SECTION 4.0

Model Calibration Process and Results

Calibrating GSWIM was a process of tuning the numerical model to simulate observed surface and subsurface flow conditions and chloride concentrations in the field, as described with measured data, to within a reasonable degree of accuracy. This process generally involved adjusting model parameters, flow formulation approaches, and prescribed boundary conditions (i.e., stresses) until the model achieved an acceptable level of accuracy. The model was generally calibrated in accordance with the *Standard Guide for Calibrating a Ground-Water Flow Model Application*, published by the American Society for Testing and Materials (1996). Section 3.0 describes the parameter values that resulted from calibration. Following are discussions of the calibration process, targets, and results.

4.1 Calibration Process

Calibrating GSWIM involved simulating both steady-state and transient surface and subsurface flow and chloride conditions.

4.1.1 Steady-state Simulation

Steady state is a condition where water outflow from a model domain is balanced by water inflow and, therefore, water levels are stable with no change in storage in the system. The purpose of the steady-state simulation was to provide stable initial conditions by establishing regional groundwater flow patterns, hydraulic gradients, and subsurface moisture conditions to be used as starting conditions for the transient calibration effort. The procedure involved averaging the 1975 boundary condition input data and completing a steady-state solution. Simulation of chloride transport was not part of the steady-state solution. The steady-state solution provided a starting point for the transient simulation, so that the system was internally stable. Starting with stable conditions minimizes artificial changes in inflows and outflows and changes in groundwater levels due to poorly defined initial conditions at the beginning of a transient simulation.

Initial conditions are required to start transient simulations. If these initial conditions are poorly defined, the numerical model will “work out” the poorly defined initial condition and not truly represent effects of boundary conditions imposed at the start of a transient model simulation. An example of poorly defined initial conditions might be a situation in which initial groundwater levels are set “flat” in a groundwater basin that has been heavily pumped prior to the start of a transient simulation. If a transient simulation began with flat initial conditions, there would be significant drawdown around the pumping centers in this hypothetical groundwater basin, which might result in major lowering of groundwater levels and significant dewatering shortly after the simulation started. If initial conditions were defined more accurately, there would be much less reduction in groundwater storage. So, a steady-state simulation is commonly used to try and provide a balanced and stable set of initial conditions, so that simulated responses of the hydrologic system are due to the stresses imposed in the model instead of poorly defined initial conditions.

4.1.2 Transient Calibration

After the steady-state flow simulation was completed and initial flow conditions were established, calibration began for transient flow processes of interest for CYs 1975 through 2005. Chloride transport was not simulated during initial calibration efforts.

4.1.2.1 Calibration Targets

As previously described, portions of the simulation domain located west of the western Piru Subbasin boundary were included in the GSWIM domain to put distance between the model boundary and the region of interest, to minimize numerical boundary effects in the area of interest. The western limit of the GSWI Study calibration area is shown on Figure 3-2. Figures 4-1a through 4-1e depict the locations of the calibration targets selected for the GSWI Study, which included the following:

- 88 groundwater-level target locations
- 50 groundwater-chloride target locations (some of which are the same as the groundwater-level target locations)
- 6 streamflow target locations
- 12 surface-water quality locations (some of which are the same as the streamflow target locations)

Calibration targets for the GSWI Study are the selected field-measured values that quantify hydrologic and chloride conditions of interest. Selecting appropriate calibration targets for the GSWI Study was an important step in the calibration process. CH2M HILL-HGL selected both qualitative and quantitative calibration targets for the surface and subsurface flow of water and chloride in GSWIM after examining available data and relevant observations with consideration of data quality.

As previously stated, the calibration period includes CYs 1975 through 2005. Consideration was given to whether to split the 31-year calibration period into two periods; one for history matching and the other for model verification (at the direction of the GSWI TAP). However, as part of the GSWI collaborative process, it was decided that it was not necessary to split the calibration period because modeling results would ultimately be evaluated over the whole 31-year period. As a result, CH2M HILL-HGL moved forward using the entire 31-year period for history matching of simulated and observed conditions.

Sufficient measured data are available for the 31-year calibration period to describe aspects of groundwater and surface-water hydrology and chloride within the GSWI Study area. It is desirable for a calibration period to have a variety of hydrologic and water use conditions. This allows model output to be evaluated against the variety of observed conditions prior to the model's use as a predictive tool under a variety of future land and water use assumptions. Significant urbanization occurred in the East Subbasin during the calibration period, as well as an associated increase in SWP imports that began in 1980. Further, local and SWP system hydrology varied considerably from 1980 through 2005, and included single-year and multi-year droughts. Consequently, this calibration period provides for a wide variety of hydrologic and operational stresses with which to demonstrate GSWIM's ability to replicate hydrologic responses to these stresses.

Qualitative Calibration Targets. Qualitative calibration targets for the GSWI Study refer to general observations of temporal or spatial patterns of the field problem that were compared to GSWIM output. These targets are as follows:

- General locations of streamflow versus dry areas in channels
- General groundwater flow directions (i.e., toward the SCR and to the west from the East Subbasin to the Piru and Eastern Fillmore Subbasins)
- General magnitudes of seasonal groundwater-level fluctuations from visual evaluation of groundwater-level hydrographs
- General magnitudes of streamflow fluctuations from visual evaluation of streamflow hydrographs
- General magnitudes of cumulative streamflows from visual evaluation of cumulative flow plots over the calibration period
- General long-term temporal trends in streamflow and groundwater levels (e.g., increasing, decreasing, or stable) from visual evaluation of hydrographs
- The general range of chloride concentrations detected in streams, especially in the SCR between the WRPs and the beginning of the Dry Gap in Ventura County
- General magnitudes of groundwater chloride concentrations and their fluctuations via visual evaluation of groundwater chemographs
- General long-term temporal trends in groundwater chloride concentrations (e.g., increasing, decreasing, or stable) from visual evaluation of chemographs

Quantitative Calibration Targets. Calibration statistics provide a quantitative measure of a model's ability to replicate field conditions. GSWIM calibration was evaluated using a variety of summary statistics, as follows:

- Residual error, computed as the simulated value minus the observed value. This statistic was computed for all calibration target locations.
- Mean error (ME), computed as the sum of all residuals divided by number of observations. This summary statistic was computed for all calibration target locations.
- Coefficient of determination (R^2), computed as the square of the correlation coefficient. This summary statistic was computed for all calibration target locations.
- Root mean squared error (RMSE), computed as the square root of the mean of all residual-squared errors. This summary statistic was computed for all groundwater-level and chloride concentration calibration target locations.
- RMSE divided by the range of observed values (RMSE/Range) at that location. This summary statistic was computed for all groundwater-level calibration target locations.
- Nash-Sutcliffe coefficient (NSC), computed as 1 minus the sum of the squared residuals divided by the sum of the squared differences between daily and mean of the daily results. This summary statistic was computed for all streamflow target locations.

Rather than setting arbitrary goals for individual summary statistics as part of quantitative calibration, the GSWI Modeling Team moved forward with the following general goals:

- To have residual error, ME, RMSE, and RMSE/Range values as small as possible
- To have R^2 and NSC values as close to 1.00 as possible

4.1.2.2 Preliminary Calibration Approach

CH2M HILL-HGL strived to incorporate as many details of the physical system into GSWIM as possible. Given the large extent of the GSWI Study area, desire of the GSWI TWG for GSWIM to provide daily output results over a 31-year historical period, dynamic local hydrology regime, and the fact that GSWIM is a physically based and spatially distributed numerical model, GSWIM run times were significant (i.e., multiple days to complete a single calibration simulation). Thus, a stepwise approach was implemented to achieve calibration in as little time as possible. This approach involved the use of monthly stress periods and subarea flow models of the study area, then use of daily stress periods and whole-model domain simulations to fine-tune the calibration of hydrologic and chloride conditions in the GSWI Study area. The following subsections describe the preliminary calibration approach taken by CH2M HILL-HGL to utilize observations made during early stages of calibration to expedite the overall calibration process.

Monthly Stress Periods. In an effort to minimize run times, flow boundary conditions were initially discretized using monthly stress periods (i.e., datasets were entered as monthly average values as opposed to daily values). This allowed a complete flow simulation of the 31-year historical period using 372 stress periods (12 months x 31 years) rather than 11,323 stress periods (365.258 days x 31 years), thereby significantly reducing GSWIM run times. Therefore, a greater number of calibration simulations could be completed within a shorter time frame and the sensitivity of model results to model input parameters could be identified more quickly, to further focus calibration efforts.

The sensitivity of the GSWIM flow solution to monthly versus daily stress periods is summarized as follows:

- Groundwater levels were similar in monthly and daily simulations.
- Monthly simulations of peak streamflows underestimated the observed daily peak streamflows at several locations in the GSWIM domain; daily simulations better matched observed daily peak streamflows.
- Streamflow recession in the monthly simulations occurred over longer periods than in the daily simulations. However, even though peak streamflows were underestimated in the monthly simulations, the longer streamflow recession periods offset the difference in cumulative simulated streamflow volumes. As a result, the cumulative simulated streamflow volumes were similar between monthly and daily simulations.

Ultimately, daily stress periods were used in the final calibration so that direct comparisons could be made with daily streamflow calibration targets.

Adaptive Time-stepping and Solver Optimization. During the early calibration phase, the adaptive time-stepping and solver parameters of GSWIM were optimized. The goal of this optimization process was to modify convergence criteria and solver options so flow simulations would converge in a robust and efficient manner. The strategy involved using observations of convergence and run times from earlier transient flow simulations to improve the performance of later transient simulations. The parameters that were adjusted as part of this optimization process and their final values are as follows (see HGL [2006] for definitions of terms):

- Maximum number of outer iterations = 75
- Backtracking residual reduction factor = 10
- Head closure criterion = 0.03 foot
- Time-step multiplier = 2
- Time-step divider = 5

These parameters are independent of parameters in GSWIM that are related to the physical conceptualization of the GSWI Study area or boundary conditions. These parameters relate only to the manner in which GSWIM solves mathematical equations. The adaptive time-stepping and solver optimization efforts decreased GSWIM run times by more than 50 percent.

Global Sensitivity Analysis. Global sensitivity analysis involved systematically changing values of selected GSWIM input parameters over the entire GSWIM domain to evaluate the magnitude of response in the simulated hydrologic system. The goals for conducting this analysis were to improve the understanding of how the simulated hydrologic system responded to ranges of input parameter values and aid in developing a calibration strategy. This analysis further helped to identify the types of post-processing tools that needed to be developed to efficiently summarize GSWIM output. Table 4-1 summarizes the results of the global sensitivity analysis. Following are notable parameter sensitivities:

- Simulated heads were sensitive to Kh; vertical leakance of the CHF, OLF, and groundwater domains; crop coefficients; moisture retention parameters; and root zone and evaporation distribution functions. Simulated heads and streamflows were less sensitive to changes in the LAI, Cint, OLF and CHF rill heights, and depth to bedrock at Blue Cut.

- Streamflows were somewhat sensitive to Manning-n, vertical leakance of the CHF and OLF domains, and Kv of the CHF and Model Layers 1 through 3. Streamflows were quite sensitive to rill heights. Cumulative simulated streamflows were not sensitive to Manning-n.

Model-derived water balance terms were also evaluated at this stage to gain insights into potentially erroneous modeling results that could mask the effects of parameter changes related to the global sensitivity analysis. Table 7-1 of the Task 2A Report (CH2M HILL-HGL, 2006b) was used as a guide for evaluating the model-derived water balance terms. Results of the initial simulations indicated that simulated groundwater levels were generally too high (especially during drought periods), cumulative streamflow volumes were too high, and ET fluxes were lower than previously estimated during development of the Task 2A Report (CH2M HILL-HGL, 2006b). Further, too much water was being simulated as groundwater inflow at Lang in the East Subbasin. The excess water in the East Subbasin portion of the domain led to excess water being simulated in portions of the domain representing the Piru and Eastern Fillmore Subbasins as well. Upon further evaluation, it was noted that the significant underestimation of ET was the main reason that GSWIM was simulating too much water in the surface and subsurface domains.

Several of the sensitivity observations listed in Table 4-1 are the result of conducting focused simulations to address the underestimation of ET (as noted by information listed in the "Average ET" column of the table). The sensitivity results indicated that the most effective way to increase simulated ET fluxes was to "hold back" more water in the bedrock areas of the OLF domain. It was discovered that the most effective way to do this was to increase the rill height values, which represent the storage in surface rills as well as in the topsoil in bedrock areas of the domain (see Section 3.2 for more discussion of rill heights in GSWIM).

Subarea Modeling. The Hopper and Pole Creek Subarea of the domain was of special interest in evaluating ET in bedrock areas because stream gages on these creeks are located downstream of areas dominated by bedrock and native vegetation. The water budget in these areas is less complex (i.e., precipitation minus ET equals runoff where infiltration is negligible) than water budgets in areas with significant water use and thick subsurface domains (i.e., where interaction of groundwater and surface water leads to more complicated water routing). Because precipitation is specified in GSWIM and the daily streamflow at the stream gages is measured, the primary variable left to calibrate in these bedrock areas was ET. To minimize run times, a subarea containing CHF segments and OLF grid-blocks representing portions of the Hopper and Pole Creek subwatersheds was "cut out" of the GSWIM domain for efficient evaluation of the parameters that control ET.

The following subsections describe results from simulating surface flow conditions in the Hopper and Pole Creek Subarea, as well as in other subareas that were also "cut out" of the GSWIM domain for similar subarea assessments. These subarea flow simulations ran quickly, allowing more rapid assessment of model behavior and parameter sensitivity. These subarea models were evaluated in order of increasing complexity of hydrologic systems to enable a progressive understanding and calibration of the hydrologic systems. Changes to parameter values or boundary conditions from the subarea models were also periodically updated in the combined domain of GSWIM to ensure that changes to subareas would not lead to problems with the overall GSWIM calibration. Figure 4-2 depicts the boundaries of the subarea models that were created from GSWIM. The subareas are as follows:

- Hopper and Pole Creek
- Mint Canyon
- Castaic
- Bouquet Canyon
- Soledad Canyon
- South Fork
- East Subbasin
- Piru Subbasin

Hopper and Pole Creek Subarea. ET in the bedrock areas of the GSWIM domain is controlled by interception storage and storage in the rills and topsoil (i.e., infiltration is expected to be relatively negligible). Therefore, calibration trials were conducted using the Hopper and Pole Creek Subarea model to calibrate parameters that control ET in bedrock areas. Results from these initial calibration trials with the Hopper and Pole Creek Subarea models were evaluated by comparing the simulated and target cumulative streamflows in Hopper Creek over the 31-year calibration period. The target cumulative observed streamflow in Hopper Creek was approximately 229,540 acre-feet over the 31-year calibration period.

The effects of rill height on the numerical solution of streamflow in Hopper Creek were first examined using input values of 5 and 10 feet. ET increased only slightly between the simulations, with rill heights of 5 and 10 feet, but cumulative streamflows exceeded the target cumulative streamflow by a large margin. Because increasing rill heights to greater than 5 to 10 feet was considered physically unreasonable, other parameters were examined to evaluate their sensitivity to simulated streamflow.

Native Vegetation, Riparian, Barren, and Vacant are the primary LUCs in the Hopper and Pole Creek Subarea. The next calibration trial focused on ET associated with these LUCs. Simulated ET is a function of both the ETo and crop coefficient. Crop coefficients for these LUCs were initially set equal to 1.00 to evaluate their sensitivity to simulated streamflow. ETo values were obtained from the Piru #101 Station (see Table 3-31), and crop coefficients for the remaining LUCs were left at the originally estimated values, which were obtained from the ITRC (2003) and information from the Internet[8]. The cumulative streamflow in Hopper Creek, when using a crop coefficient of 1.00 for the primary LUCs, was reduced to approximately half of the target cumulative streamflow. This result indicated that further examination of the crop coefficient was warranted.

The crop coefficient values for Improved Pasture were then assigned to the bedrock areas to further evaluate ET. The results from this simulation indicated an approximately 30 percent improvement in cumulative streamflow in Hopper Creek. Additional simulations were performed with the Cint values; however, modifications to Cint values were not effective in increasing ET. Through these sets of simulations, it was discovered that using crop coefficients of Improved Pasture for the Native Vegetation, Riparian, Barren, and Vacant LUCs, along with a rill height of 3.5 feet, produced the best results for matching streamflows in Hopper Creek. The Hopper Creek simulations provided estimates for the rill heights in bedrock areas (representing storage in the rills and topsoil) that facilitated the calibration process for other bedrock areas of the GSWIM domain. These simulations helped identify the main parameters that aided in calibrating ET in bedrock areas, which included rill heights and crop coefficients of various LUCs that control the potential ET.

When the simulated cumulative streamflow in Hopper Creek was similar to the target cumulative streamflow, daily streamflows in Hopper Creek were examined more closely. Changing the CHF and OLF Manning-n, rill height, and crop coefficient input values resulted in only slight differences, but did not improve the calibration significantly. The Manning-n parameter affected peak streamflow values as well as the timing and duration of the peaks. The rill height and crop coefficient did not significantly affect the peaks, but did affect the cumulative streamflow. Further inspection of the simulated streamflow hydrographs indicated that the subarea model underpredicted streamflows between approximately 1 and 50 cubic feet per second (cfs). Additional modifications were implemented to better replicate the lower streamflow rates in Hopper Creek. Implementing these modifications led to inclusion of a subsurface model layer beneath the Hopper Creek channel to help generate baseflow. The thickness of this subsurface layer was adjusted

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[8] http://www.itrc.org/etdata/waterbal.htm.

within reasonable anticipated thicknesses until the simulated daily streamflows more closely matched the observed daily streamflows (see Figure 3-16 for a map of Alluvium thickness in Model Layer 3; Alluvium thicknesses in Model Layers 1 and 2 were 1 and 5 feet, respectively). Parameter assumptions in the Hopper and Pole Creek Subarea model were then implemented in GSWIM.

Mint Canyon Subarea. The Mint Canyon Subarea model also had only one streamflow target location for calibration. However, the Alluvium is thicker in the downstream reaches of Mint Canyon than in the Hopper and Pole Creek Subarea. Thus, the water budget was more complicated in the Mint Canyon Subarea because infiltration upstream from the Mint Canyon stream gage had to be more thoroughly evaluated.

Initial subarea model simulations showed too much cumulative streamflow compared to the target cumulative streamflow over the 31-year calibration period. Changing the rill height and crop coefficients, guided by results from the Hopper and Pole Creek Subarea models, significantly reduced streamflows; however, the simulated cumulative streamflows were still too high compared to the target cumulative streamflows. With underlying Alluvium present upstream of the Mint Canyon stream gage, streamflow was reduced by allowing more stream infiltration upstream of the stream gage. Increasing the OLF and CHF vertical leakance (i.e., allowing more stream infiltration) reduced Mint Canyon cumulative streamflow significantly; however, the model underpredicted streamflow during low-flow periods.

Increasing the Alluvium Kh from 150 to 550 feet per day only had minor effects on streamflow. Reducing precipitation in the subarea by 30 percent led to lower streamflows, but the model still underpredicted streamflows during low-flow periods. Increasing the rill height in the bedrock areas to 6 feet reduced simulated cumulative streamflow, but not sufficiently to match target cumulative streamflow and increasing rill height even further did not have much impact on results.

From these various subarea model simulations, it was hypothesized that challenges in calibrating to target data were the result of either (1) errors in measured precipitation or streamflow data, or (2) the method used to spatially interpolate precipitation rates into areas of the domain where rain gages did not exist. As described in Section 3.8.2.1 of this report, it was discovered that some of the reported measured precipitation data were not reliable. After modifications were made to the precipitation data and areal extents of precipitation zones for selected gages in the East Subbasin (see Figure 3-47), streamflows better matched target streamflows in Mint Canyon.

Castaic Subarea. The Castaic Subarea model was different from those of the Hopper and Pole Creek and Mint Canyon Subareas in that groundwater elevations (i.e., heads) were the only targets available for calibration. Further, the Castaic Subarea model included an inflow boundary condition representing releases and spills from Castaic Lake and Lagoon into Castaic Creek. As with the other subarea models, the initial simulation indicated too much water in the system; heads were overpredicted by approximately 15 feet during peak periods and 5 feet during drought periods. Reviewing the results led to the observation that simulated peaks in heads were related to the upstream inflow boundary condition. Further simulations indicated that the downward trends in hydrographs during drought periods could be controlled by modifying the Alluvium Kh. Increasing the Kh from 350 to 450 feet per day provided the desired response in simulated heads during drought periods.

Bouquet Canyon Subarea. The Bouquet Canyon Subarea model included more complex hydrogeology and land use than the previously described subarea models. Unlike the previous subarea models, the Bouquet Canyon Subarea model included both the Alluvium and Saugus Formation in its downstream reaches. Furthermore, Bouquet Canyon also included portions of the CHF domain that were lined and bermed. An inflow boundary condition representing releases from Bouquet Reservoir was also included in the Bouquet Canyon Subarea model. Lastly, calibration targets included both streamflow and groundwater elevation observation data.

Because the initial Bouquet Canyon Subarea model simulation indicated too much water in the system (i.e., overpredicted cumulative streamflow and heads), additional simulations were performed to evaluate parameter sensitivities in the Bouquet Canyon Subarea. Simulation results indicated that increasing the CHF and OLF vertical leakance values reduced streamflow but increased groundwater elevations. Additional simulations indicated that increasing the Alluvium Kh provided the desired effect of reducing both streamflow and groundwater elevations, by allowing the stream infiltration water to move laterally more easily in the subsurface. In addition, lowering the vertical leakance on the lined and bermed portions of the CHF segments abated the simulated peaks in heads, which were also discovered to be related to releases from Bouquet Reservoir. These calibrated Kh values for the Alluvium are consistent with the zones delineated in the *2001 Update Report: Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems* (RCS, 2002) and are within ranges estimated by aquifer tests in the region. The specific yield of the Alluvium also helped to control the response in groundwater elevations during drought periods. The resulting values of specific yield are also consistent with those presented in the *2001 Update Report: Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems* (RCS, 2002). Furthermore, as described in Section 3.8.2.1 of this report, modifications were made to the precipitation data and precipitation zones for selected gages in the East Subbasin (see Figure 3-47). These modifications improved the capability of the Bouquet Canyon Subarea model to match streamflows and groundwater elevations.

Soledad Canyon Subarea. The Soledad Canyon Subarea model included surface and subsurface inflow boundary conditions and both the Alluvium and the Saugus Formation. Similar to the Castaic Subarea model, the Soledad Canyon Subarea model included only groundwater elevations as calibration targets. The initial simulation indicated that the simulated heads matched peak target heads well (which corresponded with peak inflows from the Acton Subbasin); however, the low target heads were being overpredicted. It was noted that the bottom elevation of the Alluvium grid-blocks was initially set higher than some of the well bottom elevations, as indicated by available well construction data and some of the observed groundwater-level data. Dropping the bottom elevations of the Alluvium grid blocks to better honor the well construction data improved the capability of the model to simulate lower head conditions (i.e., allow more lateral outflow). Further simulations indicated that adjustments of Kh and specific yield values provided the changes needed to calibrate the Soledad Canyon Subarea model. The calibrated values of Kh and specific yield values were within the range provided in the *2001 Update Report: Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems* (RCS, 2002).

South Fork Subarea. The South Fork Subarea model included the Alluvium and Saugus Formation, which included significant groundwater pumping. The South Fork Subarea model included only groundwater elevations as calibration targets. Similar to the other subarea models, the initial simulation indicated too much water in the system (i.e., overpredicted heads). Simulations to test the sensitivity of vertical leakance of the CHF, OLF, and groundwater domain (i.e., all model layers) to the numerical solution provided mixed results. Increasing crop coefficient values for the Urban Commercial/Industrial and Urban Low-density Residential LUCs (these are dominant in the South Fork Subarea) decreased groundwater elevations by approximately 5 feet, but larger reductions were needed. Increasing the Kh of the Alluvium from 150 to 550 feet per day lowered the simulated peak groundwater elevations, but the lower target groundwater elevations continued to be overpredicted. Increasing the Kh values within the lower Saugus Formation to values of the adjacent higher-Kh zones improved the match between simulated and target heads for all wells located within that zone. Decreasing the well efficiency from 100 percent to 70 percent in the FWL5 package of MODHMS provided an improved match between simulated and target heads for several of the wells, although well efficiency was not a controlling factor in previous simulations using the other subarea models.

East Subbasin Subarea. The East Subbasin Subarea model was a combination of the following subarea models:

- Soledad Canyon
- Mint Canyon
- Bouquet Canyon
- South Fork
- Castaic

As previously described, the subarea models were evaluated in order of increasing complexity of hydrologic systems to enable a progressive understanding and calibration of these hydrologic systems. Further, as subarea model calibration progressed, GSWIM was periodically updated to assess the effects of subarea model modifications. The East Subbasin Subarea model was useful in evaluating calibration to observed data for locations outside or near the boundaries of previously listed subarea models. Similar to the other subarea models, the initial simulations indicated too much water in the system. Approaches and results from previous simulations and subarea models were helpful in improving calibration of the East Subbasin Subarea model.

Piru Subbasin Subarea. The Piru Subbasin Subarea model includes the portion of the GSWIM domain located downstream of the East Subbasin Subarea. To include effects of flows from upstream of Blue Cut, the observed streamflow data from Blue Cut were input to the model as an inflow boundary condition. Similar to the other subarea models, initial simulations indicated too much water in the system (i.e., overpredicted cumulative streamflow and heads, and the Dry Gap was not being adequately simulated). Closer examination of the UWCD Modflow model parameters and zonation (initially used to parameterized the Ventura County portion of the GSWIM domain) revealed that Kh and vertical leakance values were generally divided into three zones from upstream (i.e., East) to downstream (i.e., West). Lower Kh and vertical leakance in the upstream zone limited stream infiltration in the eastern portion of the Piru Subbasin. A higher-Kh zone located downstream of the eastern zone allowed for water to rapidly infiltrate in the Dry Gap area and move laterally to the west in the subsurface, thereby lowering heads beneath streambed elevations at the Dry Gap. A lower-Kh zone located near the Piru Narrows allowed the model to simulate the downstream extent of the Dry Gap, where some groundwater discharges at the surface. Varying the Kh and vertical leakance of these three zones allowed the extent of the Dry Gap and the groundwater hydrographs to be more effectively calibrated.

4.1.2.3 Final Calibration Approach

Controlling Parameters for Flow. Because of long model run times and schedule constraints, a formal sensitivity analysis with the final calibrated version of GSWIM was not performed. However, the numerous simulations that were performed as part of the calibration process provided valuable insights to GSWIM's response to input values. Thus, further post-calibration sensitivity analysis is anticipated to provide little additional useful information. Observations and approaches described throughout Section 4.1.2.2 of this report were intended to provide a general understanding of the controlling parameters in GSWIM, in the context of sensitivity. Controlling parameters, in this report, are defined as the parameters, boundary conditions, and conceptualization details that required the most attention and had the greatest impact on model results during calibration.

Streamflows. The controlling parameters for streamflows in GSWIM are summarized as follows:

- Simulated streamflows are strongly influenced by time-series precipitation rates and the spatial zonation of precipitation.
- The Kh of Alluvium that underlies CHF segments influenced the ability of GSWIM to replicate daily and cumulative streamflow. Higher Kh values allowed for increased stream infiltration and reduced baseflow.
- The CHF vertical leakance and its Manning-n values had a strong effect on simulated streamflows. The CHF vertical leakance values influenced the volume of simulated streamflow, and the Manning-n values influenced the ability of GSWIM to replicate peak streamflow events. Higher Manning-n values reduced simulated streamflow peaks and increased streamflow peak durations.
- Rill heights played a significant role in calibration of streamflow in some areas. Rill heights were used to hold back surface-water runoff (which was then subject to ET and infiltration), reducing cumulative and peak streamflows and durations.
- The connectivity assignment of the CHF segments with the underlying groundwater domain was an important consideration when tying to match baseflow conditions in some of the simulated streams. If CHF segments were connected to one of the variably saturated model layers (Model Layers 1 and 2), baseflow would only be simulated if saturation of the subsurface layer were 100 percent.
- The width and depth of the rectangular CHF segments were important considerations when tying to match daily streamflows. Adjusting these parameters caused GSWIM to move water to and from the OLF and CHF domains. Streamflow that was simulated to

spill over the CHF banks was subject to infiltration and ET as it spread out over the adjacent OLF grid-blocks. Thus, fine-tuning CHF segment geometries was useful in calibrating to specific ranges of daily streamflow because different combinations of widths and depths helped calibrate GSWIM to different ranges of streamflow.

- The vertical resistance to flow within the Saugus Formation (Model Layers 4 through 9) was an important parameter in the downstream portion of the East Subbasin. In this area, deep groundwater is moving vertically upward, eventually passing through the Alluvium, and discharging to the SCR. Modifying the vertical leakance in subsurface layers in this portion of the domain directly affected streamflow at Blue Cut and Las Brisas Bridge in Ventura County.
- Reductions to the thickness and extent of Alluvium in the Blue Cut area increased streamflow at Blue Cut. As the cross-sectional saturated thickness of the Alluvium decreased, streamflow increased because the quantity of water available to the Blue Cut area from the East Subbasin was the same.
- The crop coefficients, ETo, RDF, and moisture retention parameters of the shallow subsurface layers strongly influenced the total ET being simulated by GSWIM, which affected streamflows throughout the domain.

Groundwater Elevations. The controlling parameters for groundwater elevations in GSWIM are summarized as follows:

- The ability to replicate shallow groundwater elevations and simulate saturation conditions in the vadose zone was strongly influenced by the thickness of shallow model layers and the type of flow formulation used for each model layer. Initially, a variably saturated flow formulation was conceptualized for all model layers via the Richards Equation. Groundwater elevation responses and vadose zone saturation conditions were not being adequately simulated with this conceptualization. By applying a variably saturated flow formulation in Model Layers 1 and 2 (which are thin layers, 1 and 5 feet thick, respectively) and an unconfined flow formulation in Model Layers 3 through 9, the match between simulated and target groundwater elevations was improved.
- Target groundwater elevations near Lang were not being replicated by GSWIM when simulating a specified-head boundary condition at Lang (as planned and described in Section 1.4.4.3 of the Task 2A Report [CH2M HILL-HGL, 2006b]). It was discovered that the specified head at Lang was creating greater groundwater inflows during drought periods. This was occurring because downstream groundwater elevations were lower during drought periods, thereby creating a large hydraulic gradient between the specified head and groundwater elevations in Soledad Canyon. Changing from a specified-head boundary condition to a specified-flux boundary condition (as described in Section 3.8.2.2 of this report) significantly improved GSWIM's ability to replicate groundwater elevations in Soledad Canyon, especially during drought periods.
- The vertical resistance to flow within the Saugus Formation (Model Layers 4 through 9) was an important parameter in the downstream portion of the East Subbasin, where deep groundwater moves vertically upward, eventually passing through the Alluvium and discharging to the SCR. Modifying the vertical leakance in subsurface layers in this

portion of the domain directly affected Saugus Formation groundwater elevations in that area. Decreasing vertical leakance increased Saugus Formation groundwater elevations.

- The thickness and extent of Alluvium played a significant role in some portions of the domain, including Soledad Canyon, Piru Creek, and Blue Cut. Increasing the thickness in Soledad Canyon and Piru Creek effectively increased transmissivity, which allowed the subsurface to move water laterally more easily, thereby lowering groundwater elevations. Decreasing Alluvium thickness in the Blue Cut area significantly reduced the underflow passing from Los Angeles County to Ventura County.
- Rill heights played a significant role in calibration of groundwater elevations in some areas. Rill heights were used to hold back surface-water runoff. Water held in rills is subject to ET and infiltration, so, depending on the presence or absence of subsurface layers, rill height adjustments resulted in less or more water available for groundwater recharge.
- The Kh and specific yield of the Alluvium influenced the ability of GSWIM to replicate magnitudes of groundwater elevation fluctuations. Higher specific yield values tended to make the simulated groundwater system less responsive to stresses. Lower specific yield values tended to make the simulated groundwater system more responsive to stresses.
- The crop coefficients, ETo, RDF, and moisture retention parameters of the shallow subsurface layers strongly influenced the total ET being simulated by GSWIM, which affected groundwater elevations throughout the domain.

Controlling Parameters for Chloride. Identifying the controlling parameters for the chloride calibration was more straightforward after flow calibration was well underway. The controlling parameters for chloride in GSWIM are summarized as follows:

- The initial chloride conditions in each model layer played a significant role in calibration to surface-water and groundwater chloride concentrations. Initial chloride concentrations were based on available data from the early to mid 1970s and inferences made from more recent chloride concentrations during the calibration process in areas where no chloride data were available. In the downstream portion of the East Subbasin, initial chloride concentrations in the Saugus Formation were inferred from water quality data for Chiquita Landfill, a Santa Clarita dewatering site, Whittaker-Bermite Saugus Formation wells, NCWD's South Fork wells, and chloride data from dry conditions.
- As described in Section 3.8.5 of this report, it was discovered that simulated groundwater chloride concentrations in Bouquet Canyon were strongly influenced by assumptions of chloride concentrations in Bouquet Reservoir releases. Because chloride concentration data were not available for Bouquet Reservoir, chloride concentrations were assigned to Bouquet Reservoir according to available chloride concentration data for the SCWD-Clark well, which is located in Bouquet Canyon.
- Chloride inflow concentrations in streamflow at Lang were initially developed as described in Section 8.1.1.3 of the Task 2A Report (CH2M HILL-HGL, 2006b). Recognizing the significant uncertainty in these chloride concentrations and the possibility of other unknown sources, the final calibration included multiplying the chloride inflow

concentrations in streamflow at Lang by a factor of 2. This added more chloride mass to the system in the eastern portion of the East Subbasin and improved simulated chloride results in Soledad Canyon groundwater wells without significantly increasing chloride concentrations at Blue Cut over the 31-year calibration period.

- The modifications to the extents of the Kh and vertical leakance zones in the Piru Subbasin near the USGS nested well pair (V-0105, V-0108, and V-0109) improved the match of multi-layer chloride concentrations in the San Pedro Formation.

The resulting parameter values, after the calibration process, are within ranges presented in previous reports for this area and relevant scientific literature. Thus, the GSWI Modeling Team considers the calibrated values reasonable.

4.2 Calibration Results

Parameter input values for the final calibration are presented in Section 3.0 of this report. The following subsections provide a review of the GSWIM calibration results.

4.2.1 Groundwater Elevation Calibration

Calibration results for groundwater elevations are discussed for the following areas in Sections 4.2.2.1 through 4.2.1.3:

- Alluvial Aquifer along the SCR in Soledad Canyon in the East Subbasin, as shown on Figure 4-3
- Alluvial Aquifer along the SCR, between Interstate 5 and Soledad Canyon in the East Subbasin, as shown on Figure 4-4
- Alluvial Aquifer along the SCR, west of Interstate 5 in the East Subbasin, as shown on Figure 4-5
- Saugus Formation, where targets are located along the South Fork SCR in the East Subbasin, as shown on Figure 4-6
- Alluvial Aquifer along Bouquet Creek in the East Subbasin, as shown on Figure 4-7
- Alluvial Aquifer along Castaic Creek in the East Subbasin, as shown on Figure 4-8
- Alluvial Aquifer in other tributary canyons to the SCR in the East Subbasin, as shown on Figure 4-9
- Alluvial Aquifer and San Pedro Formation along the SCR, east of Torrey Road in the Piru Subbasin, as shown on Figure 4-10
- San Pedro Formation along the SCR, between Hopper Creek and Torrey Road in the Piru Subbasin, as shown on Figure 4-11
- San Pedro Formation along the SCR, west of Hopper Creek in the Piru Subbasin, as shown on Figure 4-12

Summary statistics that characterize the match between simulated and measured groundwater elevations are provided on the hydrographs for wells with known well construction details on Figures 4-3 through 4-12. Hydrographs for other wells, namely the Los Angeles County Flood Control District (LACFCD) wells, were used only for qualitative calibration because well construction details were not available (results from multiple model layers are provided for these wells). Locations of the groundwater elevation calibration targets are depicted on Figures 4-1a through 4-1e.

4.2.1.1 East Subbasin

Alluvial Aquifer in Soledad Canyon. At wells throughout Soledad Canyon, GSWIM matched the range of regional groundwater elevations well throughout the calibration period (see Figure 4-3). The simulated and measured declines in groundwater elevations during drought periods were better matched for wells located in the eastern portion of this area, such as NCWD-Pinetree 1, SCWD-Lost Canyon 2, NCWD-Sand Canyon, and SCWD-Mitchell. Although the sharp increases in groundwater elevations during wet periods were modeled well, the wells in the eastern half of Soledad Canyon were unable to maintain high enough groundwater elevations during short dry periods that occurred intermittently from 1993 through 1999. During this period, wells farther west, such as SCWD-Honby, VWC-T2, and SCWD-Stadium, showed better matches between modeled and measured groundwater elevations. Errors resulting from the lack of measured stream gage data at Lang during the calibration period could be the reason GSWIM had difficulty maintaining sufficiently high groundwater elevations during dry periods in the eastern portion of the Soledad Canyon.

Alluvial Aquifer between Interstate 5 and Soledad Canyon. North of the SCR, near the mouth of Bouquet Canyon, GSWIM simulated the observed trends in groundwater elevations fairly well at VWC-Q2, especially from about 1995 (see Figure 4-4). South of the SCR, GSWIM tended to overpredict groundwater elevations by approximately 10 feet at VWC-K2 and VWC-N; however the range of simulated heads matched the range of measured heads fairly well. North of the SCR and downstream of the Saugus WRP, GSWIM consistently overpredicted groundwater elevations by approximately 20 feet at NLF-S3 and VWC-S6. However, downstream at VWC-I, GSWIM consistently underpredicted groundwater elevations by approximately 10 feet during the period of more frequent measurements, from 1996 through 2005. The area downstream of the Saugus WRP, underlying the SCR, has coalescing groundwater flowpaths from Soledad Canyon, Bouquet Canyon, and San Francisquito Canyon, which made calibration in this area challenging.

Alluvial Aquifer West of Interstate 5. GSWIM simulated somewhat greater seasonal variation in groundwater elevations than was suggested by the field measurements, and generally overpredicted groundwater elevations during the calibration period by 5 to 15 feet (see Figure 4-5). However, because the field measurements were collected infrequently, groundwater elevations might appear to be less variable as a result of measurement frequency rather than hydrology.

Saugus Formation in South Fork Santa Clara River Area. In general, GSWIM simulated the trends in groundwater elevations fairly well at each Saugus Formation well (see Figure 4-6). GSWIM tended to overpredict groundwater elevations by approximately 20 to 40 feet in the VWC and SCWD production wells. However, GSWIM closely simulated the groundwater elevation trends at each of these locations. The most problematic calibration target well in the South Fork area was NCWD-9, especially during the drought of the mid-1970s. As shown on Figure 4-6, measured groundwater elevations increased during this drought period. However, groundwater pumping data provided by the responsible agency indicated an increase in groundwater pumping at this location by approximately 40 percent per year between June 1975 and June 1977. Thus, either the measured groundwater elevations or the groundwater pumping rates are questionable at NCWD-9. Regardless, as shown on Figure 4-1b, NCWD-9 is distant from the SCR, near the headwaters of Newhall Creek, and not in the main areas of interest to the GSWI Study.

Alluvial Aquifer along Bouquet Creek. In Bouquet Canyon, GSWIM closely replicated the range in measured groundwater elevations at the SCWD-Clark production well, although the simulated groundwater elevations were approximately 20 feet too high throughout most of the simulation (see Figure 4-7).

Alluvial Aquifer along Castaic Creek. In the upper reaches of the Castaic Creek valley, GSWIM simulated the measured groundwater elevation trends well (generally within 10 feet) during drought periods at LACFCD-6980G, NCWD-Castaic 3, and LACFCD-6980E (see Figure 4-8). GSWIM simulated groundwater levels that were too high in these wells from about 1995 through 2005. Farther downstream, GSWIM closely matched the measured groundwater elevation trends at VWC-D (within 5 feet).

Alluvial Aquifer in Other Tributary Canyons to the Santa Clara River. At VWC-W6, in the lower reaches of San Francisquito Canyon, GSWIM simulated the measured groundwater elevations well, except for a possibly insufficient decline in early 1992 at the conclusion of the regional drought, and too large a decline during 2000 (see Figure 4-9). However, the difference was generally within approximately 10 feet.

4.2.1.2 Piru Subbasin

Alluvial Aquifer and San Pedro Formation East of Torrey Road. At wells throughout the eastern Piru Subbasin, GSWIM replicated regional groundwater elevation fluctuations and trends well, but generally overpredicted groundwater elevations by 15 to 36 feet (see Figure 4-10).

San Pedro Formation between Hopper Creek and Torrey Road. At wells located between Hopper Creek and Torrey Road, GSWIM replicating regional groundwater elevation fluctuations and trends well, but generally overpredicted groundwater elevations by approximately 10 to 20 feet (see Figure 4-11). The exception to this was at V-0121, where simulated groundwater elevation fluctuations were overpredicted. AlthoughV-0121 and V-0123 share a grid-block, measured groundwater elevation data for V-0121 and V-0123 were not consistent, despite being located very near each other.

San Pedro Formation West of Hopper Creek. At wells located west of Hopper Creek, GSWIM replicating regional groundwater elevation fluctuations and trends well, but generally overpredicted groundwater elevations by approximately 5 to 15 feet (see Figure 4-12).

4.2.1.3 Discussion of Calibration to Groundwater Elevations

Qualitative Calibration Targets. The following qualitative calibration targets, described in Section 4.1.2.1 of this report, relate to groundwater elevations:

- General groundwater flow directions (i.e., generally toward the SCR and to the west from the East Subbasin to the Piru and Eastern Fillmore Subbasins).
- General magnitudes of seasonal groundwater-level fluctuations from visual evaluation of groundwater-level hydrographs.
- General long-term temporal trends in streamflow and groundwater levels (e.g., increasing, decreasing, or stable) from visual evaluation of hydrographs.

Figures 4-3 through 4-12 indicate that GSWIM replicated the qualitative calibration targets well. The simulated groundwater elevations generally decreased in a westerly direction throughout the GSWIM domain. GSWIM also replicating the general magnitudes of groundwater-level fluctuations and trends well throughout the domain.

Quantitative Calibration Targets. The purpose of computing summary statistics was to quantify the goodness-of-fit between model output and observed data. Goodness-of-fit statistics that accompany model calibration are not necessarily good indicators of the predictive capabilities of a model. Summary statistics for transient models are highly sensitive to the number of observations (n), timing of the measurement in relation to the timing associated with the simulated result, quality of measured data, and outlier data. As described in Section 4.1.2.1 of this report, the goal of the quantitative calibration was to have ME, RMSE, and RMSE/Range values as small as possible, with R^2 values as close to 1.00 as possible, in the final calibrated model.

Summary statistics for individual target locations throughout the calibration period are provided on individual hydrographs on Figures 4-3 through 4-12, and the ranges of summary statistics are summarized by geographic area in Table 4-2. Summary statistics are only provided for wells with known construction details. Hydrographs for wells with unknown construction details were used only for qualitative comparisons. Figure 4-13 shows a scatterplot of simulated versus measured data, using all paired measured and simulated groundwater elevation data from all quantitative target locations at all times throughout the calibration period. The summary statistics for data presented on Figure 4-13 are as follows:

- ME = 2.9 feet
- RMSE = 24.1 feet
- R^2 = 0.99
- RMSE/Range = 0.02
- n = 11,660

The ME value of 2.9 feet indicates that the simulated volume of groundwater storage was slightly overpredicted throughout the GSWIM domain over the 31-year calibration period. However, considering that measured groundwater elevations vary by more than 1,100 feet over the GSWI Study area, an ME of 2.9 feet and an RMSE of 24.1 feet are quite small. Furthermore, GSWIM replicated the range of groundwater elevations and trends well, which is important for the purposes of the GSWI Study. Simulated groundwater elevations are considered by the GSWI Modeling Team to be well calibrated for the purposes of the GSWI Study.

4.2.2 Streamflow Calibration

Calibration results for streamflow are discussed for the East and Piru Subbasins in Sections 4.2.2.1 through 4.2.2.3. Locations of the streamflow calibration targets are depicted on Figures 4-1a through 4-1e.

4.2.2.1 East Subbasin

Data resulting from monitoring at the following stream gages in the East Subbasin were used to calibrate streamflows in GSWIM:

- Mint Canyon (F328-R) on Mint Creek
- Bouquet Canyon (F377-R) on Bouquet Creek
- Old Road Bridge (F92C-R) on the SCR

Figure 4-14 shows the comparison between simulated and measured cumulative streamflows, daily mean streamflows, and daily streamflow exceedances for the three stream gages in the East Subbasin. Cumulative streamflow and streamflow exceedance comparisons shown on Figure 4-14 only considered paired simulated and measured streamflow data. This was done so that a direct comparison could be made between simulated and measured results. However, the daily streamflow plots shown in the middle row on Figure 4-14 present all simulated streamflow data along with available measured daily streamflow data. This was done so that one can evaluate what GSWIM is simulating throughout the calibration period, even when measured streamflow data were not available.

Overall, GSWIM replicated streamflow characteristics fairly well in Mint Creek. The intermittent nature of streamflow in Mint Creek was replicated very well with GSWIM, in that no streamflow was simulated approximately 70 percent of the time (see exceedance plot on Figure 4-14). GSWIM also matched daily streamflows well between 1 and 100 cfs, and slightly underpredicted daily streamflows outside this range; however, cumulative streamflows matched well over the 31-year calibration period.

GSWIM overpredicted the duration of the no-flow periods by approximately 10 percent at the Bouquet Canyon stream gage (see exceedance plot on Figure 4-14). GSWIM matched daily streamflows well between 1 and 1,000 cfs, and slightly underpredicted daily streamflows less than 1 cfs; however, cumulative streamflows matched well over the 31-year calibration period.

Overall, GSWIM replicated streamflow well in the SCR at Old Road Bridge. Measured daily streamflow data indicate that the SCR is nearly perennial at Old Road Bridge, whereas GSWIM simulated perennial streamflow at this location. GSWIM matched daily streamflows well at 10 cfs and greater, and slightly overpredicted daily streamflows less than 10 cfs.

4.2.2.2 Piru Subbasin

Data resulting from monitoring at the following stream gages in the Piru Subbasin were used to calibrate streamflows in GSWIM:

- Blue Cut (11108500) in the SCR

- Las Brisas Bridge (11109000) in the SCR
- Hopper Creek (11110500) in Hopper Creek

Figure 4-15 shows the comparison between simulated and measured cumulative streamflows, daily mean streamflows, and daily streamflow exceedances for the three stream gages in the Piru Subbasin. Simulated and measured data pairing was consistent with results presented on Figure 4-14.

Overall, GSWIM replicated streamflow well in the SCR at Blue Cut. Both measured and simulated data indicated perennial flow conditions. GSWIM matched daily streamflows above 20 cfs well; however, some streamflow peaks in the 1,000- to 8,000-cfs range were underpredicted. Daily streamflows below approximately 20 cfs were slightly overpredicted; however, cumulative streamflows matched well over the 31-year calibration period.

Overall, GSWIM replicated streamflow well in the SCR at Las Brisas Bridge. Both measured and simulated data indicated perennial flow conditions. Streamflow peaks greater than approximately 10,000 cfs were underpredicted. Daily streamflows below approximately 20 cfs were slightly overpredicted; however, cumulative streamflows matched well over the 31-year calibration period.

Overall, GSWIM replicated streamflow well in Hopper Creek. However, GSWIM overpredicted the duration of the no-flow periods by approximately 10 percent (see exceedance plot on Figure 4-15). GSWIM matched daily streamflows well between 10 and 1,200 cfs, and slightly underpredicted daily streamflows outside this range; however, cumulative streamflows matched well over the 31-year calibration period.

4.2.2.3 Discussion of Calibration to Streamflow

Qualitative Calibration Targets. The following qualitative calibration targets, described in Section 4.1.2.1 of this report, relate to streamflows:

- General locations of streamflow versus dry areas in channels.
- General magnitudes of streamflow fluctuations from visual evaluation of streamflow hydrographs.
- General long-term temporal trends in streamflow (e.g., increasing, decreasing, or stable) from visual evaluation of hydrographs.
- General magnitudes of cumulative streamflows from visual evaluation of cumulative flow plots over the calibration period.

Figures 4-14 and 4-15 indicate that GSWIM replicated intermittent versus perennial flow conditions at the target stream gage locations. The Dry Gap is located downstream of Las Brisas Bridge and the nearest downstream stream gage along the SCR is located several miles west of the GSWI Study area. Therefore, the existing stream gage network is not sufficient for clearly defining the precise extent of the Dry Gap. However, GSWIM accurately simulated perennial streamflow at Las Brisas Bridge, meaning that the Dry Gap in the model is located downstream of this location. Modeled locations of wet and dry portions of stream channels were evaluated by visually inspecting animations of monthly output over the calibration period. These animations indicated that GSWIM accurately simulated the general location of the Dry Gap, as well as other dry stream channels. These and other animations were provided to the GSWI stakeholders as part of the collaborative process and are not provided in this report.

GSWIM slightly overpredicted lower streamflows in perennial streams and slightly underpredicted lower streamflows in intermittent streams, but matched cumulative streamflows well overall. No long-term trends were observed in either the simulated or measured streamflow data. Rather, streams in the GSWI Study area responded dynamically to storm-runoff events; streamflows can vary by orders of magnitude over short periods.

Quantitative Calibration Targets. Summary statistics for individual target locations over the whole calibration period are provided on individual stream hydrographs on Figures 4-14 and 4-15. Table 4-3 lists the summary statistics computed using the paired simulated and measured daily streamflow data.

The ME for the intermittent reaches of streams represented by stream gages in Mint Creek, Bouquet Creek, and Hopper Creek deviated from zero by only 2.2 cfs, which is good. The ME for the perennial reaches of the SCR represented by stream gages at Old Road Bridge (i.e., nearly perennial), Blue Cut, and Las Brisas Bridge deviates from zero by 13.7 cfs, which is also good, considering the large amplitude of streamflows at these locations. The R^2 and RSC values indicate that much of the variance between simulated and daily streamflow data is not explained by a simple linear relationship for the intermittent stream gages. However, the R^2 and RSC values are closer to a value of 1.00 for streamflow comparisons of the perennial stream gages. GSWIM replicated the daily streamflow dynamics and the cumulative streamflow well over the 31-year calibration period, which is important for the purposes of the GSWI Study. Simulated streamflows are considered by the GSWI Modeling Team to be well calibrated for the purposes of the GSWI Study.

4.2.3 Chloride Calibration

Calibration results are discussed for the following areas in Sections 4.2.3.1 through 4.2.3.3:

- Alluvial Aquifer along the SCR in Soledad Canyon in the East Subbasin, as shown on Figure 4-16
- Alluvial Aquifer along the SCR west of Soledad Canyon in the East Subbasin, as shown on Figure 4-17
- Saugus Formation, where targets are located along the South Fork SCR in the East Subbasin, as shown on Figure 4-18
- Alluvial Aquifer in other tributary canyons to the SCR in the East Subbasin, as shown on Figure 4-19
- Alluvial Aquifer and San Pedro Formation along the SCR, east of Torrey Road in the Piru Subbasin, as shown on Figure 4-20
- San Pedro Formation along the SCR, between Hopper Creek and Torrey Road in the Piru Subbasin, as shown on Figure 4-21

- San Pedro Formation along the SCR, west of Hopper Creek in the Piru Subbasin, as shown on Figure 4-22
- SCR-RA (upstream of Saugus WRP), SCR-RB (downstream of Saugus WRP), SCR-RC (upstream of Valencia WRP), SCR-RD (downstream of Valencia WRP), and SCR-RE (upstream of Castaic Creek confluence) in the SCR in the East Subbasin, as shown on Figure 4-23
- 04N17W29SW1 (Blue Cut), 04N18W25SW2 (Newhall Crossing), 04N18W25SW1 (near Tapo Creek confluence), SCR-RF (near Camulos Diversion), 04N18W20SW1 (Piru Creek), 04N18W30SW1 (near Torrey Road), and 04N19W33SW1 (near the Fillmore Fish Hatchery) in the Piru Subbasin, as shown on Figure 4-24

Summary statistics that characterize the match between simulated and measured chloride concentrations are provided on individual chemographs on Figures 4-16 through 4-24. Calibration target locations are depicted on Figures 4-1a through 4-1e.

4.2.3.1 Groundwater

East Subbasin. The following subsections describe the chloride calibration results for wells located in the East Subbasin.

Alluvial Aquifer in Soledad Canyon. At wells throughout Soledad Canyon, GSWIM replicated the chloride concentration trends in groundwater reasonably well throughout the calibration period (see Figure 4-16). The exceptions to this were at NCWD-Pinetree 1, SCWD-N. Oaks East, and SCWD-N. Oaks West, where GSWIM had difficulty matching short-term trends in chloride concentrations. Errors resulting from the lack of available streamflow and chloride data at Lang during the calibration period could be the reason GSWIM had difficulty matching some of the chloride trends. Other sources of chloride could be present in and upstream of Soledad Canyon that are not accounted for in GSWIM.

Alluvial Aquifer West of Soledad Canyon. At wells located west of Soledad Canyon, GSWIM also had difficulty matching some of the short-term chloride concentration trends (see Figure 4-17). Again, other sources of chloride could be present that are not accounted for in GSWIM. However, the overall match between simulated and measured chloride data improved near the western portion of the East Subbasin, which corresponds to the area of greatest interest for the GSWI Study.

Saugus Formation in South Fork Santa Clara River Area. Results in the South Fork SCR area were consistent with the previously described areas of the East Subbasin, in that GSWIM also had some difficulty matching some of the short-term chloride concentration trends, but simulated chloride concentrations were in the range of measured chloride concentrations (see Figure 4-18).

Alluvial Aquifer in Other Tributary Canyons to the Santa Clara River. GSWIM replicated the chloride concentrations trends in Bouquet Canyon, San Francisquito Canyon, and Castaic Valley reasonably well (see Figure 4-19). However, GSWIM had difficulty matching measured chloride concentrations in the range of 140 to 180 mg/L at VWC-D during a period in the early 1990s. These high chloride concentrations occurred only three times during this period, and simulated chloride concentrations after this period were approximately 10 to 15 percent lower than measured chloride concentrations.

Piru Subbasin. The following subsections describe the chloride calibration results for wells located in the Piru Subbasin.

Alluvial Aquifer and San Pedro Formation East of Torrey Road. In general, GSWIM replicated chloride concentrations well in groundwater in the eastern Piru Subbasin (see Figure 4-20). Ranges of measured chloride concentrations over the calibration period were matched fairly well, with the exception of a period during the mid-1990s at V-0031, when GSWIM under-predicted chloride concentrations in the range of 100 to 140 mg/L. Some of the differences (i.e., residual) between the simulated and measured chloride concentrations shown on Figure 4-20 for V-0031 could be a result of discretization inaccuracies. The results shown are from Model Layer 5 at V-0031. However, the chloride concentrations that were simulated in Model Layer 4 at V-0031 more closely resembled the measured chloride concentrations. This matter was discussed at the GSWI Modeling Subcommittee and TWG meetings held on February 19, 2008.

San Pedro Formation between Hopper Creek and Torrey Road. GSWIM replicated chloride concentrations well in groundwater in the central Piru Subbasin, with the exception of V-0070, where GSWIM underpredicted chloride concentrations (see Figure 4-21). GSWIM replicated the larger range of measured chloride concentrations in the shallower zones of the USGS nested well pair (i.e., V-0105 and V-0109) well, with less variability in the deeper zone (i.e., at V-0108).

San Pedro Formation West of Hopper Creek. With the exception of an elevated measured chloride concentration in 1990 at V-0176, GSWIM replicated chloride concentrations well in groundwater in the western Piru Subbasin (see Figure 4-22).

4.2.3.2 Surface Water

East Subbasin. Chloride concentration data are scarce for the ephemeral SCR reaches upstream of the Saugus WRP (see Figure 4-23). SCR-RA is a surface-water monitoring station located a few hundred feet upstream of the Saugus WRP discharge point. GSWIM simulated less variability in chloride concentrations than were observed with the limited number of measured chloride concentration data for SCR-RA. GSWIM underpredicted chloride concentrations in the SCR at SCR-RB, which is located a few hundred feet downstream of the Saugus WRP discharge point. The area near SCR-RA and SCR-RB receives surface water from Bouquet Creek, Dry Creek, and Saugus WRP discharges. GSWIM’s difficulty replicating chloride concentrations in the SCR near SCR-RA and SCR-RB likely resulted from uncertainties associated with the coalescing sources of water in this area.

GSWIM replicated chloride concentrations in the SCR upstream and downstream of the Valencia WRP at SCR-RC and SCR-RD better, and slightly overpredicted chloride concentrations in the SCR in the early to mid-2000s just upstream of the confluence of Castaic Creek at SCR-RE.

Piru Subbasin. In general, GSWIM replicated chloride concentrations well in the SCR and Piru Creek (see Figure 4-24). Measured chloride concentrations in the SCR at Blue Cut were slightly underpredicted by GSWIM during the early 1980s and slightly overpredicted during the early to mid 2000s. However, GSWIM matched chloride concentrations well during most of the 31-year calibration period. Figure 4-24 includes an exceedance plot of measured and simulated paired chloride concentrations. Figure 4-24 illustrates that GSWIM simulated most of the measured range of chloride concentrations well at Blue Cut. GSWIM slightly underpredicted smaller chloride concentrations approximately 10 percent of the time during the calibration period and overpredicted the larger chloride concentrations approximately 10 percent of the time at Blue Cut.

Chloride concentration data were only available after CY 1999 for the reach of the SCR upstream of the Dry Gap and downstream of Blue Cut. During most of this period, GSWIM slightly overpredicted the chloride concentrations in the SCR at Newhall Crossing, near Tapo Creek, and near Camulos Ranch (see Figure 4-24).

GSWIM slightly underpredicted chloride concentrations in Piru Creek, but replicated chloride trends well. Downstream of the Piru Creek confluence in the SCR, GSWIM replicating chloride concentrations and trends well.

4.2.3.3 Discussion of Calibration to Chloride Concentrations

Qualitative Calibration Targets. The following qualitative calibration targets, described in Section 4.1.2.1 of this report, relate to groundwater chloride concentrations:

- General magnitudes of groundwater chloride concentration fluctuations from visual evaluation of groundwater chemographs.
- General long-term temporal trends in groundwater chloride concentrations (e.g., increasing, decreasing, or stable) from visual evaluation of chemographs.
- General range of chloride concentrations detected in streams, especially in the SCR between the WRPs and beginning of the Dry Gap in Ventura County.

Figures 4-16 through 4-24 indicate that GSWIM replicating the qualitative calibration targets well overall. During certain periods at some locations, short-term chloride concentration fluctuations were not replicated by GSWIM. It is not clear whether this was due to errors associated with calibration target data quality or model conceptualization. With the exception of these few short-term periods, GSWIM replicated the range and trends of chloride concentrations well in both groundwater and surface water.

Quantitative Calibration Targets. Summary statistics for individual target locations throughout the calibration period are provided on individual chemographs on Figures 4-16 through 4-24. Table 4-4 lists the ranges of summary statistics by geographic area, computed using the paired simulated and measured chloride concentration data. As shown in Table 4-4, the statistics that summarize the goodness-of-fit between simulated and measured chloride concentration data are based on fewer observations than for groundwater elevation and streamflow data (compare Table 4-4 with Tables 4-2 and 4-3). Simulated chloride concentrations are considered by the GSWI Modeling Team to be well calibrated for the purposes of the GSWI Study.

Relative Chloride Concentrations in the Santa Clara River. Because the GSWI Study is being conducted to support a chloride TMDL evaluation, chloride concentrations in the SCR were further evaluated by examining the difference in chloride concentrations between selected upstream and downstream locations. The following location pairs were used for this evaluation:

- SCR-RB (downstream of Saugus WRP) and the Saugus WRP effluent
- SCR-RC (upstream of Valencia WRP) and the Saugus WRP effluent
- SCR-RD (downstream of Valencia WRP) and the Valencia WRP effluent
- SCR-RE (upstream of Castaic Creek confluence) and the Valencia WRP effluent
- NLF-NR1 (upstream of county line) and the Valencia WRP effluent
- 04N17W29SW1 (Blue Cut) and the Valencia WRP effluent
- SCR-RF (near the Camulos Diversion) and the Valencia WRP effluent
- NLF-NR3 (near Las Brisas Bridge) and the Valencia WRP effluent
- 04N17W29SW1 (Blue Cut) and SCR-RE (upstream of Castaic Creek confluence)
- SCR-RF (near the Camulos Diversion) and SCR-RE (upstream of Castaic Creek confluence)
- NLF-NR3 (near Las Brisas Bridge) and SCR-RE (upstream of Castaic Creek confluence)

The relative chloride concentration (C/Co) was computed by dividing the downstream chloride concentration by the time-coincident upstream chloride concentration throughout the 31-year calibration period. This was done to evaluate GSWIM's ability to replicate the dilution or concentration of chlorides that occurred between the paired monitoring locations over the 31-year calibration period and to gain insights into the assimilative capacity of the SCR system. Figures 4-25 through 4-27 show comparisons of the simulated and observed C/Co values along the SCR. Figure 4-28 shows the locations of the upstream and downstream pairs used in this evaluation.

Following are the ranges of C/Co values using available measured data over the 31-year calibration period:

- From 0.60 to 2.21 between the Saugus WRP effluent and SCR-RB
- From 0.24 to 1.08 between the Saugus WRP effluent and SCR-RC
- From 0.22 to 1.09 between the Valencia WRP effluent and SCR-RD
- From 0.31 to 1.96 between the Valencia WRP effluent and SCR-RE, 04N17W29SW1, and SCR-RF
- From 0.89 to 1.54 between SCR-RE and 04N17W29SW1 and SCR-RF

Reliable measured chloride concentration data were not available for monitoring locations NLF-NR1 and NLF-NR3 over the calibration period; however, these locations were included in the analysis to facilitate evaluation of C/Co values among the WRPs, county line, and Las Brisas Bridge, which are upstream of the Dry Gap.

GSWIM did not replicate C/Co between SCR-RB and the Saugus WRP effluent. The measured C/Co data values varied over a large range, with values up to 2.21; however, the simulated C/Co data rarely exceeded a value of 1.0 (see Figure 4-25). If water quality samples were collected from the effluent and at SCR-RB at different times during the same day and effluent concentrations varied between sampling times, this could be the reason that the measured C/Co data varied over such a large range. GSWIM slightly under-predicted C/Co from CYs 2000 through 2005 between the Valencia WRP point of discharge and SCR-RE. GSWIM also slightly underpredicted C/Co from CYs 1980 through 1985 between the Valencia WRP point of discharge and 04N17W29SW1. Both GSWIM and available chloride concentration data indicate periods where C/Co values were above and below a value of 1. C/Co values less than 1 indicate dilution of chlorides, whereas those greater than 1 indicate concentration of chlorides along the flow path.

Results from this evaluation suggest that C/Co varied considerably over the 31-year calibration period, from 0.01 to 2.89 according to GSWIM output. Fewer measured chloride concentration data are available to confirm the low-end C/Co estimates, which would coincide with short-term storm-runoff events. However, there is evidence both in the data record and GSWIM output that there have been periods when chloride concentrations downstream of the WRPs were greater than those in the WRP effluent. Following are possible causes:

- Chloride loading from other sources or processes downstream of the WRPs could increase chloride in the SCR downstream of the WRPs to concentrations exceeding those in the WRP effluent for some period of time.
- If samples were collected at the same time from the point of discharge and a down-stream monitoring location, before a higher-concentration discharge from the WRP had passed by the downstream location, downstream chloride concentrations could be higher than those in the effluent because of sample timing.

4.2.4 Water Budget

Table 4-3 summarizes the overall water budget for the 31-year calibration period, which was created using output from GSWIM. Table 4-5 compares well with Table 7-1 in the Task 2A Report (CH2M HILL-HGL, 2006b). The following points summarizes notable differences between the water budgets presented in Table 4-5 of this report and Table 7-1 in the Task 2A Report (CH2M HILL-HGL, 2006b):

- Modifying precipitation zones and selected time-series precipitation data at a few rainfall gages (described in Section 3.8.2.1 of this report) caused the overall precipitation results from GSWIM to differ slightly from data presented as part of the conceptual model development.
- Additional Castaic Lagoon release data were received from DWR that were not available in time for inclusion in the Task 2A Report (CH2M HILL-HGL, 2006b). The values for Castaic Lagoon releases presented in Table 4-5 reflect the latest available data that were input to GSWIM.

- Groundwater inflows at Lang are different from what was presented as part of the conceptual model development because the boundary condition was changed from specified head to specified flux, as described in Section 3.8.2.2 of this report.
- Outflow terms presented as part of the conceptual model development were estimated using results from previous modeling and by using ET to balance the annual water budgets. Outflow terms in Table 4-5 were computed by GSWIM. Thus, on an annual basis, inflows did not necessarily equal outflows, resulting in a change in storage. However, consistent with results from the conceptual model development, the 31-year average change in storage was small (542 acre-feet), which supports the concept that, over the long-term, the hydrologic system of the geographic area represented by the GSWIM domain is in equilibrium.

4.2.5 Sources of Error

Calibration target values and simulated output each have associated errors, resulting in an overall uncertainty in results. The sources of uncertainty include transient effects, human errors, scaling effects, interpolation errors, and numerical errors (Anderson and Woessner, 1992).

4.2.5.1 Transient Effects

Groundwater-level measurements in wells could reflect the presence of transient effects in the groundwater system that might not be represented in GSWIM. The only available subsurface access to directly monitor groundwater conditions is through groundwater wells. Groundwater wells allow for measurement of groundwater levels and collection of water quality samples. If transient effects of the groundwater system manifested in groundwater levels at shorter time scales than those in the numerical model, some portion of the difference (residual) between the field-measured groundwater level and the simulated output could be due to these transient effects. Thus, if the time scale of the field measurement is different than the model time step duration, some of the residual could be due to transient effects.

4.2.5.2 Human Errors

Measurement Errors. Calibration target values include measurement errors. Measurement errors relate to the accuracy and consistency of the measurement device or structure, the accuracy and consistency of the elevation survey datum, and the diligence of the field or laboratory technician who collects or analyzes the data. Thus, some portion of the residual between the field-measured data and the simulated output could also be due to measurement error in the calibration target value.

Data Management Errors. Errors can also be introduced as a result of data management activities. Examples of data management errors include, but are not limited to, associating input data with an incorrect location (resulting in spatial errors), assigning time-series data incorrectly (resulting in temporal errors), or otherwise inputting values incorrectly. Thus, some portion of the residual between the field-measured data and the simulated output could also be due to data management errors.

Conceptualization Errors. Errors can also be introduced as a result of inadequately conceptualizing the field problem. For example, if there were significant errors in the assigned initial chloride conditions or boundary conditions, some portion of the residual between the field-measured data and the simulated output would be due to conceptualization errors.

4.2.5.3 Scaling Effects

A numerical model uses discrete space to represent the hydrologic system. The GSWIM grid (see Figure 3-1) was built in an effort to strike a balance between maximizing the number of grid-blocks in key areas of the GSWIM domain and minimizing the number of grid-blocks in areas of the GSWIM domain that are less important, thereby reducing the numerical burden and associated model run times. However, all numerical grids are subject to errors resulting from scaling effects.

Errors associated with scaling effects result when and where significant spatial heterogeneities in the field problem are not represented at the scale of the numerical grid-blocks. For example, the height to which water rises in a groundwater well is the result of the average head conditions of the depth interval over which the groundwater well is screened. Groundwater wells located in the GSWIM domain have variable-length well screens. Thus, a portion of the residual between field-measured groundwater levels and the simulated output could be due to scaling effects resulting from the difference between GSWIM layer thicknesses and the well screen lengths of calibration target wells.

4.2.5.4 Interpolation Effects

Calibration target locations would ideally be represented in GSWIM to coincide perfectly with locations of the GSWIM grid-blocks and CHF segments, but in practice, this is not possible. Thus, interpolation errors are introduced in the calibration evaluation. Interpolation errors also result from spatially distributing point values of parameters or stresses (such as precipitation or ET) over the model domain. In an effort to manage interpolation errors, one of the goals for selecting calibration target locations was to seek a relatively uniform spatial distribution of calibration targets over the GSWIM domain. Having a reasonable number of spatially distributed calibration targets and types of calibration targets (e.g., qualitative and quantitative groundwater, surface water, and water quality) helps make GSWIM output more reliable over a wide range of conditions for the entire domain.

4.2.5.5 Numerical Errors

Errors associated with the way a model solves the governing flow and transport equations, coupled with the assumptions inherent in the governing equations being solved, are inherent in all numerical models. Numerical errors are also associated with the selection of convergence-closure criteria by the user. User selection of convergence-closure criteria is an iterative process during calibration that seeks to strike a balance between making calibration progress by completing as many simulations as possible within the project schedule and achieving adequate accuracy in the numerical solution. Selecting convergence-closure criteria that are too low during initial stages of model calibration will result in completing fewer simulations because of longer run times and possible convergence problems. The magnitudes of the user-defined convergence-closure criteria for GSWIM are described in Section 4.1.2.2 of this report.

4.3 Calibration Outcome

The process of calibrating GSWIM to a 31-year period of daily streamflow data and available groundwater elevation and chloride concentration data has resulted in a model that is suitable for its intended applications. As previously discussed, GSWIM was built to quantify potential cause-and-effect relationships between chloride loading from WRP discharges and the resulting responses of the hydrologic system under a variety of future hydrology, land use, and water use assumptions for CYs 2007 through 2030 (scenarios of future conditions are described in Section 5.0 of this report).

Following are the primary attributes that make GSWIM appropriate for its intended uses:

- GSWIM can simulate historical trends in groundwater elevations and streamflows during a 3-decade period that reflects increased urbanization, increased SWP water imports, and associated changes in land use and water use.
- GSWIM can simulate historical trends in groundwater elevations, streamflows, and dry gaps in the streams during a 3-decade period that reflects wet and dry periods.
- GSWIM can simulate the interacting surface and subsurface flow regimes, the transport of chlorides throughout these regimes, and the complex process of ET and evapoconcentration of chlorides.
- GSWIM can simulate, on a daily basis, historical total streamflows in the SCR and groundwater discharge to the SCR.
- GSWIM can simulate short-term and long-term time-varying trends in groundwater elevations, streamflow, and chloride concentrations throughout the domain.
- The numerical solution is adequately constrained by the 88 groundwater level, 50 groundwater chloride, 6 streamflow, and 12 surface-water quality target locations that are spatially distributed throughout the GSWIM domain. Having a variety of calibration targets (e.g., qualitative and quantitative groundwater, surface-water, and water quality data) helps make GSWIM output more reliable.
- The modeling results agree with the conceptual model that was described in the Task 2A Report (CH2M HILL-HGL, 2006b).

TABLE 4-1
Summary of Global Sensitivity Analysis
Task 2B-1 – Numerical Model Development and Scenario Results, East and Piru Subbasins

Run	Changes	Purpose	Notes	Summary Remarks	Average ET (acre-ft/yr)
0		Base run	Need more ET to match Table 7-1 in Task 2A Report. Simulated heads downstream of Lang too high during droughts. Too much simulated streamflow in general and not matching zero streamflows. Heads are generally high in all wells. Drawdowns during drought periods are underestimated with GSWIM.	Simulating too much water in the system.	319,935
1	OLF Leakance x 1E-01	Sensitivity	Largely insensitive. Slightly lower heads in Alluvium. Saugus and San Pedro heads insensitive. Higher peak streamflows at SCR-RA/RB.	Need more than only one order of magnitude of change to see effect.	
2	OLF Leakance x 1E-04	Sensitivity	Moderately sensitive. Heads slightly lower.	Not enough change.	
3	OLF Leakance in LUP x 1E-01	Sensitivity	Not sensitive.	Urbanized LUP areas are small.	
4	OLF Leakance in LUP x 1E-04	Sensitivity	Some larger head peaks in Alluvium and lower lows, but largely insensitive. Note this is applied only on urbanized areas.	Small effect overall.	
5	CHF Manning-n x 10	Sensitivity	Saugus/San Pedro insensitive (slightly higher heads). Improvements on Alluvium heads near SCWD and NLF wells.	Slowing down CHF streamflow allows more infiltration.	
6	CHF Manning-n x 0.1	Sensitivity	Streamflow peaks increased (more than doubled).		
7	OLF and CHF Rill Height x 2	Sensitivity	Largely insensitive. Small differences in some Alluvium heads.		
8	OLF and CHF Rill Height x 0.1	Sensitivity	Insensitive.		

TABLE 4-1
Summary of Global Sensitivity Analysis
Task 2B-1 – Numerical Model Development and Scenario Results, East and Piru Subbasins

Run	Changes	Purpose	Notes	Summary Remarks	Average ET (acre-ft/yr)
9	OLF and CHF Obstruction Height Options: IOBKROL and IOBKRCH = 0	Sensitivity	Insensitive.		
10	CHF Leakance x 1E-01	Sensitivity	LACFCD Saugus heads 0 to 8 feet lower. Alluvium heads 0 to 8 feet lower. NLF Saugus heads 0 to 8 feet lower. SCWD Alluvium heads almost same. VWC Alluvium head peaks flattened and more pronounced extremes in some wells. San Pedro heads 30 foot lower lows (fit much better for some). Streamflows not very sensitive.	Channels feed groundwater resulting in lower groundwater heads with lower leakance.	
11	CHF Leakance x 1E-04	Sensitivity	Lower streamflows and heads even in some Alluvium wells.	More sensitive than Run 10.	
12	CHF Leakance x 100	Sensitivity	LACFCD/SCWD Alluvium heads are higher and responsive now. Head fluctuations dampened in some VWC Alluvium wells. Saugus/ San Pedro wells not sensitive. Streamflow peaks higher (doubled in some places).	Higher groundwater recharge with higher CHF leakance (i.e., greater hydraulic connection).	
13	Crop Coefficient x 2	Sensitivity	Lower heads. Better fit during droughts in Alluvium and Saugus VWC wells.	Higher ET leads to lower heads.	
14	Crop Coefficient x 0.5	Sensitivity	Higher heads. More responsive in Alluvium wells.	Lower ET leads to higher heads.	
15	EDF for Model Layers 1,2,3 = 0.7,0.2,0.1	Sensitivity	Generally lower heads (more so to the east). Larger amplitudes in Saugus.	More water removed as ET from deeper layers.	
16	LAI x 2	Sensitivity	Insensitive.		
17	LAI x 0.5	Sensitivity	Insensitive.		

TABLE 4-1
Summary of Global Sensitivity Analysis
Task 2B-1 – Numerical Model Development and Scenario Results, East and Piru Subbasins

Run	Changes	Purpose	Notes	Summary Remarks	Average ET (acre-ft/yr)
18	Cint = 0	Sensitivity	Insensitive.		
19	IBOUND=0 for Model Layer 3 in the Blue Cut Area	Sensitivity of depth to bedrock in the Blue Cut area between Piru and Eastern Subbasins	Insensitive.		
20	Kh of San Gabriel Fault x 100 (Model Layers 1 through 7)	Sensitivity to Kh of San Gabriel fault in the Saugus Formation	Heads start out much lower. More responsive heads in some Alluvium wells. Streamflows similar.		
21	Kh of San Gabriel Fault x 1E-03 (Model Layers 1 through 7)	Sensitivity to Kh of San Gabriel fault in Saugus Formation	Largely insensitive (slightly higher heads in some wells). Streamflows similar.	Kh across fault zone is low enough.	
22	Kh x 10 (Model Layers 4 through 9)	Sensitivity of Kh in Saugus Formation	Heads similar in Alluvium. Heads in Saugus/San Pedro drop as much as 250 feet. Streamflows similar, but with slightly smaller peaks.		
23	Kh x 0.1 (Model Layers 4 through 9)	Sensitivity of Kh in Saugus Formation	Heads 80 feet higher in Model Layers 4 through 7. Heads similar in Alluvium. Some head fluctuations underestimated in Ventura County. Streamflows similar with slightly higher peaks.	Heads controlled significantly by Saugus Kh.	
24	SF1 = 1E-10 (Model Layers 4 through 9) SF2 x 0.2 (Model Layers 1 through 3 within Subbasin)	Sensitivity	Larger head fluctuations; more responsive; fits some wells better.	Lower storage terms lead to larger fluctuations.	
25	Leakance x 100 (All Model Layers)	Sensitivity	Many differences. Heads more responsive in Saugus and Alluvium. Higher heads in lower layers. Streamflows both higher and lower.	Higher leakance opens hydraulic connection between deeper layers.	

TABLE 4-1
Summary of Global Sensitivity Analysis
Task 2B-1 – Numerical Model Development and Scenario Results, East and Piru Subbasins

Run	Changes	Purpose	Notes	Summary Remarks	Average ET (acre-ft/yr)
26	Leakance x 1E-2 (All Model Layers)	Sensitivity	Alluvium wells heads lowered and flattened. Saugus heads very low (500 to 1,000 feet). Some streamflows slightly larger to doubled. Much worse fit at all nodes.		
27	Inflow Boundary at Lang x 10 (Surface and Subsurface)	Sensitivity	Insensitive except wells close to Lang.		
28	Inflow Boundary at Lang x 1E-01 (Surface and Subsurface)	Sensitivity	Insensitive except wells close to Lang.		
29	Brook-Corey x 2 (All Model Layers)	Sensitivity	Very different results spatially. Saugus heads 200 feet lower. Alluvium heads variable (some flattened, some more responsive). Streamflows similar but slightly lower.	Less streamflow at higher saturations reduces recharge to aquifers causing lower heads.	
30	Used December 1977 starting heads	Use higher starting heads	Starting heads influence only the first 3 years. Improvement seen in almost all the observation points; even higher starting heads should be used to improve further.	Higher starting heads are needed, but that may occur with further calibration.	
31	RDF= 0 (Model Layers 1 and 2) RDF = 1 (Model Layer 3)	Test the effect on the decreasing trend in heads around the 1990s drought, specifically observations downstream of Lang; test if more ET can be removed from deeper zones	Pinetree and Mitchell heads do not show improvement. LostCanyon2 (same cell as SandCanyon) shows lower head values around 1990. Clark heads much improved. Streamflows in Mint Canyon show improved intermittent flows. Excessive RDF in Model Layer 3 is not a valid option to draw more ET in some areas.	More RDF in Model Layer 3 can be used to fine tune certain observations once the overall ET numbers are achieved.	339,419
32	Cint x 2	Extract more ET	Insensitive.	ET is almost the same. A lot more ET was needed.	

TABLE 4-1
Summary of Global Sensitivity Analysis
Task 2B-1 – Numerical Model Development and Scenario Results, East and Piru Subbasins

Run	Changes	Purpose	Notes	Summary Remarks	Average ET (acre-ft/yr)
33	Skin Effect = 10 in FWL5 (Well Efficiency of ~70 percent)	Observe deeper FWL5 heads due to well efficiency	Deeper FWL5 heads were observed in Lost Canyon and Mitchell but deeper heads rebound back (lot of oscillations noted).		
34	Cint = 1E-02 for All LUCs	Extract more ET	Insensitive.		327,721
35	Cint = 0.2 for All LUCs	Extract even more ET	Insensitive to heads, though ET improved slightly.		361,252
36	Kh = 550 (downstream of Lang) SF2=0.1 (downstream of Lang) Decreased CHF leakance Hopper Creek CHF Manning-n x 1E-01	Test if simulated heads downstream of Lang follow the falling trend around the 1990s drought	Head values oscillate much more (lows fall around 40 feet and peaks go higher by 30 feet. Smoother channel bottom did not help Hopper Creek.		
37	C2 = 1 (ET slope parameter)	Increase transpiration	Insensitive – only slightly more ET obtained from base case.		327,864
38	Low OLF leakance	Test if simulated heads downstream of Lang follow the falling trend around the 1990s drought	Heads do not follow the falling trend in 1990s drought period downstream of Lang. Mint Canyon shows higher peak streamflows and lower low flows (a lot of zero flows) but higher cumulative flow.	Lower OLF leakance holds up more water causing larger streamflows.	
39	Model Layer 3 bottom elevations lowered uniformly around Lang area	Test the effect of lowering Model Layer 3 bottom elevations	Higher head oscillations (25-foot amplitude). Higher heads in Lang area wells.		
40	New Base Case - Updated Model Inputs	Update Castaic releases, Kc, LAI; adjust bottom elevations near Lang	ET numbers lowered because Kc values were corrected. Generally higher heads that stay high for longer durations before falling. Heads and streamflows more responsive than previous base case.		272,099

TABLE 4-1
Summary of Global Sensitivity Analysis
Task 2B-1 – Numerical Model Development and Scenario Results, East and Piru Subbasins

Run	Changes	Purpose	Notes	Summary Remarks	Average ET (acre-ft/yr)
41	Cint = 0.2	Capture more water in canopy to increase ET canopy	Increases ET only slightly.		287,050
42	Cint = 0.5	Estimate Cint requirement to get total ET around 400,000 acre-ft/yr	Increases ET only slightly, Cint cannot be much more than 0.5 foot for any LUC.	Need a lot more ET, which Cint cannot provide with reasonable values.	313,261
43	Rill Height = 0.2 feet overall Cint = 0.5 for all LUCs	See effect on ET	Doubling rill storage over the previous sensitivity only increases ET slightly.		327,617
44	Rill Height = 0.2 foot overall Cint = 2 for all LUCs	See what it takes with CINT to get ET required	Even with unreasonable Cint of 2 feet, ET does not increase above 400,000 acre-ft/yr.		387,233
45	Rill Height = 5 feet in outer areas Rill = 0.1 foot in inner areas Cint = original values related to LUCs	Extract even more water from rills in outside areas	High heads lowered.	Need to hold back more water in the outer areas in the topsoil to get the higher ET and lower heads needed.	393,606

TABLE 4-2
Summary Statistics for Groundwater Elevations
Task 2B-1 – Numerical Model Development and Scenario Results, East and Piru Subbasins

Geographic Area	ME[a] (feet)	RMSE (feet)	R^2	RMSE/Range	n
East Subbasin					
Soledad Canyon	-14.6 to 17.7	10.9 to 22.9	0.59 to 0.82	0.13 to 0.31	182 to 436
Between Interstate 5 and Soledad Canyon	-12.5 to 23.3	8.7 to 23.5	0.07 to 0.69	0.19 to 1.31	10 to 198
West of Interstate 5	-7.1 to 15.2	6.1 to 15.6	0.00 to 0.54	0.29 to 1.85	15 to 50
South Fork Santa Clara River	-40.3 to 35.8	18.2 to 51.6	0.33 to 0.77	0.19 to 0.29	143 to 447
Bouquet Creek	16.2	21.2	0.39	0.30	364
Castaic Creek	1.2 to 9.1	4.2 to 13.3	0.54 to 0.57	0.15 to 0.46	161 to 420
Other Tributary Canyons	-1.0	11.1	0.40	0.23	124
Piru Subbasin					
East of Torrey Road	6.4 to 32.2	15.2 to 36.2	0.28 to 0.89	0.15 to 1.00	22 to 1,153
Between Hopper Creek and Torrey Road	-3.7 to 14.1	12.6 to 22.1	0.28 to 0.83	0.11 to 1.29	33 to 164
West of Hopper Creek	2.0 to 6.9	6.5 to 12.8	0.52 to 0.89	0.11 to 0.58	22 to 165

[a]Positive values indicate results overpredicted by GSWIM, and negative values indicate underpredicted results.

Note:

See hydrographs on Figures 4-3 through 4-12 for statistical results for individual locations.

TABLE 4-3
Summary Statistics for Streamflows
Task 2B-1 – Numerical Model Development and Scenario Results, East and Piru Subbasins

Stream Gage	ME[a] (cfs)	R^2	NSC	n
Mint Canyon (F328-R)	0.1	0.26	0.10	10,817
Bouquet Canyon (F377-R)	0.0	0.18	-0.35	10,191
Old Road Bridge (F92C-R)	-4.3	0.48	0.42	8,937
Blue Cut (11108500)	1.3	0.58	0.58	7,965
Las Brisas Bridge (11109000)	-13.7	0.77	0.75	3,374
Hopper Creek (11110500)	-2.2	0.42	0.42	11,229
Combined	-1.9	0.62	0.61	52,513

[a]Positive values indicate results overpredicted by GSWIM, and negative values indicate underpredicted results.
See hydrographs on Figures 4-14 and 4-15 for statistical results for individual locations.

TABLE 4-4
Summary Statistics for Chloride Concentrations
Task 2B-1 – Numerical Model Development and Scenario Results, East and Piru Subbasins

Geographic Area	ME[a] (mg/L)	RMSE (mg/L)	R^2	n
East Subbasin				
Soledad Canyon	-37.4 to 3.6	7.5 to 42.4	0.04 to 0.84	4 to 14
West of Soledad Canyon	-51.3 to 14.3	12.7 to 53.2	0.00 to 1.00	2 to 20
South Fork Santa Clara River	-50.9 to 9.0	2.4 to 55.5	0.00 to 0.92	3 to 17
Other Tributary Canyons	-39.7 to 17.6	15.4 to 50.3	0.12 to 0.91	7 to 17
Santa Clara River	-28.0 to 16.0	17.6 to 49.0	0.00 to 0.72	6 to 80
Piru Subbasin				
East of Torrey Road	-57.4 to 10.4	10.0 to 71.8	0.17 to 1.00	2 to 23
Between Hopper Creek and Torrey Road	-41.6 to 13.8	5.6 to 41.8	0.02 to 1.00	2 to 21
West of Hopper Creek	-3.5 to 13.3	3.5 to 25.0	0.02 to 1.00	1 to 14
Piru Creek	-9.6	13.1	0.71	26
Santa Clara River	-3.0 to 6.2	9.8 to 26.9	0.09 to 0.74	5 to 199

[a]Positive values indicate results overpredicted by GSWIM, and negative values indicate underpredicted results.
See chemographs on Figures 4-16 through 4-24 for statistical results for individual locations.

TABLE 4-5
Model-derived Water Budget for the GSWIM Domain
Task 2B-1 – Numerical Model Development and Scenario Results, East and Piru Subbasins

CY	Precipitation	Lake Piru Releases and Spills	Castaic Lagoon Releases	Bouquet Reservoir Releases	SCR Stream Inflow at Lang	Groundwater Inflow at Lang	Water Imported by CLWA	Dam Underflow	Total Inflows	ET	SCR Stream Outflow to Fillmore Subbasin	Groundwater Outflow to Fillmore Subbasin	Total Outflows	Change in Total Storage
1975	246,808	20,865	0	1,392	704	195	0	1,700	271,664	263,694	13,876	27,517	305,087	-33,423
1976	257,779	12,550	0	853	259	72	0	1,705	273,218	263,774	6,497	25,367	295,638	-22,420
1977	410,475	4,072	0	790	1,610	446	0	1,700	419,093	326,953	3,378	23,364	353,695	65,398
1978	840,110	118,024	30,470	3,993	21,410	5,929	0	1,700	1,021,636	591,446	229,093	67,444	887,983	133,653
1979	444,734	78,403	0	2,178	5,492	1,521	0	1,700	534,028	460,704	94,129	47,686	602,519	-68,491
1980	569,742	117,832	14,691	2,237	10,923	3,025	1,125	1,705	721,280	489,925	178,125	54,672	722,722	-1,442
1981	298,849	45,824	4,205	2,500	2,571	712	5,816	1,700	362,177	299,045	41,091	33,943	374,079	-11,902
1982	502,142	30,020	7,968	2,193	4,712	1,305	9,659	1,700	559,699	425,693	39,272	33,736	498,701	60,998
1983	945,355	17,201	67,270	2,222	27,127	7,512	9,185	1,700	1,077,572	688,638	223,121	63,971	975,730	101,842
1984	204,963	66,928	6,933	2,192	2,018	559	10,996	1,705	296,294	300,371	60,536	36,407	397,314	-101,020
1985	205,471	21,468	428	2,209	2,418	670	11,823	1,700	246,187	284,546	25,005	30,591	340,142	-93,955
1986	452,256	20,289	2,795	2,214	3,722	1,031	13,759	1,700	497,766	451,905	42,903	34,794	529,602	-31,836
1987	296,468	32,333	0	2,226	3,192	884	16,285	1,700	353,088	237,391	22,976	30,589	290,956	62,132
1988	317,680	24,409	2,960	2,225	2,565	710	19,033	1,705	371,287	353,964	24,028	30,960	408,952	-37,665
1989	136,434	10,403	0	2,248	1,350	374	21,618	1,700	174,127	267,388	12,683	27,525	307,596	-133,469
1990	169,440	4,983	0	2,232	286	79	21,613	1,700	200,333	221,718	5,047	23,345	250,110	-49,777
1991	438,656	38,222	65	2,248	4,386	1,214	7,968	1,700	494,459	354,756	11,116	26,464	392,336	102,123
1992	635,625	78,121	16,446	2,170	4,700	1,302	13,911	1,705	753,980	512,562	96,975	60,755	670,292	83,688
1993	599,663	135,248	20,806	2,174	23,599	6,535	13,393	1,700	803,118	553,292	198,821	80,199	832,312	-29,194
1994	285,814	45,408	3,342	2,169	19,061	5,278	14,389	1,700	377,161	323,918	42,863	38,028	404,809	-27,648
1995	703,450	97,301	5,611	2,176	378	105	16,996	1,700	827,717	545,515	175,972	70,853	792,340	35,377
1996	533,071	22,201	5,632	2,121	3,649	1,010	18,093	1,705	587,482	395,793	45,632	38,855	480,280	107,202
1997	318,855	38,624	9,885	2,197	2,846	788	22,148	1,700	397,043	363,887	49,052	39,240	452,179	-55,136
1998	767,447	123,774	47,942	2,188	34,246	9,483	20,254	1,700	1,007,034	622,038	297,858	94,415	1,014,311	-7,277
1999	206,267	25,691	5,830	2,176	1,595	442	27,282	1,700	270,983	291,879	34,495	35,169	361,543	-90,560
2000	327,162	52,323	7,086	2,173	2,430	673	32,579	1,705	426,131	349,037	41,564	38,986	429,587	-3,456
2001	447,585	64,120	2,696	2,180	4,223	1,169	35,369	1,700	559,042	387,743	65,278	49,979	503,000	56,042
2002	185,566	25,567	0	2,128	281	78	41,768	1,700	257,088	216,847	24,903	32,514	274,264	-17,176
2003	311,334	32,648	3,019	2,170	1,087	301	44,419	1,700	396,678	383,637	28,762	33,853	446,252	-49,574
2004	431,679	16,158	1,122	2,456	1,569	434	47,205	1,705	502,328	315,417	20,469	30,472	366,358	135,970
2005	713,910	186,982	91,184	797	37,015	10,250	38,034	1,700	1,079,872	588,524	442,349	111,205	1,142,078	-62,206
Minimum	136,434	4,072	0	790	259	72	0	1,700	174,127	216,847	3,378	23,345	250,110	-133,469
Annual Average	425,961	51,871	11,561	2,111	7,465	2,067	17,249	1,701	519,986	391,355	83,802	44,287	519,444	542
Maximum	945,355	186,982	91,184	3,993	37,015	10,250	47,205	1,705	1,079,872	688,638	442,349	111,205	1,142,078	135,970

Note:

Units are acre-feet.

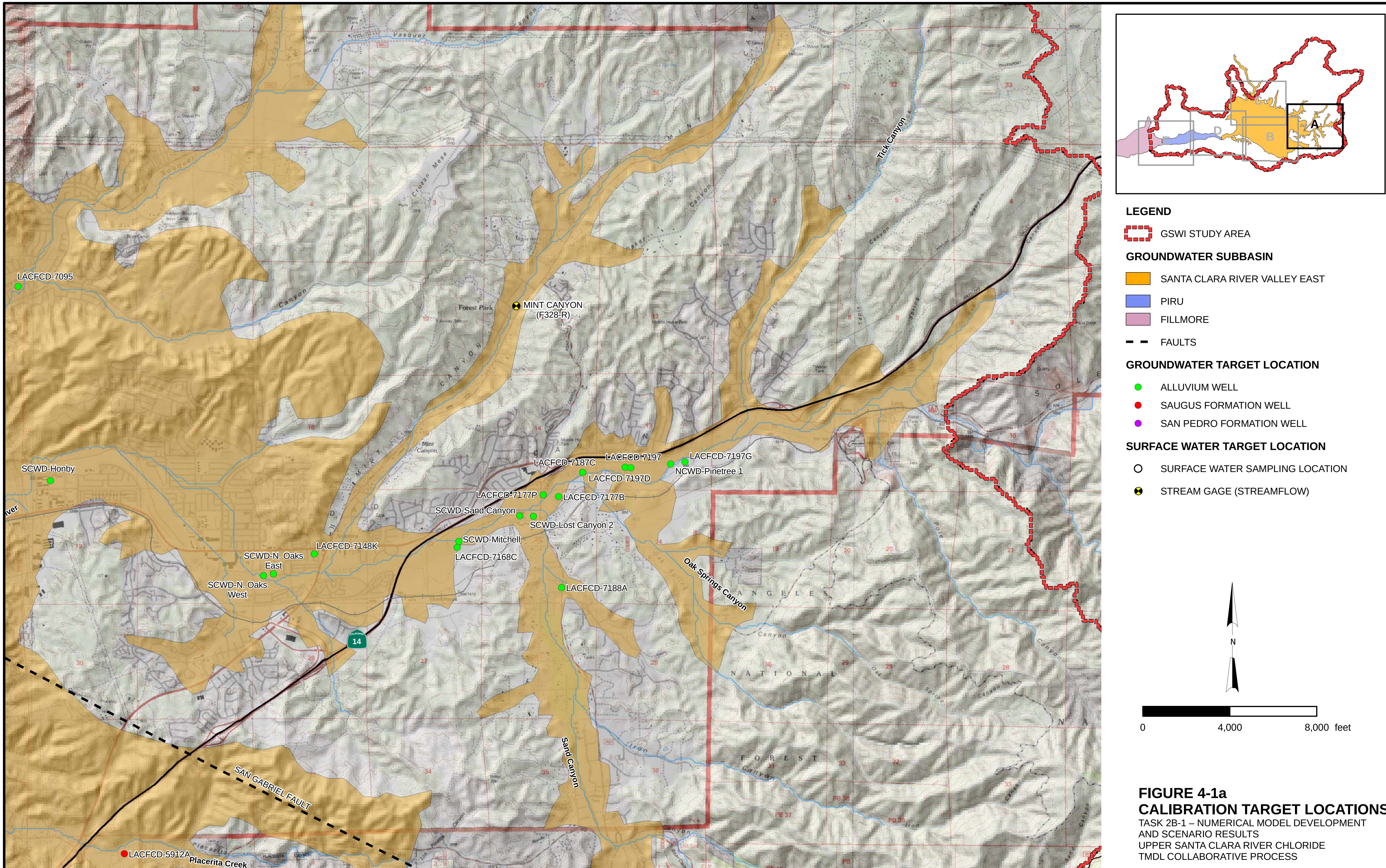
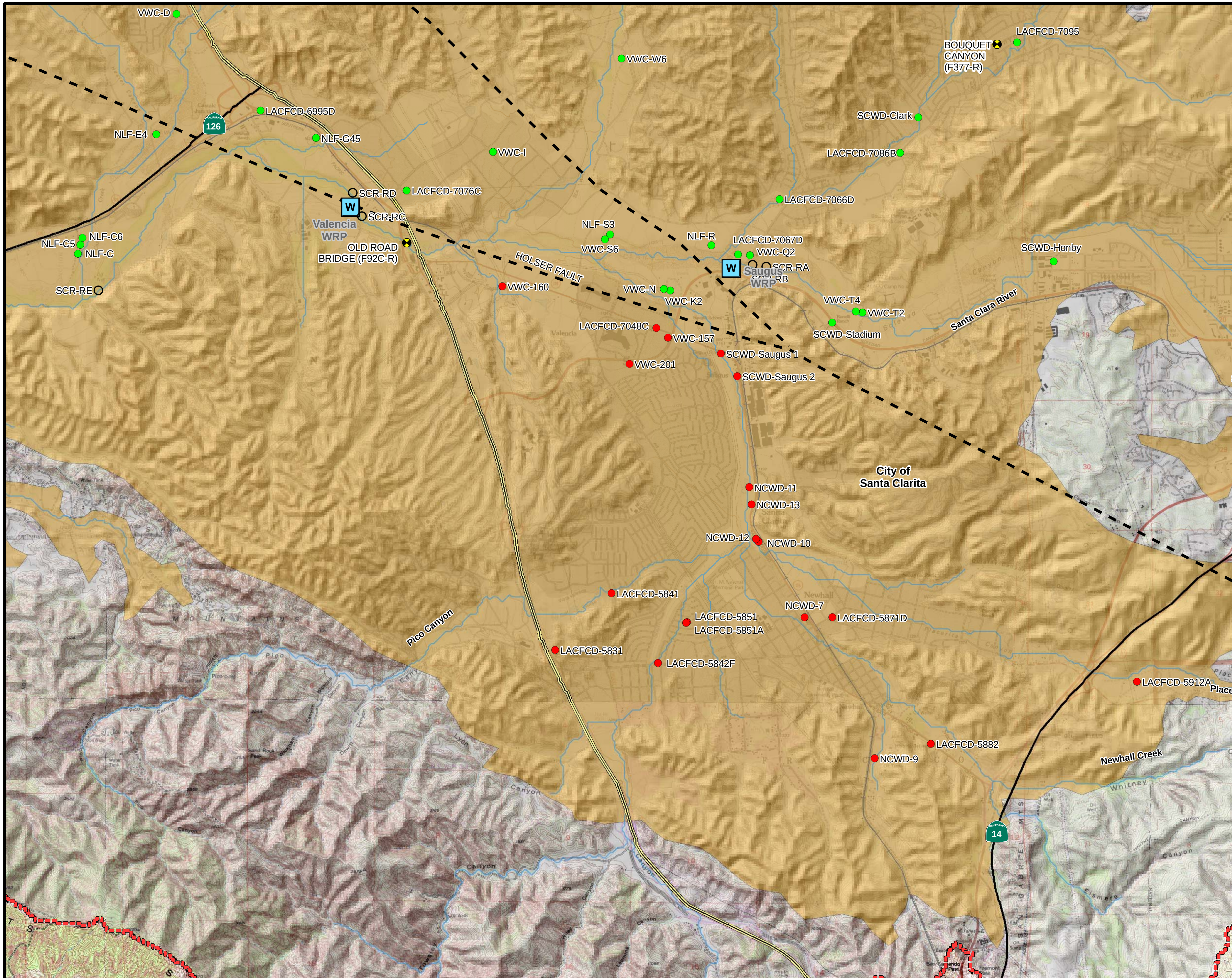
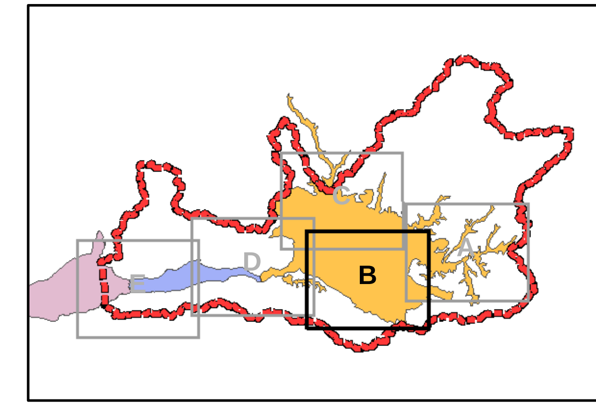


FIGURE 4-1a
CALIBRATION TARGET LOCATIONS
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL -HGL





LEGEND

GSWI STUDY AREA

GROUNDWATER SUBBASIN

SANTA CLARA RIVER VALLEY EAST

PIRU

FILLMORE

FAULTS

GROUNDWATER TARGET LOCATION

ALLUVIUM WELL

SAUGUS FORMATION WELL

SAN PEDRO FORMATION WELL

SURFACE WATER TARGET LOCATION

SURFACE WATER SAMPLING LOCATION

STREAM GAGE (STREAMFLOW)

N

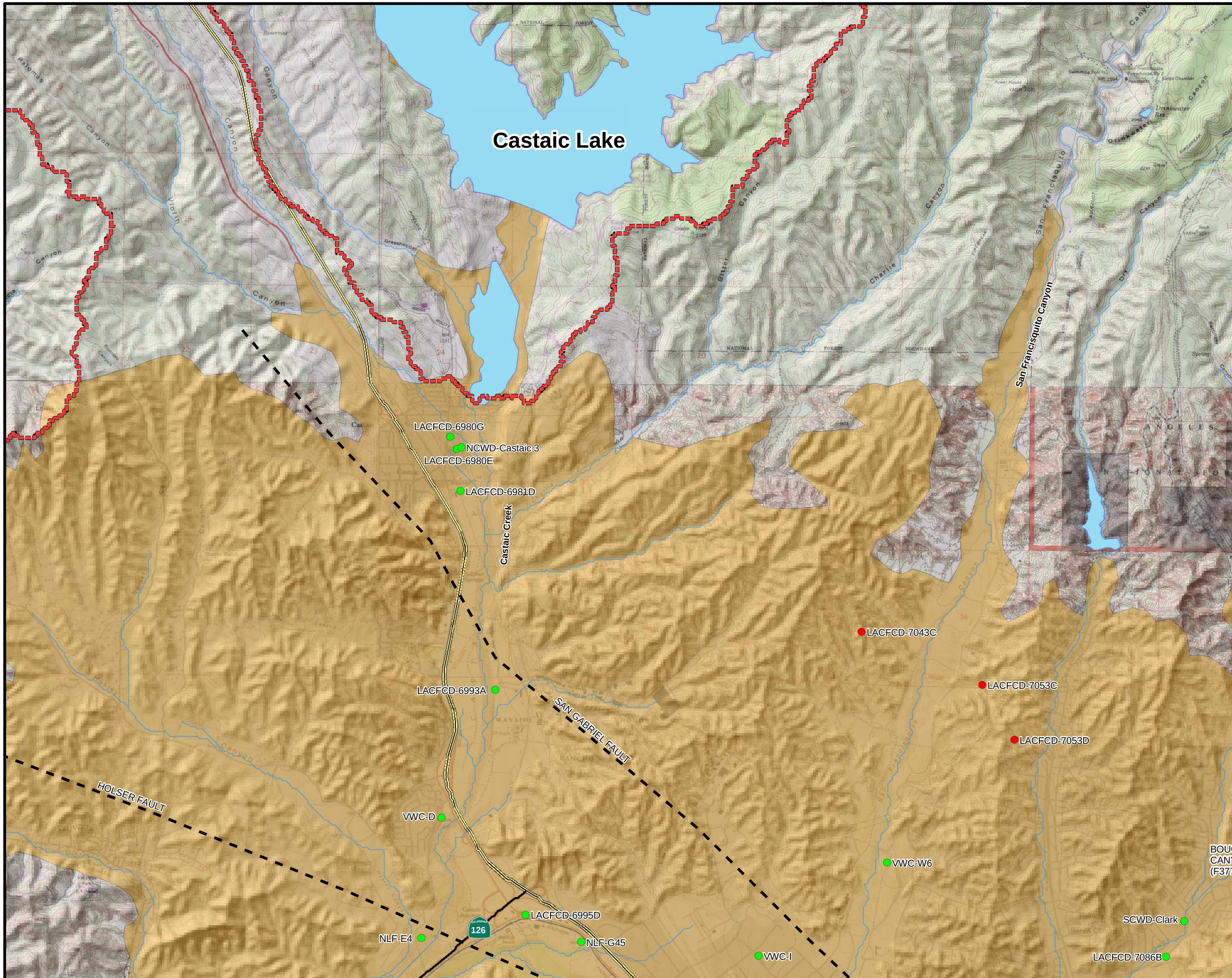
0 4,000 8,000 feet

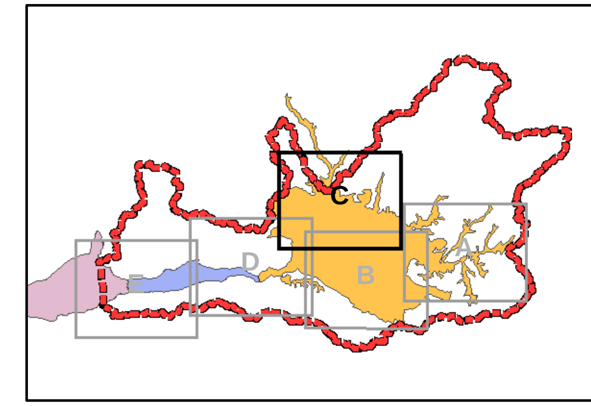
FIGURE 4-1b
CALIBRATION TARGET LOCATIONS

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL HGL

\\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2B-NUMERICALMODELDEV\DRAFT\FIGURES\MXD\FIG04-01B_CALIBRATIONTARGETS.MXD 1/18/2008 11:45:35





LEGEND

GSWI STUDY AREA

GROUNDWATER SUBBASIN

SANTA CLARA RIVER VALLEY EAST

PIRU

FILLMORE

FAULTS

GROUNDWATER TARGET LOCATION

ALLUVIUM WELL

SAUGUS FORMATION WELL

SAN PEDRO FORMATION WELL

SURFACE WATER TARGET LOCATION

SURFACE WATER SAMPLING LOCATION

STREAM GAGE (STREAMFLOW)

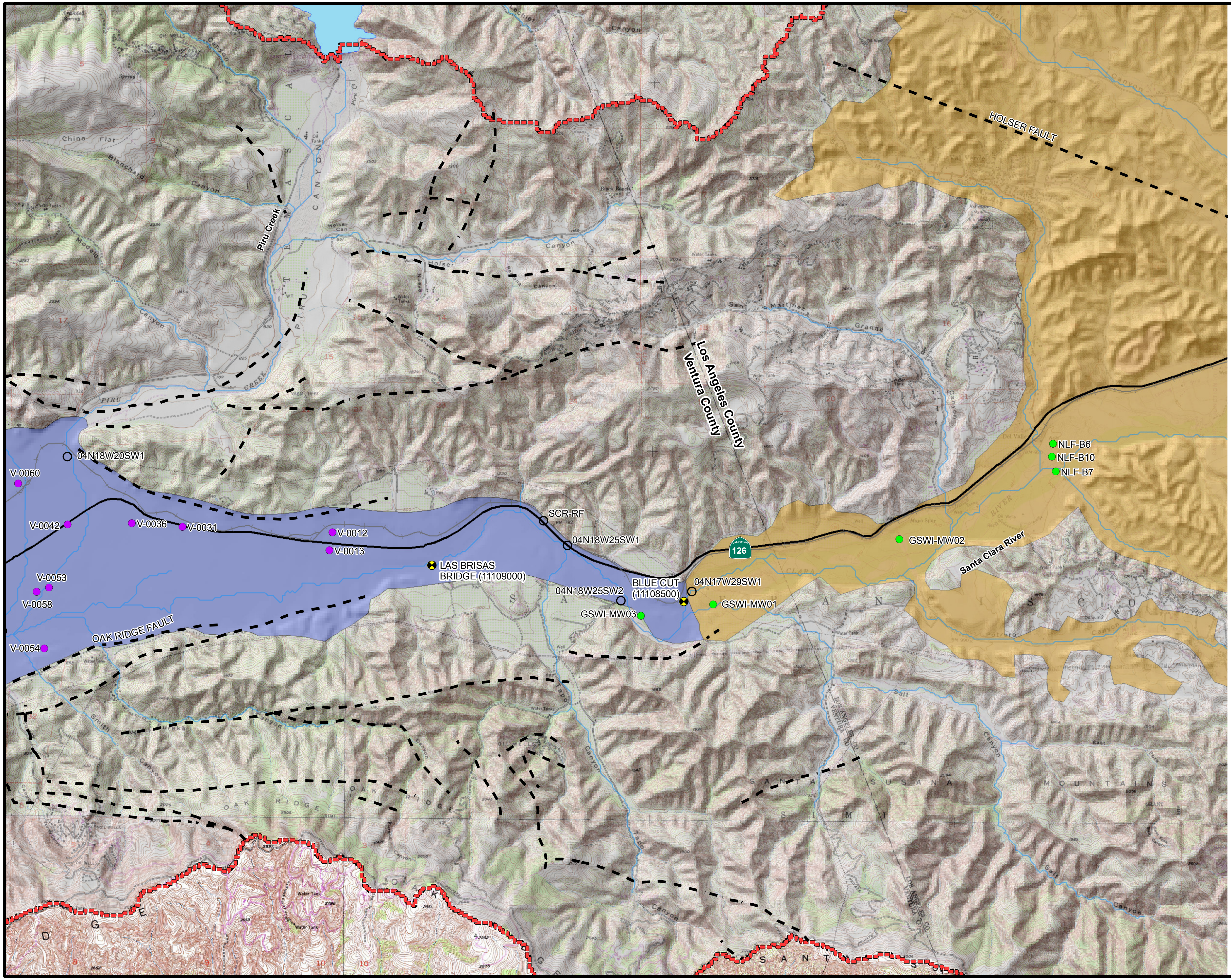
N

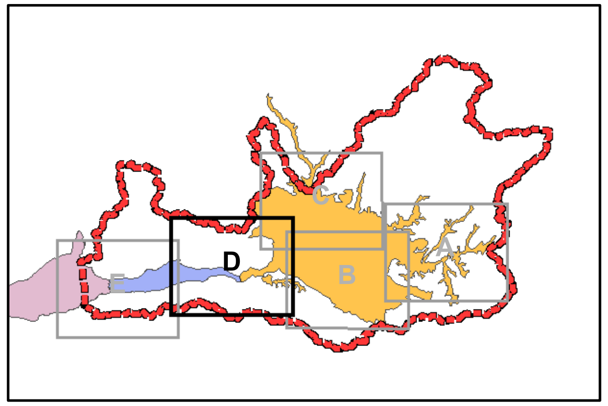
0 4,000 8,000 feet

FIGURE 4-1c
CALIBRATION TARGET LOCATIONS
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL -HGL

\\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2B-NUMERICALMODELDEV\DRAFT\FIGURES\MXD\FIG04-01C_CALIBRATIONTARGETS.MXD 1/18/2008 11:46:42





LEGEND

GSWI STUDY AREA

GROUNDWATER SUBBASIN

SANTA CLARA RIVER VALLEY EAST

PIRU

FILLMORE

FAULTS

GROUNDWATER TARGET LOCATION

ALLUVIUM WELL

SAUGUS FORMATION WELL

SAN PEDRO FORMATION WELL

SURFACE WATER TARGET LOCATION

SURFACE WATER SAMPLING LOCATION

STREAM GAGE (STREAMFLOW)

N

0 4,000 8,000 feet

FIGURE 4-1d
CALIBRATION TARGET LOCATIONS

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL -HGL

\\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2B-NUMERICALMODELDEV\DRAFT\FIGURES\MXD\FIG04-01D_CALIBRATIONTARGETS.MXD 3/9/2008 13:41:51

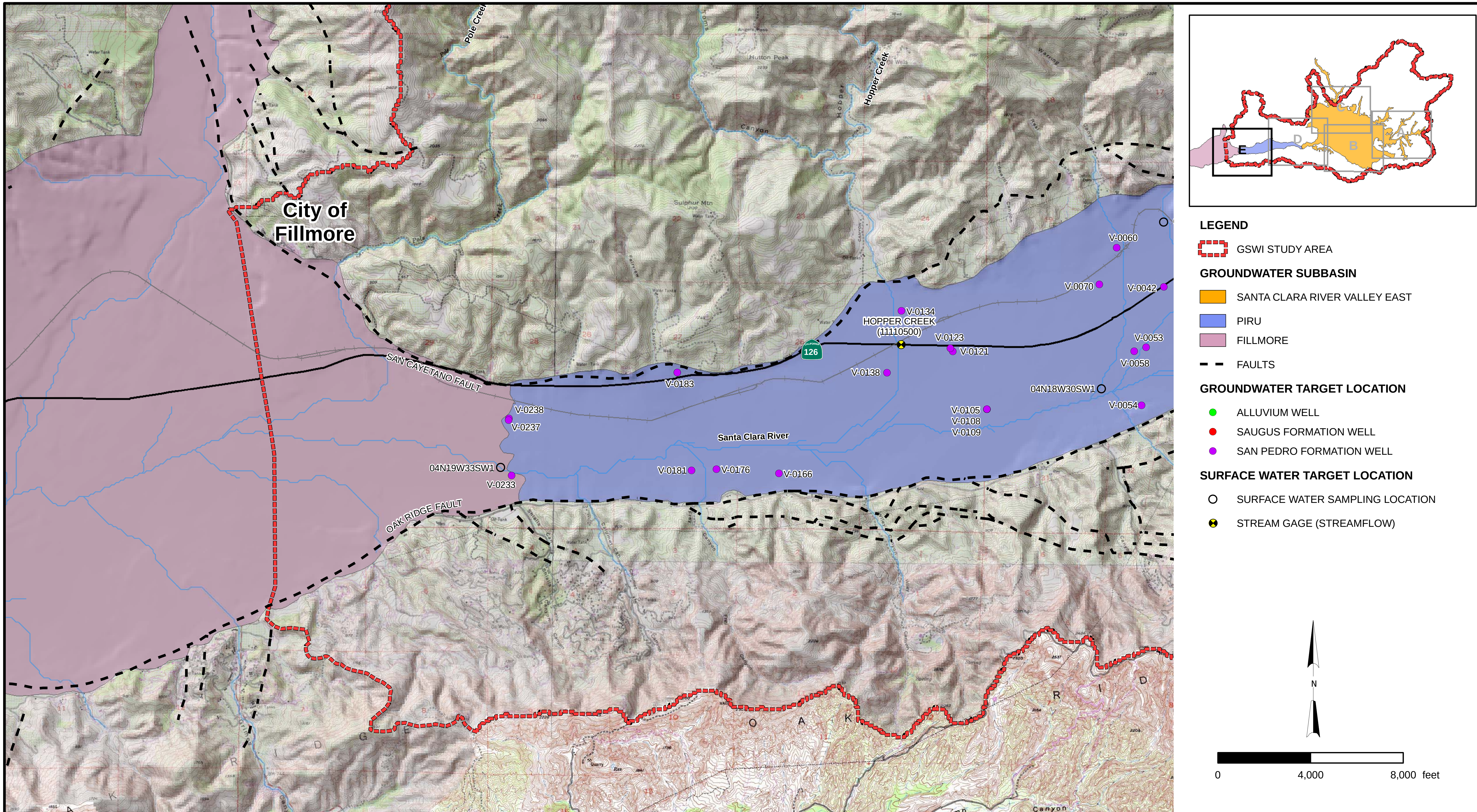


FIGURE 4-1e
CALIBRATION TARGET LOCATIONS
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL -HGL

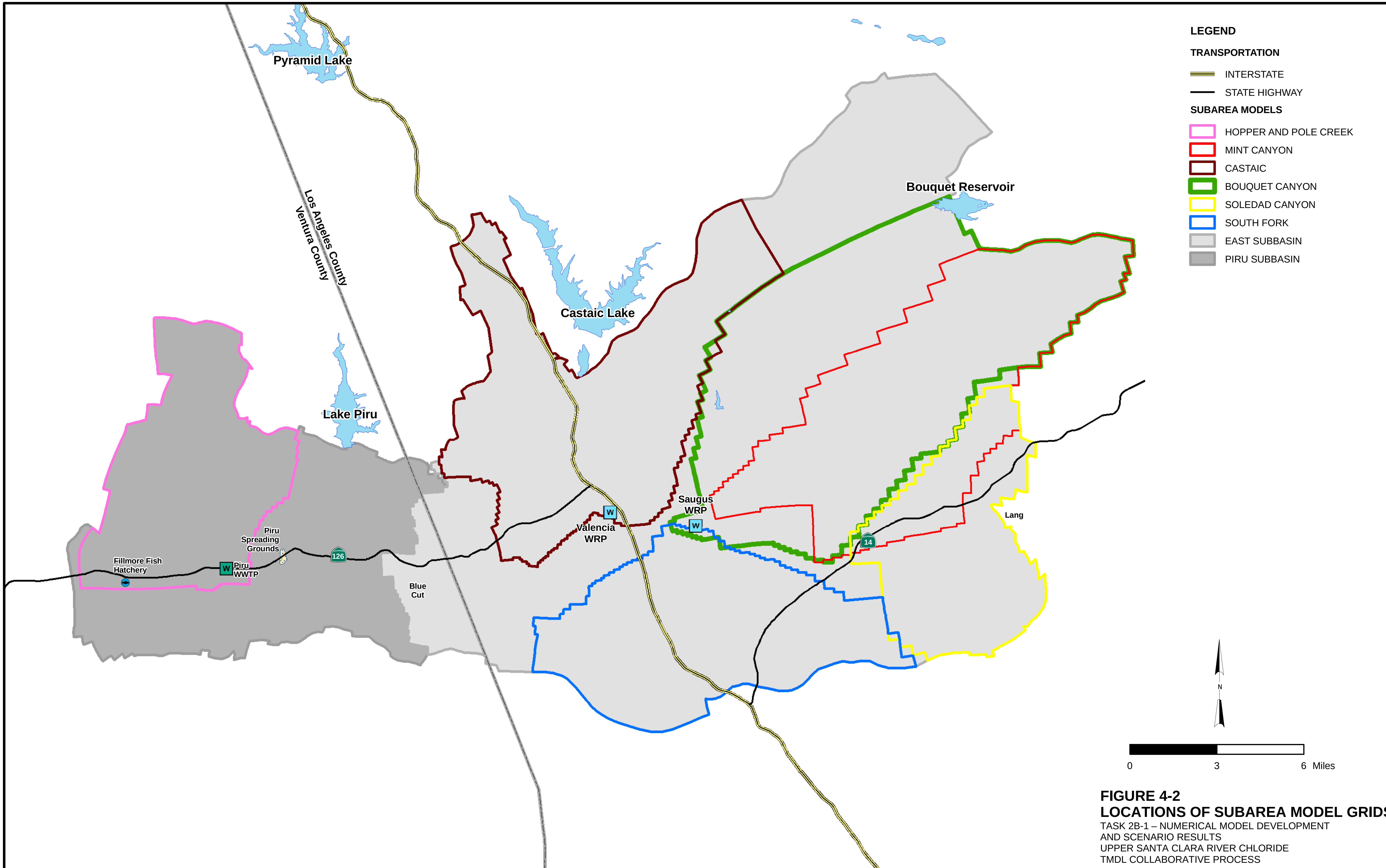
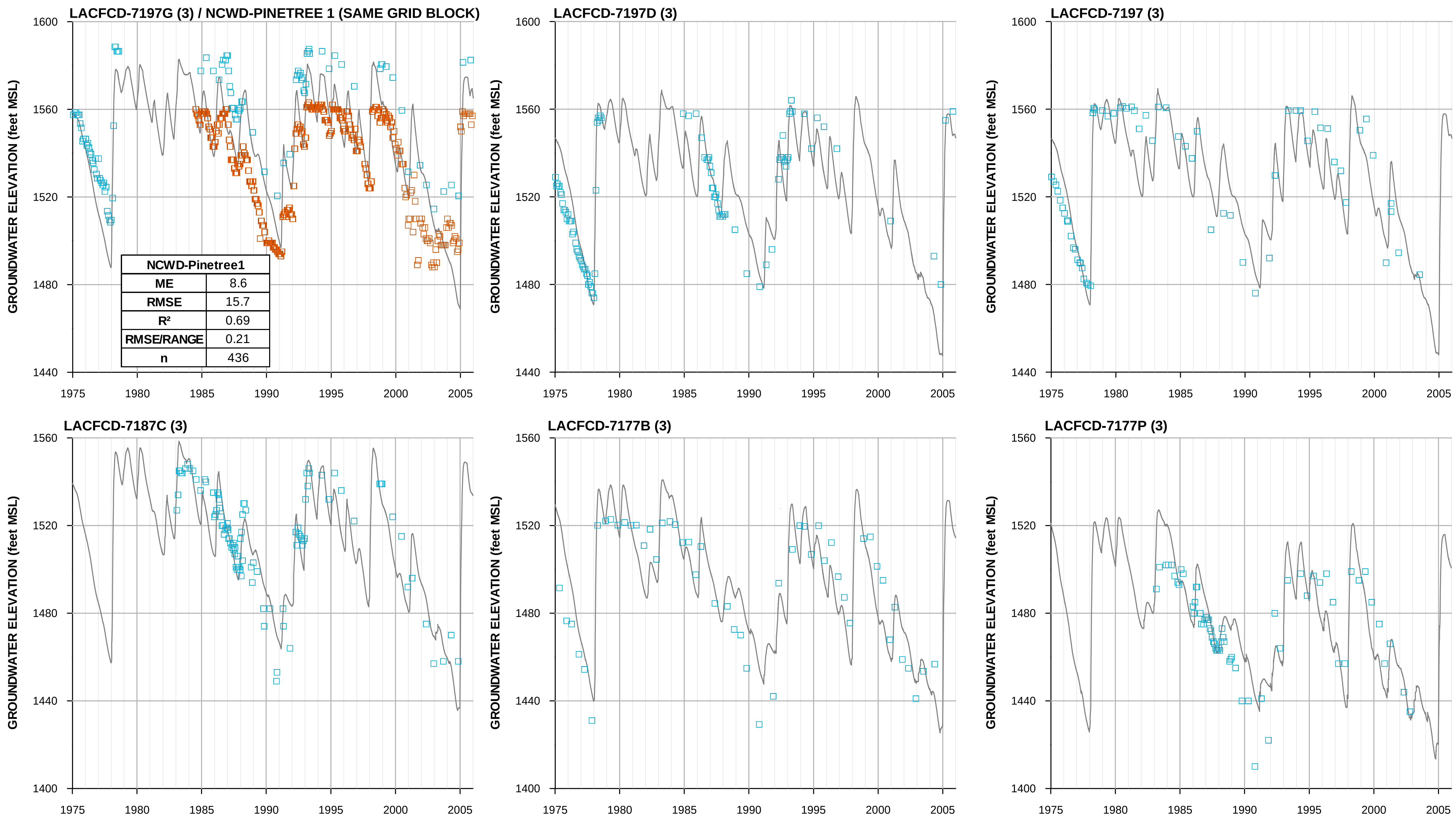


FIGURE 4-2
LOCATIONS OF SUBAREA MODEL GRIDS
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT
AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

\\ODIN\PROJ\COUNTYSANDISTLA\332056GSWI\DOC\TASK2B-NUMERICALMODELDEV\DRAFT\FIGURES\MXD\FIG04-02_SUBAREAGRIDS.MXD 1/31/2008 13:57:56

CH2MHILL -HGL



NCWD-Pinetree1	
ME	8.6
RMSE	15.7
R^2	0.69
RMSE/RANGE	0.21
n	436

NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7187C (3) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

LEGEND

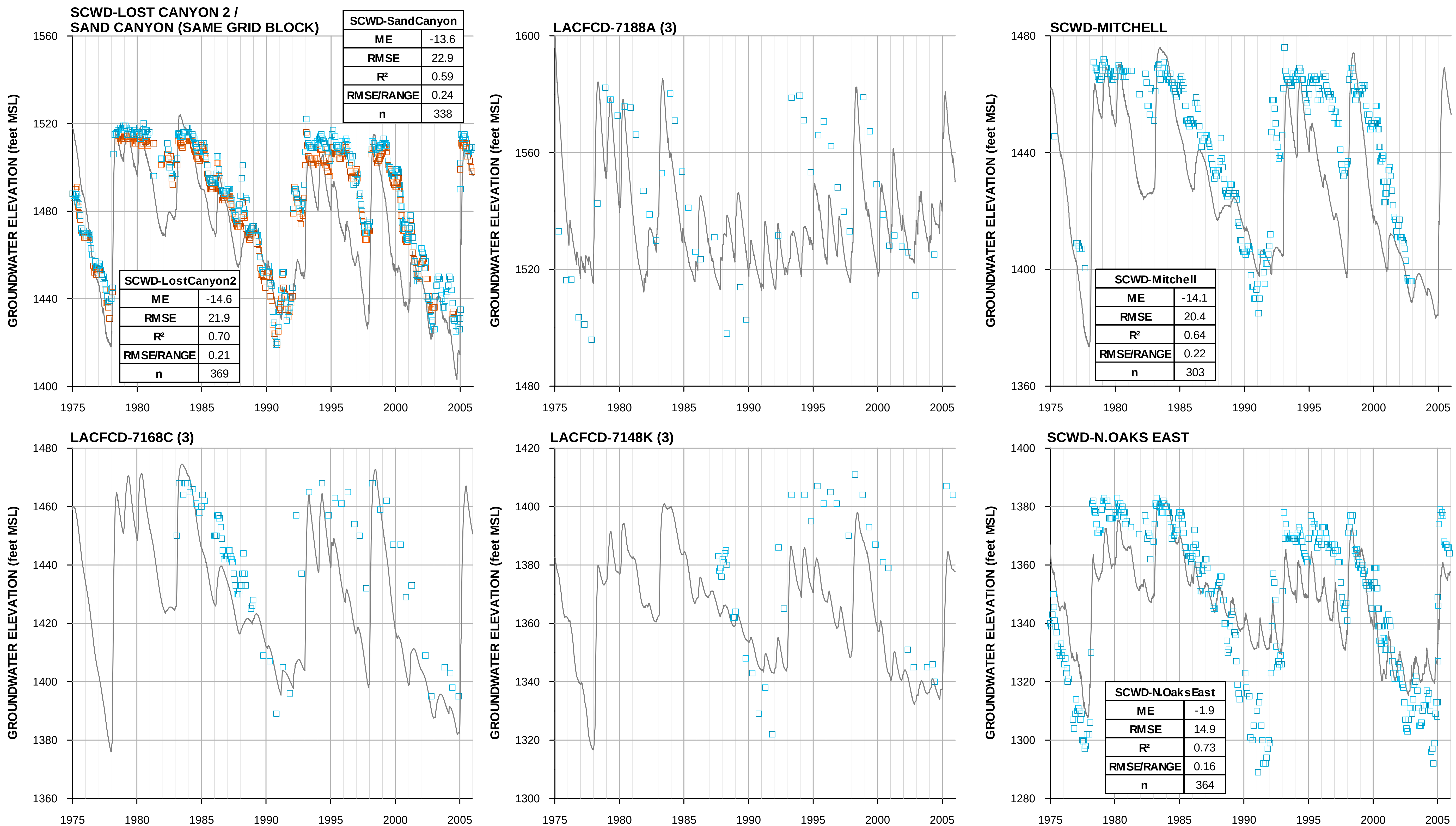
- SIMULATED GROUNDWATER ELEVATION IN WELL
- MEASURED GROUNDWATER ELEVATION
- MEASURED GROUNDWATER ELEVATION (NCWD-PINETREE 1)

FIGURE 4-3 (PAGE 1 of 3)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS LOCATED IN SOLEDAD CANYON IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL

AlluvAq_SoledadCyn1.grf



NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7168C (3) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

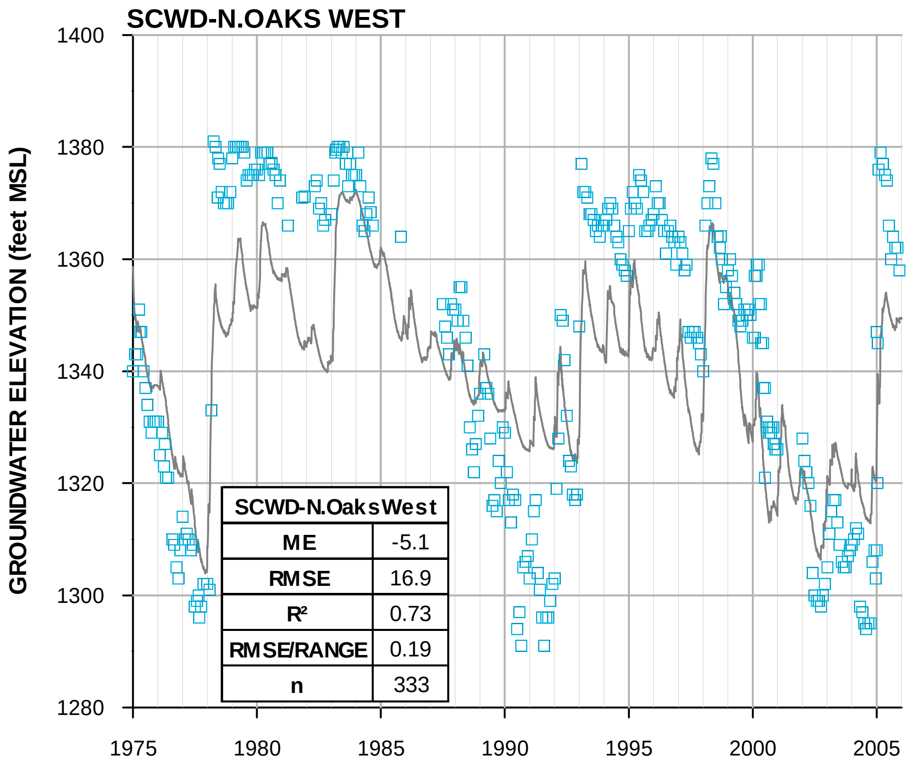
LEGEND

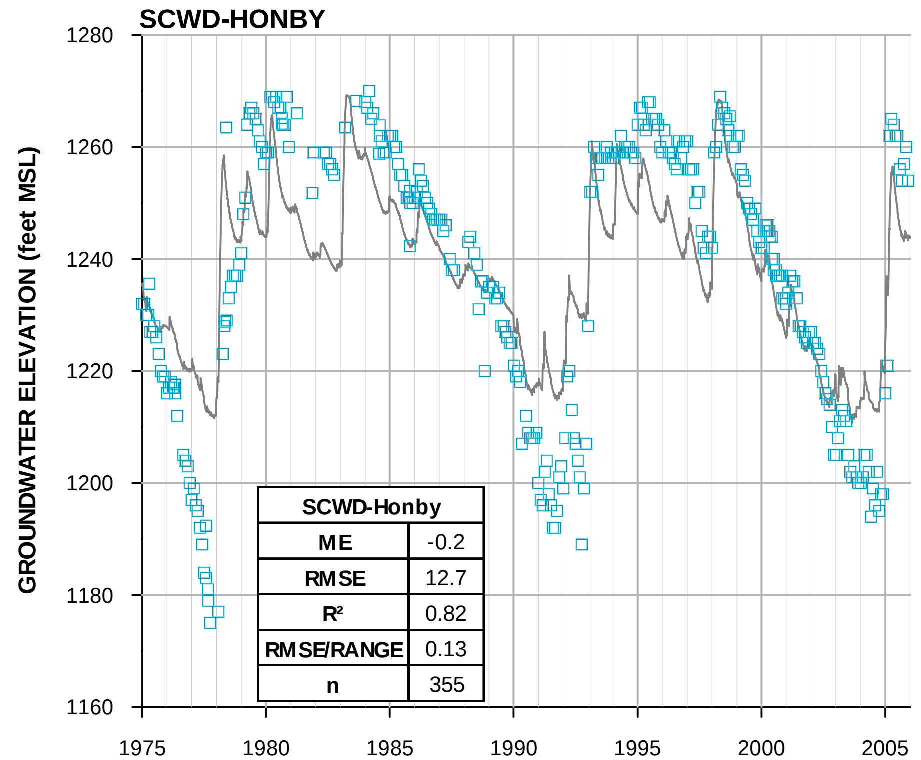
SIMULATED GROUNDWATER ELEVATION IN WELL
MEASURED GROUNDWATER ELEVATION
MEASURED GROUNDWATER ELEVATION (SCWD-SAND CANYON)

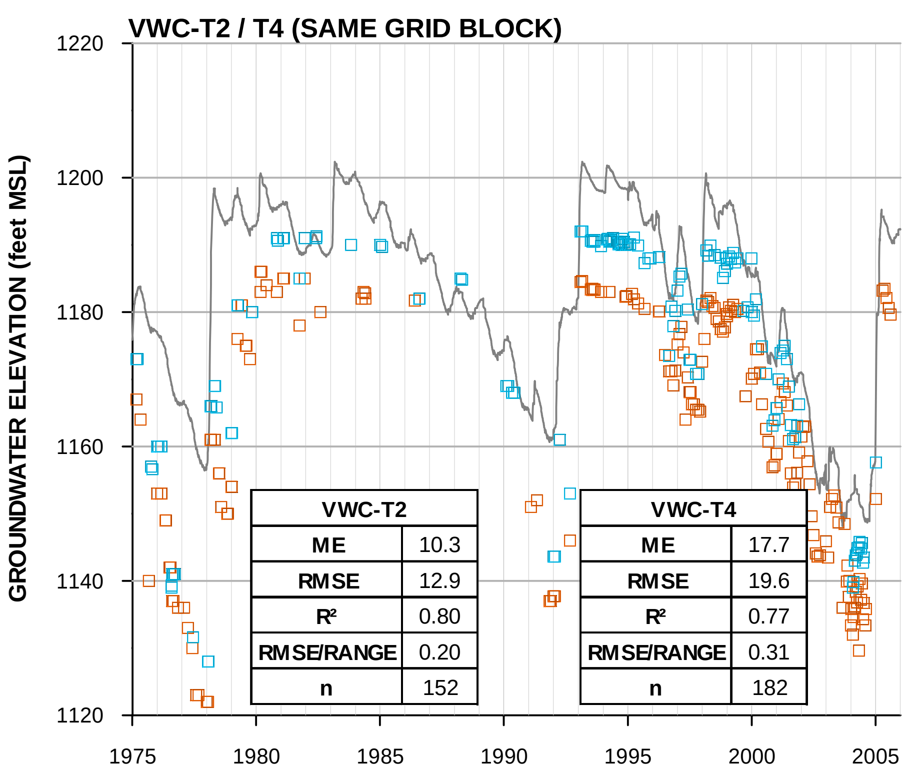
FIGURE 4-3 (PAGE 2 of 3)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS LOCATED IN SOLEDAD CANYON IN THE EAST SUBBASIN
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

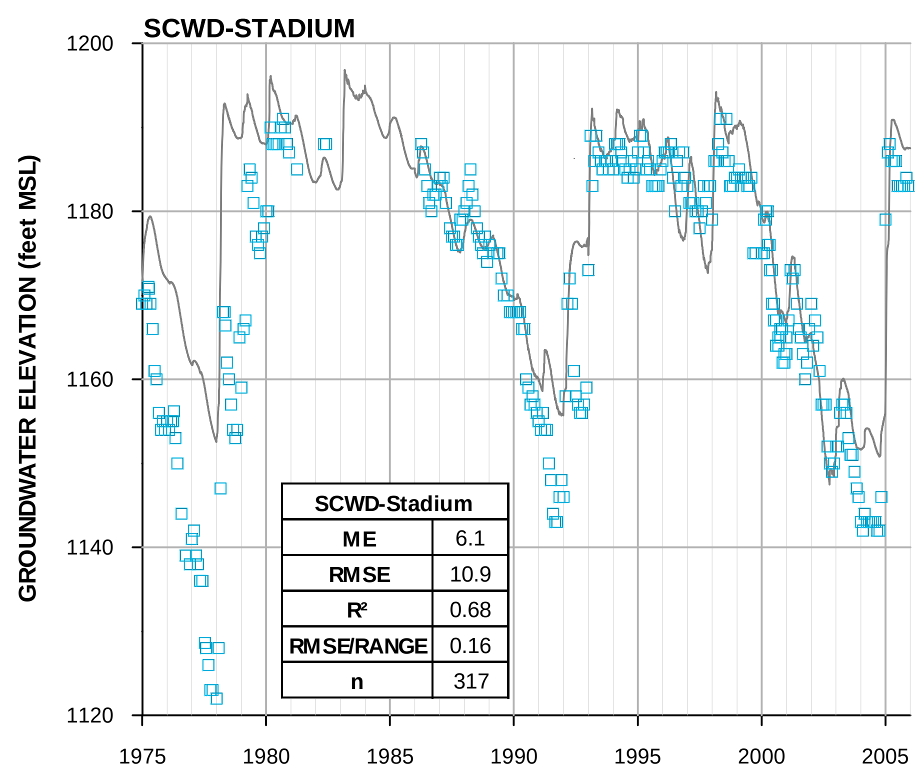
CH2MHILL –HGL

AlluvAq_SoledadCyn2.grf









NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7168C (3) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

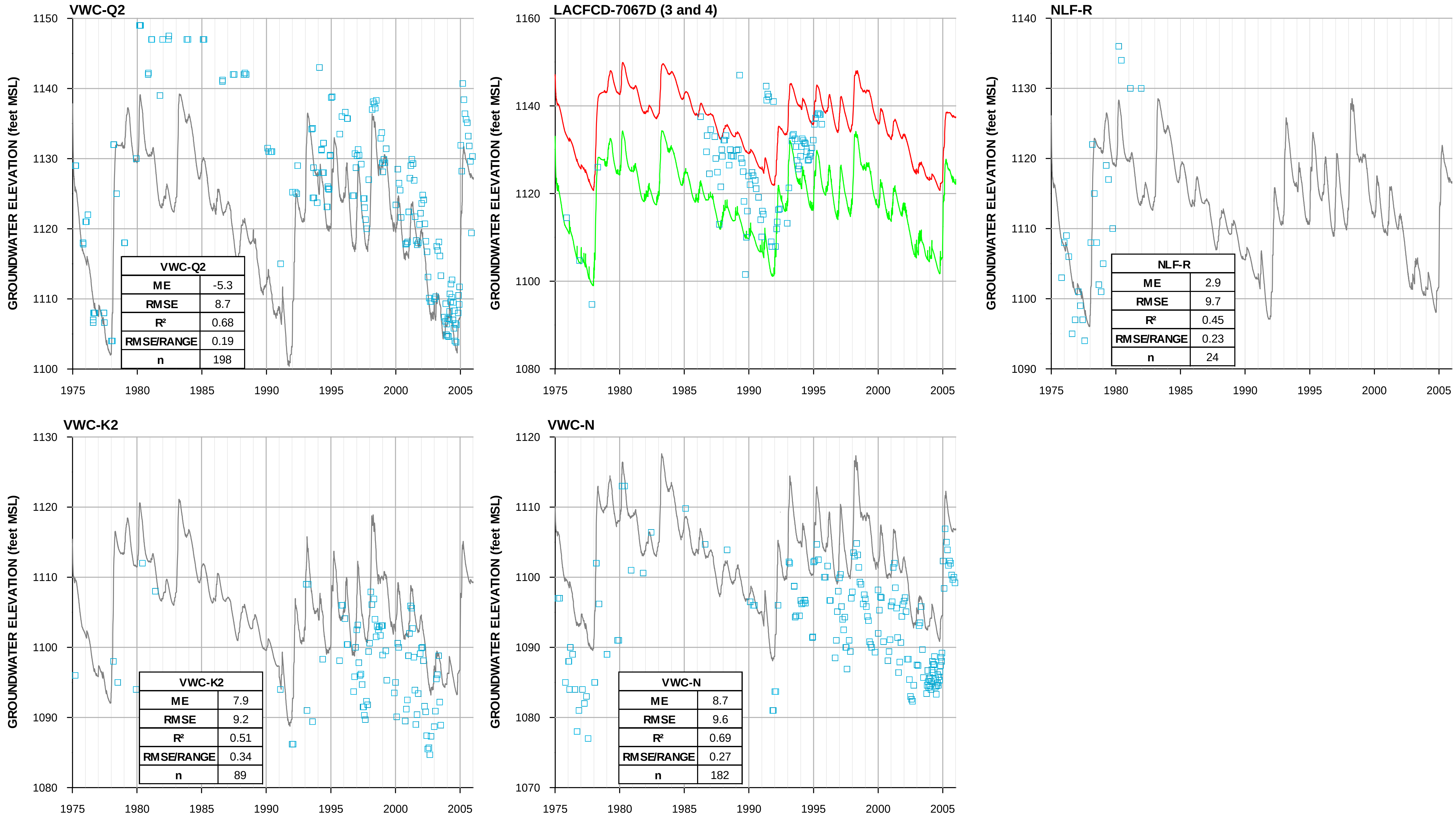
LEGEND

- SIMULATED GROUNDWATER ELEVATION IN WELL
- MEASURED GROUNDWATER ELEVATION
- MEASURED GROUNDWATER ELEVATION (VWC-T4)

FIGURE 4-3 (PAGE 3 of 3)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS LOCATED IN SOLEDAD CANYON IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–



VWC-Q2	
ME	-5.3
RMSE	8.7
R^2	0.68
RMSE/RANGE	0.19
n	198

NLF-R	
ME	2.9
RMSE	9.7
R^2	0.45
RMSE/RANGE	0.23
n	24

VWC-K2	
ME	7.9
RMSE	9.2
R^2	0.51
RMSE/RANGE	0.34
n	89

VWC-N	
ME	8.7
RMSE	9.6
R^2	0.69
RMSE/RANGE	0.27
n	182

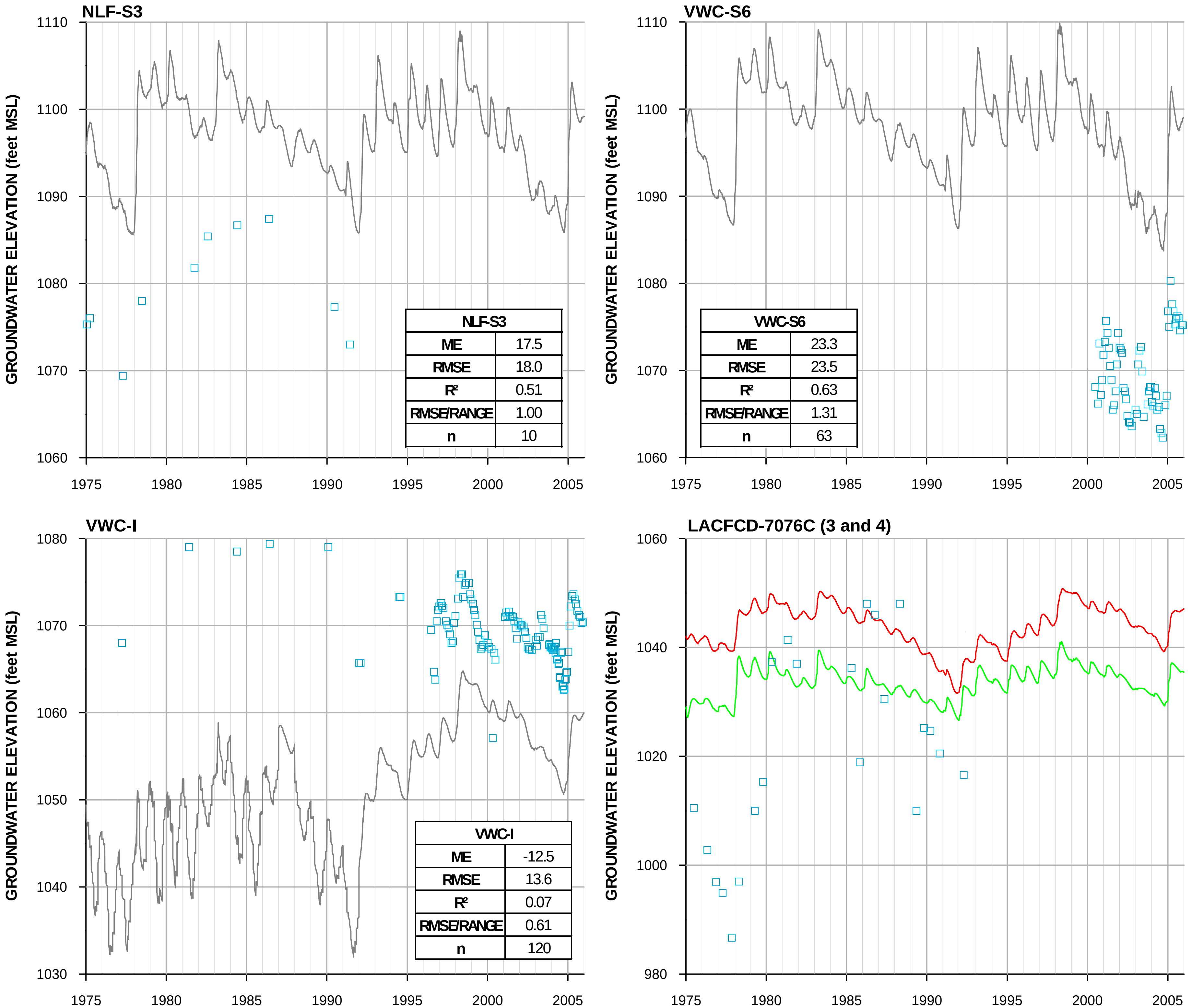
NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7067D (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

LEGEND

- SIMULATED GROUNDWATER ELEVATION IN WELL
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 3
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 4
- MEASURED GROUNDWATER ELEVATION

FIGURE 4-4 (PAGE 1 of 2)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS LOCATED BETWEEN INTERSTATE 5 AND SOLEDAD CANYON IN THE EAST SUBBASIN
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS



NLF-S3	
ME	17.5
RMSE	18.0
R^2	0.51
RMSE/RANGE	1.00
n	10

VWC-S6	
ME	23.3
RMSE	23.5
R^2	0.63
RMSE/RANGE	1.31
n	63

VWC-I	
ME	-12.5
RMSE	13.6
R^2	0.07
RMSE/RANGE	0.61
n	120

NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7076C (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

LEGEND

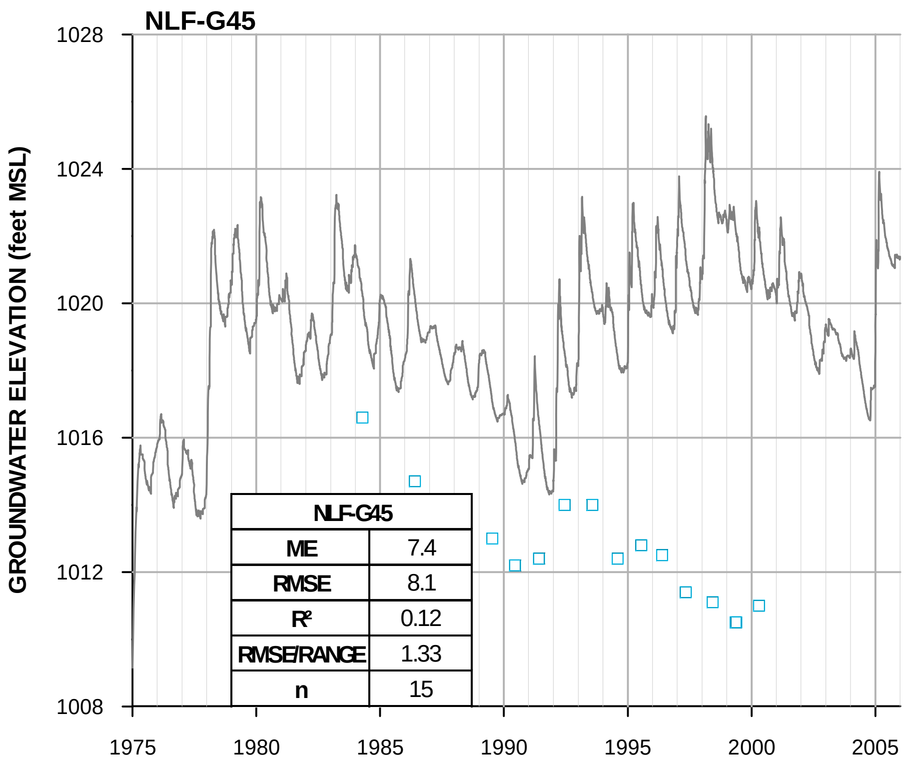
- SIMULATED GROUNDWATER ELEVATION IN WELL
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 3
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 4
- MEASURED GROUNDWATER ELEVATION

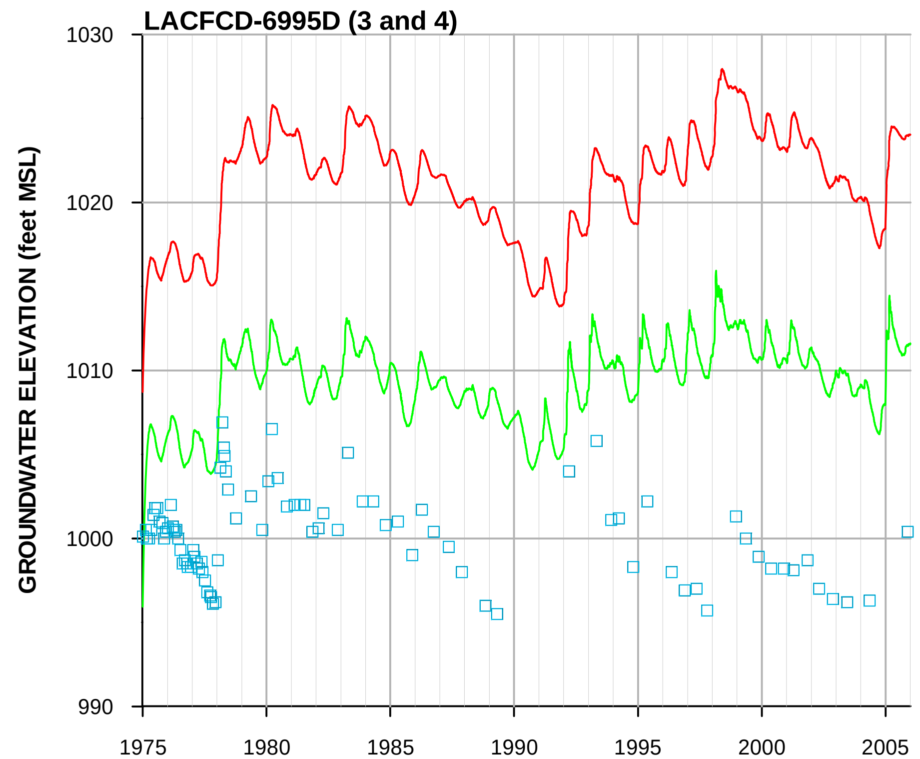
FIGURE 4-4 (PAGE 2 of 2)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS LOCATED BETWEEN INTERSTATE 5 AND SOLEDAD CANYON IN THE EAST SUBBASIN

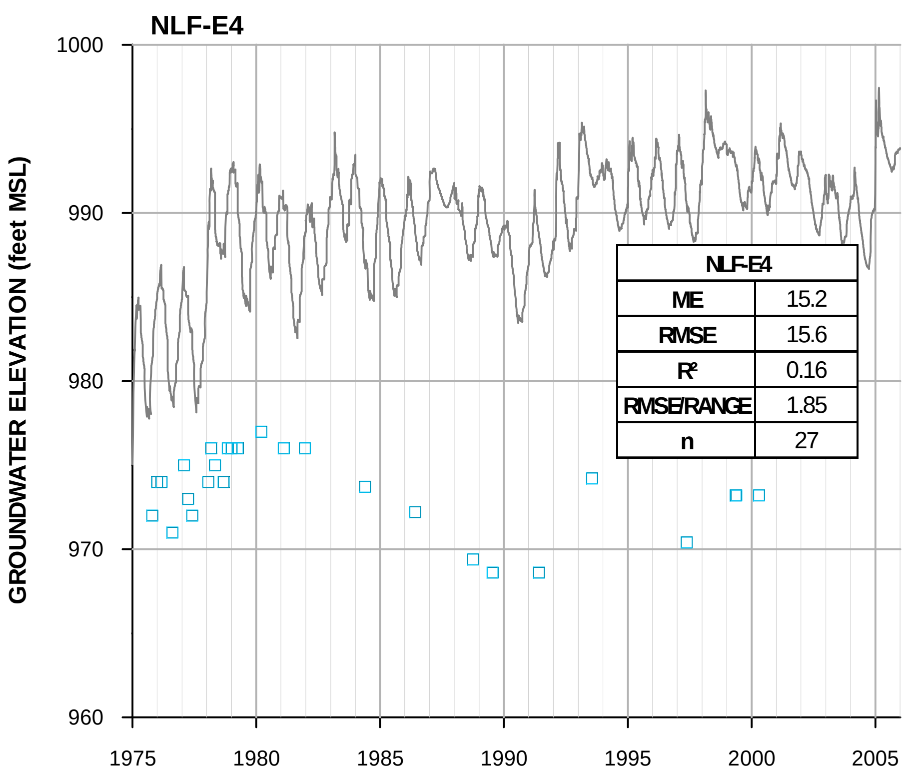
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

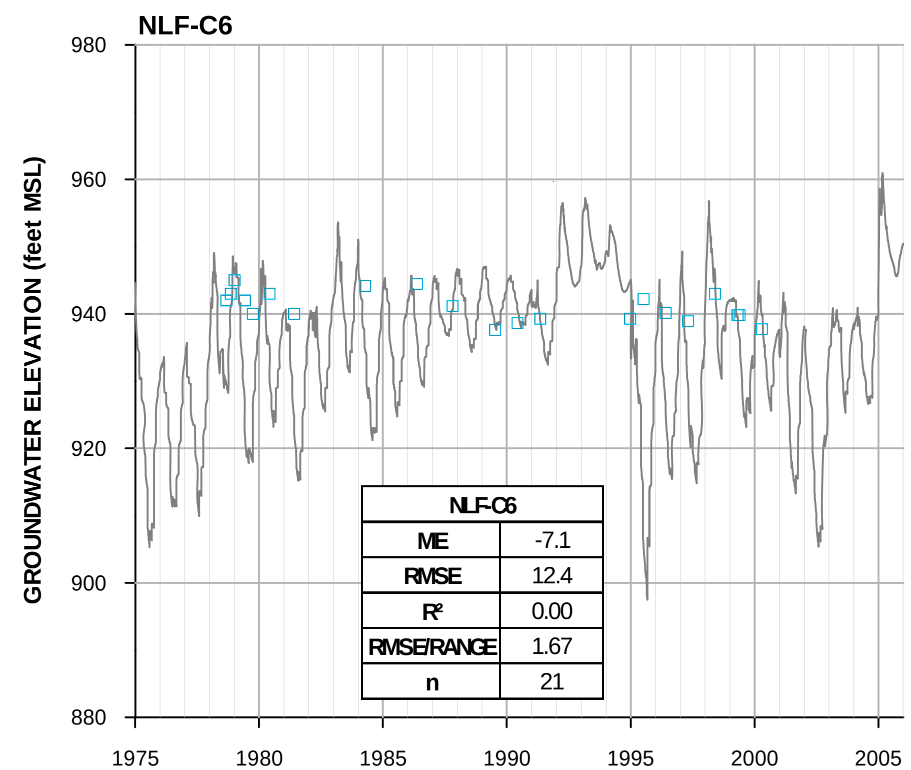
CH2MHILL –HGL–

AlluvAq_I5&SoledadCyn2.grf









NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-6995D (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

LEGEND

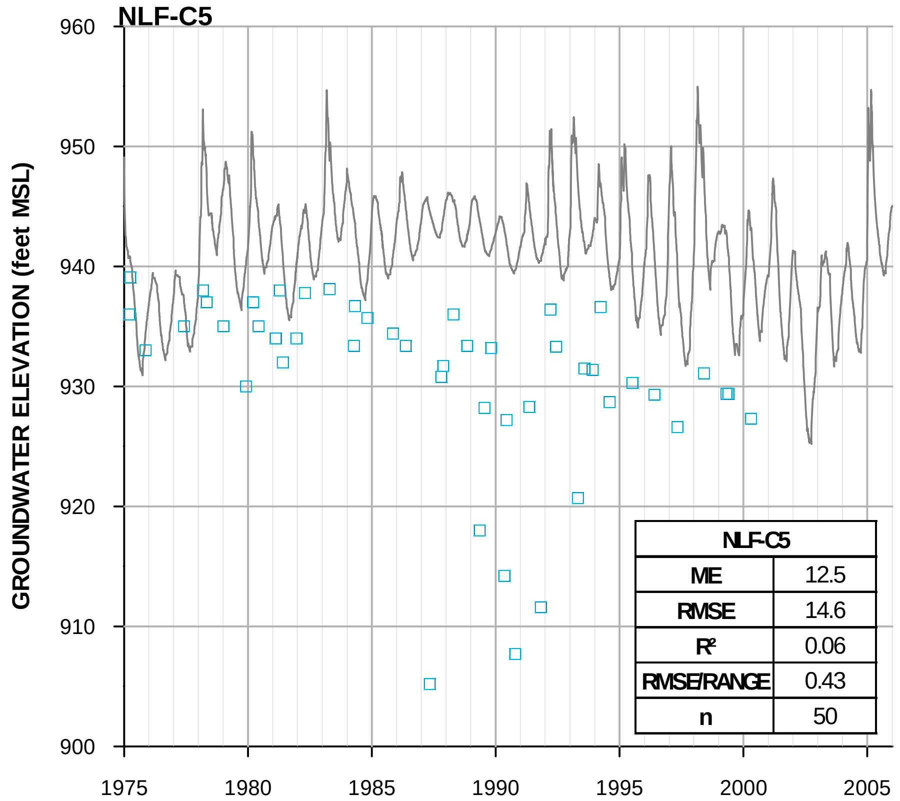
- SIMULATED GROUNDWATER ELEVATION IN WELL
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 3
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 4
- □ MEASURED GROUNDWATER ELEVATION

FIGURE 4-5 (PAGE 1 of 2)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS LOCATED WEST OF INTERSTATE 5 IN THE EAST SUBBASIN

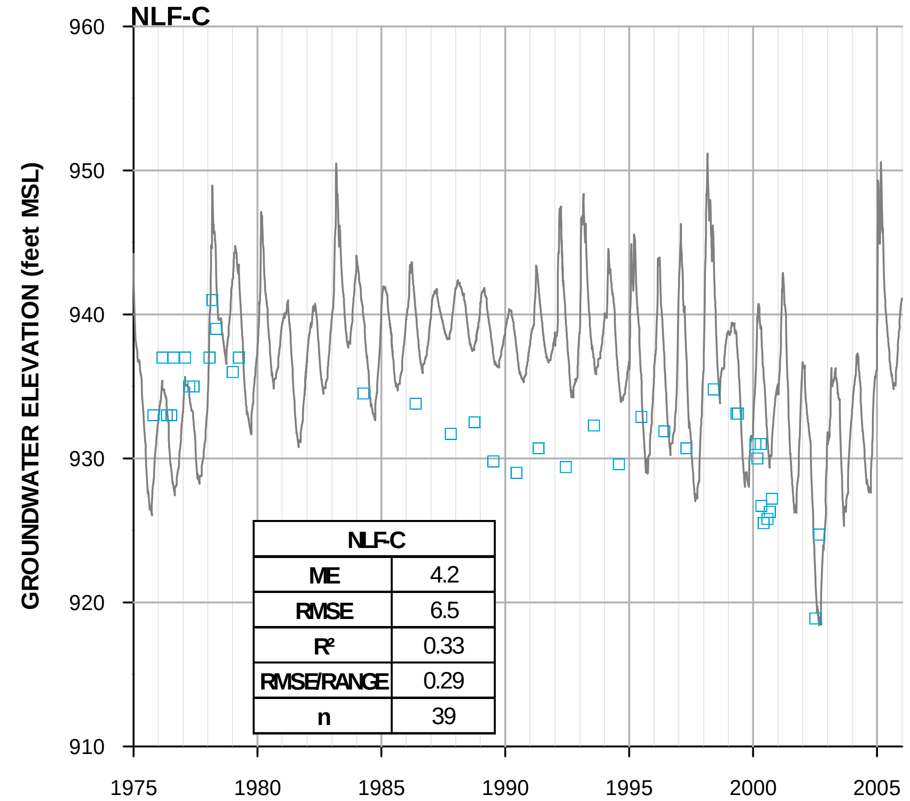
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL

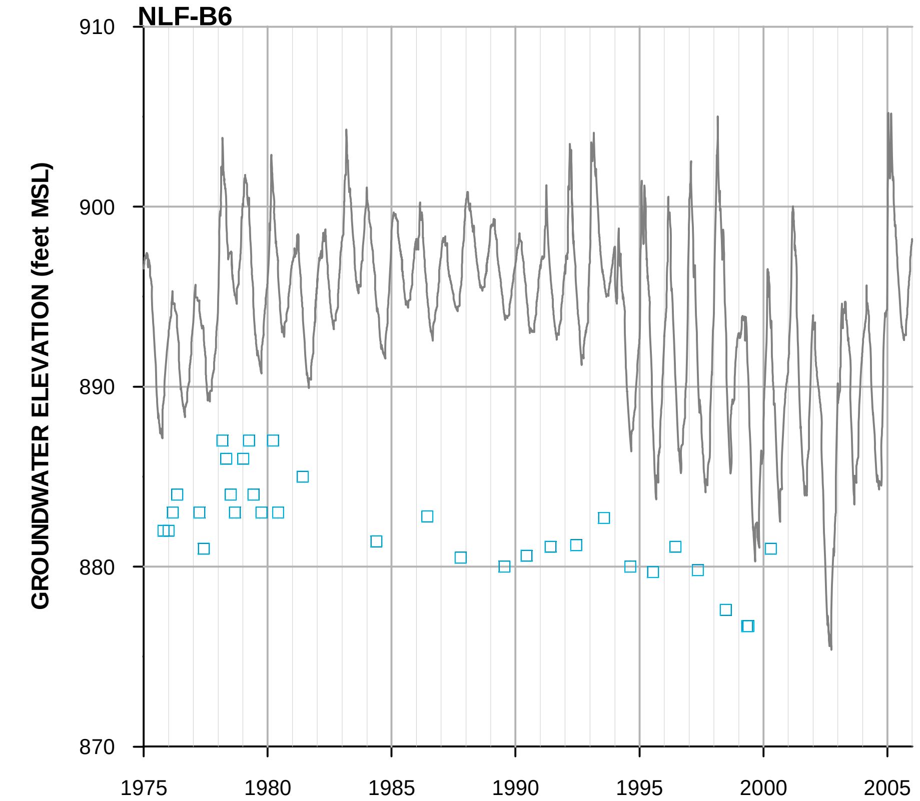
AlluvAq_WestI5_1.grf



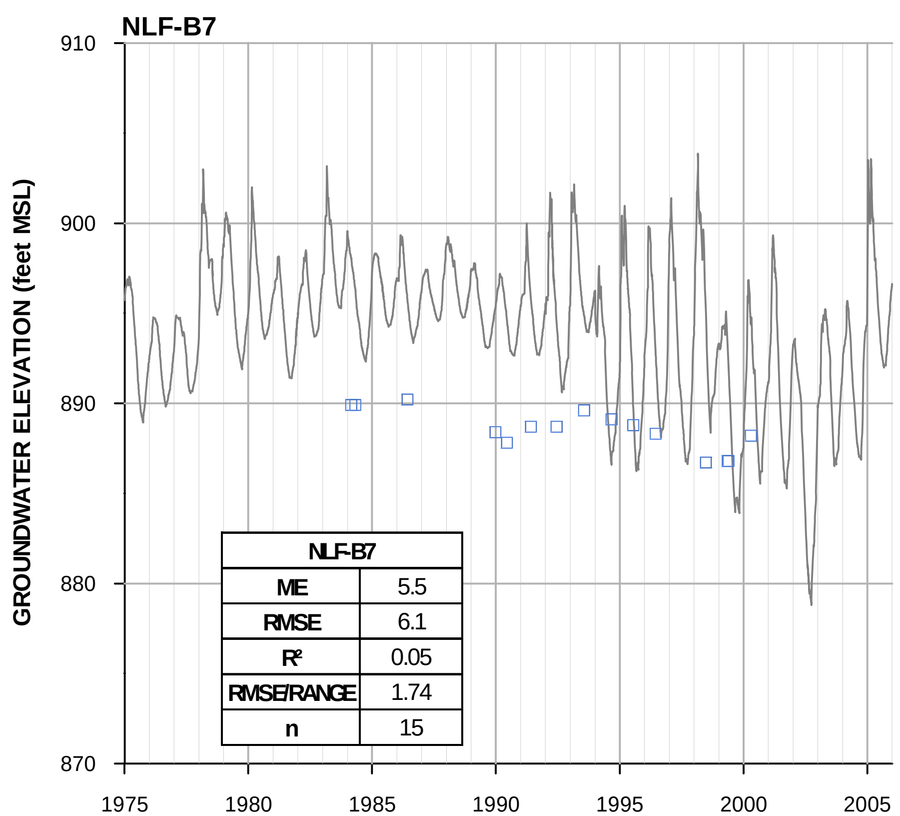
NLF-C5	
ME	12.5
RMSE	14.6
R^2	0.06
RMSE/RANGE	0.43
n	50



NLF-C	
ME	4.2
RMSE	6.5
R^2	0.33
RMSE/RANGE	0.29
n	39



NLF-B6	
ME	12.3
RMSE	12.6
R^2	0.54
RMSE/RANGE	1.22
n	33



NLF-B7	
ME	5.5
RMSE	6.1
R^2	0.05
RMSE/RANGE	1.74
n	15

LEGEND

SIMULATED GROUNDWATER ELEVATION IN WELL

MEASURED GROUNDWATER ELEVATION

NOTES:

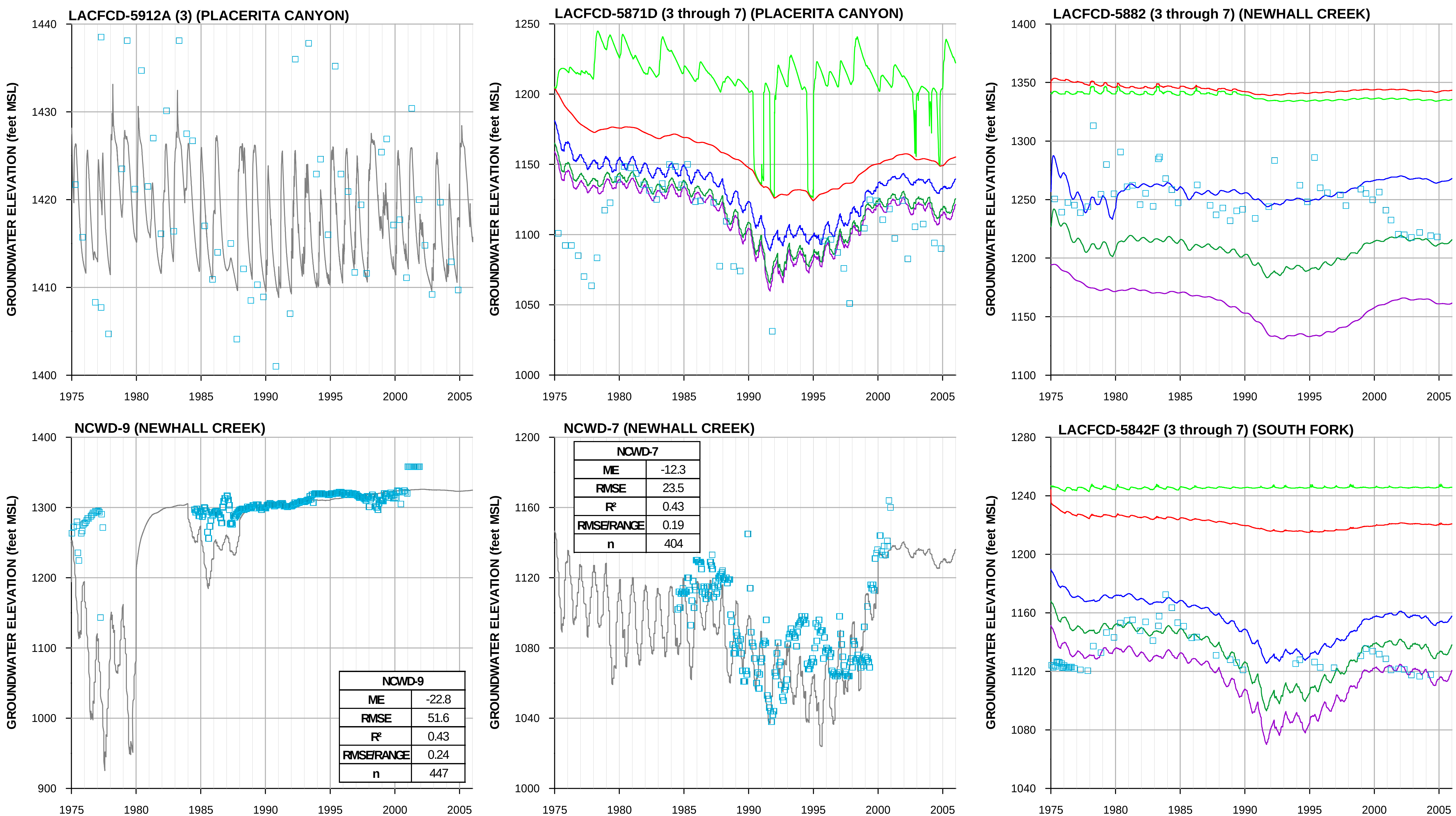
1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-6995D (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

FIGURE 4-5 (PAGE 2 of 2)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS LOCATED WEST OF INTERSTATE 5 IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–

AlluvAq_WestI5_2.grf



NCWD-9	
ME	-22.8
RMSE	51.6
R^2	0.43
RMSE/RANGE	0.24
n	447

NCWD-7	
ME	-12.3
RMSE	23.5
R^2	0.43
RMSE/RANGE	0.19
n	404

NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-5912A (3) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

LEGEND

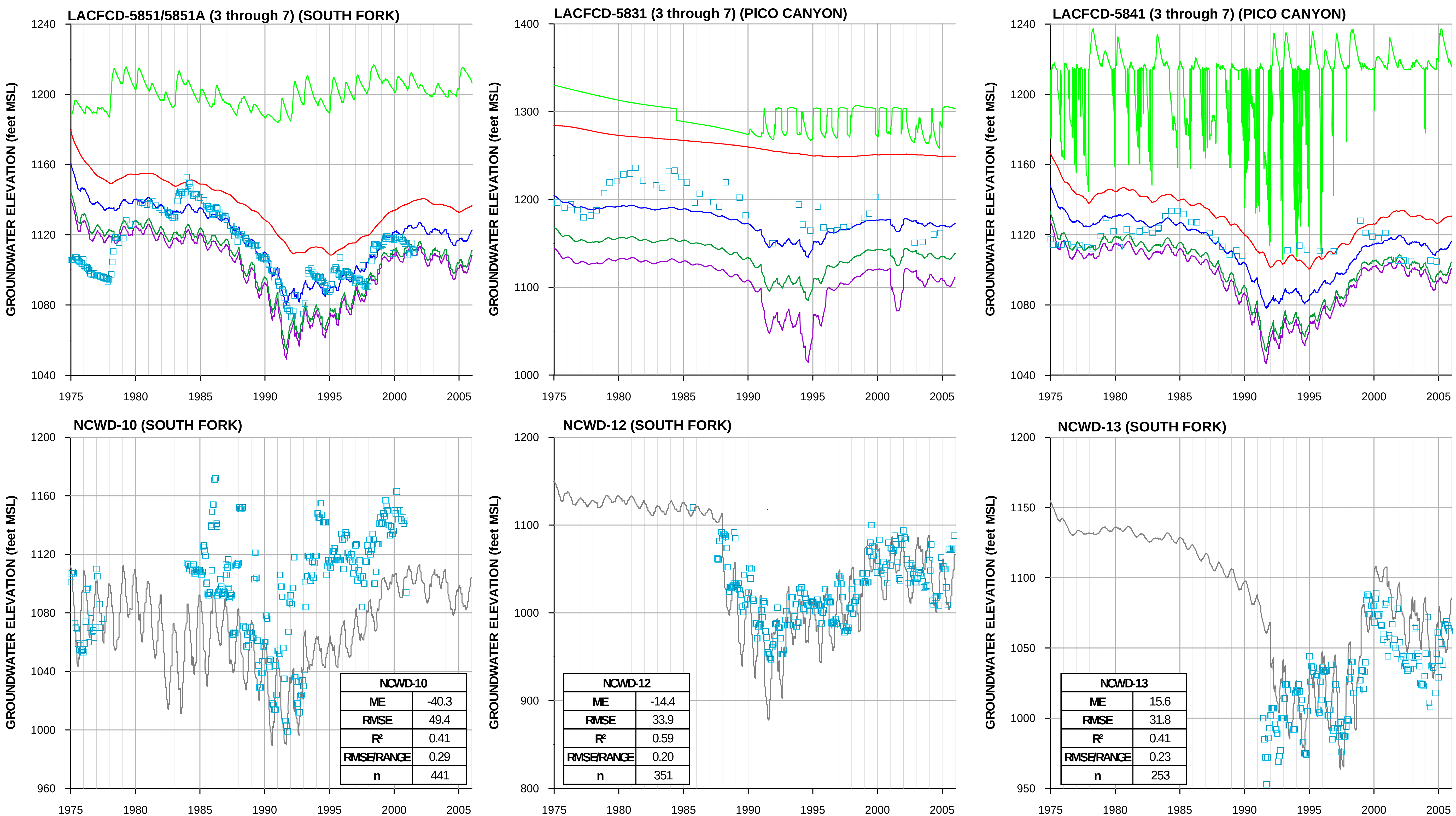
- SIMULATED GROUNDWATER ELEVATION IN WELL
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 3
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 4
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 5
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 6
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 7
- MEASURED GROUNDWATER ELEVATION

FIGURE 4-6 (PAGE 1 of 3)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN SAUGUS FORMATION WELLS LOCATED IN THE SOUTH FORK AREA IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–

SaugusAq_SouthFork1.grf



NCWD-10	
ME	-40.3
RMSE	49.4
R²	0.41
RMSE/RANGE	0.29
n	441

NCWD-12	
ME	-14.4
RMSE	33.9
R²	0.59
RMSE/RANGE	0.20
n	351

NCWD-13	
ME	15.6
RMSE	31.8
R²	0.41
RMSE/RANGE	0.23
n	253

NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-5831 (3 through 7) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYERS 3 THROUGH 7.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

LEGEND

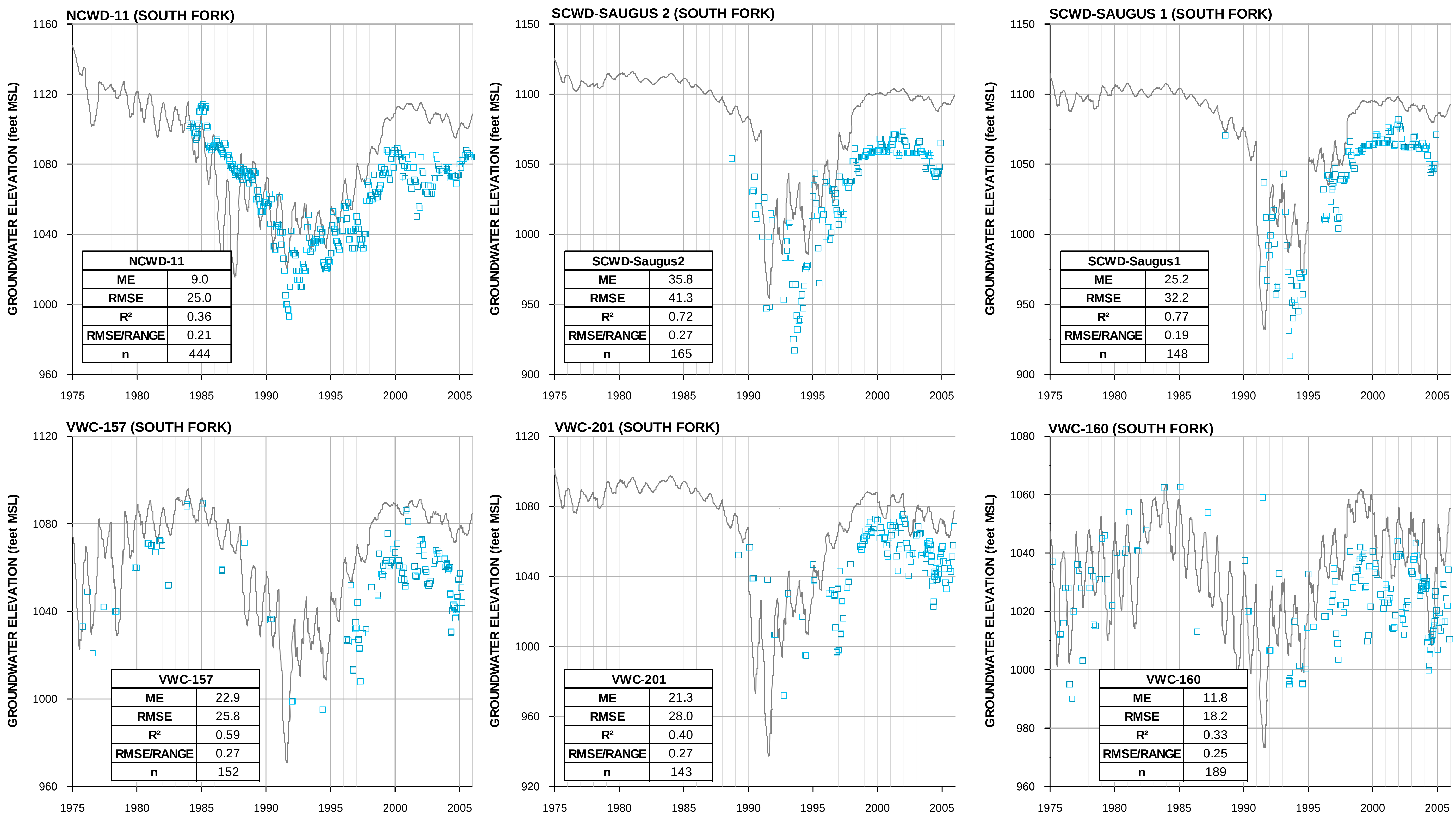
- SIMULATED GROUNDWATER ELEVATION IN WELL
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 3
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 4
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 5
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 6
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 7
- MEASURED GROUNDWATER ELEVATION

FIGURE 4-6 (PAGE 2 of 3)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN SAUGUS FORMATION WELLS LOCATED IN THE SOUTH FORK AREA IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–

SaugusAq_SouthFork2.grf



NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7095 (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

LEGEND

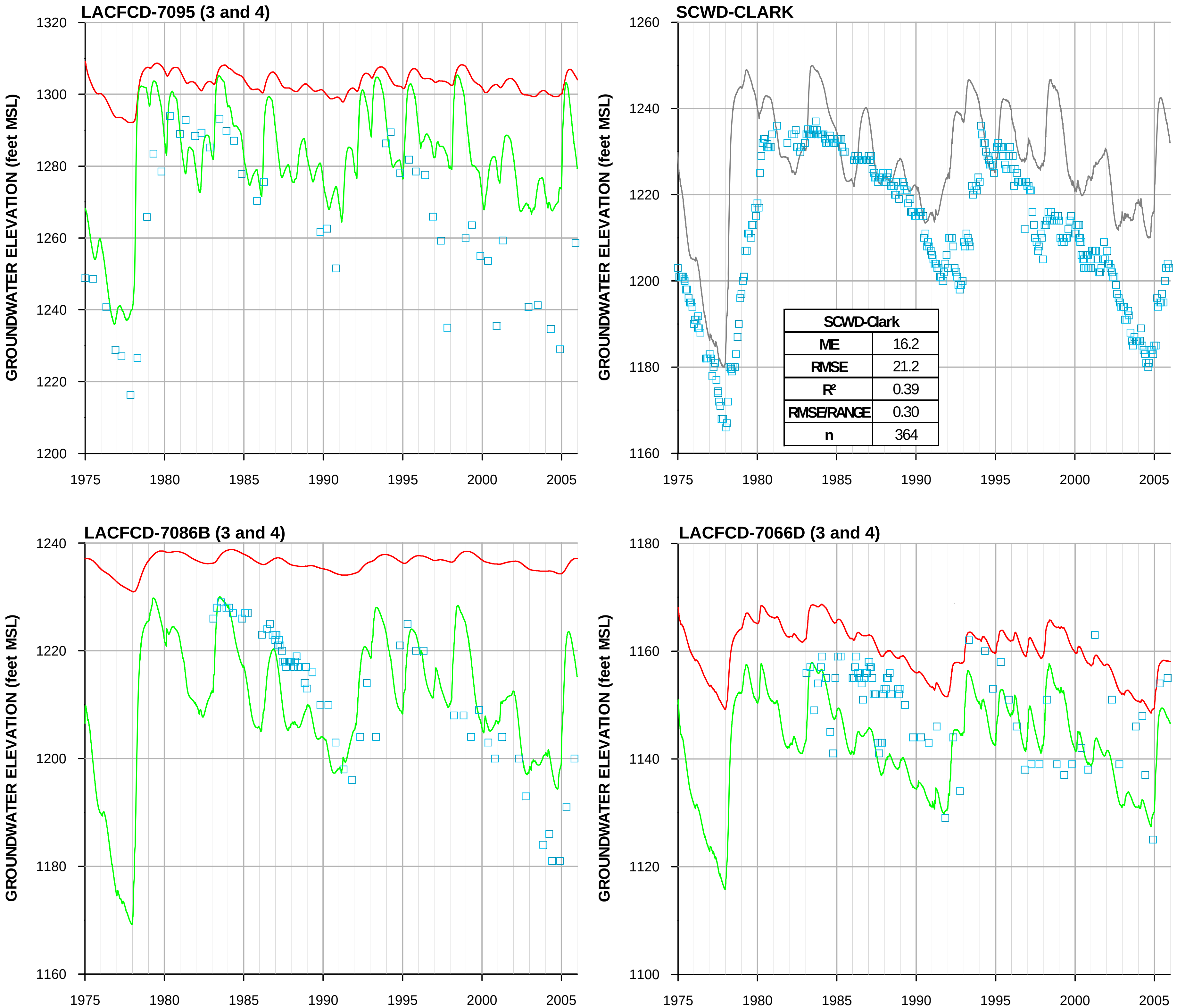
SIMULATED GROUNDWATER ELEVATION IN WELL

MEASURED GROUNDWATER ELEVATION

FIGURE 4-6 (PAGE 3 of 3)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN SAUGUS FORMATION WELLS LOCATED IN THE SOUTH FORK AREA IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–



NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7066D (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

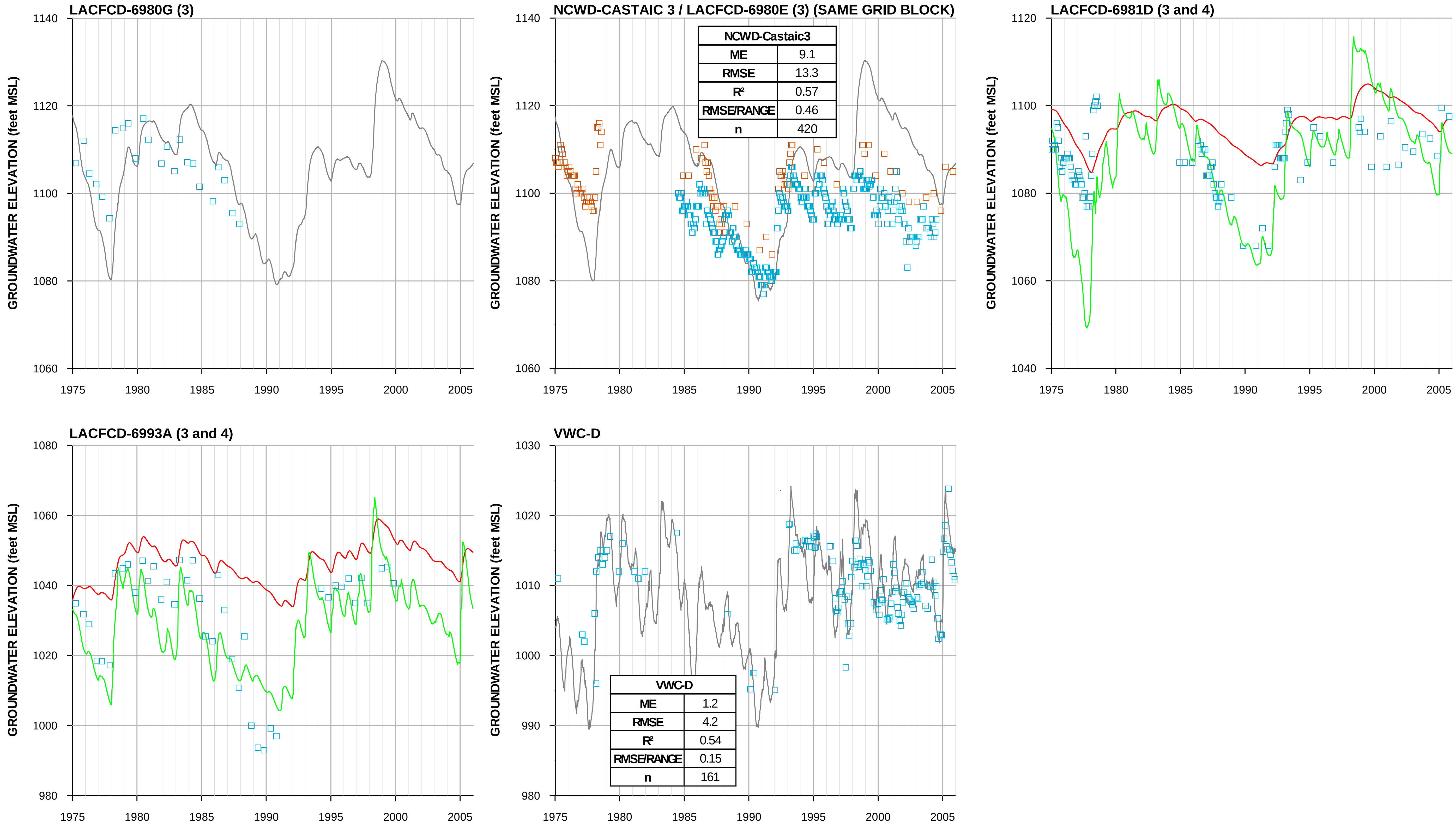
LEGEND

- SIMULATED GROUNDWATER ELEVATION IN WELL
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 3
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 4
- MEASURED GROUNDWATER ELEVATION

FIGURE 4-7
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS LOCATED IN BOUQUET CANYON IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–



NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-6993A (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

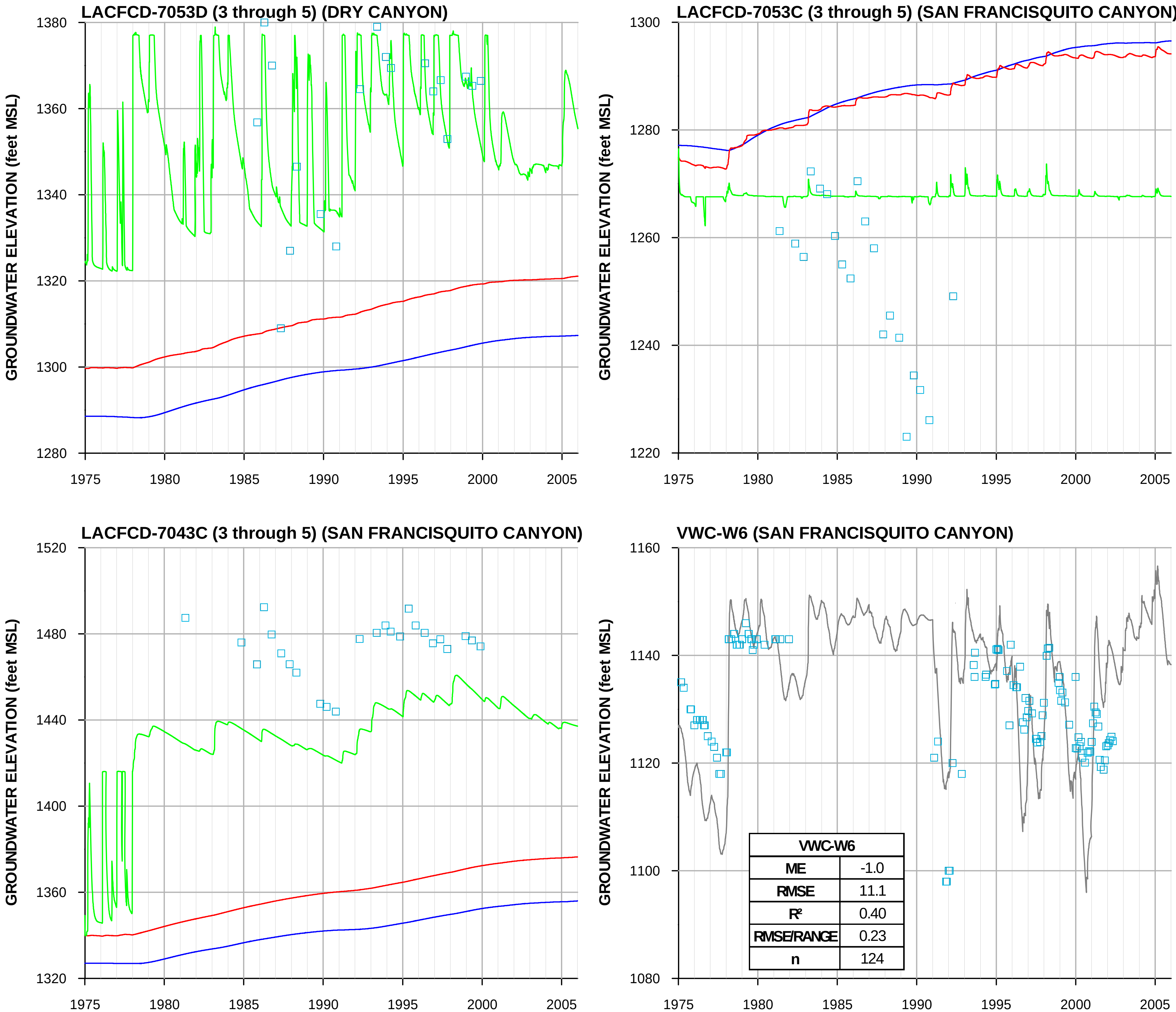
LEGEND

- SIMULATED GROUNDWATER ELEVATION IN WELL
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 3
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 4
- MEASURED GROUNDWATER ELEVATION
- MEASURED GROUNDWATER ELEVATION (LACFCD-6980E)

FIGURE 4-8
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS LOCATED ALONG CASTAIC CREEK IN THE EAST SUBBASIN
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL

AlluvAq_Castaic.grf



VWC-W6	
ME	-1.0
RMSE	11.1
R²	0.40
RMSE/RANGE	0.23
n	124

NOTES:

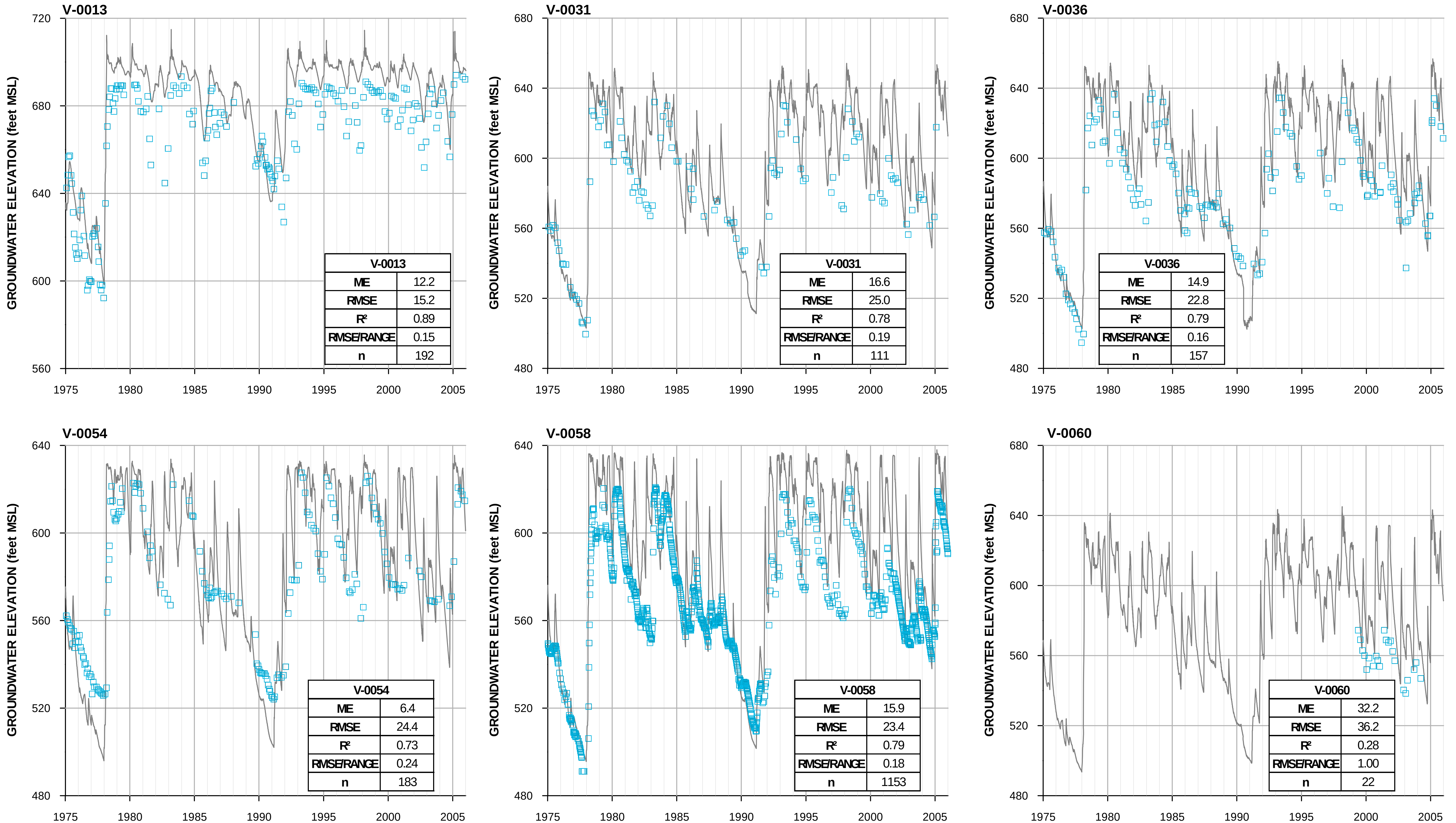
1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7043C (3 through 5) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 THROUGH 5.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

LEGEND

- SIMULATED GROUNDWATER ELEVATION IN WELL
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 3
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 4
- SIMULATED GROUNDWATER ELEVATION IN MODEL LAYER 5
- MEASURED GROUNDWATER ELEVATION

FIGURE 4-9
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN ALLUVIAL AQUIFER WELLS LOCATED IN OTHER TRIBUTARY CANYONS IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS



V-0013	
ME	12.2
RMSE	15.2
R²	0.89
RMSE/RANGE	0.15
n	192

V-0031	
ME	16.6
RMSE	25.0
R²	0.78
RMSE/RANGE	0.19
n	111

V-0036	
ME	14.9
RMSE	22.8
R²	0.79
RMSE/RANGE	0.16
n	157

V-0054	
ME	6.4
RMSE	24.4
R²	0.73
RMSE/RANGE	0.24
n	183

V-0058	
ME	15.9
RMSE	23.4
R²	0.79
RMSE/RANGE	0.18
n	1153

V-0060	
ME	32.2
RMSE	36.2
R²	0.28
RMSE/RANGE	1.00
n	22

NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7095 (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

LEGEND

SIMULATED GROUNDWATER ELEVATION IN WELL

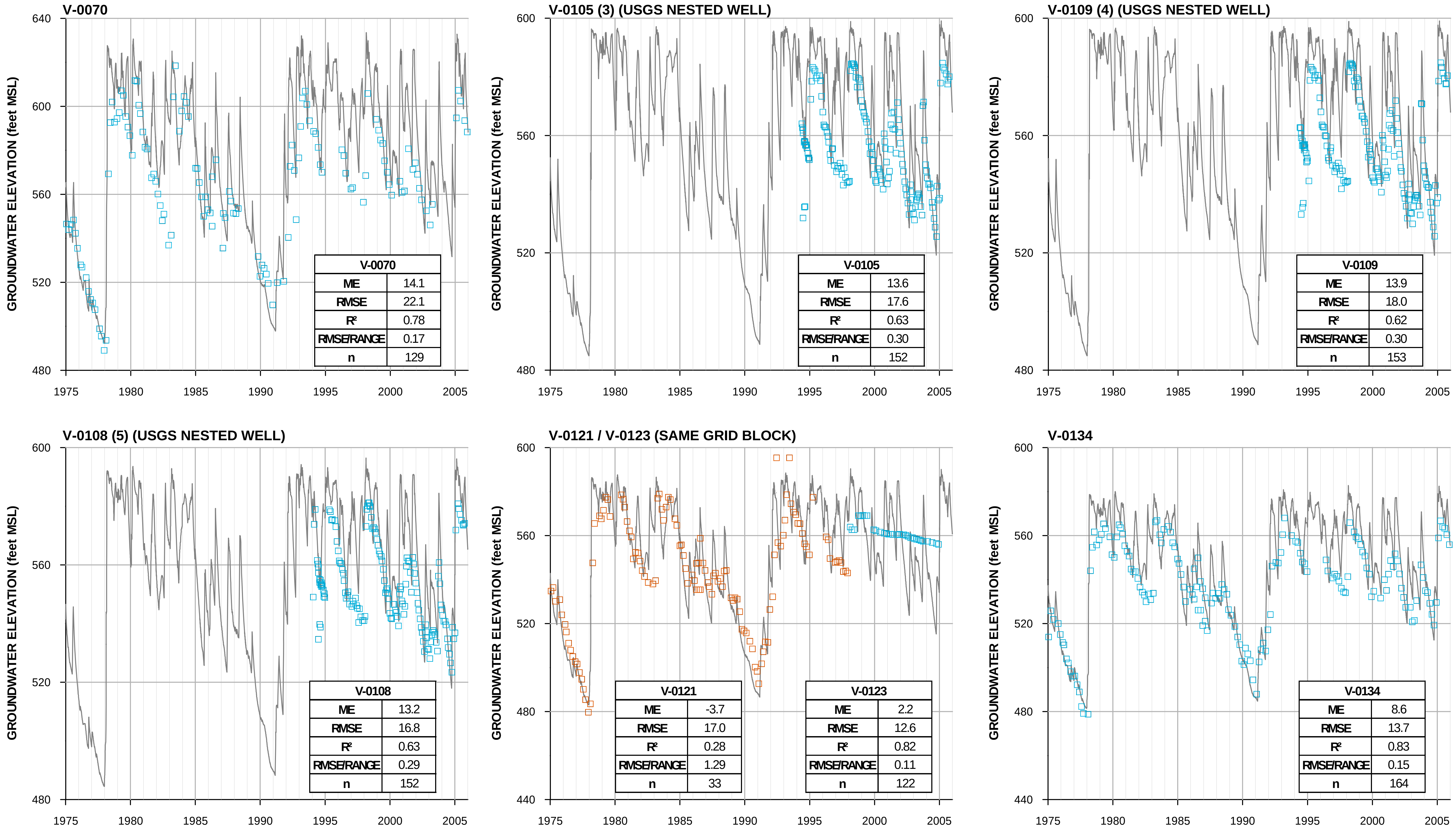
MEASURED GROUNDWATER ELEVATION

FIGURE 4-10
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN WELLS LOCATED EAST OF TORREY ROAD ALONG THE SANTA CLARA RIVER IN THE PIRU SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–

Piru_EastTorrey.grf



V-0070	
ME	14.1
RMSE	22.1
R^2	0.78
RMSE/RANGE	0.17
n	129

V-0105	
ME	13.6
RMSE	17.6
R^2	0.63
RMSE/RANGE	0.30
n	152

V-0109	
ME	13.9
RMSE	18.0
R^2	0.62
RMSE/RANGE	0.30
n	153

V-0108	
ME	13.2
RMSE	16.8
R^2	0.63
RMSE/RANGE	0.29
n	152

V-0121	
ME	-3.7
RMSE	17.0
R^2	0.28
RMSE/RANGE	1.29
n	33

V-0123	
ME	2.2
RMSE	12.6
R^2	0.82
RMSE/RANGE	0.11
n	122

V-0134	
ME	8.6
RMSE	13.7
R^2	0.83
RMSE/RANGE	0.15
n	164

NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, V-0108 (5) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 5.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

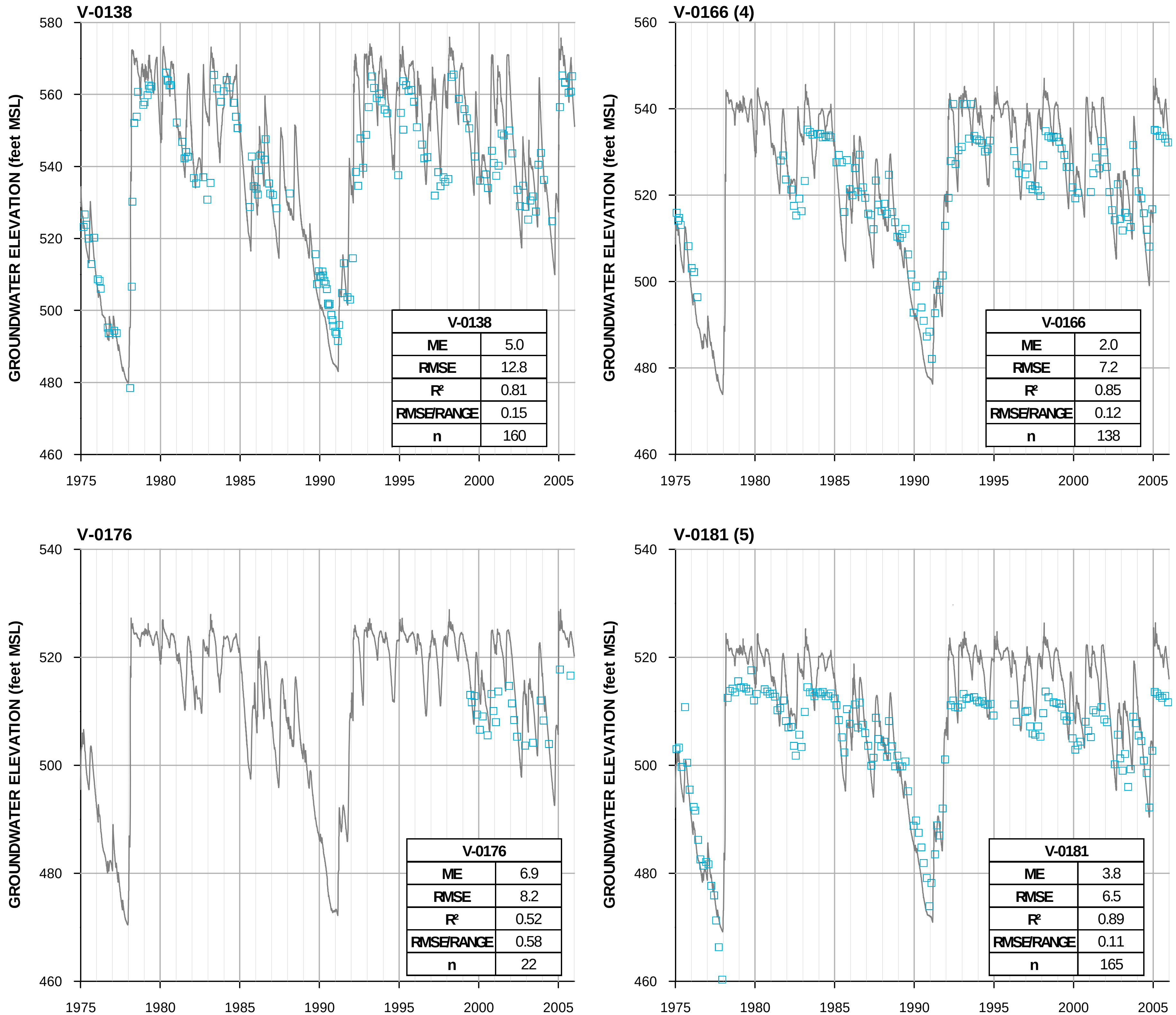
LEGEND

- SIMULATED GROUNDWATER ELEVATION IN WELL
- MEASURED GROUNDWATER ELEVATION
- MEASURED GROUNDWATER ELEVATION (V-0123)

FIGURE 4-11
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN WELLS LOCATED BETWEEN HOPPER CREEK AND TORREY ROAD IN THE PIRU SUBBASIN
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL

Piru_HopperTorrey.grf



V-0138	
ME	5.0
RMSE	12.8
R²	0.81
RMSE/RANGE	0.15
n	160

V-0166	
ME	2.0
RMSE	7.2
R²	0.85
RMSE/RANGE	0.12
n	138

V-0176	
ME	6.9
RMSE	8.2
R²	0.52
RMSE/RANGE	0.58
n	22

V-0181	
ME	3.8
RMSE	6.5
R²	0.89
RMSE/RANGE	0.11
n	165

NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, V-0181 (5) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 5.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

LEGEND

SIMULATED GROUNDWATER ELEVATION IN WELL

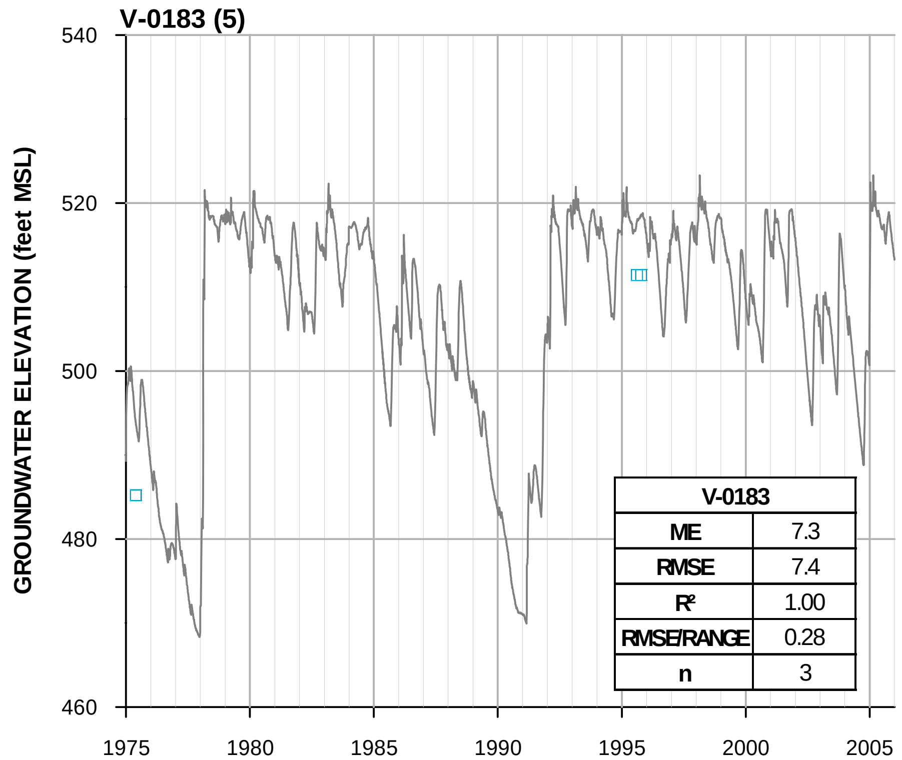
MEASURED GROUNDWATER ELEVATION

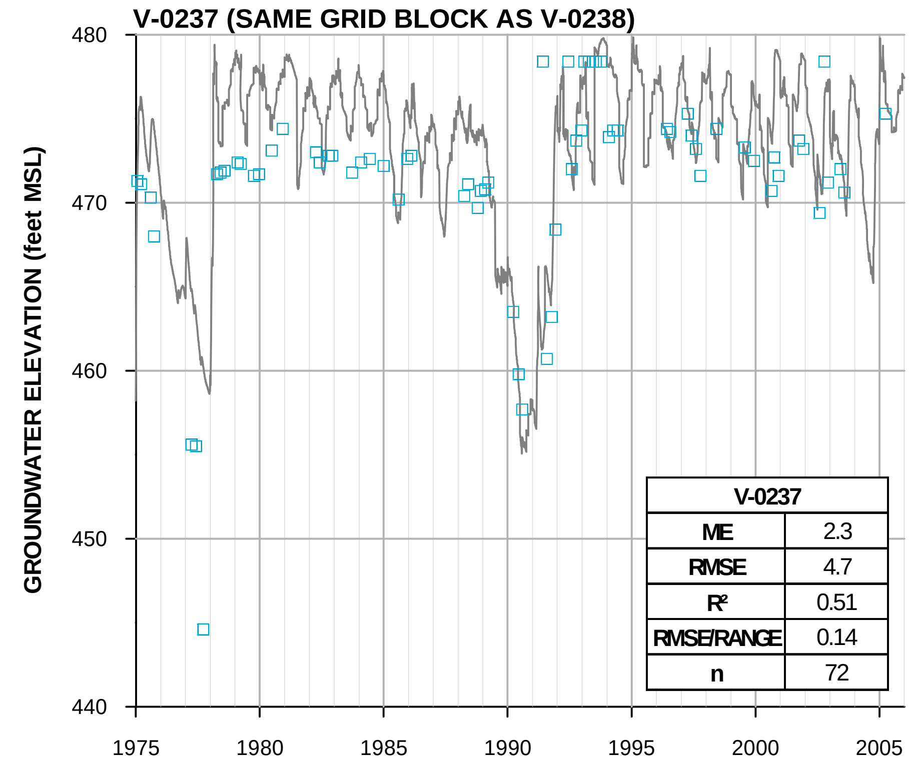
FIGURE 4-12 (PAGE 1 of 2)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN WELLS LOCATED WEST OF HOPPER CREEK IN THE PIRU SUBBASIN

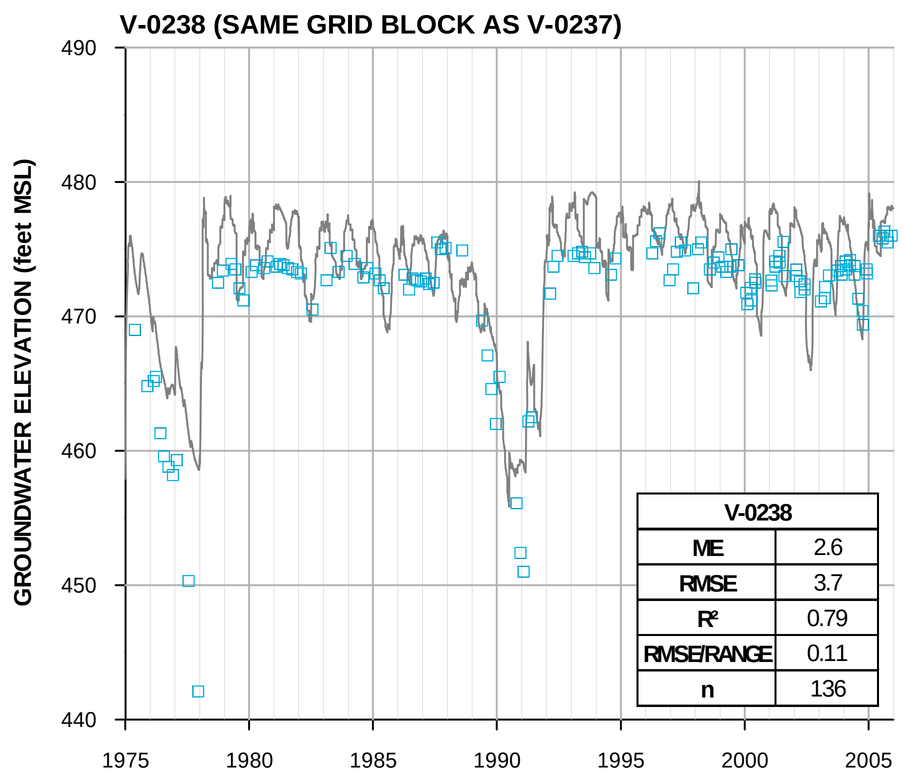
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE
TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–

Piru_WestHopper1.grf







LEGEND

SIMULATED GROUNDWATER ELEVATION IN WELL

MEASURED GROUNDWATER ELEVATION

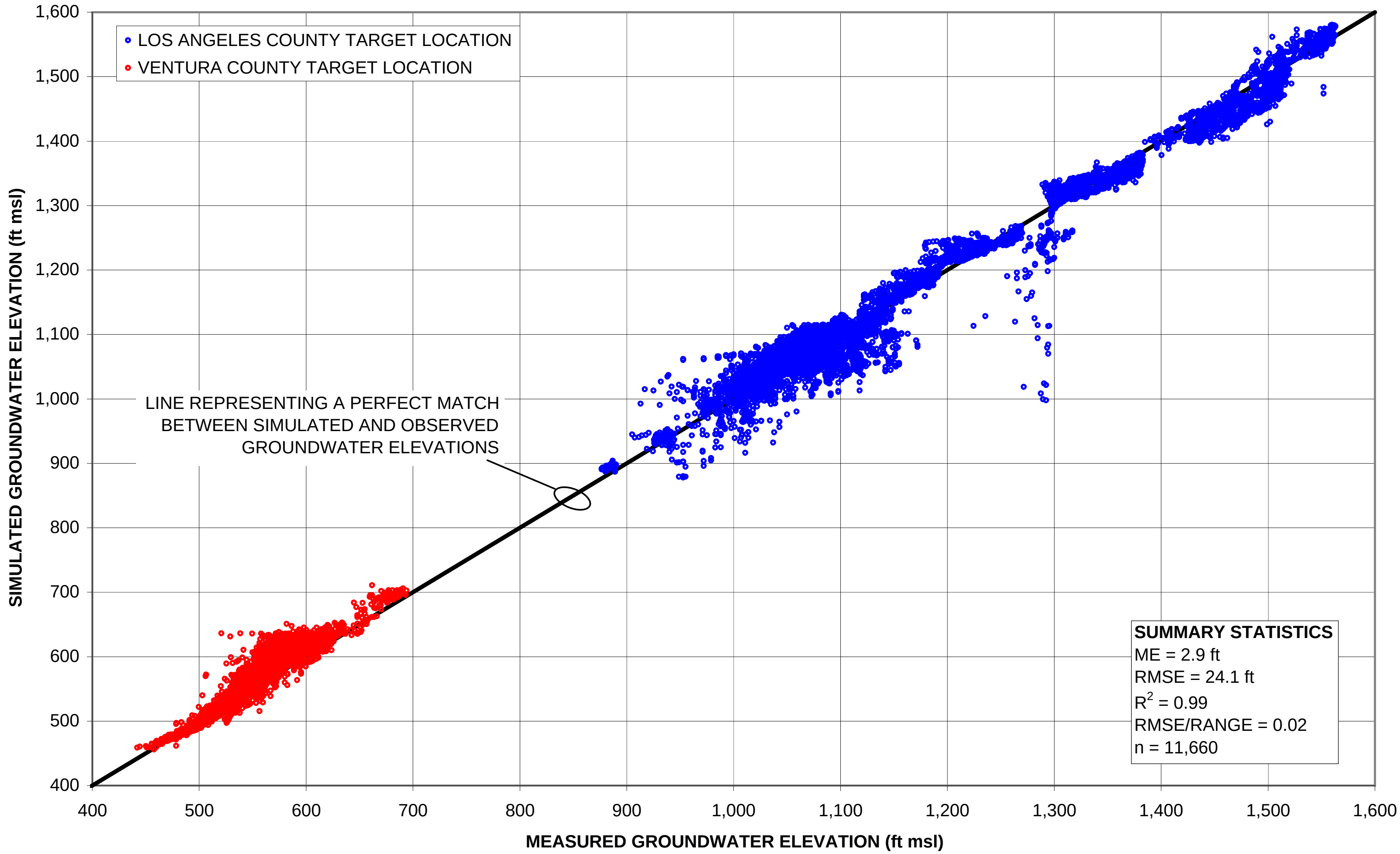
NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, V-0183 (5) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 5.
4. ME = MEAN ERROR (feet).
5. RMSE = ROOT MEAN SQUARED ERROR (feet).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. RMSE/RANGE = RMSE DIVIDED BY RANGE IN MEASURED VALUES (dimensionless).
8. n = NUMBER OF OBSERVATIONS.

FIGURE 4-12 (PAGE 2 of 2)
SIMULATED AND MEASURED GROUNDWATER ELEVATIONS IN WELLS LOCATED WEST OF HOPPER CREEK IN THE PIRU SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

Piru_WestHopper2.grf



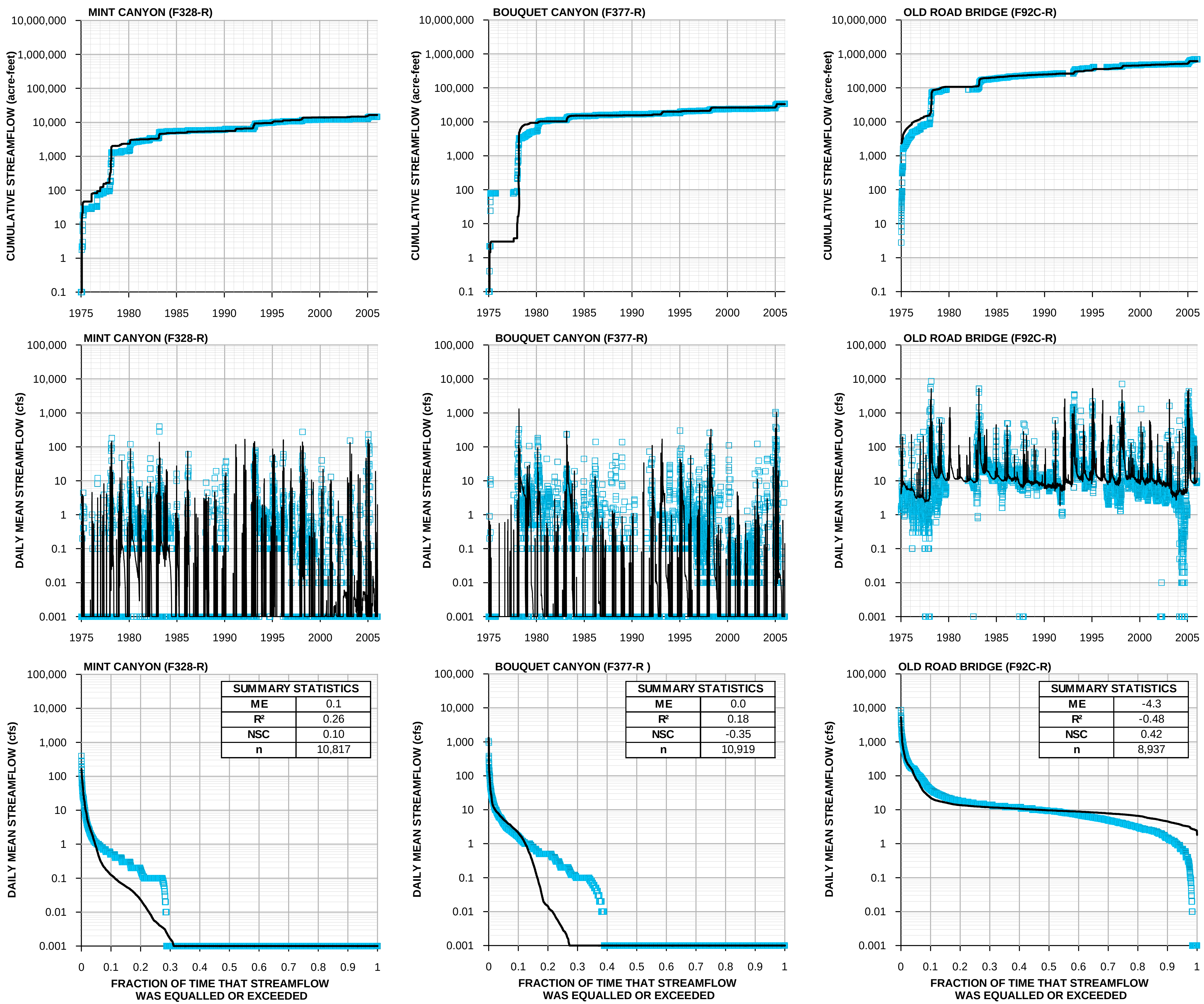
NOTES

1. THE PLOT PRESENTS ALL PAIRED SIMULATED AND MEASURED GROUNDWATER ELEVATION DATA FOR ALL TARGETS AND ALL TIMES THROUGHOUT THE CALIBRATION PERIOD.
2. SUMMARY STATISTICS WERE COMPUTED USING ALL DATA INCLUDED ON PLOT.

FinalCalibration_ScatterplotData.xls\Fig4-13

FIGURE 4-13
SIMULATED VERSUS MEASURED GROUNDWATER ELEVATIONS
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL -HGL



MINT CANYON (F328-R)

SUMMARY STATISTICS	
ME	0.1
R^2	0.26
NSC	0.10
n	10,817

BOUQUET CANYON (F377-R)

SUMMARY STATISTICS	
ME	0.0
R^2	0.18
NSC	-0.35
n	10,919

OLD ROAD BRIDGE (F92C-R)

SUMMARY STATISTICS	
ME	-4.3
R^2	-0.48
NSC	0.42
n	8,937

LEGEND

SIMULATED STREAMFLOW
MEASURED STREAMFLOW

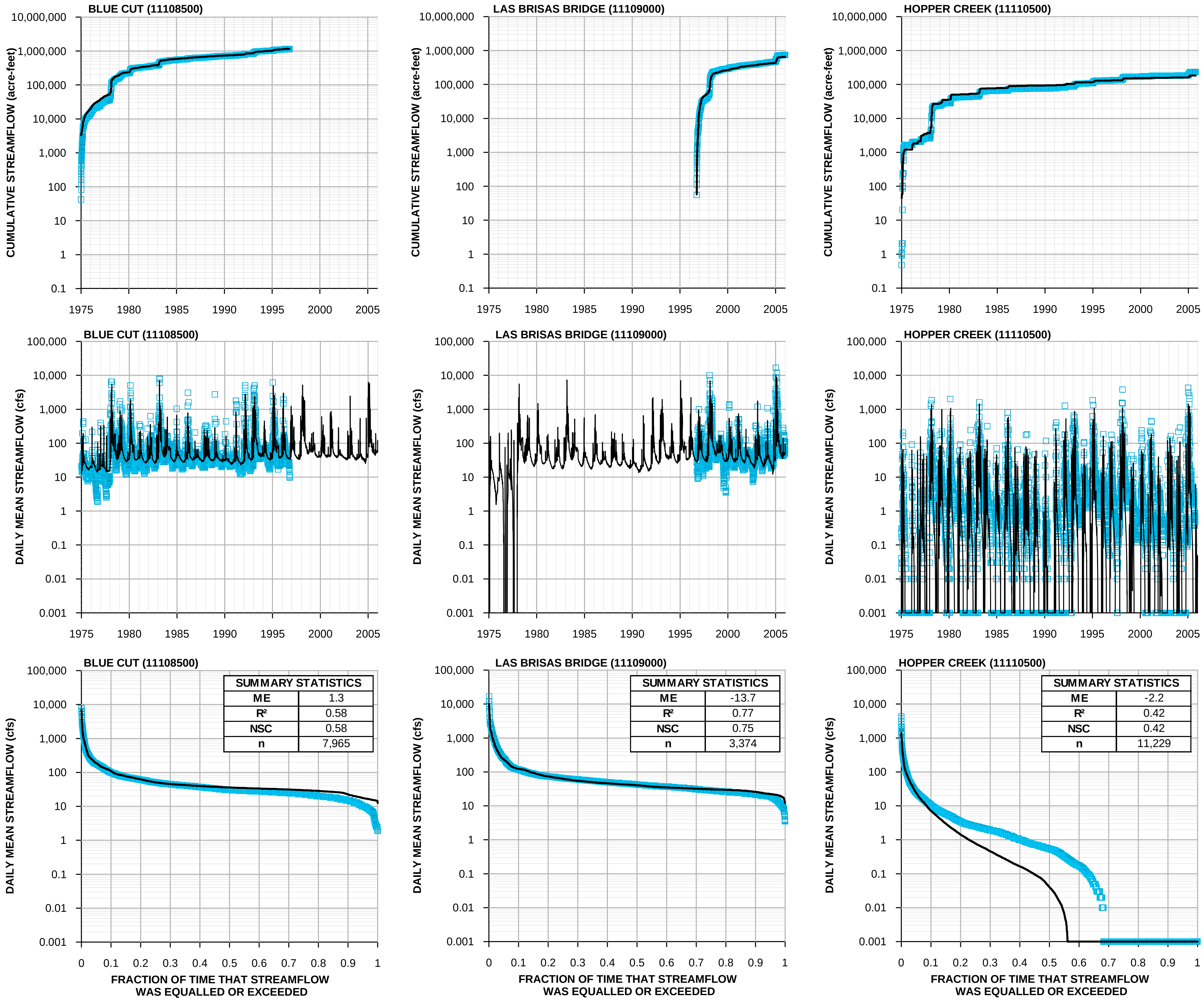
NOTES:
1. SEE FIGURES 4-1a THROUGH 4-1e FOR STREAM GAGE LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS UNLESS OTHERWISE NOTED.
3. A DAILY MEAN STREAMFLOW VALUE OF 0.001 IS USED AS THE CUTOFF POINT FOR INDICATING ZERO STREAMFLOW ON LOG SCALES.
4. ME = MEAN ERROR (cfs).
5. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
6. NSC = NASH-SUTCLIFFE COEFFICIENT (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

FIGURE 4-14
SIMULATED AND MEASURED STREAMFLOW IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–

SF_EastSubbasin.grf



BLUE CUT (11108500)

SUMMARY STATISTICS	
ME	1.3
R^2	0.58
NSC	0.58
n	7,965

LAS BRISAS BRIDGE (11109000)

SUMMARY STATISTICS	
ME	-13.7
R^2	0.77
NSC	0.75
n	3,374

HOPPER CREEK (11110500)

SUMMARY STATISTICS	
ME	-2.2
R^2	0.42
NSC	0.42
n	11,229

LEGEND

SIMULATED STREAMFLOW

MEASURED STREAMFLOW

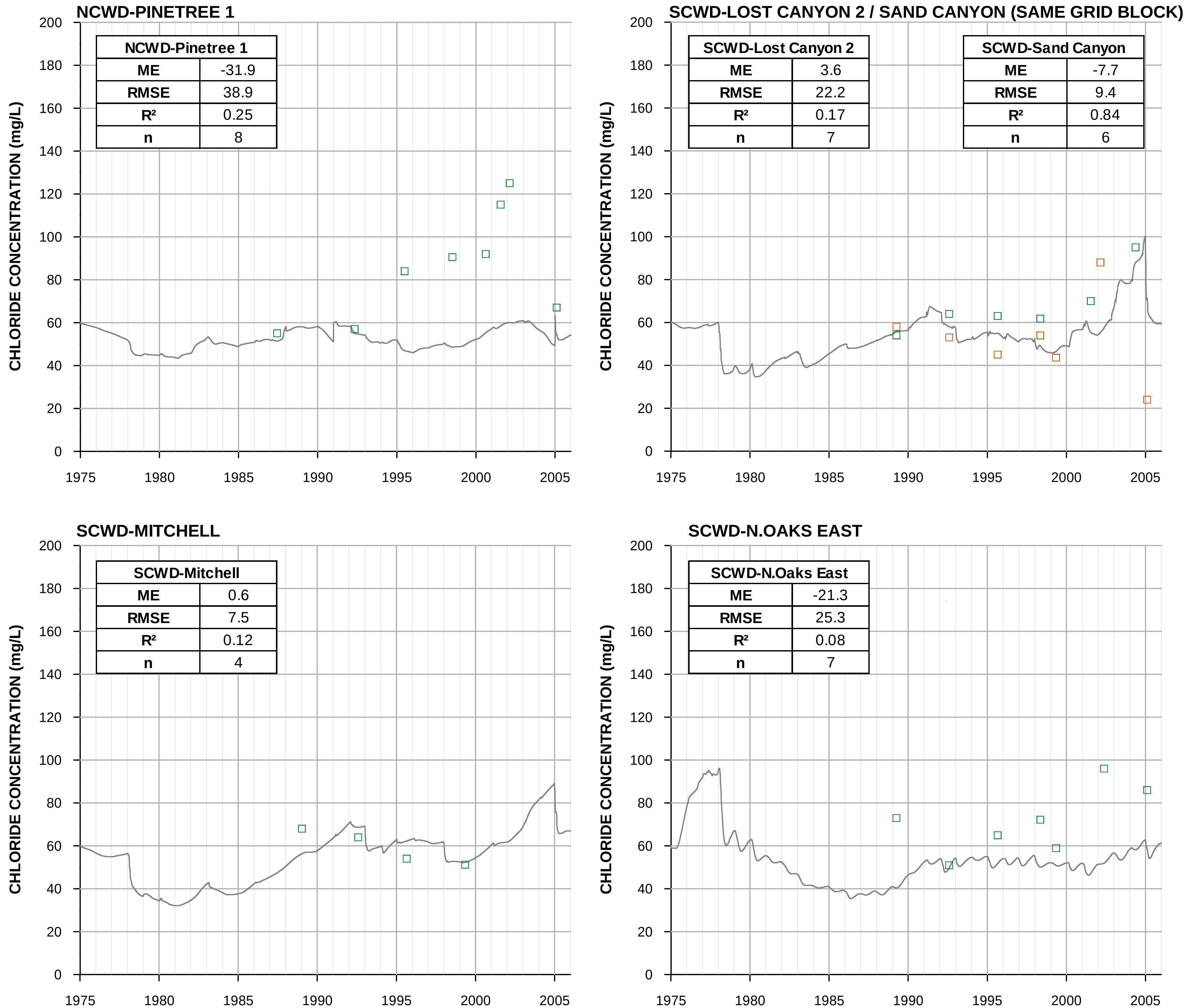
NOTES:
1. SEE FIGURES 4-1a THROUGH 4-1e FOR STREAM GAGE LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS UNLESS OTHERWISE NOTED.
3. A DAILY MEAN STREAMFLOW VALUE OF 0.001 IS USED AS THE CUTOFF POINT FOR INDICATING ZERO STREAMFLOW ON LOG SCALES.
4. ME = MEAN ERROR (cfs).
5. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
6. NSC = NASH-SUTCLIFFE COEFFICIENT (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

FIGURE 4-15
SIMULATED AND MEASURED STREAMFLOW IN THE PIRU SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–

SF_PiruSubbasin.grf



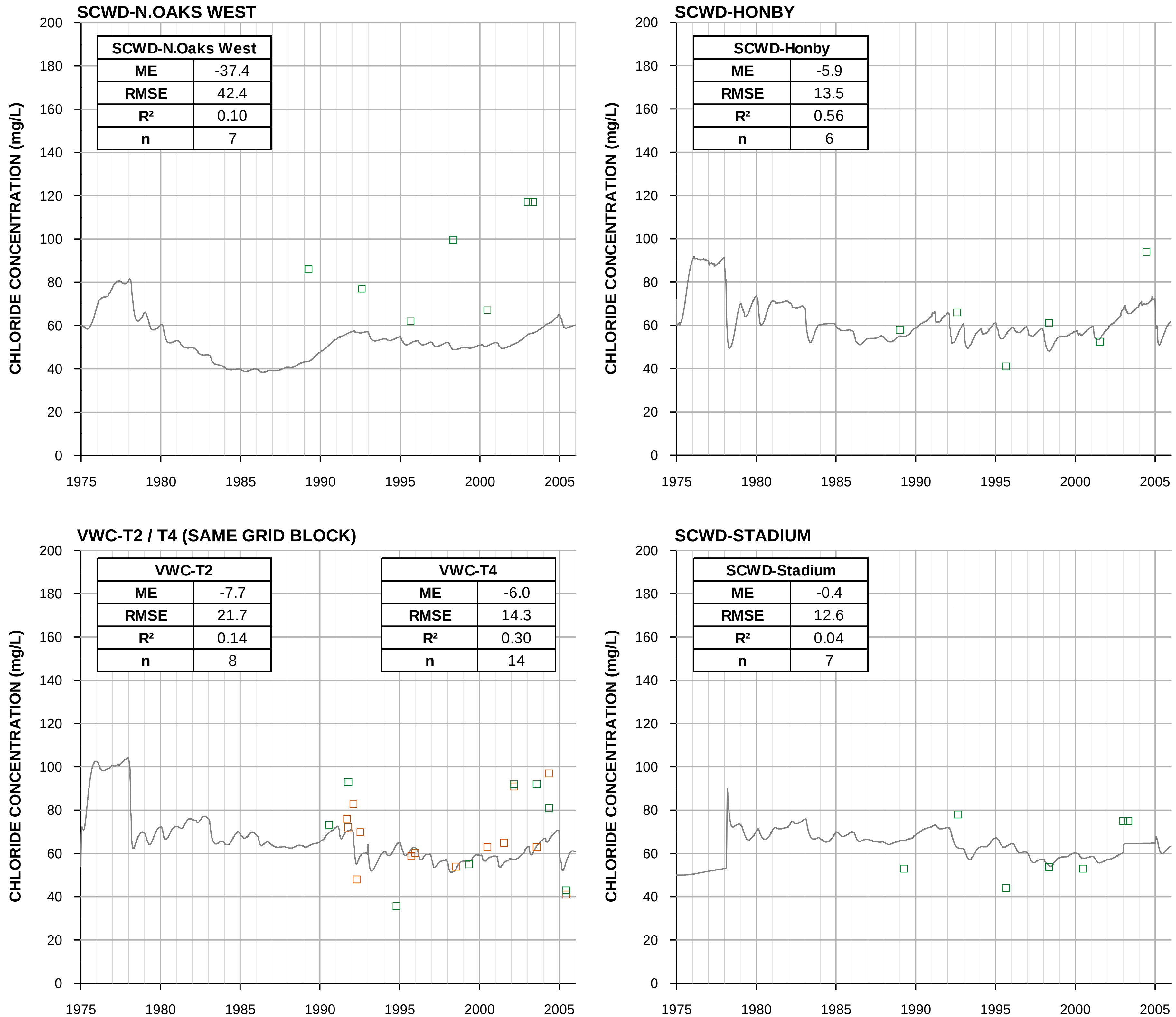
NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7066D (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

LEGEND

SIMULATED CHLORIDE CONCENTRATION
MEASURED CHLORIDE CONCENTRATION (SCWD-LOST CANYON 2)
MEASURED CHLORIDE CONCENTRATION

FIGURE 4-16 (PAGE 1 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN ALLUVIAL AQUIFER WELLS LOCATED IN SOLEDAD CANYON IN THE EAST SUBBASIN
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS



NOTES:

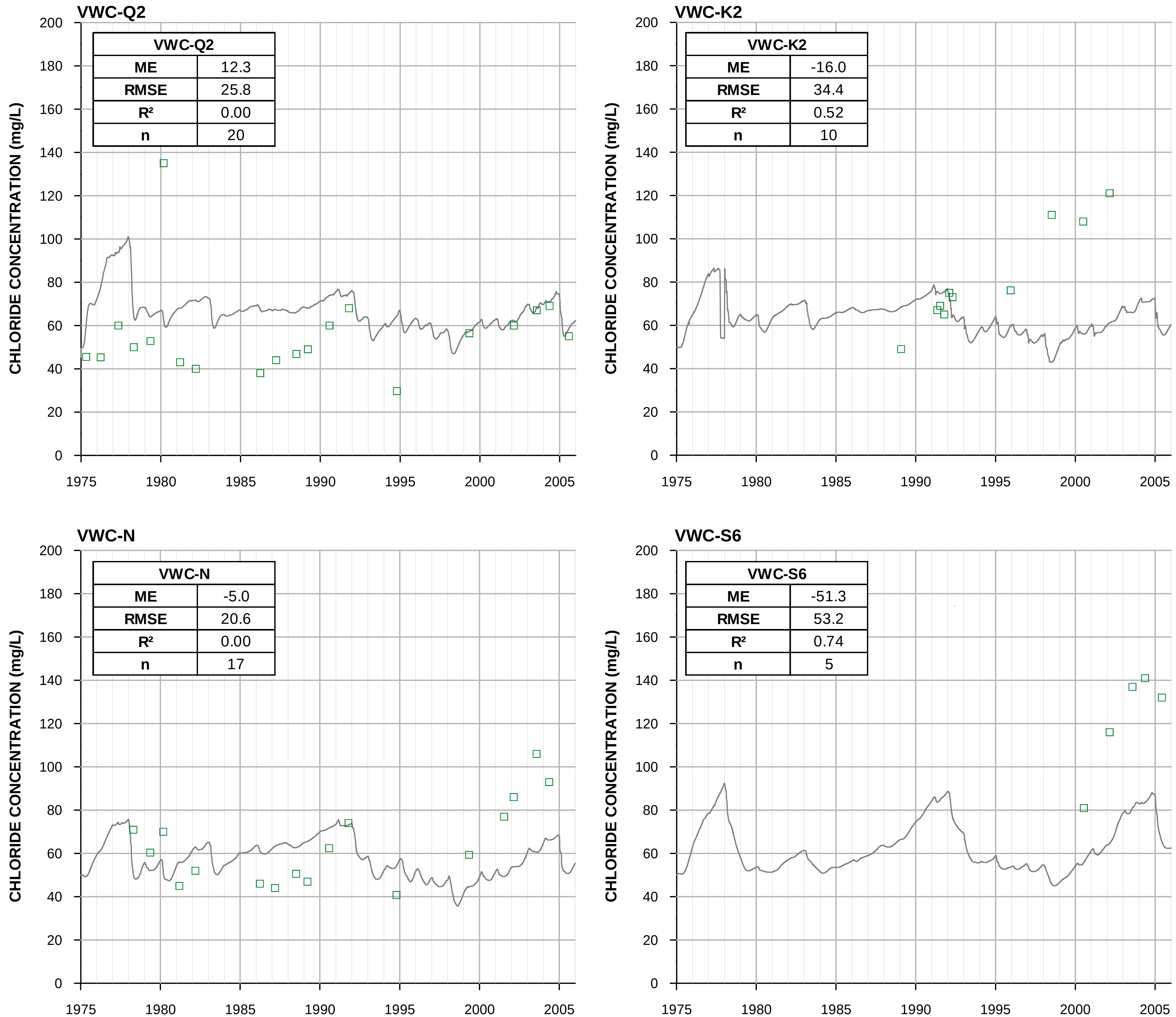
1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7066D (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

LEGEND

- SIMULATED CHLORIDE CONCENTRATION
- MEASURED CHLORIDE CONCENTRATION
- MEASURED CHLORIDE CONCENTRATION (VWC-T4)

FIGURE 4-16 (PAGE 2 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN ALLUVIAL AQUIFER WELLS LOCATED IN SOLEDAD CANYON IN THE EAST SUBBASIN
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL



NOTES:

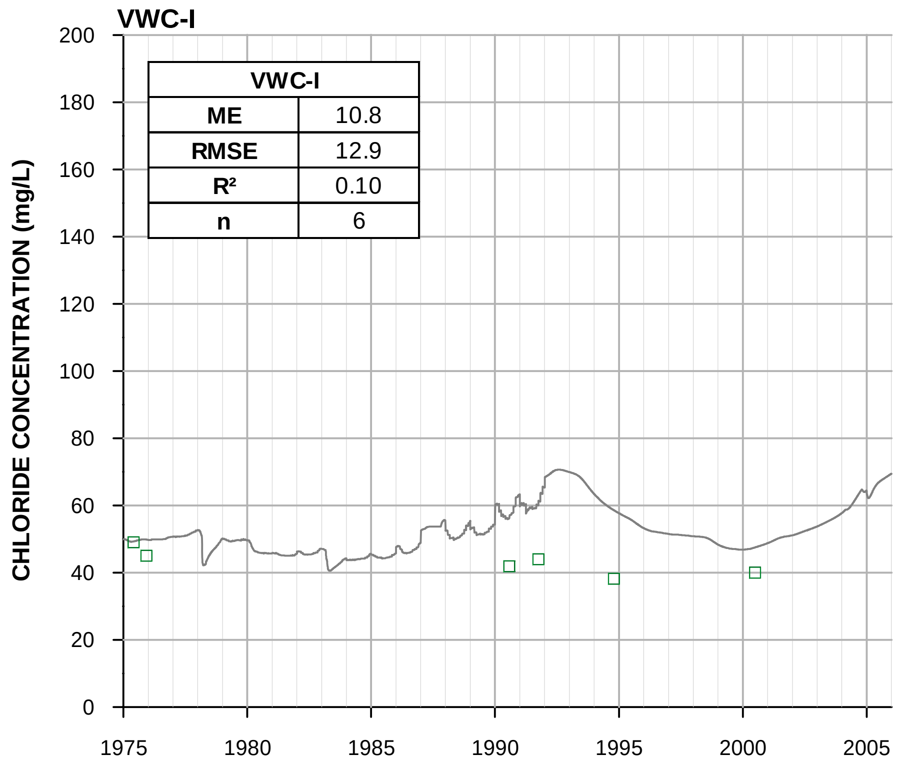
1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7066D (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

LEGEND

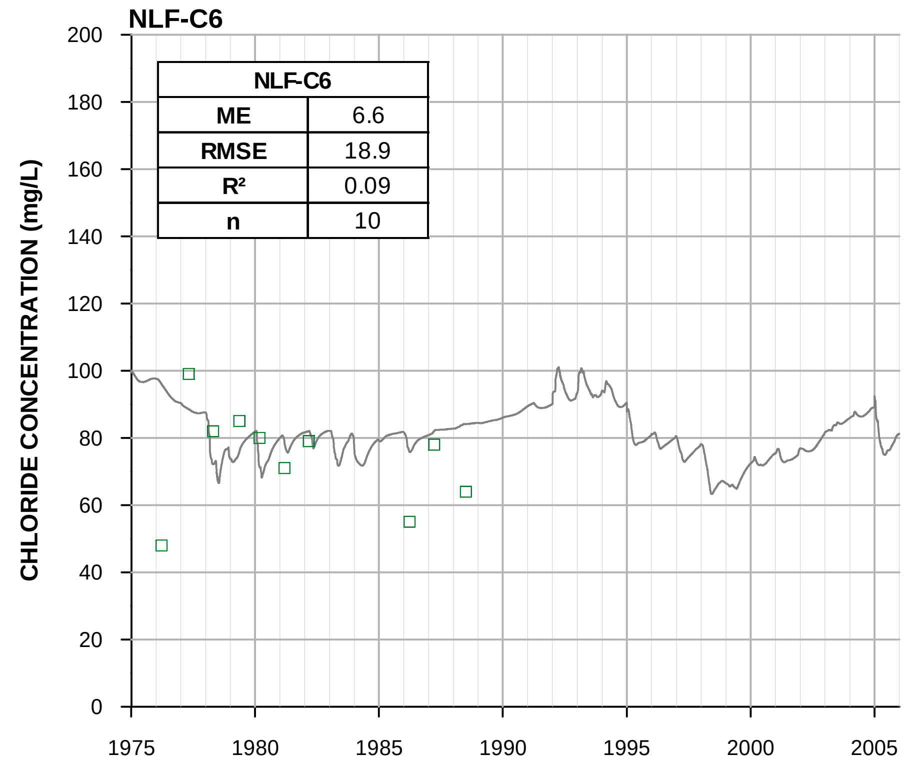
SIMULATED CHLORIDE CONCENTRATION
MEASURED CHLORIDE CONCENTRATION

FIGURE 4-17 (PAGE 1 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN ALLUVIAL AQUIFER WELLS LOCATED WEST OF SOLEDAD CANYON IN THE EAST SUBBASIN
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

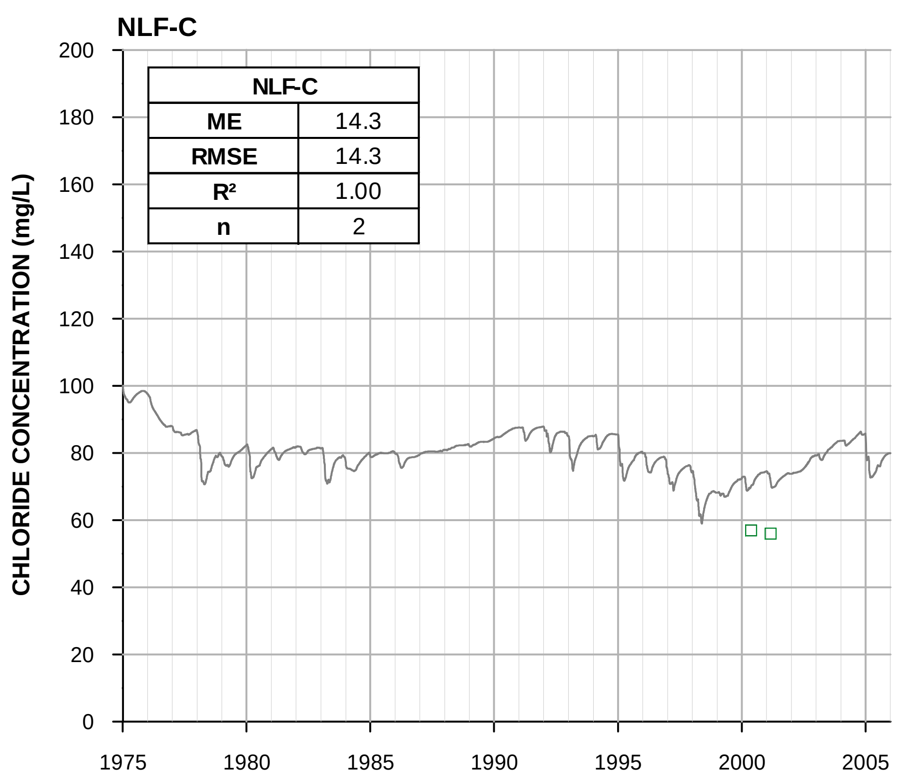
CH2MHILL –HGL–



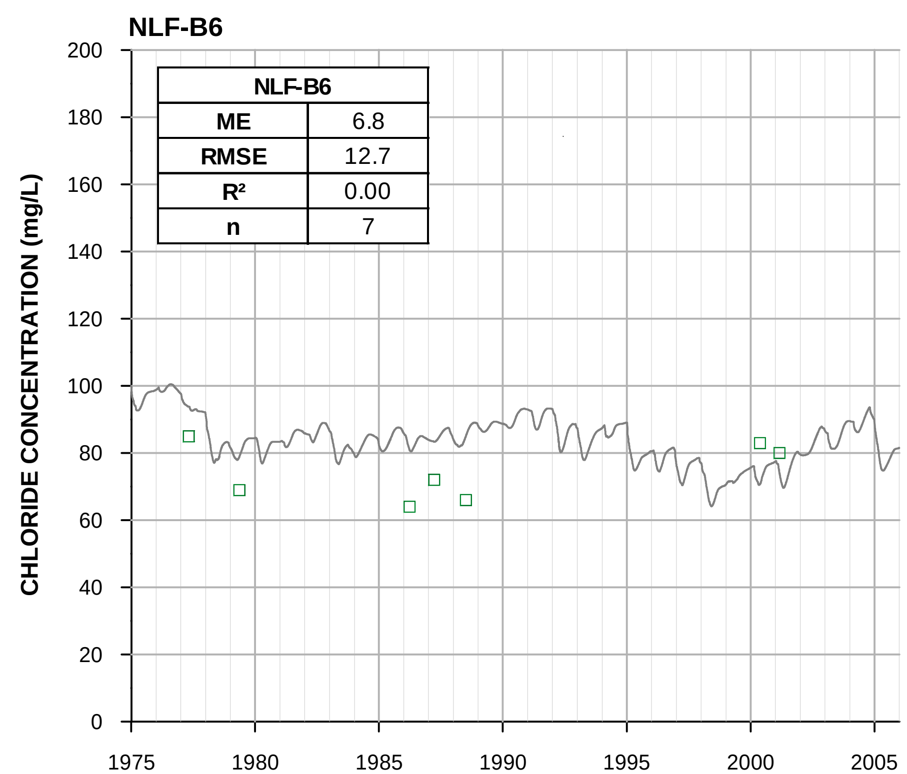
VWC-I	
ME	10.8
RMSE	12.9
R^2	0.10
n	6



NLF-C6	
ME	6.6
RMSE	18.9
R^2	0.09
n	10



NLF-C	
ME	14.3
RMSE	14.3
R^2	1.00
n	2



NLF-B6	
ME	6.8
RMSE	12.7
R^2	0.00
n	7

NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7066D (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

LEGEND

SIMULATED CHLORIDE CONCENTRATION

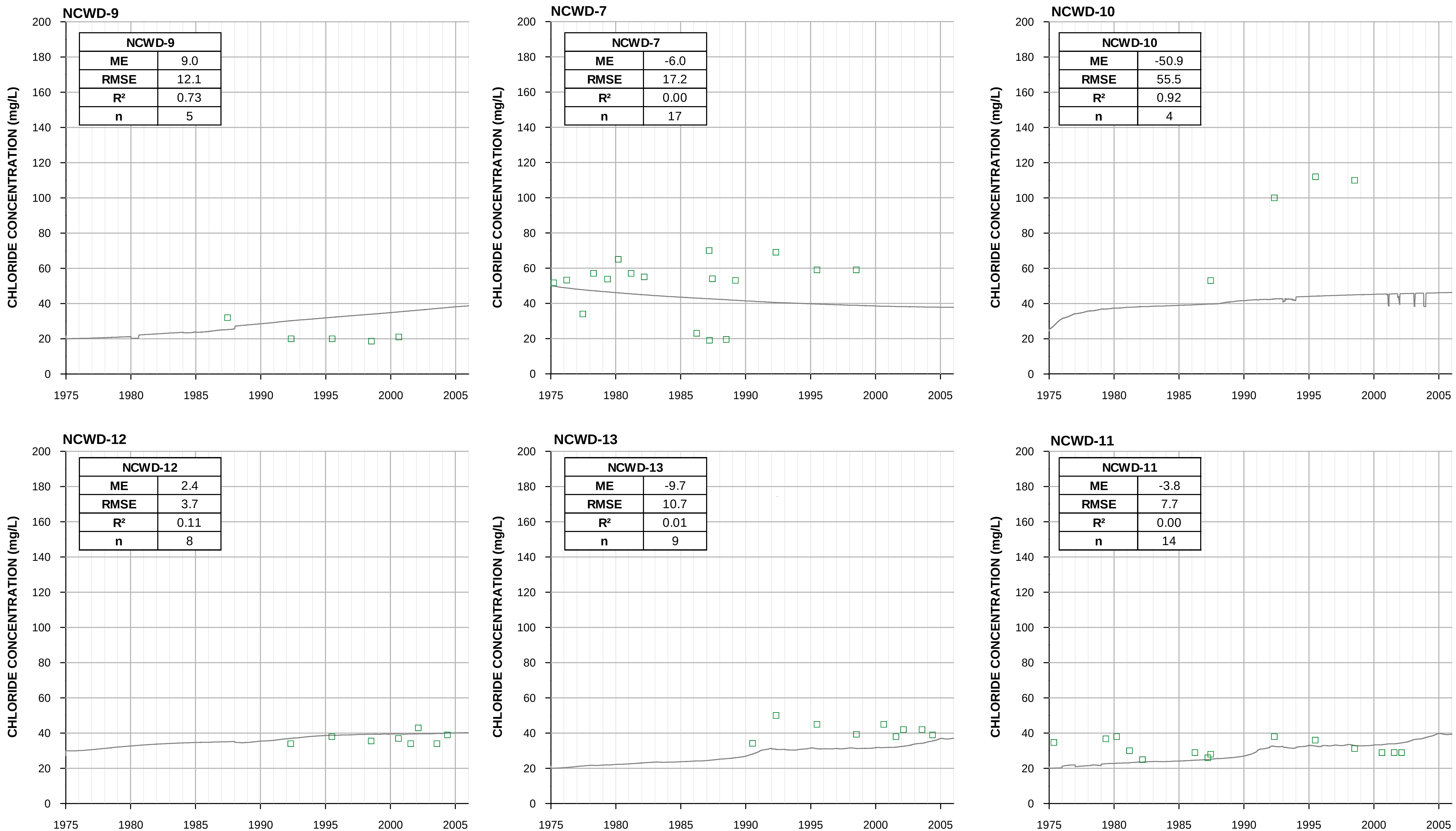
MEASURED CHLORIDE CONCENTRATION

FIGURE 4-17 (PAGE 2 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN ALLUVIAL AQUIFER WELLS LOCATED WEST OF SOLEDAD CANYON IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL

ClAlluvAq_WestSoledad2.grf



NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7066D (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

LEGEND

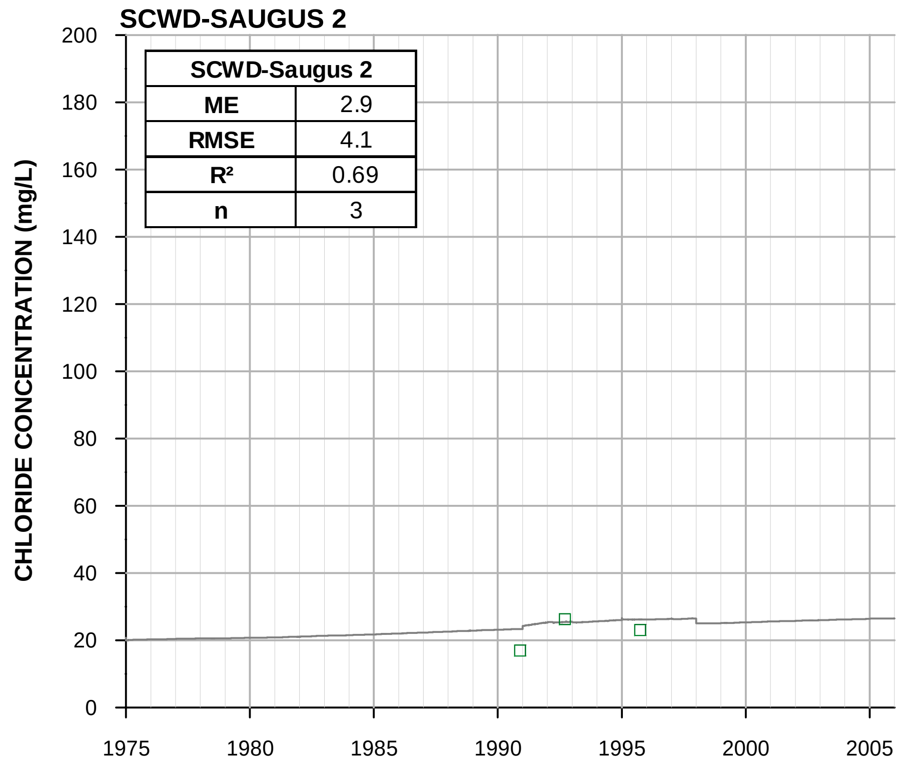
SIMULATED CHLORIDE CONCENTRATION

MEASURED CHLORIDE CONCENTRATION

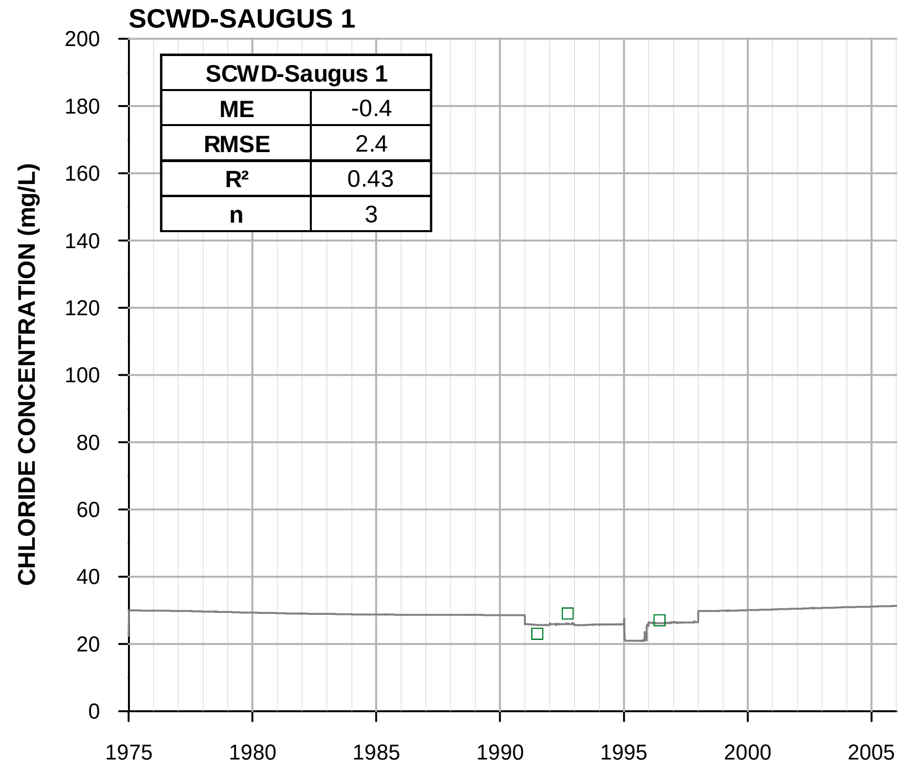
FIGURE 4-18 (PAGE 1 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN SAUGUS FORMATION WELLS LOCATED IN THE SOUTH FORK AREA IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

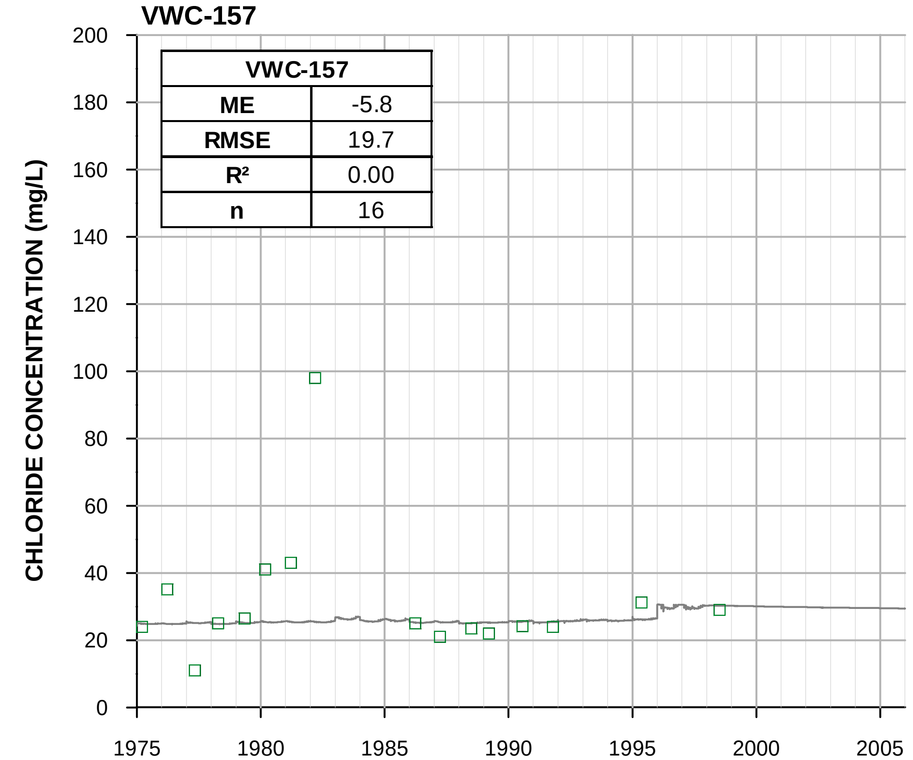
CH2MHILL –HGL–



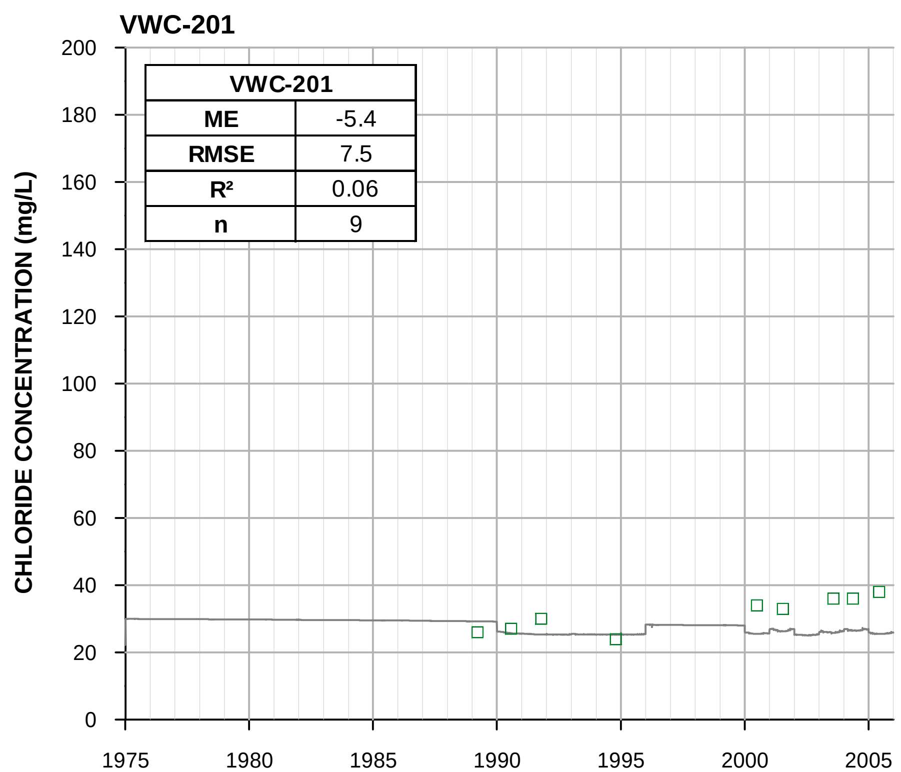
SCWD-Saugus 2	
ME	2.9
RMSE	4.1
R^2	0.69
n	3



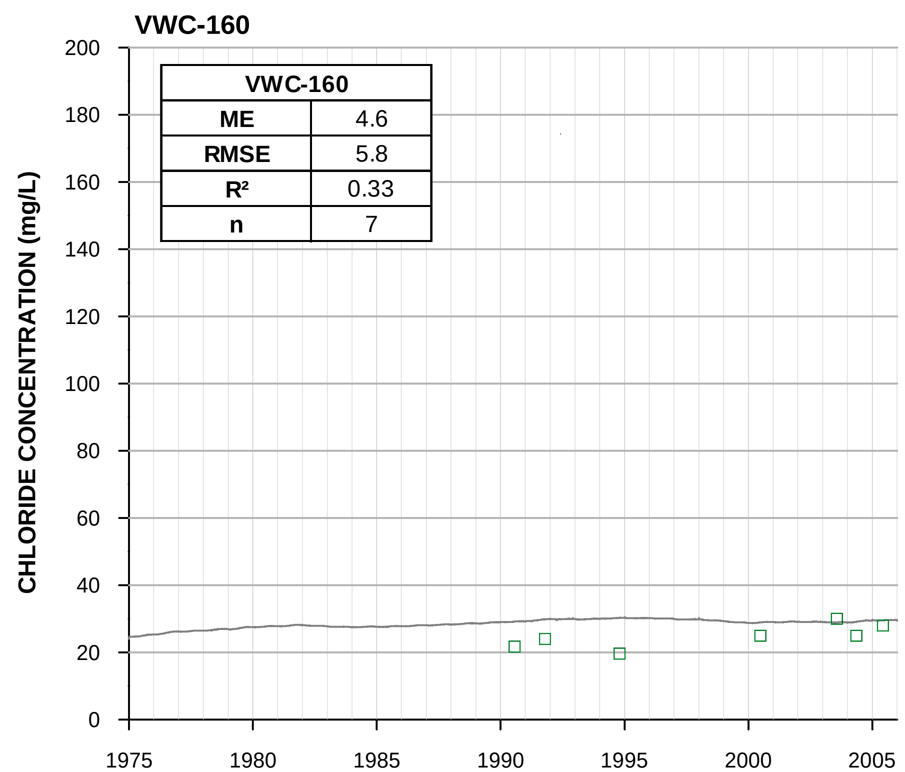
SCWD-Saugus 1	
ME	-0.4
RMSE	2.4
R^2	0.43
n	3



VWC-157	
ME	-5.8
RMSE	19.7
R^2	0.00
n	16



VWC-201	
ME	-5.4
RMSE	7.5
R^2	0.06
n	9



VWC-160	
ME	4.6
RMSE	5.8
R^2	0.33
n	7

NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, LACFCD-7066D (3 and 4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3 AND 4.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

LEGEND

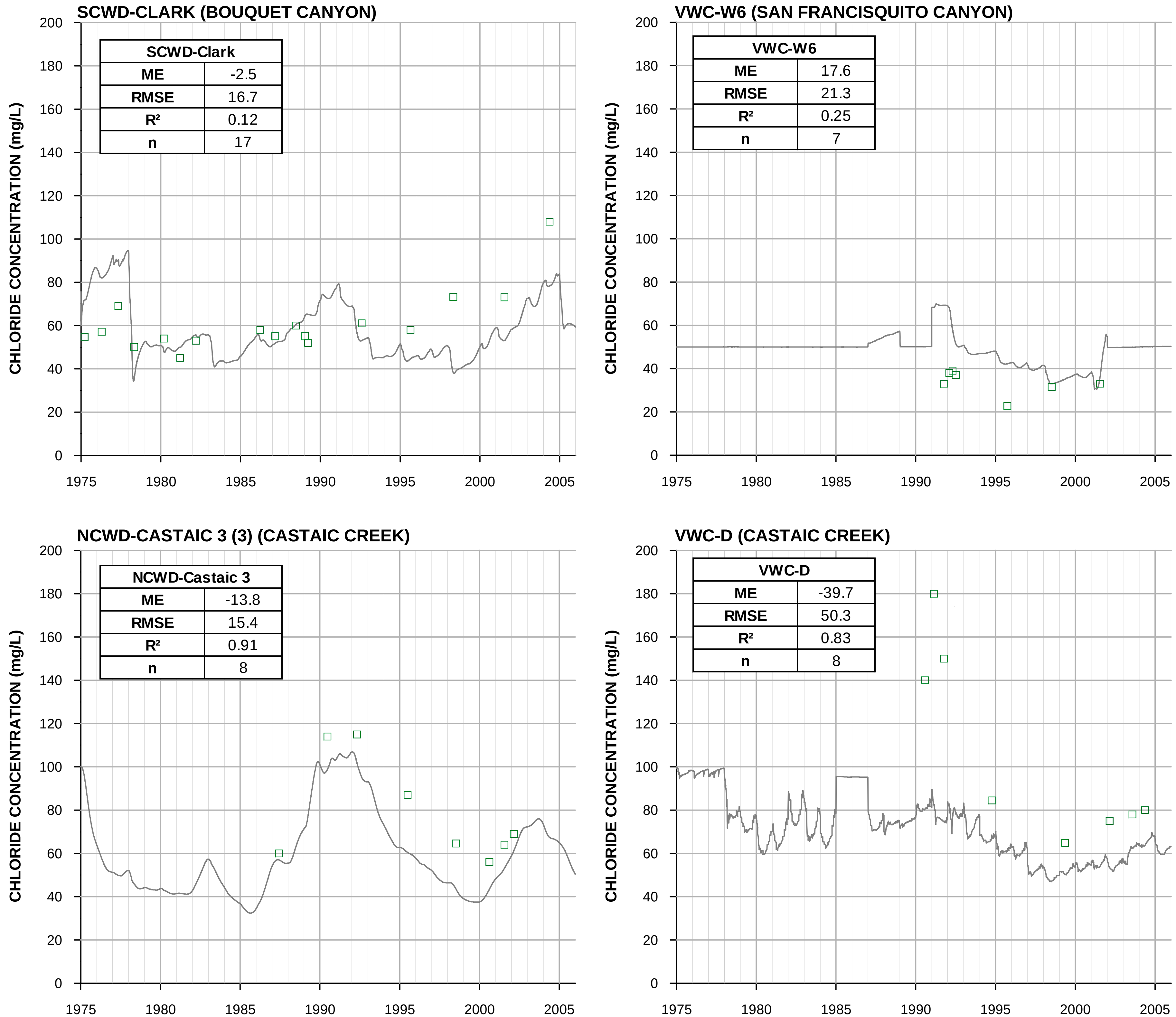
SIMULATED CHLORIDE CONCENTRATION
MEASURED CHLORIDE CONCENTRATION

FIGURE 4-18 (PAGE 2 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN SAUGUS FORMATION WELLS LOCATED IN THE SOUTH FORK AREA IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL

ClSaugusAq_SouthFork2.grf



NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, NCWD-CASTAIC 3 (3) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 3.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

LEGEND

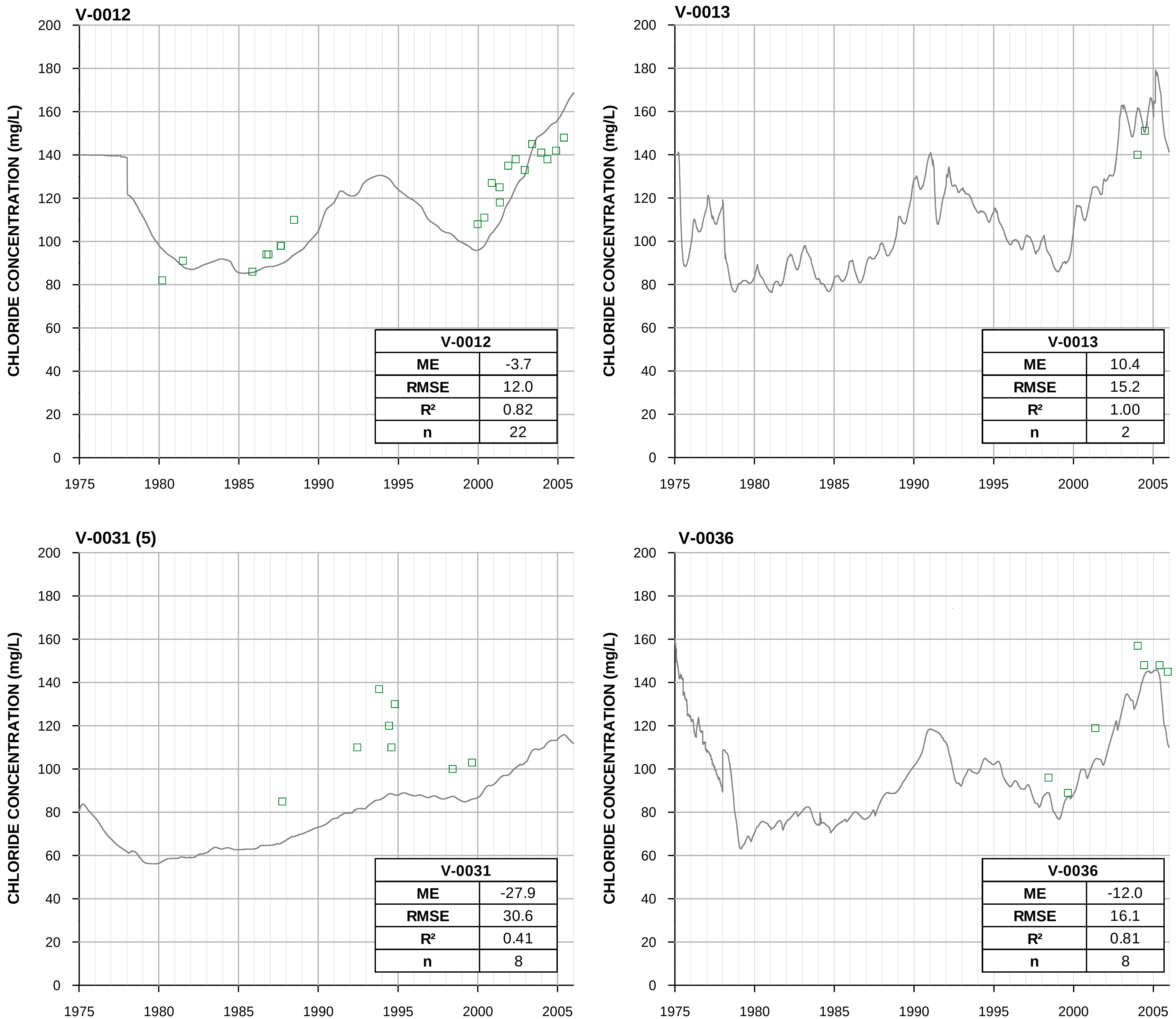
SIMULATED CHLORIDE CONCENTRATION

MEASURED CHLORIDE CONCENTRATION

FIGURE 4-19
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN ALLUVIAL AQUIFER WELLS LOCATED IN TRIBUTARY CANYONS IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–



NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, V-0031 (5) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 5.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

LEGEND

SIMULATED CHLORIDE CONCENTRATION

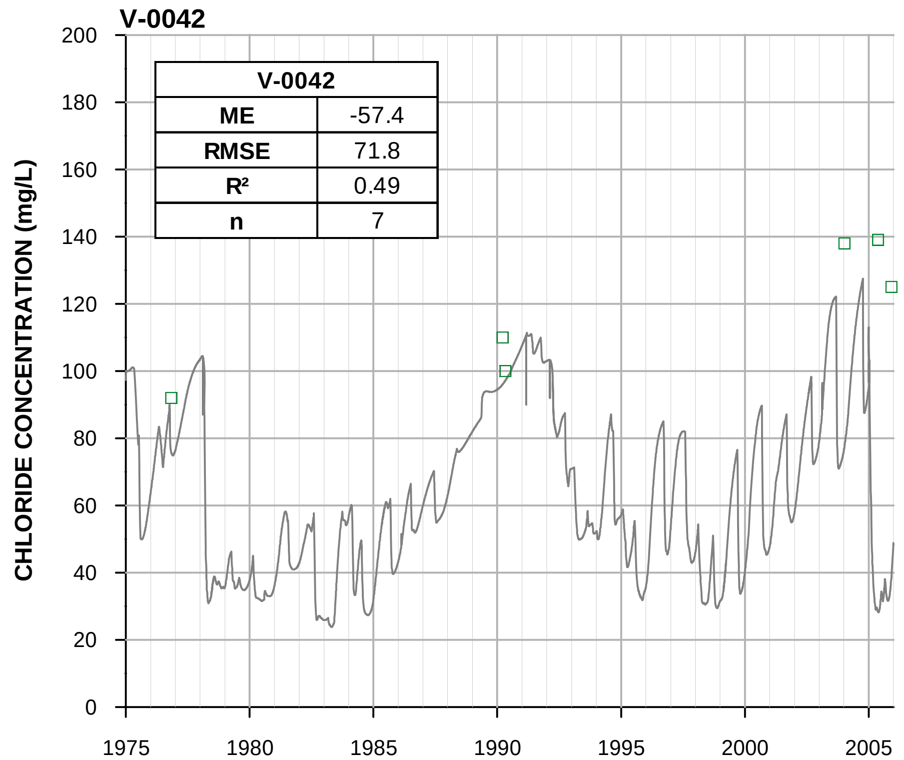
MEASURED CHLORIDE CONCENTRATION

FIGURE 4-20 (PAGE 1 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN WELLS LOCATED EAST OF TORREY ROAD IN THE PIRU SUBBASIN

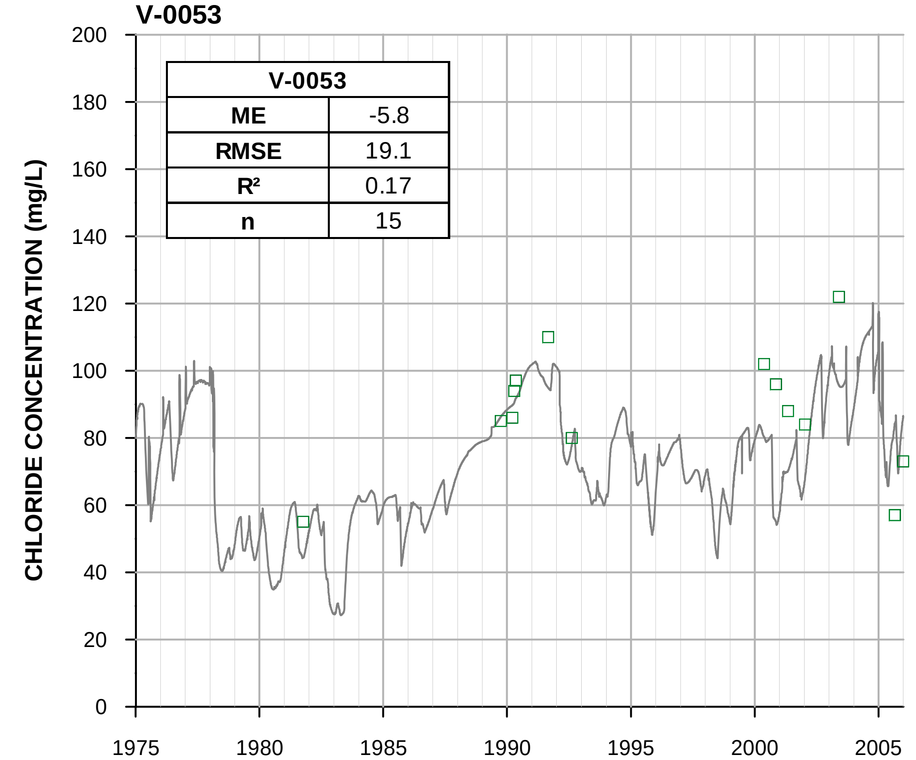
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–

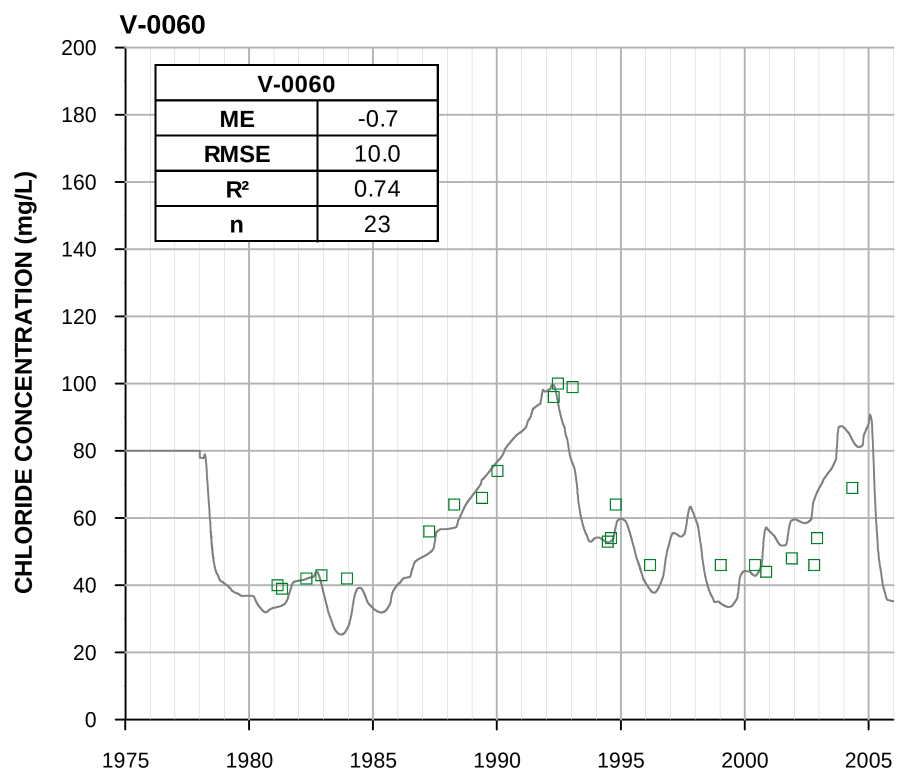
Piru_ClEast Torrey1.grf



V-0042	
ME	-57.4
RMSE	71.8
R^2	0.49
n	7



V-0053	
ME	-5.8
RMSE	19.1
R^2	0.17
n	15



V-0060	
ME	-0.7
RMSE	10.0
R^2	0.74
n	23

NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, V-0031 (5) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 5.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

LEGEND

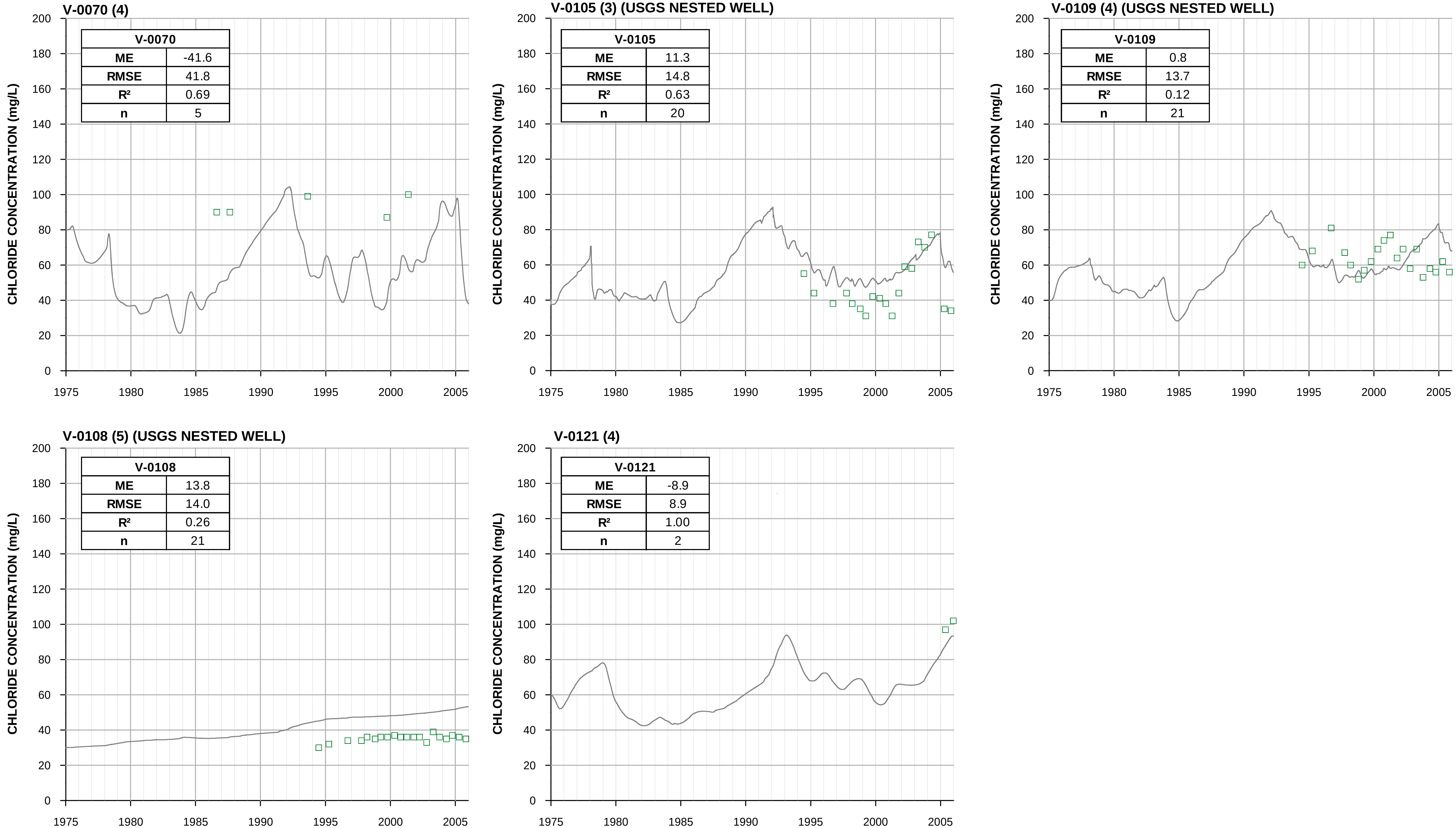
SIMULATED CHLORIDE CONCENTRATION

MEASURED CHLORIDE CONCENTRATION

FIGURE 4-20 (PAGE 2 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN WELLS LOCATED EAST OF TORREY ROAD IN THE PIRU SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–



NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, V-0070 (4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 4.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

LEGEND

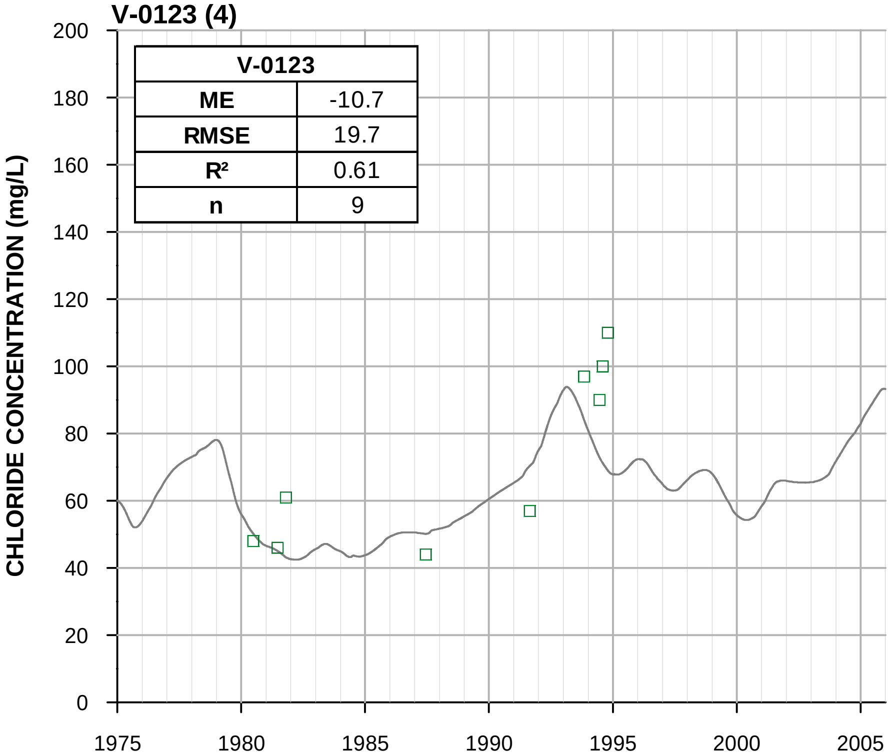
SIMULATED CHLORIDE CONCENTRATION

□ MEASURED CHLORIDE CONCENTRATION

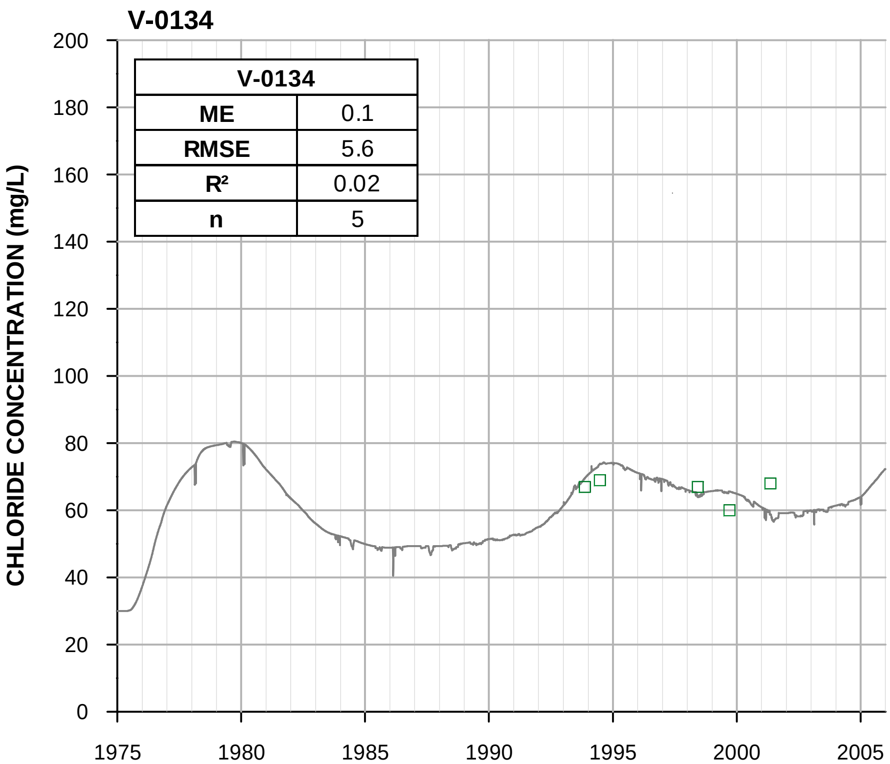
FIGURE 4-21 (PAGE 1 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN WELLS LOCATED BETWEEN HOPPER CREEK AND TORREY ROAD IN THE PIRU SUBBASIN
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL

Piru_ClHopperTorrey1.grf



V-0123	
ME	-10.7
RMSE	19.7
R^2	0.61
n	9



V-0134	
ME	0.1
RMSE	5.6
R^2	0.02
n	5

LEGEND

SIMULATED CHLORIDE CONCENTRATION

MEASURED CHLORIDE CONCENTRATION

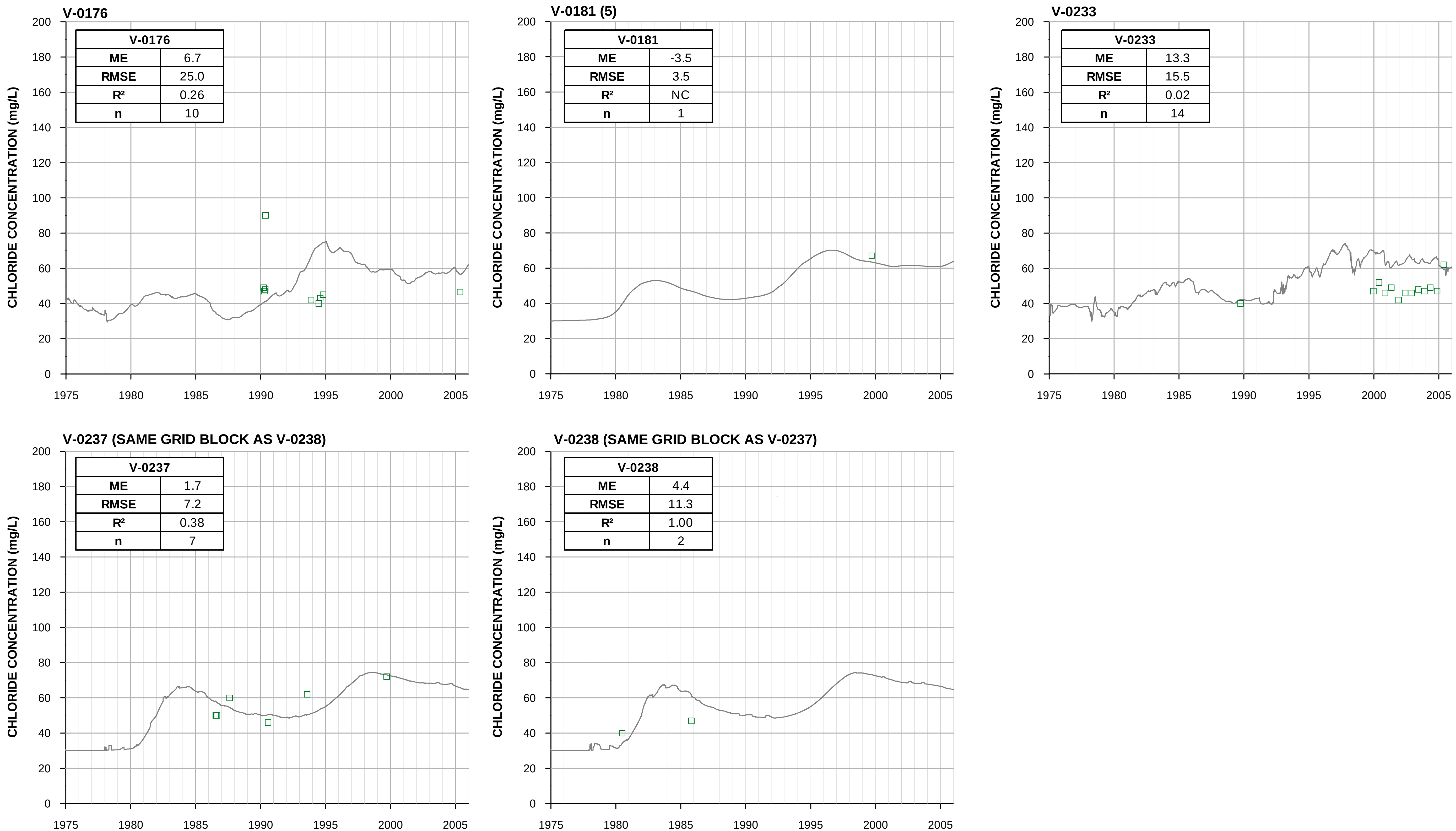
NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, V-0123 (4) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 4.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.

FIGURE 4-21 (PAGE 2 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN WELLS LOCATED BETWEEN HOPPER CREEK AND TORREY ROAD IN THE PIRU SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–



NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. MODEL RESULTS ARE TAKEN FROM THE FWL5 PACKAGE, UNLESS OTHERWISE NOTED IN THE TARGET LOCATION NAME. FOR EXAMPLE, V-0181 (5) INDICATES THE RESULTS WERE TAKEN FROM MODEL LAYER 5.
4. ME = MEAN ERROR (mg/L).
5. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
6. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
7. n = NUMBER OF OBSERVATIONS.
8. NC = NOT COMPUTED BECAUSE OF INSUFFICIENT DATA.

LEGEND

SIMULATED CHLORIDE CONCENTRATION

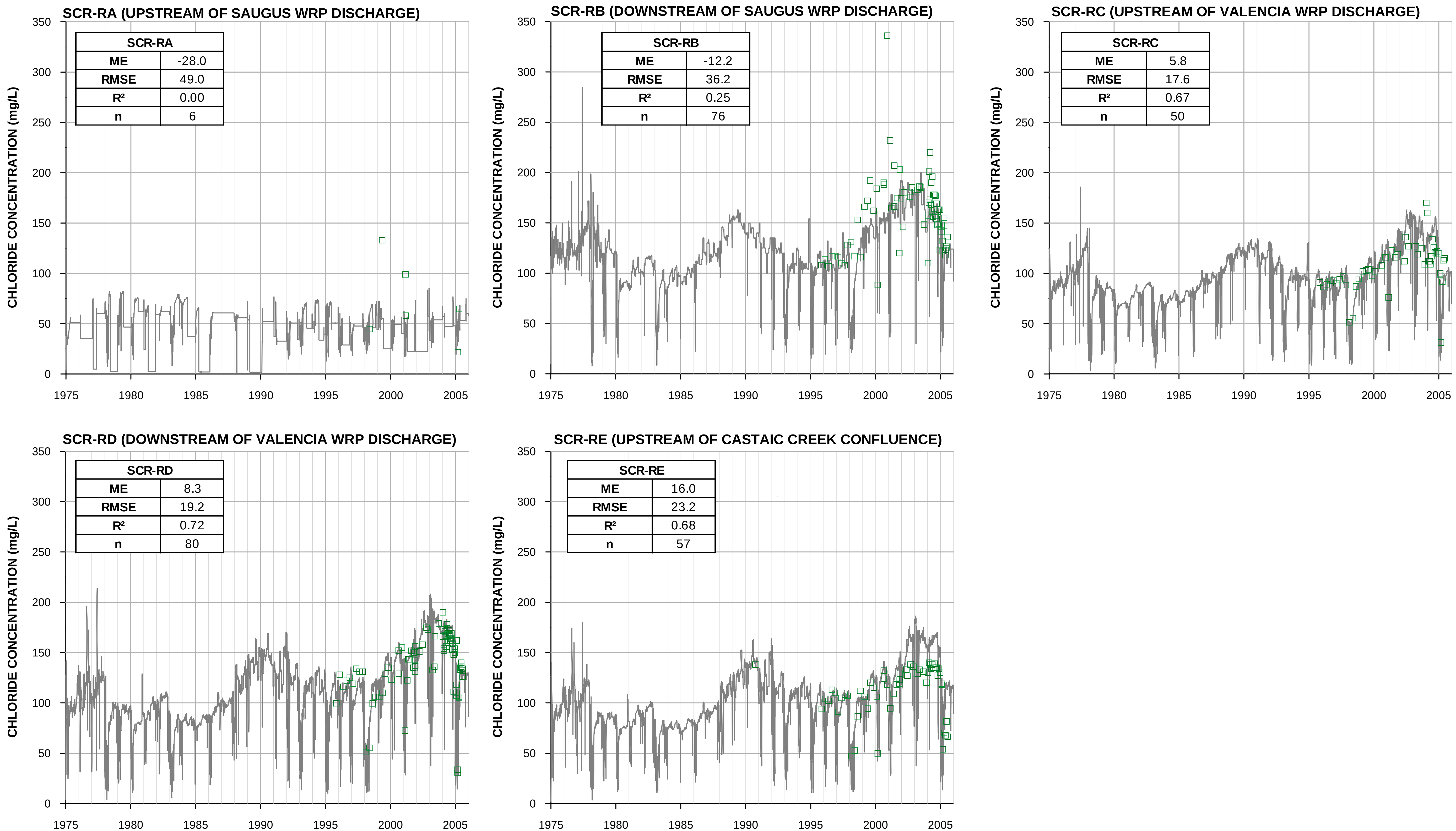
MEASURED CHLORIDE CONCENTRATION

FIGURE 4-22
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN WELLS LOCATED WEST OF HOPPER CREEK IN THE PIRU SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL

Piru_ClWestHopper.grf



SCR-RA	
ME	-28.0
RMSE	49.0
R^2	0.00
n	6

SCR-RB	
ME	-12.2
RMSE	36.2
R^2	0.25
n	76

SCR-RC	
ME	5.8
RMSE	17.6
R^2	0.67
n	50

SCR-RD	
ME	8.3
RMSE	19.2
R^2	0.72
n	80

SCR-RE	
ME	16.0
RMSE	23.2
R^2	0.68
n	57

NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. ME = MEAN ERROR (feet).
4. RMSE = ROOT MEAN SQUARED ERROR (feet).
5. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
6. n = NUMBER OF OBSERVATIONS.

LEGEND

SIMULATED CHLORIDE CONCENTRATION

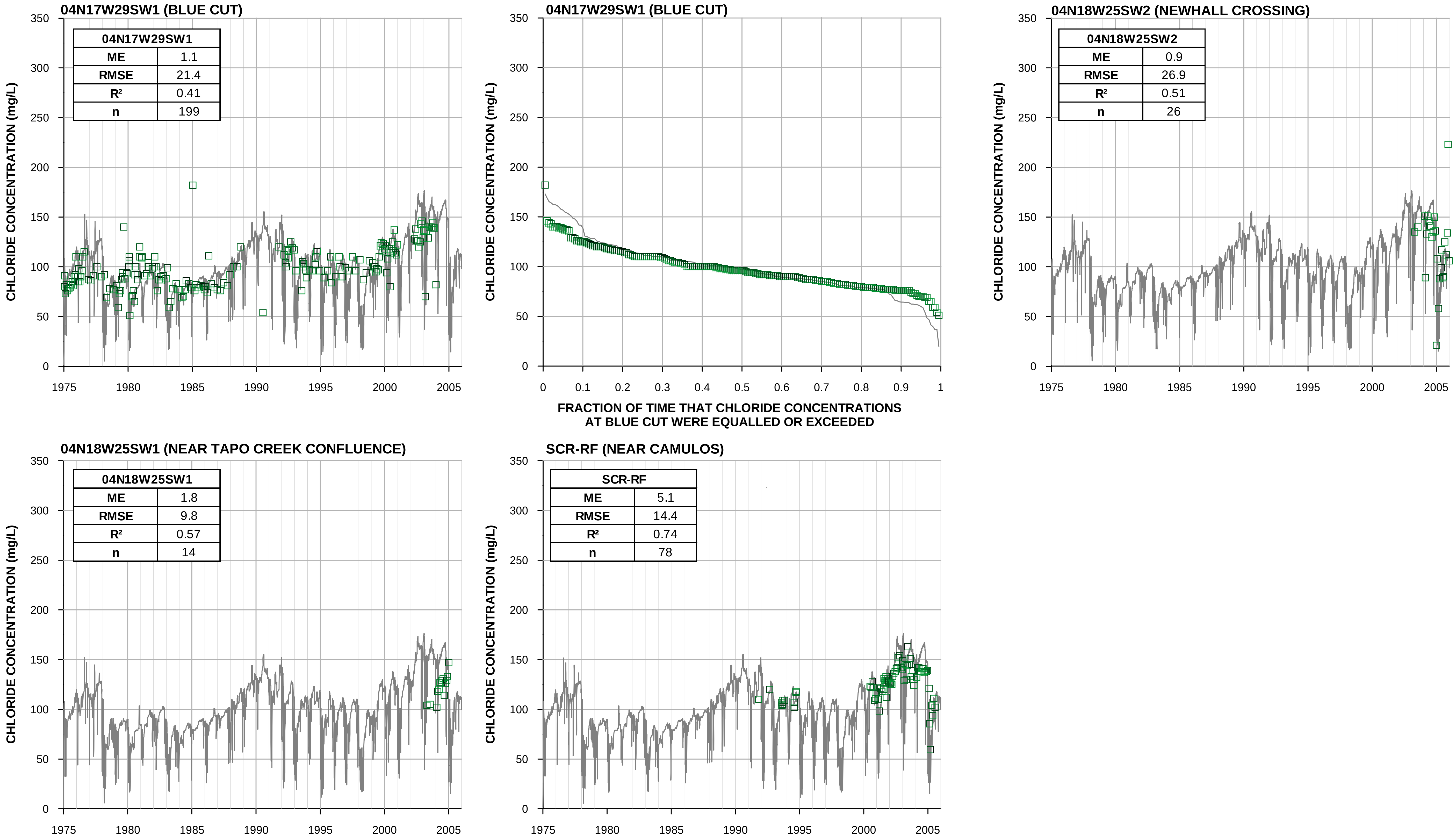
MEASURED CHLORIDE CONCENTRATION

FIGURE 4-23
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN THE SANTA CLARA RIVER IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL

Cl_SW_EastSubbasin.grf



NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. ME = MEAN ERROR (mg/L).
4. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
5. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
6. n = NUMBER OF OBSERVATIONS.

LEGEND

SIMULATED CHLORIDE CONCENTRATION

MEASURED CHLORIDE CONCENTRATION

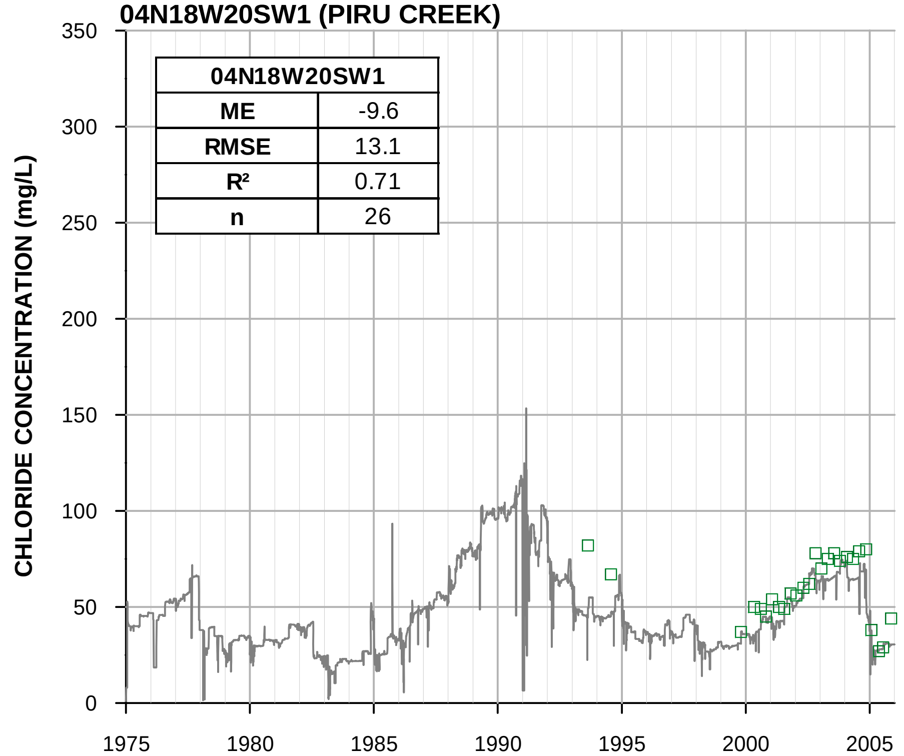
FIGURE 4-24 (PAGE 1 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN THE SANTA CLARA RIVER IN THE PIRU SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL

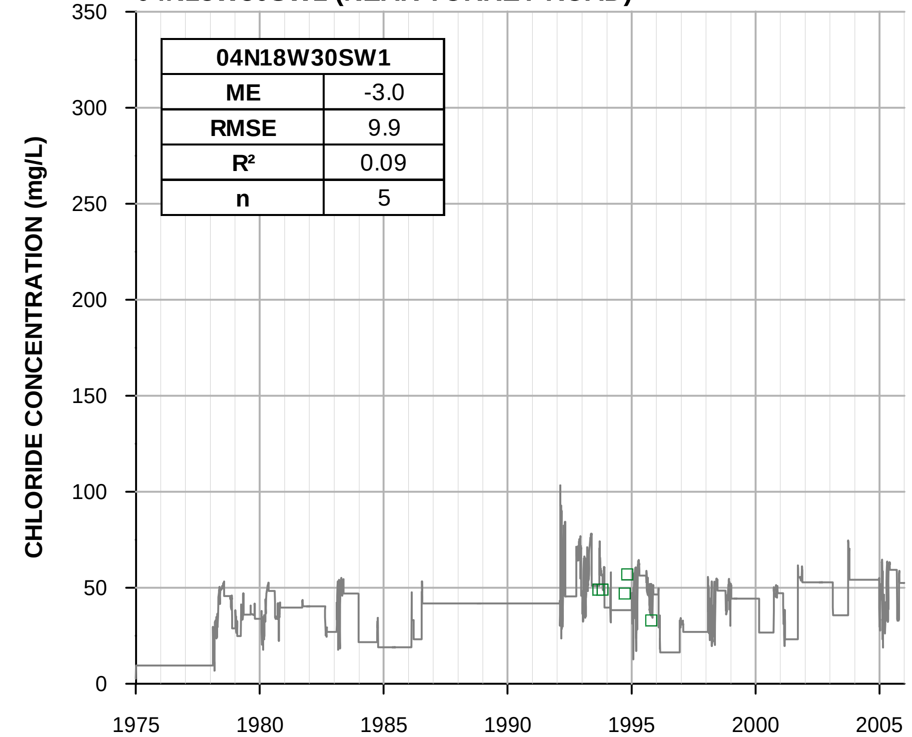
Cl_SW_PiruSubbasin1.grf

04N18W20SW1 (PIRU CREEK)



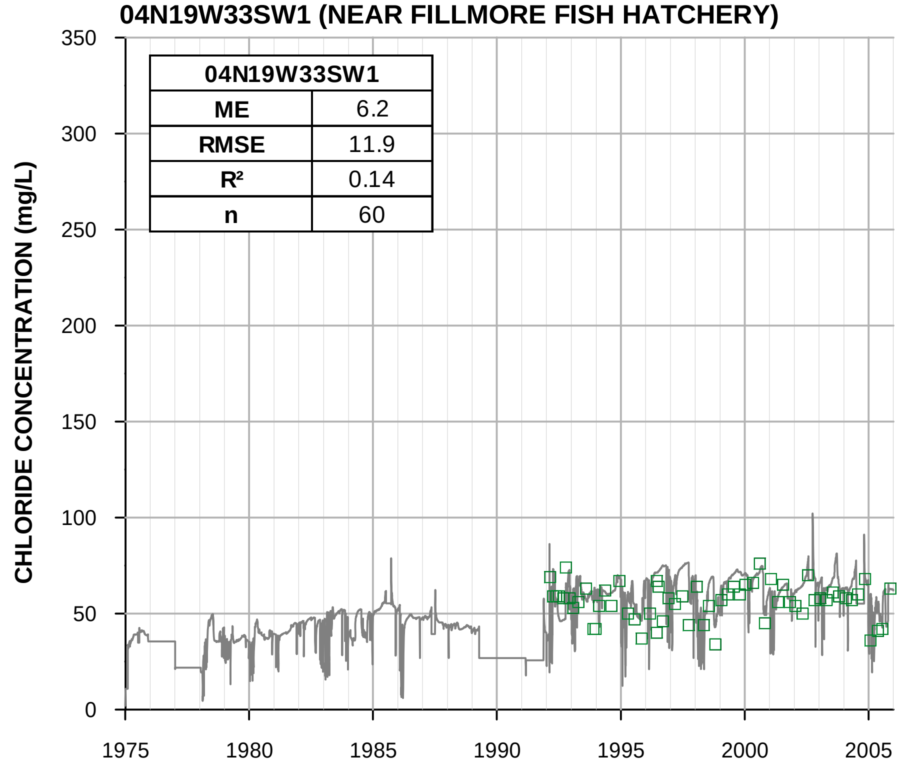
04N18W20SW1	
ME	-9.6
RMSE	13.1
R^2	0.71
n	26

04N18W30SW1 (NEAR TORREY ROAD)



04N18W30SW1	
ME	-3.0
RMSE	9.9
R^2	0.09
n	5

04N19W33SW1 (NEAR FILLMORE FISH HATCHERY)



04N19W33SW1	
ME	6.2
RMSE	11.9
R^2	0.14
n	60

LEGEND

SIMULATED CHLORIDE CONCENTRATION

MEASURED CHLORIDE CONCENTRATION

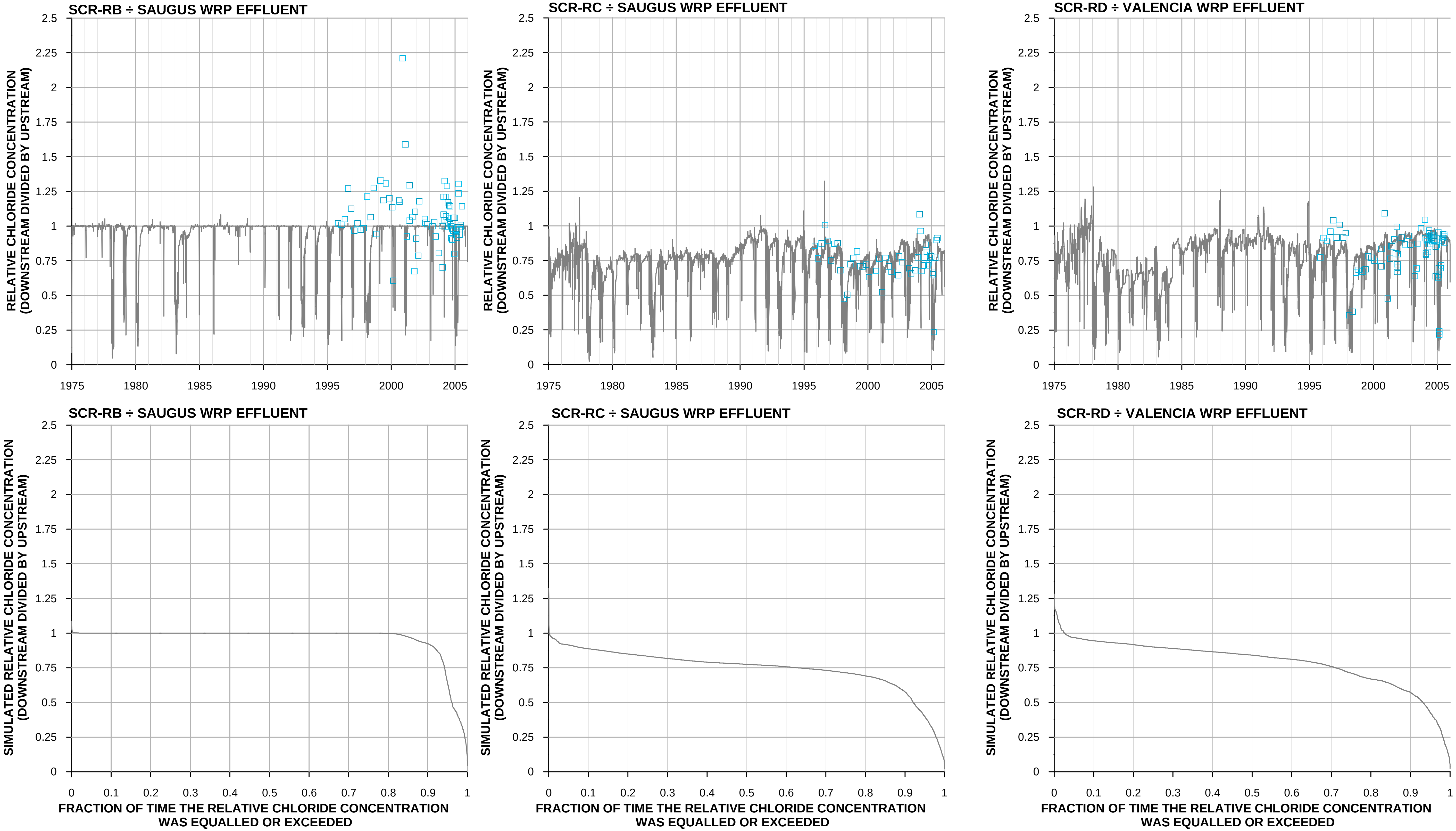
NOTES:

1. SEE FIGURES 4-1a THROUGH 4-1e FOR CALIBRATION TARGET LOCATIONS.
2. X-AXIS VALUES REPRESENT CALENDAR YEARS.
3. ME = MEAN ERROR (mg/L).
4. RMSE = ROOT MEAN SQUARED ERROR (mg/L).
5. R^2 = COEFFICIENT OF DETERMINATION (dimensionless).
6. n = NUMBER OF OBSERVATIONS.

FIGURE 4-24 (PAGE 2 of 2)
SIMULATED AND MEASURED CHLORIDE CONCENTRATIONS IN THE SANTA CLARA RIVER IN THE PIRU SUBBASIN
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL–

Cl_SW_PiruSubbasin2.grf



NOTES:
1. SEE FIGURE 4-28 FOR MAP OF PAIRED LOCATIONS.
2. SCR-RB IS LOCATED 300 FEET DOWNSTREAM OF THE SAUGUS WRP POINT OF DISCHARGE.
3. SCR-RC IS LOCATED 300 FEET UPSTREAM OF THE VALENCIA WRP POINT OF DISCHARGE.
4. SCR-RD IS LOCATED 300 FEET DOWNSTREAM OF THE VALENCIA WRP POINT OF DISCHARGE.
5. X-AXIS VALUES ON TOP THREE PLOTS REPRESENT CALENDAR YEARS .

LEGEND

SIMULATED

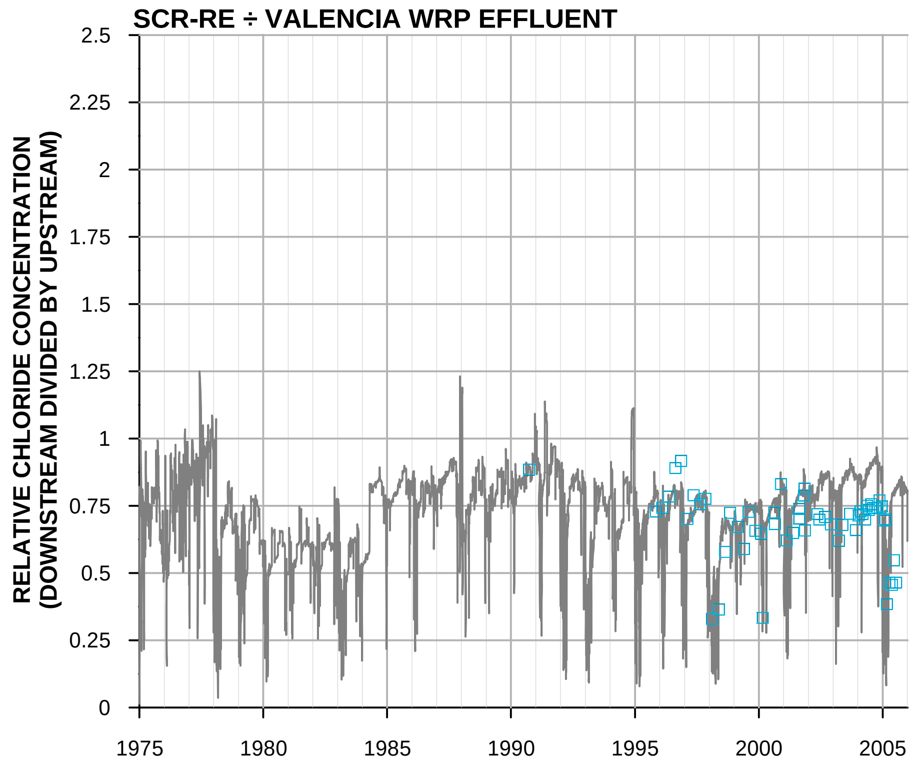
MEASURED

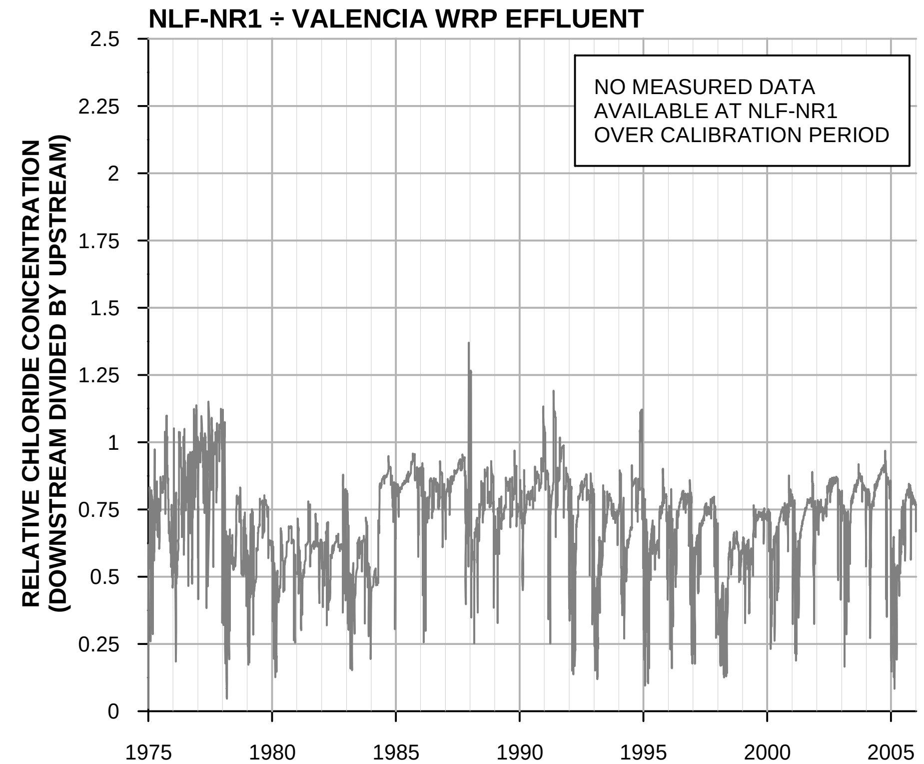
FIGURE 4-25 (PAGE 1 of 2)
SIMULATED RELATIVE CHLORIDE CONCENTRATIONS BETWEEN UPSTREAM AND DOWNSTREAM MONITORING LOCATIONS IN THE EAST SUBBASIN

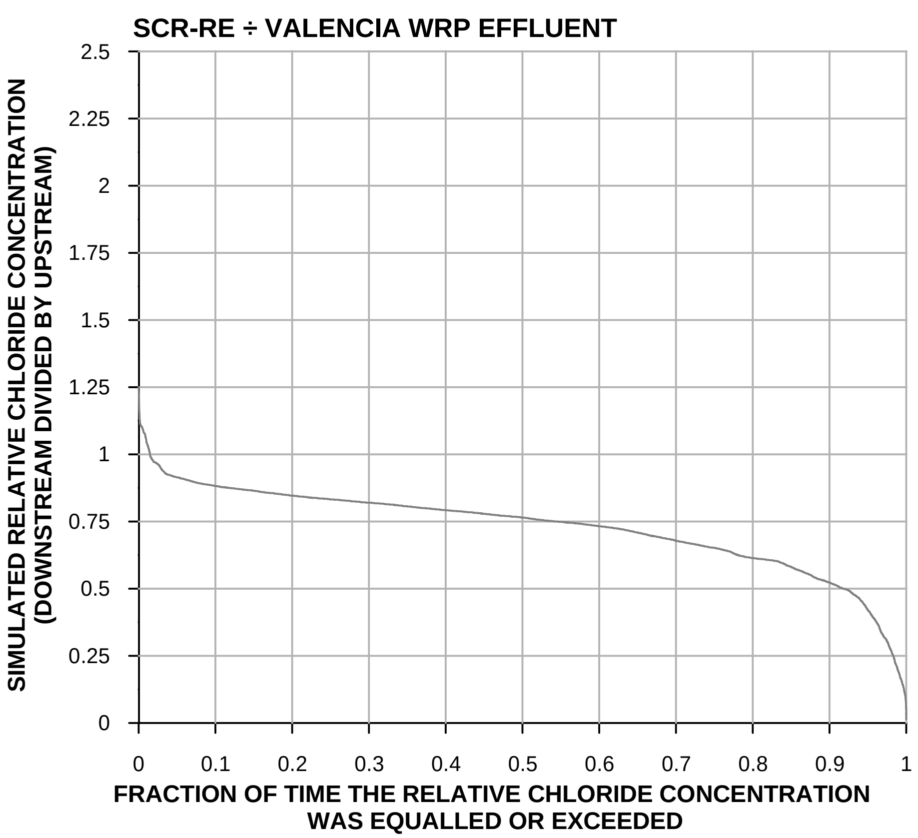
TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

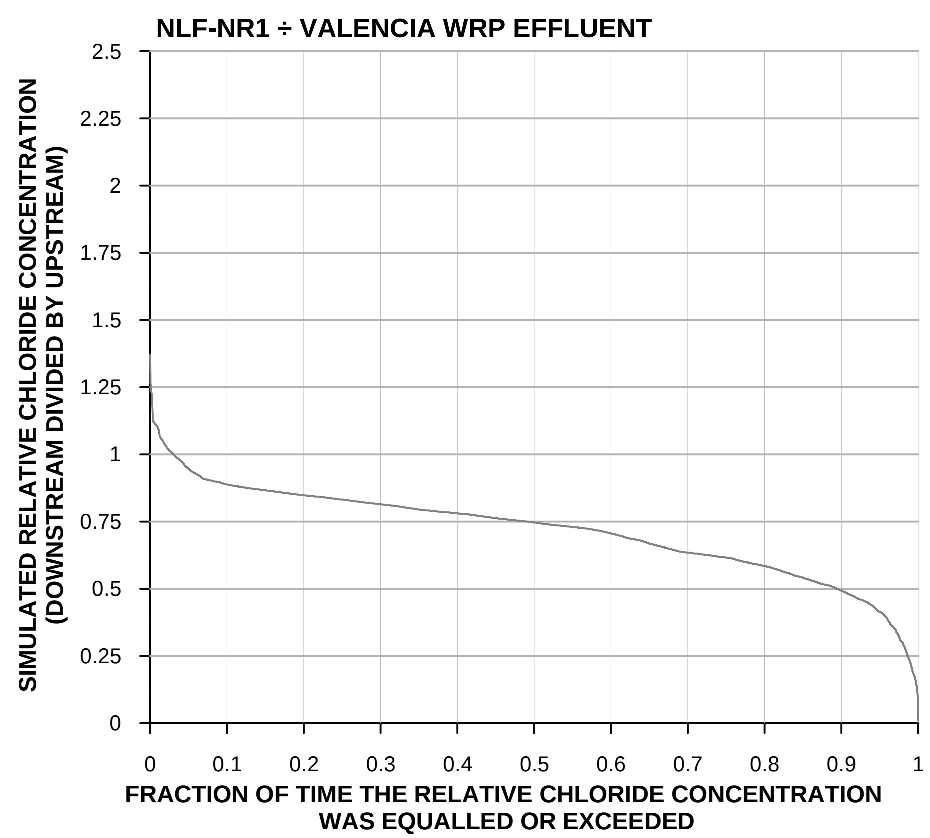
CH2MHILL –HGL

DilutionPlots_East1.grf









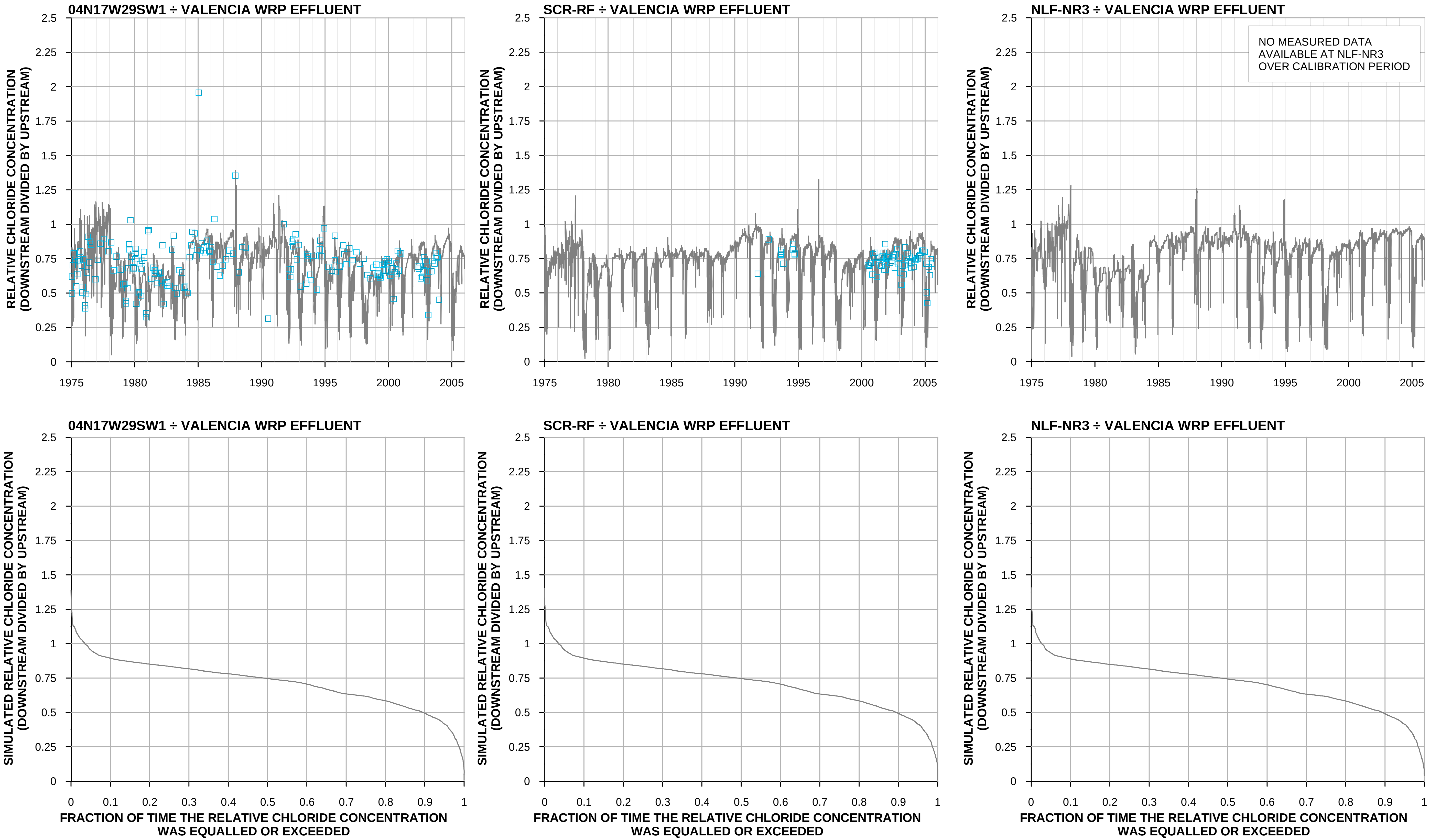
NOTES:
1. SEE FIGURE 4-28 FOR MAP OF PAIRED LOCATIONS.
2. SCR-RE IS LOCATED JUST UPSTREAM OF THE CONFLUENCE OF CASTAIC CREEK, 1.6 MILES UPSTREAM OF CHIQUITA CANYON ROAD.
3. NLF-NR1 IS LOCATED JUST UPSTREAM OF THE COUNTY LINE.
4. X-AXIS VALUES ON TOP TWO PLOTS REPRESENT CALENDAR YEARS.

LEGEND

SIMULATED
MEASURED

FIGURE 4-25 (PAGE 2 of 2)
SIMULATED RELATIVE CHLORIDE CONCENTRATIONS BETWEEN UPSTREAM AND DOWNSTREAM MONITORING LOCATIONS IN THE EAST SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS



NOTES:
1. SEE FIGURE 4-28 FOR MAP OF PAIRED LOCATIONS.
2. 04N17W29SW1 IS LOCATED AT BLUE CUT.
3. SCR-RF IS LOCATED NEAR THE CAMULOS DIVERSION.
4. NLF-NR3 IS LOCATED AT THE LAS BRISAS BRIDGE.
5. X-AXIS VALUES ON THE TOP THREE PLOTS REPRESENT CALENDAR YEARS.

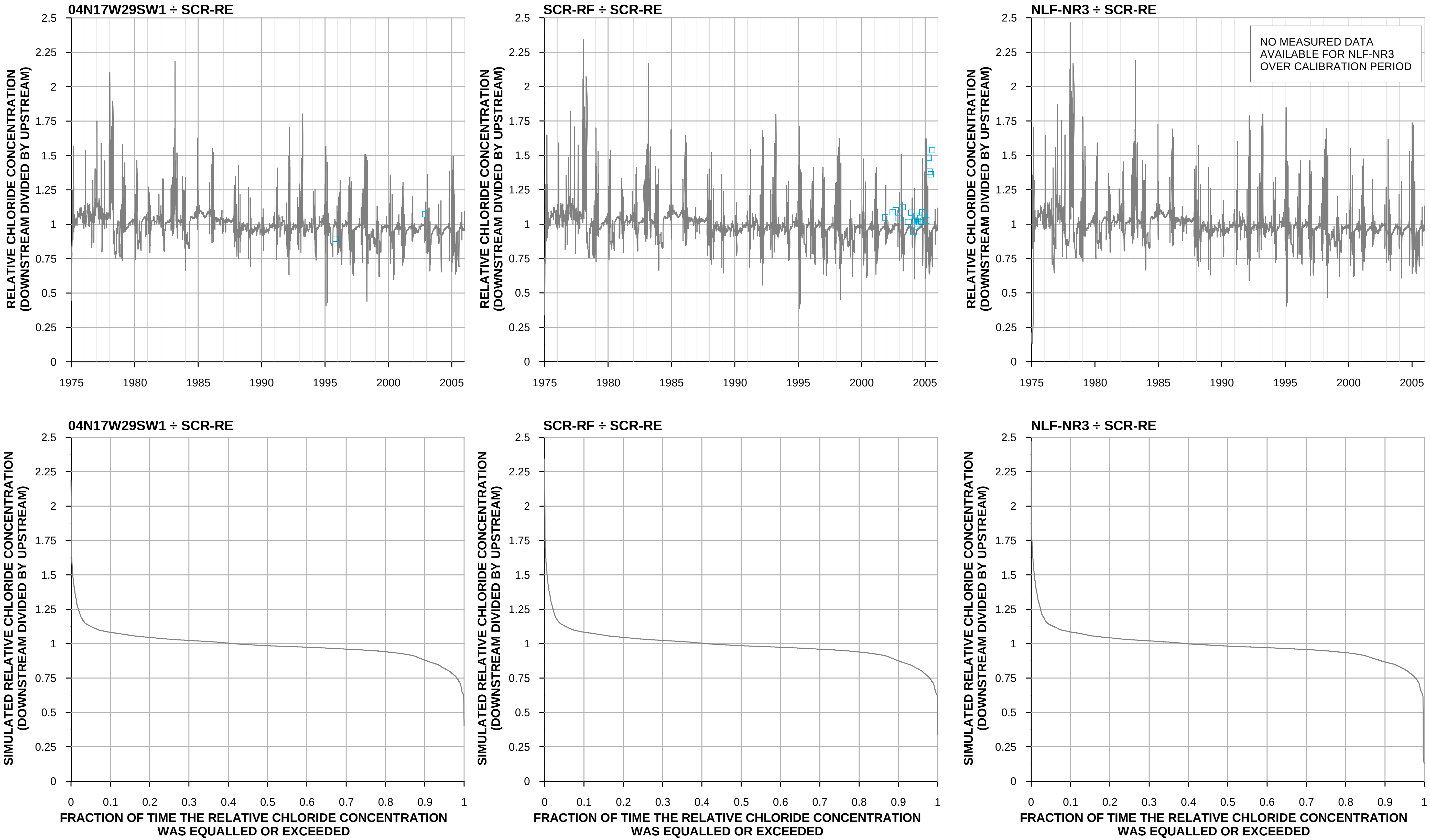
LEGEND

SIMULATED

MEASURED

FIGURE 4-26
SIMULATED RELATIVE CHLORIDE CONCENTRATIONS BETWEEN THE VALENCIA WRP AND DOWNSTREAM MONITORING LOCATIONS IN THE PIRU SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS



NOTES:
1. SEE FIGURE 4-28 FOR MAP OF PAIRED LOCATIONS.
2. 04N17W29SW1 IS LOCATED AT BLUE CUT.
3. SCR-RE IS LOCATED JUST UPSTREAM OF THE CASTAIC CREEK CONFLUENCE.
4. SCR-RF IS LOCATED NEAR THE CAMULOS DIVERSION.
5. NLF-NR3 IS LOCATED AT THE LAS BRISAS BRIDGE.
6. X-AXIS VALUES ON THE TOP THREE PLOTS REPRESENT CALENDAR YEARS.

LEGEND

SIMULATED

MEASURED

FIGURE 4-27
SIMULATED RELATIVE CHLORIDE CONCENTRATIONS BETWEEN CASTAIC CREEK AND DOWNSTREAM MONITORING LOCATIONS IN THE PIRU SUBBASIN

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL –HGL

DilutionPlots_Piru-RE.grf

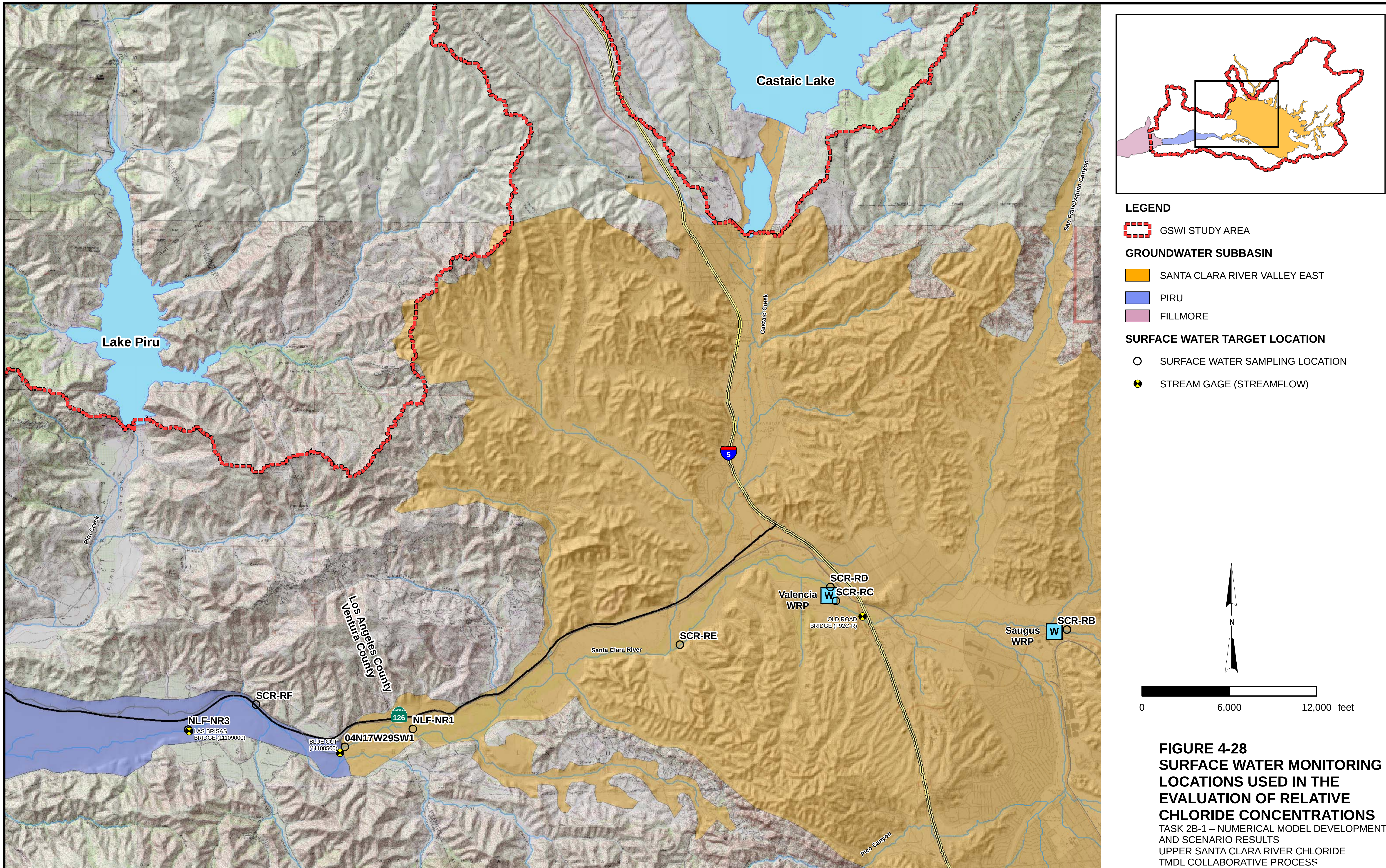


FIGURE 4-28
SURFACE WATER MONITORING LOCATIONS USED IN THE EVALUATION OF RELATIVE CHLORIDE CONCENTRATIONS

TASK 2B-1 – NUMERICAL MODEL DEVELOPMENT AND SCENARIO RESULTS
UPPER SANTA CLARA RIVER CHLORIDE TMDL COLLABORATIVE PROCESS

CH2MHILL -HGL

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