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Southern Nevada Water Authority

Hydrologic Data Analysis Report for Test Well SPR7007X in Spring Valley Hydrographic Area 184

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SOUTHERN NEVADA WATER AUTHORITY

Hydrologic Data Analysis Report for Test Well SPR7007X in Spring Valley Hydrographic Area 184

By: James P. Prieur[1], Stephen Y. Acheampong[1], and Chris S. Ashinhurst[1]

September 2010

1. Southern Nevada Water Authority, Las Vegas, NV

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

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Acronyms

AMT	audiomagnetotelluric
Barker GRFM	Barker generalized radial flow model
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
HA	hydrographic area
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
cfs	cubic feet per second
cm	centimeter
ft	foot
ft^2	square foot
gal	gallon
gpm	gallons per minute
in.	inch
in. Hg	inches of mercury
L	liter
lb	pound
m	meter
mEq	milliequivalent
mg	milligram
mi	mile
min	minute
ml	milliliter

ABBREVIATIONS (CONTINUED)

mrem	millirem
μg	microgram
μS	microsiemen
NTU	nephelometric turbidity units
‰	per mil
pmc	percent modern carbon
pCi	picocurie
psi	pounds per square inch
qt	quart
rpm	revolutions per minute
sec	second
yr	year

ES.1.0 EXECUTIVE SUMMARY

The development and hydrologic testing program at Test Well SPR7007X, located in southeastern Spring Valley (Hydrographic Area 184), White Pine County, Nevada was performed from February 7 through February 18, 2008. The test well and associated Monitor Well SPR7007M are completed within the unconfined basin fill aquifer, consisting of unconsolidated gravels with sand and clays, associated with the Swallow Canyon alluvial fan. Both wells are drilled to a depth of 1,040 ft bgs. Static depth to water is approximately 154 ft bgs.

Three wells (test, monitor, and background) and two springs (Swallow Springs and Minerva Spring) were monitored throughout the testing program. The discharge at the north and south orifices of Swallow Springs, which are located approximately 2,400 and 2,600 ft southeast of the test well, respectively, was measured. A piezometer was monitored at Minerva Spring located approximately 9,000 ft southwest of the test well. Analysis of the data collected from both of the springs indicate that they were not influenced by either the step or constant-rate tests.

The development and test pumping extracted 28,208,700 gallons of water. Development pumping improved specific capacity, a ratio of discharge (*Q*) to drawdown (*s*) in the test well, from 108 to 128 gpm/ft at a comparable duration of pumping at approximately 2,000 gpm. The turbidity improved from approximately 193 NTU to less than 1 NTU during development. A five-interval well performance step test was conducted at discharge rates ranging from 2,000 to 4,000 gpm to estimate the optimal pumping rate, evaluate well loss coefficients, and determine the discharge rate for the constant-rate test.

A 120-hour constant-rate test was performed at a discharge rate of 3,000 gpm. Site hydrogeologic data and diagnostic log-log and derivative drawdown data plots indicated that an unconfined model is the most appropriate primary solution method. The unconfined Moench solution, which considers delayed gravity drainage, wellbore storage and well bore skin effect, was selected as the primary solution and was applied to the test and monitor well pumping and recovery data. Secondary solutions using Neuman and Theis solutions were performed for comparison. Analyses were performed using AQTESOLV software.

Results of the Moench evaluation indicate a best-fit estimated hydraulic conductivity (*K*) of 40.3 ft/day. Results of the analysis estimated a transmissivity (*T)* of 35,600 ft^2/day, assuming a saturated thickness of 883 ft, and specific yield (*Sy)* of 0.22. An evaluation of increased saturated thickness and consideration of associated partial penetration effects were performed using the Moench solution to estimate variation in *T.* Saturated thickness was varied between 1,200 and 2,000 ft and a partial penetration evaluation of the test data was also performed. The resulting *K* values are 37.3 to 38.0 ft/day. *T* values ranged from 45,200 to 74,700 ft^2/day for saturated thicknesses of 1,200 and 2,000 ft, respectively.

A comparison analysis using the Neuman solution, which also considers delayed gravity drainage but not wellbore skin effects, was performed to evaluate *T* and *Sy* values. Results estimate a *T* of 29,100 ft^2/day, assuming a saturated thickness of 883 ft., and *Sy* of 0.3. Results of the more simplified Theis solution resulted in a transmissivity value of approximately 34,000 ft^2/day assuming a similar saturated thickness.

Specific capacity during the last 12 hours of the 3,000 gpm, 120-hour constant-rate test ranged from 95.6 to 96.5 gpm/ft. The initial operational pumping rate is projected to be between 3,000 and 3,500 gpm.

Groundwater samples were collected from Test Well SPR7007X and Monitor Well SPR7007M 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 are calcium-magnesium-bicarbonate facies and reflect the dominance of the carbonate-rock system in the area and the surrounding mountains. The stable isotopic compositions are very light and plotted above the Global Meteoric Water Line suggesting that the water did not undergo any significant secondary processes (e.g., evaporation) prior to recharge.

The ^{14}C activity of 57.01 was relatively high and the tritium activity of 9.3 tritium units (TU) was comparable with that of present day precipitation in the mountains surrounding Spring Valley. The relatively high ^{14}C and light $\delta^{13}C$ value, and the high tritium content suggest that the groundwater is recharged by modern precipitation and has not interacted with isotopically heavy minerals. The $^{36}Cl/Cl$ ratio of Test Well SPR7007X 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 SPR7007X and Monitor Well SPR7007M.

The two wells are completed within the unconfined basin fill aquifer in unconsolidated gravels with sand and clay associated with the Swallow Canyon alluvial fan. This report also presents groundwater-level data collected at the site post-test through June 2010. A separate document entitled *Geologic Data Analysis Report for Monitor Well SPR7007M and Test Well SPR7007X 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

The objectives of developing Test Well SPR7007X were to remove any remaining drilling fluids and improve the hydraulic connection with the formation. This phase of development consisted of pump and surge activities and was in addition to the airlifting and swabbing development that were performed immediately after well installation.

Hydraulic testing was performed to evaluate well performance and to provide data on the hydraulic properties of the 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.

1.2 Testing and Monitoring Program

The well development and hydraulic testing program was performed from January 19 through February 18, 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 120-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 SPR7007M is part of the Spring Valley regional baseline 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 appendices.

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 SPR7007X, is located on the east side of Spring Valley, on SNWA property, approximately 11.8 mi north of the Lincoln and White Pine County line in Section 5, T11N, R68E, at an elevation of 6,018 ft amsl. Access is from State Route 894 east approximately 1 mi along a dirt road. A map showing the site location and other SNWA test and monitor wells in Spring Valley installed as of June 2010 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 SPR7007X 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 south-central Spring Valley is through the basin fill generally toward the central axis of the valley with discharge occurring through evapotranspiration (ET). Groundwater flow in the southern portion of Spring Valley is postulated to occur south of the Snake Range through the fractures in the carbonates of the Limestone Hills into Hamlin Valley.

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 have been presented in several reports. These reports include:

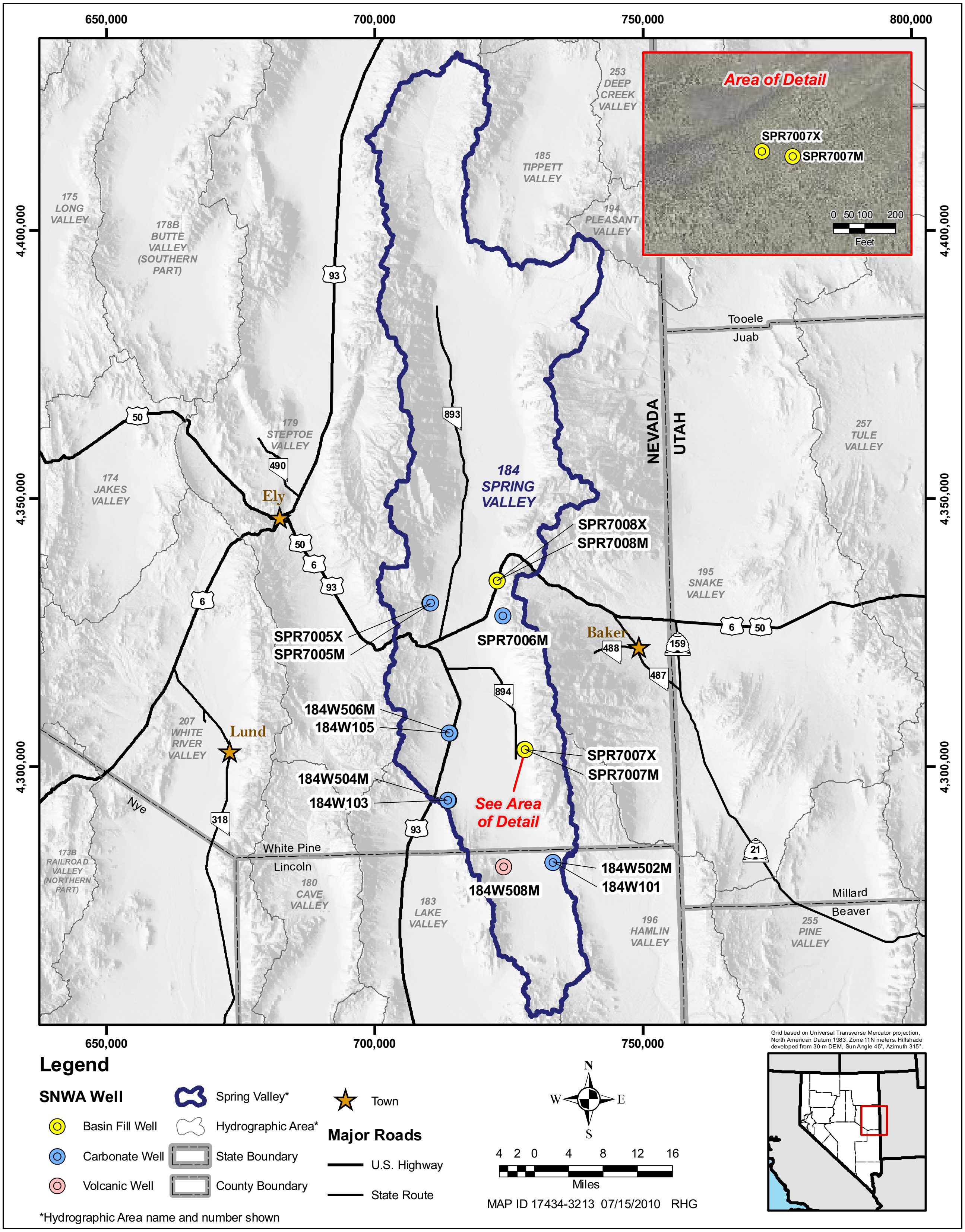


Figure 2-1
SNWA Exploratory and Test Wells in Spring Valley (as of June 2010)

- *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)
- *Geologic and Hydrogeologic Framework for the Spring Valley Area* (SNWA, 2006a)
- *Summary of Groundwater Water-Rights and Current Water Uses in Spring Valley* (SNWA, 2006b)
- *Water Resource Assessment for Spring Valley* (SNWA, 2006c)
- *Geology of White Pine and Lincoln Counties and Adjacent Areas, Nevada and Utah—The Geologic Framework for Regional Groundwater Flow Systems* (Dixon et al., 2007)
- *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)

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. Surface geophysical profiles were also performed in the vicinity of the well site by U.S. Geological Survey (USGS) and SNWA.

The test and monitor wells are completed in saturated Quaternary Alluvium associated with the Swallow Canyon alluvial fan which is comprised of gravels with sand and clay. Cambrian carbonates outcrop approximately 1.1 mi to the east of the site. A major north-south trending range front fault as identified by Dixon et al. (2007) is located approximately 0.75 mi east of the site. The site is also approximately 1.25 mi east of the modern playa deposits at the surficial extent of the alluvial fan. The basin fill at the site is estimated to be underlain by carbonate rocks. The estimates of saturated thickness of basin fill at the test well site range from 883 ft (at base of well) to 2,000 ft.

A regional gravity survey was performed by 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). The ground magnetometer and audiomagnetotelluric (AMT) study was performed at the site in 2007. AMT survey was performed from west to east just north of the site and completed to the east of Swallow Springs. The AMT results are summarized in the USGS

Open File Report 2008-1301 (McPhee et al., 2008). The survey identified the range front fault and carbonate-basin fill contact to the east of the test well.

A site map presenting the surficial geology, test well and spring monitoring locations, and AMT surface geophysical profile is 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).

2.2 Testing Program Monitoring Locations

Three wells consisting of the test, monitor, and background well, discharge at the two orifices at Swallow Springs and a piezometer at Minerva Spring were monitored throughout the testing program. Site attribute, lithologic, and hydrologic information for the locations are presented in this section.

2.2.1 Test Well SPR7007X

Test Well SPR7007X was drilled to a total depth of 1,040 ft bgs and completed to a depth of 1,020 ft bgs between December 5, 2007, and January 24, 2008, using auger and mud rotary techniques. A 40-in.-diameter conductor casing was placed to a depth of 54 ft bgs and grouted in place. A 32-in.-diameter intermediate casing was placed to a depth of 155 ft bgs and grouted in place. After the borehole was advanced to completion depth, downhole geophysical logging was performed. A 20-in.-diameter completion string, including approximately 700 ft of Ful-flo louver screen was then installed. The gravel pack extends from a depth of 112 ft bgs (within the intermediate casing) to the base of the borehole. A summary chart of Test Well SPR7007X drilling and well construction statistics and well schematic are presented in Table 2-1 and Figure 2-3, respectively. The borehole lithologic log for Test Well SPR7007X is presented in Figure 2-4.

2.2.2 Observation Wells and Background Monitoring

Monitoring Well SPR7007M, located 99 ft to the east-southeast of the test well, was drilled to a total depth of 1,040 ft bgs and completed to a depth of 1,020 ft bgs between July 26 and August 17, 2007. A 20-in.-diameter conductor casing was set to a depth of 76 ft bgs and grouted in place. A 16-in.-diameter borehole was then advanced to completion depth. The 8-in.-diameter completion string, including approximately 700 ft of slotted casing, was then installed. The gravel pack extends from a depth of 112 ft bgs to the base of the borehole. A well construction schematic for Monitor Well SPR7007M is presented on Figure 2-5. A summary chart of well drilling and well construction statistics for Monitor Well SPR7007M is presented in Table 2-2. The borehole lithologic log for this well is presented in Figure 2-6.

Monitor Well 184W502M, located 13.5 mi southwest of the test well in the southeast portion of the valley, was monitored during the hydraulic testing to observe regional groundwater trends and to identify outside influences affecting regional water levels, such as changes in barometric pressure, earthquakes, and lunar effects. The hydrologic conditions affecting the water levels in this well are expected to be generally the same as those affecting the test well. This 8-in.-diameter well is

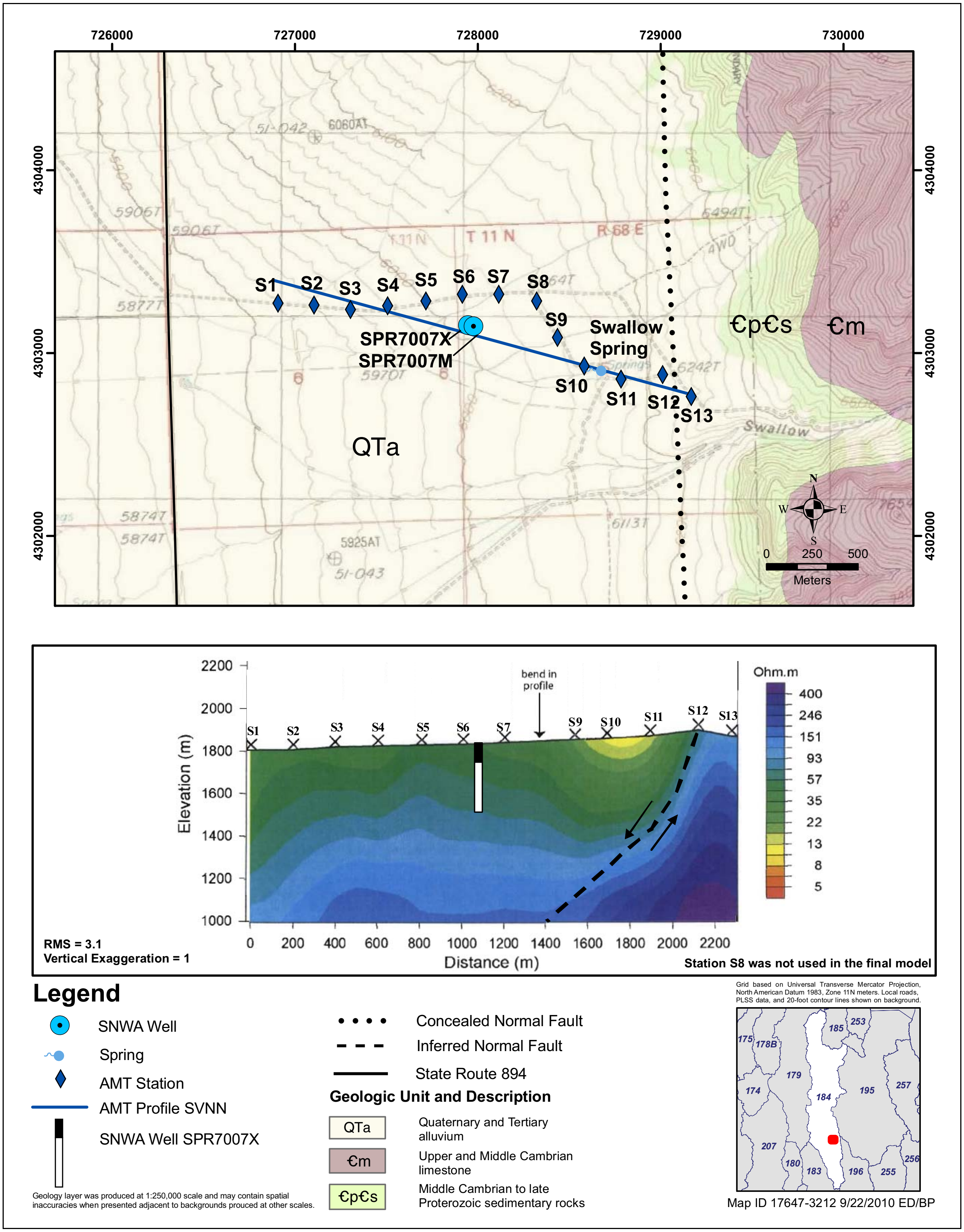
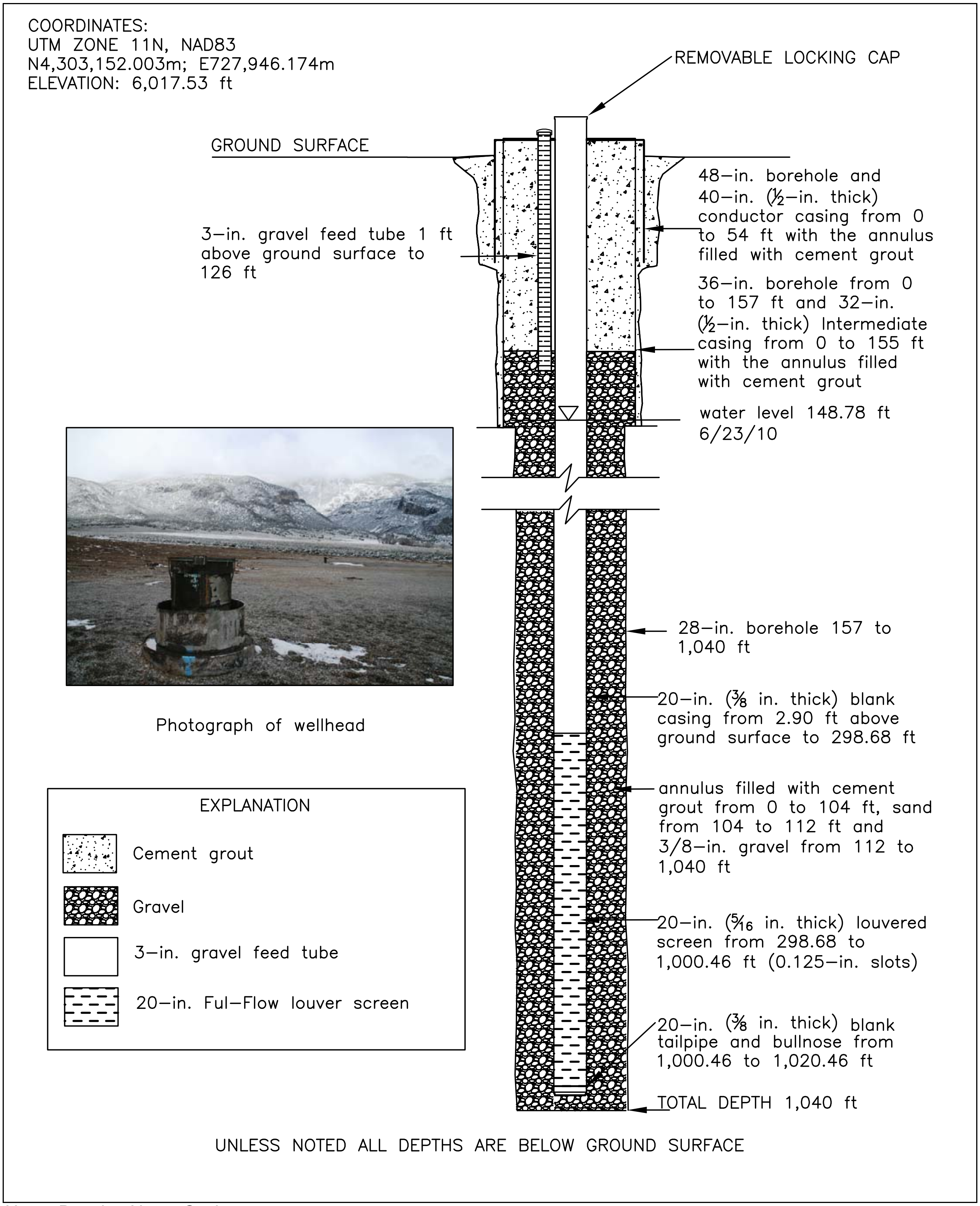


Figure 2-2
Geologic Map and Surface Geophysical Profile at Test Well SPR7007X

Table 2-1
Test Well SPR7007X Borehole and Well Statistics

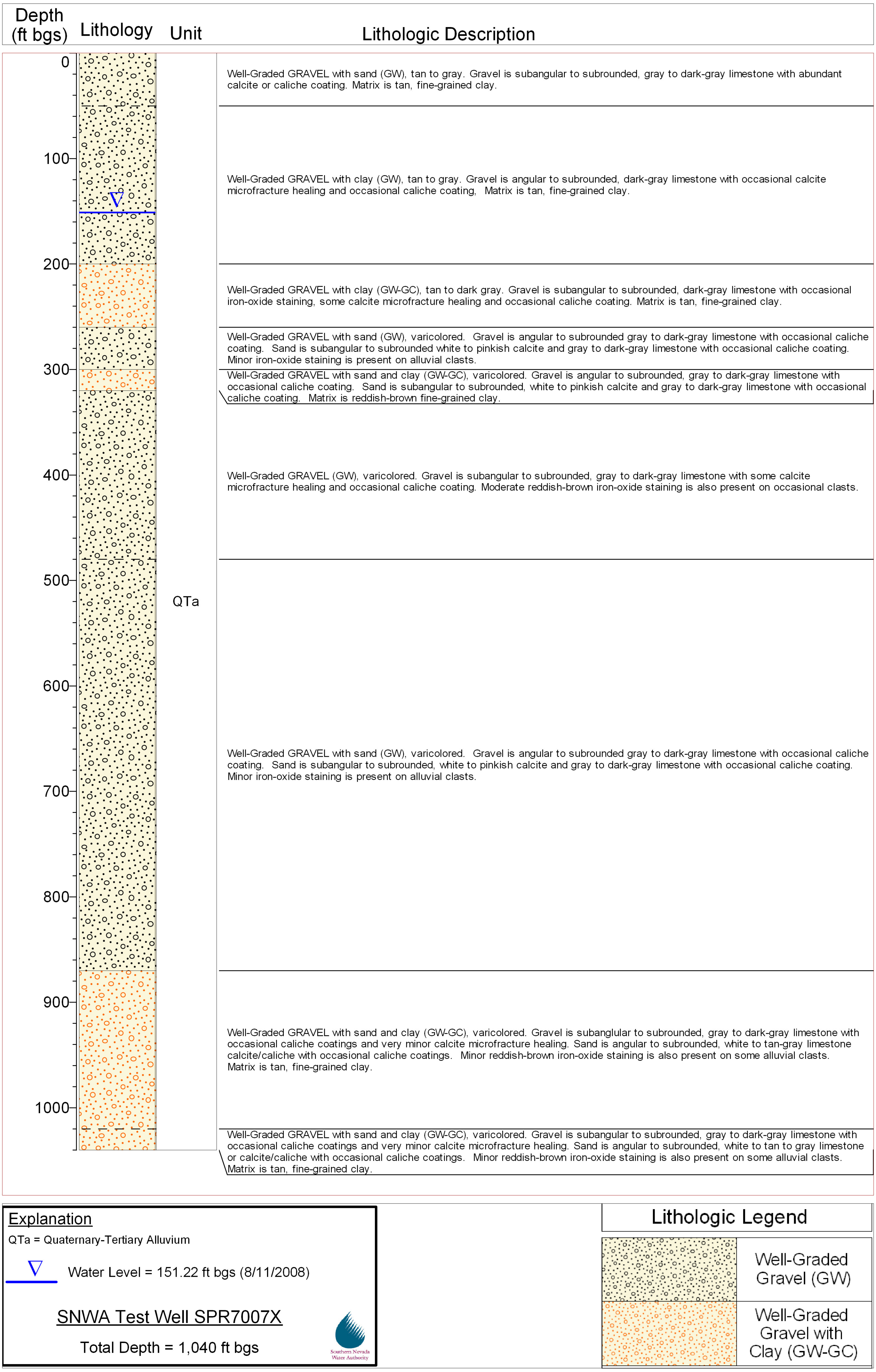
LOCATION DATA Coordinates	N 4,303,152.003 m; E 727,946.174 m (UTM, Zone 11N, NAD83)
Ground Elevation	6,017.53 ft amsl
DRILLING DATA Spud Date	12/5/2007
Total Depth (TD)	1,040 ft bgs
Date TD Reached	1/13/2008
Date Well Completed	1/24/2008
Hole Diameter	48-in. from 0 to 54 ft bgs 36-in. from 54 to 157 ft bgs 28-in. from 157 to 1,040 ft bgs
Drilling Techniques	Auger from 0 to 54 ft bgs Flooded Reverse Circulation from 54 to 1,040 ft bgs
Drilling Fluid Materials Used	Gel = (229) 50-lb bags Soda Ash = (36.5) 50-lb bags EZ-Mud = (10.25) 5 gal buckets EZ-Mud Gold = (2.25) 5 gal buckets
Drilling Fluid Properties	Viscosity Range = 27 to 33 sec/qt Weight Range = 8.5 to 9.1 lbs Filtrate Range = 8 to 21 ml Filter Cake Range = 1/64 to 1/32 in.
CASING DATA	40-in. MS Conductor Casing from 0 to 54 ft bgs 32-in. MS Intermediate Casing from 0 to 154.98 ft bgs 20-in. HSLA Completion Casing from -2.90 to 1,020.46 ft bgs
WELL COMPLETION DATA	301.58 ft of blank 20-in.HSLA casing from -2.9 to 298.68 ft bgs 701.78 ft of 20-in HSLA louver screen from 298.68 to 1,000.46 ft bgs 20.0 ft blank 20-in tailpipe and bullnose casing from 1,000.46 to 1,020.46 ft bgs Cement, Plug and Gravel Pack Depth 0 to 54 ft on outside of 40-in. conductor casing (cement) 0 to 155 ft on outside of 32-in. intermediate casing (cement) 155 to 157 ft on outside of 32-in. intermediate casing (fill) 0 to 104 ft on outside of 20-in. completion casing (cement) 104 to 112 ft on outside of 20-in. casing (sand plug) 112 to 1,040 ft from bottom of sand plug to TD (3/8 in. gravel pack)
MONITOR WELL	Static Water Level: 148.78 ft bgs (6/23/2010) Groundwater Elevation: 5,868.75 ft amsl (6/23/2010)
DRILLING CONTRACTOR	WDC
GEOPHYSICAL LOGS BY	Pacific Surveys, LLC (Claremont, CA)
OVERSIGHT	S.M. Stoller Corporation

HSLA = High strength low alloy
MS = Mild steel



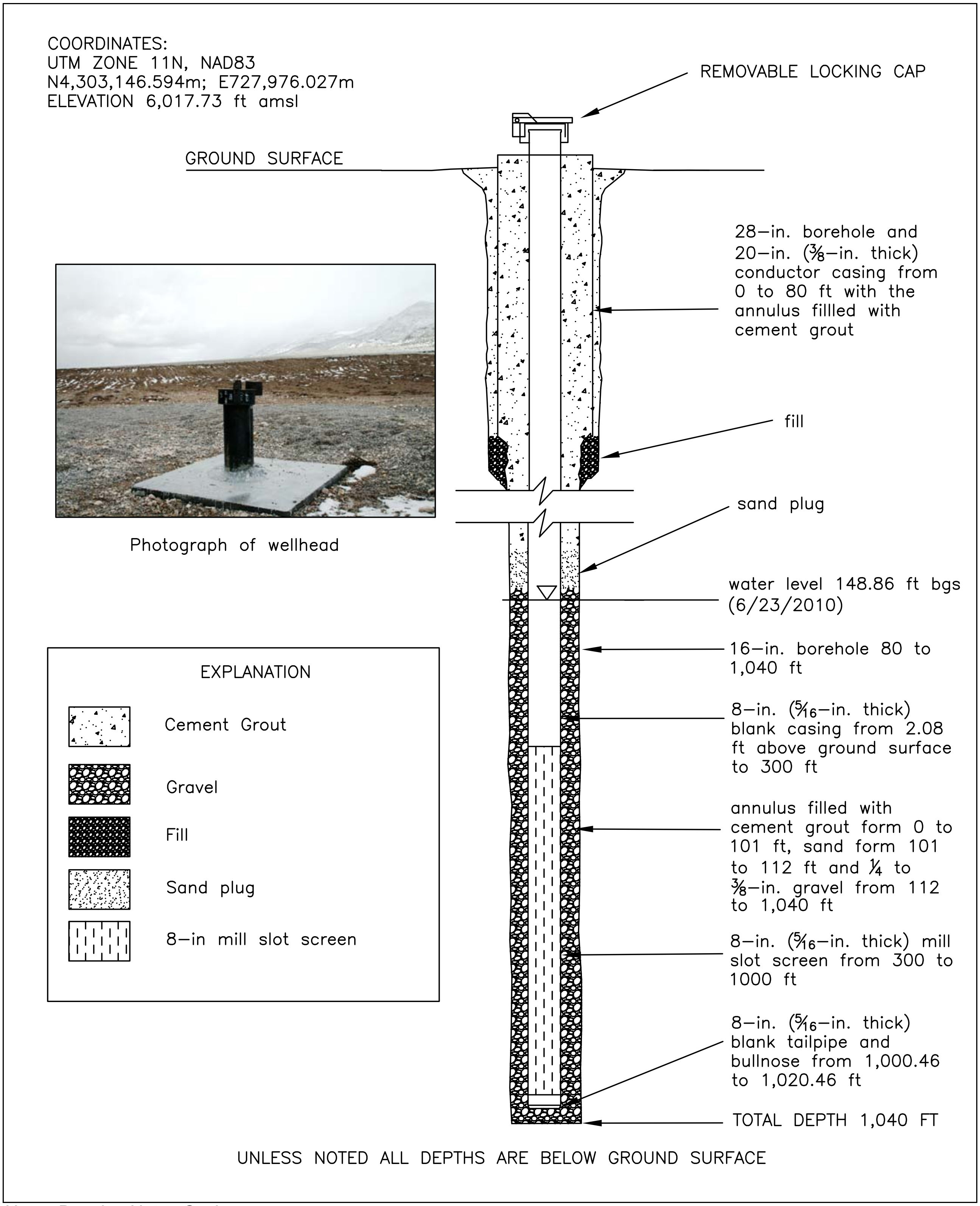
Note: Drawing Not to Scale

Figure 2-3
Test Well SPR7007X Well Diagram



Source: Mace and Muller (2010)

Figure 2-4
Borehole Stratigraphic Column of Test Well SPR7007X

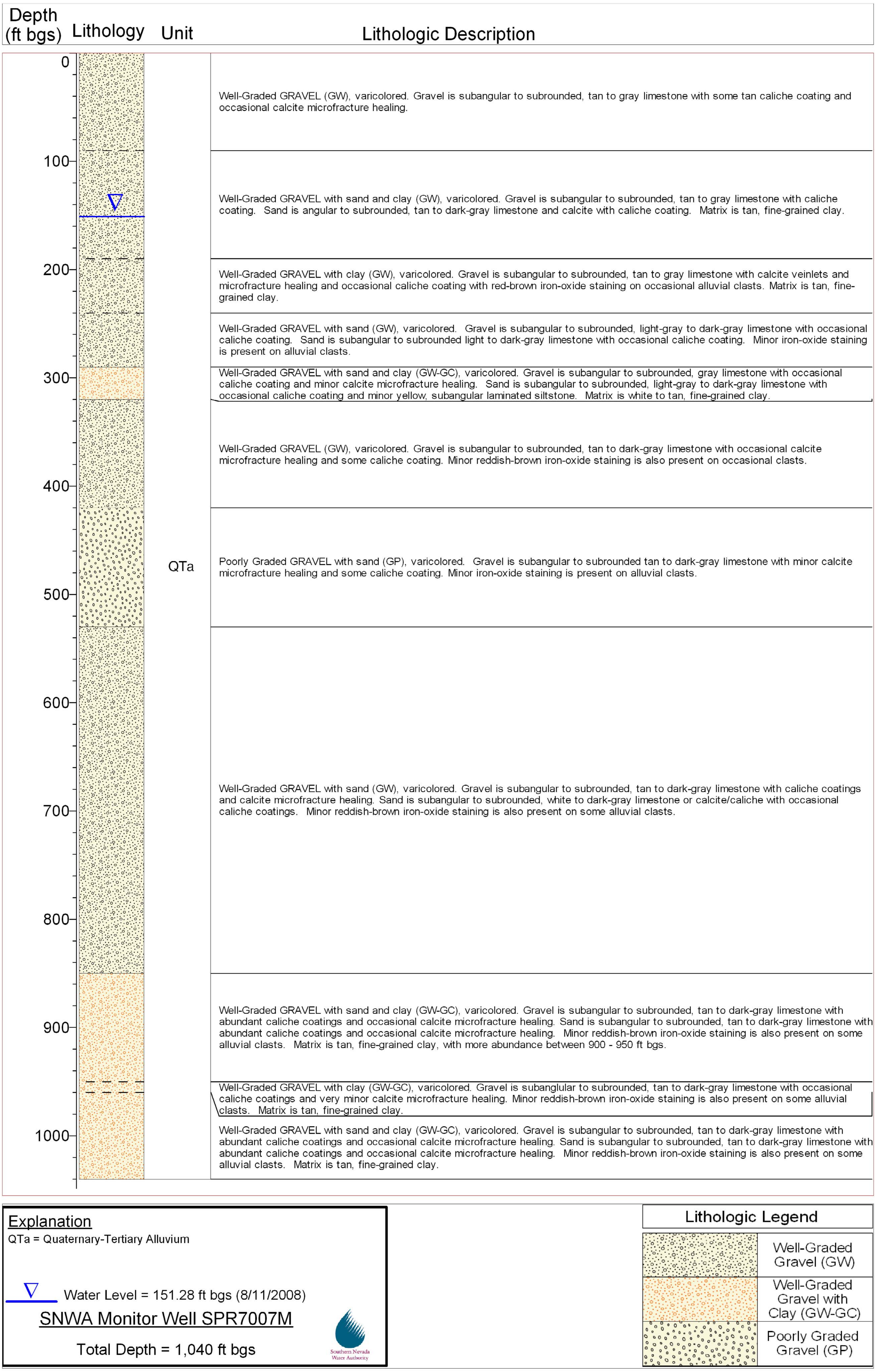


Note: Drawing Not to Scale

Figure 2-5
Monitor Well SPR7007M Well Diagram

Table 2-2
Monitor Well SPR7007M Borehole and Well Statistics

LOCATION DATA Coordinates	N 4,303,146.594 m; E 727,976.027 m (UTM, Zone 11, NAD83)
Ground Elevation	6,017.73 ft amsl
DRILLING DATA Spud Date	7/26/2007
Total Depth (TD)	1,040 ft bgs
Date TD Reached	8/01/2007
Date Well Completed	8/17/2007
Hole Diameter	28-in. from 0 to 80 ft bgs 16-in. from 80 to 1,040 ft bgs
Drilling Techniques	Conventional Circulation from 0 to 80 ft bgs Flooded Reverse Circulation from 80 to 1,040 ft bgs
Drilling Fluid Materials Used	Quick Gel = (128) 50-lb bags Soda Ash = (7) 50-lb bags EZ-Mud = (6) 5-gal buckets BenSeal = (1) 50-lb bags QuickTrol = (9) 2-lb bags
Drilling Fluid Properties	Viscosity Range = 32 to 42 sec/qt Weight Range = 8.6 to 9.0 lbs Filtrate Range = 15 to 30 ml Filter Cake Range = Up to 1/32 in.
CASING DATA	20-in. MS Conductor Casing from 0 to 80 ft bgs 8-in. MS Completion Casing from -2.08 to 1,020 ft bgs
WELL COMPLETION DATA	302.8 ft of blank MS 8-in. casing from -2.08 to 300.0 ft bgs 700 ft of 8-in. slotted screen from 300.0 to 1,000 ft bgs 20.0 ft blank 8-in. tailpipe and bullnose from 1,000 to 1,020 ft bgs <u>Cement, Plug and Gravel Pack Depth</u> 0 to 80 ft on outside of 20 in. conductor casing (cement) 0 to 101 ft on outside of MS 8-in. completion (cement) 101 to 112 ft on outside of MS 8-in. casing (sand plug) 112.0 to 1,040.0 ft from bottom of sand plug to TD (1/4 to 3/8 in. gravel pack)
WATER	Static Water Level: 148.46 ft bgs (6/23/2010) Groundwater Elevation: 5,869.27 ft amsl (6/23/2010)
DRILLING CONTRACTOR	WDC
GEOPHYSICAL LOGS BY	Pacific Surveys (Claremont, CA)
OVERSIGHT	S.M. Stoller Corporation



Source: Mace and Muller (2010)

Figure 2-6
Borehole Stratigraphic Column of Monitor Well SPR7007M

completed in the unconfined, fractured carbonate-aquifer system at a depth of 1,828 ft bgs with an open borehole interval of 58 to1,828 ft bgs. Other regional wells completed in the basin fill were not selected as background wells due to the distance from the test well site and potential influence by other pumping wells.

Swallow and Minerva Springs, which are shown on Figure 2-2, were used as additional observation points during testing. No influence from testing activities was observed at the springs.

Spring discharge was monitored at the north and south orifices of Swallow Springs which are located approximately 2,400 and 2,600 ft southeast of the test well, respectively. Miscellaneous discharge measurements at Swallow Springs are available from July 12, 1966 to July 27, 2010. Discharge during the period of record at the north channel ranged from 0.07 to 0.28 cfs. The range of discharge of the southern channel was 0.50 to 1.0 cfs.

A shallow piezometer (SPR7007Z) was monitored at Minerva Spring located approximately 9,000 ft southwest of the test well. Minerva Spring consists of multiple orifices with a spring pool reservoir controlled for irrigation purposes. Miscellaneous discharge measurements at Minerva Spring are available from June 15, 1968 to July 26, 2010. Discharge varies considerably due to the operation of the spring pool as an irrigation reservoir. Measured discharge ranges from 0.36 to 5.0 cfs during the period of record. Piezometer water levels near Minerva Spring provide more consistent data on hydrologic conditions at the spring. Depth to water at the piezometer was not influenced during testing. The piezometer has ranged from approximately 8 to 14 ft bgs from measurements collected during the period of record from the testing program to present.

2.2.3 Well Survey and Water-Level Data

A professional survey of the wells utilized in the testing program was performed to determine the location and elevation of the measuring points and ground-surface elevations. Results of the survey of the wells are presented in Table 2-3.

Table 2-3
Monitor Well Survey Data

Well ID	Well Use During Testing	Location[a]		Temporary MP[b] (ft amsl)	Permanent MP[b] (ft amsl)	Ground Surface Elevation[b] (ft amsl)
		UTM Northing (m)	UTM Easting (m)			
SPR7007X	Test Well	4,303,152.00	727,946.17	6,021.15	6,020.43	6,017.53
SPR7007M	Monitor Well	4,303,146.59	727,976.03	---	6,019.81	6,017.73
SPR7007Z	Minerva Spring Piezometer	4,301,057.50	726,134.41	---	5,831.31	5,828.66
184W502M	Background Well	4,282,116.35	733,294.42	---	6,191.69	6,189.72

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

Depth-to-groundwater measurements were obtained, relative to the marked reference point, at the testing program well locations. Static levels prior to the 120-hour constant-rate test were measured at 156.83 and 156.81 ft bgs) for Test Well SPR7007X, and Monitor Well SPR7007M, respectively. The distance of the measuring points above land surface for these two wells is 3.62 and 2.08 ft. The temporary reference measuring point for the Test Well SPR7007X was the top of the transducer access tube associated with the turbine pump vertical shaft well head assembly.

Static groundwater-elevation data were collected on a continuous basis at Monitor Well 184W502M, which was used as a background well during the testing program, with an In-Situ MiniTroll pressure transducer from preceding the test to February 19, 2008. At that time, the integrated pressure transducer failed and was removed. Periodic measurements were collected regularly until a Design Analysis H-310 pressure transducer and XL-500 data logger were installed on July 13, 2009, as part of the long-term monitoring program. Periodic, manual depth-to-water measurements are taken at least quarterly. Background well 184W502M static groundwater elevation is approximately 5,706 to 5,712 ft amsl, which corresponds to a depth of water of approximately 483 to 478 ft bgs, respectively.

Static groundwater-elevation data have been collected on a six-week basis at Monitor Well SPR7007M from September 2007, to the present. Continuous groundwater-elevation data has been collected at this well since it was equipped with a Design Analysis H-312 pressure transducer and XL 500 data logger on May 19, 2009, as part of the long-term monitoring program. Periodic, manual depth-to-water measurements are taken at least quarterly. Static groundwater elevation ranged from approximately 5,859 to 5,871 ft amsl at Monitor Well SPR7007M, which corresponds to a depth of water of approximately 158 to 147 ft bgs, respectively.

Physical measurements are collected from Test Well SPR7007X on a six-week to quarterly frequency. Static groundwater elevation ranged from approximately 5,859 to 5,871 ft amsl at Test Well SPR7007X, which corresponds to a depth of water of approximately 158 to 147 ft bgs, respectively.

Period-of-record hydrographs for the wells, with the period of the hydraulic testing program highlighted, are presented in Figures 2-7 through 2-9. A background hydrograph for well 184W502M during the hydraulic testing program is presented in Section 3.4. Static water levels at Test Well SPR7007X and Monitor Well SPR7007M have large seasonal fluctuations. The seasonal rises in water levels correlate to recharge associated with snow melt from the spring thaw from the nearby Snake Range.

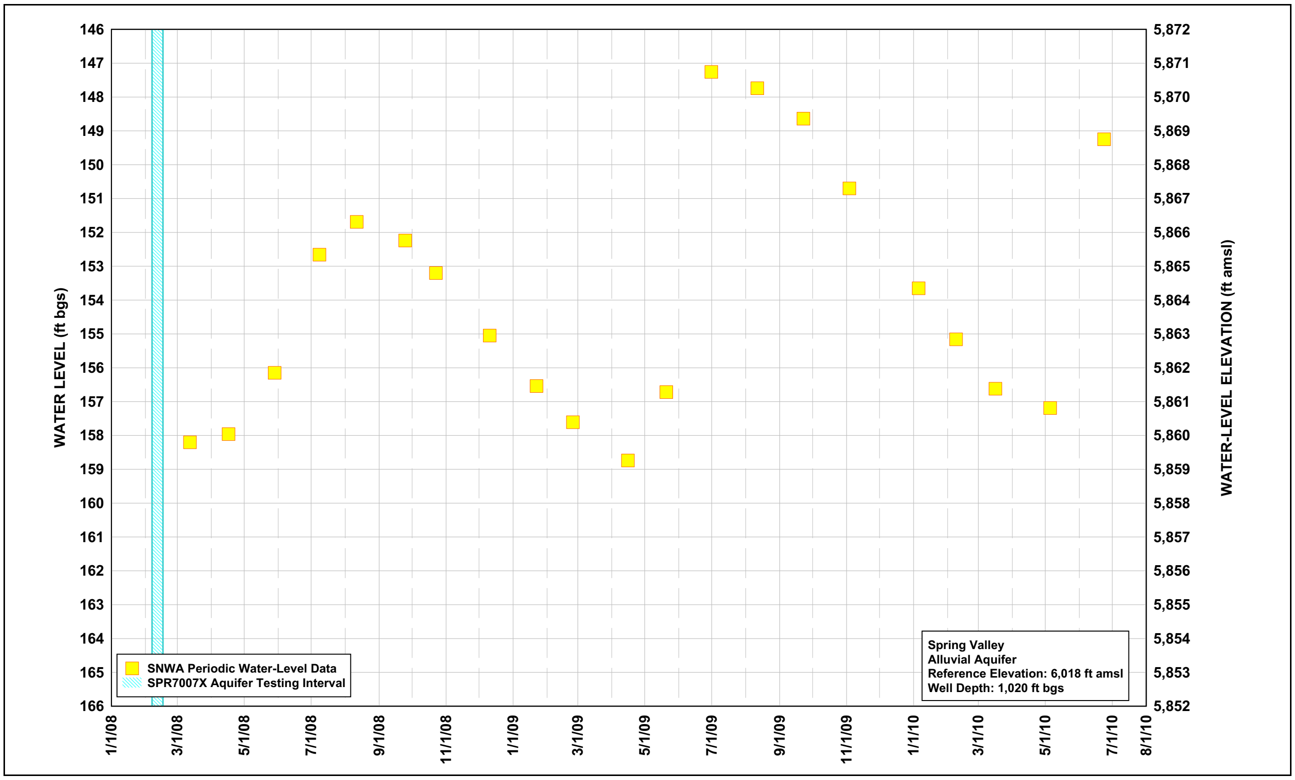


Figure 2-7
Test Well SPR7007X Historical Hydrograph

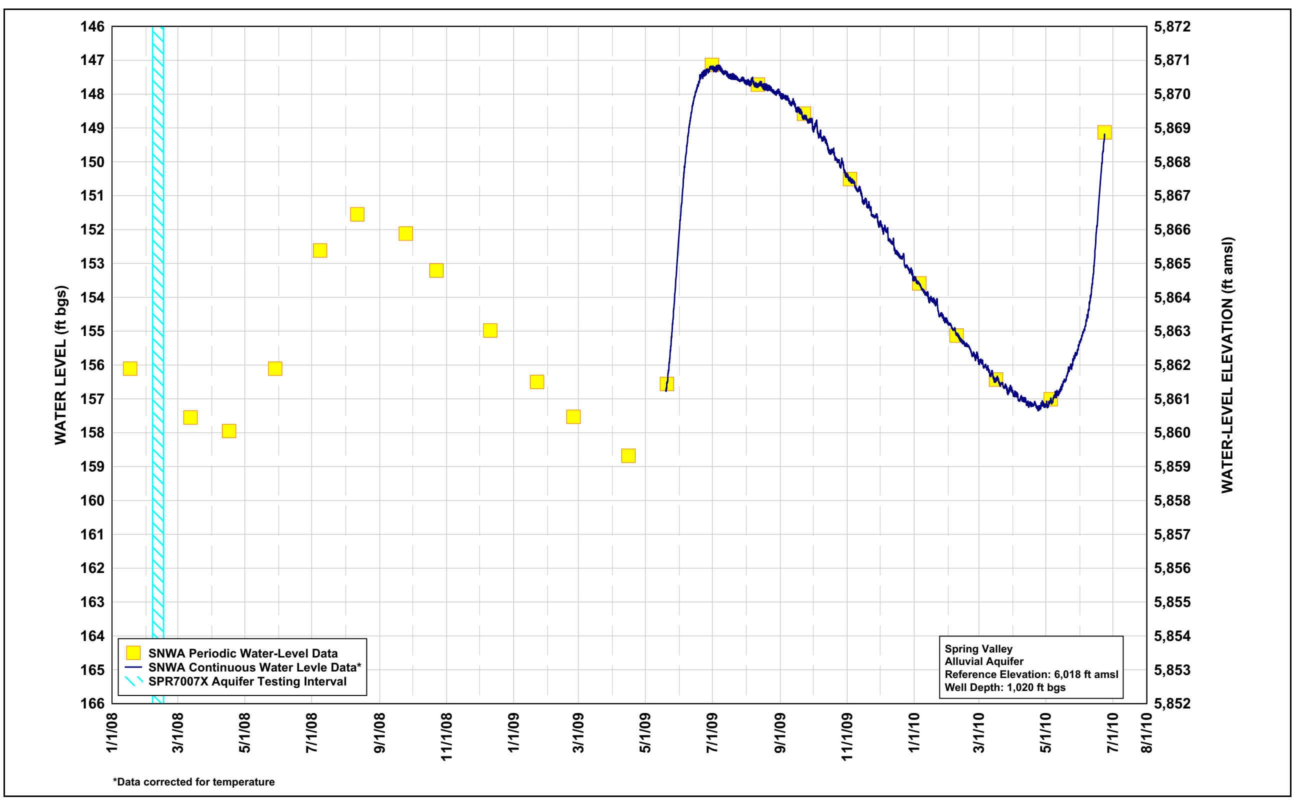


Figure 2-8
Monitor Well SPR7007M Historical Hydrograph

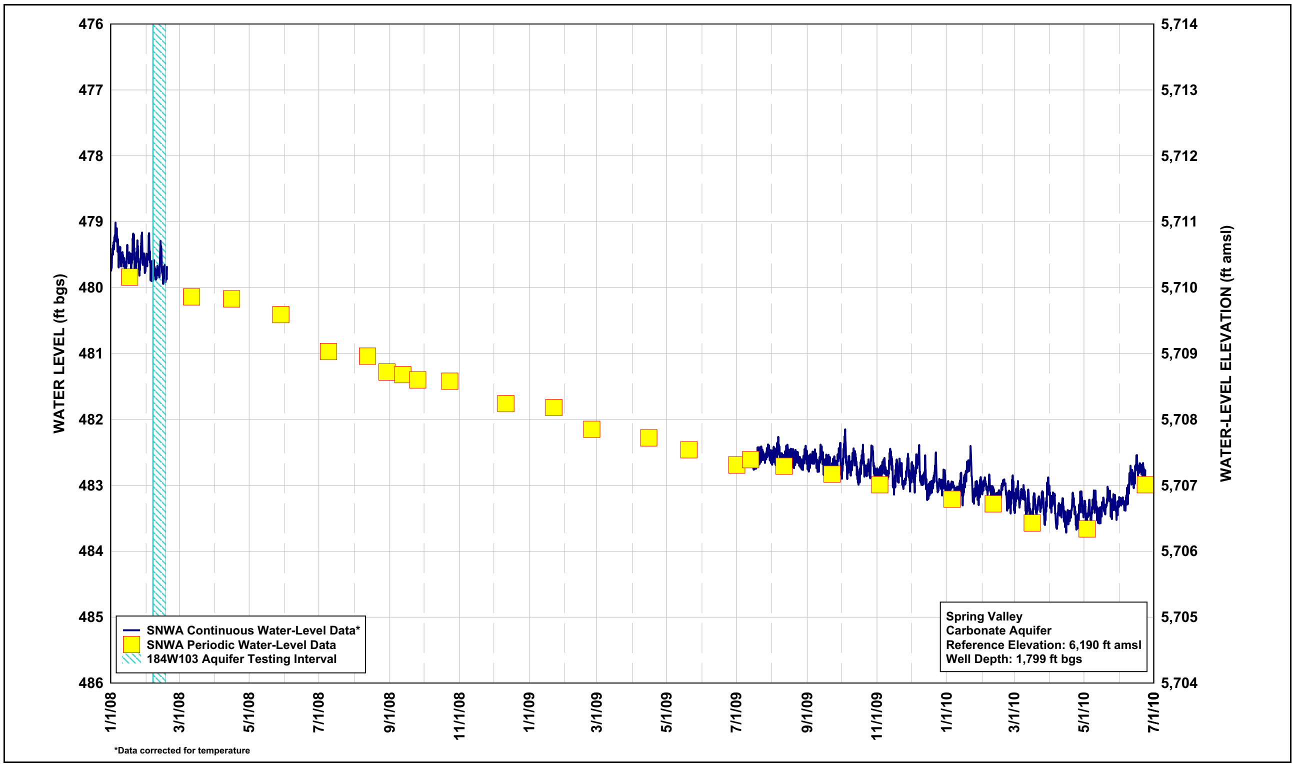


Figure 2-9
Monitor Well 184W502M Historical Hydrograph

3.0 TEST DESCRIPTION AND BACKGROUND DATA

This section describes the activities, pump equipment, and monitoring instrumentation associated with development and hydraulic testing of Test Well SPR7007X. Background hydrologic data and regional trends associated with the testing program are also presented and evaluated in this section.

3.1 Site Activities

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

- January 19 to 23: Developed the test well using airlift and dual swab techniques.
- February 7 to 8: Final well development, using surge and pump methods. The well was developed at rates ranging from 750 to 4,660 gpm.
- February 10: Performed a five-interval step-drawdown tests at rates ranging from 2,000 to 4,000 gpm.
- February 12 to 18: Performed a 120-hour constant-rate test at 3,000 gpm and subsequent water-level recovery measurements.
- February 14: Collected groundwater samples for laboratory chemical analysis. Groundwater chemistry samples were collected from well Test Well SPR7007X at 10:00 AM during performance of the constant-rate test. A total of 15,648,000 gal of water had been extracted from the well (including pumping during well development, step test, and the constant-rate test) at the time of sampling.

3.2 Test Equipment and Site Layout

A National Pump Company vertical line shaft turbine pump was used in Test Well SPR7007X. The intake was set at 408 ft bgs. The transducer was set at approximately 380 ft below the measuring point during development and step test. Approximately 1.5 hours into the step test a second transducer was installed in the test well at approximately 210 ft below the measuring point. 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 through approximately 600 ft of 12 in. diameter discharge line downgradient and to the south of the site into a stream channel of Swallow Springs. This channel flows into a small reservoir located approximately 3,000 ft west of the terminus of the test discharge line. A total of 28,208,700 gal of water were pumped during the program. This consists of pumpage totals of 21,611,300 gal during the 120-hour constant-rate test, 1,577,300 gal during the step test, and 5,020,100 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 SPR7007X and Monitor Well SPR7007M. At Test Well SPR7007X continuous groundwater levels were measured with an In-Situ PXD-261 50 psi pressure transducer and recorded using an In-Situ Hermit 3000 Data Logger. At Monitor Well SPR7007M two sets of equipment were utilized to measure continuous groundwater levels. The first set consisted of an In-Situ PXD-261 50 psi pressure transducer connected to an In-Situ Hermit 3000 data logger. The second set consisted of an In-Situ Level Troll 700 30 psi integrated pressure transducer and data logger. Two sets of equipment were utilized at the monitor well due to complications with the equipment, and the need to ensure accurate data were collected at the site.

One background well and two springs were also monitored during the tests. The background well was used to record background conditions and influences outside of the test. Regional water-level trends were evaluated from data collected at background Monitor Well 184W502M, located approximately 13.5 mi southwest of the site. A Mini-Troll Pro 30 psi. integrated pressure transducer and data logger was used to measure and record background water levels at that site.

Swallow and Minerva Springs were monitored during the step and constant-rate testing of Test Well SPR7007X. Swallow Springs consists of two orifices, which discharge into two separate channels. The north and south channel contains an “H” type flume and a 6-in. parshall flume, respectively. A second temporary 3-in. modified parshall flume was installed on the north channel approximately 30 ft downstream of “H” flume. A pressure transducer was installed on the north channel to continuously record stage. An In-Situ 5 psi Mini-Troll pro pressure transducer was placed in the stilling well of the 3-in. modified parshall flume.

A shallow piezometer (SPR7007Z), located approximately 50 ft from Minerva Spring, was used to monitor groundwater levels near the spring. An In-Situ Mini-Troll Pro 5 psi pressure transducer was installed in the shallow piezometer during testing of Test Well SPR7007X.

Data collected from background well 184W502M were used to identify any significant regional trend in groundwater level. A hydrograph for background well 184W502M during the test period is presented on Figure 3-1. An average daily cycle of water-level change of 0.26 ft was observed during the constant-rate test. A larger daily fluctuation was observed during development which was attributed to greater tidal effects.

Barometric pressure was recorded at the test well and at ET Station SV1 located approximately 7.1 mi southwest of the test well. Figure 3-2 presents a plot of barometric pressure variation data and groundwater level measurements in Monitor Well SPR7007M collected during the testing of Test Well SPR7007X. A rapid and substantial barometric shift occurred at 1,800 min into the test. The record was adjusted to compensate for the shift during analysis. No other influences, such as the

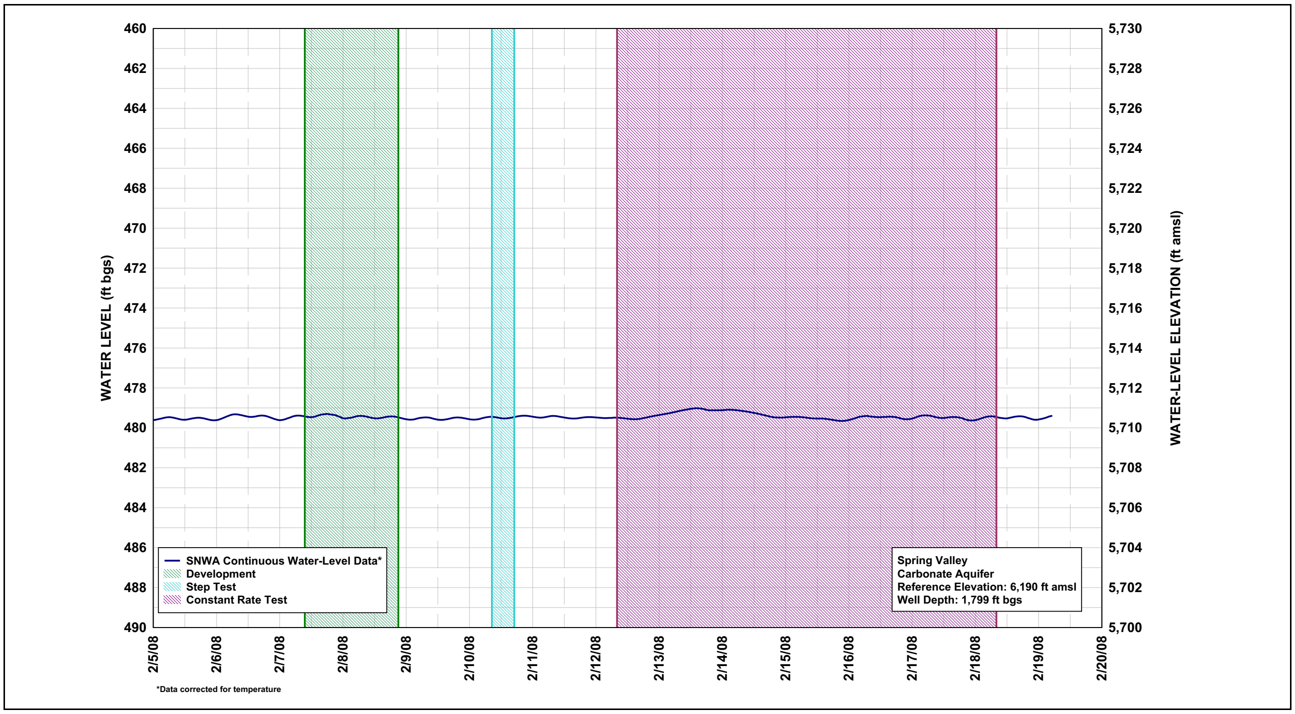


Figure 3-1
Hydrograph for Background Well 184W502M
During Testing Activities at Test Well SPR7007X

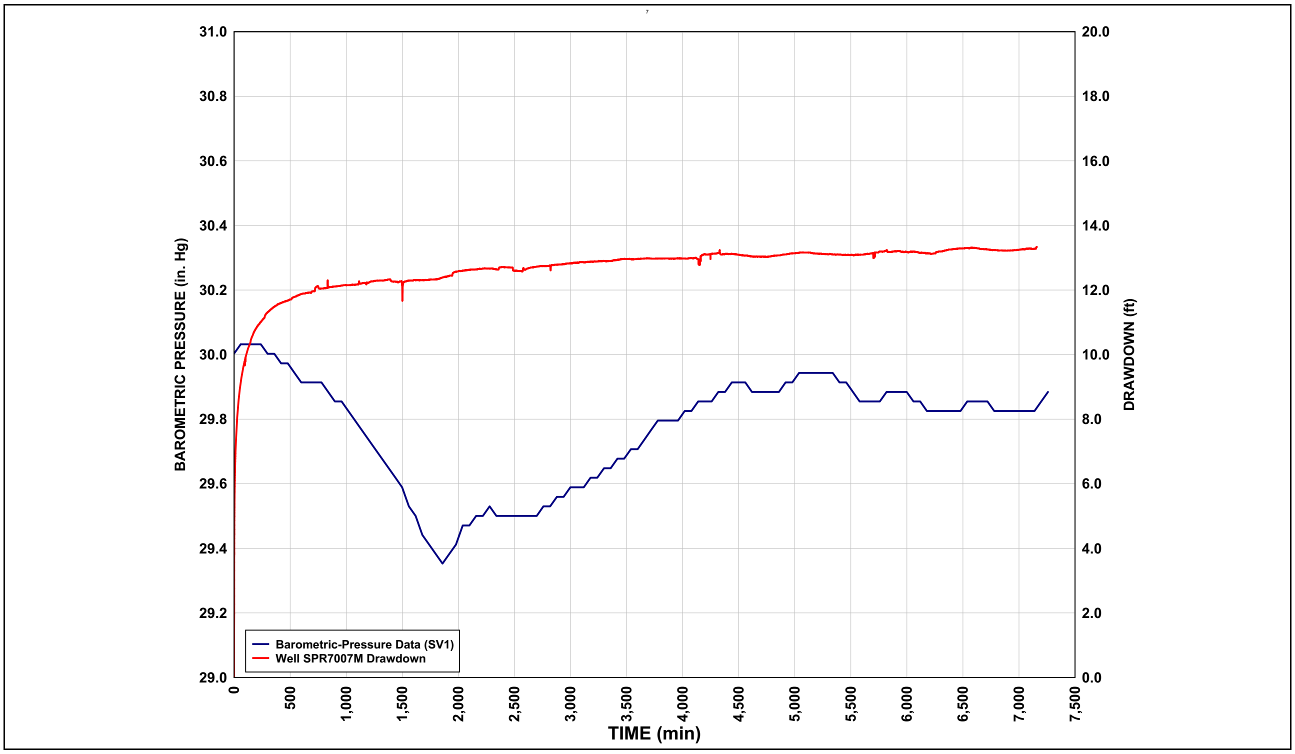


Figure 3-2
Local Barometric-Pressure Variation and
Groundwater-Level Measurements at Monitor Well SPR7007M

existence of other pumping wells in the vicinity of Test Well SPR7007X, were identified. Figure 3-2 presents a plot of barometric-pressure data and groundwater-level measurements in Monitor Well SPR7007M collected during the constant-rate test. The barometric-pressure record, recorded at Test Well SPR7007X and ET station SV1, covers the time period during the constant-rate test. During the record period, a barometric pressure shift occurred at 1,800 min into the test of approximately 0.68 in. Hg. This equates to 0.77 ft water based on 100 percent barometric efficiency of the well. The record was adjusted to compensate for the shift during analysis.

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

Transducer data at the test and monitor wells were compared to manual data collected throughout the test period. Evaluation of the data sets indicated no significant variations, with the exception of some turbulence and vibration in the test well during pumping. 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. Manually collected data at the test well was used to check the transducer test well record.

The respective borehole deviations for Test Well SPR7007X and Monitor Well SPR7007M 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.

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 SPR7007X was initially developed after drilling using a dual-swab technique. A dual swab was used prior to and after placement of the gravel pack. A polymer dispersant, AQUA-CLEAR PFD, was added to the well to break up residual drilling mud, and a final swab was performed the length of the screen.

Test Well SPR7007X 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 5,020,100 gal of water was pumped during this phase of development which resulted in an improvement of approximately 18.6 percent in specific capacity. The specific capacity improved from 108.29 gpm/ft on February 7, 2008, to 128.43 gpm/ft on February 10, 2008 at a discharge rate of approximately 2,000 gpm and similar pumping durations.

4.2 Step-Drawdown Test

A step-drawdown test was performed using five different pumping rates ranging from 2,000 to 4,000 gpm. The pumping periods ranged from 90 to 120 min in duration during which the pumping rate was held constant. Pumping rates were increased in each subsequent pumping period. Figure 4-1 presents a graph showing plots of the drawdown versus time for each pumping interval during the step test.

4.2.1 Well Performance and Specific Capacity

Well specific capacity is a measure of the well's productivity and efficiency. Specific capacity generally decreases with pumping duration and increased discharge rate. Graphs of drawdown versus

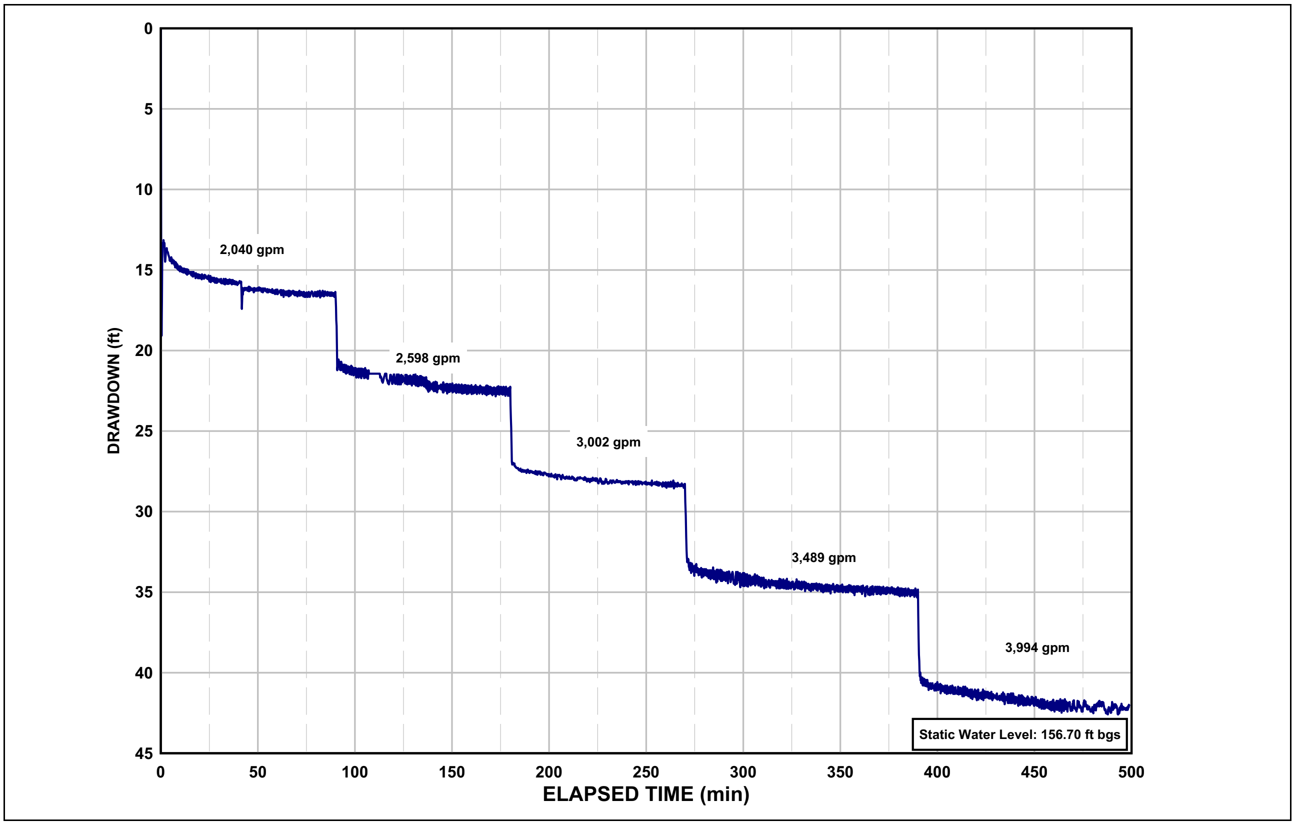


Figure 4-1
Linear Plot of Drawdown for Each Pumping Interval
During Step-Drawdown Testing of Test Well SPR7007X

discharge rate and specific capacity versus discharge rate are presented on Figures 4-2 and 4-3, respectively.

Results of the step-drawdown test indicate specific capacity values ranging from 94.2 to 123.8 gpm/ft for associated short term pumping rates of 3,994 to 2,040 gpm, respectively. Specific capacity during the last 12 hours of the 120-hour constant-rate test ranged from 95.6 to 96.5 gpm/ft of drawdown at 3,000 gpm.

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 inside the well screen, pump column and the zone adjacent to the well. Higher well losses caused by the formation are expected to be more pronounced in a fractured bedrock aquifer due to

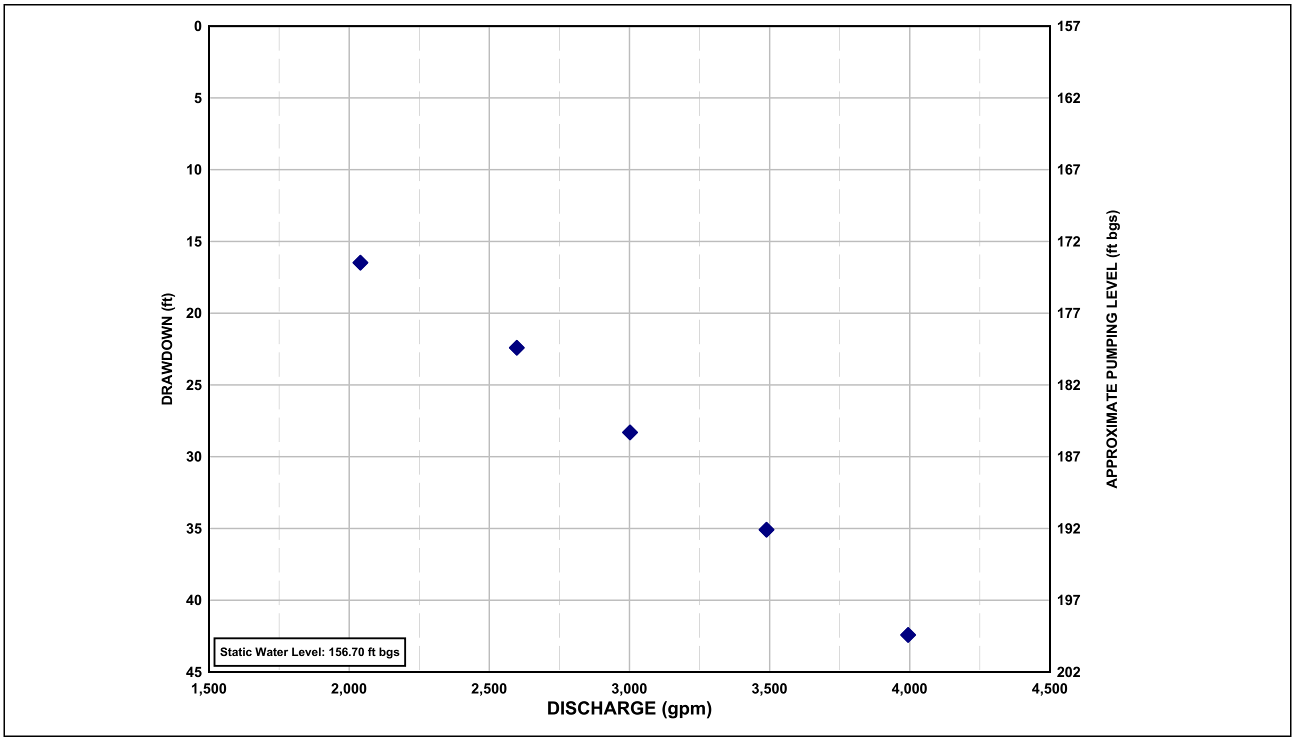


Figure 4-2
Linear Plot of Step-Test Drawdown and Depth-to-Pumping Level for Various Discharge Rates for Test Well SPR7007X

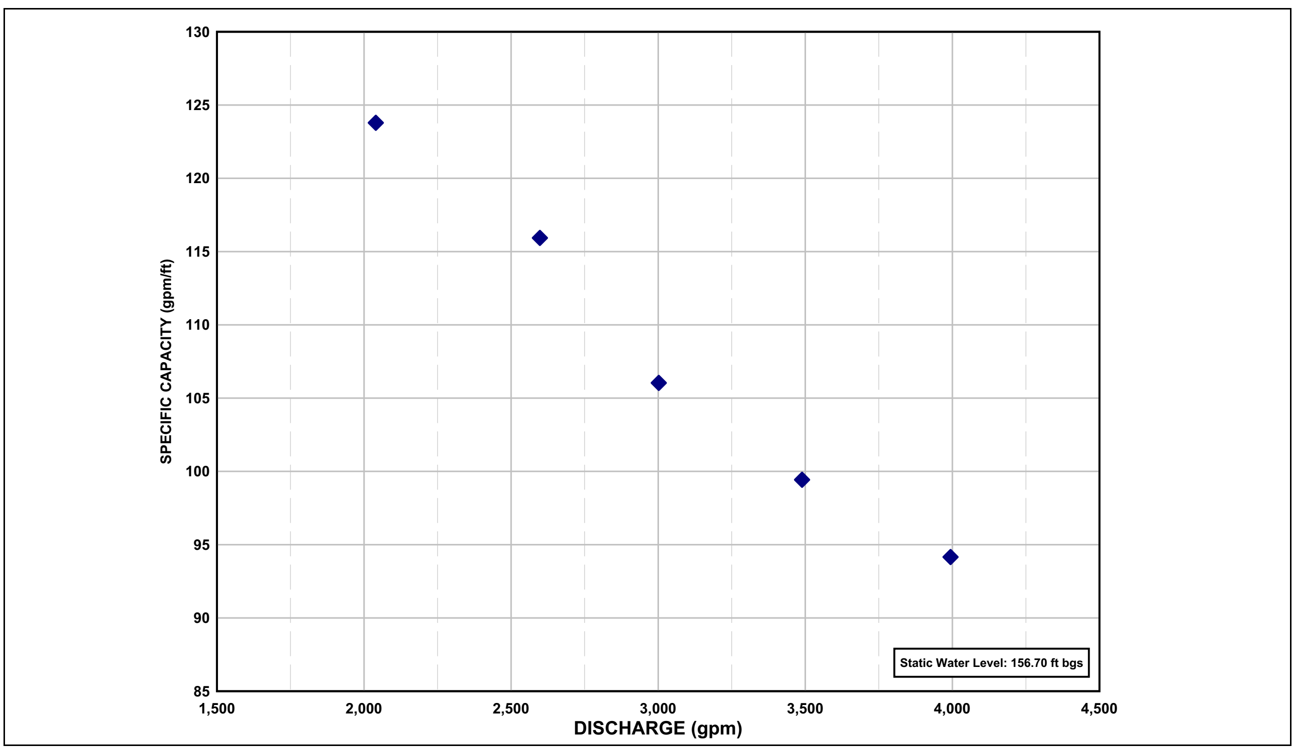


Figure 4-3
Step-Drawdown Test Specific Capacity Versus Discharge Rate for Test Well SPR7007X

turbulence occurring within the fractures than in a granular porous media as is present at Test Well SPR7007X.

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 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
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 6.5×10^{-3} and C of 7.9×10^{-7} was calculated using the Hantush-Bierschenk method. The coefficient of determination, R^2, 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:

$$\frac{s}{Q} = 6.5\times10^{-3} + 7.9\times10^{-7}Q \qquad \text{(Eq. 4-2)}$$

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

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

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

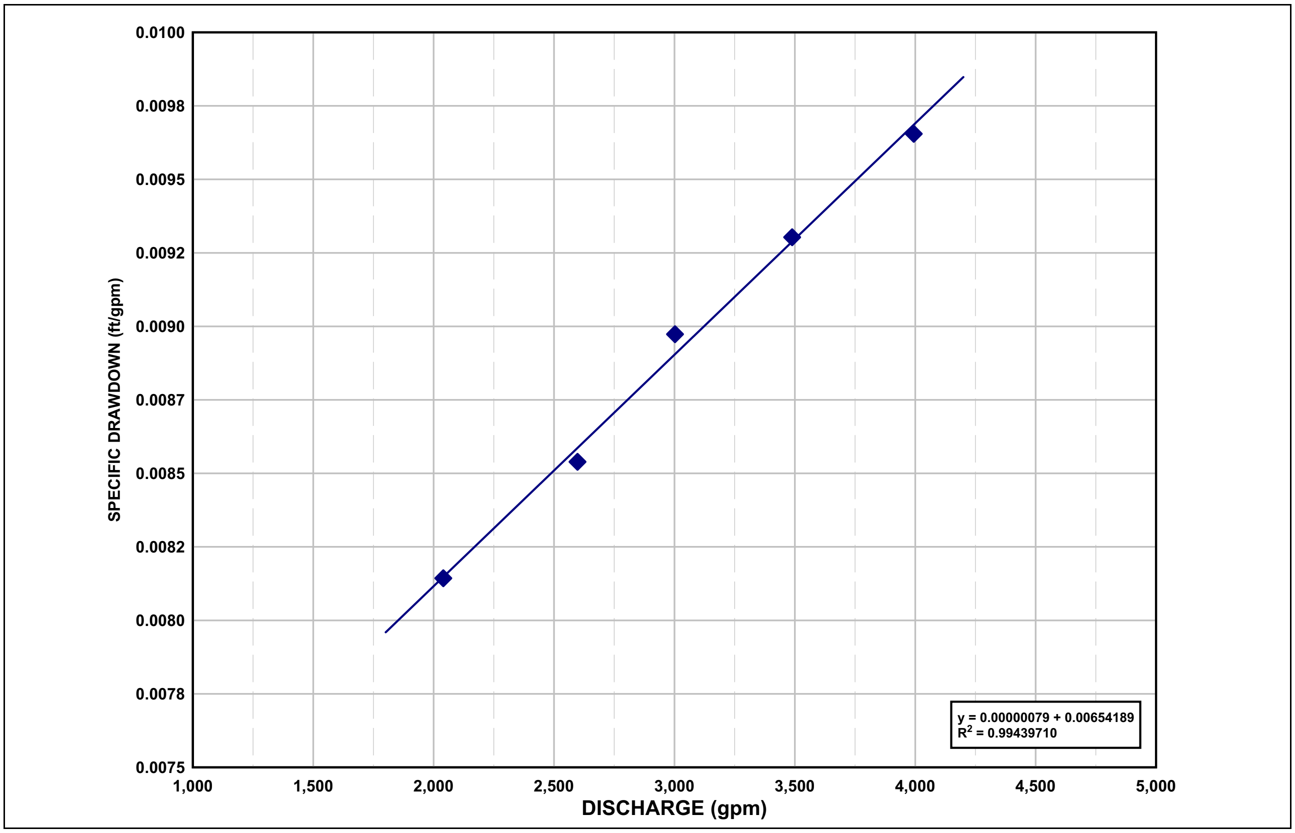


Figure 4-4
Evaluation of Head Loss Coefficients Using Hantush-Bierschenk Method from Step-Drawdown Test Results

Table 4-1 shows that the nonlinear losses compose about 20 to 33 percent of the drawdown within the pumping discharge range of approximately 2,000 to 4,000 gpm used in the step test, the percentage increasing with increasing production rate. The nonlinear losses at the pumping rate of 3,000 gpm used in the constant-rate test is 27 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 (%)
2,040	16.61	0.0081433	3.29	13.35	16.63	20
2,598	22.18	0.0085392	5.33	16.99	22.32	24
3,002	26.94	0.0089732	7.12	19.64	26.76	27
3,489	32.46	0.0093032	9.62	22.82	32.44	30
3,994	38.56	0.0096549	12.60	26.13	38.73	33

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5.0 CONSTANT-RATE TEST EVALUATION

This section summarizes the hydraulic testing data, selection of analytical solutions for evaluation of drawdown and pumping data, and analysis results of the 120-hour constant-rate and recovery at Test Well SPR7007X.

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.

Outside effects, such as changes in barometric pressure, regional water-level trends, and precipitation events, were monitored during the test period. No other pumping wells were present in the area to influence the test results. A rapid and substantial barometric shift occurred at 1,800 min into the test. The record was adjusted to compensate for the shift during analysis. Snow and melting events occurred during the testing. However, the ground was frozen within an inch of the surface at several locations inspected around the test area outside the Swallow Springs discharge channel area. A discussion of background data and outside influences is presented in Section 3.4.

Totalizer readings indicated a total volume of 21,611,300 gal were pumped during the 120-hour test, an average of approximately 3,000 gpm during the test. No significant flow adjustments or interruptions occurred during the test. However, multiple minor flow adjustments were made during the constant-rate test to keep the discharge rate within 10 percent of the target rate. The adjustments made are listed in Table 5-1. Of particular note is the flow adjustment that occurred at 1,496 min into the test. The engine rpms dropped unexpectedly which decreased the flow rate down to 2,500 gpm briefly. The engine was throttled back up and flow stabilized back to 3,000 gpm within 5 min. According to the pump crew, the throttle lock had some play which allowed the throttle to slip. The throttle lock was repaired.

During the initial four minutes of the test, small variations in drawdown associated with pump activation were observed. These were the result of borehole storage effects, water filling the pump column, and pressure variations at the flow control valve. Vertical flow losses within the well were considered during analysis. The friction losses within the test well were calculated to be relatively small compared to the drawdown observed in the well.

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 created a short-term injection pulse into the well that

Table 5-1
Pumping Rate Adjustments

Date	Time	Elapsed Time (min)	Discharge (before gpm)	Discharge (after gpm)
2/12/2008	8:45	14	2,980	3,010
2/12/2008	10:29	118	2,979	3,010
2/12/2008	12:34	243	2,970	3,009
2/12/2008	16:34	483	2,979	3,002
2/12/2008	19:39	668	2,973	3,005
2/12/2008	20:37	726	3,035	3,000
2/12/2008	22:00	809	2,995	3,001
2/13/2008	2:35	1084	2,991	3,000
2/13/2008	7:30	1379	3,030	3,005
2/13/2008	9:00	1496	2,500	3,000
2/13/2008	23:23	2332	2,981	3,007
2/13/2008	16:27	1916	2,978	3,009
2/14/2008	2:55	2544	3,043	3,001
2/15/2008	5:00	4109	2,965	3,015
2/15/2008	6:00	4169	3,029	3,015
2/15/2008	8:00	4289	3,020	3,010
2/15/2008	10:00	4409	3,020	3,010
2/16/2008	9:00	5789	3,026	3,000
2/17/2008	7:13	7122	2,970	3,000

is superimposed on the recovery record. The recovery water level then quickly decayed back to the aquifer recovery response. This effect is observed in both the test well and the monitor well and does not influence the analysis of the recovery data after the pulse reaches equilibrium.

5.2 Constant-Rate Test Data

The constant-rate test was performed for a duration of 120 hours at a target pumping rate of 3,000 gpm. A summary of drawdown data for Monitor Well SPR7007M and Test Well SPR7007X is presented graphically in log-log and semi-log form on Figures 5-1 through 5-4. Transducer and physical test data are presented in Appendix A.

5.3 Analytical Model Selection

The analytical models used for the aquifer-properties evaluation were selected based upon observed site hydrogeologic conditions and diagnostic log-log and drawdown derivative plots. The drawdown curve and derivative plot are representative of a unconfined system which would be expected in a course grained alluvial fan environment. The Moench (1997) unconfined solution, which incorporates delayed gravity drainage, wellbore storage, and wellbore skin effect, was selected as the primary evaluation method. Neuman (1975) unconfined solution, which considers delayed gravity drainage, and Theis (1935) were used as secondary analytical solutions for comparison purposes.

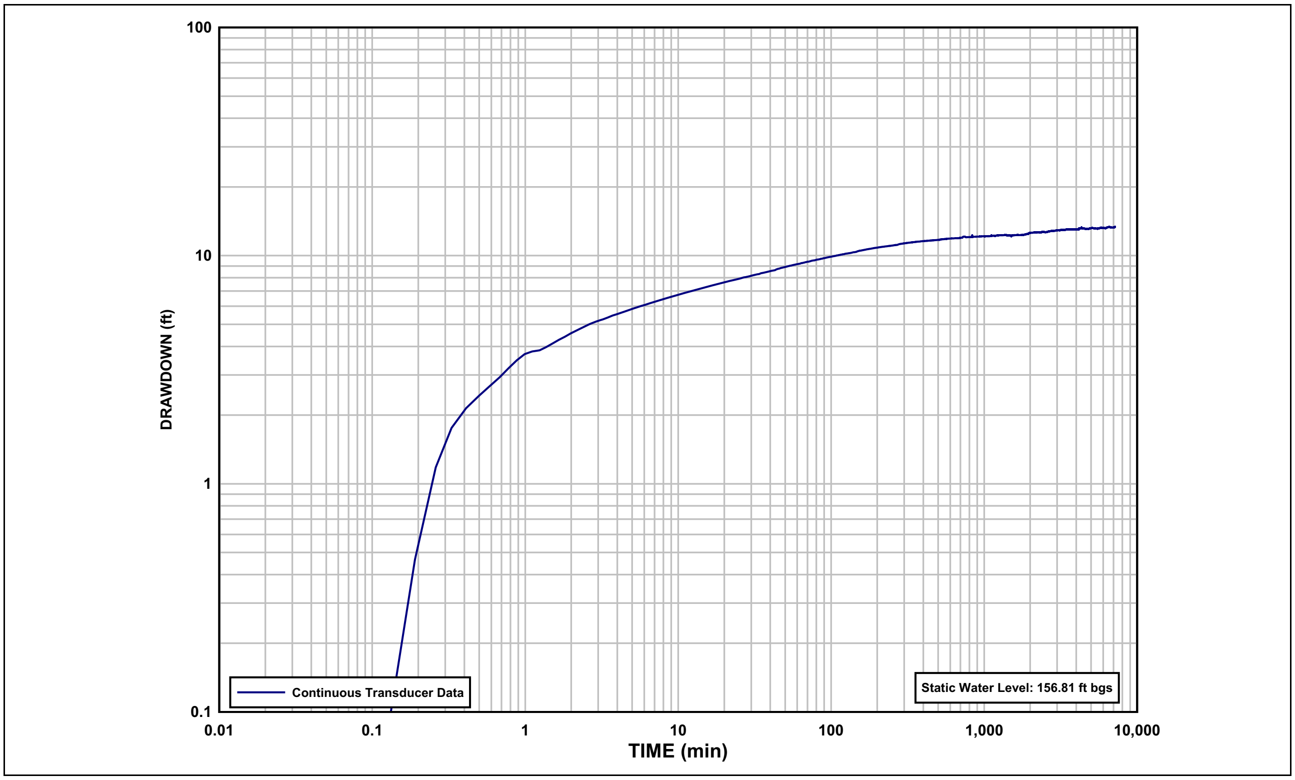

Figure 5-1
Log-Log Data Plot of Drawdown versus Time from Monitor Well SPR7007M

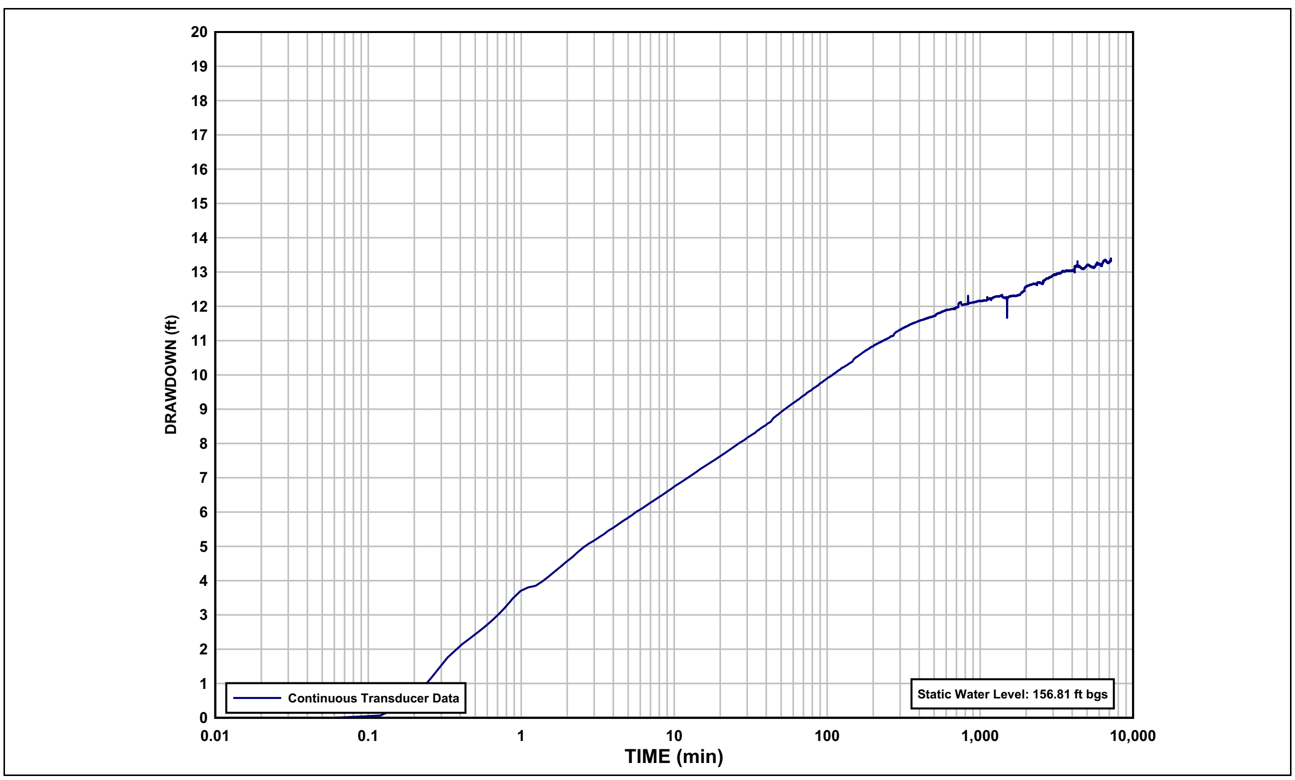

Figure 5-2
Semi-Log Data Plot of Drawdown versus Time from Monitor Well SPR7007M

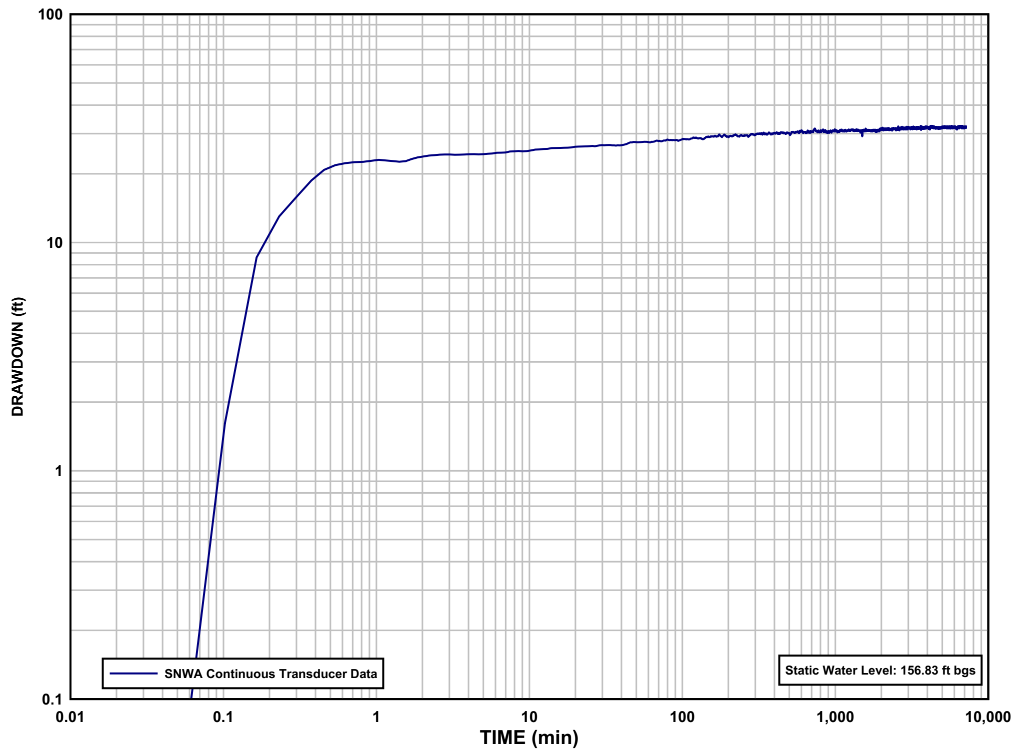

Figure 5-3
Log-Log Data Plot of Drawdown versus Time from Test Well SPR7007X

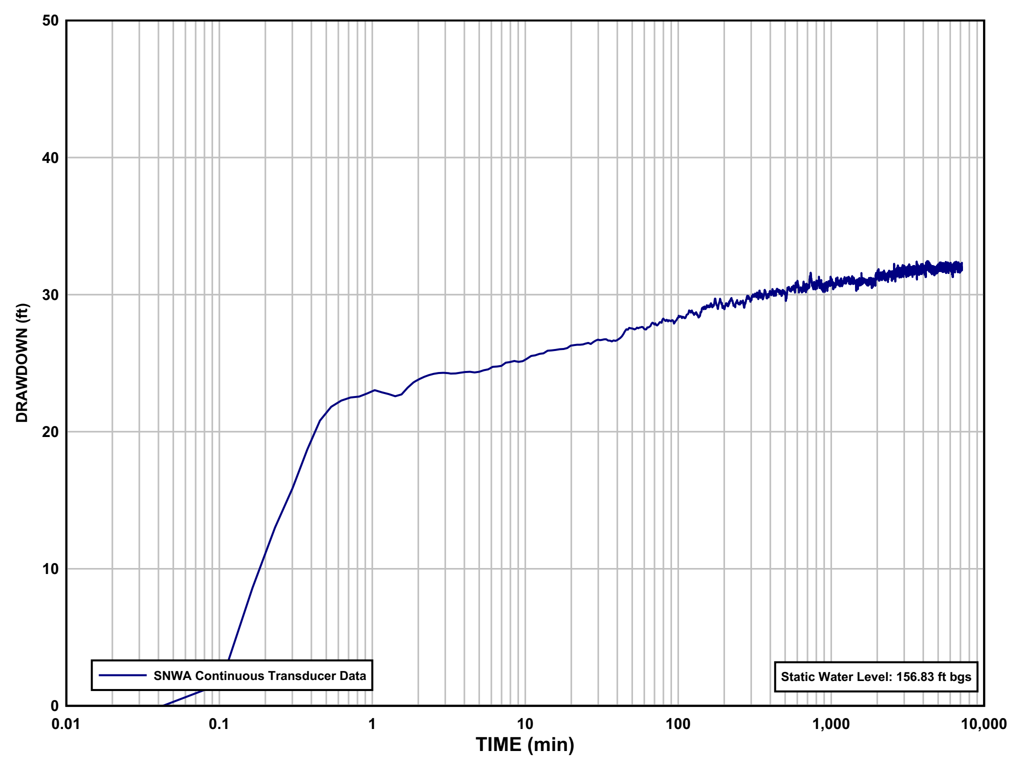

Figure 5-4
Semi-Log Data Plot of Drawdown versus Time from Test Well SPR7007X

General assumptions associated with the Moench solution include:

- The aquifer has infinite extent and uniform extent of flow.
- Pumping and observation wells are fully penetrating.
- Flow is unsteady.

The complexities of the aquifer system do not fully conform to the assumptions of the analytical model. However, the Moench solution is the most appropriate of the analytical solutions available for the observed hydrogeologic conditions at this test location and allows for analysis of delayed gravity drainage and test well losses. 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

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 time representing the measurement at the start of identifiable drawdown at the test well was used as the start time to determine the elapsed time and drawdown magnitude. The 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

r(w) Radius of the well	1.17 ft
r(c) Radius of the well casing	0.83 ft
r(e) Radius of the production tubing	0.44 ft
r Radial distance from SPR7007X to SPR7007M	99 ft
b Aquifer saturated thickness[a]	883 ft

[a]Static water level to bottom of the borehole

Parameter symbols used in this section are presented below:

K = Aquifer hydraulic conductivity (ft/day)
Q = Pumping discharge rate (gpm)
Sw = Wellbore skin factor or well loss coefficient value (dimensionless)
s = Drawdown at pumping well
b = Saturated thickness
t = Time
T = Transmissivity (ft^2/day)
Sy = Specific Yield (dimensionless)

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. As a result, a dewatering correction was not applied to the data set.

The Moench solution was fitted to the drawdown and recovery responses of both the test well and the 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. The monitor well response provides information on the formation hydraulic properties independent of linear and nonlinear head losses associated with the pumping well and theoretically provides the information necessary to determine storage. However, the information from the single monitor well is not as definitive as multiple observation wells to evaluate and define asymmetry and horizontal anisotropy.

5.4.2 Test Analysis Result Summary

The Moench unconfined solution was derived through an extensive iterative analysis process that converged to provide an optimal match for all test data. The primary solution was verified through application of the Neuman unconfined secondary solution and a more simplified Theis solution using data from the monitor well which is uneffected by test well losses. Results of the solutions are summarized in Table 5-3.

Table 5-3
Summary of Analysis Results

Primary Solution				
Solution Method	***T*[a] (ft^2/day)**	***K* (ft/day)**	***Kz/Kr***	***Sy***
Moench	35,600	40.3	0.03-0.07	0.22
Secondary Solution				
Solution Method	***T*[a] (ft^2/day)**	***K* (ft/day)**	***Kz/Kr***	***Sy***
Neuman	29,100	33.0	0.01	0.3
Theis	34,000	38.5	0.01	N/A
Theis Recovery	34,600	39.2	N/A	N/A

[a]Assume saturated thickness of 883 ft to derive *K*.

5.4.3 Test Analysis

The Moench unconfined solution was fitted to the data iteratively to refine the fit and produce an overall model that was consistent with all site and literature data and 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.

The results of the Moench analyses for transmissivity (*T*) was 35,600 ft^2/day. This corresponds to an aquifer hydraulic conductivity (*K*) 40.3 ft/day assuming a saturated thickness of 883 ft. Specific yield was 0.22. The effects of delayed gravity drainage were observed to begin at approximately 100 min. The anisotropy ratio of vertical to horizontal *K* (*Kz/Kr*) values was calculated at 0.03 indicating relatively low vertical hydraulic conductivity consistent with a stratified environment. The optimal log-log and semi-log time analysis plot for the pumping period using the Moench solution are presented in Figures 5-5 and 5-6.

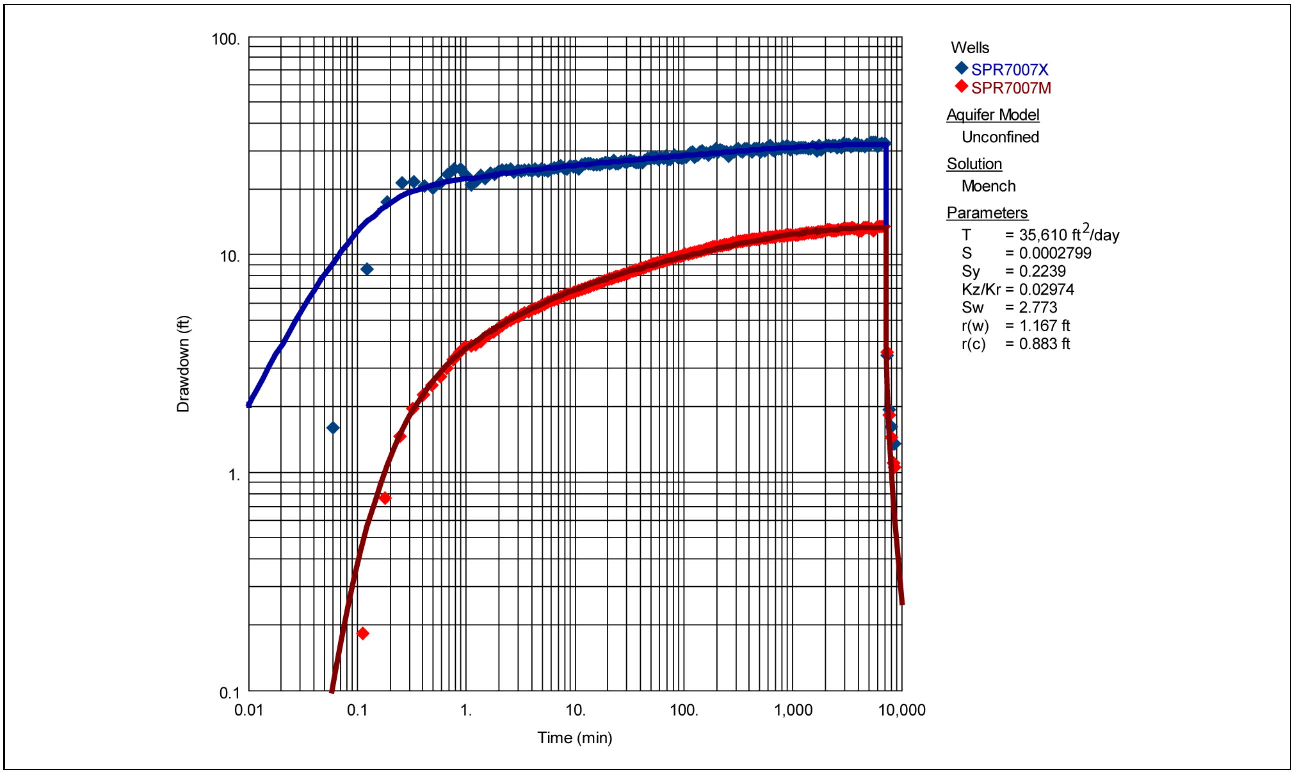

Figure 5-5
Optimal Moench Solution Pumping Period Log-Log Plot

An evaluation of increased saturated thickness and consideration of associated partial penetration effects were performed using the Moench solution to estimate variation in *T.* The conservative estimate is based upon the saturated thickness of the formation as the difference between static water level and the depth of the gravel pack at the base of the well which is 883 ft. The exact saturated thickness is not know. However, based upon estimates of saturated thickness from geophysical surveys, an analysis range of 1,200 to 2,000 ft was selected. This resulted in a range of *K* from 37.3 to 38.0 ft/day. *T* values ranged from 45,200 to 74,700 ft^2/day for saturated intervals of 1,200 and 2,000 ft, respectively. *T* values are directly proportional to *K* and the estimated saturated thickness.

The secondary Neuman unconfined solution, which also considers delayed gravity drainage but not wellbore skin effect, resulted in an *T* of 29,100 ft^2/day. This corresponds to an aquifer *K* of

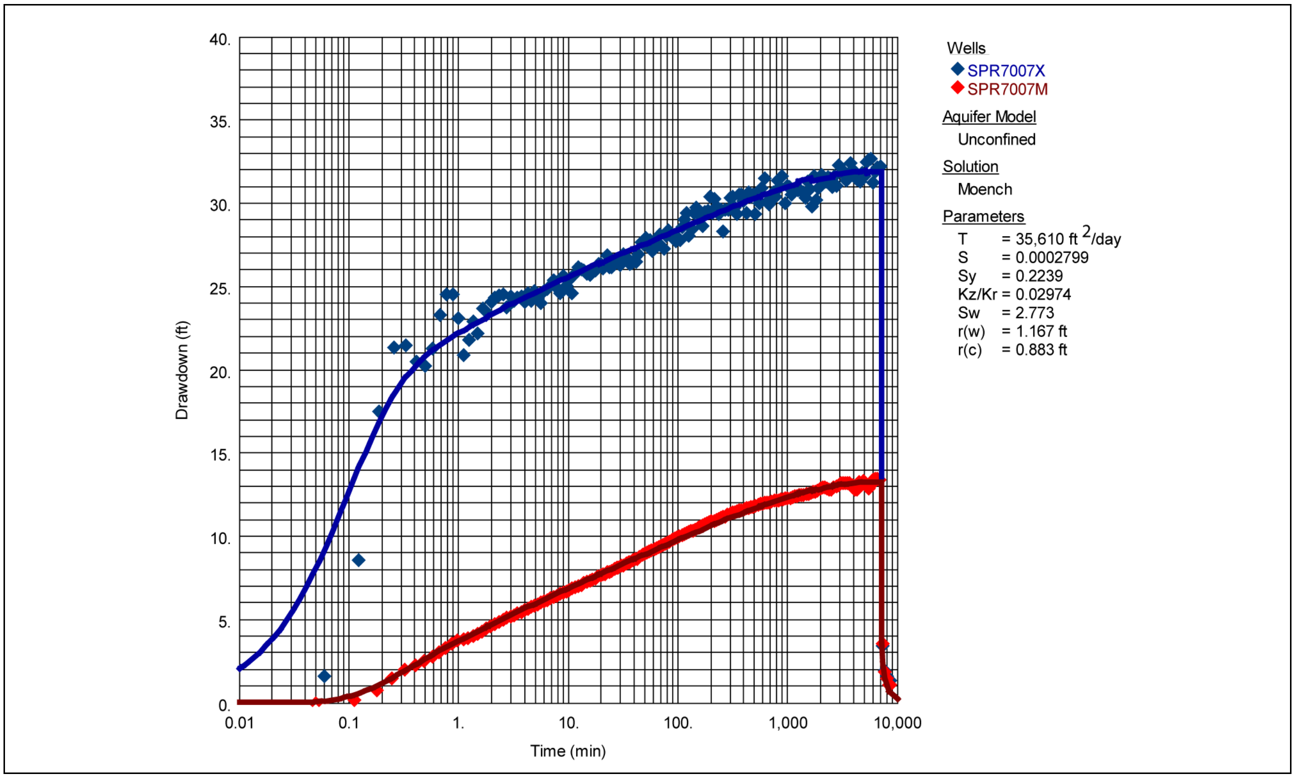

Figure 5-6
Optimal Moench Solution Pumping Period Semi-Log Plot

33.0 ft/day assuming a saturated thickness of 883 ft. The analysis result for specific yield is 0.3. The Neuman analysis results were used for comparison and only considered monitoring well data. Results of the more simplified Theis solution, which does not consider delayed gravity drainage resulted in *T* values of approximately 34,000 ft^2/day.

Analysis results of recovery data collected from the monitor well are presented in Figure 5-7. 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. The recovery data from Monitor Well SPR7007M was analyzed using the Theis recovery method with a result of 34,600 ft^2/day.

Wellbore skin or loss evaluation of Test Well SPR7007X was incorporated into the Moench analysis. This provides an indication of drawdown in the formation in the vicinity of the test well outside of the drawdown distortion caused by well losses from turbulent flow and well construction. This calculation of drawdown without well losses provides a more realistic value of aquifer drawdown in the vicinity of the test well during testing. Approximately 27 percent of drawdown in the test well at 3,000 gpm is considered to be associated with nonlinear well loss based upon the step test analysis. At the end of the 3,000 gpm constant-rate test, observed drawdown at the test well was 31.4 ft. This equates to an approximately 22.9 ft of drawdown from aquifer loss and 8.5 ft from nonlinear well loss.

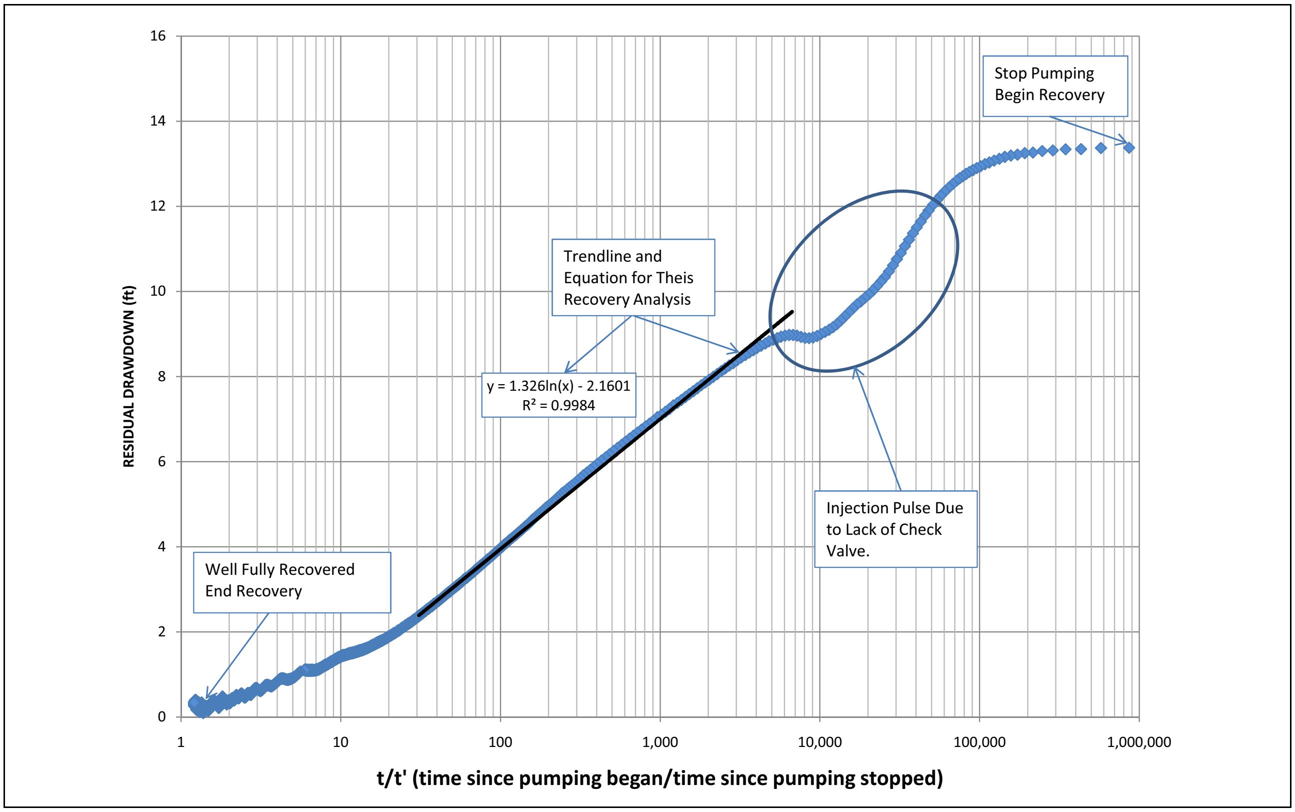

Figure 5-7
Monitor Well SPR7007M Recovery Data Presenting Residual Drawdown versus the Log of the Ratio of t/t'

The short-term pumping period, availability of one observation well, and expected aquifer heterogeneities limit the ability to scale results to determine horizontal anistropy 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.

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6.0 GROUNDWATER CHEMISTRY

Groundwater-chemistry data for Test Well SPR7007X and Monitor Well SPR7007M are presented within this section. Additional data for other SNWA wells located in 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 by SNWA from Test Well SPR7007X on February 14, 2008 at 10:00 AM after pumping approximately 16 million gal (following well development, step-drawdown testing, and a portion of the constant-rate test). 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 methods published by U.S. Environmental Protection Agency (EPA) in *Standard Methods for the Examination of Water and Wastewater* (Eaton et al., 2005). The parameters analyzed for and the corresponding EPA analytical method 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 by SNWA for analysis of oxygen and hydrogen isotopes by University of Waterloo's Environmental Isotope Laboratory, carbon isotopes by the University of Arizona's National Science Foundation (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 U.S. Geologic Survey (USGS) Earth Surface Processes Radiogenic Isotope Laboratory.

Water samples were collected by SNWA from Monitor Well SPR7007M on September 5, 2007 at 1:15 PM after pumping approximately 53,360 gal. Samples were sent to Weck for analysis of major solutes and trace and minor constituents. A sample was also collected by SNWA 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 during sampling. Monitor Well SPR7007M was used as the water source for drilling Test Well SPR7007X.

The groundwater chemistry of additional wells in the area are presented on a Piper diagram in this section for comparison. The aquifer material and total depths of all the wells drilled by SNWA in the vicinity of Test Well SPR7007X (see Figure 2-1), are given below (Table 6-1).

Table 6-1
Total Depths for Wells Drilled by SNWA

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
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 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. All the measured parameters in the Test Well SPR7007X fell below the EPA's MCL. However, the 60 µg/L of aluminum measured in the Monitor Well SPR7007M falls within the EPA's secondary MCL of 50 to 200 µg/L. Exceedances will be discussed further in Sections 6.3.3 and 6.3.6.

6.3 Groundwater-Chemistry Results

In this section, the field measurements and analytical results for the groundwater of Monitor Well SPR7007M and Test Well SPR7007X are presented and the major ion constituents are compared to those of groundwater samples from the other wells within the vicinity on Piper diagram in Figure 6-1. Data for the other wells in the vicinity are presented in their respective reports.

6.3.1 Field Results

Field measurements of turbidity, pH, specific conductance, and temperature were performed periodically throughout the development and testing of Test Well SPR7007X and for the samples collected for laboratory analysis (see Table B-1). For Test Well SPR7007X, these parameters stabilized within the first hour of the constant-rate test. Measurements ranged from 0.10 to 2.27 NTU for turbidity, 6.76 to 7.94 for pH, 243 to 305 µS/cm for specific conductance, and 7.3°C to

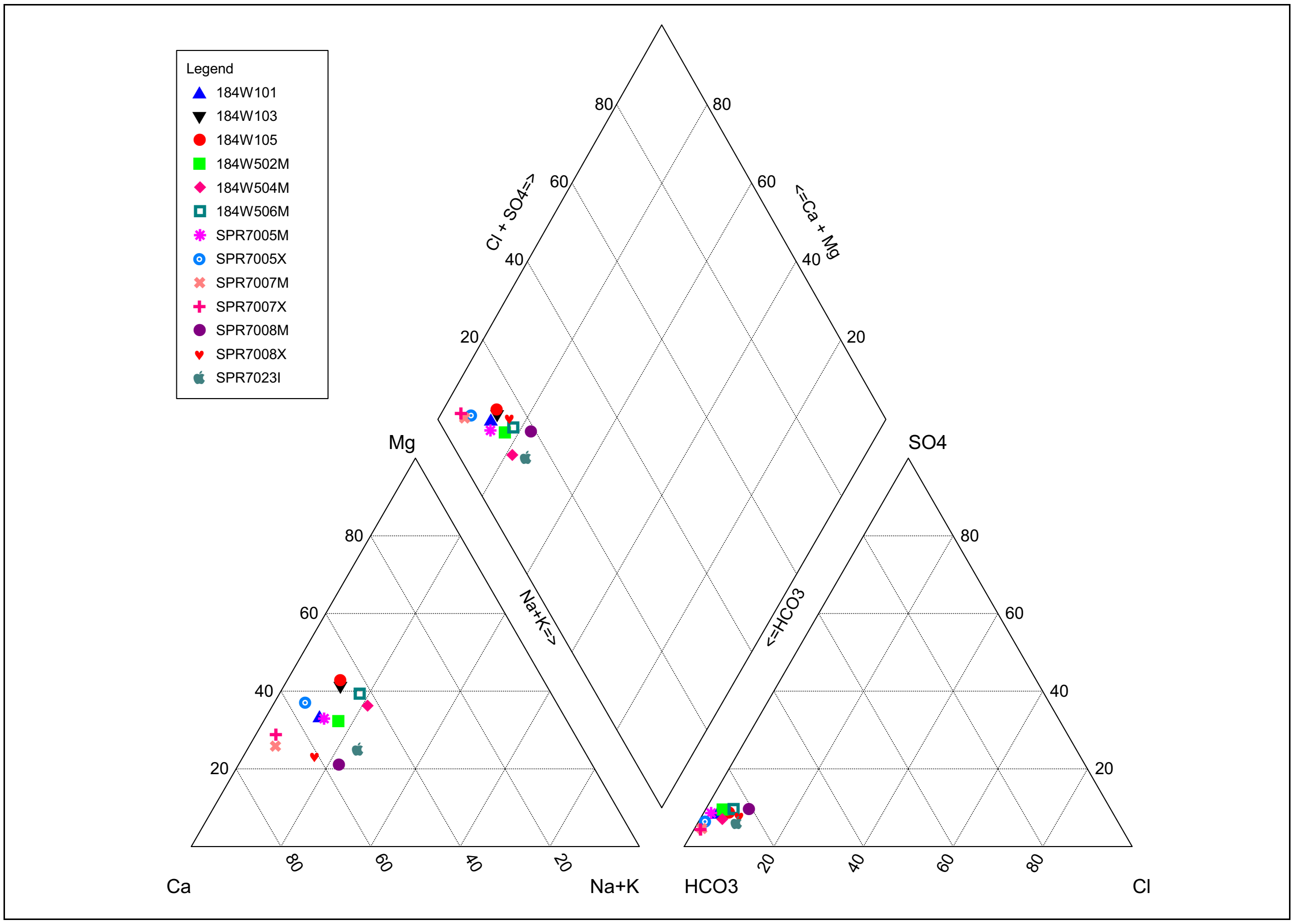

Figure 6-1
Piper Diagram Illustrating Relative Major-Ion Compositions

12.5°C for temperature with no observable trends. Field measurements made at the time of sample collection are reported as 0.52 NTU, 305 µS/cm, 7.58, 9.1°C, and 7.4 mg/L for turbidity, specific conductance, pH, water temperature, and dissolved oxygen concentration respectively.

During an 8-hour constant-rate test for Monitor Well SPR7007M, turbidity continued to decrease from 520 to 40.2 NTU. Field measurements of pH and specific conductance ranged from 7.43 to 7.93 and 210 to 320 µS/cm, respectively. No dissolved oxygen concentration measurements were made for the groundwater of Monitor Well SPR7007M. Field measurements made at the time of sample collection are reported as 343 µS/cm, 7.86, and 14.3°C for specific conductance, pH, and water temperature, respectively.

The water temperatures measured in Test Well SPR7007X and Monitor Well SPR7007M were relatively low but were not significantly different from those measured in other carbonate-rock aquifer wells (e.g., Test Wells 184W103 and 184W105 had temperatures of 12°C and 13°C, respectively). They were however lower than the temperatures of 24.1°C and 24.3°C measured in the relatively deeper wells Test Wells 184W101 and SPR7005X, respectively. The specific conductance of 305 µS/cm measured in Test Well SPR7007X is slightly lower than the value of 343 µS/cm measured in the corresponding Monitor Well SPR7007M but is not significantly different from the values measured in the wells in the vicinity. The range in pH between the monitor wells and the test wells in the area is quite small, and, with a few exceptions, those measured in the test wells are generally lower than those measured in the monitor wells probably due to the relatively longer aquifer testing of the test wells prior to sampling. With the exception of the of Test Well 184W101 with a dissolved oxygen (DO) concentration of 2.3 mg/L, the DO concentrations of all the test wells are greater than 3.0 mg/L and suggest oxidizing conditions in the area. The high DO value of 7.4 mg/L measured in Test Well SPR7007X is not uncommon in alluvial basins in the Great Basin (Robertson, 1991).

6.3.2 Major Constituents

The concentrations of the major constituents in groundwater samples from Test Well SPR7007X and Monitor Well SPR7007M 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 SPR7007X and Monitor Well SPR7007M groundwater analyses, 1.6 and 2.8 percent, respectively, indicate that the analyses were adequately performed. (Table B-1).

The relative major-ion compositions in the groundwater samples are illustrated by a Piper diagram 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 or differences in major-ion compositions of groundwater 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 the major ions are similar for all the groundwater samples. The predominant cations are calcium and magnesium, and the predominant anion is bicarbonate. Most of the groundwater samples can be classified as calcium-magnesium-bicarbonate facies. This water type is typical of dissolution of calcite and dolomite in waters of carbonate-rock aquifer which is the predominant aquifer in the area. This is because the composition of groundwater is determined by reactions of water with minerals present in the aquifer material through which the water flows. The relative concentrations of sodium plus potassium (Na + K) are slightly greater in the groundwater samples from Monitor Well SPR7008M and Test Well SPR7023I.

6.3.3 Trace and Minor Constituents

The concentrations of trace elements in the groundwater from Test Well SPR7007X and Monitor Well SPR7007M are presented in Table B-1. The concentrations of trace elements in the Test Well SPR7007X are generally lower than those in the Monitor Well SPR7007M and could be due to the short-term development and pumping of the monitor well (8 hours) in comparison with the test well which was developed and pumped for about 72 hours before sampling. The trace element concentrations of the test well are all less than the primary and secondary MCLs of drinking water established by the EPA. In particular, the concentration of arsenic with an MCL of 10 μg/L was nondetect in Test Well SPR7007X. Similarly, with the exception of aluminum, the trace element concentrations of Monitor Well SPR7007M fell below the EPA's MCL. The aluminum concentration of 60 μg/L measured in Monitor Well SPR7007M is above the minimum value of the secondary MCL for aluminum which ranges from 50 to 200 μg/L. The concentrations of strontium in the Test Well SPR7007X and Monitor Well SPR7007M were relatively high, and were 180 and 170 μg/L, respectively.

6.3.4 Stable Isotopes and Environmental Tracers

The stable hydrogen, oxygen, and carbon isotopic compositions of the groundwater samples from Test Well SPR7007X and the stable hydrogen and oxygen isotopic compositions of the groundwater samples of Monitor Well SPR7007M are presented in Table B-1. Table B-1 also presents chlorine-36, strontium-87/86, and uranium-234/238 data for the groundwater sample collected from Test Well SPR7007X.

6.3.4.1 Hydrogen and Oxygen Isotopes

Stable isotopes of hydrogen and oxygen behave conservatively in most groundwater systems and, therefore, can be used to indicate groundwater source, trace groundwater flowpaths, evaluate possible mixing of groundwater along a flowpath, and evaluate water budgets. Isotopic concentrations are reported using the 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 SPR7007X and Monitor Well SPR7007M are presented in Table B-1 and Figure 6-2 (mean values). The mean δD values are -109.7 and -109.1‰ for Test Well SPR7007X and Monitor Well SPR7007M, respectively, and their mean $\delta^{18}O$ values are -15.2 and -14.95‰. 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). Data for the other wells are in their respective reports. The groundwater samples exhibit similar relatively light stable isotope ratios that are typical of recharge at high elevations and cold temperatures. The samples from Test Well SPR7007X and Monitor Well SPR7007M plot slightly above the GMWL, similar to those of Test Well SPR7008X and Monitor Well SPR7008M. The location of the plots above the GMWL suggests that the water did not undergo any significant evaporation prior to recharging. It also rules out any isotopic exchange between the water and the aquifer material.

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

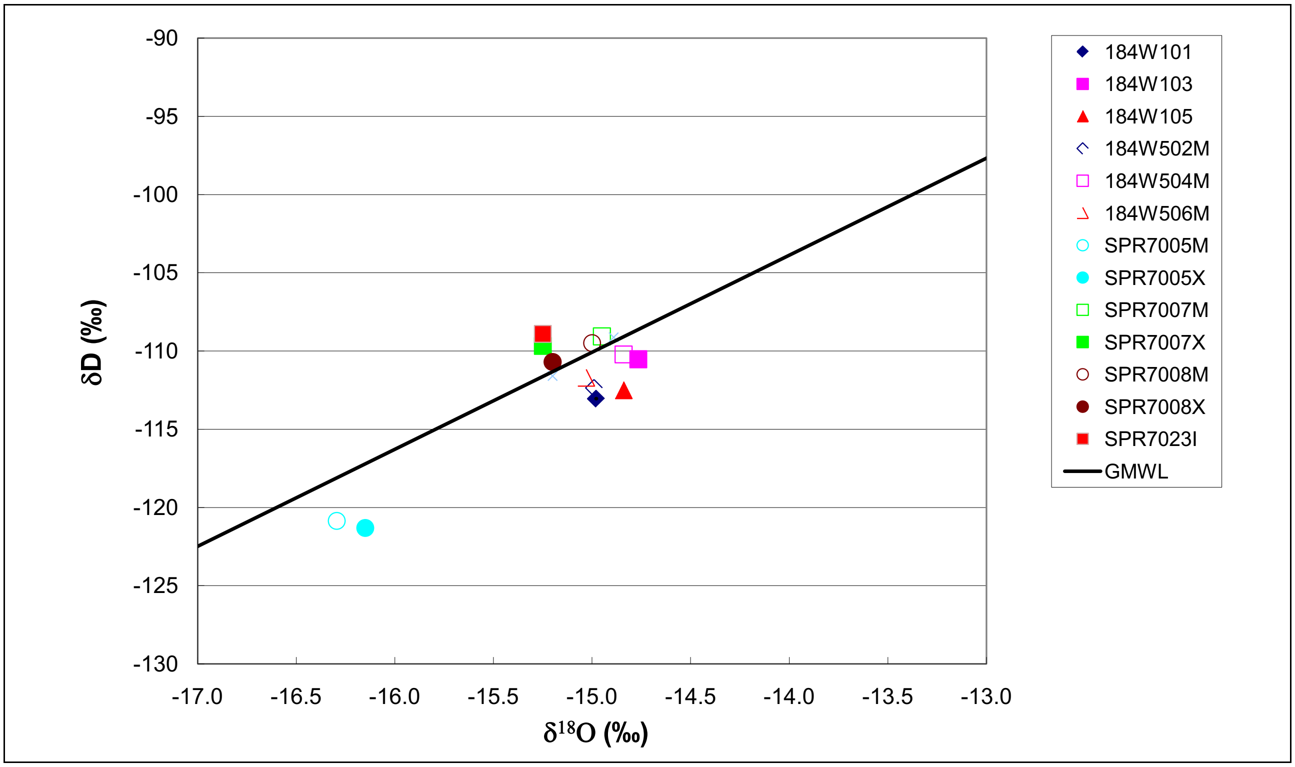

Figure 6-2
Plot of δD versus δ^{18}O

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 1,000 TU during the early 1960s (Drever, 1988). 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 for precipitation samples, collected by Desert Research Institute and analyzed through SNWA in 2008, from the Egan, Schell Creek, and Snake Ranges in east-central Nevada were 8.4, 12.3 and 9.4 TU, respectively.

Two measurements on samples from Test Well SPR7007X resulted in values of 9.3 and 9.4 TU. These values were similar to the values measured in precipitation collected in the study area in 2008 by SNWA. The measured high tritium content suggests that the groundwater in Test Well SPR7007X is quite young and has a very high component of modern recharge. No samples from Monitor Well SPR7007M were collected for tritium analysis.

6.3.4.3 Carbon Isotopes

The δ^{13}C value of groundwater is used to assess the extent of isotope mass transfer that occurs 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 δ^{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 Test Well SPR7007X were −7.6‰ and 57.01 pmc, respectively. Carbon isotopes were not measured for the Monitor Well SPR7007M. The relatively high ^{14}C and relatively light value of $\delta^{13}C$ suggest that the groundwater is quite young and has not interacted with isotopically heavier carbonate minerals. From these data, it appears that water-rock interactions have not occurred to any great extent along the groundwater flowpath.

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 $^{36}Cl/Cl$ ratios are consistent with precipitation in the southwestern United States (Davis et al., 1998). The $^{36}Cl/Cl$ ratios for two samples taken from the Test Well SPR7007X were 567×10^{-14} and 500×10^{-15} and the chloride concentrations were each 1.6 mg/L. These numbers are very comparable with measurements made elsewhere in Nevada (Plummer et al., 1997).

6.3.4.5 Strontium and Uranium Isotopes

The ratio of radiogenic to nonradiogenic strontium ($^{87}Sr/^{86}Sr$) has been used to identify groundwater sources, to evaluate potential mixing components, and to identify rock types through which groundwater has flowed. Groundwater $^{87}Sr/^{86}Sr$ ratio for Test Well SPR7007X is 0.71261, 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 Test Well SPR7007X is 2.314, and is relatively similar to the ratio of 2.545 measured for Test Well SPR7005X. The $^{234}U/^{238}U$ activity ratios of the samples are greater than one, the equilibrium value, probably due to the oxidizing nature of the aquifer. Preferential dissolution of ^{234}U in the oxidizing zones of the aquifer in addition to some recoil of ^{234}Th could result in the higher $^{234}U/^{238}U$ activity ratios. The uranium concentration in Test Well SPR7007X was 0.576 μg/L.

6.3.5 Radiological Parameters

Radiological parameters were analyzed in groundwater from Test Well SPR7007X and the corresponding results are presented in Table B-1. The activities of the samples are generally less than the reporting limits for each of the parameters and are consistent with background activities in natural groundwater.

6.3.6 Organic Compounds

A large suite of organic compounds was analyzed for groundwater samples collected from Test Well SPR7007X. The corresponding minimum detection levels and MCLs (where applicable) are presented in Table B-1. No organic compounds were detected. No analyses for organic compounds were performed for the groundwater samples from Monitor Well SPR7007M.

6.4 Summary

Groundwater samples were collected from Test Well SPR7007X and Monitor Well SPR7007M and analyzed for a suite of chemical parameters. Both wells were completed in the alluvial system. 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 to data from samples collected from other SNWA wells in the vicinity on a Piper diagram. Groundwater in both wells was calcium-magnesium-bicarbonate facies and reflects the dominance of the carbonate system in the area and the surrounding mountains. The stable isotopic compositions were very light and plotted above the GMWL, suggesting that the water did not undergo any significant secondary processes (e.g., evaporation) prior to recharge.

The ^{14}C activity of 57.01 was relatively high and the tritium activity of 9.3 TU was comparable with that of present day precipitation in mountains surrounding Spring Valley. The relatively high ^{14}C and light $\delta^{13}C$ value, and the high tritium content suggest that the groundwater is recharged by modern precipitation and has not interacted with isotopically heavy minerals. The $^{36}Cl/Cl$ ratios measured for two samples collected from Test Well SPR7007X were consistent with modern precipitation in the southwestern United States. The samples from the monitor wells were not analyzed for $^{36}Cl/Cl$, $\delta^{13}C$, ^{14}C, and tritium activity.

The data were also evaluated with respect to the EPA Safe Drinking Water Act standards. No constituent exceeded the secondary MCL.

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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, SPR7007X and SPR7007M, were 184W118 and 184W519M, 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 provide an overview of the well site and testing program locations. The well site and equipment is presented in Figure A-1. A view of Swallow Canyon and Swallow Springs facing ESE from the well site is shown in Figure A-2. The wellhead setup and discharge line are shown in Figure A-3 and Figure A-4, respectively. Figures A-5 through A-8 presents test monitoring instrumentation at Monitor Well SPR7007M, Swallow Springs North Flume, Swallow Springs South Flume, and Minerva Spring piezometer.

A.1.2 Read-Me File

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

A.1.3 Background Water-Level Data

A spreadsheet containing the continuous water-level data from SNWA Monitor Well 184W502M. This well was used to monitor background conditions during development and testing at Test Well SPR7007X.

A.1.4 Barometric-Pressure Data

Barometric-pressure data are located in the continuous record data files associated with Test Well SPR7007X and ET Station SV1. An In-situ HERMIT 3000 data logger recorded the barometric pressure during the development and testing at well SPR7007X. These data can be found in files labeled "SPR7007X Constant Rate 3,000 gpm XDR Data.xls" for the constant-rate test and

Figure A-1
Test Well SPR7007X Wellhead Hydraulic Testing Equipment and Discharge Line

Figure A-2
Looking ESE toward Swallow Springs from Test Well SPR7007X

Figure A-3
Test Well SPR7007X WellHead Equipment and Piping Configuration

"SPR7007X Step Test Data and Analysis.xls" for the step-drawdown test. Barometric data from SNWA ET site SV1 are also included and can be found in the file labeled "SV1 Barometric Pressure Data for Testing at SPR7007X.xls."

All barometric-pressure data are reported in inches Hg.

A.1.5 Step-Drawdown Test Data

All manual and pressure transducer data are provided in the spreadsheet labeled "SPR7007X Step Test Data and Analysis.xls."

A.1.6 Constant-Rate Test Data

The constant-rate test data from Test Well SPR7007X are provided in the spreadsheets labeled "SPR7007X Constant Rate 3,000 gpm Manual Data.xls" for the manual data for the 3,000 gpm test; and "SPR7007X Constant Rate 3,000 gpm XDR Data.xls" for the continuously recorded transducer data for the 3,000 gpm test. The constant-rate test data from the observation well SPR7007M are provided in the spreadsheets labeled "SPR7007M Constant Rate 3,000 gpm OBS Manual Data test

Figure A-4
Test Well SPR7007X Hydraulic Testing Discharge Line

Figure A-5
Monitor Well SPR7007M with Water Level Measurement Instrumentation

Figure A-6
North Swallow Springs Flume and Temporary Transducer

Figure A-7
South Swallow Springs Flume and Transducer

Figure A-8
Minerva Spring Piezometer (SPR7007Z) and
Water Level Measurement Instrumentation

well SPR7007X.xls" for the manual data and "SPR7007X Constant Rate 3,000 gpm XDR Data.xls" for the continuously recorded transducer data.

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 Groundwater-Chemistry Data

The laboratory results from Weck Labs, Inc., are included in PDF format and labeled "SPR7007X(184W118)_8021527.pdf" for well SPR7007X and "SPR7007M(184W519M)_7091114 FINAL.pdf" for well SPR7007M.

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 SPR7007X and Monitor Well SPR7007M
(Page 1 of 3)

Constituent Name	Unit	Analysis Method	RL	SPR7007X (184W118) 2/14/2008 10:00	SPR7007M (184W519M) 10/31/2006 13:15	Primary MCL	Secondary MCL
Field Measured							
pH	units	Field	---	7.58	7.86	---	6.5 to 8.5
Conductivity	mS/cm	Field	---	305	343	---	---
Dissolved Oxygen	mg/L	Field	---	7.4	---	---	---
Temperature	°C	Field	---	9.1	14.3	---	---
Turbidity	NTU	Field	---	0.52	3.1	---	---
Stable Isotopes and Environmental Tracers							
Carbon-14 (^{14}C)	pmc	NA	---	57.01	---	---	---
Carbon-13/12 ($\delta^{13}C$)	per mil (‰)	NA	---	-7.6	---	---	---
Chlorine-36/Chloride ($^{36}Cl/Cl$)	ratio	NA	---	5.67E-12	---	---	---
Hydrogen-2/1 (δD)	per mil (‰)	NA	---	-109.7	-109.1	---	---
Oxygen-18/16 ($\delta^{18}O$)	per mil (‰)	NA	---	-15.25	-14.95	---	---
Tritium	TU	NA	0.8	9.4/9.3	---	---	---
Strontium 87/86	Ratio	NA	---	0.71261	---	---	---
Uranium 234/238	Activity Ratio	NA	---	2.314	---	---	---
Major Solutes							
Alkalinity Bicarbonate	mg/L as HCO_3	SM 2320B	2	180	190	---	---
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	150	150	---	---
Calcium	mg/L	EPA 200.7	0.1	42 | 42[b]	48	---	---
Chloride	mg/L	EPA 300.0	0.5	1.6	1.8	---	250
Fluoride	mg/L	EPA 300.0	0.1	ND	ND	4	2.0
Magnesium	mg/L	EPA 200.7	0.1	11 | 11[b]	11	---	---
Nitrate	mg/L as N	EPA 353.2/300.0	0.1/0.5	0.39	H 0.41	10	---
Potassium	mg/L	EPA 200.7	0.1	ND | 0.65[b]	0.69	---	---
Silica	mg/L	EPA 200.7	0.1	9.1	8.6	---	---
Sodium	mg/L	EPA 200.7	1 | 0.5	2.8 | 2.8[b]	4.2	---	---
Sulfate	mg/L	EPA 300.0	0.5	6.6	7.3	---	250
Cation/Anion Balance	%	Calculation	---	1.6	2.8	---	---

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 SPR7007X and Monitor Well SPR7007M
(Page 2 of 3)

<table>
<tr><th>Constituent Name</th><th>Unit</th><th>Analysis Method</th><th>RL</th><th>SPR7007X (184W118) 2/14/2008 10:00</th><th>SPR7007M (184W519M) 10/31/2006 13:15</th><th>Primary MCL</th><th>Secondary MCL</th></tr>
<tr><td colspan="8">Trace and Minor Constituents</td></tr>
<tr><td>Aluminum</td><td>µg/L</td><td>EPA 200.8</td><td>5</td><td>7.9 | ND[b]</td><td>60</td><td>---</td><td>50 to 200</td></tr>
<tr><td>Antimony</td><td>µg/L</td><td>EPA 200.8</td><td>0.5</td><td>ND | ND[b]</td><td>ND</td><td>6</td><td>---</td></tr>
<tr><td>Arsenic</td><td>µg/L</td><td>EPA 200.8</td><td>0.4</td><td>ND | ND[b]</td><td>0.44</td><td>10</td><td>---</td></tr>
<tr><td>Arsenic (III)</td><td>µg/L</td><td>EPA 200.8</td><td>2</td><td>ND</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>Arsenic (V)</td><td>µg/L</td><td>EPA 200.8</td><td>2</td><td>ND</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>Barium</td><td>µg/L</td><td>EPA 200.8</td><td>0.5</td><td>32 | 32[b]</td><td>36</td><td>2,000</td><td>---</td></tr>
<tr><td>Beryllium</td><td>µg/L</td><td>EPA 200.8</td><td>0.1</td><td>ND | ND[b]</td><td>ND</td><td>4</td><td>---</td></tr>
<tr><td>Boron</td><td>µg/L</td><td>EPA 200.7</td><td>10</td><td>18 | ND[b]</td><td>19</td><td>---</td><td>---</td></tr>
<tr><td>Bromide</td><td>µg/L</td><td>EPA 300.1</td><td>10</td><td>15</td><td>16</td><td>---</td><td>---</td></tr>
<tr><td>Cadmium</td><td>µg/L</td><td>EPA 200.8</td><td>0.1</td><td>ND | ND[b]</td><td>ND</td><td>5</td><td>---</td></tr>
<tr><td>Chlorate</td><td>µg/L</td><td>EPA 300.1</td><td>10</td><td>ND</td><td>ND</td><td>---</td><td>---</td></tr>
<tr><td>Chromium</td><td>µg/L</td><td>EPA 200.8</td><td>0.2</td><td>0.33 | ND[b]</td><td>0.29</td><td>100</td><td>---</td></tr>
<tr><td>Chromium (III)</td><td>µg/L</td><td>Calculation</td><td>0.2</td><td>ND</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>Chromium (VI)</td><td>µg/L</td><td>EPA 218.6</td><td>0.3</td><td>ND</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>Copper</td><td>µg/L</td><td>EPA 200.8</td><td>0.5</td><td>0.86 | 0.70[b]</td><td>0.98</td><td>1,300[C]</td><td>1,000</td></tr>
<tr><td>Iron</td><td>µg/L</td><td>EPA 200.7</td><td>20</td><td>ND | ND[b]</td><td>44</td><td>---</td><td>300</td></tr>
<tr><td>Lead</td><td>µg/L</td><td>EPA 200.8</td><td>0.2</td><td>ND | ND[b]</td><td>0.88</td><td>15[C]</td><td>---</td></tr>
<tr><td>Lithium</td><td>µg/L</td><td>EPA 200.7</td><td>10</td><td>ND | ND[b]</td><td>ND</td><td>---</td><td>---</td></tr>
<tr><td>Manganese</td><td>µg/L</td><td>EPA 200.8</td><td>0.2</td><td>1.1 | 0.97[b]</td><td>4.4</td><td>---</td><td>50</td></tr>
<tr><td>Mercury</td><td>µg/L</td><td>EPA 245.1</td><td>0.1</td><td>ND | ND[b]</td><td>ND</td><td>2.0</td><td>---</td></tr>
<tr><td>Molybdenum</td><td>µg/L</td><td>EPA 200.8</td><td>0.1</td><td>0.17 | 0.16[b]</td><td>0.34</td><td>---</td><td>---</td></tr>
<tr><td>Nickel</td><td>µg/L</td><td>EPA 200.8</td><td>0.8</td><td>ND | ND[b]</td><td>ND</td><td>---</td><td>---</td></tr>
<tr><td>Nitrite</td><td>µg/L as N</td><td>EPA 353.2</td><td>0.1</td><td>ND</td><td>---</td><td>1</td><td>---</td></tr>
<tr><td>Orthophosphate</td><td>µg/L as P</td><td>EPA 365.1</td><td>2</td><td>H 3.4</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>Phosphorus</td><td>µg/L as P</td><td>EPA 365.1</td><td>10</td><td>ND</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>Selenium</td><td>µg/L</td><td>EPA 200.8</td><td>0.4</td><td>ND | ND[b]</td><td>ND</td><td>50</td><td>---</td></tr>
<tr><td>Silver</td><td>µg/L</td><td>EPA 200.8</td><td>0.2</td><td>ND | ND[b]</td><td>ND</td><td>---</td><td>100</td></tr>
</table>

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 SPR7007X and Monitor Well SPR7007M
(Page 3 of 3)

Constituent Name	Unit	Analysis Method	RL	SPR7007X (184W118) 2/14/2008 10:00	SPR7007M (184W519M) 10/31/2006 13:15	Primary MCL	Secondary MCL
Trace and Minor Constituents (Continued)							
Strontium	µg/L	EPA 200.7	5	180 | 180[b]	170	---	---
Thallium	µg/L	EPA 200.8	0.2	ND | ND[b]	ND	2	---
Uranium	µg/L	---	---	0.576	---	---	---
Vanadium	µg/L	EPA 200.8	0.5	0.60 | 0.57[b]	0.54	---	---
Zinc	µg/L	EPA 200.8	5	ND | 5.3[b]	ND	---	5,000
Miscellaneous Parameters							
Total Dissolved Solids	mg/L	SM 2540C	10	210	210	---	500
Total Organic Carbon	mg/L	SM 5310C	0.3	ND	0.31	---	---
Total Suspended Solids	mg/L	SM 2540D	5	ND	---	---	---
Hardness	mg/L as $CaCO_3$	EPA 200.7	1	150	---	---	---
Langelier Index	@ 60°C	SM 2330B	-10	0.501	---	---	---
Langelier Index	@ Source Temp.	SM 2330B	-10	-0.187	---	---	---
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	0.064	2.0	---	15	---
Gross Beta	pCi/L	EPA 900.0	0.018	4.8	---	4 mrem/yr	---
Radium, total gross	pCi/L	EPA 903.1	0.3	ND	---	5	---
Radium-226	pCi/L	EPA 903.1	0.3	ND	---	---	---
Radium-228	pCi/L	EPA 904	0.3	ND	---	---	---
Radon-222	pCi/L	SM 7500	---	245	---	---	---
Strontium-90	pCi/L	EPA 905.0	0.6	ND	---	---	---
Tritium	pCi/L	EPA 906.0	312	ND	---	---	---
Uranium	pCi/L	EPA 200.8	0.13	0.5	---	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 SPR7007X, 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 SPR7007X, 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.