Appendix I. Groundwater Modeling

This appendix describes current and future groundwater modeling efforts associated with the Seepage Management Plan.

I.1 Current Objectives of Groundwater Modeling Efforts

The objectives of groundwater modeling efforts include

- Evaluation of the maximum lateral extent of SJRRP flow impacts on the groundwater table;
- Determination of areas within the hydraulic influence of the San Joaquin River which will be vulnerable to seepage effects from Restoration flows and are most susceptible to developing shallow groundwater conditions that could harm crops;
- Provide decision support in the evaluation of potential seepage mitigation projects; and
- Assessment of the spatial and temporal robustness of monitoring thresholds;
- Evaluation of local seepage effects on susceptible lands; and
- Provide historical water level estimates in areas that have not been historically monitored.

I.2 Groundwater Model Development

Groundwater models built at different scales will be used by the SJRRP is the seepage management process.

I.2.1 SJRRPGW

Building on the backbone of the USGS Central Valley Hydrologic Model (CVHM; Faunt, 2009), the SJRRP has developed a groundwater model of most of the area within five miles of the San Joaquin River and bypass system. The San Joaquin River Restoration Program Groundwater Model (SJRRPGW) is spatially refined from the CVHM, at one-quarter-mile laterally (CVHM uses a one mile square grid), and vertically (i.e., the upper 50 feet (a single layer in CVHM) was subdivided into three layers of equal thickness. Figure I-1 shows the CVHM and SJRRPGW horizontal model grids. Both models were constructed using MODFLOW-FMP2 (Schmid and Hanson, 2009), which is based on MODFLOW-2005 (Harbaugh, 2005).

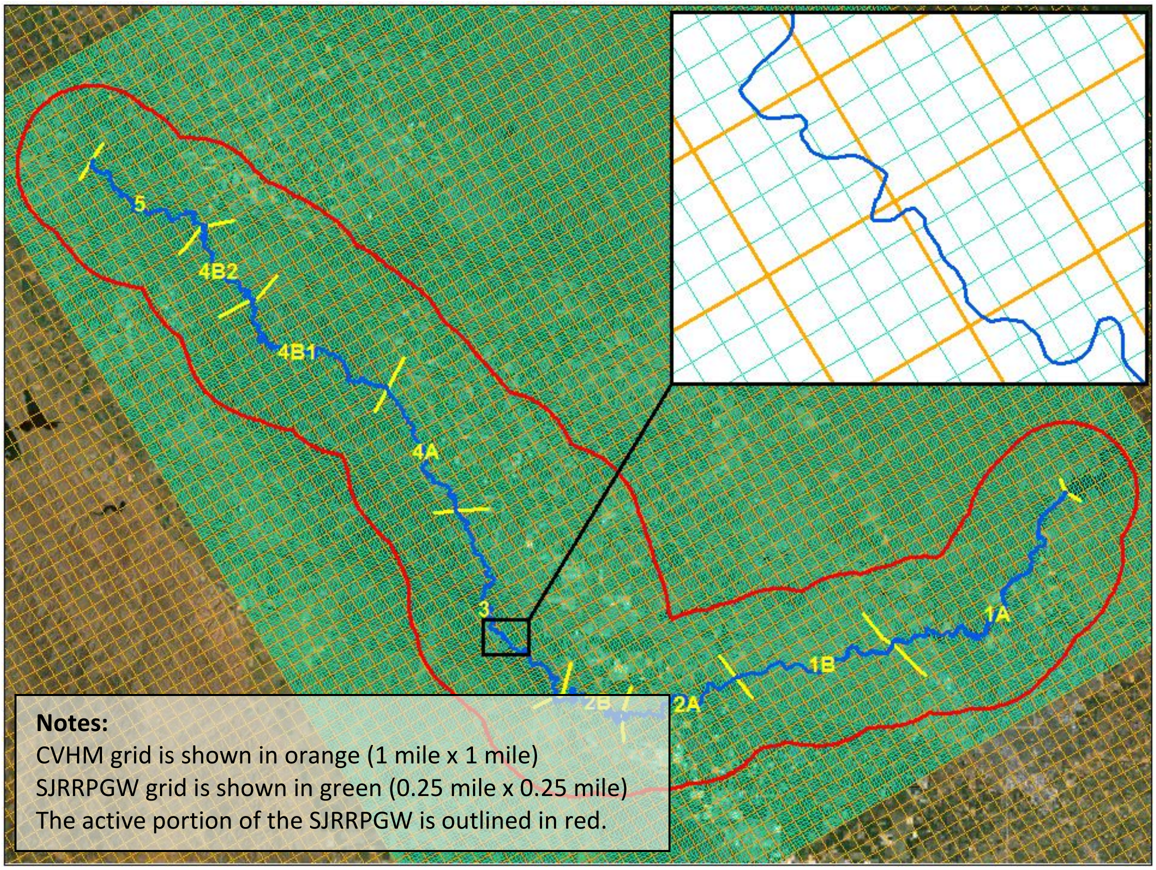

Figure I-1.
CVHM and SJRRPGW Horizontal Grid.

Boundary conditions for the SJRRPGW are constrained by the CVHM results for model cells along the outer and lower boundaries. The lower boundary is the top of the Corcoran Clay. The simulation period for SJRRPGW is the same for the CVHM (1961 through 2003) with a monthly timestep and stress period. To simulated Restoration flows more precisely, the monthly stress periods were sub-divided into two equal length time steps. The monthly stress The CVHM is currently being extended in time, after which the SJRRPGW also will be extended.

Irrigated agriculture is simulated in the SJRRPGW using the Farm Process, a sophisticated tool that incorporates data on crop characteristics, soils, climate, and other factors affecting landscape processes (Schmid, 2009). The Farm Process accounts for root uptake of shallow groundwater and decreased transpiration in waterlogged conditions, and allows for changes in cropping patterns, irrigation methods, etc. The basis for water accounting in the Farm Process is the water budget subregions; those for the SJRRPGW are shown in Figure I-2 (from Traum, 2014).

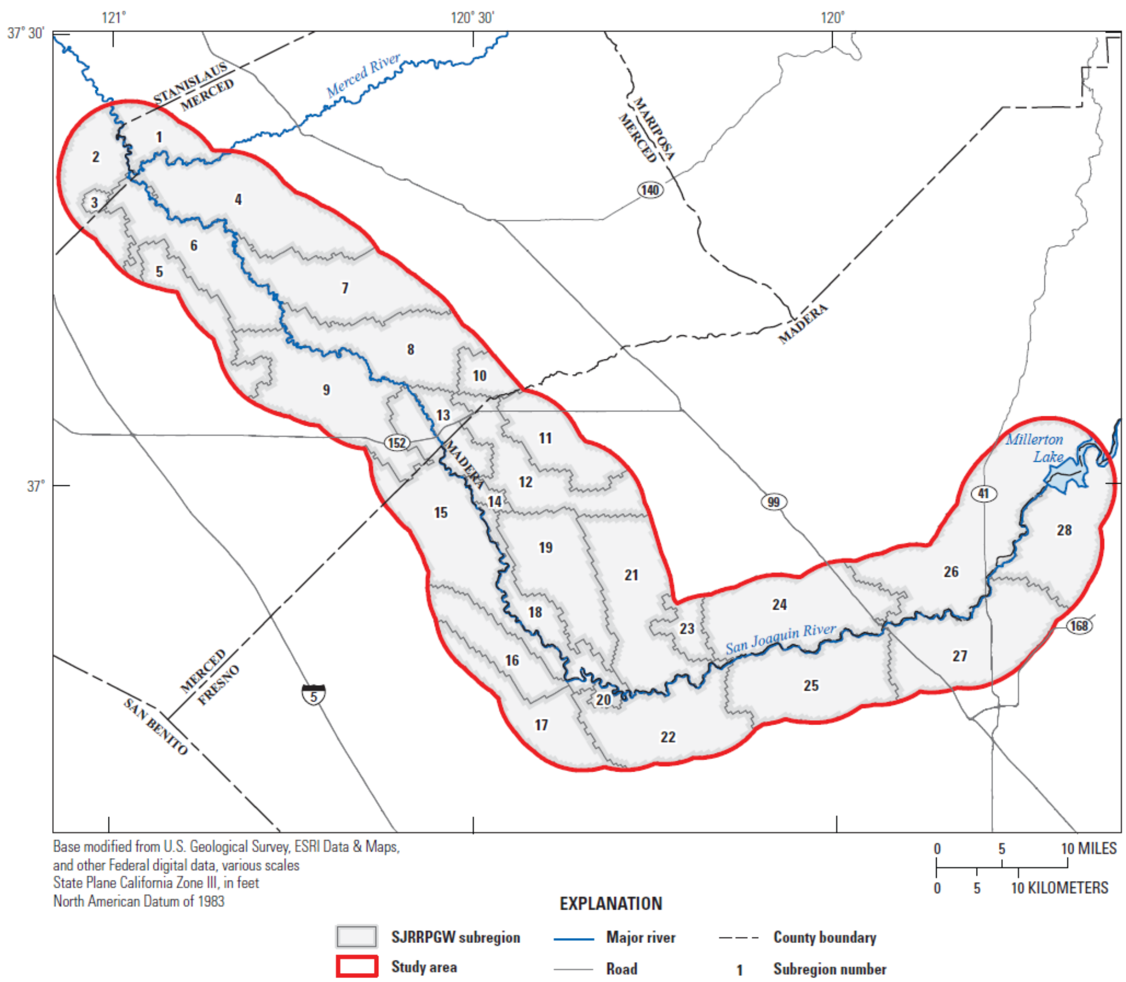

Figure I-2.
Water Budget Subareas Defined Within SJRRPGW

Surface-water flow is included in SJRRPGW to allow for estimation of groundwater/surface-water interaction and associated seepage losses. Figure I-3 (from Traum, 2014) shows the surface-water features included in the model. The flow/stage relationship used in SJRRPGW was derived from simulation results from the HEC-RAS (Tetra Tech 2009) model of surface-water flow developed for the SJRRP.

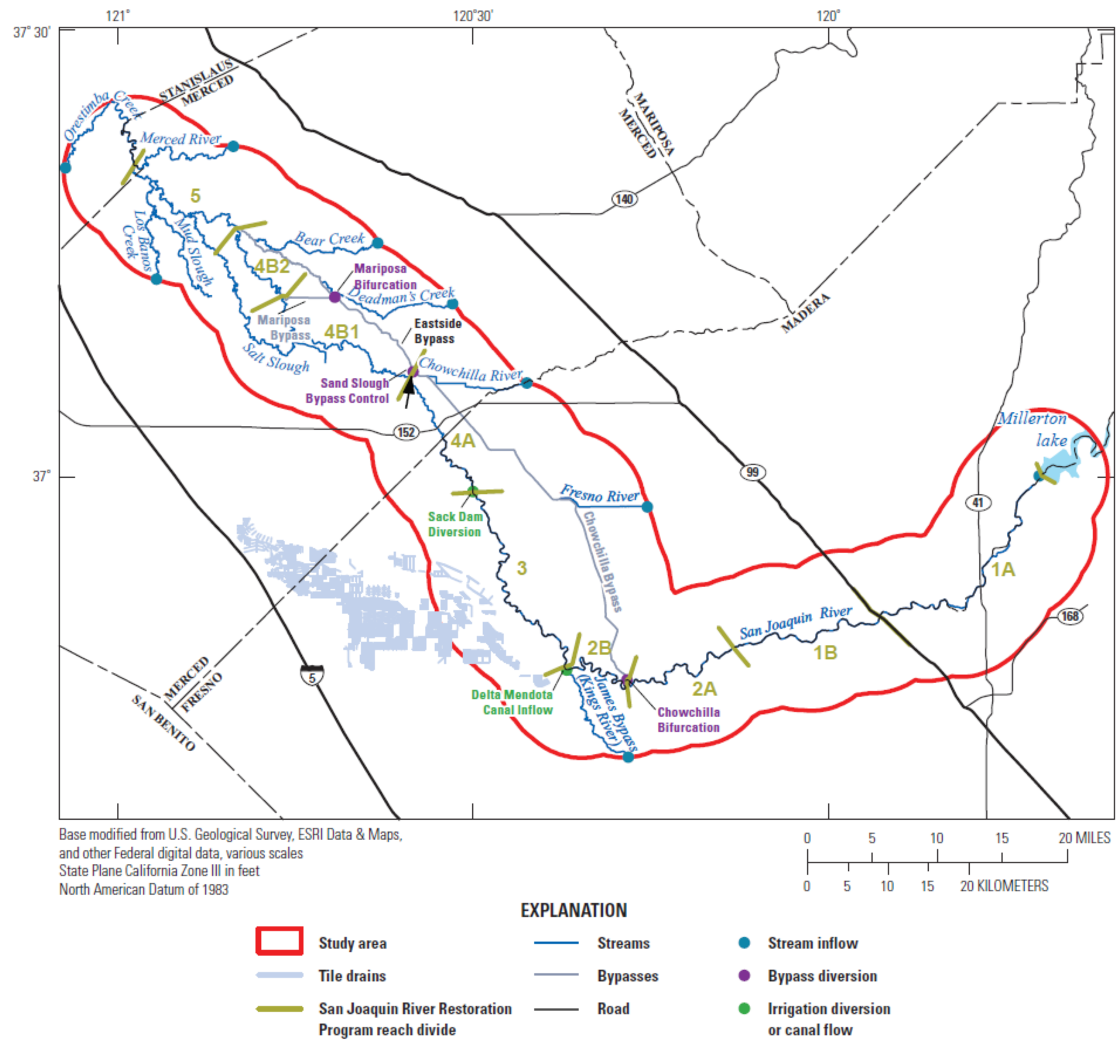

Figure I-3.
Surface Water Features Simulated in SJRRPGW

The distribution of hydraulic conductivity in the aquifer system was defined on the basis of the sediment texture model described in Appendix D, which in turn was derived from information on drillers' logs.

The SJRRPGW was calibrated for the 1961 through 2003 period using groundwater level and streamflow data described in Appendix B. Locations of the wells and stream gages used for model calibration are shown in Figures I-4 and I-5 (both from Traum, 2014).

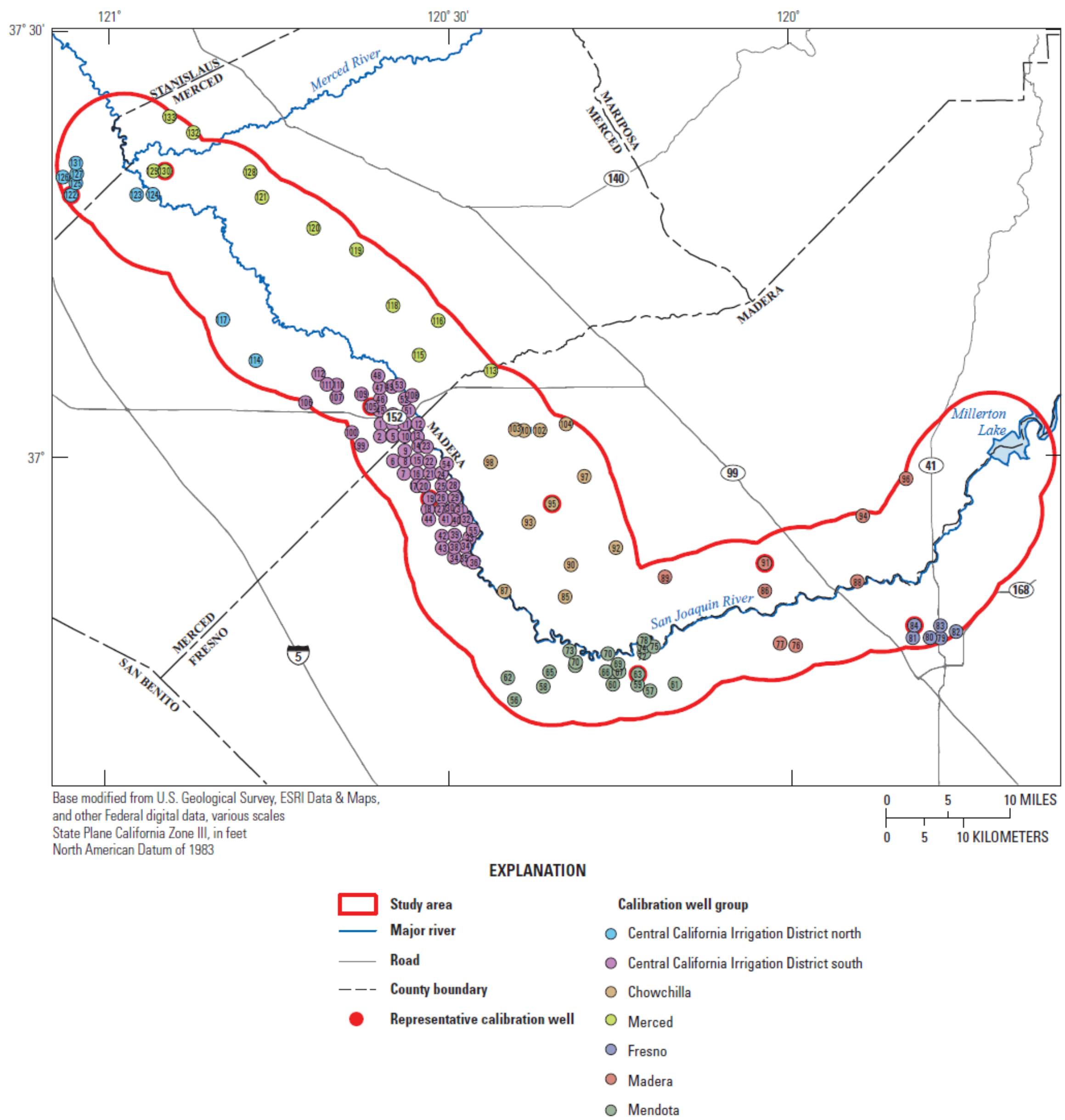

Figure I-4.
Locations of Wells Used in SJRRPGW Calibration

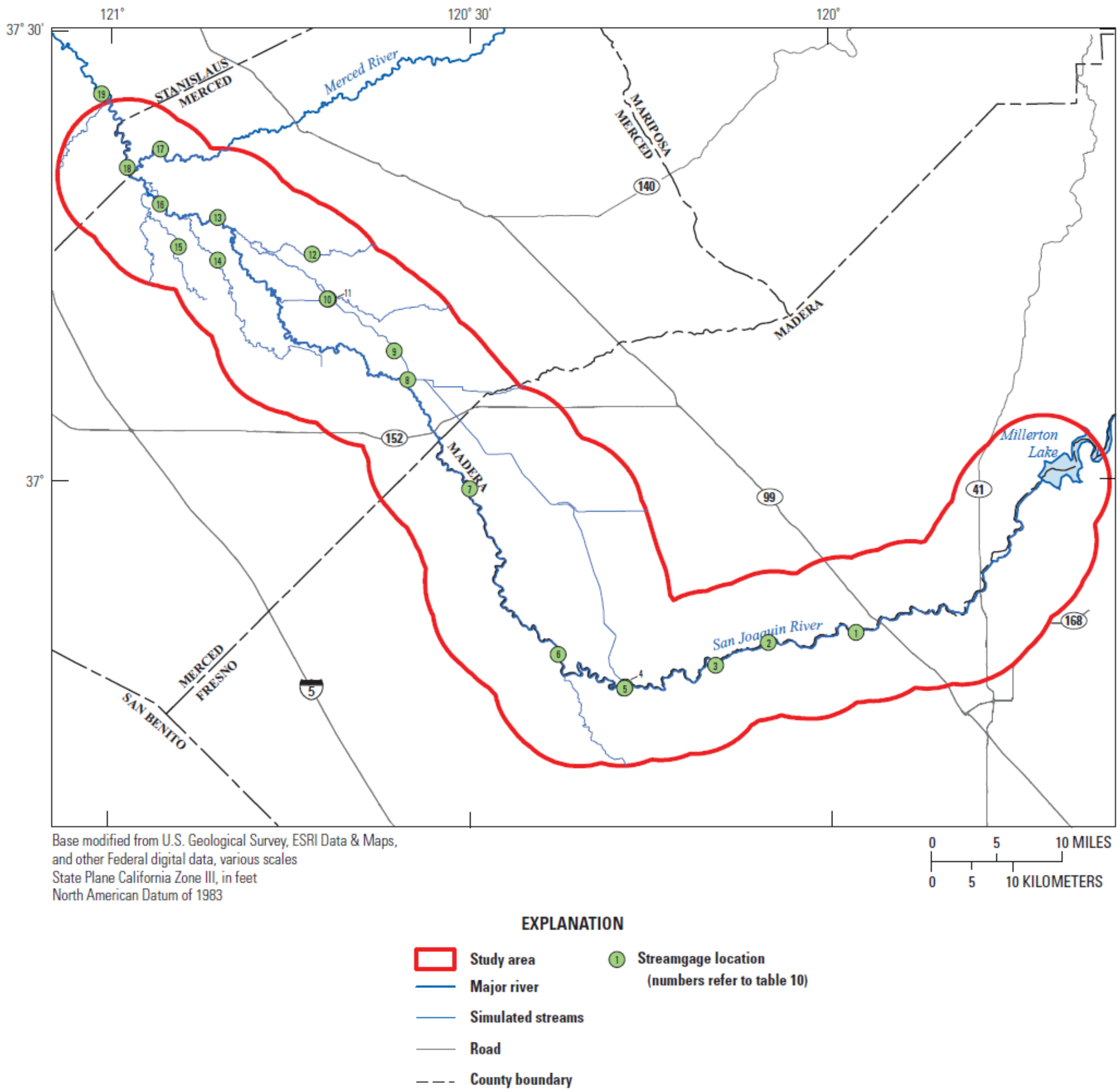

Figure I-5.
Locations of Stream Gages Used in SJRRPGW Calibration

The 1961 through 2003 version of SJRRPGW is fully documented in Traum et al., 2014. This version of the model will be used to evaluate the maximum lateral extent of SJRRP flow impacts on the groundwater table, estimate seepage losses, and to provide preliminary results for other objectives listed above.

Following the extension in time of the CVHM to October 2013, the SJRRPGW will also be extended in time and calibrated to groundwater levels and streamflows measured during Interim flows, beginning in the fall of 2009. Additional improvements will also be done at that time. The resulting updated SJRRPGW is anticipated to be available in 2015.

Although the one-quarter mile grid of the SJRRPGW is substantially refined compared to the CVHM, it is too coarse to meet some of the modeling objectives. For example, adequate simulation of an interceptor drain, for which the Drain Package of MODFLOW will be used, will require even smaller grid spacing. For problems of finer scale, such as this one, highly refined local-scale models will be developed; SJRRPGW will provide the boundary conditions for the local models, just as CVHM provides for SJRRPGW.

I.2.1 Local-Scale Models

For some applications, refinement also will be required in temporal scale, allowing for sub-monthly changes in river flows and other processes. New “local scale” versions of SJRRPGW are being developed for simulation of conditions at the scale of individual properties.

One model, the IRPGW, has already been developed. Four additional models (LM1 through LM4) are under development. Figure I-6 shows the extents of each of these five local scale models.

The IRPGW model covers an area 6.5 by 9.5 miles near the Sand Slough Control Structure. The IRPGW uses a model grid of 1/16-mile (330 feet) square cells, as compared to the 1/4-mile (1,320 feet) cells in the SJRPGW, to allow a more accurate simulation of potential seepage projects. All the datasets used in the IRPGW were downscaled from SJRRPGW. The stress periods and time steps were also reduced to weekly in the IRPGW. A week is typically the smallest interval for which Restoration flow releases can be ramped up. The IRPGW is being used to simulate potential seepage projects on properties within the model domain.

The other four local models (LM1 through LM4) will be developed in a manner similar to the IRPGW.

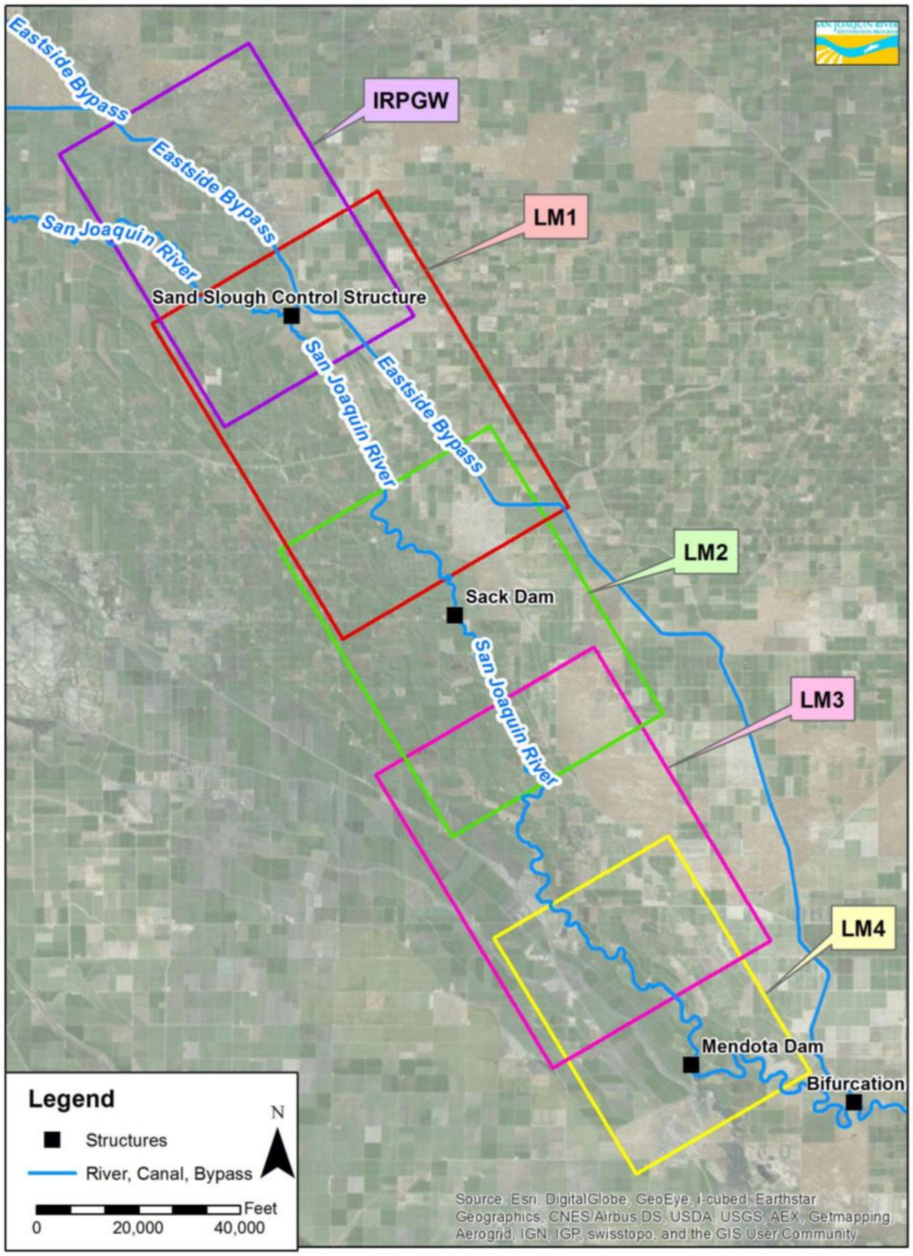

Figure I-6.
Locations of Five Local Scale Groundwater Models

I.3 Model Results and Uses

The following subsections list a few of the models results and uses for the SJRRPGW and/or local scale models.

I.3.1 Groundwater Levels

The USGS has developed two interactive animations to show the simulated groundwater elevation and simulated depth to groundwater from the SJRRPGW for the period of 1961 through 2003.

- Groundwater Elevation: http://ca.water.usgs.gov/GWE_yr2_JT.swf
- Depth to Groundwater: http://ca.water.usgs.gov/D2GW_yr2_JT.swf

I.3.2 Groundwater/Surface Water Interaction

Estimation of where seepage losses occur, and the rate at which they occur, is key to developing an understanding of potential seepage issues and various means for reducing or eliminating associated impacts. These losses can reasonably be estimated at the scale of the SJRRPGW and/or local scale models.

The USGS has developed an interactive animation to show the simulated groundwater/surface water interaction from the SJRRPGW for the period of 1961 through 2003.

- Groundwater/Surface Water Interaction: http://ca.water.usgs.gov/StreamSeepage_yr3_JT.swf

I.3.3 Maximum Lateral Extent of SJRRP Flow Impacts

The geographic extent of water-table response to Restoration Flows is currently unknown. The current monitoring plan focuses on a zone within one mile of the river, but there are anecdotal accounts of water levels in wells as far as three miles from the river responding to high flows. The current version of the SJRRPGW will be used to continue to define this geographic extent and design an appropriate monitoring corridor surrounding the river.

I.3.4 Effects of Precipitation, Irrigation, and River Flows on Groundwater Levels

The relative effects on the water table of precipitation, irrigation, and high river flows are unknown, and water level data of adequate frequency for separating these effects are only available for a small number of locations. A more refined version of the SJRRPGW may be required to adequately address this question.

I.3.5 Assessment of Monitoring Thresholds

The SJRRP groundwater monitoring thresholds were developed using multiple methods and have evolved over time as hydrologic conditions have varied year to year. Simulation of a variety of hydrologic conditions not yet experienced, using varying antecedent conditions, will be done to the robustness of the current set (and alternate sets) of thresholds, and the Restoration Flows possible under those thresholds. The current version of the SJRRPGW will provide a conservative assessment; the assessment will improve with a temporally refined version.

I.3.6 Local Seepage Effects on Susceptible Lands

The evaluation of local effects of river seepage will require a locally refined grid, in which case the SJRRPGW will provide the boundary conditions.

I.3.7 Potential Response Actions

Evaluation of the relative effectiveness of potential response actions requires a range of spatial and temporal resolution. It may not be practical to simulate all potential responses, but most can be reasonably simulated at the local to SJRRPGW scale and daily to monthly time scale.