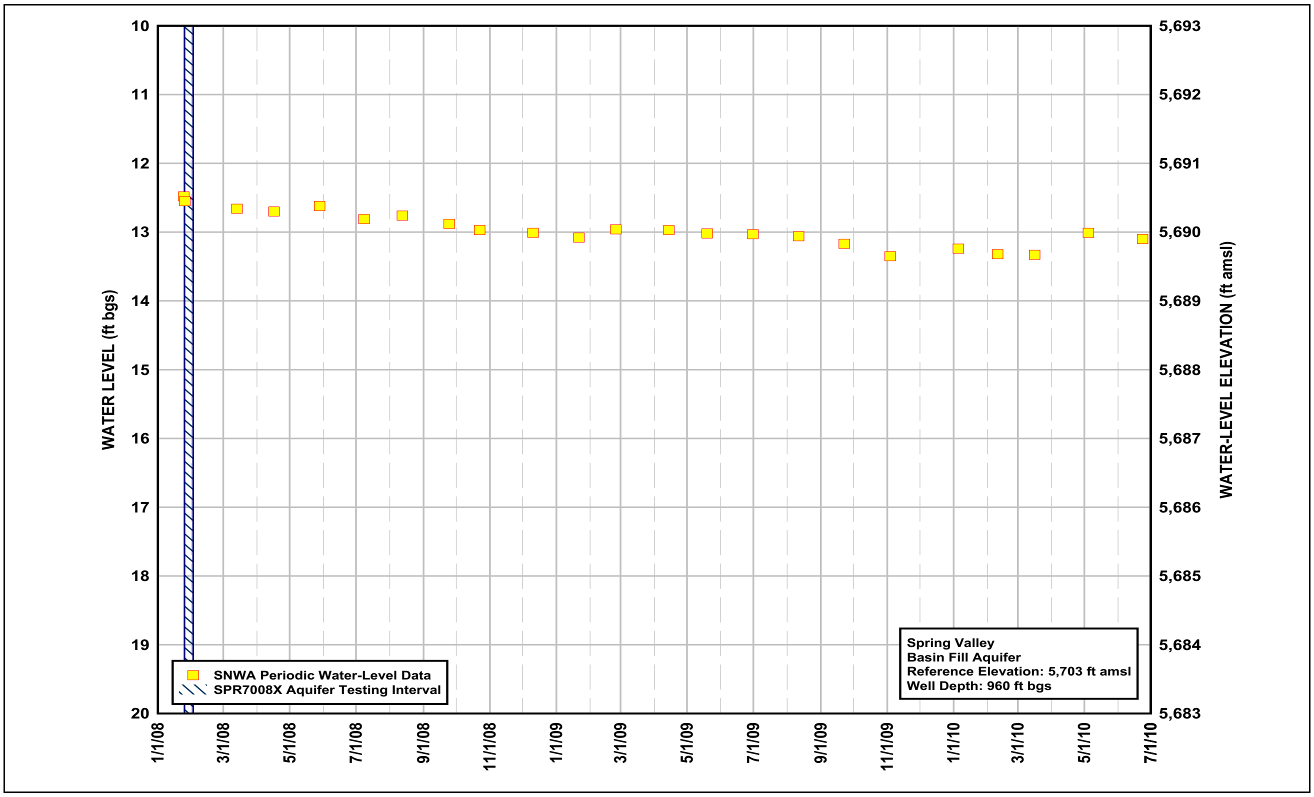


Figure 2-7
Test Well SPR7008X Historic Hydrograph

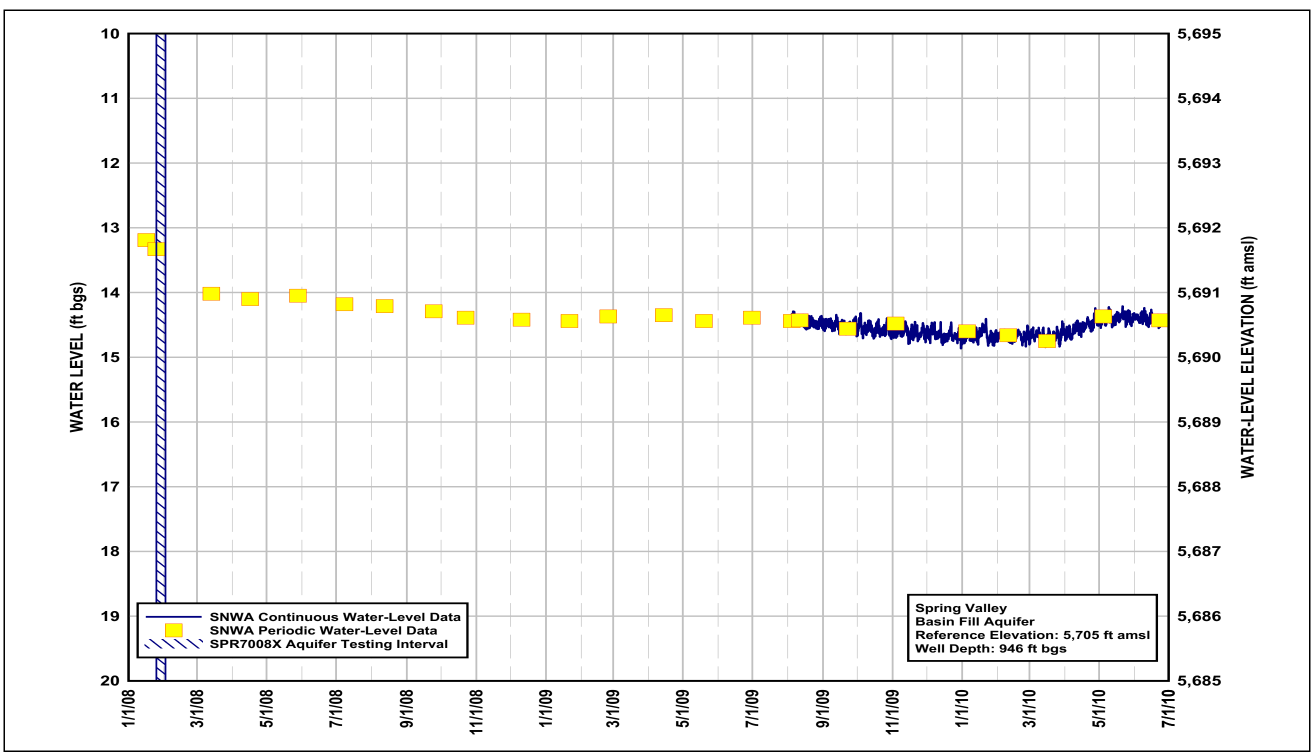


Figure 2-8
Monitor Well SPR7008M Historic Hydrograph

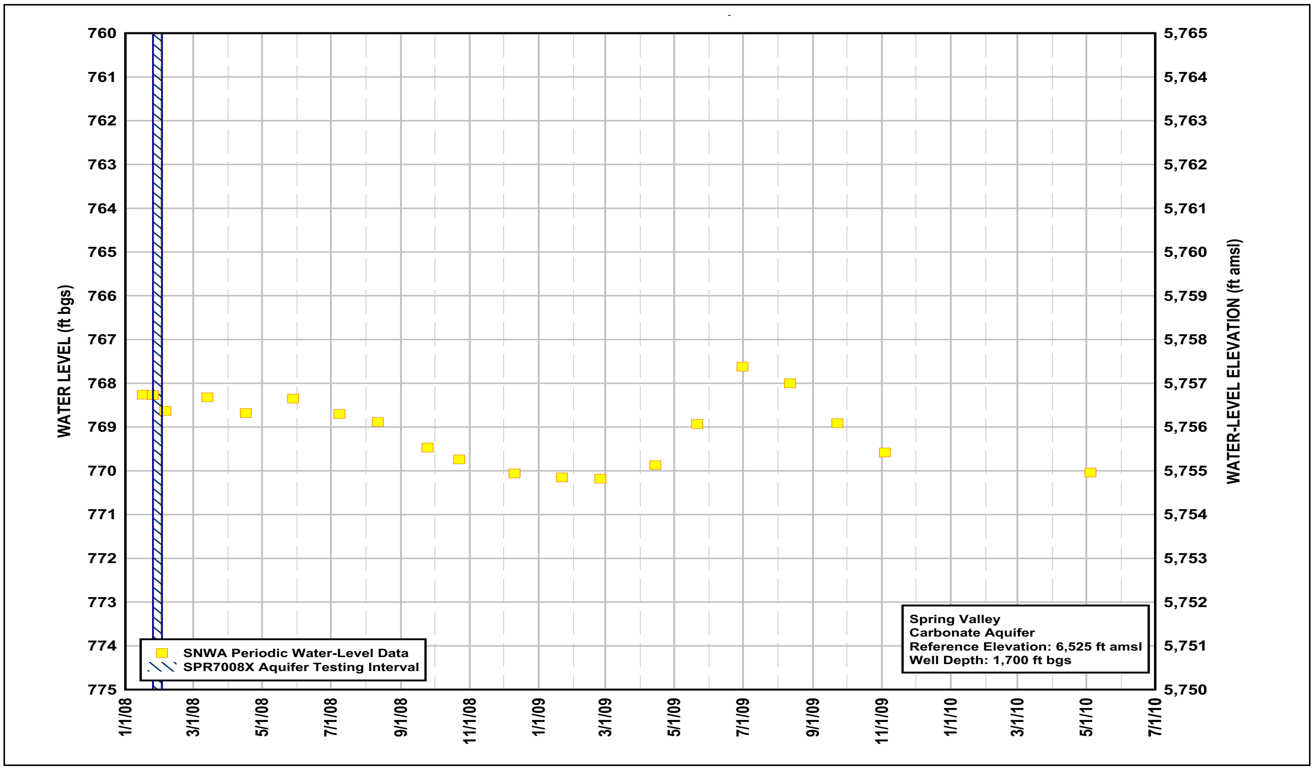


Figure 2-9
Monitor Well SPR7006M Historic Hydrograph

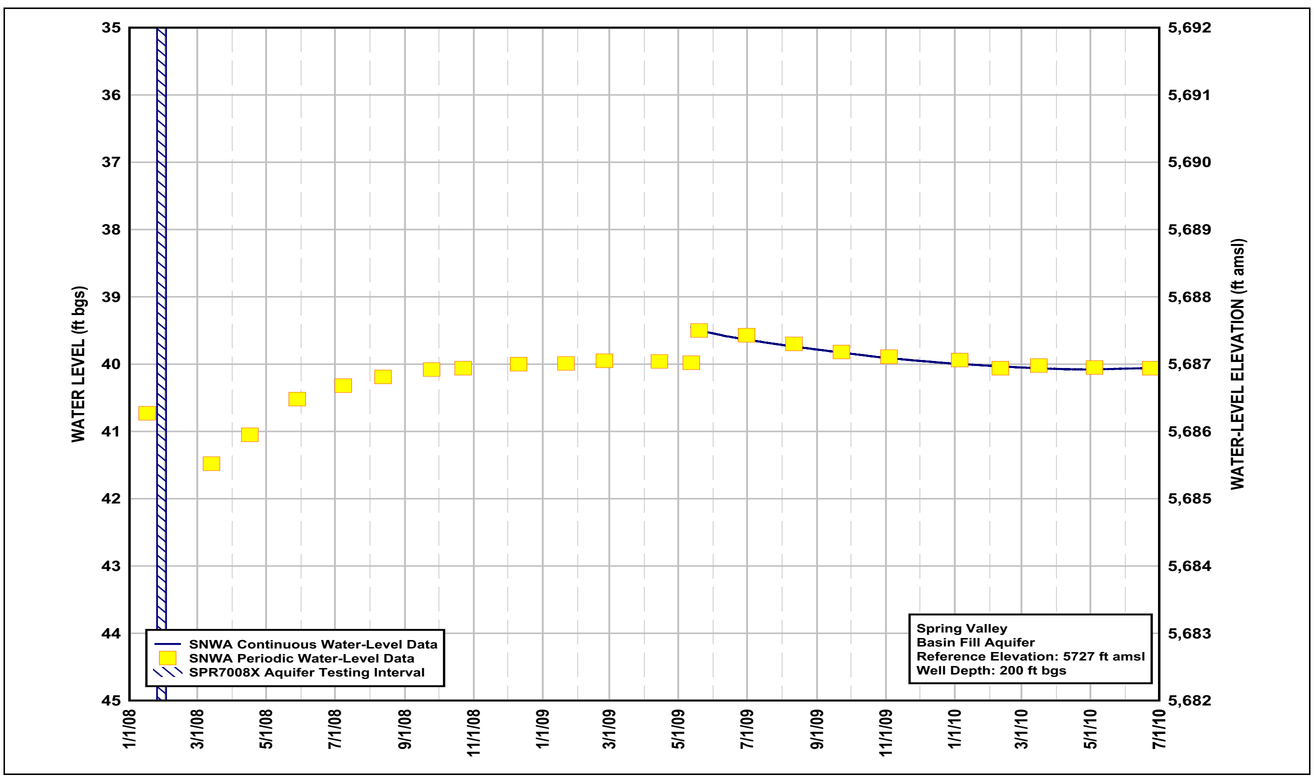


Figure 2-10
Monitor Well 390803114251001 Historic Hydrograph

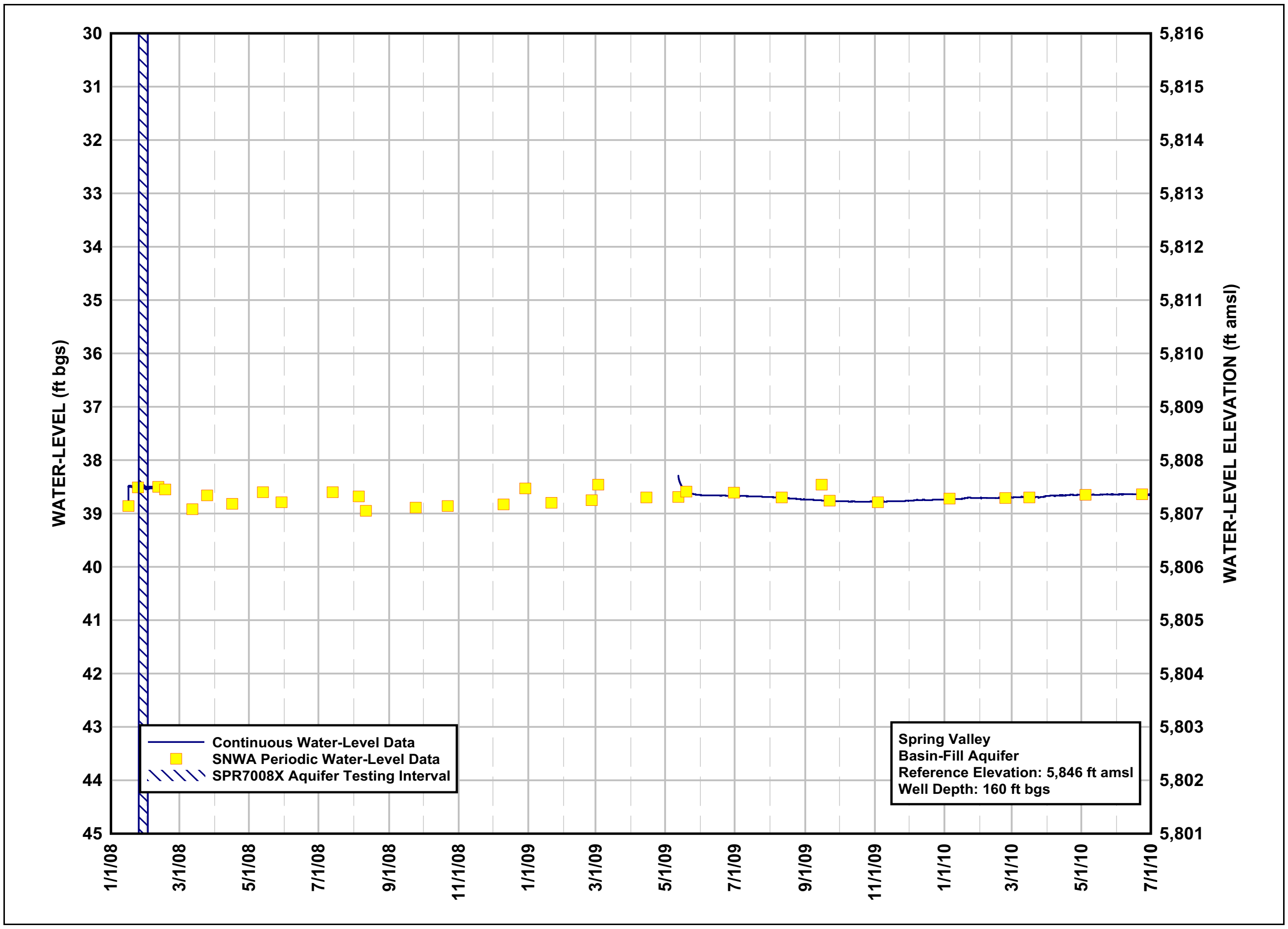


Figure 2-11
Monitor Well 390352114305401 Historic Hydrograph

3.0 TEST DESCRIPTION AND BACKGROUND DATA

This section describes the activities, pump equipment, and monitoring instrumentation associated with development and hydraulic testing of SPR7008X. 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 at the well site:

- November 17 to 26, 2007: Developed the test well using airlift and dual swab techniques.
- January 25 to 26, 2008: Final well development, using surge and pump methods. The well was developed at rates ranging from 960 to 3,500 gpm.
- January 28, 2008: Performed a five-interval step-drawdown test at rates ranging from 1,460 to 3,280 gpm.
- January 30 to February 2, 2008: Performed a 72-hour constant-rate test at 2,000 gpm and subsequent water-level recovery measurements.
- January 31, 2008: Collected groundwater samples for laboratory chemical analysis. Groundwater chemistry samples were collected from well SPR7008X at 08:30 a.m. during performance of the constant-rate test. A total of 7,242,220 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.

3.2 Test Equipment and Site Layout

A National Pump Company vertical line shaft turbine pump was used in Test Well SPR7008X. The intake was set at 408 ft bgs. The transducer was set at approximately 375 ft below the well measuring point during development and step test. A pump discharge-line check valve was not used during the test to allow more effective development activities.

3.3 Discharge Information

Pumped water was discharged west of the site through approximately 600 ft of 12-in.-diameter discharge line down gradient of the test well.

During development, the range of the flowmeter was set for 0 - 2,500 gpm. At flows exceeding 3,000 gpm the primary flowmeter (Krohne Optiflux Electromagnetic Flowmeter) did not function properly. During these periods when the primary flowmeter was not functioning, the secondary flowmeter (Dynasonics TFXL Flowmeter) was used to monitor discharge. Based on the primary flowmeter/totalizer a total of 3,224,400 gal were pumped during development. The accuracy of this value is in question, and is assumed to be less than the actual volume discharged, since the flowmeter was malfunctioning at higher flow rates. Therefore, this value can be used as a minimum for total discharge during development.

A total of 13,122,316 gal of water were recorded to be pumped during the program. This consists of pumpage totals of 8,632,416 gal during the 72-hour constant-rate test, 1,265,500 gal during the step test, and 3,224,400 gal during pumping development.

3.4 Instrumentation and Background Data

Regional and site background water levels were continuously recorded prior to, during, and after the test period at Test Well SPR7008X and Monitor Well SPR7008M. At Test Well SPR7008X continuous groundwater levels were measured with an In-Situ PXD-261 250 psi pressure transducer and recorded using an In-Situ Hermit 3000 Data Logger. At Monitor Wells SPR7008M and 390803114251001 continuous water levels were measured with In-Situ PXD-261 100 psi and 50 psi pressure transducers, respectively, and recorded using an In-Situ Hermit 3000 Data Logger. Manual water level measurements were performed at both the test and monitor wells using Heron 2,000 and 1,000 ft electronic water-level indicator probes, respectively. These measurements were performed at prescribed intervals and in accordance with *SNWA Water Resources Division Field Operating Procedure for Well Development and Aquifer Testing* (SNWA, 2007).

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, with the exception of some turbulence and vibration in the test well during pumping. Manually collected data at the test well was used to check the transducer test well record.

Two background wells, one spring, and one flowing well were also monitored during the tests. The background wells were used to record background conditions and influences outside of the test. Regional water-level trends were evaluated from data collected at background Monitor Well SPR7006M, and USGS MX Well 390352114305401. Background water levels at well SPR7006M were continuously measured using an In-Situ PXD-261 15 psi pressure transducer and recorded using an In-Situ Hermit 3000 data logger. Background water levels at well 390352114305401 were continuously measured using an In-Situ Level TROLL 700 30 psi integrated pressure transducer and data logger.

Historic water level data at SPR7006M collected since the test indicate that the background well responds differently over time that the other wells used in the test. As a result the background well was used for more general observation purposed versus as a correction to test data for background influences.

Well 390352114305401 was selected as a background well due to both its proximity to the test well and the fact that it was completed in basin fill. Analysis of the physical water-level data collected in conjunction with the continuous water-level data indicates that the other background well 390352114305401 may have limited communication with the surrounding aquifer. On multiple occasions, installation and removal of pressure transducers and cables caused corresponding water level rises and declines on the order of 0.3 to 0.4 ft in the small diameter well. When the currently installed Design Analysis H-312 pressure transducer was installed, the water level rose by approximately 0.1 ft, and took approximately 4 months to decay back to the pre-installation static water level.

The background data collected from the two wells are not suited to provide regional trends in either the basin fill or the regional carbonate aquifer. This is based on comparison water level variation of the long term hydrographs from the two background wells compared to the test and monitor well on site. However, the data is suitable to provide insight into the local barometric pressure changes inside the well bore.

Layton Spring, located 2.5 mi southwest of the site, and a flowing well, located 0.7 mi north of the site, were monitored during development and once per day during the constant-rate test. According to ERTEC Western, Inc. (1981) the flowing well was initially monitored in conjunction with the MX missile siting investigation. Simple volumetric discharge measurements were obtained at these sites.

During the course of the constant-rate test, the water level at 390352114305401 remained relatively stable and had a maximum daily fluctuation of approximately 0.04 ft. The total decline in the background well was less than about 0.02 ft, which was insignificant relative to the amount of drawdown produced in the test well or in the monitoring well for the test. A hydrograph for well 390352114305401 for the development and testing periods is presented in Figure 3-1.

Data collected from background well SPR7006M, within the limitations previously mentioned, were used to evaluate any significant regional trend in groundwater level. A hydrograph for background well SPR7006M during the test period is presented on Figure 3-2. An average daily cycle of water-level change of 0.12 ft was observed during the constant-rate test.

Barometric pressure was recorded at the test well and at ET Station SV-2b, located approximately 16.7 mi northwest of the test well. Figure 3-3 presents a plot of barometric pressure variation data and the groundwater level measurements in Monitor Well SPR7008M collected during the hydraulic testing of Test Well SPR7008X. No other influences, such as the existence of other pumping wells in the vicinity of Test Well SPR7008X, were identified. During the record period, the maximum barometric pressure change was approximately 0.24 in. Hg. The barometric change effect on groundwater levels is insignificant compared to the observed drawdown.

The respective borehole deviations for wells SPR7008X and SPR7008M are presented in the geophysical logs in the Closure Distance plots provided in the Geologic Data Analysis Report (Mace and Muller, 2010). Evaluation of borehole deviation and depth to groundwater indicated negligible influence on depth-to-water measurement results.

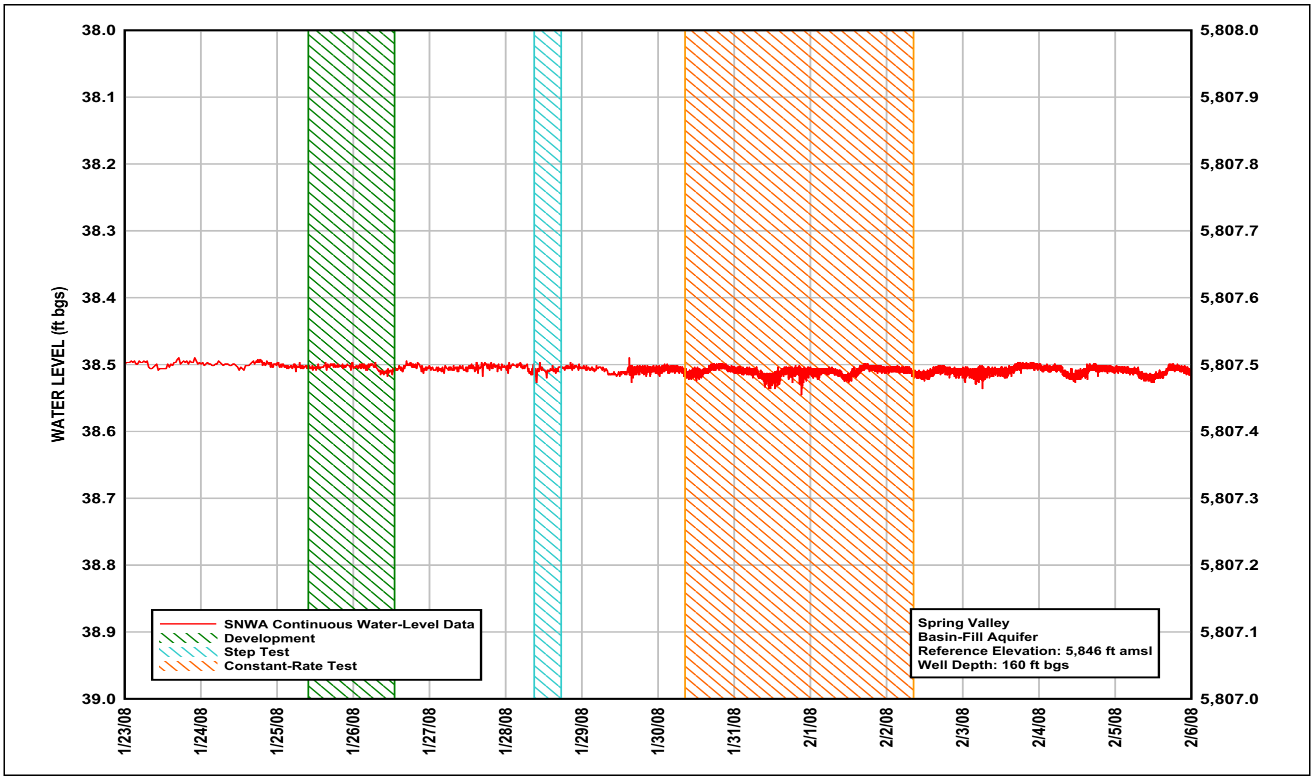


Figure 3-1
Hydrograph for Background Well 390352114305401 During Test Period

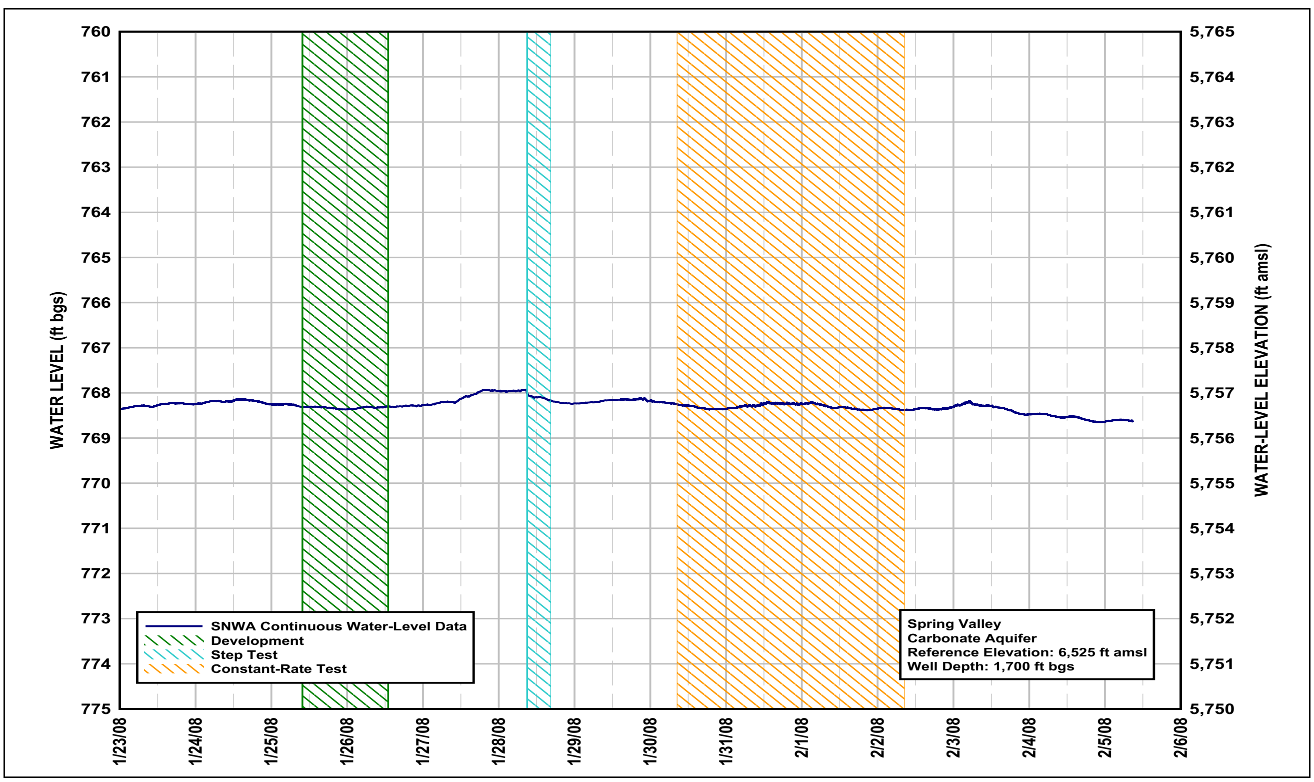


Figure 3-2
Hydrograph for Background Well SPR7006M During Test Period

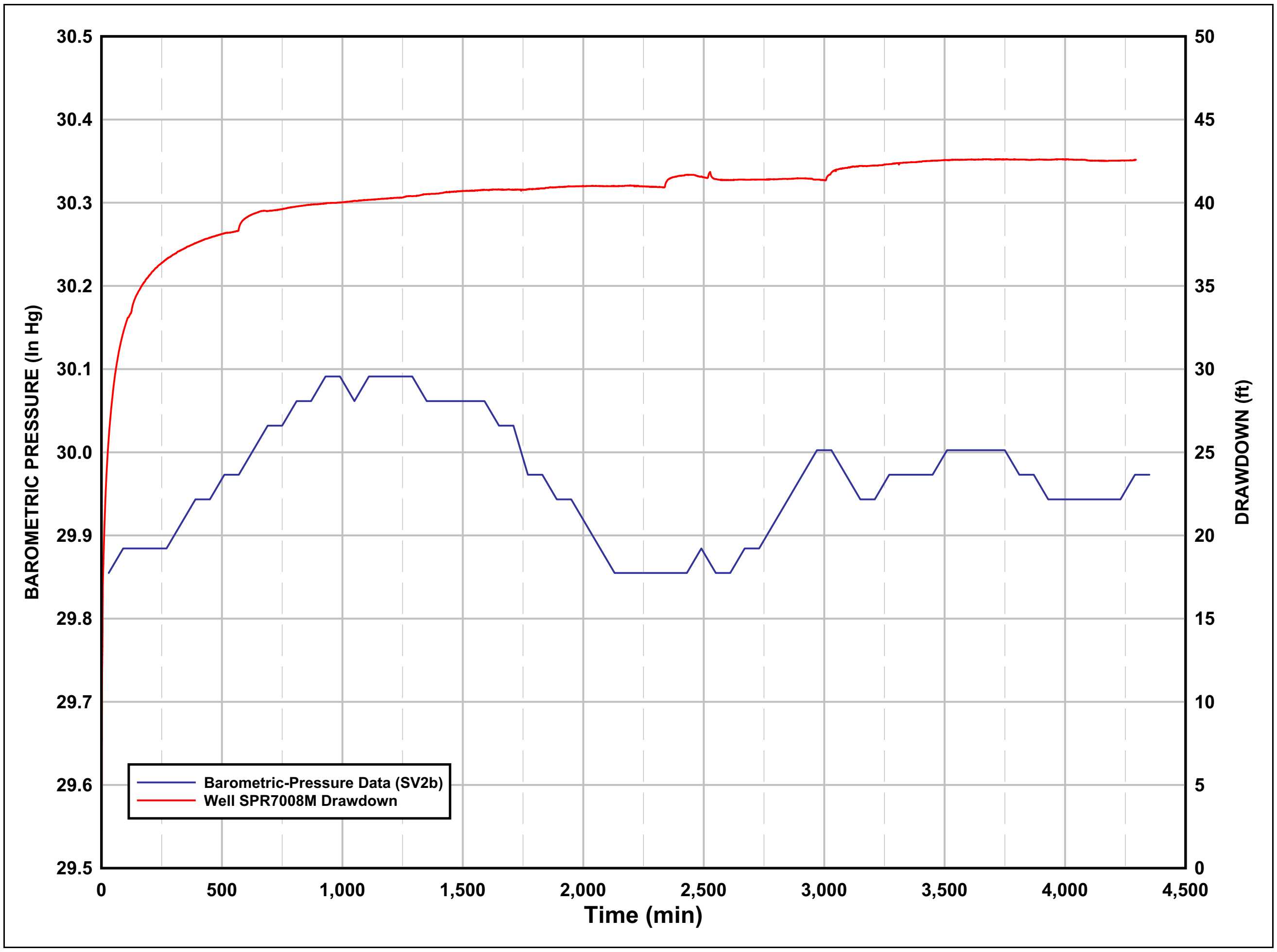


Figure 3-3
Local Barometric-Pressure Variation and
Groundwater-Level Measurements at Monitor Well SPR7008M

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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, Test Well SPR7008X was 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 SPR7008X was then 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 and field groundwater-quality 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.

4.1.1 Development Results

A total of 3,224,400 gal of water was pumped during this phase of development. This volume is based on the totalizer readings. The totalizer was malfunctioning at higher flow rates, which indicates that this volume is the minimum volume that was pumped during this phase of development. This phase of development resulted in an improvement in specific capacity of less than 1 percent, which is less than the error range of the measurement, which indicates that the well did not improve significantly as a result of additional development. The specific capacity improved from 14.82 gpm/ft on January 25, 2008, to 14.95 gpm/ft on January 28, 2008 at similar pumping rates (approximately 1,500 gpm) and pumping durations (approximately 25 min).

4.2 Step-Drawdown Test

A step-drawdown test was performed using five different pumping rates ranging from 1,460 to 3,280 gpm (totalizer based averages). The pumping periods were 90 minutes in duration and were continuous. Figure 4-1 and 4-2 present graphs showing plots of the drawdown versus time for each pumping interval and drawdown versus discharge rate.

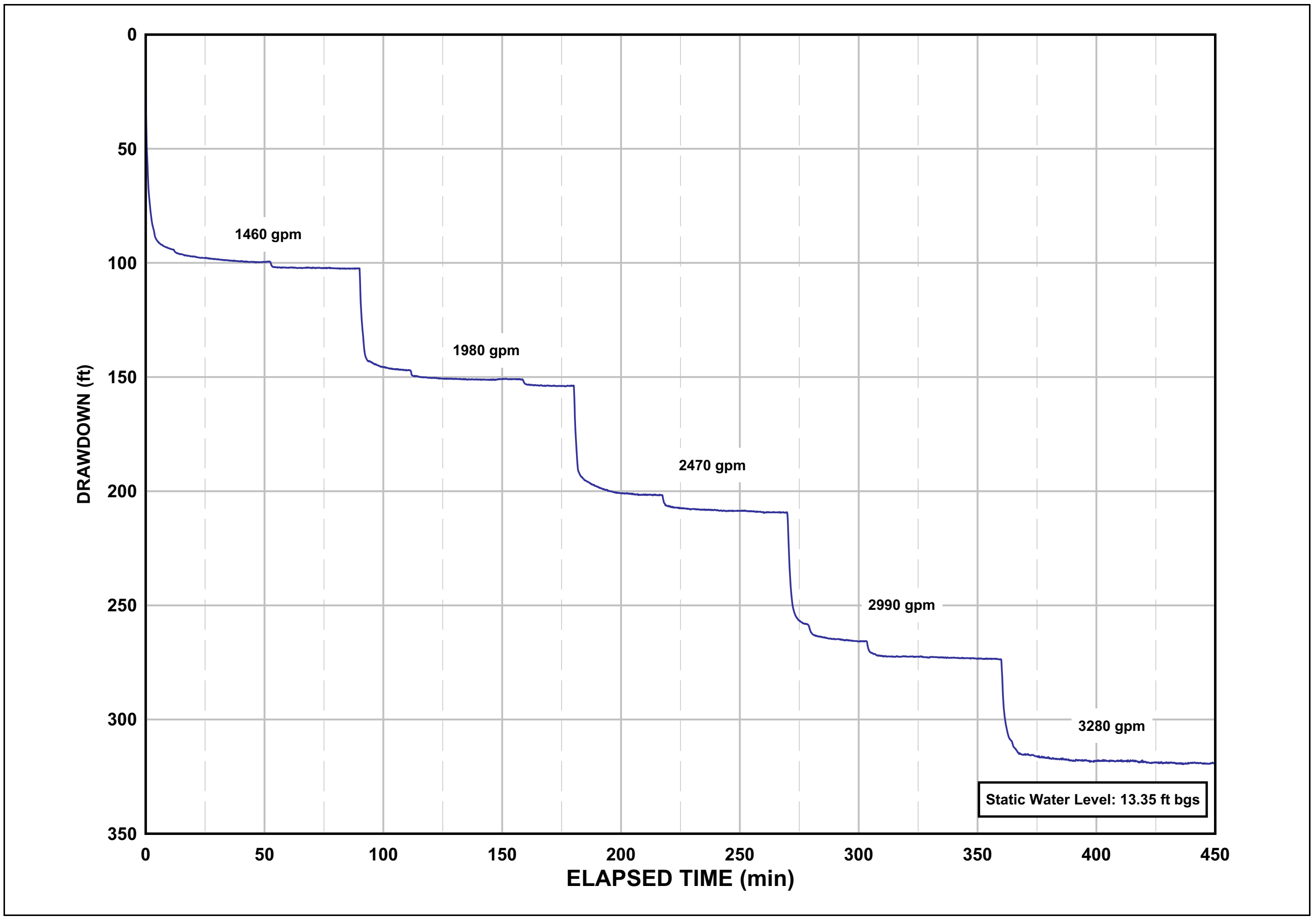

Figure 4-1
Linear Plot of Drawdown for Each Pumping Interval During Step-Drawdown Testing of Test Well SPR7008X

4.2.1 Well Performance and Specific Capacity

Results of the step-drawdown test indicate specific capacity values ranging from 10.3 to 14.3 gpm/ft for associated short term pumping rates of 3,280 to 1,460 gpm, respectively. Specific capacity during the last 12 hours of the 72-hour constant-rate test ranged from 11.70 to 11.77 gpm/ft of drawdown at 2,000 gpm. Specific capacity versus discharge rate is displayed graphically in Figure 4-3.

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 observed in the pumping well caused by turbulent flow and frictional head loss effects in or adjacent to the well. Loss components are also classified as linear and nonlinear. Linear well losses are usually caused by 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 at the well screen, pump column and the zone adjacent to the well.

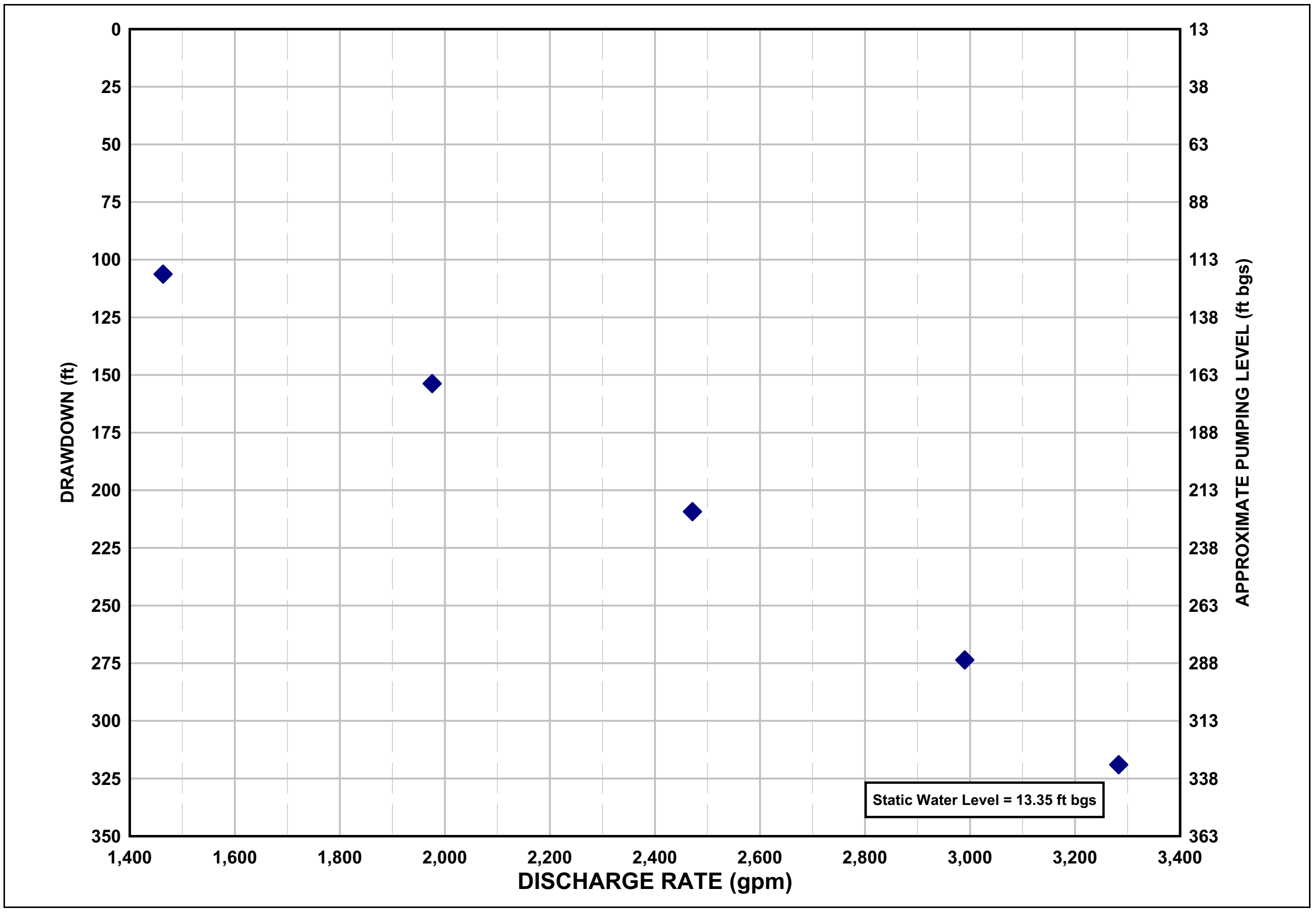

Figure 4-2
Linear Plot of Step-Test Drawdown and
Depth-to-Pumping Level for Various Discharge Rates for Test Well SPR7008X

Determination of well loss allows the calculation of 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 to some degree at higher pumping rates because of an increase of turbulent flow at the well screen or near the well and a decrease in saturated thickness at the borehole wall under unconfined conditions. The evaluation of well losses 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 pumping and well inefficiencies, friction loss, and turbulent flow.

Head loss coefficients are calculated by the equation:

$$s = BQ + CQ^2 \qquad \text{(Eq. 4-1)}$$

where,

s = Drawdown in the pumping well
B = Linear loss coefficient

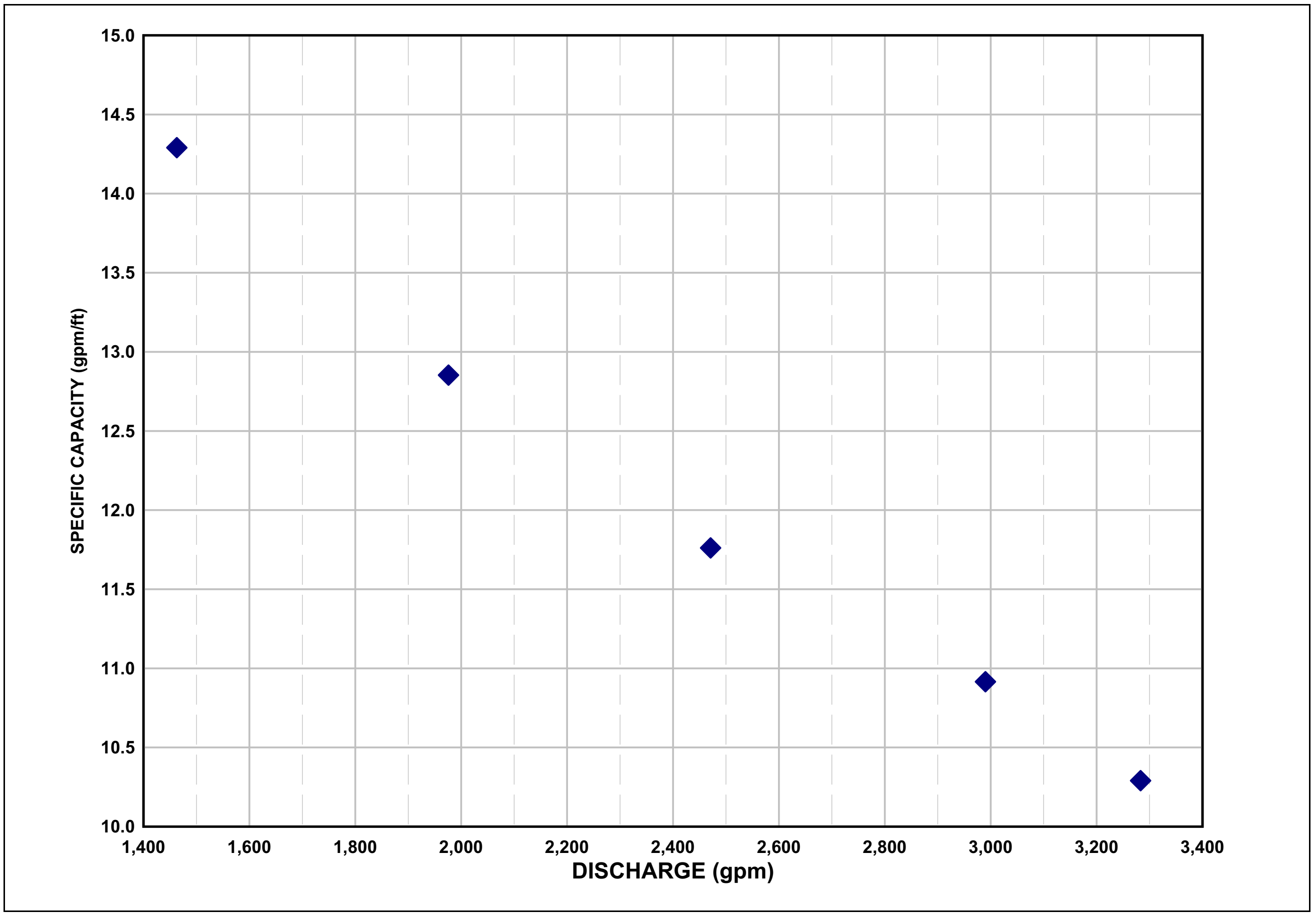

Figure 4-3
Step-Test Specific Capacity versus Discharge Rate for Test Well SPR7008X

C = Nonlinear well loss coefficient caused by turbulent flow
Q = Discharge rate

Results of the evaluation and a graph of specific drawdown (drawdown/discharge) versus discharge rate used to calculate head loss coefficients using the Hantush-Bierschenk method (Bierschenk, 1963; Hantush, 1964) are presented in Figure 4-4. The drawdown at the end of each step was used in the analysis to derive the head loss coefficients.

The loss coefficient for B is 0.04871494 and C equals 1.463×10^{-5} using the Hantush-Bierschenk Method. R^2 is the coefficient of determination, which is the proportion of variability in a data set. Using these values, specific capacity and drawdown estimates can be projected for any pumping rate using the equation:

$$s/Q = 0.04871494 + 1.463 \times 10^{-5} Q \qquad \text{(Eq. 4-2)}$$

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

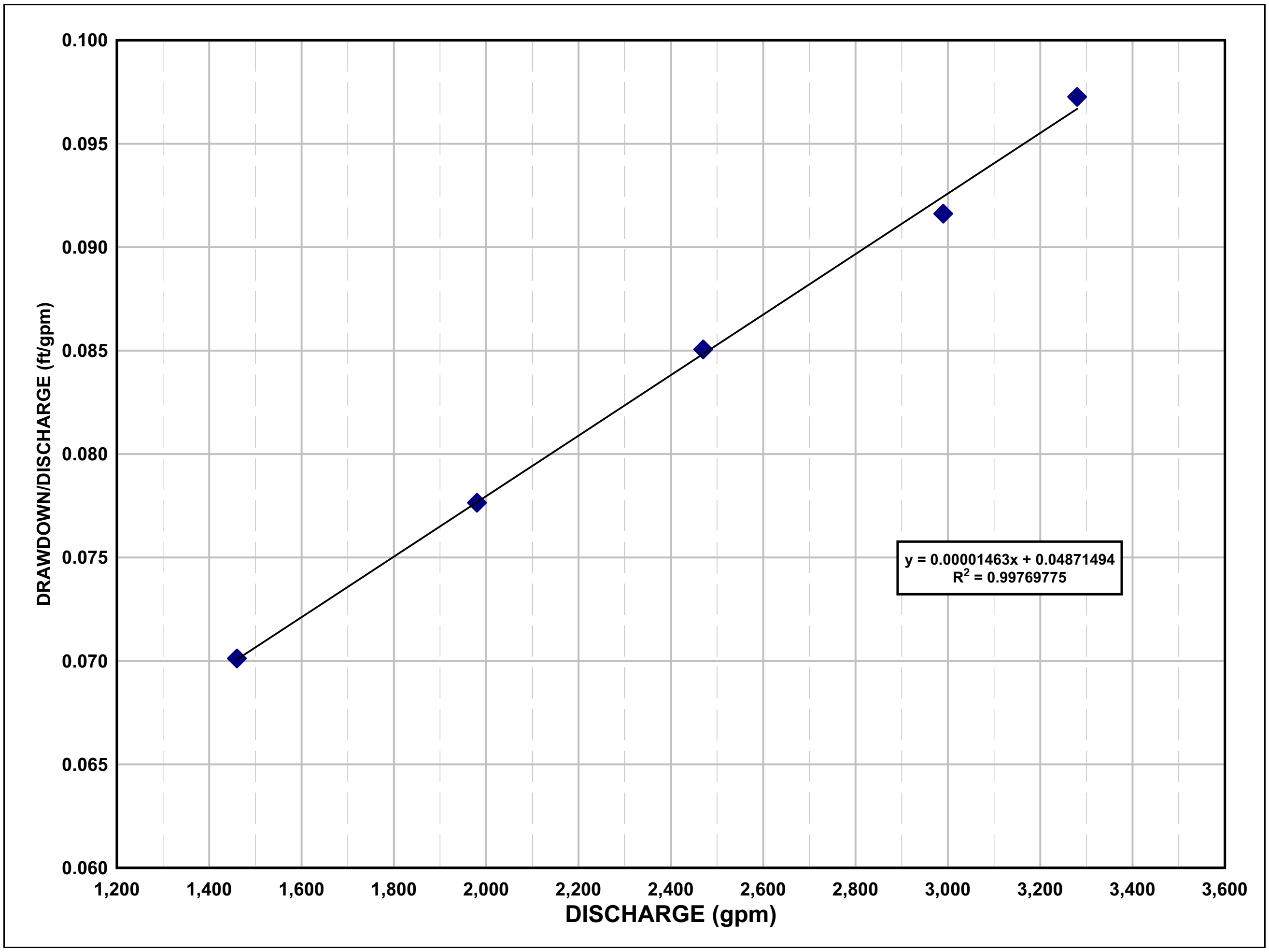

Figure 4-4
Evaluation of Head Loss Coefficients Using Hantush-Bierschenk Method from Step-Drawdown Test Results

The percent of head loss attributed to linear and nonlinear losses can also be estimated using the equation:

$$[BQ/(BQ + CQ^2)] \times 100 \qquad \text{(Eq. 4-3)}$$

Table 4-1 shows that the nonlinear losses compose about 30 to 50 percent of the drawdown within the pumping discharge range of approximately 1,460 to 3,280 gpm used in the step test, the percentage increasing with increasing production rate. The non-linear losses at the pumping rate of 1,980 gpm, similar to the rate used during the constant-rate test (2,000 gpm) is 37 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)	*s*/*Q* (ft/gpm)	Nonlinear Losses (ft)	Linear Losses (ft)	Total Losses (ft)	Nonlinear Total (%)
1,460	102.38	0.070121	31.19	71.12	102.31	30
1,980	153.74	0.077645	57.36	96.46	153.81	37
2,470	210.10	0.085060	89.26	120.33	209.58	43
2,990	273.93	0.091616	130.79	145.66	276.45	47
3,280	319.04	0.097267	157.40	159.79	317.18	50

5.0 CONSTANT-RATE TEST EVALUATION

This section summarizes the hydraulic testing data, analytical solution selection, and analysis results of the 72-hour constant-rate and recovery test at Test Well SPR7008X.

5.1 Data Review and Adjustments

Water-level data were collected with transducer and manual 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 test well constant-rate record was 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 major barometric pressure changes that would influence the results of the test were observed. No other pumping wells were present in the area to influence the test results. A discussion of background data and outside influences is presented in Section 3.4.

Totalizer readings indicated a total volume of 8,632,416 gal were pumped during the 72-hour test, an average of approximately 2,000 gpm. There were six flow adjustments made during the performance of the constant-rate test. These flow adjustments were made to keep the discharge rate near the target rate of 2,000 gpm. The adjustments made are listed in Table 5-1.

Table 5-1
Pumping Rate Adjustments

Date	Time	Elapsed Time (min)	Discharge (before gpm)	Discharge (after gpm)
1/30/2008	09:05	35	1,987	2,013
1/30/2008	10:34	124	1,975	2,019
1/30/2008	17:58	568	1,960	2,015
1/31/2008	23:25	2,335	1,970	2,015
2/1/2008	02:32	2,522	2,037	1,980
2/1/2008	10:37	3,007	1,965	2,016

At the beginning of the constant-rate test, the discharge line gate valve was frozen. The frozen gate valve caused large fluctuations in the flow rate during the initial six minutes of the test, until the gate valve was thawed and returned to normal operation. During this time, the pump crew attempted to vary the engine speed to control the flow rate. The discharge rate fluctuated between 1,200 and 3,500 gpm during the six minute period. This can be seen in the drawdown record in both the Test Well SPR7008X, and the nearby observation well SPR7008M.

A synthetic production record was used to characterize the first six minutes of the constant-rate test due to fluctuations of pumping rate. This was accomplished by assigning discharge rates to each drawdown response segment such that the type curve closely mimicked the measured response during this time, and that the total calculated volume pumped closely matched the totalizer volumes at each recording time interval. After the first six minutes of the test the production record was represented in the analysis by flow meter record. The total discrepancy is insignificant over the total volume produced during testing. The synthetic record for the early time does not determine the analysis result, but provides an appropriate production history for locating the type curve for the late-time curve matching. A sensitivity analysis was performed adjusting the early period synthetic record with insignificant effects on the final results.

Flow up the well screen and casing to the pump is subject to frictional losses that are a function of the screen and casing diameter, friction coefficient, and flow rate. Since the flow rate varies with depth within the well screen due to distributed water intake along the screen, the losses increase with depth, reducing the applied stress. Due to the large screen diameter, however, the friction losses within the well would have been relatively small compared to the drawdown imposed by testing, and were not considered.

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 well recovery record for the initial five minutes. This pulse is not observed in the monitor well recovery record.

5.2 Constant-Rate Test Data

The constant-rate test was performed for a duration of 72 hours at a target pumping rate of 2,000 gpm. Summary drawdown data for Monitor Well SPR7008M, USGS MX Well 390803114251001 and Test Well SPR7008X are presented graphically in log-log and semi-log form on Figures 5-1 through 5-6. Transducer and physical test data are presented 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 model used for the aquifer test evaluation was selected based upon observed site hydrogeologic conditions and diagnostic log-log and drawdown derivative plots. The Moench confined, leaky (1985) analytical model was determined to be most appropriate analytical solution after review of the alternatives.

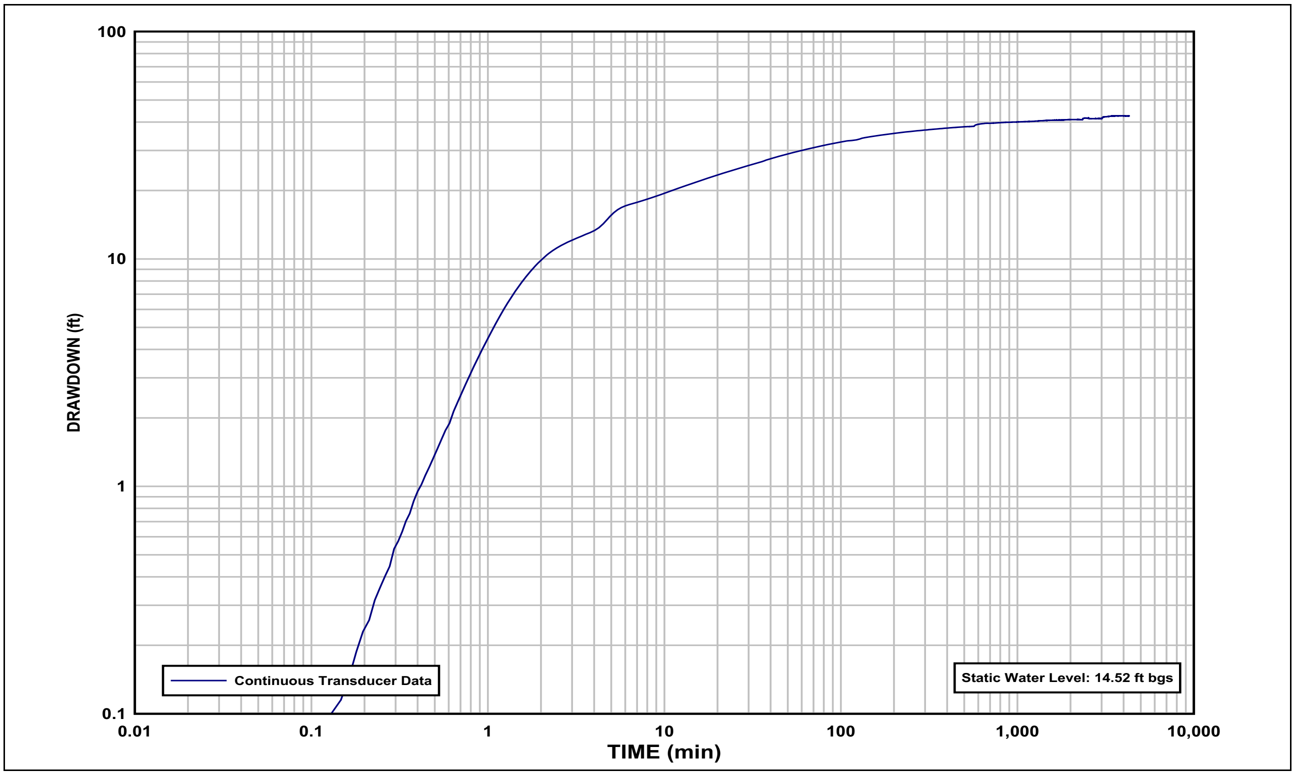

Figure 5-1
Log-Log Data Plot of Drawdown versus Time from Monitor Well SPR7008M

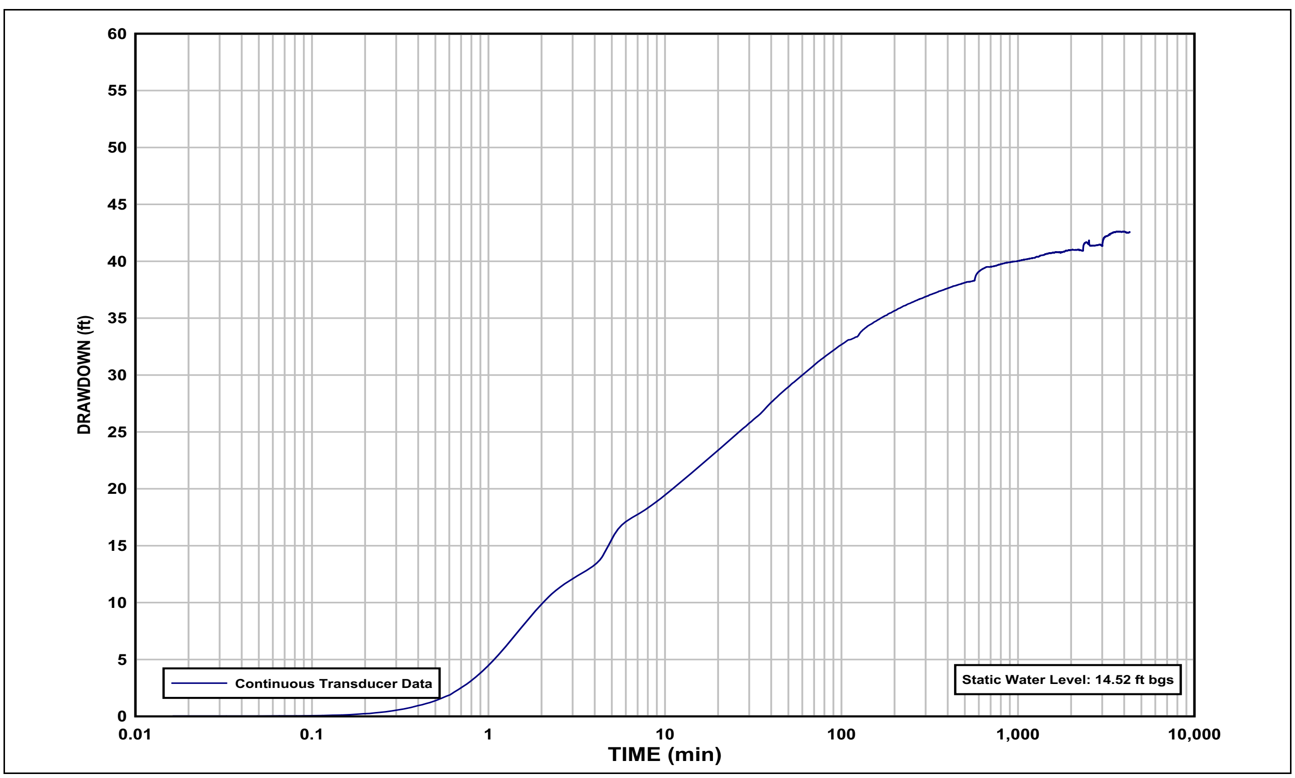

Figure 5-2
Semi-Log Data Plot of Drawdown versus Time from Monitor Well SPR7008M

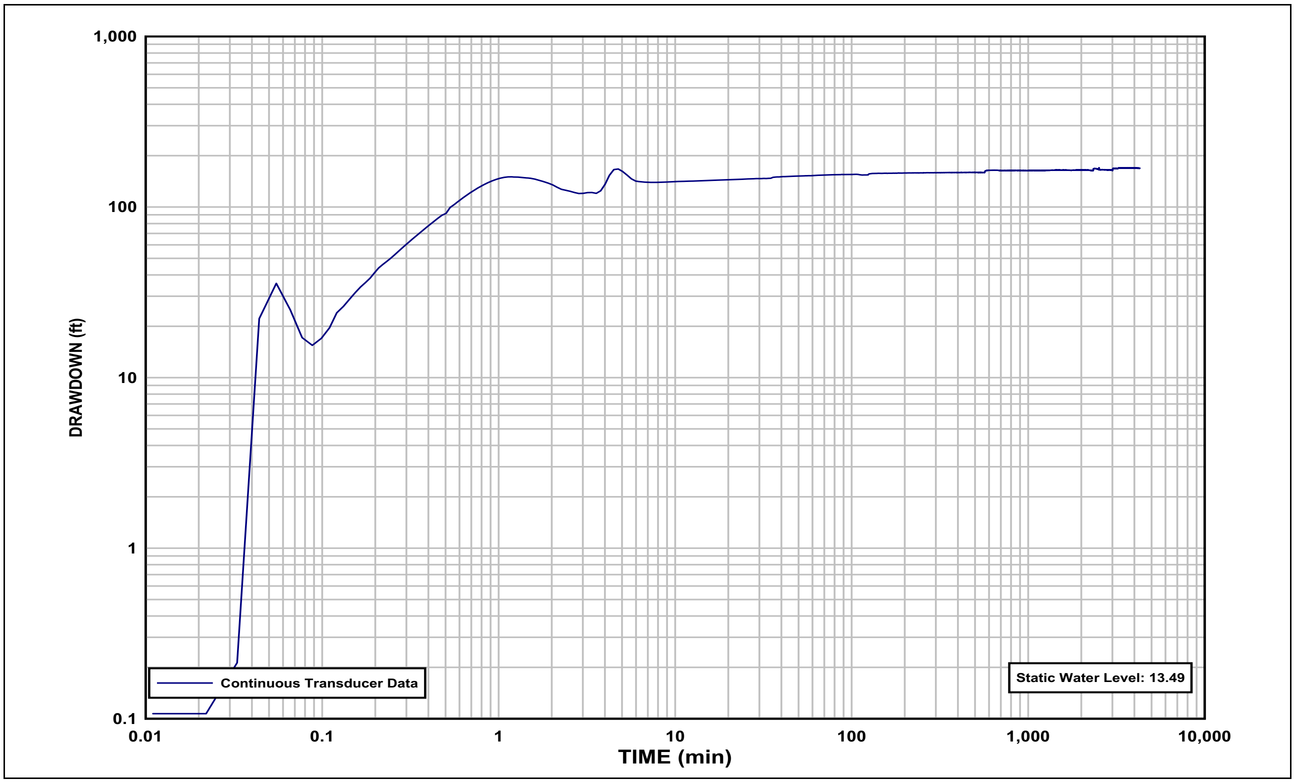

Figure 5-3
Log-Log Data Plot of Drawdown versus Time from Test Well SPR7008X

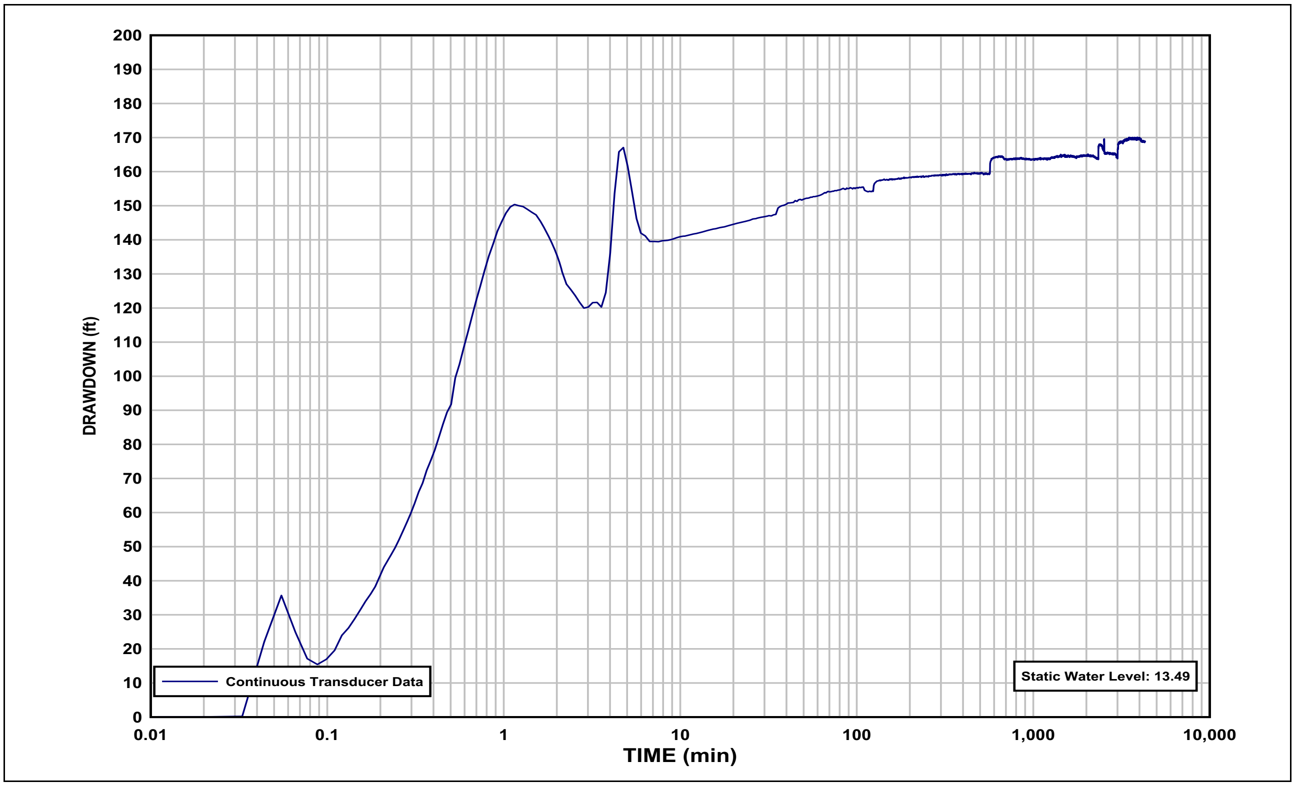

Figure 5-4
Semi-Log Data Plot of Drawdown versus Time from Test Well SPR7008X

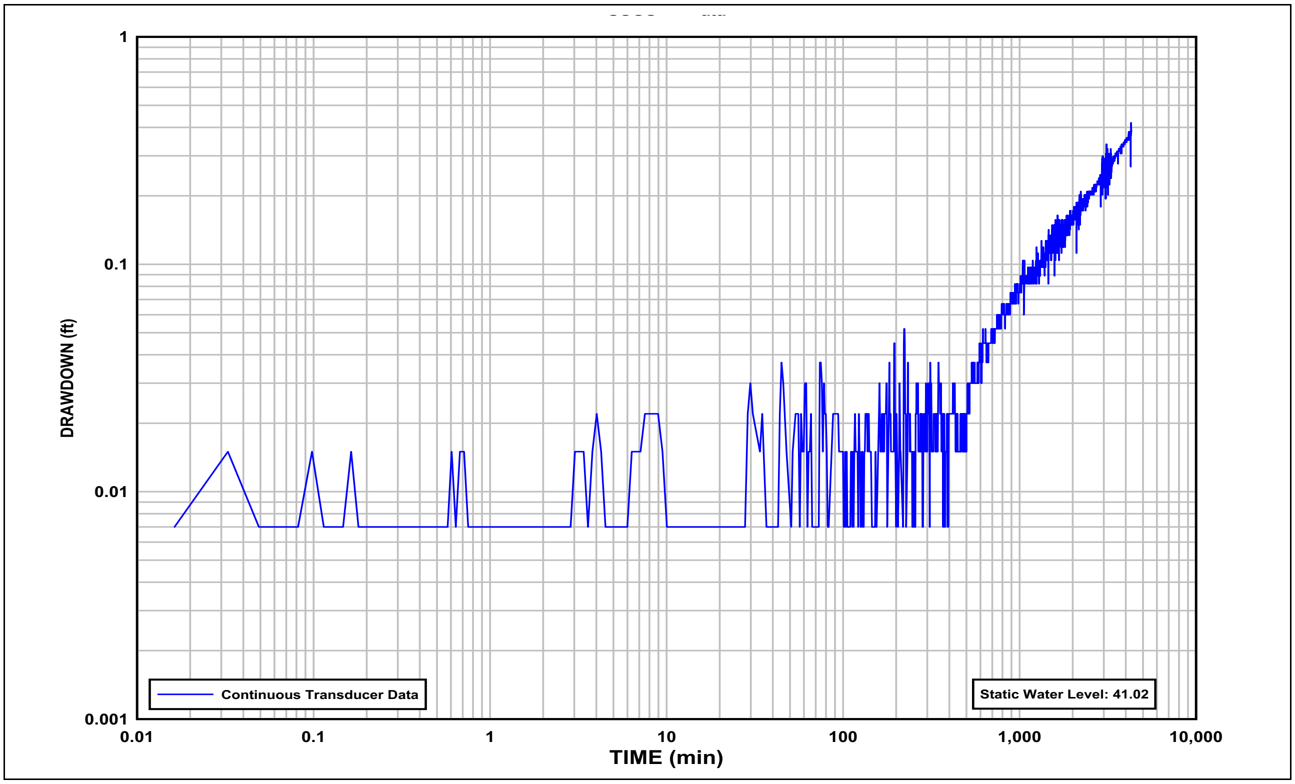

Figure 5-5
Log-Log Data Plot of Drawdown versus Time from Monitor Well 390803114251001

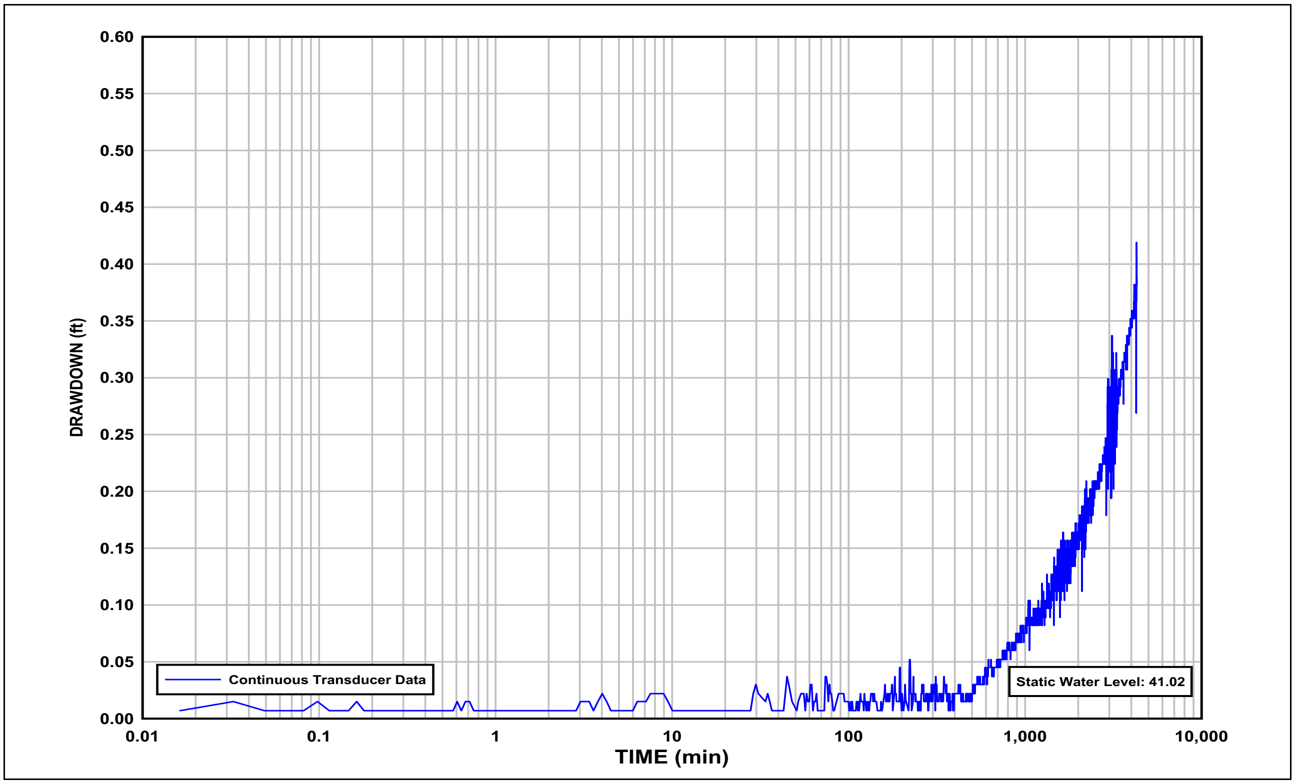

Figure 5-6
Semi-Log Data Plot of Drawdown versus Time from Monitor Well 390803114251001

The hydrogeologic setting at this site consists of an alluvial formation which could be viewed as an unconfined aquifer of unknown thickness or as a semi confined test interval defined by the upper clayey interval. The upper clayey interval was observed in SPR7008M. However, the test well did not have a very strong gamma signature at the same interval and the cuttings description did not clearly identify the clayey interval as a contrasting low conductivity material, so it was not clear that the upper clayey interval would act as a strongly contrasting confining layer. The well constructions (test well, monitoring well) do not place screen across the clayey interval; the top of the screens are some distance below the bottom of the clayey interval.

The alluvium above the clayey interval should act as unconfined with delayed gravity drainage, but such an effect upon the test interval response is not clear. The small drawdown in the USGS MX observation well suggests that the upper alluvium is affected by some connection; and there are two distinctly different possible modes. The clayey interval may be relatively conductive for a confining interval, and drawdown may be transmitted vertically across it albeit with substantial head loss. The lateral extent of the clay unit is not know. The drawdown may reflect a stress transmitted through the gravel pack or less clayey natural material in the vicinity of the well to the upper alluvium, which then produces radial drawdown. There is some static head information that may indicate that there is higher head below the clayey interval, or conversely that the alluvium above the clayey interval has relatively low permeability, reflected by slow equilibration. An additional factor is that the drawdown in the test well may have extended below the bottom of the clayey interval, resulting in a shift to unconfined conditions in the near-well vicinity near the end of the test, bringing unconfined-type storage into play.

Analysis models applicable to site hydrogeologic conditions were evaluated including Papadopulos-Cooper confined (1967), Moench unconfined (1997), and Moench confined, leaky (1985). The Papadopulos-Cooper, confined model (simulates the Theis model but includes casing storage) cannot account for the late-time reduction in drawdown rate (log-time), although that decline may explained by the conversion to unconfined conditions beneath the confining layer. The Moench unconfined model incorporates delayed gravity drainage which could account for the late-time decline in drawdown rate. The Moench confined, leaky model includes leakage from the confining layer which could account for the late-time decline in drawdown rate. Each model produces distinct type curves using parameter values within expected and plausible ranges for the formation type.

After review of the alternatives, the Moench confined, leaky (1985) analytical model was determined to be the most appropriate analytical solution.

General assumptions associated with the Moench confined, leaky solution include:

- aquifer has infinite areal extent
- aquifer is homogeneous, isotropic, and of uniform thickness
- aquifer potentiometric surface is initially horizontal
- pumping and observation wells are fully penetrating

- flow to pumping well is horizontal
- flow is unsteady
- aquifer is leaky confined
- water is released instantaneously from storage with decline of hydraulic head
- confining bed(s) has infinite areal extent, uniform vertical hydraulic conductivity and storage coefficient, and uniform thickness
- vertical flow in the aquitard(s)

The complexities of the aquifer system do not fully conform to the assumptions of the analytical model. However, the Moench confined, leaky solution is the most appropriate of the analytical solutions available for the observed hydrogeologic conditions at this test 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.

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.

5.4.1 Test Analysis Methodology

The aquifer test analysis software AQTESOLV V4.50 (Duffield, 1996-2007) was used for curve fitting. The data logger records of pressure transducer output were used to create AQTESOLV input files of the drawdown and recover data. The Moench confined, leaky solution was fitted to the drawdown and recovery responses of both the test well and monitor well sequentially and iteratively to determine the model parameter set that would best fit all of the data. Well borehole skin as related to nonlinear flow losses at the test well distorting actual drawdown near the test well was also evaluated. Analysis was performed with a range of wellbore skin factors. Borehole diameter of the test well used nominal drilling diameter and a larger diameter value observed in the caliper downhole log to evaluate the effect on analysis results. The monitor well response provides information on the formation hydraulic properties independent of linear and nonlinear head losses associated with the pumping well.

5.4.2 Test Analysis Results

The Moench leaky confined 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 and constraints is optimal within a relatively restricted range for the major parameters. The initial fitting was first to the observation well drawdown, then to the test well drawdown, then to the observation well recovery, and then to the test well recovery.

A correction equation for dewatering (Jacob, 1944) 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. The site hydrogeologic conditions behaves as a leaky confined or semi-confined system. As a result, a dewatering correction was not applied to the dataset.

Parameter symbols used in this section are presented below:

K = Aquifer hydraulic conductivity (ft/day)
T = Transmissivity (ft^2/day)
K' = Aquitard vertical hydraulic conductivity (ft/day)
Q = Pumping discharge rate (gpm)
Sw = Wellbore skin factor (dimensionless)
s = Drawdown (ft)
b = Saturated thickness (ft)
t = Time
S = Storativity (dimensionless)
r/B' = Aquitard leakage parameter (dimensionless)
b' = Aquitard thickness (ft)
r(w) = Well radius (ft)
r(c) = Nominal casing radius (ft)

The basic input measurement and parameter values used for analysis are shown in Table 5-2.

Table 5-2
Measurement and Parameter Values Used for Analysis

Parameter	Value (ft)	Data Source
r(w) Radius of the test well borehole (SPR7008X)	1.167/1.5	Based on drilled diameter/caliper log
r(c) Radius of the test well casing	0.833	Diameter of casing/screen
r(e) Radius of production tubing	0.417	Diameter of production tubing (estimate)
Saturated thickness (test, monitoring well)	800	Base of clayey interval to well depth
Distance from SPR7008X to SPR7008M	100.0	Surface measurement
r(w) Radius of monitor well (SPR7008M)	0.667	Based on drilled diameter
r(c) Radius of monitoring well casing	0.359	Diameter of casing/screen
Distance from SPR7008X to USGS MX well	376.0	Surface measurement
Saturated thickness (observation well)	160	Static WL to bottom of the well
r(w) Radius of USGS MX observation well	0.5	Estimate of drilled diameter
r(c) Radius of USGS MX observation well casing	0.08	Estimate of casing/screen

The results of the Moench confined, leaky solution analyses are summarized in Table 5-3. The optimal log-log and semi-log time analysis plot for the pumping period using the Moench solution are presented in Figures 5-7 through 5-9. Figures 5-7 and 5-8 use slightly different early time synthetic discharge rate records during the initial six minutes of testing as described in Section 5.1. Nominal drilling borehole radius of 1.167 ft was utilized in Figure 5-7 and 5-8. A caliper log derived test well borehole radius of 1.5 ft was used in the analyses presented in Figure 5-9 for comparison of results.

Calculated T values ranged from 3320 to 4730 ft^2/d. This corresponds to an aquifer horizontal K range of 4.15 to 5.91 ft/d assuming a saturated thickness of 800 ft. The plots also present expected drawdown at the MX observation well if the well was in similar hydraulic connection to the aquifer as SPR7008M. Actual observed drawdown at the MX well was approximately 0.40 ft at the end of the constant-rate test. Vertical hydraulic conductivity (K') of the aquitard derived from the test results ranged from 0.04 to 0.19 ft/d.

Table 5-3
Summary of Optimal Analysis Results

Data Set	Analytical Model	Figure	Test Well Borehole Radius	T (ft^2/day)	S	K^a (ft/day)	Sw	K' (ft/day)
SPR7008X,M	Moench 1985	5-7	1.167	3319	3.03E-04	4.15	2.2	0.19
SPR7008X,M	Moench 1985	5-8	1.167	3539	3.03E-04	4.42	2.7	0.17
SPR7008X,M	Moench 1985	5-9	1.5	4729	3.03E-04	5.91	5.3	0.04
SPR7008M	Theis Recovery	5-10	---	4467	---	5.58	---	---

[a]Assumed saturated thickness of 800 ft to derive *K*.

Analysis results of recovery data collected from the test and monitor well is presented in 5-10. This figure presents a plot of residual drawdown versus log t/t' (ratio of total pumping elapsed time to time since pumping stopped). In this plot, initial recovery is to the right and later recovery is to the left.

5.5 Discussion

Analysis of the test results indicates an optimal aquifer transmissivity and hydraulic conductivity value based upon the data collected during the 72-hour constant-rate test and subsequent recovery period. The results of the testing provide a composite hydraulic conductivity over the length of the saturated interval of the wells. The test also provides an estimate of vertical hydraulic conductivity of the clayey aquitard.

An evaluation and removal of well loss components provide an indication of drawdown in the formation in the vicinity of the test well. The calculation removes drawdown distortion caused by well losses from turbulent flow and well construction and provides an estimate of aquifer loss drawdown in the vicinity near the pumping well during aquifer testing.

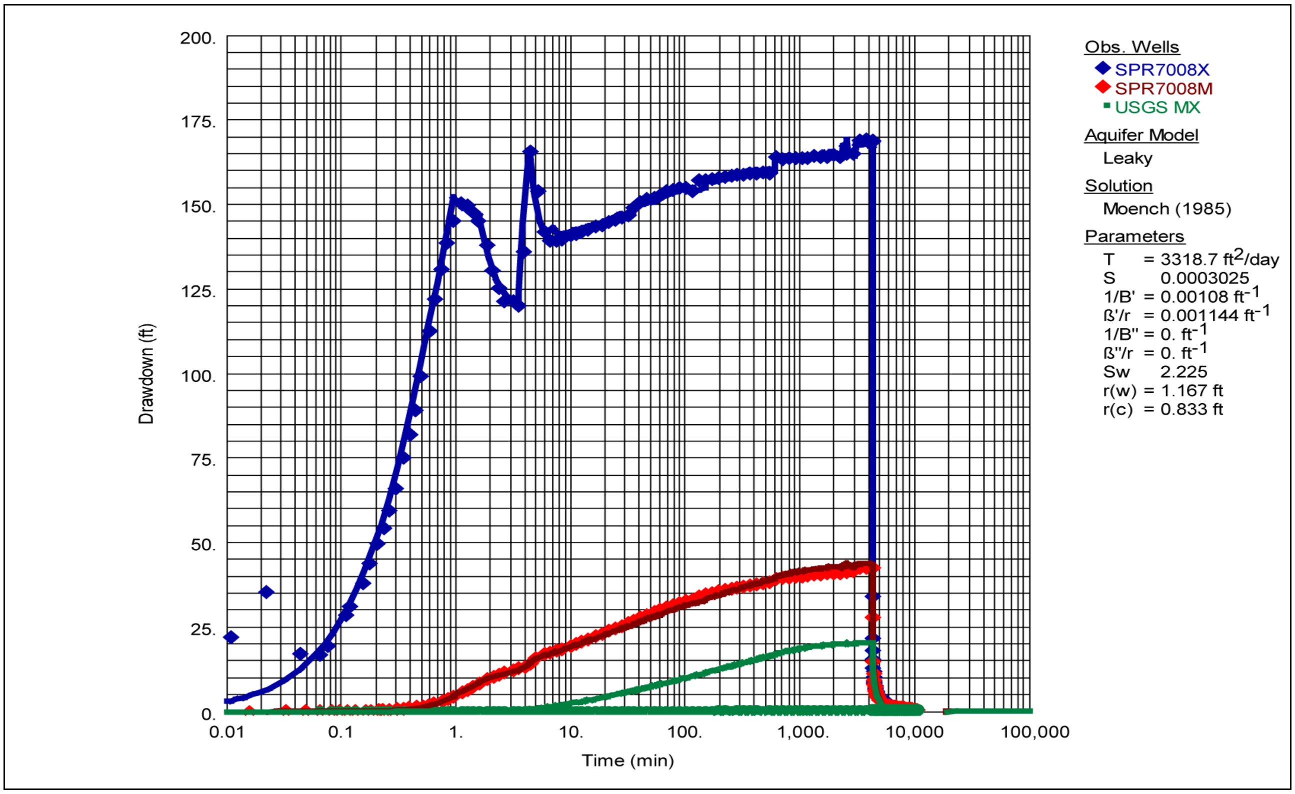

Figure 5-7
Moench Solution Test Well SPR7008X Nominal Borehole Diameter

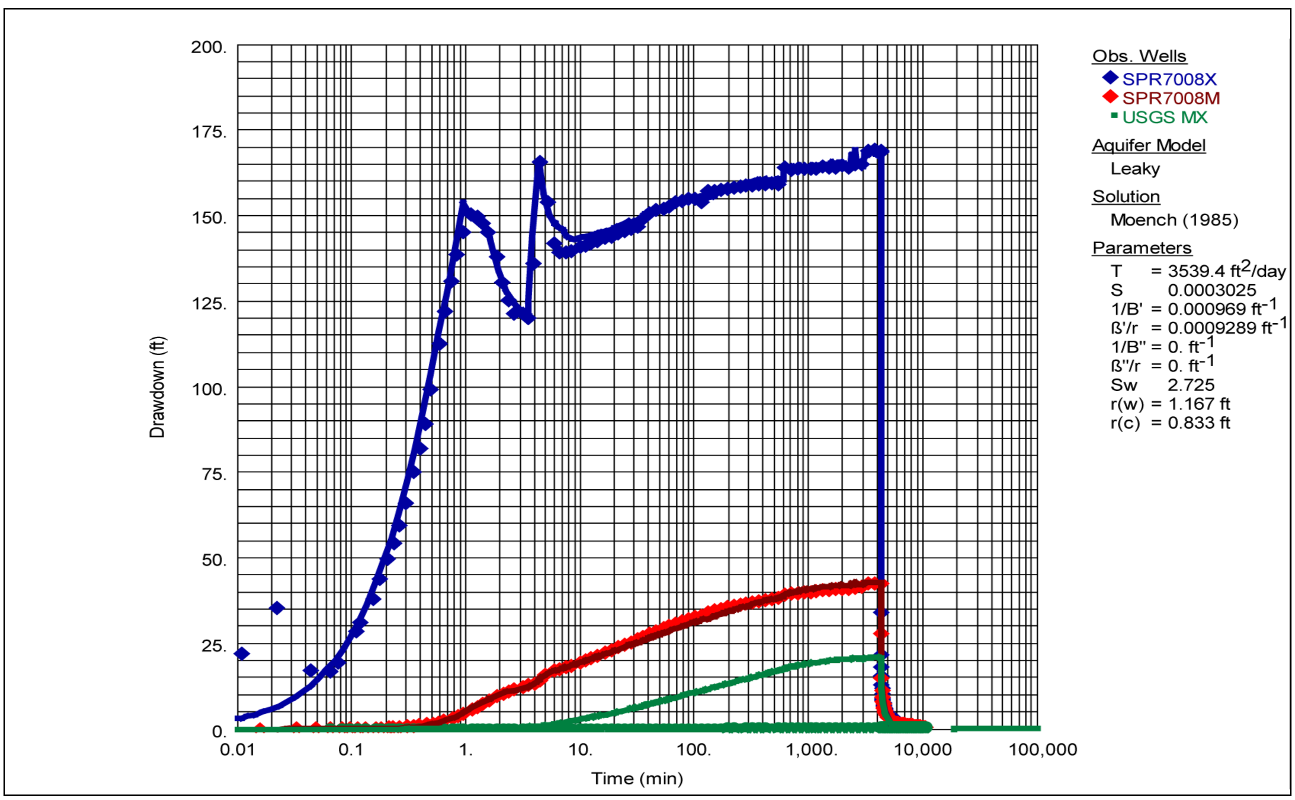

Figure 5-8
Moench Solution Test Well SPR7008X Nominal Borehole Diameter (Larger Sw)

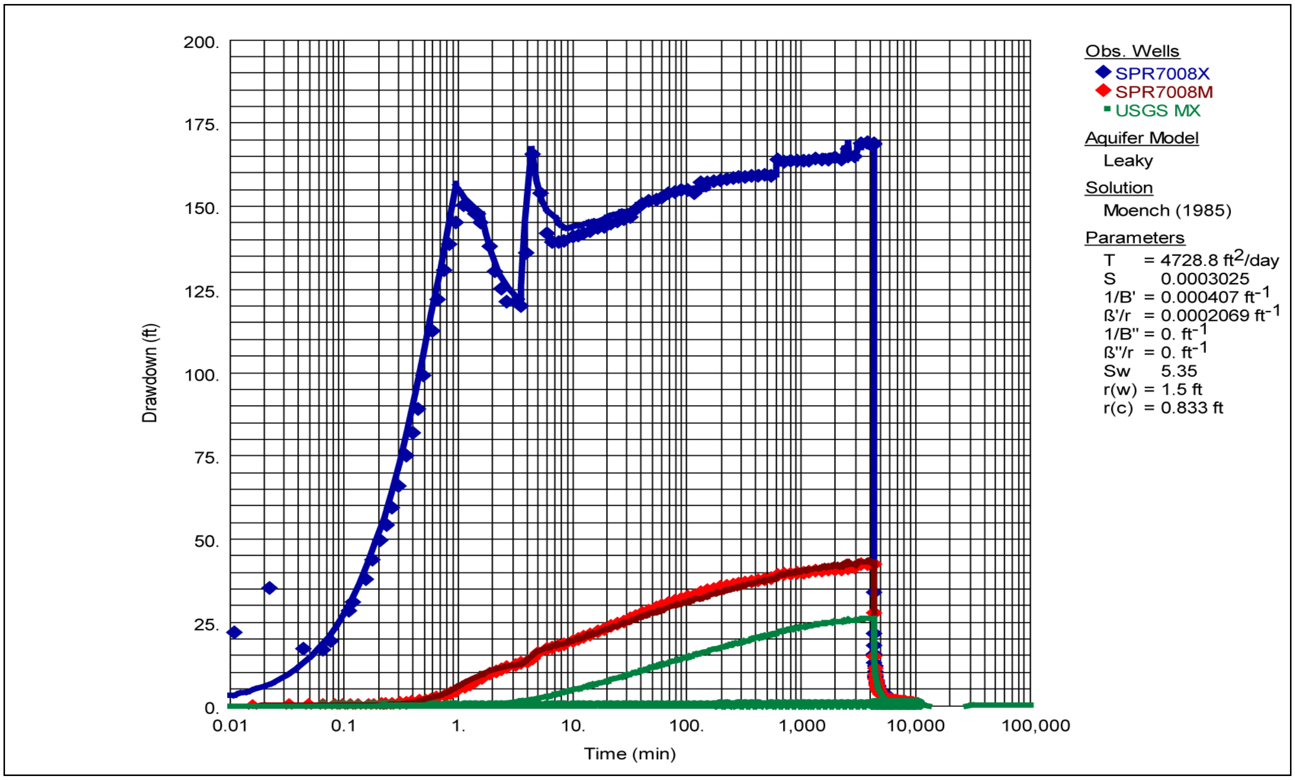

Figure 5-9
Moench Solution Test Well SPR7008X Caliper Borehole Diameter

Well loss analysis of Test Well SPR7008X utilizing results from the step drawdown tests presented in Section 4.2.2 indicates approximately 37 percent of drawdown in the test well at 2,000 gpm is considered to be associated with nonlinear well loss. Aquifer losses represent 63 percent of drawdown. This comparable to the aquifer loss drawdown range at the end of the 2,000 gpm constant-rate test, when the borehole skin is set to 0 using the constant-rate test results simulating a nearly 100 percent efficient well. Test well drawdown analysis plots using 0 borehole skin factor for the constant-rate test is presented for scenarios applying a nominal borehole radius of 1.167 and caliper log recorded borehole radius of 1.5 ft. These plots are presented in Figure 5-11 and 5-12, respectively.

The short-term pumping period and expected aquifer heterogeneities limit the ability to scale results to determine horizontal anisotropy or evaluate potential boundary conditions. No significant recharge or barrier condition boundaries were identified in the data results. However, the presence of boundaries and/or higher or lower hydraulic conductivity zones that may be encountered after extended pumping cannot be evaluated until extended pumping is performed. Additional analysis and review should be performed as longer-term operational pumping data become available for the well site or as additional regional hydrogeologic data are obtained.

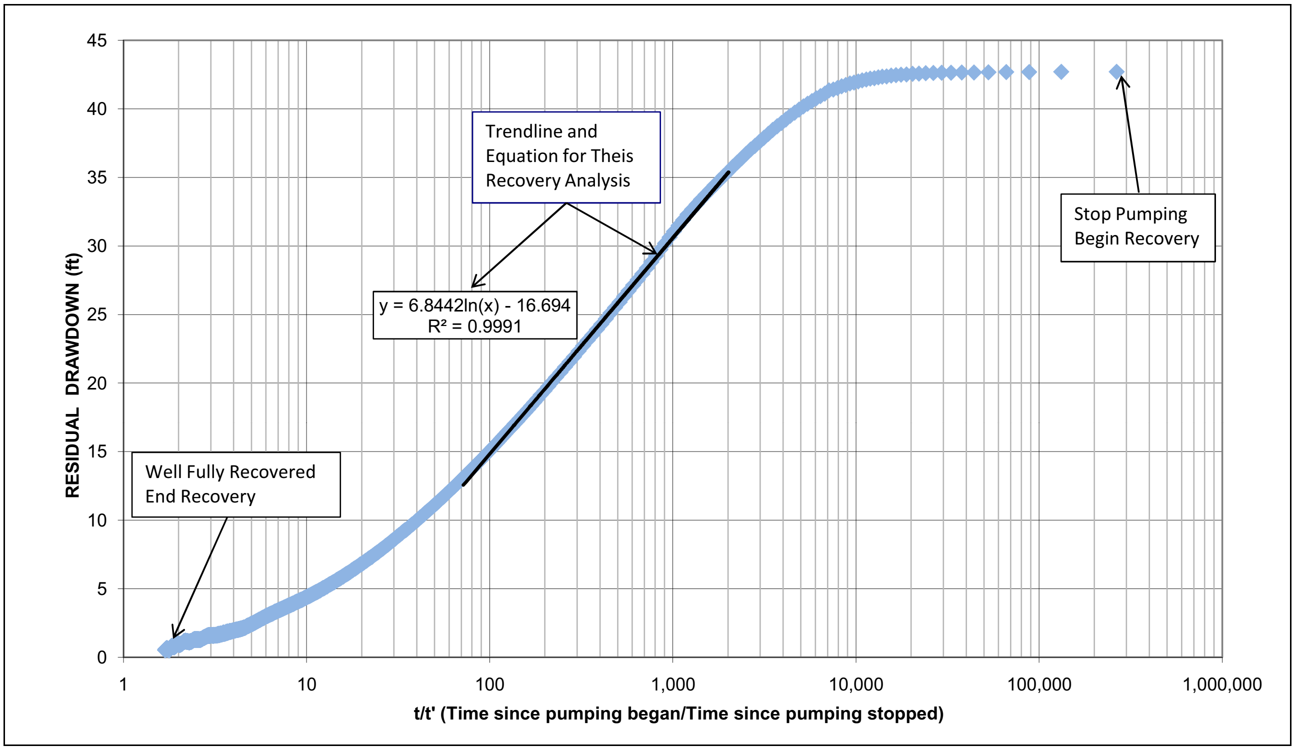

Figure 5-10
Monitor Well SPR7008M Recovery Data Presenting Residual Drawdown versus the Log of the Ratio of t/t'

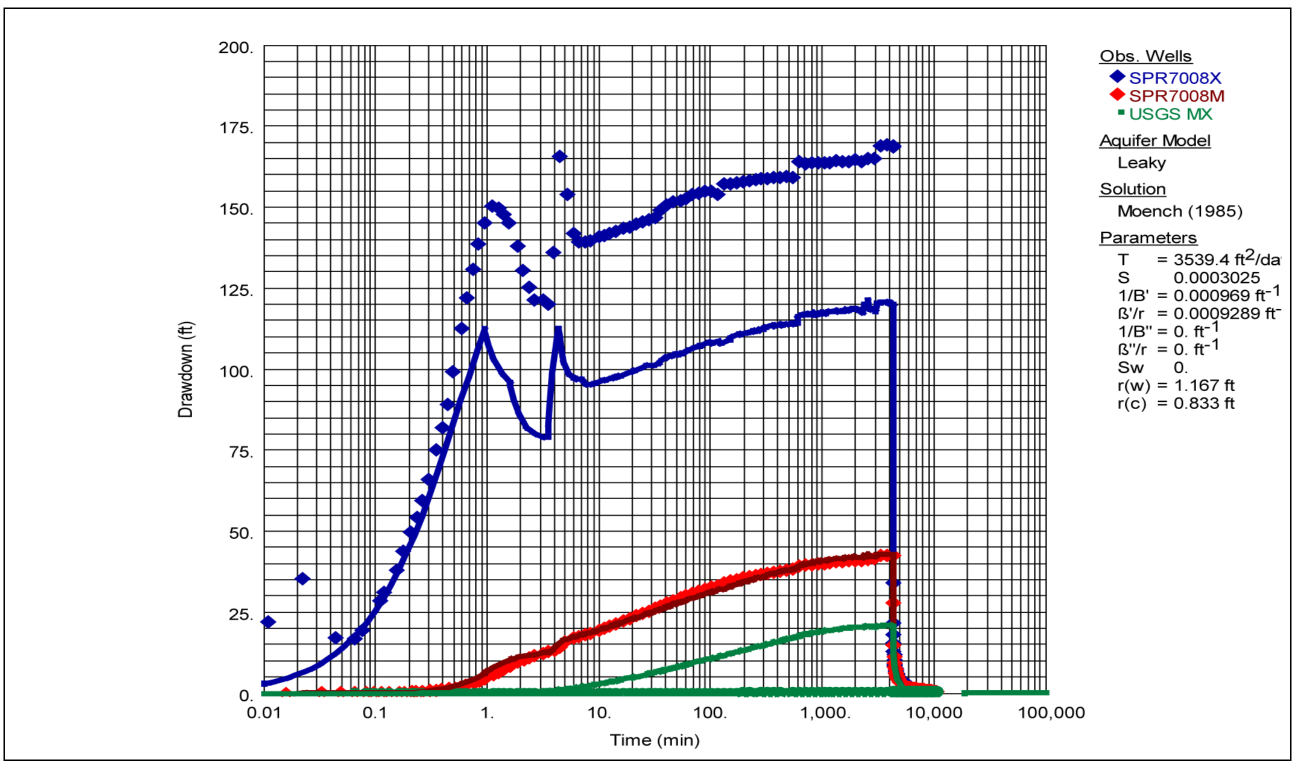

Figure 5-11
Test Well SPR7008X Well Losses Removed Borehole Radius of 1.167 ft

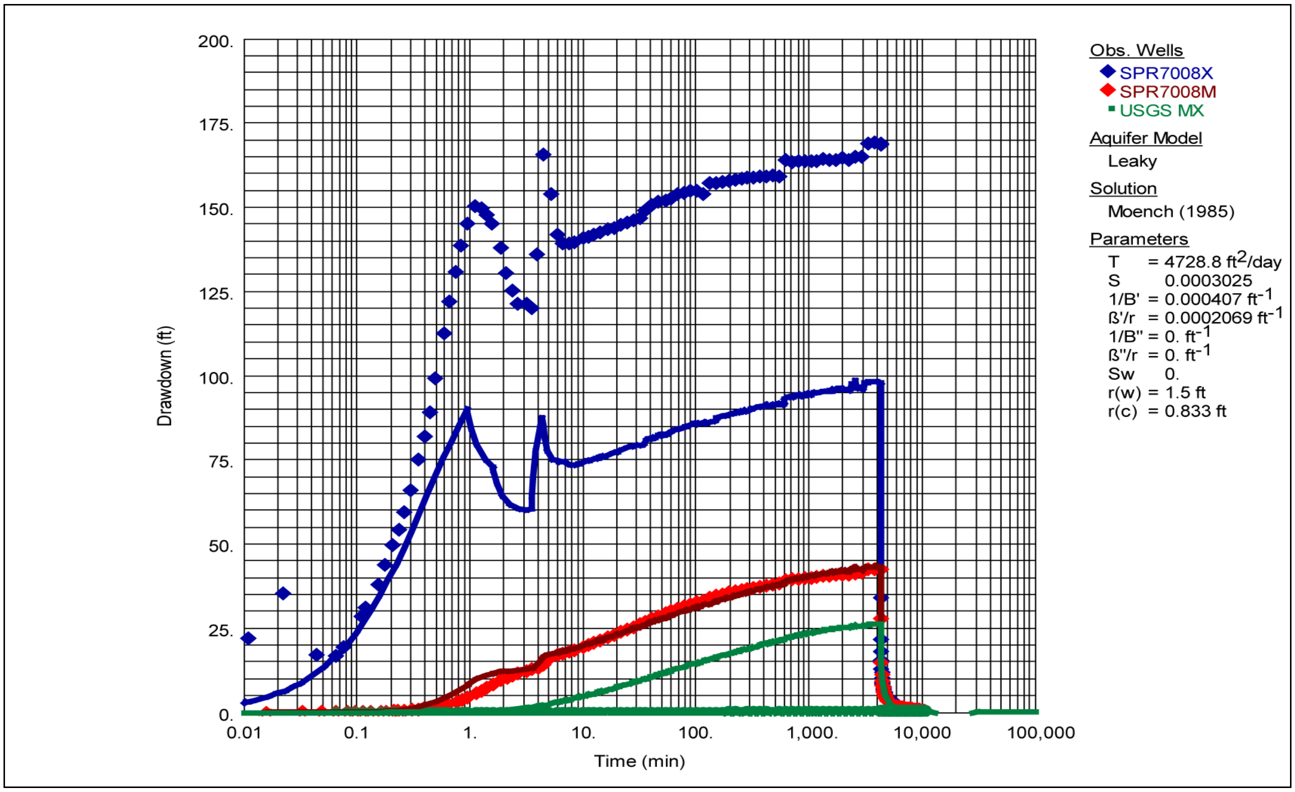

Figure 5-12

Test Well SPR7008X Well Losses Removed Borehole Radius of 1.5 ft

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6.0 GROUNDWATER CHEMISTRY

Groundwater chemistry data for Test Well SPR7008X (184W120) and Monitor Well SPR7008M (184W521M) 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 on a Piper diagram for comparison.

6.1 Groundwater Sample Collection and Analysis

Water samples were collected from Test Well SPR7008X on January 31, 2008 at 08:00 a.m. after pumping over 7 million gal (following well development, step-drawdown testing, and a portion of the constant-rate test) pumping at a rate of 2000 gpm. For these samples, turbidity, pH, specific conductance, dissolved oxygen, and temperature were measured in the field. With the exception of dissolved oxygen, 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 methods are presented in Tables B-1 and B-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 by University of Arizona's NSF-Arizona Accelerator Mass Spectrometry Laboratory, chlorine-36 by Purdue University's Purdue Rare Isotope Measurement (PRIME) Laboratory, and strontium and uranium isotopes (and uranium concentration) by the USGS Earth Surface Processes Radiogenic Isotope Laboratory.

Water samples were collected from Monitor Well SPR7008M on September 18, 2007 at 4:42 p.m. after pumping approximately 197,805 gal pumping at a rate of 364 gpm. 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 B-1). The pH, specific conductance, and temperature associated with these samples were measured in the field and the results are given in the results section. Monitor Well SPR7008M was used as the water source for drilling Test Well SPR7008X.

For comparison, the groundwater chemistry of additional wells in the area are presented on a Piper diagram in this section. The wells, all drilled by the SNWA (see Figure 2-1), were completed in either alluvial or carbonate-rock aquifer, are given below (Table 6-1).

Table 6-1
Total Depths of Wells Drilled by SNWA in Spring Valley, Nevada

Well	Aquifer Material	Total Drilled Depth (ft bgs)
184W101	Carbonate	1,760
184W502M	Carbonate	1,828
184W103	Carbonate	1,046
184W504M	Carbonate	1,040
184W105	Carbonate	1,160
184W506M	Carbonate	1,160
SPR7005X	Carbonate	1,395
SPR7005M	Carbonate	1,412
SPR7007X	Alluvial	1,040
SPR7008X	Alluvial	970
SPR7023I	Alluvial	1,220

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 B-1 and B-2. These national health-based standards are established to protect against both naturally occurring and man-made contaminants that may be found in drinking water. Also presented in Table B-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. None of the measured constituents in both Test Well SPR7008X and Monitor Well Monitor Well SPR7008M exceeded the primary and secondary MCLs of drinking water established by EPA.

6.3 Groundwater-Chemistry Results

In this section, the field measurements and analytical results for the groundwater of Monitor Well SPR7008M and Test Well SPR7008X are presented and compared to those of groundwater samples from wells in the vicinity on a Piper diagram.

6.3.1 Field Results

Field measurements of turbidity, pH, specific conductance, and temperature were performed periodically throughout well development and testing of Test Well SPR7008X and for the samples collected for laboratory analysis (see Table B-1). For Test Well SPR7008, these parameters stabilized within the first hour of the constant-rate test. During development, measurements ranged from less than 1.38 to 177 nephelometric turbidity units (NTUs) for turbidity, 7.42 to 8.34 for pH, 129 to 274 µS/cm for specific conductance, and 19 to 19.7°C for temperature over the remaining period of pumping (71 hours) with no observable trends. Field measurements made at the time of sample collection are reported as 0.37 NTU, 250 µS/cm, 7.93, and 18.1°C for turbidity, specific conductance, pH, and water temperature respectively.

Monitor Well SPR7008M was tested for 8 hours. During the 8-hour constant-rate test, field measurements of pH, specific conductance, and turbidity ranged from 7.44 to 7.97, 294 to 324 µS/cm 0.28 to 4.14 NTU respectively. No dissolved oxygen concentration measurements were made for the groundwater of Monitor Well SPR7008M. Field measurements made at the time of sample collection are reported as 294 µS/cm, 7.87, and 20.4°C for specific conductance, pH, and water temperature, respectively.

6.3.2 Major Constituents

The concentrations of the major constituents in groundwater samples from Test Well SPR7008X and Monitor Well SPR7008M are presented in Table B-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 charges of major cations should equal the sum of the charges 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 balance for Test Well SPR7008X and Monitor Well SPR7008M groundwater analyses were 0.9 and 3.2 percent respectively, and indicate that the analyses were adequately performed (Table B-1).

To illustrate the relative major-ion compositions in the groundwater samples from these wells and other wells in the vicinity, a Piper diagram of samples from all the wells 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 most of the 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.

6.3.3 Trace and Minor Constituents

The concentrations of trace elements in the groundwater from Test Well SPR7008X and Monitor Well SPR7008M are presented in Table B-1. The dominant trace element present in the groundwater from Test Well SPR7008X is barium with a concentration of 240 µg/L. The concentrations of the trace and

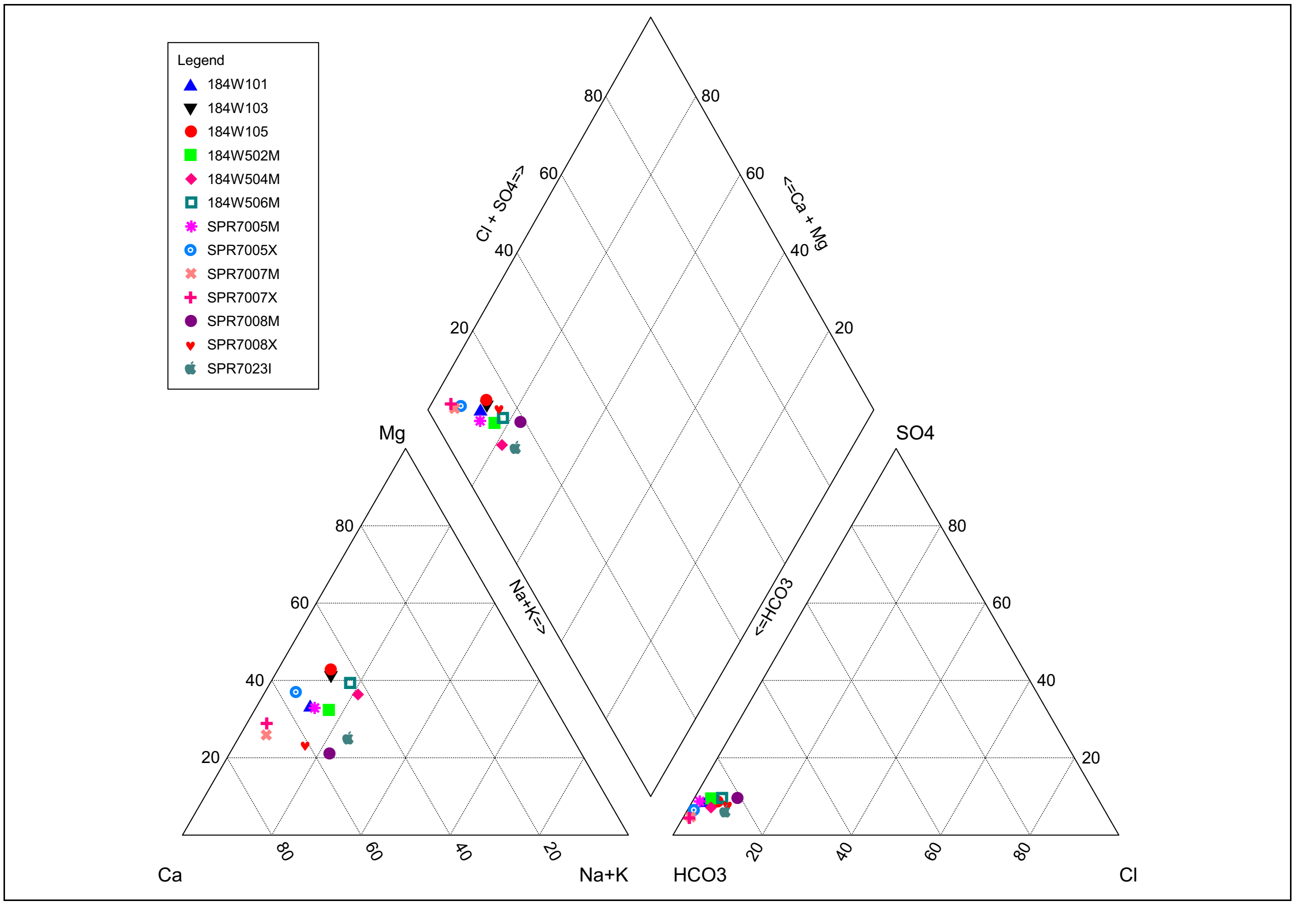

Figure 6-1
Piper Diagram Illustrating Relative Major-Ion Compositions

minor elements are generally low and mostly less than the primary and secondary MCLs established by the EPA. Relatively higher concentrations of aluminum, boron, iron and manganese were observed in the groundwater from Monitor Well SPR7008M (Table B-1) in comparison with the concentrations in the Test Well SPR7008X. The elevated concentrations of these elements in the monitor well is thought to result from the shortness of the aquifer testing of that well. The Test Well SPR7008X was developed and tested for 72 hours and the Monitor Well SPR7008M was tested for only 8 hours.

6.3.4 Stable Isotopes and Environmental Tracers

The stable hydrogen, oxygen, and carbon isotopic compositions of the groundwater samples from Test Well SPR7008X and the stable hydrogen and oxygen isotopic compositions of the groundwater samples of Monitor Well SPR7008M are presented in Table B-1. Table B-1 also presents chlorine-36, (^{36}Cl/C), strontium-87/86, (^{87}Sr/^{86}Sr) and uranium-234/238 (^{234}U/^{238}U) data for the groundwater sample collected from Test Well SPR7008X.

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 flow paths, 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 SPR7008X and Monitor Well SPR7008M are presented in Table B-1 and Figure 6-2 (mean value). Figure 6-2 also presents data for the SNWA wells in the vicinity along with the Global Meteoric Water Line (GMWL) ($\delta D = 8\delta^{18}O + 10$) (Craig, 1961). With the exception of Test Well SPR7005X and Monitor Well SPR7005M, all the samples plot either on or close to the GMWL and some of them exhibit slight evaporative enrichment in stable isotopes. Samples from both Test Well SPR7008X and Monitor Well SPR7008M plot above the GMWL, suggesting that the water did not undergo any meaningful evaporation prior to recharge.

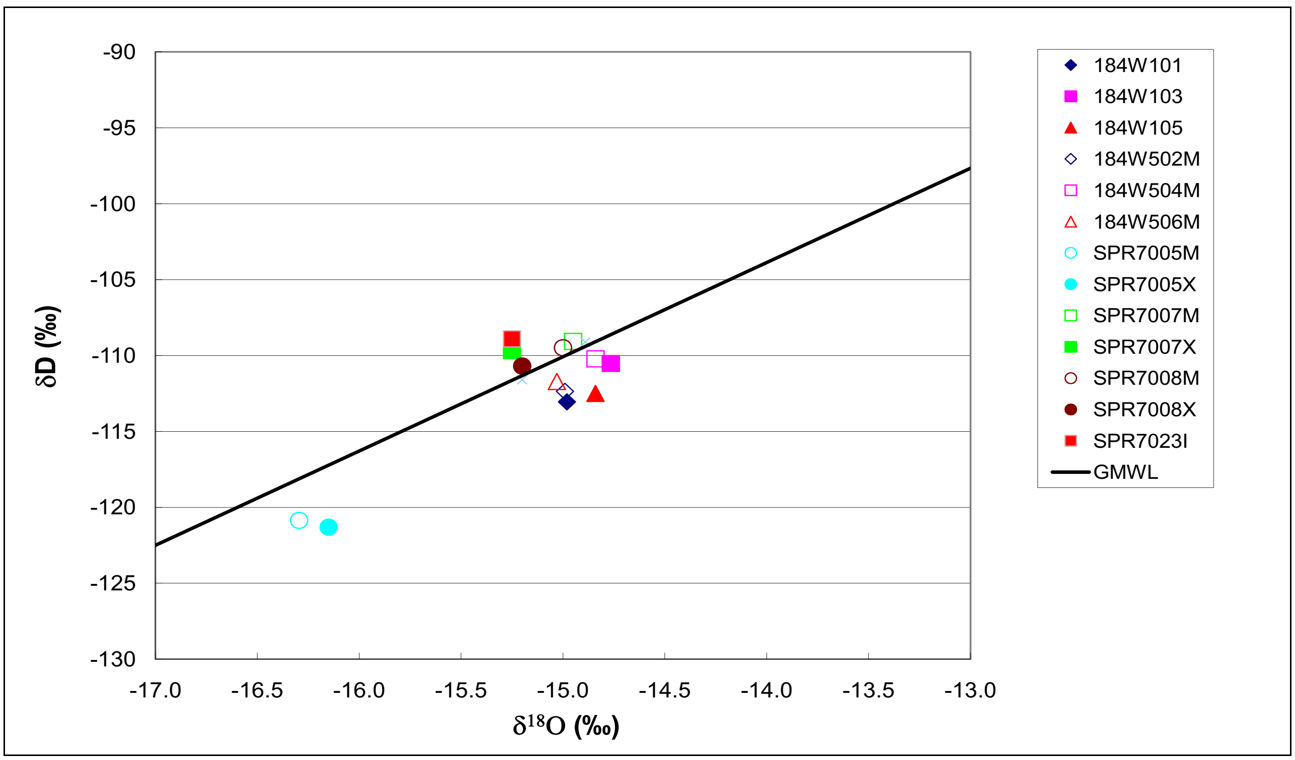

Figure 6-2
Plot of δD versus $\delta^{18}O$

6.3.4.2 Tritium Content

Tritium, a short-lived isotope of hydrogen with a half-life of 12.43 years, is commonly used to identify modern recharge. Natural ^{3}H is formed in the upper atmosphere by cosmic radiation (Clark and Fritz, 1997). The era of thermonuclear bomb testing in the atmosphere from 1951 to 1976 provided the ^{3}H input signal that defines modern water. Modern ground waters are those recharged within the past few decades and are part of an active hydrologic cycle (Clark and Fritz, 1997). Tritium activities are measured by gas counting on enriched samples. The concentrations are expressed in tritium units (TU) with a detection limit of ±0.8 TU. Tritium concentrations in the atmosphere exceeded 1000 TU during the early 1960s (Drever, 1988; Yang and others, 1996, p. 25 and 53). Prior to nuclear testing in the 1960s, the amount of ^{3}H in the atmosphere was very small, and concentrations in precipitation were not well known. Thatcher (1962) estimated a probable range in concentration of 2 to 8 TU. Tritium values measured by SNWA for precipitation samples collected from the Egan, Schell Creek, and Snake Ranges in east-central Nevada in 2008 were 8.4, 12.3 and 9.4 TU, respectively.

Tritium concentration of a sample from Test Well SPR7008X was less than the reporting limit of 0.8 TU. This value is very different from the values measured in precipitation collected in the study area by SNWA in 2008. The very low tritium content suggests that groundwater in Test Well SPR7008X relatively old. No sample was collected from SPR7008M for tritium analysis.

6.3.4.3 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.

The values of $\delta^{13}C$ and ^{14}C measured in the groundwater for the Test Well SPR7008X were -7.2‰ and 21.6 pmc respectively. No carbon isotopes were measured for the Monitor Well SPR7008M. The relatively low ^{14}C and the value of $\delta^{13}C$ suggest that the groundwater has interacted with isotopically heavy carbonate minerals.

6.3.4.4 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 for Test Well SPR7008X is 393×10^{-15} and is quite consistent with precipitation in the southwestern United States (Davis et al., 1998). The chloride concentration is 8.6 mg/L.

6.3.4.5 Strontium and Uranium Isotopes

The ratio of radiogenic to non-radiogenic 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. Groundwater $^{87}Sr/^{86}Sr$ ratio for Test Well SPR7008X is 0.71357, and is quite similar to the value of 0.71293 measured for Test Well SPR7005X.

The ratio of uranium-234 activity to that of uranium-238 ($^{234}U/^{238}U$ Activity Ratio) has also been used to evaluate groundwater flow systems. As observed earlier with the strontium ratios, the $^{234}U/^{238}U$ activity ratio of SPR7008X is 2.734, and is relatively similar to the ratio of 2.545 measured for Test Well SPR7005X.

6.3.5 Radiological Parameters

Radiological parameters were analyzed in groundwater from Test Well SPR7008X, and the corresponding results are presented in Table B-1. The reported activity for each of these parameters is consistent with background concentrations in natural groundwater. No analyses for radiological parameters were performed for the groundwater of Monitor Well SPR7008M.

6.3.6 Organic Compounds

A large suite of organic compounds was analyzed for groundwater samples collected from Test Well SPR7008X. The corresponding minimum detection levels and MCLs (if applicable) are also presented in Table B-1. No organic compounds were detected. No analyses for organic compounds were performed for the groundwater of Monitor Well SPR7008M.

6.4 Summary

Groundwater samples were collected from Test Well SPR7008X and Monitor Well SPR7008M and analyzed for a suite of chemical parameters. Field measurement of water-quality parameters was also performed during aquifer testing and used to demonstrate stabilization of the water chemistry prior to collection of the samples. The resulting data were compared on a Piper diagram to data from samples collected from other SNWA wells in the vicinity; the wells were completed in either alluvial or carbonate-rock aquifer. The groundwater represents a calcium-magnesium-bicarbonate facies. Light stable isotope compositions of Test Well SPR7008X and Monitor Well SPR7008M are highly depleted and plot above the GMWL. The groundwater is typical of recharge at high elevations.

The $^{36}Cl/Cl$ ratio measured for the sample collected from Test Well SPR7008X was consistent with precipitation in the southwestern United States. The relatively low ^{14}C and $\delta^{13}C$ values suggest that the groundwater has interacted with isotopically heavy carbonate minerals. The $^{87}Sr/^{86}Sr$ ratios were similar between the samples collected from the Test Well SPR7008X and Test Well SPR7005X and were typical of water-rock interaction with marine carbonates. The $^{234}U/^{238}U$ activity ratios were also relatively similar for the groundwater samples of the two test wells. The data were also evaluated with respect to the EPA Safe Drinking Water Act standards. For Test Well SPR7008X, no constituent exceeded the primary and secondary MCLs.

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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, SPR7008X and SPR7008M, were 184W120 and 184W521M, 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.

A.1.1 Photos

The following photos show an overview of the well site and testing program locations. The well site and equipment is presented in (Figure A-1), the Test Well SPR7008X wellhead configuration (Figure A-2), the Test Well SPR7008X wellhead and motor setup (Figure A-3), discharge line (Figure A-4), Monitor Well SPR7008M (Figure A-5), and energy dissipation at the terminus of the discharge line (Figure A-6).

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

Included is a spreadsheet containing the continuous water-level data from SNWA Monitor Well SPR7006M, and USGS MX well. This well was used to monitor background conditions during development and testing at Test Well SPR7008X.

A.1.4 Barometric-Pressure Data

Barometric-pressure data are located in the continuous record data files associated with Test Well SPR7008X and ET Station SV2b. An In-situ HERMIT 3000 data logger recorded the barometric pressure during the development and testing at the testing Site. These data can be found in files labeled "SPR7008X, SPR7008M and USGS MX Const Rate 2000 gpm XDR Data.xls" for the constant-rate test and "SPR7008X Step Test XDR.xls" for the development and the step-drawdown test. Barometric pressure data from SNWA ET site SV2b are also included and can be found in the file labeled “SV2b Baro.xlsx.”

All barometric-pressure data are reported in inches Hg. The barometric pressure reported from site SV1 is corrected to meas sea level, while that reported at the well site is absolute barometric pressure.

A.1.5 Step-Drawdown Test Data

There are three files associated with the step-drawdown test. They are labeled “SPR7008X Step Test Manual Data.xlsx”, “SPR7008X Step Test XDR.xls”, and “SPR7008X Step Drawdown Analysis.xlsx”.

A.1.6 Constant-Rate Test Data

The manual constant-rate test data from Test Well SPR7008X are provided in the spreadsheet labeled “SPR7008X Const Rate 2000 gpm Manual Data.xls”. The manual constant-rate test data from the observation wells are provided in a spreadsheet labeled “SPR7008M and USGS MX Const Rate 2000 gpm Manual Data.xls”. The continuous transducer constant-rate test data from the test and observation wells are provided in the spreadsheet labeled “SPR7008X, SPR7008M and USGS MX Const Rate 2000 gpm XDR Data.xls”.

A.1.7 AQTESOLV

The input files for using AQTESOLV software for aquifer analysis are provided. The input files are in the form of Excel spreadsheets with water-level and discharge data for both the step-drawdown and constant-rate tests. AQTESOLV files have also been included with basic information, such as casing, borehole, and downhole equipment radius, as well as approximate saturated thickness.

A.1.8 Water Chemistry

The laboratory results from Weck Labs, Inc., are included in PDF format and labeled “184W120_SPR7008X_8020105 FINAL.pdf” for well SPR7008X and “184W521_SPR7008M_7092132 FINAL.pdf” for well SPR7008X.

Figure A-1
SPR7008X Test Well Site, Facing West

Figure A-2
SPR7008X Test Wellhead

Figure A-3
SPR7008X Test Wellhead Equipment with Generator

Figure A-4
Discharge Piping, Facing West from Well Site SPR7008X

Figure A-5
Monitor Well SPR7008M

Figure A-6
Energy Dissipation at Terminus of Discharge Line

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Appendix B

Groundwater-Chemistry Data

Table B-1
Field and Analytical Results, Analytical Methods, Reporting Limits, and Maximum Contaminant Levels for Inorganic, Stable Isotopic, and Radiological Constituents in Groundwater Samples from Test Well SPR7008X and Monitor Well SPR7008M
(Page 1 of 3)

Constituent Name	Unit	Analysis Method	RL	SPR7008X (184W120) 1/31/2008 07:30	SPR7008M (184W521M) 9/18/2007 16:42	Primary MCL	Secondary MCL
Field Measured							
pH	units	Field	---	7.93	7.87	---	6.5 to 8.5
Conductivity	µS/cm	Field	---	250	294	---	---
Temperature	°C	Field	---	18.1	20.4	---	---
Turbidity	NTU	Field	---	0.37 | 0.17	0.28	---	---
Stable Isotopes and Environmental Tracers							
Carbon-14 (^{14}C)	pmc	NA	---	21.60	---	---	---
Carbon-13/12 ($\delta^{13}C$)	per mil (‰)	NA	---	-7.2	---	---	---
Chlorine-36/Chloride ($^{36}Cl/Cl$)	ratio	NA	---	3.93E-13	---	---	---
Hydrogen-2/1 (δD)	per mil (‰)	NA	---	-110.7	-109.5	---	---
Oxygen-18/16 ($\delta^{18}O$)	per mil (‰)	NA	---	-15.20	-15.00	---	---
Tritium	TU	NA	0.8	ND	---	---	---
Strontium 87/86	Ratio	NA	---	0.71357	---	---	---
Uranium-234/238	Activity Ratio	NA	---	2.734	---	---	---
Major Solutes							
Alkalinity Bicarbonate	mg/L as HCO_3	SM 2320B	2	150	140	---	---
Alkalinity Carbonate	mg/L as $CaCO_3$	SM 2320B	2	ND	ND	---	---
Alkalinity Hydroxide	mg/L as $CaCO_3$	SM 2320B	2	ND	ND	---	---
Alkalinity Total	mg/L as $CaCO_3$	SM 2320B	2	120	110	---	---
Calcium	mg/L	EPA 200.7	0.1	35 | 34[b]	34	---	---
Chloride	mg/L	EPA 300.0	0.5	8.6	9.6	---	250
Fluoride	mg/L	EPA 300.0	0.1	0.25	0.24	4	2.0
Magnesium	mg/L	EPA 200.7	0.1	8.1 | 7.9[b]	7.7	---	---
Nitrate	mg/L as N	EPA 353.2/300.0	0.1	0.46	H 0.43	10	---
Potassium	mg/L	EPA 200.7	1	2.1 | 1.9	2.3	---	---
Silica	mg/L	EPA 200.7	0.1	17	16	---	---
Sodium	mg/L	EPA 200.7	1 | 0.5	9.1 | 8.9	14	---	---
Sulfate	mg/L	EPA 300.0	0.5	11	13	---	250
Cation/Anion Balance	%	Calculation	---	0.9	3.2	---	---

Table B-1
Field and Analytical Results, Analytical Methods, Reporting Limits, and Maximum Contaminant Levels for Inorganic, Stable Isotopic, and Radiological Constituents in Groundwater Samples from Test Well SPR7008X and Monitor Well SPR7008M
(Page 2 of 3)

Constituent Name	Unit	Analysis Method	RL	SPR7008X (184W120) 1/31/2008 07:30	SPR7008M (184W521M) 9/18/2007 16:42	Primary MCL	Secondary MCL
Trace and Minor Constituents							
Aluminum	µg/L	EPA 200.8	5	10 | ND[b]	19	---	50 to 200
Antimony	µg/L	EPA 200.8	0.5	ND | ND[b]	ND	6	---
Arsenic	µg/L	EPA 200.8	0.4	5.3 | 5.7[b]	5.4	10	---
Arsenic (III)	µg/L	EPA 200.8	2	ND	---	---	---
Arsenic (V)	µg/L	EPA 200.8	2	4.9	---	---	---
Barium	µg/L	EPA 200.8	0.5	240 | 260[b]	240	2,000	---
Beryllium	µg/L	EPA 200.8	0.1	ND | ND[b]	ND	4	---
Boron	µg/L	EPA 200.7	10	14 | 31[b]	64	---	---
Bromide	µg/L	EPA 300.1	10	53	50	---	---
Cadmium	µg/L	EPA 200.8	0.1	ND | ND[b]	ND	5	---
Chlorate	µg/L	EPA 300.1	10	ND	ND	---	---
Chromium	µg/L	EPA 200.8	0.2	0.28 | 0.25[b]	0.2	100	---
Chromium (III)	µg/L	Calculation	0.2	0.28	---	---	---
Chromium (VI)	µg/L	EPA 218.6	0.3	ND	---	---	---
Copper	µg/L	EPA 200.8	0.5	7.6 | 2.3[b]	0.7	1,300[C]	1,000
Iron	µg/L	EPA 200.7	20	ND | ND[b]	32	---	300
Lead	µg/L	EPA 200.8	0.2	1.9 | ND[b]	1	15[C]	---
Lithium	µg/L	EPA 200.7	10	12 | 11[b]	ND	---	---
Manganese	µg/L	EPA 200.8	0.2	1.6 | 1.3[b]	6.8	---	50
Mercury	µg/L	EPA 245.1	0.1/0.2	ND | ND[b]	ND	2.0	---
Molybdenum	µg/L	EPA 200.8	0.1	1.2 | 1.2[b]	1.5	---	---
Nickel	µg/L	EPA 200.8	0.8	ND	ND	---	---
Nitrite	mg/L as N	EPA 353.2/300.0	0.1/0.15	ND	H ND	1	---
Orthophosphate	µg/L as P	EPA 365.1	2	7.4	---	---	---
Phosphorus	µg/L as P	EPA 365.1	10	ND	---	---	---
Selenium	µg/L	EPA 200.8	0.4	ND | ND[b]	ND	50	---
Silver	µg/L	EPA 200.8	0.2	ND | ND[b]	ND	---	100

Table B-1
Field and Analytical Results, Analytical Methods, Reporting Limits, and Maximum Contaminant Levels for Inorganic, Stable Isotopic, and Radiological Constituents in Groundwater Samples from Test Well SPR7008X and Monitor Well SPR7008M
(Page 3 of 3)

Constituent Name	Unit	Analysis Method	RL	SPR7008X (184W120) 1/31/2008 07:30	SPR7008M (184W521M) 9/18/2007 16:42	Primary MCL	Secondary MCL
Trace and Minor Constituents (Continued)							
Strontium	µg/L	EPA 200.7	5	140 | 140[b]	140	---	---
Thallium	µg/L	EPA 200.8	0.2	ND | ND[b]	ND	2	---
Vanadium	µg/L	EPA 200.8	0.5	1.0 | 0.94[b]	1.1	---	---
Uranium	µg/L			0.991	---	---	---
Zinc	µg/L	EPA 200.8	5	32 | 20[b]	ND	---	5,000
Miscellaneous Parameters							
Total Dissolved Solids	mg/L	SM 2540C	10	160	190	---	500
Total Organic Carbon	mg/L	SM 5310C	0.3	ND	0.34	---	---
Total Suspended Solids	mg/L	EPA 2540D	5	ND	ND	---	---
Hardness	mg/L as $CaCO_3$	EPA 200.7	1	120	120	---	---
Langelier Index	@ 60°C	SM 2330B	-10	0.695	---	---	---
Langelier Index	@ Source Temp.	SM 2330B	-10	0.144	---	---	---
MBAS	mg/L	SM 5540 C	0.05	ND	---	---	---
Cyanide	mg/L	SM 4500CN E	0.005	ND	---	0.2	---
Radiochemical Parameters							
Gross Alpha	pCi/L	EPA 900.0	0.074	7.1	---	15	---
Gross Beta	pCi/L	EPA 900.0	0.018	4.9	---	4 mrem/yr	---
Radium, total gross	pCi/L	EPA 903.1	0.4	ND	---	5	---
Radium-226	pCi/L	EPA 903.1	0.4	ND	---	---	---
Radium-228	pCi/L	EPA 904	0.3	ND	---	---	---
Radon-222	pCi/L	SM 7500	---	345	---	---	---
Strontium-90	pCi/L	EPA 905.0	0.6	ND	---	---	---
Tritium	pCi/L	EPA 906.0	315	ND	---	---	---
Uranium	pCi/L	EPA 200.8	0.13	0.85	---	30 µg/L	---

[a]Holding time was exceeded.
[b]Sample was filtered; concentration represents dissolved constituent.
[c]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 B-2
Organic Compounds Analyzed in Groundwater Samples from Test Well SPR7008X, 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	0.05	--	Endosulfan II	0.01	--	PCB 1016 Aroclor	0.1	--
BHC (Alpha)	0.01	--	Endosulfan sulfate	0.05	--	PCB 1221 Aroclor	0.1	--
BHC (Beta)	0.05	--	Endrin	0.05	2	PCB 1232 Aroclor	0.1	--
BHC (Delta)	0.05	--	Endrin aldehyde	0.05	--	PCB 1242 Aroclor	0.1	--
Chlordane (tech)	0.1	2	Heptachlor	0.01	0.4	PCB 1248 Aroclor	0.1	--
Chlorothalonil	0.05	--	Heptachlor Epoxide	0.01	0.2	PCB 1254 Aroclor	0.1	--
4,4'-DDD	0.02	--	Hexachlorobenzene	0.5	1.0	PCB 1260 Aroclor	0.1	--
4,4'-DDE	0.01	--	Hexachlorocyclopentadiene	0.05	50	Propachlor	0.5	--
4,4'-DDT	0.02	--	Lindane	0.05	0.2	Toxaphene	1	3
Dieldrin	0.02	--	Methoxychlor	0.05	40	Trifluralin	0.01	--
Endosulfan I	0.02	--	Polychlorinated biphenyls (PCBs)	0.5	0.5			

Purgeable Organic Compounds by EPA 524.2 (µg/L)								
tert-Amyl methyl ether	3	--	Di-isopropyl ether	3	--	Methyl tertiary butyl ether (MTBE)	3	--
Benzene	0.5	5	1,1-Dichloroethane	0.5	--	Naphthalene	0.5	--
Bromobenzene	0.5	--	1,2-Dichloroethane	0.5	--	n-Propylbenzene	0.5	--
Bromochloromethane	0.5	--	1,1-Dichloroethylene	0.5	5	Styrene	0.5	100
Bromodichloromethane	0.5	--	cis-1,2-Dichloroethylene	0.5	7	Tetrachloroethylene	0.5	5
Bromoform	0.5	--	trans-1,2-Dichloroethylene	0.5	70	1,1,1,2-Tetrachloroethane	0.5	--
2-Butanone	5	--	Dichlorodifluoromethane	0.5	100	1,1,2,2-Tetrachloroethane	0.5	--
n-Butylbenzene	0.5	--	1,2-Dichloropropane	0.5	--	Toluene	0.5	1,000
sec-Butylbenzene	0.5	--	1,3-Dichloropropane	0.5	5	1,2,3-Trichlorobenzene	0.5	--
tert-Butylbenzene	0.5	--	2,2-Dichloropropane	0.5	--	1,2,4-Trichlorobenzene	0.5	70
tert-Butyl ethyl ether	3	--	1,1-Dichloropropene	0.5	--	1,1,1-Trichloroethane	0.5	200
Carbon tetrachloride	0.5	5	cis-1,3-Dichloropropene	0.5	--	1,1,2-Trichloroethane	0.5	5
Chlorobenzene	0.5	100	trans-1,3-Dichloropropene	0.5	--	Trichloroethylene	0.5	5
Chloroethane	0.5	--	total-1,3-Dichloropropene	0.5	--	Trichlorofluoromethane	5	--
2-Chloroethylvinyl ether	1	--	Ethylbenzene	0.5	700	1,2,3-Trichloropropane	0.5	--
Chloroform	0.5	--	Hexachlorobutadiene	0.5	--	1,1,2-Trichloro-1,2,2-trifluoroethane	5	--
2-Chlorotoluene	0.5	--	2-Hexanone	5	--	1,2,4-Trimethylbenzene	0.5	--
4-Chlorotoluene	0.5	--	Isopropylbenzene	0.5	--	1,3,5-Trimethylbenzene	0.5	--
Dibromochloromethane	0.5	--	p-Isopropyltoluene	0.5	--	Vinyl chloride	0.5	2
Dibromomethane	0.5	--	Methyl bromide	0.5	--	Xylene (m,p) isometric pair	1.0	--
m-Dichlorobenzene	0.5	--	Methyl chloride	0.5	--	Xylenes, total	0.5	10,000
o-Dichlorobenzene	0.5	600	Methylene chloride	0.5	5	o-Xylene	0.5	--
p-Dichlorobenzene	0.5	75	4-Methyl-2-pentanone	5	--			

Table B-2
Organic Compounds Analyzed in Groundwater Samples from Test Well SPR7008X, Including the EPA Method, Reporting Limit, and Maximum Contaminant Level
(Page 2 of 2)

Organic Compounds by EPA 525.2 (µg/L)								
Alachlor	0.1	2	Di(2-ethylhexyl) phthalate	3	6	Prometon	0.2	--
Atrazine	0.1	3	Diazinon	0.1	--	Prometryn	0.1	--
Benzo(a)pyrene	0.1	0.2	Dimethoate	0.2	--	Simazine	0.1	4
Bromacil	1	--	Metolachlor	0.1	--	Thiobencarb	0.2	--
Butachlor	0.2	--	Metribuzin	0.1	--			
Di(2-ethylhexyl) adipate	5	400	Molinate	0.1	--			
Chlorinated Acids by EPA 515.3 (µg/L)								
2,4,5-T	0.2	--	Acifluorfen	0.4	--	Dichlorprop	0.3	--
2,4,5-TP (Silvex)	0.2	50	Bentazon	2	--	Dinoseb	0.4	7
2,4-D	0.4	70	Dalapon	0.4	200	Pentachlorophenol	0.2	1
2,4-DB	2	--	DCPA	0.1	--	Picloram	0.6	500
3,5-Dichlorobenzoic acid	1	--	Dicamba	0.6	--			
N-Methylcarbamoyloximes and N-Methylcarbamates by EPA 531.1 (µg/L)								
3-Hydroxycarbofuran	2	--	Baygon	5	--	Methomyl	2	--
Aldicarb	2	--	Carbaryl	2	--	Oxamyl (Vydate)	2	200
Aldicarb sulfone	2	--	Carbofuran	5	40			
Aldicarb sulfoxide	2	--	Methiocarb	3	--			
Organics by Other EPA Methods (µg/L)								
Glyphosate (EPA 547)	5	700	Diquat (EPA 549.2)	4	20	1,2-Dibromo-3-chloropropane (EPA 504.1)	0.01	0.2
Endothall (EPA 548.1)	45	100	Dioxin (EPA 1613)	5 pg/L	30 pg/L	Ethylene dibromide (EPA 504.1)	0.02	0.05

MCL = Maximum contaminant level
RL = Reporting Limit

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.