4.0 SCENARIO SIMULATION AND RESULTS

A description of the scenario modeling and the results of the groundwater development scenario simulations introduced in Section 3.0 are summarized in this section. Detailed simulation results are provided in electronic form for each scenario on the DVD set provided separately.

4.1 Scenario Modeling

All groundwater modeling scenarios described in Section 3.0 were simulated with the modified numerical model (SNWA, 2009b and 2010). The specific scenario simulations are presented in this section.

4.1.1 Simulations

A total of 17 simulations were performed using the calibrated modified numerical model (SNWA, 2009b and 2010) to estimate the potential pumping effects of the alternatives described in Section 3.0. Each scenario simulation is listed in Table 4-1. The 17 simulations consist of 16 groundwater development scenarios corresponding to the 7 alternatives described in Section 3.0. Eight of these simulations represent the alternatives and the other eight, their NEPA cumulative scenarios. The last simulation (Scenario A-Cessation) was performed to simulate a cessation of SNWA pumping after pumping 75 years beyond full build-out under Alternative A.

Two additional simulations of the No Action scenario were necessary to accommodate the LCCRDA scenarios (Alternative D and the cumulative pumping for Alternative D) (Table 4-1). The two No Action simulations (ucpd955 and ucpd966) represent the same No Action scenario described in Section 3.0, with the only differences being the definition of the stress periods selected to match the timing of the pumping in the LCCRDA scenarios and the smaller time steps needed for the MODFLOW-2000 solutions to converge.

The cessation of pumping simulation (ucpd951) (Table 4-1) was conducted to evaluate the effects to the system after pumping under the Distributed Pumping-Reduced Quantities scenario (Alternative A) stops. The well distribution and water-use schedule is identical to that of Alternative A described in Section 3.0 (Table 3-3) from the start of pumping until December 31, 2124. After the end of 2124, all Project pumping was shut off. In this simulation, the No Action pumping continued as scheduled until the end of the simulation period, December 31, 2249.

4.1.2 Model Setup

All modeling scenarios were set up starting with the calibrated modified transient numerical model files (SNWA, 2009b) in a similar fashion. The setup of the water-use schedules (pumping wells and

Table 4-1
Scenario Simulations

Alternative Name	Alternative Description	Simulation Number	NEPA Cumulative Simulation Number	Full Build-Out
No Action	No Action	ucpd949 ucpd955 (LCCRDA)	ucpd960 ucpd966 (LCCRDA)	2050 2043
Proposed Action	Distributed Pumping – Full Application Quantities	ucpd999	ucpd1001	2050
Alternative A	Distributed Pumping – Reduced Quantities[a]	ucpd950	ucpd998	2050
Alternative B	Points of Diversion – Full Application Quantities	ucpd1000	ucpd1003	2050
Alternative C	Intermittent Pumping[a]	ucpd954	ucpd1004	2050
Alternative D	LCCRDA Corridor[a]	ucpd956	ucpd967	2043
Alternative E	Spring, Dry Lake, Delamar, Cave (acronym: Spring/DDC)[a]	ucpd970	ucpd969	2050
Alternative A - Cessation	Cessation of Pumping --Distributed Pumping – Reduced Quantities[a]	ucpd951	NA	2050

[a]Reduced pumping rates

stream diversions), the time discretization, the initial conditions, and the observations in the numerical model are described in the following text.

4.1.2.1 *Water-Use Schedules*

The water-use schedules corresponding to the scenarios were summarized in Section 3.0 and are provided in electronic form (DVD set).

The water-use schedules were set up in the numerical model by modifying the input files for the well and stream flow packages according to each modeling scenario. The stream diversions were set up as described in the numerical model report (SNWA, 2009b). The MODFLOW Multi-Node Well (MNW) module (Halford and Hanson, 2002) was used to simulate all pumping wells, including historical pumping. The MNW module was used so that pumping from a single well could be distributed over multiple model layers in a realistic manner. The MNW module apportions pumping to each model layer based on the layer's material properties and relative saturated thickness. The setup for historical pumping was described in the numerical model report as well (SNWA, 2009b). Additional pumping wells were added to represent either the Project wells or wells that are part of the Cumulative Pumping scenarios (not historical wells used in calibration) as described in the following text.

- For the Proposed Action and all Project alternatives, other than for the LCCRDA scenarios, the top of the open interval was set to the initial water table (January 1, 2005) or to the top of the regional modeling unit (RMU) as follows:

  - If a well is completed in the Upper Valley Fill (UVF) RMU, the open interval was extended from the water table to the bottom of the UVF RMU. Although no depth limit was imposed on UVF wells, the MNW module automatically limits the length of the interval from which a given well draws water to the most transmissive model layers. Because of the decrease of hydraulic conductivity with depth implemented in the numerical model (SNWA, 2009b), the most transmissive layers correspond to the upper model layers.

  - If a well is completed in the Lower Carbonate (LC3) RMU, the open interval was extended from the top of the LC3 RMU (or water table, if lower) toward the bottom of the LC3 RMU. However, the total open interval was not allowed to exceed 1,000 m.

  - If a well is completed in the Lower Valley Fill (LVF) RMU, the open interval was extended from the top of the LVF RMU (or water table, if lower) toward the bottom of the LVF RMU. However, the total screened interval was not allowed to exceed 1,000 m.

- For the NEPA Cumulative Pumping scenarios, except for wells used to extract reasonably foreseeable, future uses, all wells were set up as in the Proposed Action scenario. The wells representing reasonably foreseeable, future uses were open to single RMUs, the preferential order being UVF, LC3, and LVF.

- For the LCCRDA scenarios, the completion depths and open intervals of the proposed pumping wells were extended to greater depths to allow the model to maintain stability while simulating the removal of large volumes of water from limited areas.

It is noted that estimating screened intervals for the CCRP model is relatively unimportant because only a limited number of the pumping wells intersect more than one model layer. In addition, most of the multi-node wells likely resulted from the arbitrary vertical discretization of the model with flat-lying layers that arbitrarily range between 0 and 300 m thick at the water table rather than being wells with more than 300 m of screen.

4.1.2.2 Time Discretization

Two primary time-discretization schedules used in the scenario simulations were as follows: (1) the 2050 schedule which included the period from January 1, 2005 through December 31, 2249, 200 years after full SNWA production is reached; (2) the 2043 schedule which included the period from January 1, 2005 through December 31, 2242, 200 years after full SNWA production is reached. The 2050 schedule was used for all scenarios, except the LCCRDA scenario and its corresponding No Action scenarios.

The period of interest in the 2050 schedule (2005 to 2250) was subdivided into 85 stress periods while the period of interest in the 2043 schedule was subdivided into 78 stress periods (2005 to 2243). Two additional stress periods are defined in the scenario model files and were reserved for testing purposes only during the modeling activities. These stress periods were left in the scenario model files to avoid problems during pre- and post-processing because the corresponding scripts had previously been designed to handle 87 stress periods. These 2 stress periods (86 and 87) will not be discussed any further in this document.

The discretization of the stress periods was different depending on the scenario. For all scenarios, except the LCCRDA scenarios, the simulation period was discretized as follows:

- One-year stress periods with 12 time steps were used from January 1, 2005, through the stress period just before full build-out of Project pumping was reached (stress periods 1 through 45).
- Five-year stress periods with five time steps were then used for 200 years (stress periods 46 through 85).
- The Proposed Action (ucpd999) required more refined time steps for the last 6 stress periods of interest (80 to 85) because of the larger pumping rates. For this case, ten time steps were used instead of five.

For the LCCRDA scenarios, the time discretization was adjusted to match the different evaluation times (Table 4-1) and to achieve model convergence. Initially, the time steps in the LCCRDA scenario (ucpd956) were also the same as in the No Action scenario (ucpd955). However, during modeling of the LCCRDA scenarios, it was necessary to further refine selected stress periods into smaller time steps for MODFLOW-2000 to converge. The finer discretization of the stress periods makes the model simulate slightly different results for the same stress conditions; however, these differences are negligible. In these two cases, the following changes were made:

- For the three stress periods starting at the beginning of full build-out of Project pumping, 60 equal-length time steps were used instead of 5 variable-length (1.1 multiplier) time steps.
- For the subsequent stress periods, 20 equal-length time steps were used instead of 5 variable-length (1.1 multiplier) time steps.

The LCCRDA scenario required a second version of the No Action scenario simulation (ucpd955) with the same stress periods and output times, so the incremental effects of this scenario could be evaluated.

4.1.2.3 Initial Conditions

Initial conditions were set to be the same as the conditions simulated by the calibrated transient numerical model for the end of 2004 (SNWA, 2009b). Initial conditions are represented in the calibrated transient numerical model by the hydraulic-head distribution of each model layer. This initial hydraulic-head distribution, together with the calibrated distributions of all model parameters, produces initial values for all other simulated variables, such as groundwater ET rates, spring flow, and boundary flow.

4.1.2.4 Observations

Observation wells were originally set to those used in the transient numerical model calibration (SNWA, 2009b). To reduce the number of observation wells, control memory requirements, and allow the simulation of a significant number of transient observations, the number of hydraulic-head observations was reduced from 1,815 to 424, using the following criteria:

- If more than one observation well occurred in a model cell, the first listed well was retained, and the remaining wells were discarded.
- If many observation wells occurred in more than five model cells in a hydrographic area (HA), up to 50 percent of the remaining wells were removed (every other listed well). The final number of hydraulic-head observation wells was not allowed to drop below five in a given hydrographic area.
- In large hydrographic areas where the remaining number of wells was still large, another 50 percent of these wells were removed, but geographic distribution was considered during removal to ensure a relatively-even spatial distribution.

4.2 Effects of Proposed Action and Alternatives

The simulated effects of pumping under the Proposed Action and Project alternatives are summarized in terms of changes in water levels, external boundary flows, groundwater ET, and spring and stream flows. In some instances, the incremental hydraulic effects attributable to the Proposed Action and each alternate groundwater development scenario were calculated by subtracting the effects due to the No Action scenario for selected points in time. In other instances, these incremental effects were presented graphically without subtracting the corresponding values of the No Action scenario. The simulated effects of these scenarios on interbasin flow and the details on all groundwater-budget components are provided in electronic form (DVD set).

4.2.1 Effects on Water Levels

The simulated effects of pumping on the water table within the model area are summarized in this section in the form of drawdown maps and hydrographs for selected observation wells. The simulated effects on all selected observation points (see Section 4.1.2.4) are provided on the DVD.

4.2.1.1 Extent of Drawdown

The extents of the simulated drawdowns of the water table from its levels on January 1, 2005, are presented in the form of maps on Plate 1. Plate 1 shows the net drawdowns caused by Project pumping only. Another plate provided in electronic form shows the total simulated drawdowns caused by Project and No Action pumping combined (DVD set).

The simulated drawdown maps are arranged in three rows and seven columns. Each row of maps represents a year of particular interest, i.e., full build-out year, 75 years after full build-out, and 200 years after full build-out. Each column of maps represents one scenario. The drawdown maps for the No Action scenario are placed in the first column, followed by maps for the Proposed Action scenario and the alternatives pumping scenarios. The maps shown on Plate 1 for the No Action and Proposed

Action scenarios and the alternatives are described in this section, while those of the Cumulative Pumping scenarios are presented in Section 4.3.

The No Action scenario drawdowns are those calculated by the model as the differences between the initial hydraulic heads, (those simulated at the end of 2004 by the calibrated modified numerical model) reduced by the simulated hydraulic heads. The drawdowns (Plate 1) for the Proposed Action and Project alternatives (A through E), were further reduced by the No Action scenario drawdowns to depict the extent of incremental drawdown due to Project pumping alone.

Under the No Action scenario, most of the large drawdowns in the water table (larger than 10 ft) simulated for the beginning of full build-out occur in southern Lake Valley (HA 183) and northern Patterson Valley (HA 202) (Plate 1). At the same time, smaller areas of large drawdowns are also simulated for some basins located south and north: Dry Valley (198), Panaca Valley (203), Clover Valley (204), Lower Meadow Valley Wash (205) to the south, and southern Spring Valley (HA 184) to the north. By 75 years after full build-out, the extents of these cones of depression are more extensive, and new areas of large drawdowns appear in northern White River Valley and in the southern end of the model area, in an area straddling Las Vegas Valley (HA 212) and the Black Mountains Area (HA 215). By the end of the simulation period, the cone of depression centered on southern Lake Valley (HA 183) and northern Patterson Valley (HA 202) is deeper (more than 80 ft) and extends over a larger area joining all drawdown cones located immediately to the south. This cone of depression is also simulated to extend into Cave and Dry Lake valleys and to Hamlin Valley (HA 196) by this time. The other cones of depression are simulated to extend over slightly-larger areas and are shallower. Although, relatively large volumes of groundwater are withdrawn for irrigation from Lake Valley, larger groundwater withdrawals occur in other basins (Snake Valley, for example) (Figure 3-1). And yet, drawdowns simulated in southern Lake Valley are the largest because all groundwater withdrawn from this basin originates from storage. This causes the relatively-large drawdowns, as no groundwater ET area is present to capture like in White River, Spring, or Snake valleys.

For the Proposed Action and Project alternatives, small areas of relatively-large incremental drawdowns (larger than 10 ft) occur in Spring (HA 184), Cave, Dry Lake and Delamar valleys (HAs 180, 181, and 182) by full build-out (Plate 1). No drawdowns appear in Snake Valley, as Project pumping from this basin has just been initiated. By 75 years after full-build out, as expected, the simulated drawdowns caused by Project pumping occur in all project basins and are greatest in the vicinity of the pumping centers. By this time, the cones of depression in Cave, Dry Lake, and Delamar valleys overlap, as do the cones of depression caused by Project pumping from southern Spring and Snake valleys. By 200 years after full build-out, the cones of depression due to Project pumping extend over most of Delamar, Dry Lake, and Cave valleys and slightly into neighboring basins, such as Pahroc and Pahranagat valleys. The largest drawdowns occur in the southern parts of Spring, Snake, and Cave valleys. The drawdown cones are the largest and deepest in areas of little or no groundwater ET for the same reasons as for the No Action scenario. As expected, the Intermittent Pumping scenarios (Scenarios 4 and 6) appear to cause the smallest drawdowns.

4.2.1.2 Simulated Water Levels at Selected Wells

As shown on Plate 1, the magnitude of drawdown is a function of location relative to the Project pumping centers. The greater the distance the observation point is from the pumping centers, the lesser the drawdown. Thus, wells were selected within the Project basins to illustrate how the water table might decline close to the pumping centers under the Proposed Action and Project alternatives. Six observation wells located in the project basins were selected, and their locations are shown in Figure 4-1. The simulated drawdowns for each groundwater development scenario and all selected hydraulic-head observation points are provided in the enclosed DVD.

The effects of pumping under each groundwater development scenario are reflected in the hydrographs that depict changes in hydraulic head at selected observation points represented in the model. The simulated water-level hydrographs for Cave, Dry Lake, and Delamar valleys are presented in Figure 4-2. The simulated water-level hydrographs for the wells selected for Spring and Snake valleys are shown in Figure 4-3. An interval of 300 ft was used for the y-axis to represent the change in water-level elevation for all six hydrographs to facilitate comparisons. An observed water level was added to the hydrographs where possible to also aid comparison.

All selected hydrographs (Figures 4-2 and 4-3) exhibit declining water-level trends. The most pronounced declining trends are simulated in the Cave Valley observation well, and the least pronounced trend is simulated in the Snake Valley observation well located in Eskdale.

4.2.2 Effects on External Boundary Flows

External flow boundaries that exhibit effects of simulated pumping were selected for presentation in this summary. Their locations are shown in Figure 4-4.

The simulated flows across these boundaries are presented in Table 4-2 for all groundwater development scenarios and for each year of interest. Flows simulated by the model for the No Action scenario are included for comparison. Flows simulated for the Proposed Action scenario and the alternatives are presented as incremental changes from the No Action scenario. Pumping associated with the Proposed Action and Project alternatives only affected flow across external boundaries that are located near the project basins.

The effects are considered to be negligible for all scenarios. The largest relative decrease occurs at the flow boundary between Snake Valley and Pine Valley under the Proposed Action scenario and Alternative B at the end of the simulation period. Although the decrease in simulated outflow at this boundary (-1,141 afy) is large relative to the calibrated value of outflow (1,414 afy), it is still considered unconsequential given the limited flow across this boundary and the uncertainty associated with the available interpretations (SNWA, 2009a). The outflow decrease for the Proposed Action scenario at this boundary after 200 years represents only about 2 percent of the annual groundwater pumped in Snake Valley. Also, the direction of flow is uncertain at this boundary, as some authors interpreted inflow rather than outflow to occur across this boundary (Harrill et al., 1988).

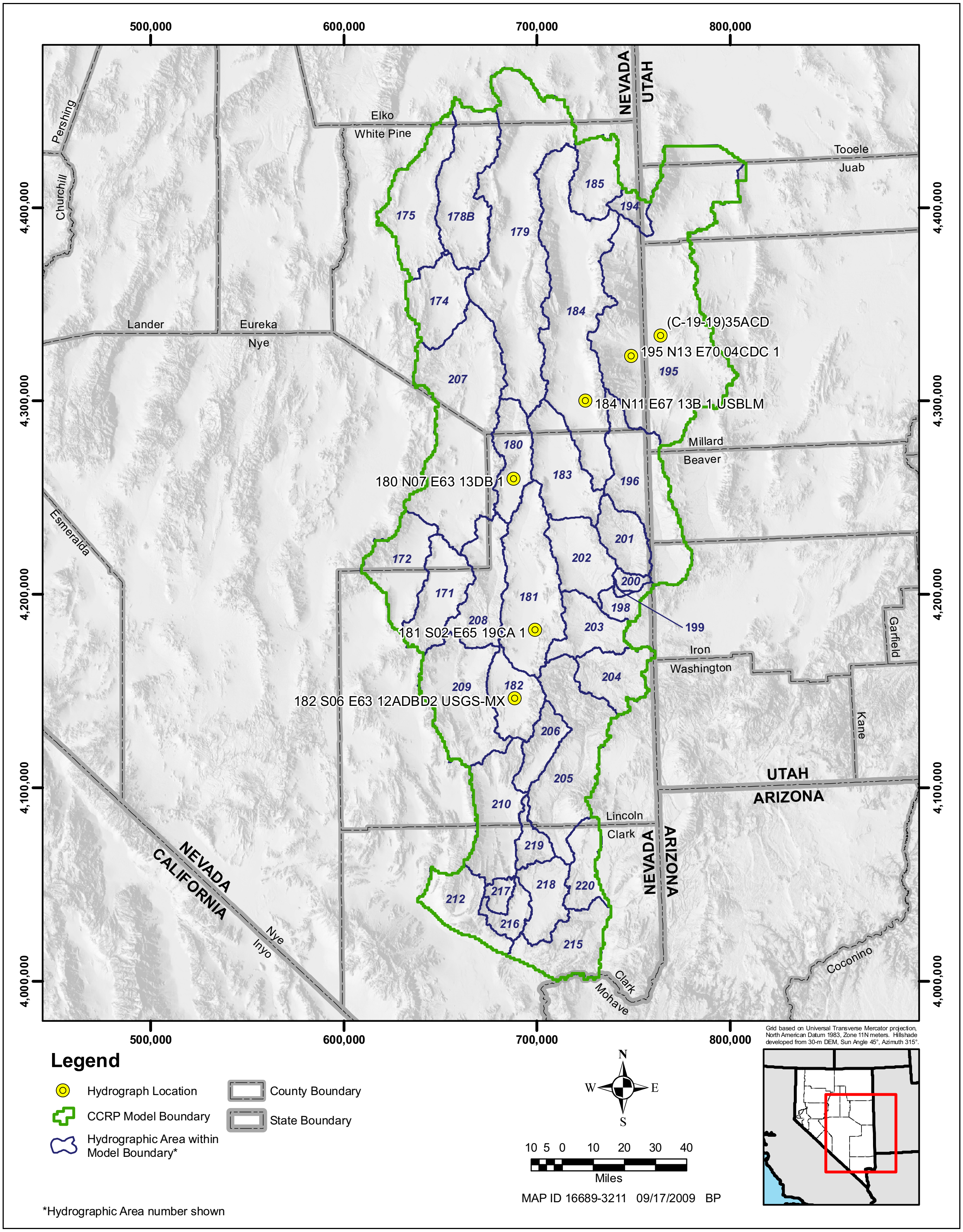
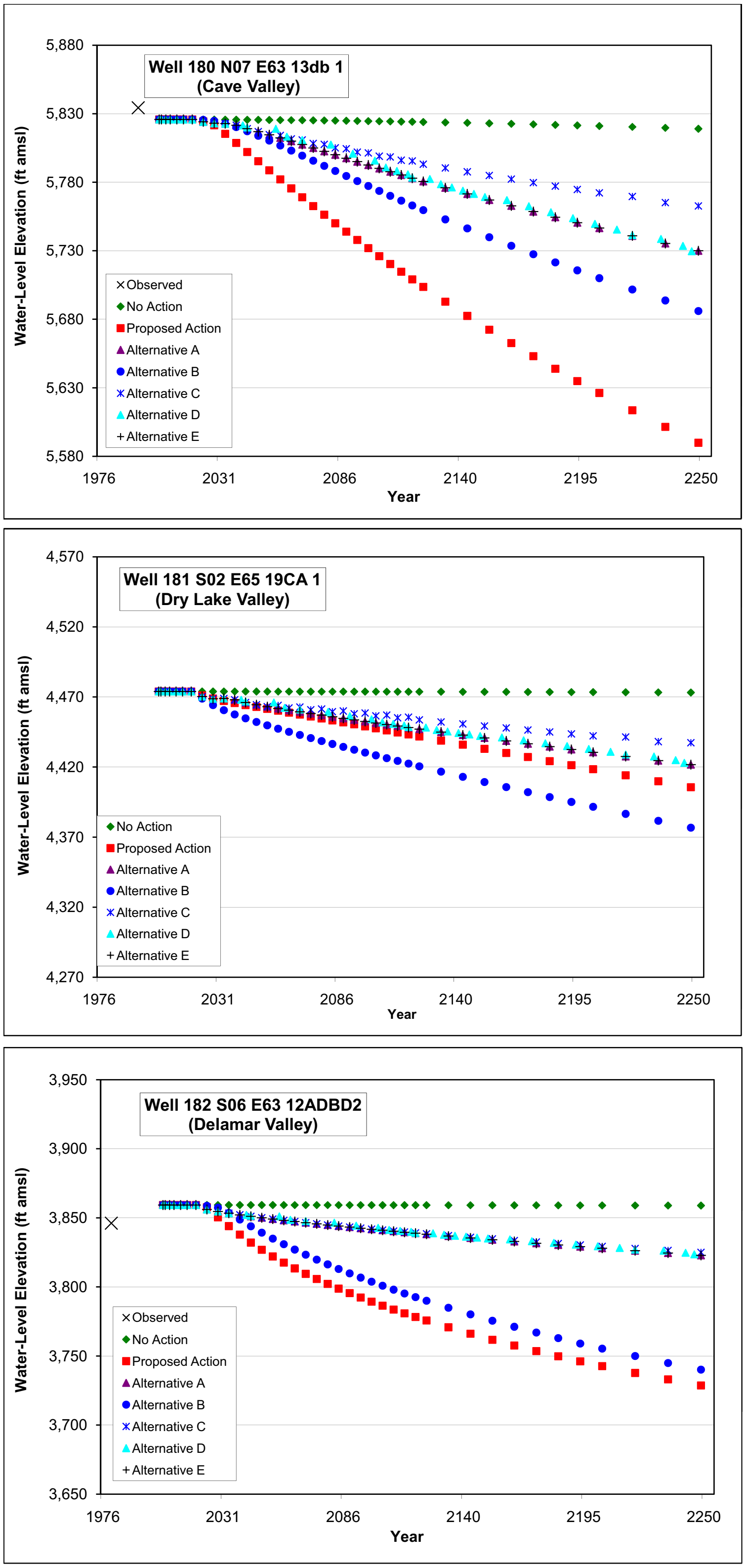
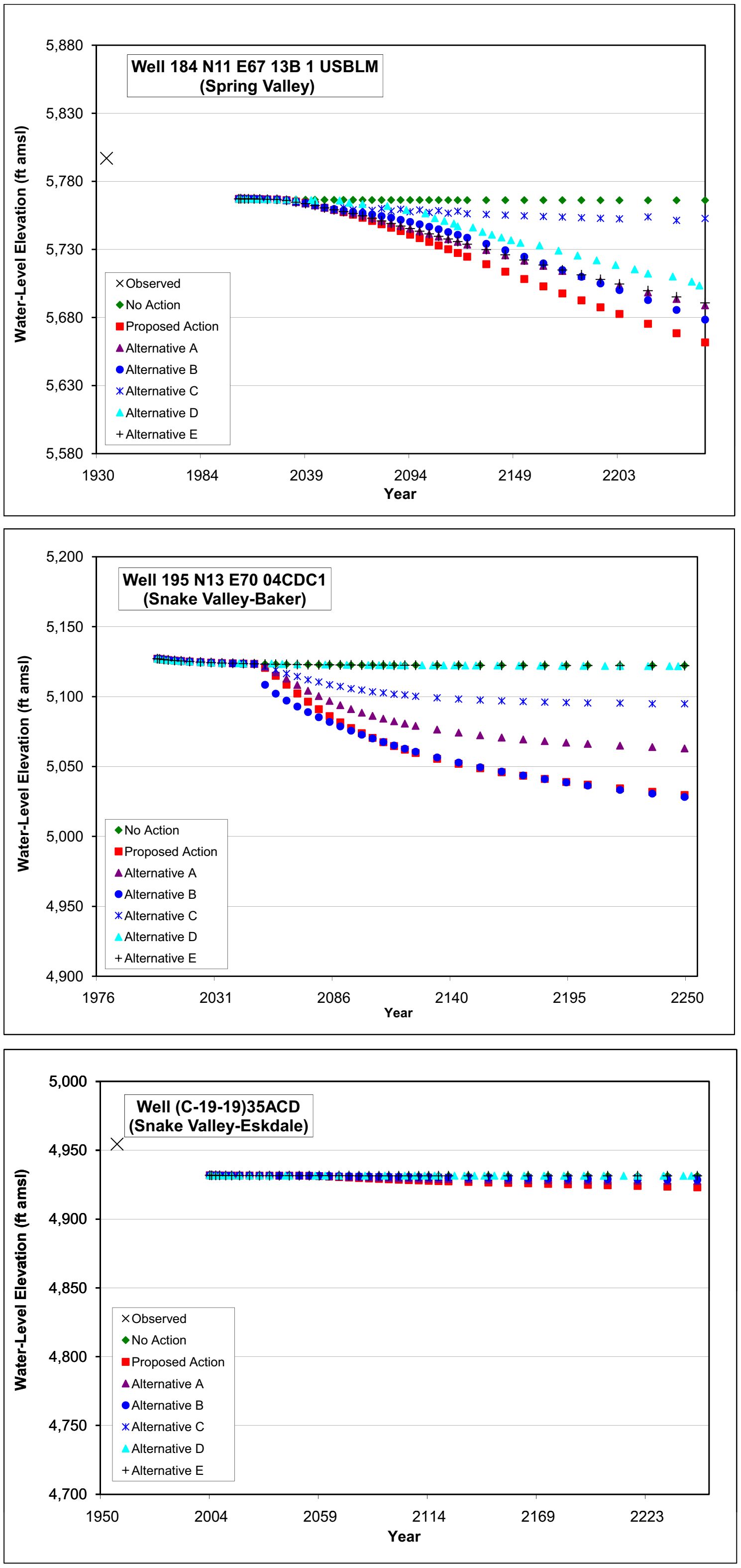


Figure 4-1
Location of Selected Observation Wells



Note: See Figure 4-1 for well locations.

Figure 4-2
Simulated Water Levels at Selected Wells in Cave, Dry Lake, and Delamar Valleys



Note: See Figure 4-1 for well locations.

Figure 4-3
Simulated Water Levels at Selected Wells in Spring and Snake Valleys