Appendix 7A

Groundwater Model Documentation

This appendix provides information about the assumptions, modeling tools, and the methods used for the Remanded Biological Opinions on the Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP) Environmental Impact Statement (EIS) impact analysis including information for the No Action Alternative simulation. The appendix also describes model output processing and interpretation methods used for the impacts analysis and descriptions. Additional information pertaining to the development of the analytical tools, incorporating climate change, and using input data from other models is also provided.

This appendix is organized into three main sections that are briefly described below:

- Section 7A.1: Groundwater Modeling Methodology
  - The EIS groundwater impacts analysis uses the Central Valley Hydrologic Model (CVHM) to forecast effects of the alternatives on the long-term operations and the environment. This section provides information about the overall analytical framework and how some of the model input information obtained from other models was processed using analytical tools.
- Section 7A.2: CVHM Modeling Simulations and Assumptions
  - This section provides a brief description of the assumptions for CVHM simulations of the No Action Alternative, Second Basis of Comparison, and the other EIS alternatives.
- Section 7A.3: CVHM Modeling Results
  - This section describes the model simulation outputs used in the analysis and interpretation of modeling results for the alternatives impacts assessment. A description of post-processing tools is provided along with the different types of output display to facilitate data interpretation.

7A.1 Groundwater Modeling Methodology

This section summarizes the groundwater modeling methodology used for the EIS No Action Alternative, Second Basis of Comparison, and other alternatives. It describes the overall analytical framework and contains descriptions of the key analytical and numerical tools and approaches used in evaluating the alternatives. The project alternatives include several major components that will influence CVP and SWP operations and the hydrologic and hydrogeologic responses of the system.

In evaluating the No Action Alternative, Second Basis of Comparison, and the other alternatives, climate change assumptions centered on year 2025 (for assumed conditions at 2030) were used to develop modified climate input files. The modeling assumptions are provided in more detail in Section 7A.2.

The impacts on groundwater in the Central Valley and the CVP and SWP export service areas because of the project were analyzed using CVHM (USGS 2009). CVHM is a three-dimensional saturated groundwater flow model based on the widely used MODFLOW code (USGS 2000) and incorporates a number of modeling packages to simulate streamflow, crop demand, groundwater pumping, and subsidence.

7A.1.1 Overview of the Modeling Approach

To support the groundwater impact analysis of the alternatives, modeling of the physical groundwater system in the Central Valley has been undertaken to forecast changes to conditions affecting groundwater resources in areas that use CVP and SWP surface water deliveries.

CVHM is a calibrated historical model that includes a 42-year simulation period from water years 1962 through 2003. The model domain encompasses the entire Central Valley, including Sacramento Valley, San Joaquin Valley (including Tulare Basin), and the Sacramento-San Joaquin Delta. CVHM simulates primarily subsurface and limited surface hydrologic processes using a uniform grid-cell spacing of 1 mile.

CVHM was run over the 42-year hydrologic period, and boundary conditions were modified to reflect anticipated changes in surface water availability, including some potential effects of climate change. Surface water flows from operations models (descriptions of CalSim II methodology is included in Appendix 5A) were used to define selected surface water boundary conditions in CVHM. The linkage between CalSim II surface flows and CVHM inputs is further described below.

Future climate parameters centered on year 2025 were developed using the Variable Infiltration Capacity (VIC) model. Changes to the historical hydrology related to the future climate were applied in the CalSim II model and combined with the assumed operations for each alternative (Appendix 5A). The CalSim II model simulates the operation of the major CVP and SWP facilities in the Central Valley and generates river flows, exports, reservoir storage, deliveries, and other parameters for use with each alternative. River flows based on operational assumptions and reflected in the reservoir releases simulated in CalSim II are included in selected boundary conditions in the CVHM input files, along with the Delta exports to San Joaquin and Tulare service areas, and the surface water deliveries to CVP and SWP users in the Sacramento Valley. CVHM was used to forecast the changes in groundwater levels and groundwater pumping because of the alternatives, and results are processed for input into the Statewide Agricultural Production (SWAP) model. The SWAP model then forecasts impacts on agricultural production based on pumping lifts and cost of groundwater pumping, as described in Chapter 12, Agricultural Resources. Figure 7A.1 shows the modeling tools applied in the groundwater impacts assessment and the relationship between these tools. Each model included in Figure 7A.1 provides information to the subsequent “downstream” model in order to support the impacts analysis.

The results from this suite of computer models were used to assess potential groundwater effects from implementing each alternative considered in the EIS.

Modeling objectives included evaluating the following potential changes related to groundwater resources because of the various alternatives:

- Changes in groundwater elevations, which result from changes in groundwater use and could affect nearby municipal, agricultural, and domestic well yields
- Changes to groundwater quality based on a potential inducement of migration of poor-quality groundwater because of groundwater flow changes

7A.1.2 Key Components of the Groundwater Modeling Framework

7A.1.2.1 Model Function

CVHM was used to forecast groundwater level changes and other impacts to groundwater resulting from changes in assumed surface water deliveries from the CVP and SWP into the service areas located north and south of the Delta. More specifically, surface water operational changes from project implementation along with the effects of climate change were incorporated into CVHM as modified boundary inflows into the model domain and as semi-routed and nonrouted surface water deliveries to each CVHM water balance subregion (WBS). In addition, forecast climate variations were incorporated as modified precipitation and reference evapotranspiration (ET) rates in the model input files.

The overall construction and calibration of CVHM was left unchanged during this analysis. The only modifications to CVHM involved the prescribed surface water inflows and deliveries, which were modified based on simulations performed using CalSim II, as well as modified reference ET and precipitation input files to reflect potential climate change conditions centered on year 2025. CalSim II flows reflect operations in the Delta based on assumptions related to future operations of the project (see Chapter 5, Surface Water Resources and Water Supplies).

The active CVHM domain was subdivided into 21 WBSs, as originally defined by the California Department of Water Resources (DWR) (Figure 7A.2). During model simulations, applied water requirements for each WBS were computed based on crop type and available water from precipitation, shallow groundwater, and surface water (limited by surface water rights).

Selected major streams flowing through the Central Valley were explicitly represented in CVHM. Observed USGS gage flows were used as inflows into the model domain for natural, unregulated rivers and streams. Reservoir releases on regulated rivers were also used as boundary inflows into the model domain. The reservoir releases were modified for each alternative according to operational changes and are represented by modified time-series flow data obtained from the

CalSim II simulations. Surface water deliveries to meet a portion of the applied water demands were diverted directly from the rivers, according to water rights constraints. Additional surface water was delivered through "nonrouted" methods in the model. Nonrouted surface water deliveries represent water transfers or surface water deliveries to a WBS not connected to a stream or major canal. This conveyance typically occurs through small canals or diversion ditches (USGS 2009). Some irrigation canals and aqueducts were not included in CVHM, such as the California Aqueduct and the Delta-Mendota Canal. Water delivered through these conveyances was simulated in CVHM as nonrouted deliveries, directly added to the destination WBS. The deliveries to WBSs south of the Delta from the CVP and SWP and associated conveyance losses were estimated from CalSim II simulations and included in CVHM. The surface water diversion flows for the CVP and SWP contractors and settlement contractors in the Sacramento Valley were also obtained from CalSim II simulations for each alternative.

7A.1.2.2 Computer Code Description

CVHM is a regional groundwater modeling application based on the MODFLOW-2000 (MF2K) computer code (USGS 2000) and incorporates a variety of additional modules that were specifically developed to interact with MF2K and increase the capabilities of the overall modeling package. The additional modules incorporated into the CVHM application are summarized in Table C1 of USGS Professional Paper 1766 (USGS 2009). The package that is responsible for simulating the majority of the agricultural water balance is the Farm Process (FMP) (USGS 2006). Within the FMP documentation, the WBSs are referred to as "farms"; WBS and farms are used interchangeably in this text. FMP computes the applied water demand for each farm based on crop types specified in each model cell and computes the availability of water from "natural" sources such as precipitation and shallow groundwater. After the available natural water is allocated, FMP computes the amount of water that needs to be delivered from other sources, such as surface water deliveries (routed and nonrouted) and groundwater pumping to meet the remaining applied water demand.

Another important module integrated into CVHM is the Stream Flow Routing (SFR1) package. This package simulates the routing of surface water through virtual channels within the model domain, accounts for surface water diversions and deliveries to individual WBSs, tracks the flow and associated stage in surface water reaches, and computes stream-aquifer exchange.

CVHM was chosen to simulate the impacts of the EIS alternatives for three main reasons:

1. Readily available and peer-reviewed. CVHM was developed, calibrated, and tested by USGS and is based on a widely recognized computer code. It is publicly available, and extensive documentation has been published describing CVHM as well as all the modules and packages that make up the model.

2. Geographic extent. A large potentially impacted area to be evaluated as part of this project includes the Sacramento Valley and the San Joaquin Valley (including the Tulare Lake area). Surface water operational changes resulting from project operations are defined at the margins of the Central Valley. The CVHM domain covers the entire Central Valley and allows for the efficient imposition of boundary conditions throughout the basin.
3. Model subareas and discretization. CVHM is divided into 21 WBSs that correspond to the historical water balance regions identified by DWR. Water balances are computed for each WBS by the model. This distribution of areas in the Central Valley is consistent with models used by other resource teams, provides for consistent model reporting to the other teams, and allows for efficient sharing of data with other models.

7A.1.2.3 General Numerical Model Description

CVHM simulates surface water flows, groundwater flows, and land subsidence in response to stresses from water use and climate variability throughout the entire Central Valley. It uses the MF2K (USGS 2000) groundwater flow model code combined with the FMP modular package to simulate groundwater and surface water flow, irrigated agriculture, and other key processes in the Central Valley on a monthly basis from April 1961 through September 2003. CVHM is discretized laterally over a 20,000-square-mile area and vertically into 10 layers ranging in thickness from 50 feet near the land surface to 400 feet at depth. Layers 4 and 5 represent the Corcoran Clay member where it exists in portions of the San Joaquin Valley. In the Sacramento Valley, the Corcoran Clay member is not present; therefore, the model layering effectively consists of eight layers.

The FMP allocates water deliveries, simulates crop-applied water demand processes, and computes mass balances for the 21 WBSs (or farms) in CVHM. The FMP was developed for MF2K to estimate applied irrigation water allocations from conjunctively used surface water and groundwater. It is designed to simulate the demand components representing crop irrigation requirements and on-farm inefficiency losses, and the supply components representing surface water deliveries and supplemental groundwater pumping. The FMP also simulates additional head-dependent inflows and outflows such as canal losses and gains, surface runoff, surface water return flows, evaporation, transpiration, and deep percolation of excess water. Unmetered pumping and surface water deliveries for the 21 WBSs are also included within the FMP (USGS 2006).

The original calibration of CVHM by USGS was accomplished using a combination of trial-and-error and automated methods. An autocalibration code called UCODE-2005 (USGS 2005) was used to help assess the ability of CVHM to estimate the effects of changing stresses on the hydrologic system. Simulated changes in water levels, streamflows, streamflow losses, and subsidence through time were compared by USGS to those measured in wells, at streamflow gages, and at extensometer sites. For model calibration, USGS screened groundwater levels and surface water stages to obtain a calibration target data set that is distributed spatially (geographically and vertically) throughout the Central Valley;

distributed temporally throughout the simulation period (1961–2003); and available during both wet and dry climatic regimes. From the available wells records, a subset of 170 comparison wells was selected based on perforation depths, completeness of record, and locations throughout the Central Valley (USGS 2009). No changes were made to physical parameter values in CVHM for this project. A more detailed description of CVHM is in USGS Professional Paper 1766 (USGS 2009).

7A.2 CVHM Modeling Simulations and Assumptions

As described in Section 7A.1, groundwater modeling was performed for evaluating the alternatives considered in the EIS. This section describes the assumptions for the CVHM simulations of the No Action Alternative, Second Basis of Comparison, and other alternatives.

The following model simulations were performed as the basis of evaluating the impacts of the other alternatives:

- No Action Alternative
- Second Basis of Comparison

The following CVHM simulations of other alternatives were also performed:

- Alternative 1 – for CVHM simulation purposes, considered the same as Second Basis of Comparison
- Alternative 2 – for CVHM simulation purposes, considered the same as No Action Alternative
- Alternative 3
- Alternative 4 – for CVHM simulation purposes, considered the same as Second Basis of Comparison.
- Alternative 5

Assumptions for each of these alternatives were developed with the surface water modeling tools and are described in Appendix 5.

The general CVHM modeling assumptions described below pertain to all the baseline and alternative runs.

7A.2.1 Climate Change Assumptions

Climate variables of interest from a climate-change perspective within CVHM include precipitation and reference ET, which are among the required inputs for the FMP module to compute the applied water demand. These two variables are formatted as two-dimensional model array input files with one value assigned to each surficial model grid cell.

The original historical climate input data for CVHM were developed for the simulation period 1961-2003 from Parameter-Elevation Regressions on Independent Slopes Model (PRISM) data (Climate Source 2006). For precipitation, PRISM data were interpolated onto the model domain, and reference ET data were computed from PRISM temperature data. Reference ET data were computed using the Penman-Monteith estimate of potential ET and are used to evaluate the crop potential ET in combination with crop coefficients, and minimum and maximum temperatures for each stress period (USGS 2009).

For the EIS alternative simulations, climate conditions centered on year 2025 were assumed. Therefore, to be consistent with the other water supply and economics models, the climate input data for CVHM were modified to represent potential climate conditions centered on year 2025. A more detailed description of how climate change was incorporated into the CVHM forecast simulations follows.

The CVHM historical monthly precipitation and reference ET values were modified to incorporate potential climate change based on the median climate change scenario for the early long-term period (centered on 2025) (DWR, Reclamation, USFWS, and NMFS 2013). The analysis uses five statistically representative climate change scenarios to characterize the central tendency and the range of the ensemble uncertainty, including projections representing drier, less warming; drier, more warming; wetter, more warming; and wetter, less warming conditions as compared with the median projection. Climate change scenarios were developed from an ensemble of 112 bias-corrected, spatially downscaled global climate model (GCM) simulations. These GCM simulations were from 16 climate models for Special Report on Emissions Scenarios (SRES) A2, A1B, and B1 (Maurer et al. 2007) from the Coupled Model Intercomparison Project Phase 3 that are part of the Intergovernmental Panel on Climate Change Fourth Assessment Report. The forecast changes over the 30-year climatological period centered on 2025 (i.e., 2011-2040 to represent 2030 timeline) were combined with a set of historically observed temperature and precipitation (Hamlet and Lettenmaier 2005) to generate climate sequences that maintain important multiyear variability. The approach uses a technique called “quantile mapping”, which maps the statistical properties of climate variables from one data subset with the time series of events from a different data subset.

Historical temperature and precipitation data gridded to a 1/8 degree (°) spatial resolution across California (Hamlet and Lettenmaier 2005) were obtained from the Surface Water Modeling Group at the University of Washington (http://www.hydro.washington.edu). These data are based on the National Weather Service cooperative network of weather observations stations, augmented by information from the higher quality Global Historical Climatology Network stations. The Hamlet and Lettenmaier (2005) dataset includes the period from January 1915 through December 2003.

The historical and modified temperature (maximum and minimum values) based on the median early long-term climate-change scenario (centered on 2025) were used in the VIC hydrological model (Liang et al. 1994; Reclamation 2011) to simulate reference ET using the Penman–Monteith method (Allen et al. 1998).

Based on the above assumptions and methods, two sets of monthly fractional changes (i.e., perturbation factors) were computed to adjust the CVHM historical precipitation and reference ET input model array files. The first set of monthly fractional changes was computed from the historical and modified precipitation at each 1/8° VIC grid cell (future precipitation divided by historical precipitation). Similarly, the second set of monthly fractional changes was computed from reference ET simulated using historical and modified climate inputs that were computed using the Penman–Monteith method (Allen et al. 1998) embedded in the VIC hydrological model (simulated future reference ET divided by simulated reference ET). The fractional changes were computed for the historical period April 1961 through September 2003 for consistency with the CVHM simulation period.

The monthly fractional changes at 1/8° VIC grid cell were then applied to each CVHM monthly precipitation and reference ET data set at the corresponding CVHM grid cells by spatially mapping the two sets of grids. A utility tool was developed for intersecting the CVHM grid cells with the 1/8° VIC grids to assign fractional changes from the 1/8° VIC grid cell to historical precipitation and reference ET at each surficial CVHM cell to produce modified precipitation and reference ET values for planning level CVHM simulations that incorporate potential future climate change centered on year 2025. Figure 7A.3 illustrates the relationship between the VIC model grid and the CVHM grid.

7A.2.2 Land Use Assumptions

In CVHM, "the land use attributes are defined in the model on a cell-by-cell basis and include urban and agricultural areas, water bodies, and natural vegetation. The land use that covered the largest fraction of each 1-mi^2 model cell was the representative land use specified for that cell" (USGS 2009). Further, the agricultural land use is divided into 12 DWR Class 1 crop categories, also referred to as "virtual crops". As described in USGS 2009, the process of identifying a representative land use type and crop category for each model cell is very complex over the 42-year hydrologic period with different climate variations. This type of data is not readily available publicly, and other land use coverages require extensive processing to convert it into a format suitable for CVHM simulations. Thus, generating future land use changes for each cell of the CVHM grid was not undertaken in the impacts analysis in this EIS. In addition, other related FMP input files (such as crop coefficients and irrigation efficiencies) change over time and need to be updated accordingly with the land use.

For the EIS groundwater modeling, the land use distribution for water year 2003 was used for the entire forecast simulation period. This was the most recent land use data available in a format appropriate for the model simulations. The limitation of using the 2003 land use distribution is that some of the most recent changes to crop production in the Central Valley over the past decade are not included in the simulations. In addition, projections of land use changes because of economic effects and climate change are not considered in CVHM, nor are the potential crop changes in response to water supply availability from CVP and SWP operational changes from the alternatives (see Chapter 12, Agricultural Resources, for a discussion of changes in crops because of water supply availability and costs). However, these assumptions are adequate for the comparative analysis required in the EIS.

7A.2.3 Stream Boundary Inflows Assumptions

CVHM includes 43 stream boundary inflows, which represent smaller natural streams as well as managed reservoir outflows. Of these, 13 inflows were linked to CalSim II reservoir releases. Natural stream inflows were kept unchanged from the original CVHM and therefore are linked to the historical climate data. It should be noted that CalSim II does not include the Tulare Lake area, and all stream inflows in that area were kept the same as those from the original CVHM.

For each alternative simulation, the surface water inflows at specific locations are updated in the SFR input file based on time series computed by CalSim II. Table 7A.1 lists the CVHM inflow locations at which updated CalSim II flows were applied based on simulation results from the corresponding CalSim II nodes. Figure 7A.4 provides a map with the stream boundary inflow locations in CVHM.

Table 7A.1 CVHM Modified Inflow Locations

CVHM Node ID	Description	CalSim II Equivalent Nodes
AMER_374	American River Downstream of Lake Natoma + South Folsom Canal	C9 + D9
MOKE_173	Mokelumne River below Comanche Reservoir	I504 + Original CVHM Diversions on Mokelumne River
CALV_161	Calaveras River (release from New Hogan Reservoir)	C92
STAN_146	Stanislaus River (below Goodwin + Oakdale Canal + SSJ Canal)	C520 + D520B + D520C
TUOL_135	Tuolumne River (Don Pedro Reservoir Release)	C81
SACR_205	Sacramento River (Keswick Reservoir Release)	C5
STON_263	Stony Creek (Black Butte Reservoir Release)	C42
FEAT_341	Feather River below Oroville + Palermo Canal	C6 + D6
YUBA_349	Yuba River below Englebright + Deer Creek inflow + French Dry Creek inflow	C230 + D230
MERC_116	Merced River (Lake McClure outflow)	C20
CHOW_080	Chowchilla River (Eastman Lake outflow)	C53
FRES_069	Fresno River (Hensley Lake outflow)	C52
SANJ_054	SJR at Friant Dam (Millerton Lake outflow)	C18

7A.2.4 Project Deliveries Assumptions

CVHM includes two different methods to deliver surface water diversions to a WBS: semi-routed deliveries and nonrouted deliveries. These deliveries occur through the interaction of the SFR and FMP modules and the WBS.

Semi-routed deliveries occur through the SFR package to account for water that is routed through stream networks. With the SFR package, CVHM conveys water from streams and canals as semi-routed deliveries to WBSs through the FMP based on model-computed applied water demand (USGS 2009).

The nonrouted delivery process allows the model to obtain surface water from a source that is not simulated with the stream network. For instance, not all canals are physically simulated within CVHM, but the water conveyed through those canals can still be delivered to the appropriate WBSs without actually simulating the conveyance features explicitly.

In the CVHM simulations, the nonrouted surface water supply components have first delivery and use priority, and semi-routed surface water deliveries have second priority. If the WBSs water delivery requirements computed by the crop consumptive use through FMP are not met using surface water, the FMP computes the amount of supplemental groundwater necessary to be pumped from "farm" (agricultural production) wells to satisfy the total WBS water demand (USGS 2009). The nonrouted and semi-routed surface water deliveries are simulated as monthly transient time series that set the upper bound of available surface water for the WBSs. The actual diversions and deliveries for each WBS are driven by agricultural water demand.

Within the CVHM configuration, nonrouted deliveries tend to be associated with the south-of-Delta exports to the San Joaquin Valley service areas, because the California Aqueduct and the Delta-Mendota Canal are not simulated in the model. Semi-routed deliveries occur in areas where diversions from streams and canals are simulated for both settlement contractors and riparian diverters. Because of the difference in water rights allocations and the different CVHM characteristics in the Sacramento Valley versus the San Joaquin Valley, the surface water allocations are simulated differently, as described below. Figure 7A.5 shows the surface water delivery types for each WBS as simulated in CVHM.

For the EIS groundwater impacts simulations, the calibrated historical CVHM was set up to run in a "predictive mode" (for future planning simulations) with the diversion time series fixed at water year 2003 for all semi-routed diversions that represent riparian or other water rights users. This method provides the latest available (2003) diversion flows to agricultural water users for an average hydrology year with seasonal patterns. Project water deliveries were developed from CalSim II time series, as described below.

7A.2.4.1 Sacramento Valley

The Sacramento Valley is defined in CVHM as WBSs 1 through 8 (Figure 7A.2). In the Sacramento Valley, the diversion time series for the CVP and SWP settlement contractors and CVP contract agricultural diverters were linked to

CalSim II time series for consistent project delivery estimates for each alternative. Table 7A.2 shows the detailed linkage between CalSim II nodes and CVHM diversions nodes for the Sacramento Valley (also shown in Figure 7A.6).

Table 7A.2 CVHM Diversions linked to CalSim II Flows in the Sacramento Valley

CVHM WBS	CVHM Node ID	Type of Flow	Description – CVHM (CalSim II)	CalSim II Equivalent Node
1	BELL_0206	–	Bella Vista Conduit (ag only)	0.57*D104_PAG
1	SACR_A223	CVP Settlement Ag + CVP Ag Delivery	Diversions – Sacramento River between Keswick and Red Bluff (ag only)	D104_PAG - (BELL_0206) + (0.86*D104_PSC)
0a	SACR_B223	CVP M&I + CVP Settlement M&I Delivery	Diversions – Sacramento River between Keswick and Red Bluff (M&I only)	D104_PMI + 0.14*D104_PSC
2	CORN_0232	CVP Ag Delivery	Corning Canal	D171
2	TE10_0232	CVP Ag Delivery	Tehama Colusa Canal	D172
3	TE12_0323	CVP Ag Delivery	Tehama Colusa Canal	D174 + D178
3	GLEN_0261	CVP Settlement Ag Delivery	Glenn Colusa Canal	D143A + D145A
3	COL_0328	CVP Settlement	Colusa Basin Drain for Irrigation Supply (Colusa Drain MWC)	D180 + D182A + D18302
3	DS12_0282	CVP Settlement	Sacramento River Right Banks Exports (Princeton-Cordova-Glenn ID, Provident ID, Maxwell ID)	D122A
4	DS15_0331	CVP Settlement	HD from Sacramento River between Red Bluff and Knights Landing (Maxwell ID, Sycamore Family Trust, Roberts Ditch IC, RD 108, River Garden Farms, Meridian Farms WC, Pelger Mutual WC, RD 1004, Carter MWC, Sutter MWC, Tisdale Irrigation and Drainage Co)	D122B + D129A + D128

CVHM WBS	CVHM Node ID	Type of Flow	Description – CVHM (CalSim II)	CalSim II Equivalent Node
6	DS65_0381	CVP Settlement	Sacramento River Right Banks Diversions between Knights Landing and Sacramento	D163_PSC
5	DS69_0366	SWP Settlement Contractors in FRSA	DSA 69 HD from Feather River; aggregated deliveries for DSA 69 including from Thermalito Complex and Feather River diversions	D7A + D7B + D202 + D206A + D206B
5	YUBA_0351	–	HD from Yuba River - Diversions for "Big 3" diverters, primarily YCWA	D230
7	DS70-0381	CVP Settlement Ag Delivery	HD from Sac River between Knights Landing and Sacramento - all but City water	D162

NOTE:

[a] WBS 0 means that water is diverted from the stream but not delivered to any to any of the WBSs. This occurs for M&I diversions not used for crop irrigation.

The linkage was based on the definition and assumptions of CalSim II and CVHM deliveries, and on the spatial approximation of the stream diversion location in CVHM. Each time series is updated in the SFR input file for each alternative simulation.

In addition to the semi-routed deliveries, WBSs 5 and 7 receive water from nonrouted deliveries. However, most of these deliveries are either linked to riparian (nonproject) water rights or deliveries from outside the model domain. Therefore, WBS 5 and 7 nonrouted deliveries remained unchanged from the calibrated CVHM model.

7A.2.4.2 San Joaquin Valley

In CVHM, the San Joaquin Valley is defined as WBSs 10 through 21 and includes the Tulare Lake portion of the San Joaquin Valley (Figure 7A.2). In the San Joaquin Valley, the majority of agricultural surface water deliveries are provided through south-of Delta exports from the CVP and SWP contract allocations. CalSim II time series representing project water deliveries for the San Joaquin Valley WBSs were aggregated into one time series for each WBS using a spreadsheet-based preprocessing tool. These time-series data were then used for the FMP nonrouted deliveries input file. The semi-routed deliveries in the San Joaquin Valley are either of riparian nature or for other non-project use, and therefore were not changed from the historical CVHM. The only exception occurred in WBS 11, in the East San Joaquin area, where two CVP agricultural deliveries were linked to CalSim II time series (Figure 7A.6):

- Deliveries for Oakdale Irrigation District North and South San Joaquin Irrigation District, simulated in CVHM as the diversions at the South San Joaquin Canal near Knights Ferry (SSJK_0147 in Figure 7A.6), were linked to CalSim II node D520B
- Deliveries for Oakdale Irrigation District South, simulated in CVHM as the diversions at the Oakdale Canal near Knights Ferry (OAKK_0147 in Figure 7A.6), were linked to CalSim II node D520C

These two semi-routed diversions and deliveries were incorporated into the SFR input file along with all the other surface water diversion and boundary inflow modifications for each alternative.

7A.2.5 Model Application Methodology

For each simulation scenario (project alternatives), boundary inflows in CVHM, WBS surface water estimates, and farm delivery estimates were updated with the appropriate CalSim II model outputs, which account for assumed operational changes for each alternative. The original 42-year hydrology for water years 1962 through 2003 was updated with climate conditions centered on year 2025 for each predictive simulation. Thus, impact evaluations assume the dry to wet hydrology patterns as indicated from climate model simulations centered on year 2025. The simulated groundwater levels for each alternative were compared to the No Action Alternative and Second Basis of Comparison simulations. Model outputs were processed such that impacts to groundwater were shown on an average monthly basis by water year type, and the analysis was centered on potential impacts occurring during the month with the largest agricultural deliveries, which generally is July. The simulation period did not intend to provide groundwater levels at exact future dates, but rather provide a range of groundwater level changes that could occur from implementing each alternative, given assumed future fluctuations in hydrology.

7A.2.5.1 No Action Alternative and Second Basis of Comparison Models

The overall purpose of the No Action Alternative and Second Basis of Comparison models is to provide a set of baseline conditions for comparison with the forecasts of the alternative models to assess whether implementing the proposed alternatives are likely to result in substantial changes to groundwater resources.

Preparing the CVHM No Action Alternative model and the Second Basis of Comparison model was based on the modified CalSim II flow time series for the reservoir outflows and the deliveries to the WBSs in the export service areas. The following are additional assumptions inherent in the predictive version of CVHM:

- The urban groundwater pumping locations for 2003, the most recent available in CVHM, were assumed to remain for the duration of the 42-year predictive simulation period.

- The original CVHM 2003 surface water diversions were assumed for the duration of the predictive simulation for nonproject diversions.
- The land use distribution and associated cropping patterns available in the calibrated CVHM at approximately year 2000-2003 were kept constant throughout the predictive simulation.
- The climatic data were updated to represent a wet to dry precipitation pattern centered on year 2025.

7A.2.5.2 Other Alternatives Models

For each alternative model simulation, the same procedure as described for the No Action Alternative and Second Basis of Comparison models was used, with similar assumptions, to update flows from the CalSim II simulations. Detailed modeling processes and impacts analysis procedures are described in the next section.

7A.3 CVHM Modeling Results

A complex and detailed model such as CVHM requires developing and applying preprocessing and post-processing tools to create input files, run the model, and view and interpret results. The processing tools range from geographic information system (GIS) and spreadsheet-based tools to custom-coded programming utilities that use viewing programs such as Golden Software Surfer. The general preprocessing and input files development are described in Section 7A.2. The following subsections describe data analyses and results.

7A.3.1 Post-Processing and Results Analysis

Output data resulting from CVHM simulations for each alternative were processed to provide a graphical depiction of applicable information that support the analysis and description of potential impacts to groundwater resources. As discussed previously, the primary outputs from CVHM used in this analysis were simulated heads and agricultural groundwater pumping to meet applied water demands.

CVHM outputs simulated hydraulic heads (heads) and groundwater fluxes for each model grid cell in each model layer. Based on analysis of common screen elevations of agricultural pumping wells, Model Layer 6 of the original CVHM includes the majority of the groundwater extraction. Actual locations of agricultural wells are not represented in the model; they are represented as “virtual wells” in model cells representing areas with known groundwater pumping and having a corresponding agricultural land use. The simulated heads in each cell for Model Layer 6 only are interpolated using triangulation with linear interpolation to facilitate viewing results for the entire Central Valley for each alternative. Because July generally has the highest agricultural groundwater pumping during the CVHM timeframe, the results analysis focuses on this month for each alternative. A post-processing utility was developed to create monthly average heads for July for each water-year type. The difference in monthly average heads between each alternative and No Action Alternative and each alternative and Second Basis of Comparison was then computed, interpolated, and displayed on a Central Valley map for change visualization. The differences were computed by subtracting the simulated heads for No Action Alternative and Second Basis of Comparison from the simulated heads for the alternatives, respectively.

A resulting positive head difference indicates that heads in the alternative simulation are higher than those from the No Action Alternative or Second Basis of Comparison simulation to which the alternative simulation is being compared. Conversely, a resulting negative head difference indicates that heads in the alternative simulation are lower than those from the No Action Alternative or Second Basis of Comparison simulation to which the alternative simulation is being compared. Results are provided in Figures 7.15 through 7.60 and a narrative of the forecast head differences (i.e., project effect to groundwater levels) is provided in Chapter 7, Groundwater Resources and Groundwater Quality.

The results give an indication of the horizontal distribution of the potential impacts to groundwater levels in Model Layer 6 for an average month of July for each water year type. To assess the temporal variations in groundwater level fluctuations, head difference hydrographs at eight model cells were developed to show a range of typical groundwater level variations and changes between alternatives and No Action Alternative and Second Basis of Comparison at different locations in the Central Valley. The location of the simulated groundwater level time series were chosen based on general areas of USGS wells that were used for calibrating CVHM. The hydrograph plots are shown on a CVHM WBS map for the Sacramento Valley and San Joaquin Valley (Figures 7.20, 7.21, 7.29, 7.30, 7.38, 7.39, 7.45, 7.46, 7.52, 7.53, 7.59, and 7.60).

In addition to spatial and temporal representations of groundwater level changes associated with the alternatives, agricultural groundwater pumping differences are also depicted on a map of the WBSs. This graphical representation shows which areas of the Central Valley are impacted the most by changes in surface water deliveries for each alternative. The data for these results were processed from the FMP output files, which include the amount of water used from each available source by the farm, based on the computed applied water demand for each WBS (Figures 7.22, 7.23, 7.31, and 7.32).

7A.3.2 Output Data for Other Models

Simulated heads from CVHM were post-processed for use in evaluating agricultural economic impacts related to each alternative. An agricultural economic impact evaluation of each alternative was performed using the SWAP model. For more information on using this model and the results, refer to Chapter 12, Agricultural Resources and Appendix 12A. The simulated heads output file was processed to average the July head data for Model Layer 6 for each SWAP region. In addition, processing of CVHM heads for the SWAP model further separates the average simulated head between irrigated portions and non-irrigated portions of each SWAP region.

As a result, each SWAP region includes one estimated average head change representing the agricultural pumping impacts. This average value was used to compute a pumping lift for SWAP input, to compute average electrical cost to pump groundwater for irrigation.

7A.3.3 Model Limitations and Applicability

Although it is impossible to predict future hydrology, land use, and water use with certainty, CVHM was used to forecast impacts to groundwater resources that could result from implementing the EIS alternatives to aid in developing the EIS. CVHM was used in a comparative manner to estimate potential changes by implementing EIS alternative operations versus base conditions. Mathematical models like CVHM can only approximate processes of physical systems. Models are inherently inexact because the mathematical description of the physical system is imperfect, and the understanding of interrelated physical processes is incomplete. However, CVHM is a powerful tool that, when used carefully, can provide useful insight into processes of the physical system. The following are some known limitations that should be considered when evaluating the forecast impacts.

- CVHM simulates groundwater conditions in the Central Valley with cells on 1-mile centers. Therefore, surface water and groundwater features that occur at a scale smaller than 1 mile cannot be simulated explicitly in CVHM. Likewise, CVHM simulates groundwater conditions using monthly stress periods. Thus, groundwater variations cannot be simulated explicitly in CVHM over timeframes shorter than 1 month.
- The “predictive” (future planning) version of CVHM used for the impacts analysis does not include land use changes after year 2003. Thus, land use changes that have occurred since 2003 and those that might occur in the future are not considered in the impacts analysis.
- The future planning version of CVHM incorporates potential climate-change effects centered on year 2025 (assumed conditions at year 2030). It is not possible to know whether these potential climate-change effects will actually occur in the future, as modeled.
- Operation of groundwater banks and groundwater transfer programs and how implementing the alternatives could affect them is not included in the future planning level CVHM simulations.
- The future planning version of CVHM does not include potential affects from planned or unplanned changes in groundwater regulations in California (i.e., implementation of California Sustainable Groundwater Management Act).

- The subsidence package, as implemented in the version of CVHM used for the impacts analysis, does not consider the potential reduction in the rate of subsidence that would occur as the magnitude of compaction approaches the physical thickness of the affected fine-grained interbeds. Thus, subsidence forecasts from the predictive versions of CVHM were judged to be overly conservative. Therefore, a qualitative approach was used for estimating the potential for increased land subsidence in areas of the Central Valley that have historically experienced inelastic subsidence because of the compaction of fine-grained interbeds.

7A.4 References

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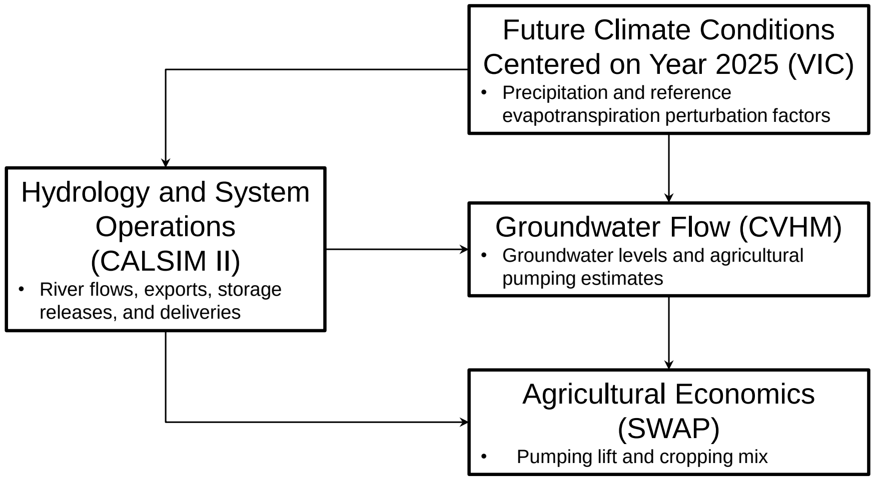

Figure 7A.1 Relationships among the Different Modeling Tools Used in the Groundwater Impacts Analysis Framework

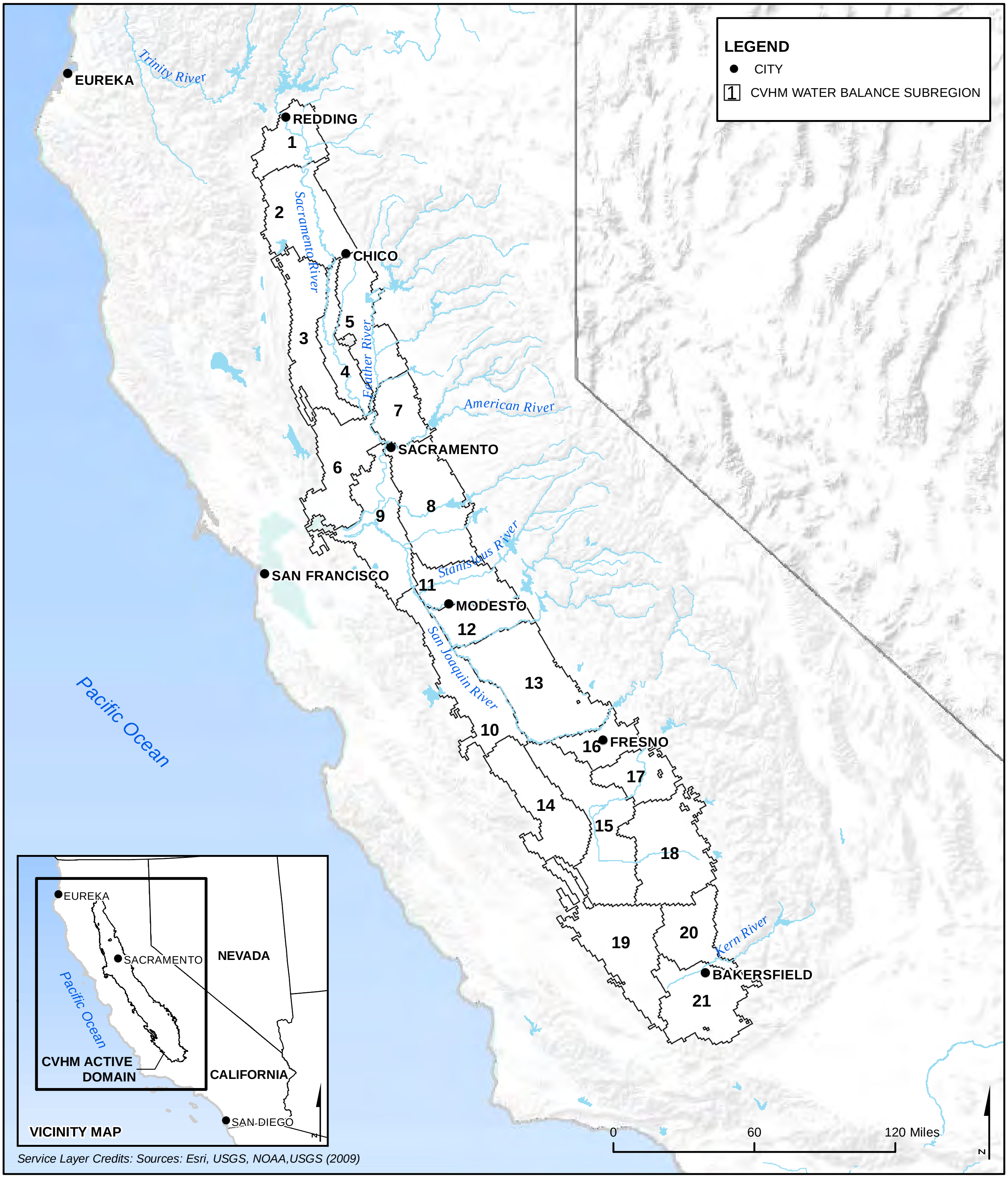

Figure 7A.2 Groundwater Model Domain and Water Balance Subregions in the Central Valley

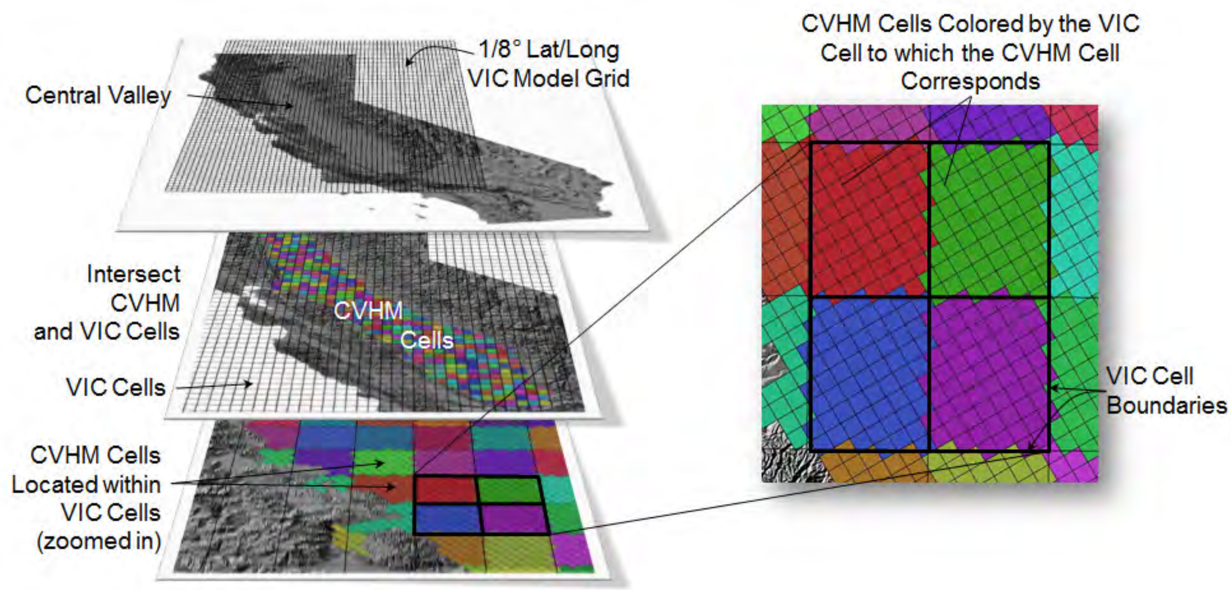

Figure 7A.3 Relationship between VIC and CVHM Grid Cells

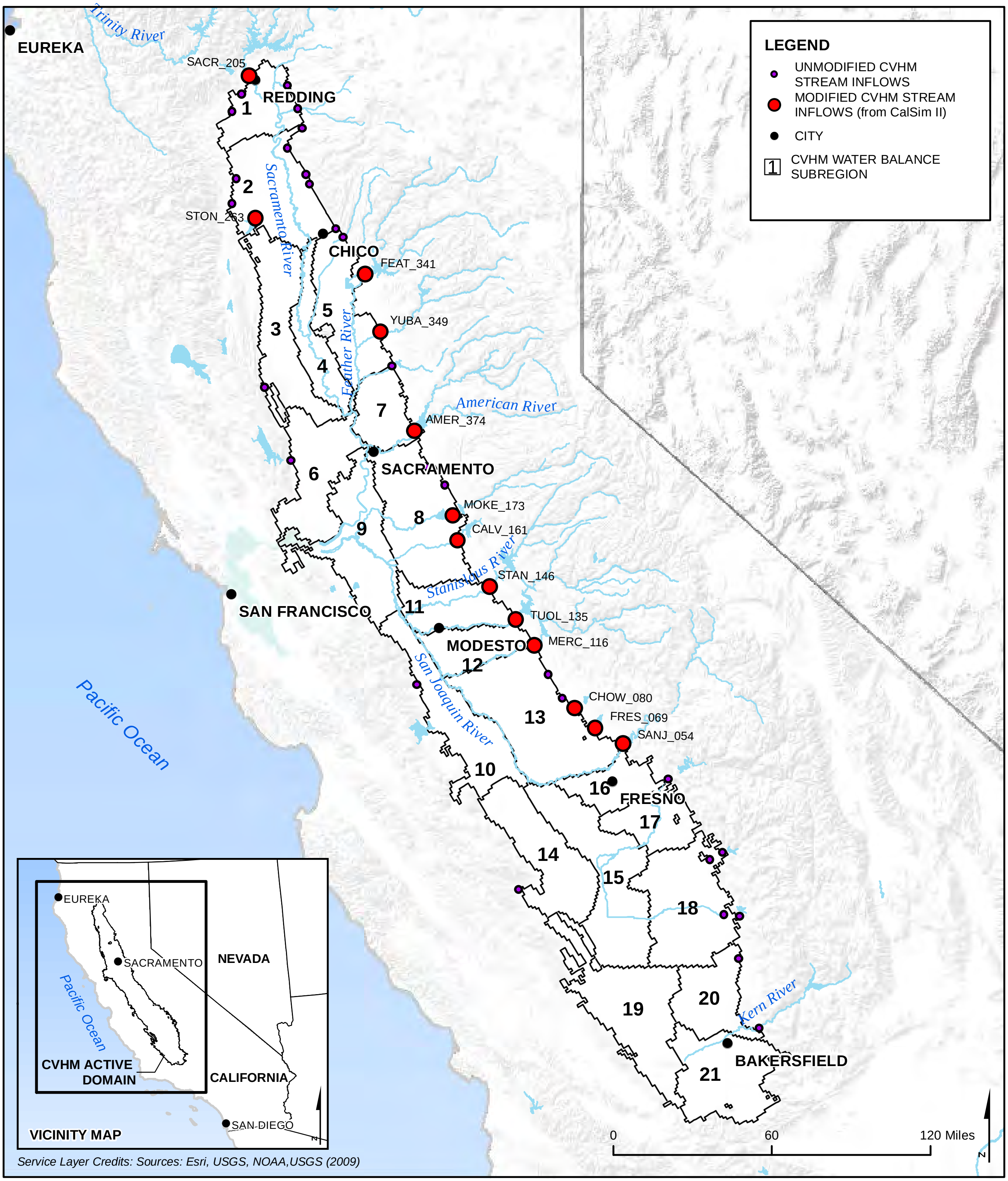

Figure 7A.4 Groundwater Model Stream Inflow Locations

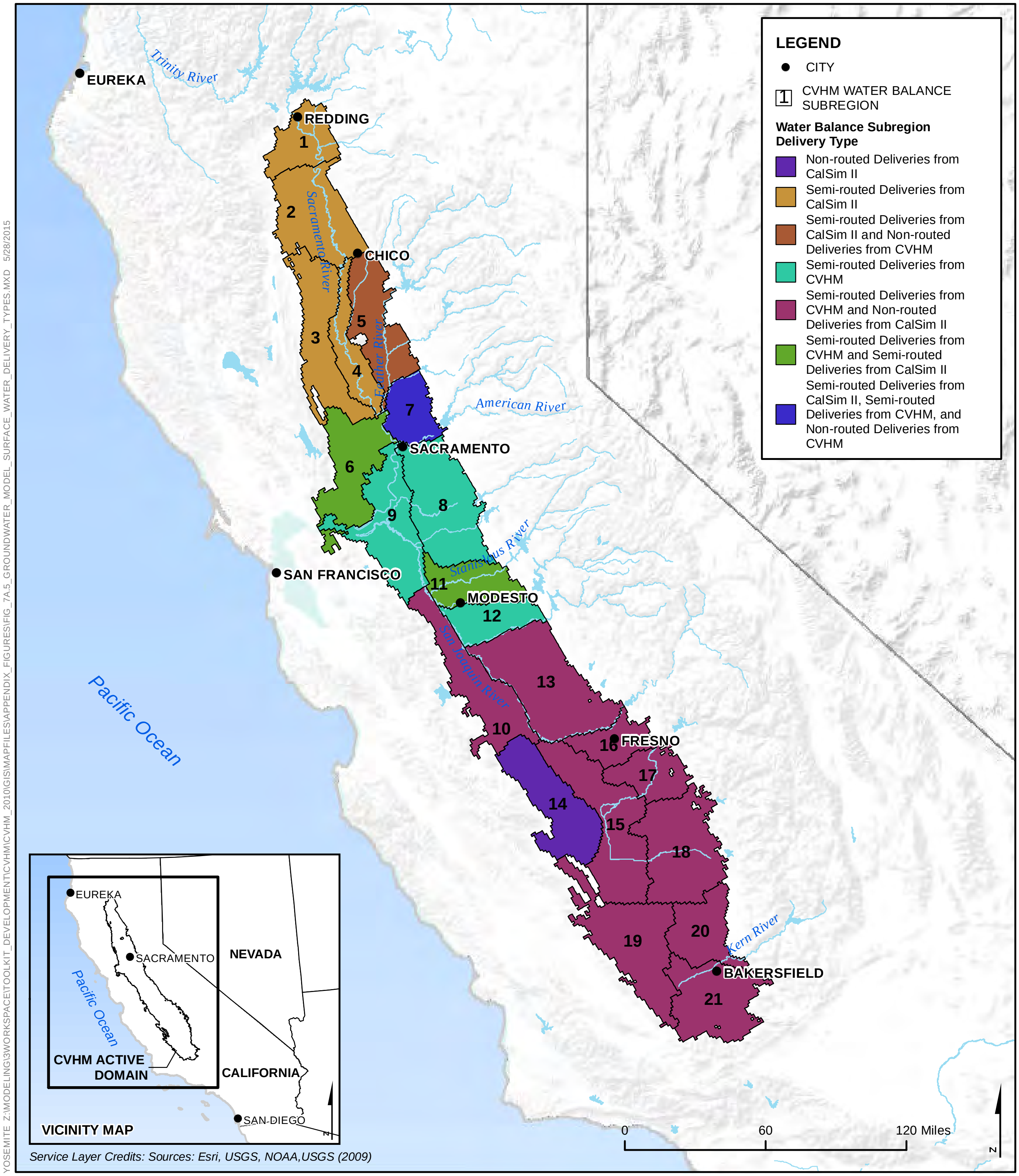

Figure 7A.5 Groundwater Model Surface Water Delivery Types by Water Balance Subregion

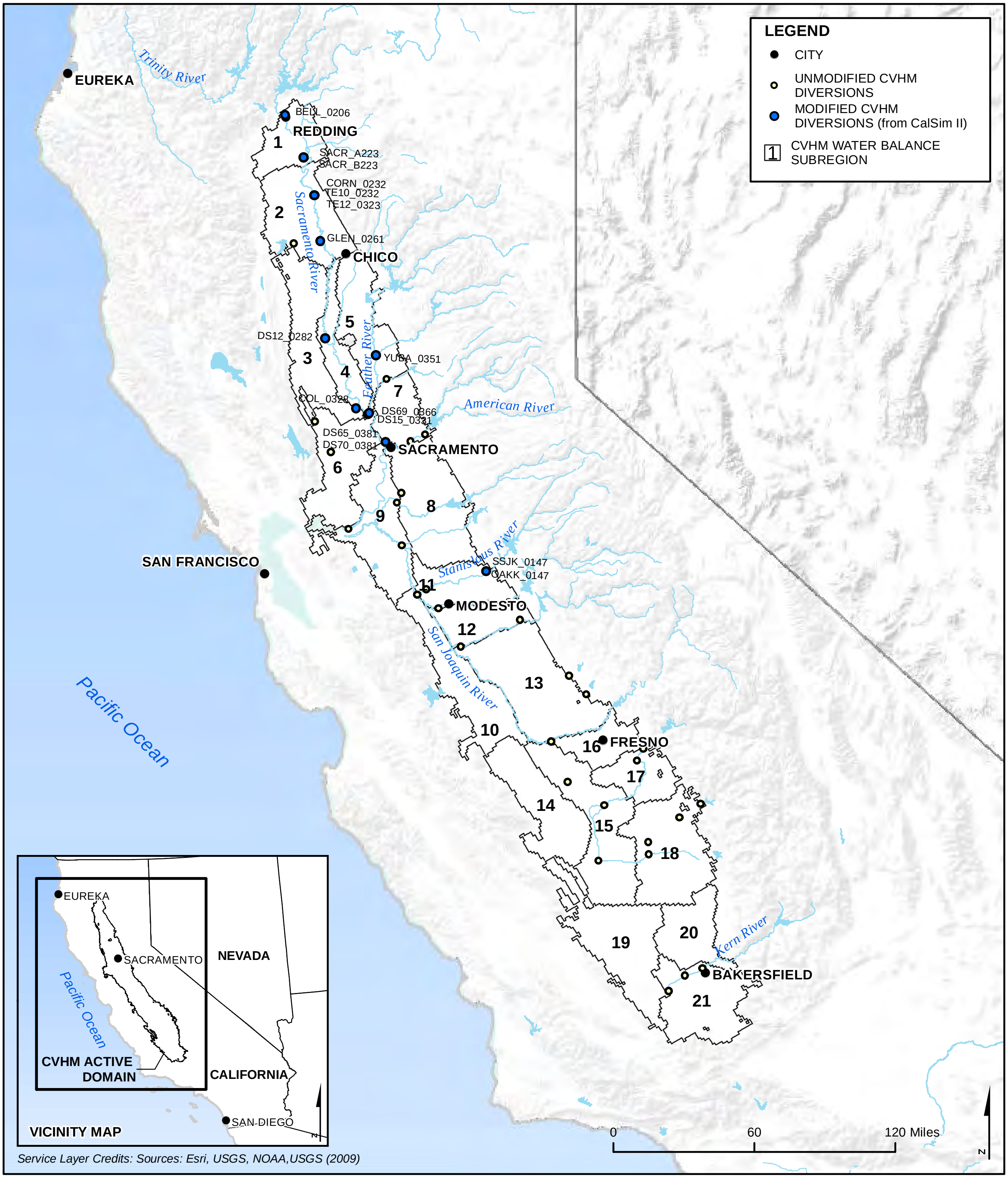

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Figure 7A.6 Groundwater Model Surface Water Semi-routed Deliveries Locations