5.0 GROUNDWATER RESOURCES

The SNWA has studied and thoroughly described the wells and water levels of the study area in a report titled "Water-Level Data Compilation and Evaluation for the Clark, Lincoln, and White Pine Counties Groundwater Development Project" (SNWA, 2007d). In the report, SNWA documented the development of a comprehensive and updated water-level database. The database was then used to accomplish several objectives including:

- Characterization of hydraulic head within aquifers in the study area for evaluation of conceptual flow paths and gradients.
- Prepare data sets from which a numerical groundwater flow model may be calibrated, including interpretations of steady-state water levels and identification of non-steady-state conditions that might be present in the study area.
- Characterize depths to water for use in reviewing groundwater discharge by evapotranspiration.

An electronic version of the report has been attached as Volume 4 on the CD-ROM accompanying this report. This section provides an overview of the water-level information presented in that report.

5.1 Data Compilation and Evaluation

Approximately 17,000 individual depth-to-water measurements were compiled for 1,719 groundwater sites in the study area. The data were assembled from a variety of sources including published and unpublished reports, and from databases or spreadsheets maintained by different agencies and documented in Volume 4. In addition to the site location and depth-to-water data, well construction and lithologic information were also compiled for each site, if available. The compiled data were then integrated into a Microsoft Access® 2000 database.

After compilation of the site location and depth-to-water data, the compiled data were evaluated to check for duplicate data, inconsistencies in a site's reported land-surface elevation in comparison to a DEM, and inconsistencies in a site's data in comparison to data for the surrounding area.

5.2 Data Reduction

Prior to the analysis of the compiled water-level data, the water-level data set was reduced to a data set appropriate for analysis. This data reduction consisted of determining the effective open interval of a well, calculating water-level elevations from the depth-to-water data, identifying outlier and non-steady state water-level measurements, and determining the hydrogeologic unit in which a given well is completed. Volume 4 discusses each of these steps in greater detail. The process of determining water-level elevations and identifying outlier and non-steady state water-level measurements, however, are summarized in the following sections.

5.2.1 Water-Level Elevation Calculation

For each individual depth-to-water measurement, a corresponding water-level elevation was calculated as the land-surface elevation (or reference point elevation) minus the depth-to-water measurement, as shown by the following equation:

$$H = LSE - DTW \qquad \text{(Eq. 5-1)}$$

where,

H = Water-level elevation or hydraulic head value (ft-amsl)
LSE = Land-surface elevation (ft-amsl)
DTW = Depth to water (ft)

Water-level elevations are necessary for the creation of the water-level elevation contour maps and to construct hydrographs that can be used for additional data analysis including the calculation of mean steady-state water-level elevations for a given site. The hydrographs are used to examine steady-state trends and to identify abnormal or inconsistent depth-to-water measurements that would be unsuitable for inclusion into a steady-state hydraulic head data set.

5.2.2 Identification of Outlier or Non-Steady-State Water-Level Measurements

In Volume 4, "steady state" was defined as there being no trend in the available water-level elevations for a well other than natural fluctuations. "Transient conditions," or non-steady state, were defined as water-level elevations collected during pumping or elevations affected by pumping. To identify water-level measurements that are outliers, or non-steady state, and, therefore, not representative of predevelopment groundwater flow conditions, a temporal and spatial data analysis was performed for each site with ten or more water-level measurements. For wells with less than ten water-level measurements, it could not be determined which measurements represented steady state; therefore, all measurements were included for completeness and qualified.

The identification of non-steady-state water-level measurements consisted of constructing hydrographs for each well with ten or more water-level measurements in the study area. The hydrographs were reviewed to identify outlier and non-steady-state data. The non-steady-state measurements were flagged in the compiled data set, and an additional flag was assigned to those measurements, documenting the inconsistency. For example, individual depth-to-water measurements might be flagged as being "anomalously low," "anomalously high," or as "not representative of steady-state or predevelopment conditions." Anomalously low or high measurements were defined as the water level being lower or higher in magnitude than equivalent data at the same site. The water-level measurements that were flagged as "inconsistent" were then excluded from further steady-state data analysis (i.e., mean hydraulic head calculations). Wells having non-steady-state measurements that could be attributed to groundwater pumping were flagged to indicate transient-state behavior.

5.3 Data Analysis

Analysis of the site location and water-level data for this study consisted of (1) calculating mean steady-state hydraulic heads and evaluating the uncertainty associated with the steady-state hydraulic heads, and (2) using the mean steady-state hydraulic heads to investigate the predevelopment groundwater conditions in the study area by creating basin-fill composite water-level maps, depth-to-water maps in phreatophyte areas, and a carbonate-rock water-level contour map that shows the locations of well and spring locations that penetrate the carbonate-rock aquifer system.

5.3.1 Steady-State Hydraulic Heads

To prepare a water-level data set for use in the calibration of a steady-state numerical groundwater flow model, it was necessary to determine the predevelopment hydraulic head value from the water-level data for each site. This process consisted of first excluding hydraulic head data from the complied data set that were not considered representative of steady-state conditions. Data that were not considered representative of steady-state conditions included water-level elevation data qualified as “pumping,” “recently pumping,” or “a nearby site is pumping,” Other data considered abnormal or inconsistent with the steady-state conditions for a given site were also removed from the data set. Once the process of excluding non-representative data was completed, a mean steady-state hydraulic head value for a given site was calculated as follows:

$$\bar{H} = \frac{\sum H_t}{n} \qquad \text{(Eq. 5-2)}$$

where,

$\bar{H}$ = Mean hydraulic head value representative of steady-state conditions (ft-amsl)
H_t = Hydraulic head value for a given time (ft-amsl)
n = Number of water-level elevation measurements available for the period of record.

For sites with only one water-level elevation, that value was assumed to represent the steady-state value for that site. In addition, for springs that were included in the compiled data set, the land-surface elevation of the location was used as an approximate steady-state hydraulic head value.

An assessment of the uncertainty associated with the mean hydraulic head value for a given site was also completed for this study. This assessment of uncertainty was based on methods documented by IT Corporation (1996) and D’Agnese et al. (2002). A mean hydraulic head value for a site is derived from the land-surface elevation and the average water-level elevation measurement. As a result, the uncertainty associated with a mean water-level elevation for a given site results from four main sources of error: (1) the error associated with estimating the land-surface elevation, (2) the error associated with the location of a site, (3) the error associated with measuring the depth to water, and (4) the error associated with reducing multiple water-level measurements to a mean value (i.e., water-level variability). To quantify the overall accuracy of the mean hydraulic head measurements, estimates of the variances associated with the hydraulic head errors are summed and used to assign weights to the hydraulic head values. More information on the quantification of the uncertainty associated with the mean hydraulic head measurements can be found in Volume 4.

5.3.2 Characterization of Predevelopment Groundwater Conditions

The characterization of predevelopment groundwater conditions consisted of creating basin-fill composite water-level maps, creating depth-to-water maps in phreatophyte areas, and creating a carbonate-rock water-level contour map of well and spring locations that penetrate the regional carbonate-rock aquifer system. The characterization of predevelopment groundwater conditions in the study area was complicated due to the lack of a consistent temporal distribution of measurements in the study area. For example, water levels range from 1912 to 2006 for the most recent water-level measurement. For the purpose of this study, predevelopment groundwater conditions in the study area were examined using the mean water-level elevation values determined as calibration targets for the groundwater flow model. Due to the fact that there has been relatively limited groundwater development in most areas of the study area, it was felt that the steady-state hydraulic heads were analogous to predevelopment conditions. It is noted, however, that significant pumping occurs in Steptoe, Snake, Lake, and Panaca valleys.

Basin-fill composite water-level maps were drafted by hand at 100-ft intervals for most basins. Water-level data used in the development of the water-level contour maps consisted of water-level elevations from 1,755 wells and 83 spring heads in the study area. The contours incorporated several factors including geologic structures, topography, and data point reliability. The 100-ft contour intervals were based on the quantity and inferred quality of the data set. Contour lines are dashed where uncertain or inferred. The drafted water-level contour lines were then transferred to digital base maps that included both well or spring location and the water-level elevation for each point.

Depth-to-water maps were prepared for those hydrographic areas in the study area generally containing over 300 acres of phreatophytes. The depth-to-water maps were created by hand-contouring the depth-to-water data at 50-ft contours for most of the hydrographic areas. Contour lines are dashed where uncertain or inferred. The depth-to-water contours also incorporated several factors including geologic structures, topography, and data point reliability.

The carbonate-rock water-level contour map was constructed by plotting the well and spring locations that are known to penetrate or emanate from the regional carbonate-rock aquifer (see Figure 5-1). Water-level data used in the development of the regional carbonate-rock water-level map consisted of water-level elevations from 109 wells and 19 spring heads in the study area. Contour lines for the regional carbonate-rock aquifer system were hand drafted at 500-ft intervals for the entire study area. The contours incorporated several factors including geologic structures, topography, data point reliability, and the extent of the carbonate-rock aquifer in the study area. The 500-ft contour intervals were based on the quantity and inferred quality of the data set. Contour lines are dashed where uncertain or inferred. Previous investigations by Thomas et al. (1986), Bedinger and Harrill (2004), Prudic et al. (1995), and Wilson (2007) were used as guides to supplement the limited amount of data in the study area.

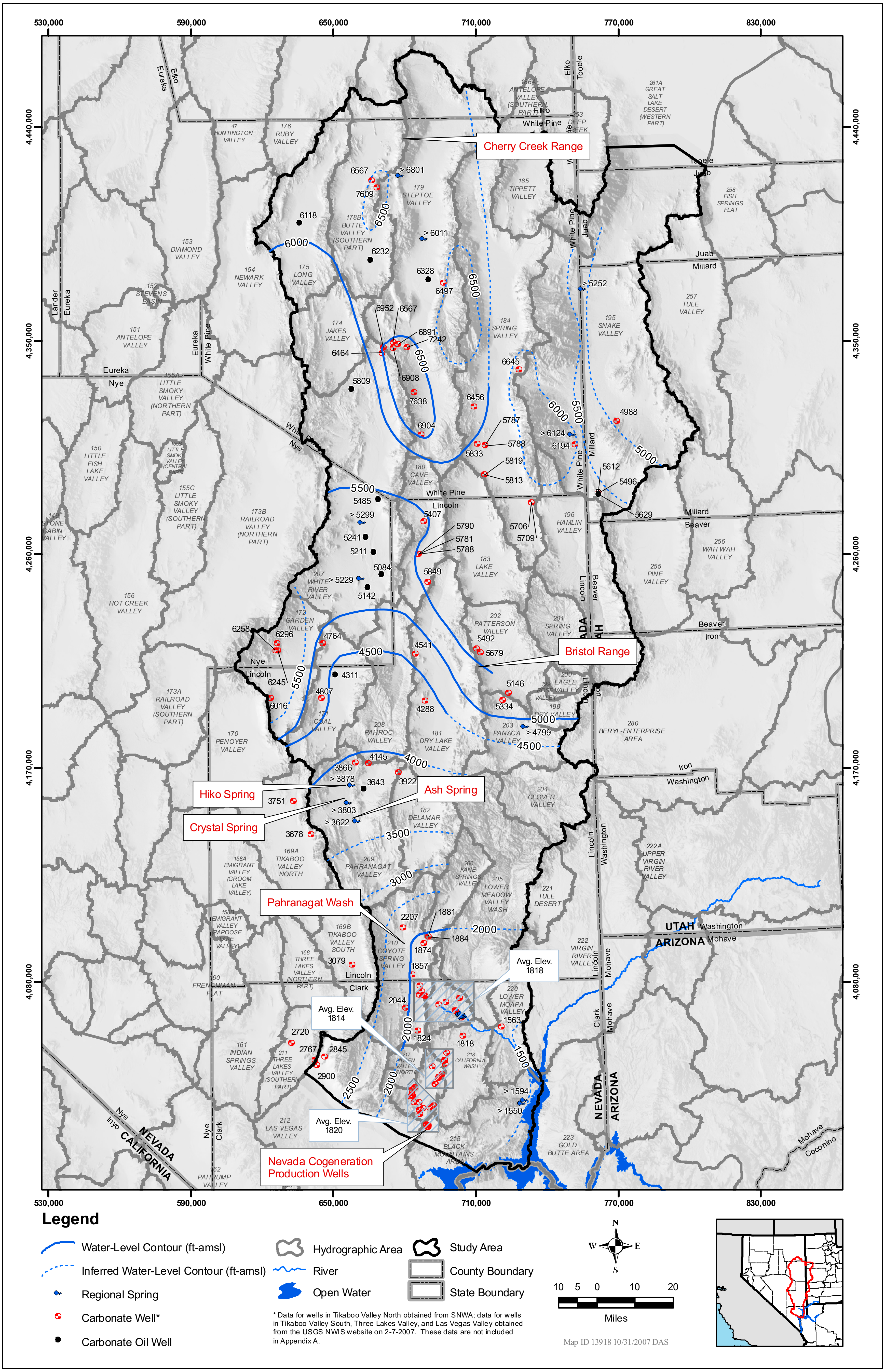

Figure 5-1
Carbonate-Rock Aquifer Water-Level Map

5.4 Project Basin Water-Level Analysis Results

The following sections describe the water-level analysis results for the Project Basins.

5.4.1 Spring Valley

Most wells in Spring Valley are relatively shallow, less than 300 ft in depth, with about a third less than 100 ft in depth. Two wells, however, have depths greater than 900 ft in depth. Production rates from large-diameter wells reported on the driller's logs are in the range of a few hundred to 2,000 gpm. Most lithologic descriptions reported on the drillers' logs contain references to interbedded sands, gravels, and clays. These descriptions support the characterization of the basin-fill sediments described by previous investigators including Rush and Kazmi (1965). The lithology of the basin-fill and the flowing wells that can be found in the southern half of the valley (e.g., the flowing wells near The Cedars) suggest that the primary aquifers are confined or semi-confined. A shallow unconfined aquifer is also likely to exist.

Basin-Fill Aquifer

Groundwater occurs at shallow depths throughout most of Spring Valley. For example, depths to water in Spring Valley range from above ground surface (i.e., flowing wells) to depths over 400 ft-bgs. It can be seen from Figure 5-2 that depths to water in Spring Valley are shallow over much of the central valley floor, and there are a number of ponds, small playa lakes, and springs in the central portion of the valley. Depths to water are greatest on the alluvial fans and increase to over 400 ft-bgs in the southern most portion of the valley east of the Fortification Range. Figure 5-3 shows that water-level elevations in Spring Valley range from approximately 6,600 ft-amsl in the northernmost portion of the valley to approximately 5,500 ft-amsl in the central portion of the valley near the Yelland Dry Lake. The figure also shows that water-level elevations in the southern portion of the valley near the topographic divide with Hamlin Valley are approximately 5,700 ft-amsl. The water-level elevations and contour lines shown on Figure 5-3 indicate that there is a north-to-south hydraulic gradient in the northern portion of the valley and a south-to-north hydraulic gradient in the southern portion of the valley. The hydraulic gradient for the northern portion of the valley is approximately 25 to 30 ft/mi to the south, while the hydraulic gradient in the southern portion of the valley is approximately 5 ft/mi to the north. These gradients suggest that groundwater flows from both the northern and southern portions of the valley toward the central portion of the valley. The water-level contours on Figure 5-3 also show that a groundwater divide exists within the southern portion of the valley, north and west of the Limestone Hills near the topographic divide with Hamlin Valley.

Carbonate Aquifer

Prior to 2006, there were three wells in Spring Valley known, or assumed, to be completed in carbonate rocks. The wells were identified based on driller's logs and their location relative to carbonate-rock outcroppings. All three wells are located south of U.S. Highway 50 along the mountain range fronts as shown on Figure 5-1. The water-level elevations for the three wells range from approximately 5,800 to 6,600 ft-amsl. Well 184 N15 E68 17DD 1, located on the east side of the valley near Sacramento Pass, has a water-level elevation of 6,645 ft-amsl and may be influenced by the underlying clastic rocks, which act as a lower confining unit. Well 184 N12 E66 05ACAB1,

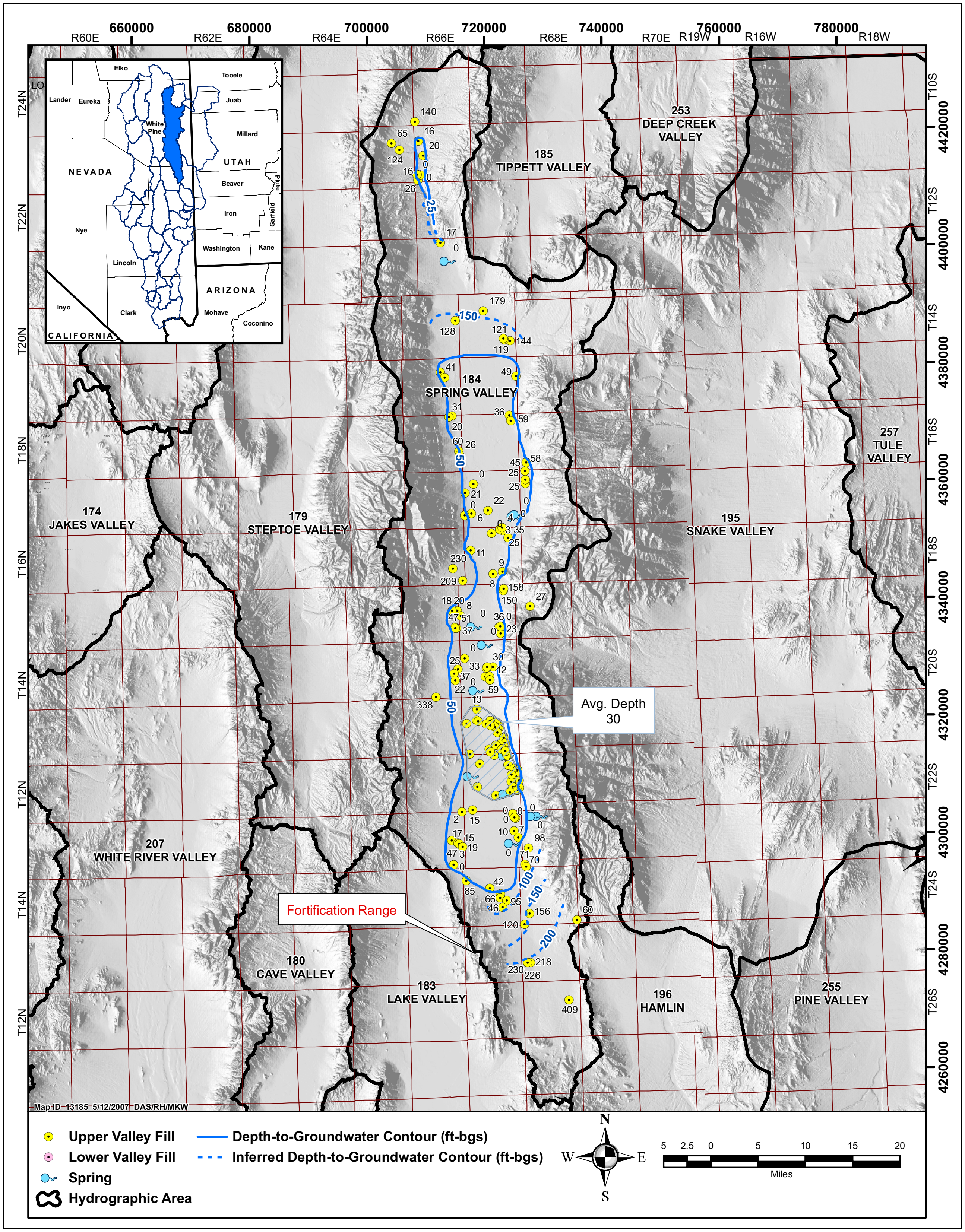

Figure 5-2
Spring Valley Depth to Water Map

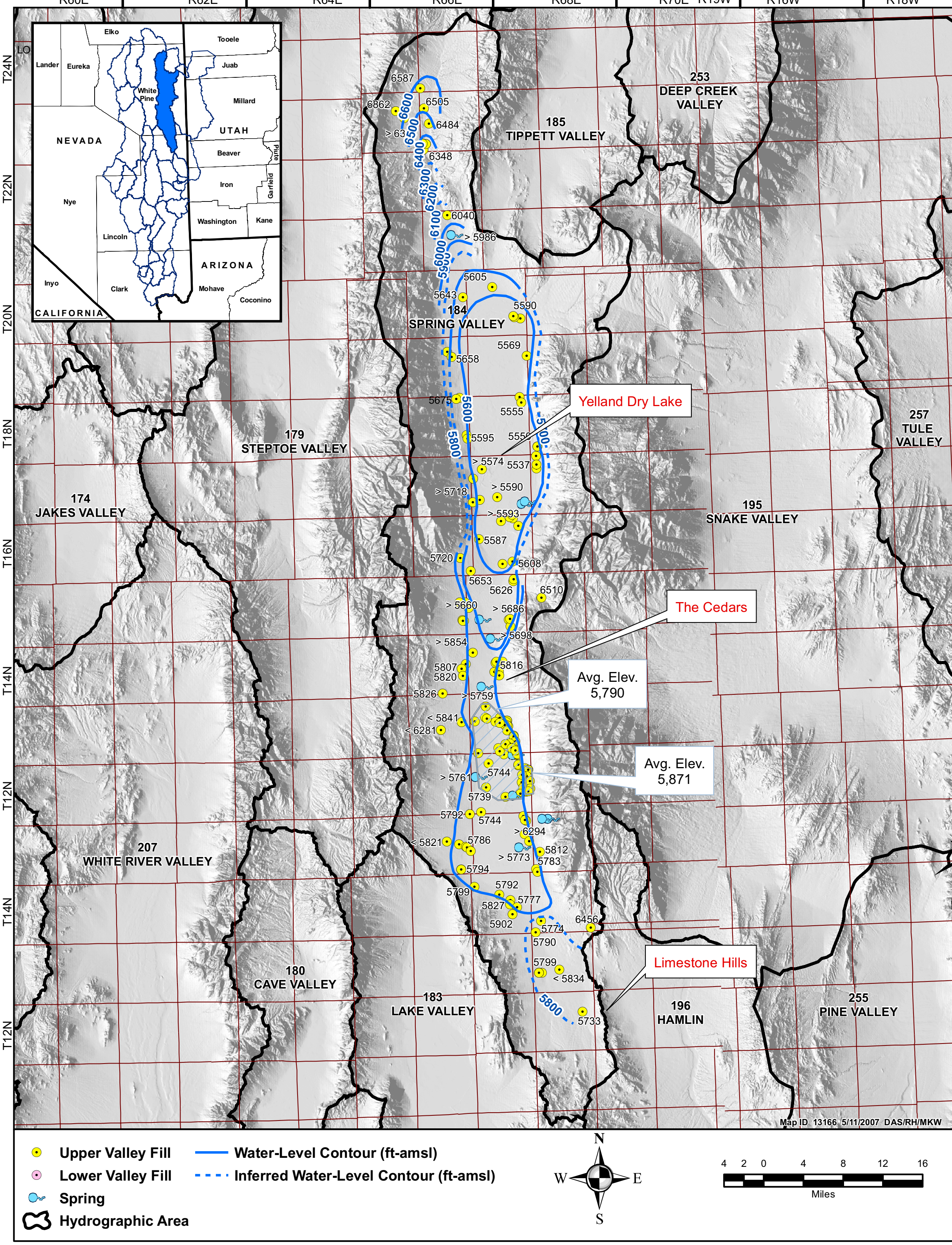

Figure 5-3
Spring Valley Water-Level Elevation Map

located near the intersection of U.S. Highways 50 and 93, has a water-level elevation of 6,456 ft-amsl. This well is assumed to be completed in carbonate rocks based on the driller's log that indicates a borehole penetration of "hard lime" from 20 to 40 ft-bgs. The third well, 184 N12 E66 21CD 1, is located in the southern portion of the valley and has a water-level elevation of 5,833 ft-amsl.

The SNWA installed seven wells in Spring Valley in 2006 and 2007 as part of an exploratory drilling program. Six of the wells were completed in the carbonate-rock aquifer. The six wells consisted of both a test well and a monitoring well at three different locations in southern Spring Valley (i.e., 184W105/184W506M, 184W103/184W504M, and 184W101/184W502M). The preliminary water-level elevations for the three sites are shown on Figure 5-1. The northernmost SNWA sites had carbonate-rock water-level elevations of 5,787 and 5,788 ft-amsl, while the middle SNWA sites had carbonate-rock water-level elevations of 5,819 and 5,813 ft-amsl. The southernmost SNWA sites near Hamlin Valley had carbonate-rock water-level elevations of 5,706 and 5,709 ft-amsl. From the available data shown on Figure 5-1, it appears that the water-level elevations decrease from 6,645 ft-amsl in the middle portion of Spring Valley to approximately 5,700 ft-amsl in the southern portion of Spring Valley.

Water-Level Trends

There are a number of wells in Spring Valley that have more than ten depth-to-water measurements. In general, the hydrographs that were constructed for wells in Spring Valley reveal that water-level trends are dependent on spatial location and proximity to agricultural areas. For example, well 184 N09 E68 30AAAB1 USGS-MX (Spring Valley S.), in the southern portion of Spring Valley, has shown an increase in water-level elevations since the early 1980s (Figure 5-4). This well is not near agricultural areas and there are no groundwater production wells in the vicinity. Well 184 N11 E68 19DCDC1 USGS-MX (Spring Valley), however, is approximately 12 mi north of the previous well and shows a decrease in water-level elevations of approximately 7 ft over the past 15 years (Figure 5-5). This well is still in the southern portion of Spring Valley, but is within two miles of an agricultural area. It can be seen from the figure, however, that approximately three feet of the water-level decline appears to be coincident with the region-wide drought beginning in late 1998. The figure also shows that water-level elevations have increased approximately five feet since the middle of 2006 after a year of above normal precipitation in 2005. Water-level elevations for wells in the northern portion of Spring Valley have shown relatively consistent water-level trends. For example, Figure 5-6 shows that water-level elevations for well 184 N19 E67 13AAAC1 have varied approximately six feet over the last 60 years. Inspection of all the hydrographs for Spring Valley, found within Volume 4, reveals that most hydrographs show variations of 5 to 10 ft over the period of record for a given well. These changes may be related to changes in hydrologic conditions and measurement accuracy rather than anthropogenic effects.

5.4.2 Snake Valley

Over 250 well and spring locations have been compiled for Snake Valley. Even with the relatively large amount of data in Snake Valley, this basin still has some of the most complicated water-level contour interpretations for basins in the study area, particularly with regard to outflows through carbonate bedrock.

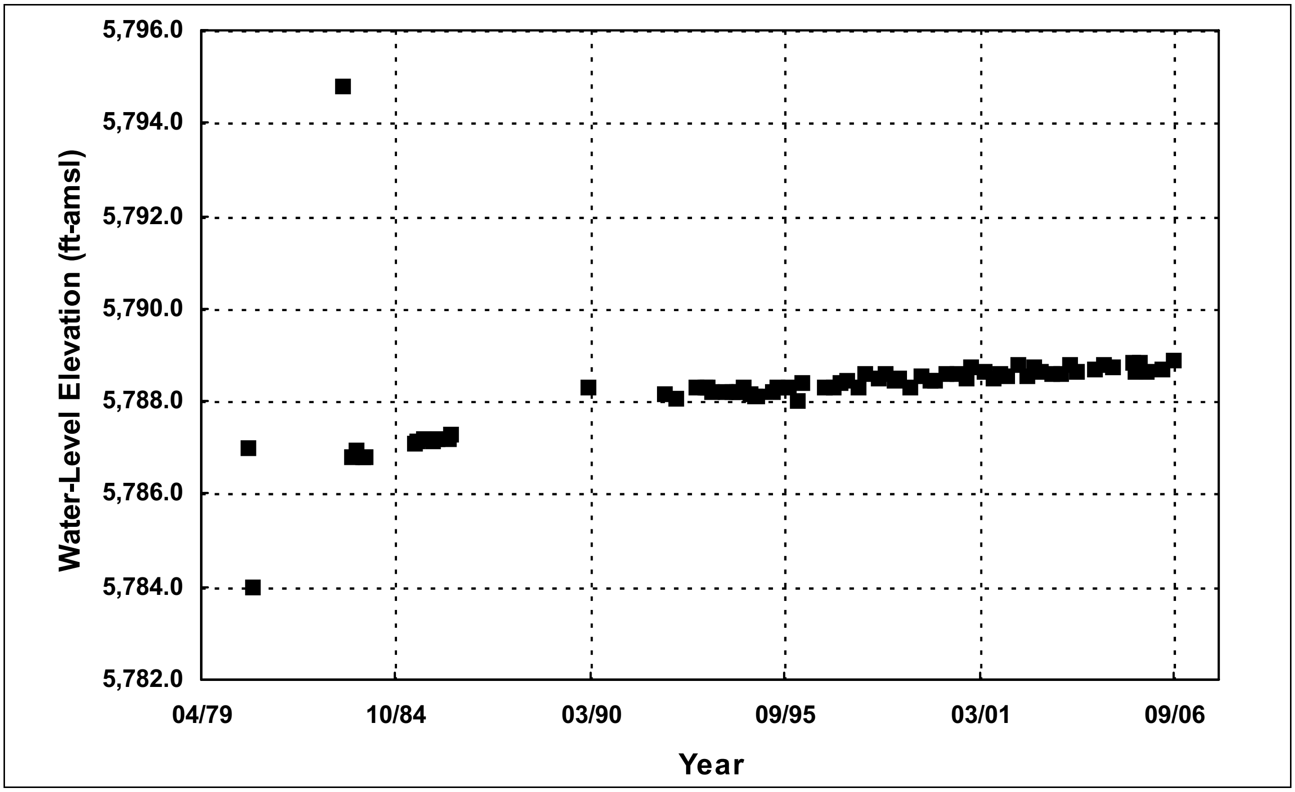

Figure 5-4
Historical Water-Level Elevations at 184 N09 E68 30AAAB1 USGS-MX (Spring Valley)

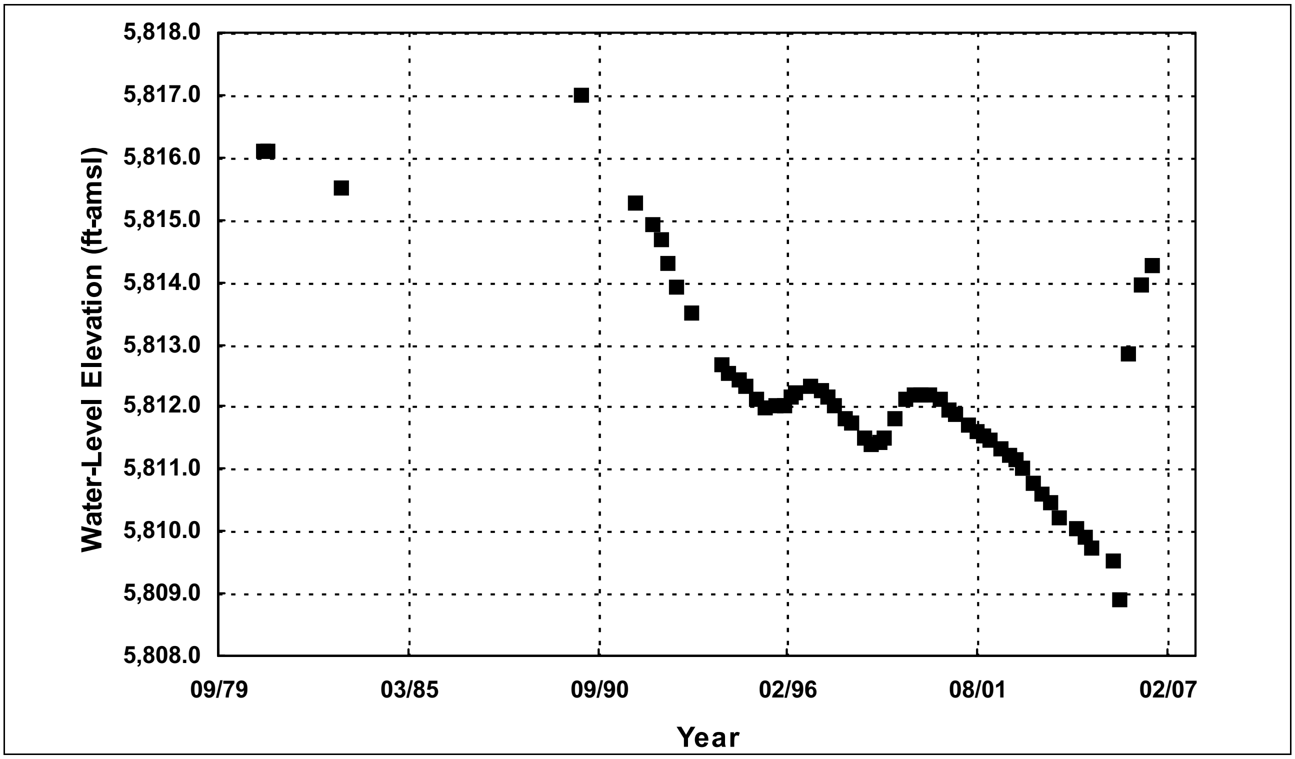

Figure 5-5
Historical Water-Level Elevations at 184 N11 E68 19DCDC 1 USGS-MX (Spring Valley)

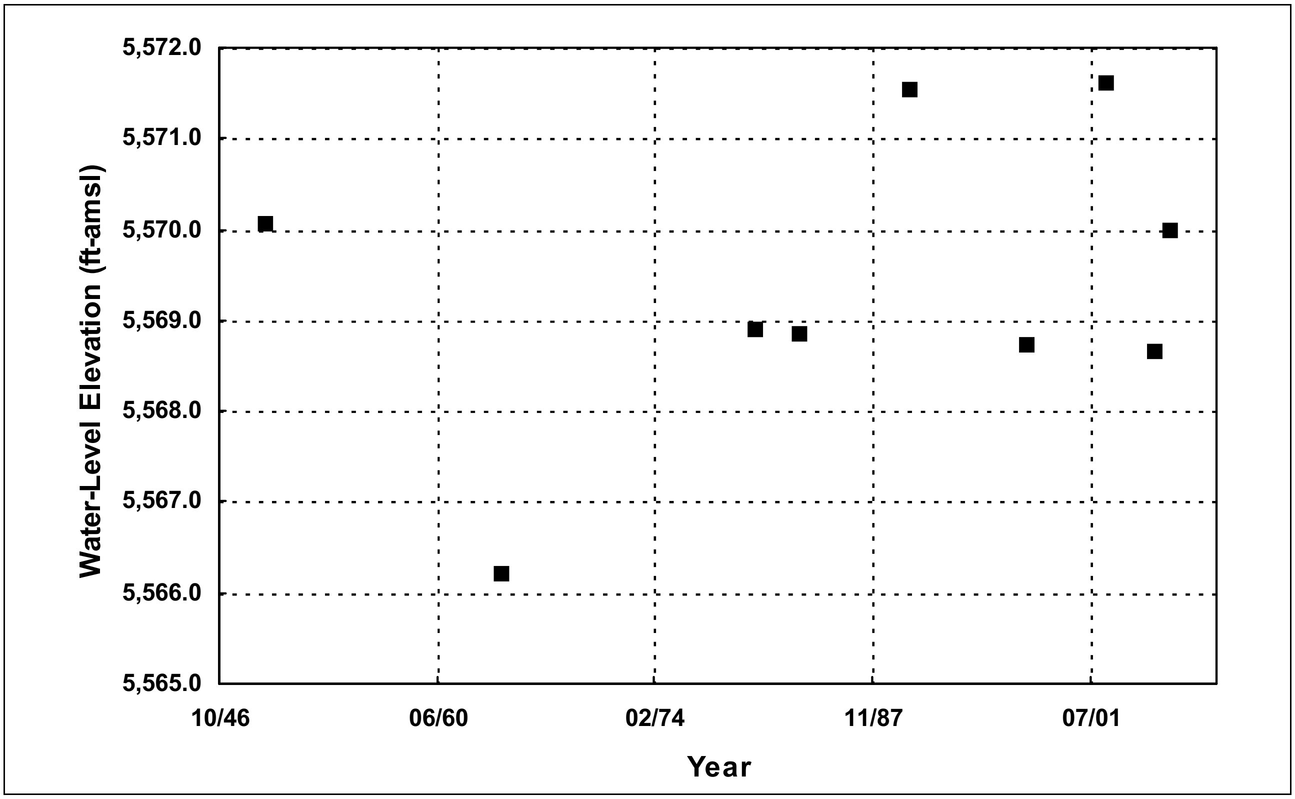

Figure 5-6
Historical Water-Level Elevations at 184 N19 E67 13AAAC1

Basin-Fill Aquifer

According to Ertec Western Inc. (1981c), the valley-fill deposits in Snake Valley consist of clay, silt, and sand in lacustrine areas in the center of the valley, and gravels and sands in the alluvial fan deposits along the valley margins. Groundwater production data that was reported on the NDWR driller's logs for wells in Snake Valley range from 20 gpm to a reported production rate of 950 gpm for one well in the southernmost portion of Snake Valley. Based on the lithology of the basin-fill wells and numerous springs and flowing wells in Snake Valley, groundwater occurs under both confined and unconfined conditions.

Depths to water in Snake Valley for basin-fill wells range from above land surface to greater than 500 ft-bgs. Areas of shallow groundwater can be found throughout the valley especially along the main axis of the valley from the town of Baker in the south to Partoun and Trout Creek in the north (Figure 5-7). Depths to water tend to increase along the valley margins closer to the mountain ranges surrounding the valley. Depths to water are greatest on the east side of the valley and in the southernmost portion of the valley near the Burbank Hills. Figure 5-8 shows that water-level elevations for wells located on the valley floor range from approximately 5,500 ft-amsl in the southern portion of the valley to approximately 4,300 ft-amsl in the northernmost portion of the valley. It can also be seen from the figure that water-level elevations are higher closer to the surrounding mountain ranges than on the valley floor. The water-level elevations and composite water-level contours indicate that there is a south-to-north hydraulic gradient of approximately 11 ft/mi in the valley in the direction of the Great Salt Lake Desert hydrographic area.

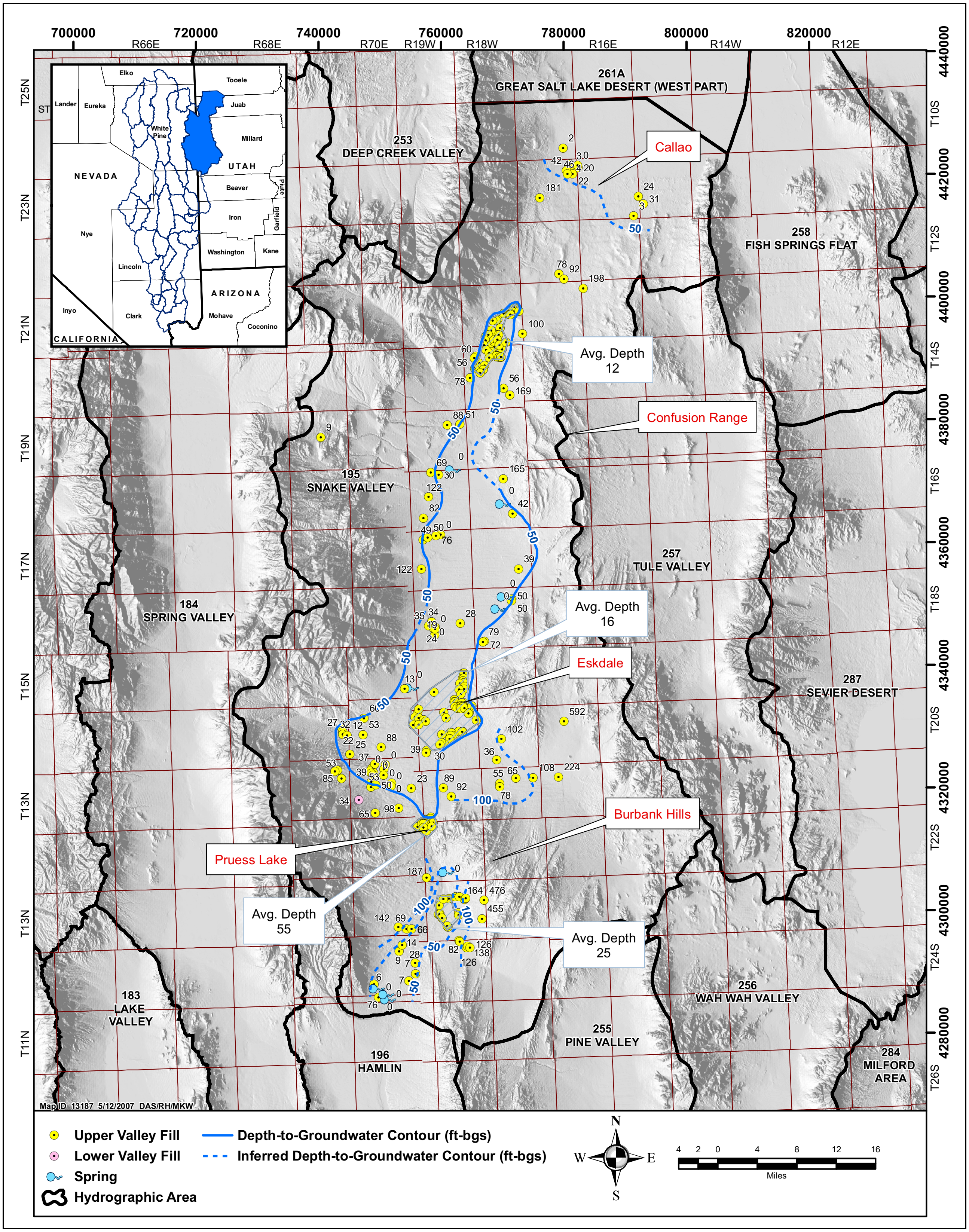

Figure 5-7
Snake Valley Depth to Water Map

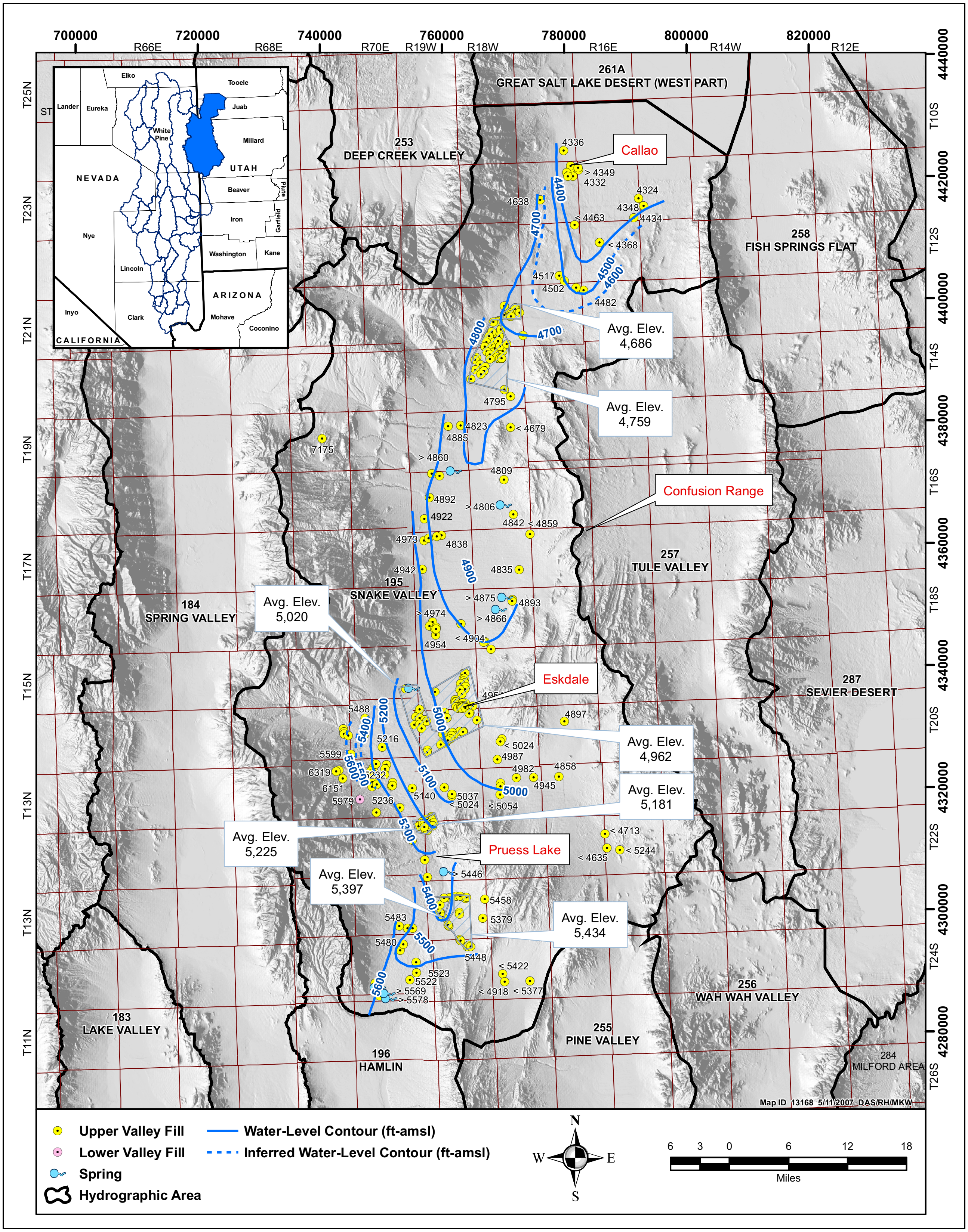

Figure 5-8
Snake Valley Water-Level Elevation Map

Carbonate Aquifer

A number of wells in Snake Valley are known to penetrate the carbonate-rock aquifer including several oil wells in the southern portion of the valley. The water-level elevations for the carbonate-rock wells and regional springs used for control range from approximately 5,000 to 6,200 ft-amsl (Figure 5-1). It can be seen from the figure that the carbonate-rock water-level elevations and spring heads decrease toward the north and northeast suggesting a northeastward groundwater gradient.

Water-Level Trends

Numerous wells exist in Snake Valley with sufficient data to construct water-level hydrographs. The hydrographs constructed for Snake Valley represent the basin-fill aquifer only and do not necessarily reflect trends in the carbonate-rock aquifer. This discussion will only focus on a few select wells to illustrate general observations in the northern, central, and southern portions of Snake Valley. In general, inspection of the hydrographs reveals that water-level elevations vary with time and spatial location within Snake Valley. For example, the hydrographs show that the maximum water-level fluctuations in Snake Valley range from 40 to 50 ft, with most wells commonly having water-level fluctuations less than 10 ft. A subtle upward trend over the past 7 decades can also be observed at some locations, while others have no particular trend or a decreasing trend (see Volume 4 for all of the constructed hydrographs for Snake Valley). Figure 5-9 shows that water-level elevations for well (C-11-17)12cbb-1 in the northern portion of Snake Valley near the town of Callao have varied on the order of 10 ft since the mid 1980s. There are numerous agricultural areas near the town of Callao suggesting that the water-level fluctuations could be attributed to pumping for irrigation. Hood and Rush (1965) stated, however, that the flow of Basin and Thomas Creeks is diverted and used in those areas. Water levels in this area, or any area of significant perennial streamflow, can be affected by the availability of surface waters and supplemental groundwater production. The proportion of either, however, cannot be determined due the limitations of the available data. As a result, it is difficult to determine the exact cause for the observed fluctuations. Another well in the northernmost portion of Snake Valley is well (C-11-16)36cdb-1 (Figure 5-10). This well is approximately 7 mi southeast of the previous well and shows very little change in water-level elevations over the past 25 years. This well is not near any current agricultural area. Another area of significant agriculture is in the central portion of Snake Valley near the community of Eskdale. Wells near this area also show similar water-level variations (i.e., in magnitude) as those in the northern portion of Snake Valley. For example, Figure 5-11 shows that water-level elevations have varied approximately 7 ft for the period of record for well (C-19-19)26aba-1. It can also be seen from the figure that there has been a subtly declining water-level trend for the well since approximately 1985. This well is also located in close proximity to agricultural areas.

Finally, Figure 5-12 shows an increasing water-level trend for the entire period of record for well (C-23-19)9cdb-1. This well is located in the southern portion of Snake Valley approximately 4 mi south of Pruess Lake. It is also located near current agricultural areas. Overall, water-level trends in Snake Valley can likely be attributed to temporal variations in hydrologic conditions.

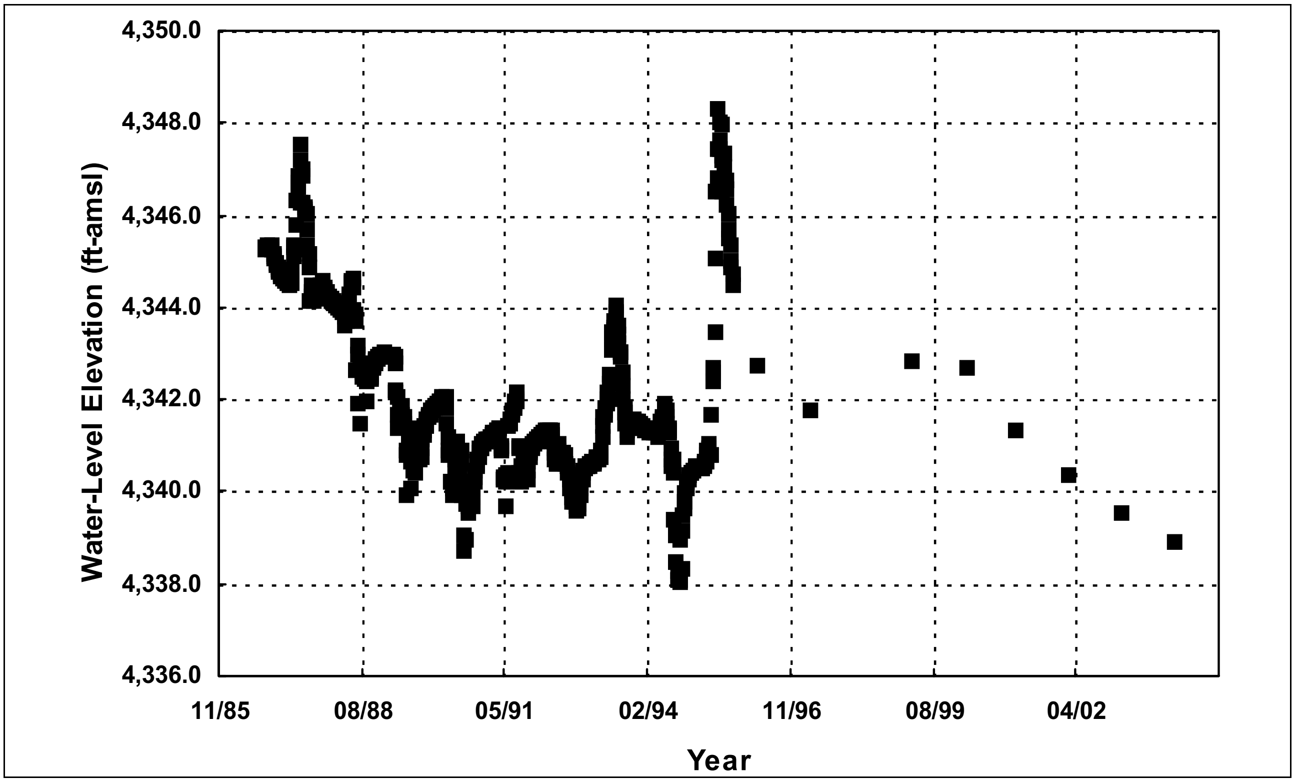

Figure 5-9
Historical Water-Level Elevations at (C-11-17)12cbb-1

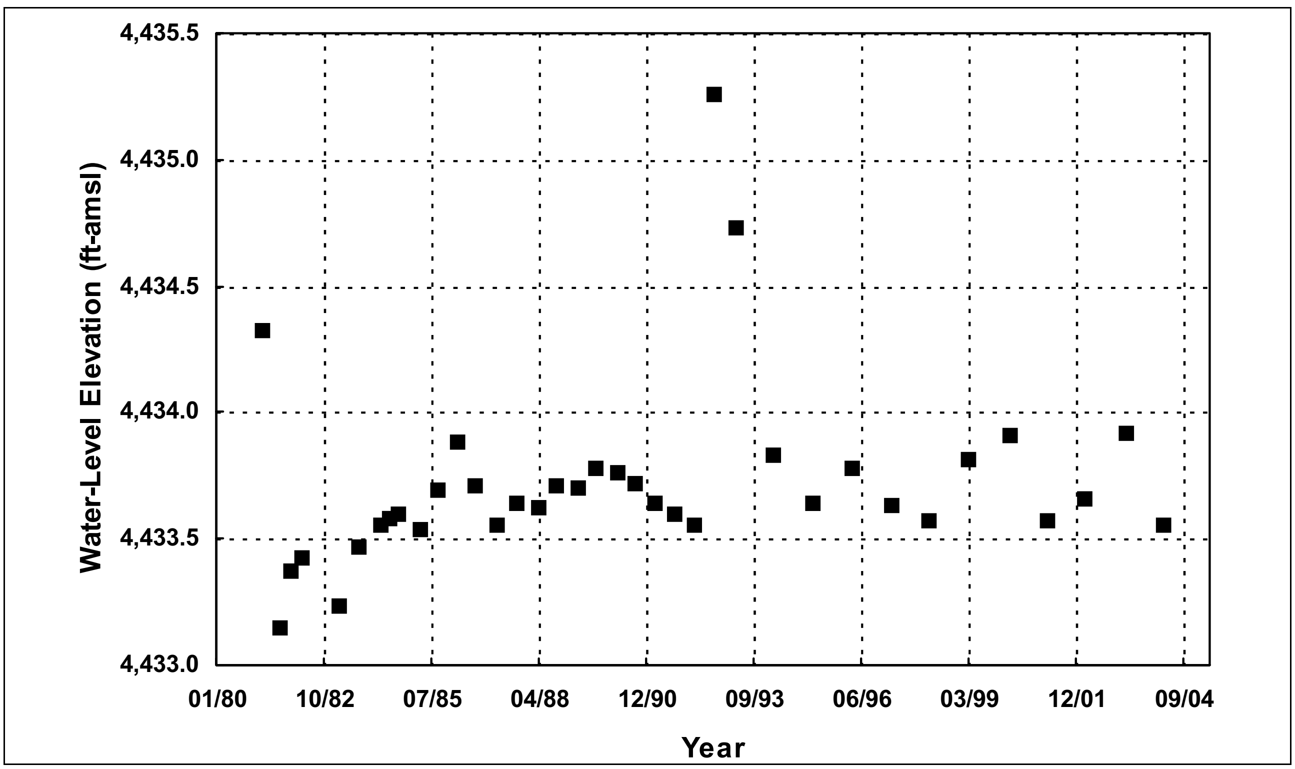

Figure 5-10
Historical Water-Level Elevations at (C-11-16)36cdb-1

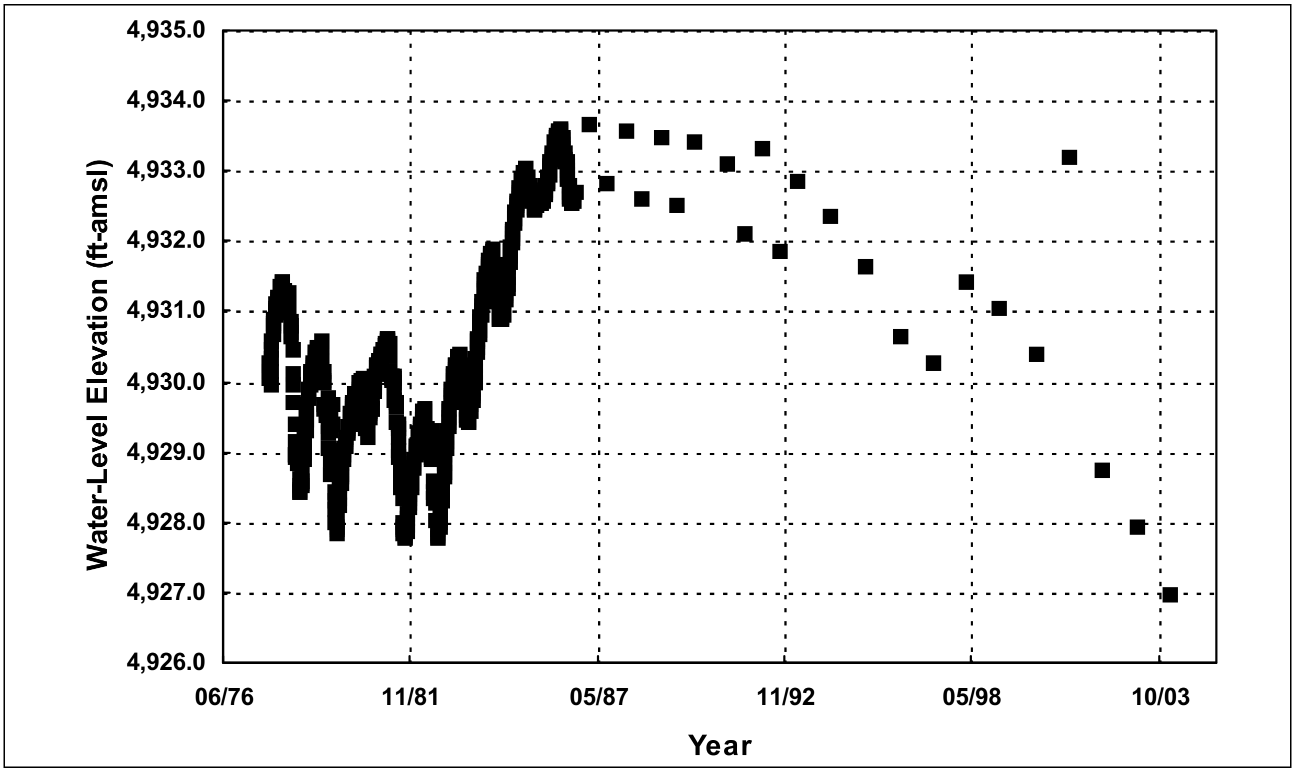

Figure 5-11
Historical Water-Level Elevations at (C-19-19)26aba-1

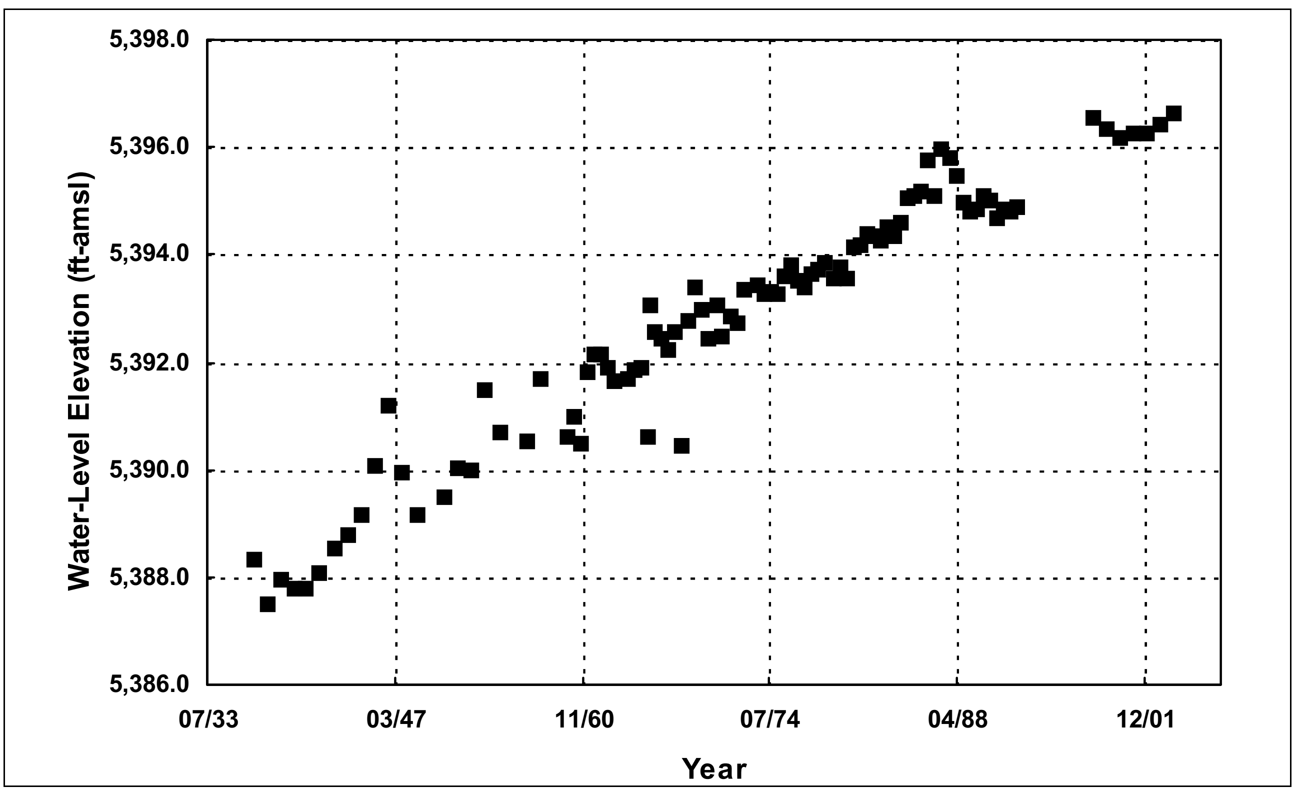

Figure 5-12
Historical Water-Level Elevations at (C-23-19)9cdb-1